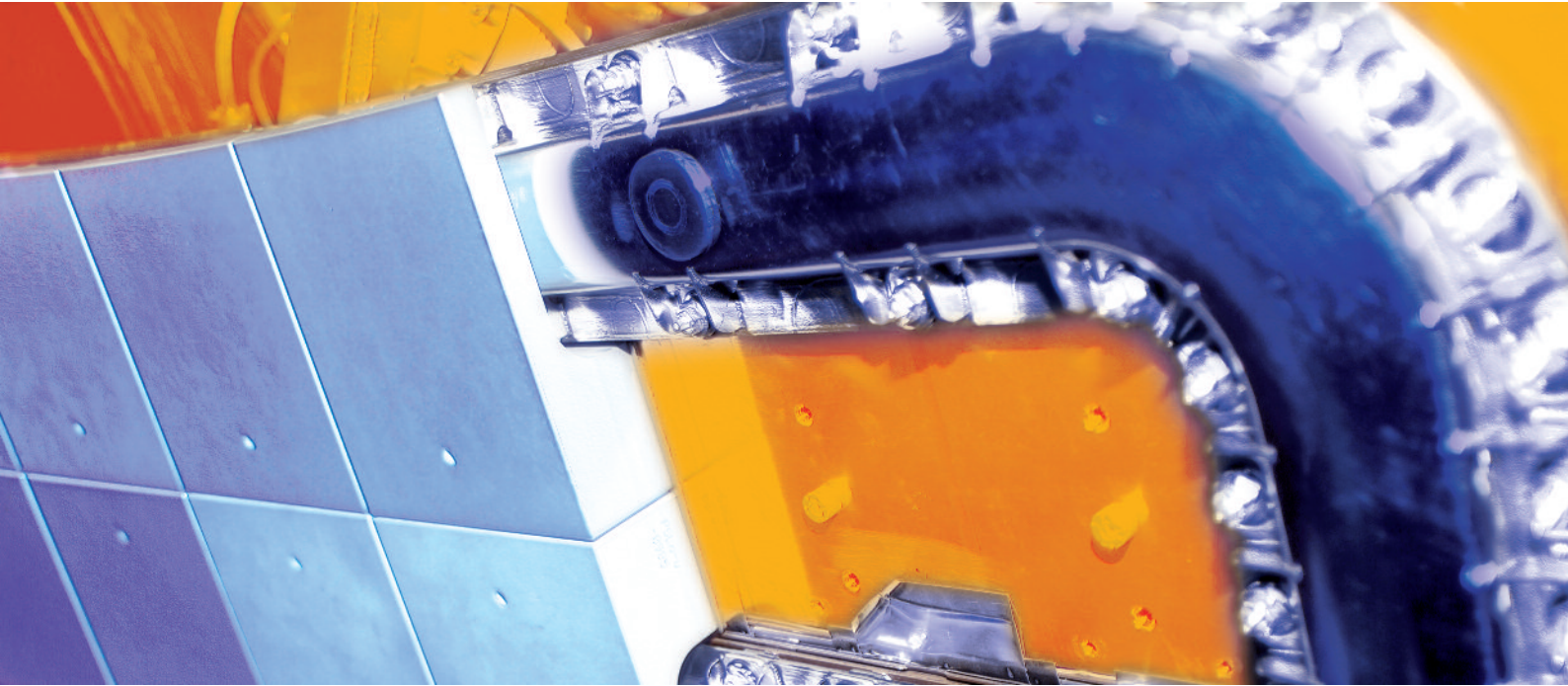




Max-Planck-Institut  
für Plasmaphysik

# Annual Report 2010



MAX-PLANCK-GESELLSCHAFT



EURATOM Association



Active inner vessel coil during assembly at the low-field side of the inner wall, partly with and without protection tiles. The first set of eight coils is operational. These coils are being used to mitigate ELMs and other detrimental MHD activities. The full set of coils will consist of 24 active coils.



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# Annual Report 2010

The Max-Planck-Institut für Plasmaphysik is an institute of the Max Planck Gesellschaft, part of the European Fusion Programme (Euratom) and an associate member of the Helmholtz-Gemeinschaft Deutscher Forschungszentren.







Photo: IPP, Stefanie Graul

This year the Max Planck Institute for Plasma Physics (IPP) was able to look back on five decades of successful research work – with its foundation on 28 June 1960, it began a long-term programme with intensive basic research. The object under investigation, a high-temperature hydrogen plasma, proved to be considerably more complex than had been assumed by the founders of the institute. The plasma data attainable in the first stellarator and tokamak devices were equivalent to fusion powers of just a few milliwatts. Nowadays, for comparison, we have the world's record-breaking experiment of the European joint project, JET, which in 1997 attained a brief peak power of 16 megawatts. The ITER large-scale international test device, which is currently under construction, is now due to produce the first self-heating and energy-yielding plasma – an impressive development to which IPP has made significant contributions with its experimental and theoretical work. Though being 50, in its jubilee year IPP has continued to push scientific work on high level, as the paragraphs to follow show.

In 2010, the assembly of the superconducting magnetic field coils for Wendelstein 7-X was successfully completed. Providing the magnetic field which confines the hot fusion plasma, the 70 coils constitute the heart of the device. They are arranged in five similar modules, three of which have already been installed in their final positions in the experiment hall by the end of the year. The coils are enclosed by a cryostat vessel. Equipped with super-insulation, it acts as a huge Dewar vessel. Inside, the magnetic field coils will be operated close to absolute zero temperature. The superconductors can thus provide – almost without losses – the specially optimized magnetic field cage of Wendelstein 7-X. Special thanks go to our collaborators, who significantly contribute to the project's success. At the end of June the team at the Forschungszentrum Jülich was able to celebrate the successful development and construction of the bus bar system, which provides the electrical connection of the magnetic field coils. Another breakthrough was the successful prototype test and subsequent start of series production of the current leads, provided by the Karlsruhe Institute of Technology. The current leads connect the superconductors inside the cryostat to the normally conducting power supplies. While progress of the assembly work on Wendelstein 7-X can be perceived on a daily basis, the focus is now shifting to diagnostics and heating systems, which are necessary for successfully commissioning the device in 2014 and starting the scientific programme.

The ASDEX Upgrade tokamak was shut down for most of 2010 to allow the installation of a number of hardware upgrades. A modified ICRF antenna was installed, aiming at reduced impurity production during ICRF heating. The ECRH system was further upgraded and will allow more than 4 MW of power to be injected into the plasma, heating the electrons at a microwave frequency of 140 GHz. Finally, the first half of a set of  $2 \times 8$  in-vessel coils was installed for studying the effect of resonant magnetic perturbations on the plasma, most notably the influence on Edge Localised Modes (ELMs). These MHD instabilities are a big worry for ITER, since they may lead to excessive transient power loads. In December 2010, ASDEX Upgrade resumed operation and has already been able to show that large ELM bursts can be suppressed by using the new coil set in a certain plasma parameter range. This important result is of great importance for ITER since further analysis and interpretation should lead to a better understanding of this effect, previously discovered on the DIII-D tokamak in San Diego. This clarification will allow for an educated decision whether to include such a coil set in the ITER design. The set of  $2 \times 8$  coils will be completed during a shutdown in summer 2011, thus further increasing the experimental flexibility of these experiments.

JET has laid the foundations for the next cycle of its exploitation. The major shutdown, which started in 2009 for the installation of the ITER-like wall, is in its final phase and has to be considered as the largest modification of JET since the installation of the pumped divertor in the early 1990s. Preparation of the 2011-12 JET campaigns is nearing completion. The amount of work carried out by the Association staff within the JET Task Forces has been substantial with important contributions from IPP, in particular for the management of the JET Task Force E1. JET's future financial situation is still rather unclear.

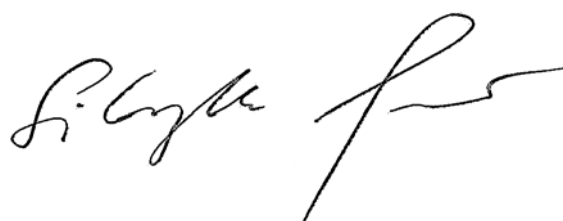
Scientific exploitation of the new hardware is ensured for one year of operation only, but will hopefully be extended to the end of 2015. For the final step of operation with the ITER-like wall a deuterium-tritium campaign is currently being discussed with the Fusion Committees.

The ITER cooperation project at IPP is continuing its activities on the major topics: The ELISE test facility, a major step on the pathway to the ITER neutral beam injection system, is being built, R&D on the bolometer diagnostic for ITER continues, as does the work on the design of the ITER ICH antenna within the CYCLE Consortium. A major R&D task on fast switches for high power microwaves was finished successfully and on time. Additionally, IPP is contributing to various heating systems, diagnostics and, in particular, preparation of the physics basis through some direct contracts with ITER or F4E and a number of tasks within the EFDA work programme.

The aim of the work in theoretical plasma physics carried out at IPP's Garching and Greifswald sites is to understand the behaviour of tokamak and stellarator plasmas from first principles. In addition, there is a programme of collaboration with the Max Planck Institute for Solar System Research in Katlenburg-Lindau, where similar methods are being applied to the study of space plasmas. During the year, significant advances were made in the understanding of how fusion plasmas respond to magnetic perturbations. In tokamaks, such perturbations are applied with external coils and affect the density, temperature and rotation profiles as well as the MHD stability. These effects have opened a new research field, and first results were already achieved in 2010. In stellarators, small adjustments in the magnetic field can be used to manipulate the pressure-driven current and the confinement of fast ions as well as the thermal plasma components, which should be highly useful for operation of Wendelstein 7-X. The High Level Support Team of the European High Performance Computing initiative is now fully operational and has already made substantial contributions.

Researchers from edge plasma physics at ASDEX Upgrade and Wendelstein 7-X, from ITER Technology and from the materials research department collaborate in the "Plasma-facing Materials and Components" project, which for many years has provided a field of core competence at IPP with a worldwide reputation. In 2010, one highlight was the understanding of modification of plasma-facing tungsten and beryllium surfaces by nitrogen seed impurities as used in ASDEX Upgrade. In both cases, stable nitrides are formed, saturating at thicknesses comparable to the range of the incident ions. For tungsten the surface nitride layer strongly reduces the sputtering yield. The activities in this field are coordinated with the EU Task Force on Plasma-Wall Interactions, which in turn has been substantially managed by IPP personnel since 2002. Currently, the task force leader position and two special expert working group leader positions are taken by scientists from IPP. Furthermore, the project coordinates the EU coordination action, FEMaS (Fusion Energy Materials Science), as well as the Helmholtz Russia Joint Research Group, "Hydrogen Isotopes Retention in First-Wall Materials for ITER and Fusion Power Reactors".

On behalf of the Directorate and Scientific Board I would like to take this opportunity to thank all staff members for their substantial contribution to the success of fusion research at IPP in the past year.

A handwritten signature in black ink, appearing to read 'Sibylle Günter', with a long, sweeping horizontal stroke extending to the right.

Scientific Director Sibylle Günter

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## Tokamak Research





# ASDEX Upgrade

Head: Prof. Dr. Arne Kallenbach (Dr. Otto Gruber till July 2010)

## 1 Overview

### 1.1 Status of the Machine

The fusion experiment ASDEX Upgrade (AUG) is a medium size divertor tokamak (major radius  $R=1.65$  m, minor radius  $a=0.5$  m, plasma current  $I_p$  up to 1.4 MA, toroidal magnetic field  $B_t$  up to 3.1 T). It has a high shaping capability and versatile heating and current drive systems comprising 20 MW neutral beam heating (NBI), an ion cyclotron resonance system (ICRF) with up to 6 MW coupled power and 5 MW installed power of electron cyclotron resonance heating (ECRH). The extension of the ECRH system was continued in 2010, resulting in presently 3 long pulse (10 s) gyrotrons of the ECRH II system installed. The system is equipped with fast steerable mirrors allowing for mode tracking in NTM stabilisation experiments or for fast changes of power deposition or current drive locations. The main enhancement of the ICRF system was the installation of an antenna with broad limiters, which is expected to allow code validation for the antenna design tools directed towards a reduction of tungsten sputtering caused by ICRF operation. AUG's fast integrated control and data acquisition system (CODAC) is being continuously extended in its real time control capabilities. Complementary, several diagnostics have been adapted to real time data processing and evaluation. The plasma facing components in AUG remained completely covered with tungsten, while feedback control of the divertor heat flux with impurity injection is fully embedded into standard high power operation. With the installation of an additional brake for the flywheel generator EZ4, full generator power and energy capability in routine operation has been re-established in December 2010. The newest element for advanced plasma control is the first set of 8 magnetic perturbation coils ('B-coils'), which have been installed during the 2010 vent. These coils have been initially used for ELM control studies, providing urgent results for the ITER decision on the installation of a corresponding coil system.

### 1.2 Recent Results from Data Analysis in 2010

Due to the substantial machine vent dedicated to hardware extensions from January to November, extensive data analysis of the 2009 experimental campaign was performed, which resulted in a number of important findings. Refinement of the spatial and temporal resolution of pedestal diagnostics allowed a better characterisation of the pedestal structure and gradient recovery during the ELM cycle. Current diffusion calculations revealed the subsequent ELM to occur with a significant delay compared to the edge current redistribution time,

The current ASDEX Upgrade program is directed towards physics input for ITER and a future DEMO design. During 2010, a major vent was undertaken from January till November. Meanwhile, data analysis of previous campaigns revealed important findings. First experiments with the newly installed magnetic perturbation coils showed a drastic reduction of the ELM size without any detrimental effects on plasma stored energy, density or impurity content.

suggesting a missing element in the peeling-ballooning model. Dedicated core transport studies with variations of ECRH deposition in NBI heated H-mode discharges allowed to test predictions of non-linear (GYRO) and quasi-linear (GS2) gyrokinetic modeling of electron and boron impurity density gradients in the core plasma. A key element of this study was the

use of experimental  $T_e/T_i$ ,  $R/L_T$  and toroidal rotation values for the simulation, since their theoretical prediction is less accurate. A very good reproduction of the normalised electron density gradient was obtained, where the real frequency of the most unstable mode worked as almost perfect proxy of both measured and predicted  $R/L_{ne}$ . The transport calculations revealed a transition of the dominant transport mechanism from ITG to TEM turbulence when central ECRH is applied. Concomitantly, a pronounced reduction of the toroidal plasma rotation and the ion temperature in the inner part of the plasma has been observed.

Further transport studies were devoted to reveal the origin of the improved energy confinement routinely observed with nitrogen seeding in AUG, an effect, which has not been obtained in other tokamaks so far. The improvement could be attributed to higher temperatures at the pedestal top, which then proceed to the plasma center via profile stiffness. Fuel dilution by nitrogen ions is supposed to be an important ingredient for the formation of higher pedestal temperatures. Hollow  $Z_{eff}$  profiles cause a reduction of the dilution towards the plasma center, which results in the positive effect on the total plasma pressure and energy.

Operational restrictions in case of a damaged tungsten divertor are an important question for the ITER program planning and risk analysis. Dedicated tungsten melting experiments with a pin inserted into the divertor plasma were analysed with the EMC3-Eirene code with regard to the penetration probability of evaporated tungsten into the core plasma. The AUG experiments revealed a very good divertor retention for evaporated tungsten atoms, which could be reproduced by the EMC3-Eirene calculations. Nevertheless, further experiments and modeling work will be required to strengthen the predictive capability of the calculations.

### 1.3 Experimental Programme in 2010/11 and Technical Enhancements

The AUG programme is directed towards physics input to remaining critical elements of the ITER design and the preparation of ITER operation, as well as addressing physics issues for a future DEMO design.

The 2010/11 programme is coordinated by five Task forces, namely

- Improvement of H-mode and integrated scenarios
- Pedestal physics including tolerable ELMs
- SOL & divertor physics and first wall materials
- MHD instabilities and their active control
- Transport

The 2010/11 programme consists of 208 individual proposals led by 93 first authors from IPP as well as from 24 European associations and fusion labs in the US and Japan. A substantial fraction of the proposals is devoted to collaborative ITPA studies, EFDA tasks or experiments proposed by the EU PWI Task Force or EU Topical Groups. About one third of the requested discharges has an external proposal first author. Also one third of the AUG publications in refereed journals over the last years had an external first author.

The current experimental programme, which started in December 2010, gives priority to the exploitation of the newly installed hardware components. Experiments with the magnetic perturbation coils ('B-coils') mounted above and below the midplane aim at the characterisation and understanding of ELM mitigation by magnetic perturbations in order to improve the predictions for a corresponding system in ITER. The ECRH II enhancement brought in total 5 MW installed ECRH power at the end of 2010, which will give a high flexibility for transport studies, NTM stabilisation, operation with low momentum input and better central impurity control. ICRF studies, which are currently hampered by strong tungsten sputtering at the antenna limiters, are directed towards the development of an antenna, which is compatible with tungsten plasma facing components. In a step-wise approach, individual measures to reduce the tungsten source caused by ICRF operation were implemented, and, in parallel used to benchmark antenna design tools.

First AUG experiments in December 2010 were devoted to the characterisation of the plasma response to the B-coil operation, aiming predominantly at ELM control. Already during the conditioning phase for vessel and heating systems, first results on small ELM operation were obtained. A pronounced reduction of the ELM size in type-I ELMy H-mode has been obtained both for even and odd parity in  $n=2$  coil configuration. No density pump-out or energy confinement degradation has been observed under these conditions, and the core tungsten content even slightly decreases. Upcoming experiments will be devoted to the characterisation and explanation of the physics mechanisms leading to the reduction of ELM size and to explore and widen the operational region where ELM mitigation is possible.

The technical enhancement of AUG will proceed in 2011. In completion of the ECRH II project, another gyrotron (with either 2 or 4 frequencies) will be installed in the second half of 2011. During the next machine vent, which is planned

from August till December 2011, another set of eight magnetic perturbation 'B'-coils will be installed. They will allow to investigate perturbations with mode numbers  $n=3$  and  $n=4$ . Further modifications to ICRF antennas are foreseen, which should set the path towards full tungsten compatibility. Preparation work continues for the upcoming major hardware extensions, namely the massive tungsten outer divertor target (Divertor III, presently scheduled for autumn 2012) and a further set of 8 magnetic perturbation coils ('A-coils') in the midplane, which are designed for rotating field studies with frequencies up to 3 kHz.

In conclusion, the AUG programme heads towards the development of a high performance reactor scenario, integrated with optimised power and particle exhaust in a high-Z environment and active ELM mitigation.

## 2 Plasma Rotation with ECRH

The realisation of the connections between rotation and plasma stability and confinement has made the predictive capability and active control of the rotation profile a critical area of tokamak research. In particular, the impact of ion and electron cyclotron heating (I/ECRH) on plasma rotation is an important topic that is not yet understood. The following reports on the effect of ECRH on the toroidal rotation in low plasma current, NBI heated H-mode discharges. In these plasmas the core ion and electron temperatures tend to be quite similar.

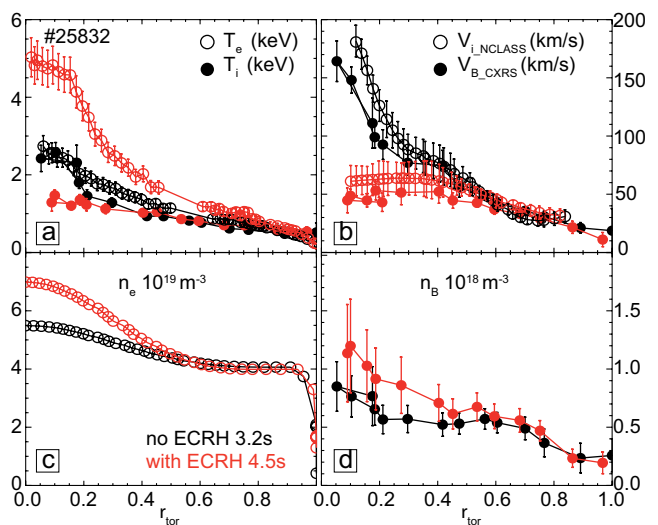


Figure 1: Plasma profiles from discharge # 25832. (a) ion (boron) and electron temperatures, (b) deuterium and boron toroidal rotations, (c) electron density, (d) boron density.

However, as shown in figure 1a, the addition of ECRH power decouples the profiles. Here, the core electron temperature and temperature gradient increase significantly concomitant with a drastic decrease and flattening of the ion temperature profile.

The electron and boron density profiles, (figure 1c&d) also react to the addition of the ECRH. The electron density profile, initially only moderately peaked, is observed to peak further with the largest change in the gradient around mid-radius. Similarly, the boron density profile is initially flat or slightly hollow at mid-radius and is observed to peak with ECRH increasing by of order 50 percent in the plasma core. A detailed analysis of the electron and boron particle transport at mid-radius in these plasmas show that the experimental behaviors are well described by the theoretical modeling (see section 3). The most dramatic change is seen in the toroidal rotation profile. In purely NBI heated discharges the plasma spins up in the co-current direction and forms peaked rotation profiles. When ECRH is added the rotation decreases significantly leading to flat and occasionally even slightly hollow profiles. An example of this rotation change is shown in figure 1b. The change in the core rotation can be as large as 100 km/s and the effect normally extends over more than half of the plasma radius. In the highest ECRH power cases ( $P_{\text{ECRH}} \sim 2$  MW) the change in rotation is observed to extend all the way to the top of the pedestal. However, for  $P_{\text{ECRH}} < 1.5$  MW the edge profiles appear entirely unaffected. Based on these observations, this appears to be entirely a core effect. The rotation change is sensitive to both the amount of ECRH power as well as to the deposition location. The latter was tested using a series of three identical discharges, in which 1.1 MW of ECRH power were injected at different locations from mid-radius to on-axis. With the deposition at mid-radius no change was observed in the rotation profiles and when the ECRH deposition was moved further inward to  $\rho_{\text{tor}} = 0.2$  only a slight decrease inside of the deposition radius was observed. However, when the power was placed on axis the rotation profile collapsed ( $\Delta V_{\phi} > 80$  km/s). In these plasmas the increase in  $T_e$  and the decrease in  $T_i$  were smallest for the off-axis case and largest for the on-axis one. This suggests a link between the rotation and temperature changes most likely through corresponding changes in the plasma turbulence; with sufficiently high  $T_e/T_i$  the plasma moves from an ion temperature gradient (ITG) to a trapped electron mode (TEM) dominated regime. This hypothesis is also consistent with the rotation being a core effect localised to the area, in which the changes in the temperature profiles are greatest. A direct examination of the relationship between the temperature profiles and the rotation supports this hypothesis as it reveals a clear separation of peaked and flattened rotation profiles with increasing  $T_e$ . The flattest and most hollow rotation profiles occur for the highest values of  $T_e$ ,  $T_e/T_i$ , and  $P_{\text{ECRH}}$ . A number of mechanisms that could help to explain the observed rotation behavior including an increase in momentum diffusivity, a change in the NBI torque deposition, a decrease in the Coriolis momentum pinch, an increase in the loss of fast ions, and the braking of the plasma

through the coupling of core modes with the wall, have been examined and rejected. In fact, several of the mechanisms considered, such as the Coriolis pinch and a change in torque deposition, act to increase the plasma rotation rather than decrease it. Altogether, the data suggest the presence of either an ECRH triggered outward convection of momentum or an intrinsic, counter-current directed torque. As there is no way for ECRH to impart significant momentum directly to the plasma, the physical mechanism behind the rotation change is presumed to be related to a Reynolds stress momentum flux triggered by the ECRH induced changes in the temperature profiles and plasma turbulence. The magnitude of the missing convection or torque can be estimated by using computed NBI torque density profiles and making reasonable assumptions on the other quantities in the momentum conservation equation.

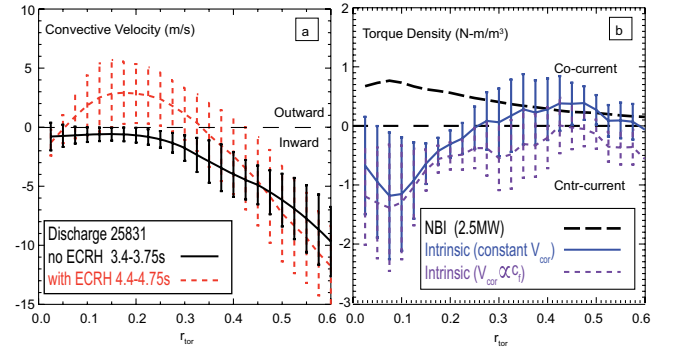


Figure 2: (a) Calculated convective velocities with and without ECRH. (b) NBI torque density profile and calculated intrinsic torque densities using two different assumptions for the convective velocity.

In figure 2a the convective velocities ( $V_c$ ) calculated via this method for a non-ECRH and ECRH case are shown. Here, it is clear that with ECRH a core localised outward convection of momentum of a few m/s is required to explain the observed rotation profiles. Figure 2b shows the calculated intrinsic torque densities ( $S_{\text{ECRH}}$ ) for the same ECRH case. Here, the intrinsic torque was calculated using two different assumptions for the convective velocity; first,  $V_c$  was assumed to remain unchanged from the NBI only case and second, it was assumed to scale with the ion thermal diffusivity. Both assumptions produce  $S_{\text{ECRH}}$  profiles that are effectively zero outside of  $\rho_{\text{tor}} = 0.4$  and are negative in the core with magnitudes that are of the same order as the NBI delivered torque density. The intrinsic torques and convective velocities presented here do not necessarily represent the actual behavior occurring in the plasma discharges. Rather, they seek only estimate the magnitude and direction of additional terms in the momentum conservation equation that could describe the experimental observations. The results of these experiments suggest that in discharges with  $T_e > T_i$  an intrinsic momentum flux can exist, which is able to significantly alter the plasma rotation profile.

If  $T_e > T_i$  is indeed a necessary condition then this effect will probably not contribute to the rotation profiles in large future devices since significant deviations between  $T_e$  and  $T_i$  will not be possible in these machines. However, as this effect can alter the rotation profile on present day tokamaks, it should be kept in mind when using data from these devices to extrapolate to future experiments.

### 3 Particle and Impurity Transport

An important aspect of particle and impurity transport research, relevant also for the prediction of a fusion reactor behaviour, is the effect of electron heating on the electron and impurity density. ECRH is an external means, by which electron and impurity density profiles can be modified. From the operational standpoint this has been used for preventing impurity accumulation, but it also offers the potential for controlling the electron density profile shape. From the physics point of view it is an important tool for identifying the main parameters, on which particle and impurity transport depend. During 2010 research on this topic focused on a set of complementary activities with the aim of investigating the impact of ECRH on both light and heavy impurities in L-mode and H-mode, as well as on the electron density profile. In addition, the potential of using ECRH as an actuator to control the shape of the density profile has been explored. As shown in figure 1 of section 2, applying central ECRH in low  $I_p$ , NBI heated, H-mode plasmas led simultaneously to an increase of the electron temperature, a flattening of the ion temperature and the toroidal rotation velocity profile, an increase in the electron density profile peaking, and a more moderate increase in the boron density profile peaking. These results confirm that central electron heating does not lead to “density pump-out” in all conditions. While density flattening in response to central ECRH is regularly observed in low density L-mode plasmas, increased profile peaking can occur at intermediate densities in both L-mode and H-mode plasmas, particularly when there is a significant increase in both the ratio of electron to ion temperature and their corresponding logarithmic gradients; as in these experiments. In addition, in these plasmas it is observed that around mid-radius the boron density profile is flat, or hollow, during the NBI only heated phase, but becomes moderately peaked with the addition of 2 MW of central ECRH. However, around mid-radius the logarithmic density gradient of boron always remains significantly smaller than the logarithmic electron density gradient. These experimental results have been modelled with local linear and nonlinear gyrokinetic simulations (see chapter “Theoretical Plasma Physics”, paragraph “Transport Analysis Group”). Neoclassical transport has been included, but found to be negligible in these conditions at mid-radius. The results of the modelling are shown in figure 3, and compared to the corresponding experimental values. A satisfactory agreement between predictions and observations is found.

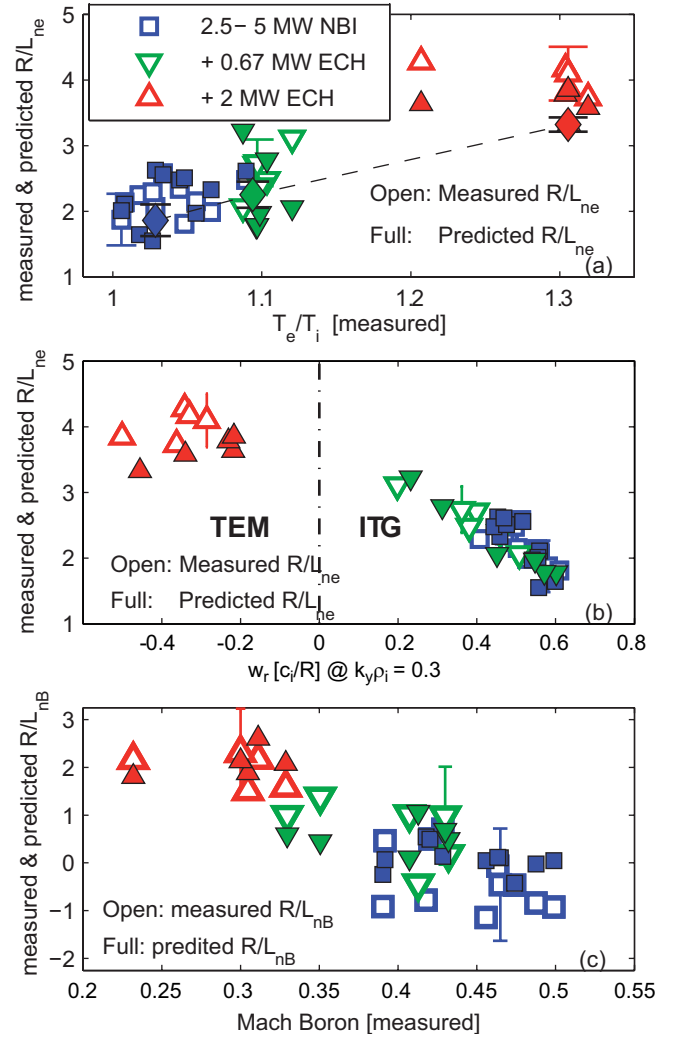


Figure 3: Analysis of representative cases of the three heating phases corresponding to plasma discharges described in section 2. a) Comparison of predicted quasi-linear GS2 (full symbols with squares, triangles pointing down and up), nonlinear GYRO (diamonds connected by a dashed line) and measured (open symbols) values of  $R/L_{ne}$  as a function of the temperature ratio  $T_e/T_i$ . b) Real frequency of the most unstable mode at  $k_y \rho_i = 0.3$ . c) Same comparison on the normalised logarithmic gradient of boron vs. the toroidal Mach number.

This allows the identification of the main parameters and related physical processes, which are responsible for the observed density profile behaviour. The increase in the density peaking with increasing central ECRH power is due to a combination of effects arising from an increase in the temperature ratio and their corresponding logarithmic gradients; with dominant TEM instabilities in the high ECRH power phase, and with ITG modes otherwise. The dependences of the logarithmic density gradient on all these parameters are revealed by the variation of the real frequency of the most unstable mode (which turns out to be a valid ordering parameter



over the entire dataset considered). The modelling of boron turbulent transport suggests that the toroidal rotation and its radial gradient are important ingredients to reproduce the observed boron density behaviour. “Roto-diffusion” is significant, particularly in the cases with NBI only, and allows the observed increase of the logarithmic boron density gradient with increasing ECRH power to be reproduced in the modelling. However, it appears not to be large enough to predict locally hollow density profiles in the phases with NBI only.

The effect of the ECRH deposition position on a medium Z impurity (Argon) has been studied in 0.8 MA ECRH L-modes. A new methodology for the experimental determination of the total impurity ion density produces transport coefficient profiles with high spatial resolution, thus resolving local effects not previously visible, as shown in figure 4.

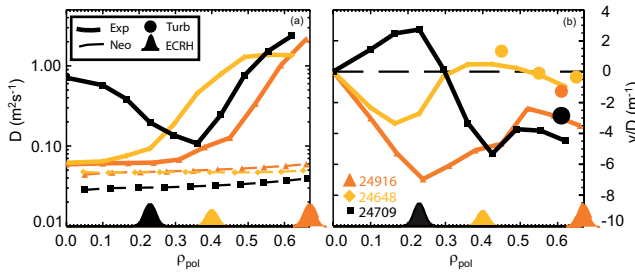


Figure 4: Profiles of  $D$  (a) and  $v/D$  (b) of Ar for three analysed discharges. Dashed lines in (a) are the neoclassical values calculated with NEOART, large dots in (b) are results from GS2 calculations.

Moving the ECRH deposition inward results in an increase in diffusivity up to one order of magnitude (figure 4a) and a transition of the convection from negative to positive (figure 4b) around the ECRH deposition radius. For deposition close to, or outside of the  $q=1$  surface (localised at  $r/a=0.3-0.4$ ) the central diffusivity is at neoclassical levels. Linear gyrokinetic calculations of the turbulent drift parameter  $v/D$  (figure 4 b) reproduce qualitatively the decrease of  $v/D$  with increasing radius outside of the intermediate deposition location. Since the positive drift parameter  $v/D$  is predicted to be approximately constant with increasing Z, the effect is expected to persist also for heavier impurities such as tungsten.

The response of the electron density profile to central ECRH enables this heating system to be used to control the shape of the plasma density profile. A real-time density profile reconstruction algorithm has been developed and active feedback control of the shape of the density profile using ECRH as an actuator has been demonstrated. Since the effect of ECRH on the density profile depends on plasma conditions, a controlled increase or decrease of the density peaking has been obtained by the application of central ECRH in L-modes at low or moderately high densities respectively.

#### 4 Improved Confinement with $N_2$ Injection

To ensure the compatibility of a tungsten wall tokamak with high power advanced scenarios, radiative cooling by  $N_2$  seeding at the plasma edge has proved to be efficient and reliable in reducing the heat load on the divertor plates, together with central ECRH to prevent impurity accumulation and density peaking. A positive side effect has been a systematic confinement enhancement, with  $H_{98}$  factors increasing by 10-20 % (figure 5).

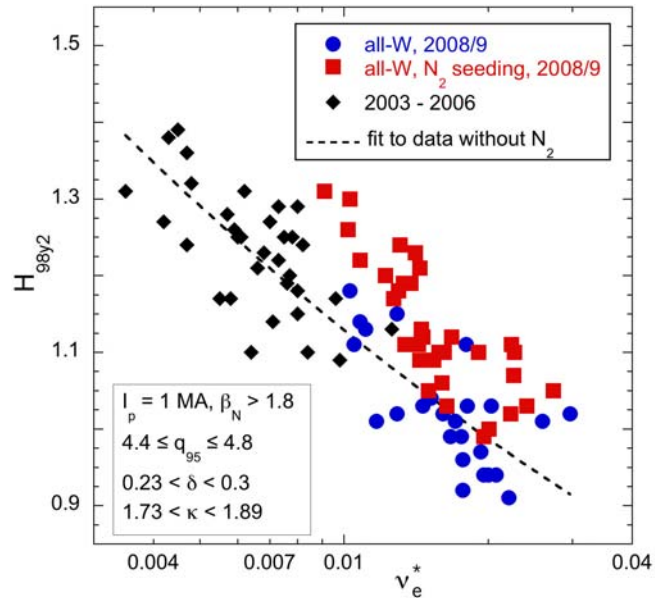


Figure 5:  $H_{98}$  as a function of collisionality for early heated improved H-modes. The seeded data points (red) have systematically higher confinement compared to the blue ones without nitrogen. Black triangles are from previous campaigns (before completing the W wall). The lower collisionality is not accessible in the all-W AUG so far.

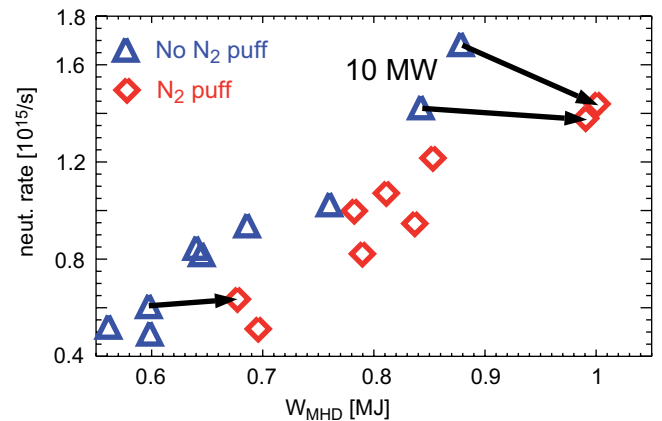


Figure 6: Neutron rate as a function of the plasma energy for pairs of similar discharges with (red) and without (blue)  $N_2$  seeding. The arrows connect some of the pairs. The neutron rate is roughly constant, despite the improved confinement.

The improvement occurs in freshly boronised as well as in unboronised conditions. The neutron yield, however, shows less or no increase, a result of the higher impurity content, with N compensating the higher amount of fast beam ions due to the higher slowing down time of the seeded plasmas, as shown in figure 6.

To identify the causes of the high confinement the core transport has been analysed. The main contribution is provided by the increase of both temperature profiles, in the core and in the plasma edge (see figure 7).

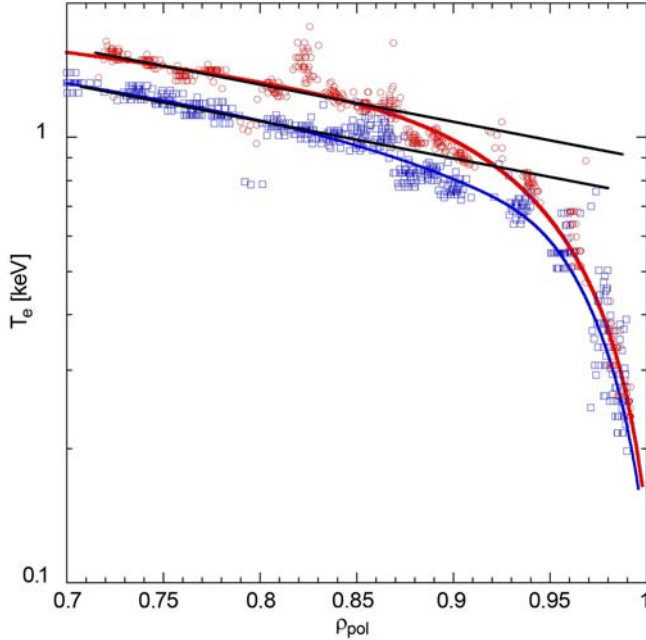


Figure 7:  $T_e$  profiles for the seeded (red) and unseeded (blue) cases, in semi-logarithmic scale.  $R/L_{Te}$  is constant within  $\rho_{pol}=0.85$ .

$Z_{eff}$  is higher in the seeded case, in particular at the plasma edge, as figure 8 shows. This implies that N does not penetrate too deep into the core, while radiating a significant amount of power in the divertor. An independent diagnostic for the

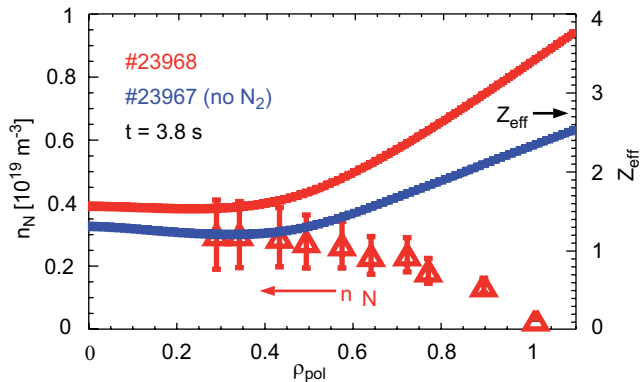


Figure 8:  $Z_{eff}$  profile from bremsstrahlung for the seeded (red) and unseeded (blue) cases, and N density profile from CX.

nitrogen content is the charge exchange recombination spectroscopy (CX). The measurements are in the correct range but are not entirely consistent with the  $Z_{eff}$  deduced from Bremsstrahlung. In particular, the N density profiles from CX are usually not hollow, but rather flat or slightly peaked (see figure 8). Unfortunately N density profiles are available only for a few discharges. A definitive conclusion requires more experimental profiles in the forthcoming campaign.

In figure 9 the temperature gradient length  $R/L_T$  appears to be unaffected by the  $N_2$  seeding within  $\rho_{pol}=0.85$ . In fact the core transport is almost unaffected by N; the dilution effect being compensated by higher  $T_e$  and hence stronger profile stiffness, as non-linear gyro-kinetic simulations in figure 9 show.

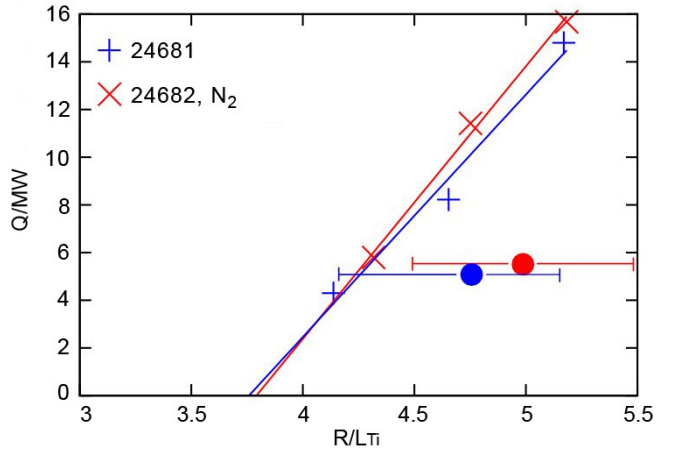


Figure 9: Gyrokinetic calculation of the heat flux as a function of  $R/L_{Ti}$  at half radius. The dilution effect on the ITG mode is compensated by stronger profile stiffness at higher  $T_e$ . As a result,  $R/L_{Ti}$  is unchanged.

Between ELMs,  $R/L_T$  does change, however, outside  $\rho_{pol}=0.85$ , i.e. inside of the pedestal region. The ELM frequency roughly doubles in the seeded case, but the energy loss at each ELM crash is significantly reduced (see figure 10).

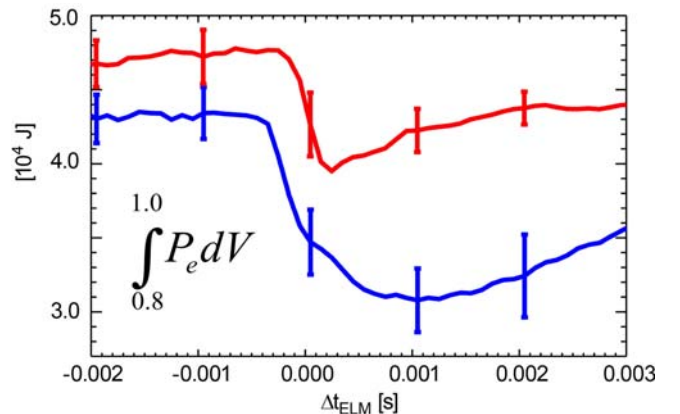


Figure 10: Pedestal energy loss per ELM in the seeded (red) and unseeded (blue) discharge. ELMs crashes are milder in the seeded case.



The fast energy content increases due to the longer slowing down time of the beam ions with higher  $T_e$ , but, it accounts only for a small fraction of the improvement. It comes on top of an improved thermal confinement. The confinement degradation with power in  $N_2$  seeded discharges can be reconciled with that for unseeded discharges by adding a  $Z_{\text{eff}}^{0.6}$  dependence. The observed power dependence is lower than predicted by the IPB98(y,2) scaling (-0.54 instead of -0.69), which results in higher  $H_{98}$  factors, for both seeded and unseeded discharges, at higher  $\beta_N$ .

### 5 Controlled Tungsten Pin Melting Experiments

Although AUG has operated successfully as a full-tungsten device for several years now, the fear that off-normal heat flux excursions or a small misalignment of divertor tile castellations in ITER could provoke melting of the material is still considered an argument against the use of tungsten as a plasma facing (divertor) material. In order to test the impact of such an event on the plasma performance a  $1 \times 1 \times 3 \text{ mm}^3$  tungsten pin was introduced at the outer target plate by the divertor manipulator. By moving the strike point towards the pin melting was induced at a given moment (2.1 s) during the discharge. Weight measurements before and after the experiment showed that 20.6 mg or  $N_{W,\text{pin}} = 6.7 \cdot 10^{19}$  W atoms were lost during the plasma exposure. A first qualitative result was that the discharge is only little affected by this massive impurity event. The total radiation increases by only about 10 % during some 500 ms and consequently no notable effect is seen on either the line averaged density or the stored energy. The melting event was accompanied by the ejection of W droplets, which were observed and tracked by a fast framing camera equipped with an  $D_\alpha$  rejection filter (figure 11).

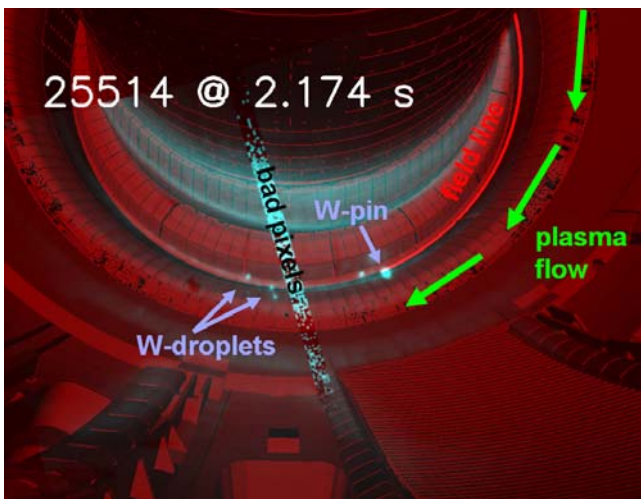


Figure 11: Ejection of droplets from a melting W pin in the divertor observed by a fast framing camera.

This diagnostic provided another important qualitative observation, namely that the droplets all move into the direction of the plasma flow, i.e. away from hot regions of the plasma. This macroscopic transport contributes efficiently to the expulsion of material by the plasma. In order to evaluate the impact on the core plasma quantitatively and to compare it to a main chamber source in the same discharge,  $N_{W,\text{LBO}} = 4 \cdot 10^{17}$  W atoms were also injected into the edge plasma at the low field side close to the mid plane by means of laser ablation (LBO).

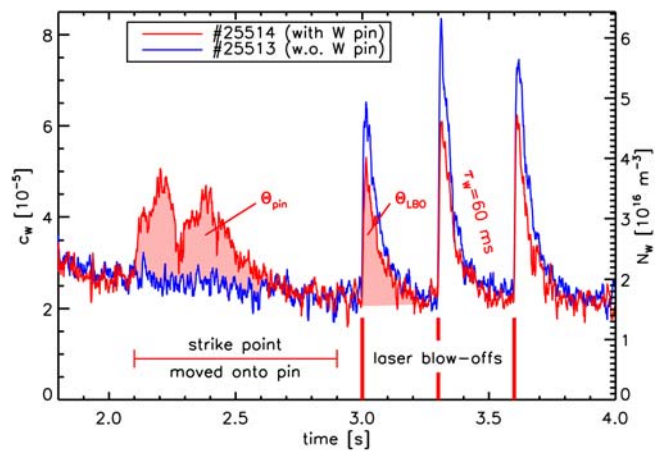


Figure 12: Spectroscopic measurement of the core W concentration during impurity events caused by the melting W pin and laser blow-off.

Simultaneously the core W concentration  $c_W$  was monitored spectroscopically as shown in figure 12. Multiplying  $c_W$  by the average electron density  $n_e$  and the core volume  $V_c$  immediately gives the total number of W atoms stored in the core  $N_W = c_W n_e V_c$  at a given time (right scale of figure 11). Since the melting event (duration  $\sim 500$  ms) and the LBO (laser duration 10 ns) occur on quite different time scales, the temporal behaviour of  $N_W$  has to be taken into account – here by using a simple 0D model  $dN_W/dt = \Phi_{\text{in}} N_W/\tau_w$ . For this model the total flux to the core is divided into an influx  $\Phi_{\text{in}}$  and an outflux given by  $N_W$  divided by an average particle confinement time  $\tau_w = 60$  ms, which is determined directly from the decay time after the LBO. From this model and the measurement in figure 12  $\Phi_{\text{in}}$  and also its temporal integral, the core throughput  $\Theta$  can be determined. Subtracting the W influx from background sources measured during a reference discharge (blue curve) it is found that only  $\Theta_{\text{pin}} = 7.9 \cdot 10^{16}$  of the eroded W atoms penetrate the core, which corresponds to a screening efficiency of  $S = N_{W,\text{pin}}/\Theta_{\text{pin}} = 850$ . In comparison to that a much higher fraction  $\Theta_{\text{LBO}} = 3.0 \cdot 10^{16}$  of the atoms originating from the LBO cross the separatrix, which reflects the much lower screening efficiency  $S_{\text{mc}} = N_{W,\text{LBO}}/\Theta_{\text{LBO}} = 13$  for main chamber sources. An important parameter is also the divertor screening efficiency normalised to that of the main chamber  $R = S_{\text{div}}/S_{\text{mc}} = 65$ , the so-called retention factor.

$R$  is a robust number since it does not depend on the absolute calibration of the spectroscopic measurement.

It has to be pointed out that although the nature of the sources in main chamber and divertor is quite different, in both cases the total number of W atoms was used to determine  $R$ . At least for the divertor source, however, it is known that a significant fraction of the material remains in the liquid state without ionizing. The fraction of material vaporizing and ionizing from the droplets was estimated from a model describing the power and the momentum balance of the droplet. Here, W is a particular material since above its melting temperature the blackbody radiation emitted from the droplet becomes the dominant energy loss channel. This self-cooling effect strongly suppresses the vaporisation and therefore the disintegration of the droplet. Assuming an ELM averaged parallel heat flux of  $60 \text{ MW/m}^2$  and a number of droplets between 10 and 100 it was found that about 30 % of the material is ionised giving a retention for ionised W of  $R_{W+} = 0.3 \cdot R = 20$ . In this model, however, neither the possible poloidal motion of the droplet, nor the extreme interaction phase when an ELM interacts with the pin are taken into account. In addition to the experiments, simulations with the Edge Monte Carlo 3D (EMC3) – Eirene code package were performed to model the deuterium plasma as well as the W impurity and the neutral particle transport. An important result of this analysis was that  $R$  depends very sensitively on the source position relative to the strike point. At the strike point large gradients of the friction and thermal forces are found, which strongly affect the probability for the impurities to reach the main chamber. In particular the so called flow reversal phenomenon is responsible for this effect. In order to validate these theoretical results against the experiment, further discharges scanning the source to strike point distance are planned for 2011.

## 6 Technical Systems

2010 was dominated by a major venting to install the first set of magnetic perturbation coils. In-vessel work started on January 11<sup>th</sup> and was finished with the closing of the entrance port on Friday, 12<sup>th</sup> November. After leak detection and an extensive baking of about 7 days, the first plasma break-down could be achieved on Tuesday, 7<sup>th</sup> December. During the remaining 6 shot days in 2010, 101 discharges were started, 59 of them were useful for the physics program that was concentrated on exploring magnetic perturbation coil effects on ELMs. ELM suppression could be successfully demonstrated.

The in-vessel inspection immediately after the vessel opening revealed an excellent status of the machine. Local surface modifications from arcs burning in remote areas of the divertor and on selected components deep in the limiter shadow were observed.

### 6.1 B-coil Installation and Machine Modifications

During the 10 month of vessel opening the following main tasks had to be fulfilled: (i) Installation of  $2 \times 4$  B-coils at the upper and lower PSL (figure 15) (ii) a modification of the outer divertor (figure 13) and the ICRH antenna limiter contour, (iii) modification of the pumping system to free space for the installation of current feed through for the lower B-coils and installation of a new vacuum system for the coil feed throughs, and (iv) modification and installation of new diagnostics.

In total  $2 \times 8$  ELM control coils will be finally installed onto the upper and lower PSL, respectively, in 2010/2011. Forces, in particular during AC operation, require a solid fixing of the coils. Altogether, about 800 M6 and 400 M8 screw threads had to be manufactured inside the vessel and 16 cut outs had to be milled into the PSL.

The B-coil installation was organised in three phases. First, the vessel was prepared for machining of the PSL, i.e. the protection tiles of the PSL and the outer divertor were removed during the first month. This phase was followed by a 3 months machining period to prepare the fixing of all  $2 \times 8$  coils. During this time, the vessel was wrapped in thick plastic foils to protect in vessel components against metal slivers. After an intensive cleaning of the inner vessel, the installation of the B-coils, the divertor and the diagnostics started in May. In September 2010  $2 \times 4$  B-coils were installed and the conditioning of the PEEK insulation separating the vessel potential of the current feed through from the PSL potential of the coil casing and acting as CF gasket was done by applying routine baking procedures. Due to the strong and non-uniform shrinking, the baking had to be performed 3 times.

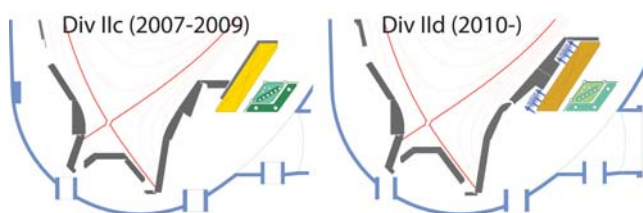


Figure 13: Modification of the outer divertor as a consequence of B-coil installation.

The installation of B-coil current feed throughs required a modification of pumping ducts. AUG is evacuated by 14 turbo molecular pumps (TMP) connected by special pumping ducts to 14 lower C-ports. A subset of 6 C-ports has to be used for the current feed through of the B-coils. The maximum length of a current feed through is 2.2 m, which allows installing them in the short version of pumping ducts. Long ( $> 3 \text{ m}$ ) pumping ducts had to be reassembled to short versions. This was done for pumping ducts in sector 12 and 3 in 2009 and 2010, respectively. In addition, in sector 1 and 7 two current feed throughs are installed. Here, the pumping ducts were removed.

A third pumping duct in sector 14 will be removed in 2011. The removal of 3 TMP and the reduction of the conductance in the ports that are shared with current feed throughs result in an overall reduction of the effective pumping speed from 10 m<sup>3</sup>/s in 2008 to 8 m<sup>3</sup>/s in 2011/12.

The vessel opening was used to modify existing and to install new diagnostics. Diagnostic modification was necessary because for a few diagnostics located in the upper C-ports, the field of view was reduced due to the upper B-coils and the B-coil protections. The X-point manipulator located in the lower C-port in S10 had to be removed to free space for a current feed through. Here a new slim manipulator was designed, manufactured and installed. Further, a new valve for massive gas injection at the inner wall of the torus was designed and installed. The CXRS diagnostics were completed by a poloidal system and a system measuring at the high field side. A third fast ion loss detector was installed at the low field side in the upper part, about 0.5 m above the midplane, of the torus. The gas feeding system below the roof baffle was extended by 8 additional tubes.

## 6.2 Experimental Power Supply

The main achievement of the Experimental Power Supplies department was the installation and commissioning of a Mechanical Braking System for the flywheel generator EZ4. The goal is to have two independent braking possibilities for every generator in case of emergency. EZ4 has a combined motor/generator. Therefore the easy application of additional braking resistors at the generator side, as implemented previously at the generators EZ2 and EZ3, was not possible. Furthermore, the space available at the generator building is very limited. The solution is a combination of a 7 MW hydraulic dynamometer (water brake) for the speed range from 1650 down to 200 rpm and a 40 kNm disk brake engaged by a clutch at 200 rpm. This system allows a brake time below 10 minutes and thus within the lubrication capabilities of the oil tank, if all pumps would fail. The first step in spring 2010 was the extension of the generator foundation by a 14 tons supporting structure. The Mechanical Braking System has been installed in August, followed by the installation of the water cooling and the control system. To ensure a smooth work-flow and to reduce costs, the project management coordinating the various contractors and the complete design, installation and commissioning of the water cooling control system have been carried out by IPP staff. The commissioning of the complete system took place in December 2010. It turned out that some modifications of the disk brake assembly were necessary. Therefore the disk brake and clutch were disconnected. The dynamometer operates at the generator under experimental conditions without problems. The disk brake will be re-installed in spring 2011.

During the thorough maintenance of generator EZ2, the complete assembly has been dismantled, inspected and re-

assembled. Ultrasonic testing revealed a delamination of one of the generator bearings. The bearing had to be refurbished. Furthermore, damage of the flexible connections of the damper cage have been detected. At generator EZ3, improvements of the control and protection system, as previously implemented on generator EZ4 have been installed. Generator EZ4 has been re-balanced to reduce the vibration level.

The crossbar distributor of the high current power supplies has been extended to allow for a more flexible supply of the vertical coils. The required power and control facilities for the supply of the new saddle coils with 1 kA DC from an existing converter have been prepared.

The re-installation and modification of an old W7-AS high voltage power supply makes good progress. Most of the installation has been completed. The commissioning is scheduled for summer 2011. In addition, a driver stage for the ICRH has been enhanced and an additional “spare” driver stage for the new ICRH test facility has been commissioned.



Figure 14: Mechanical Braking System EZ4.

## 6.3 Neutral Beam Heating

The eleven months shut-down in 2010 for the installation of the first set of B-coils was used by the NBI group for extended maintenance and upgrades beyond the standard overhaul of the titanium sublimation pumps and a thorough cleaning and inspection of the interior of the two injectors. The biggest task was the replacement of the ageing S5 SIMATIC programmable logic controllers of injector I with up-to-date S7 systems and porting and/or rewriting of their software. Extensive early testing helped to reduce problems at the beginning of the new campaign to a minimum. The experience gained in this S5-to-S7 transition will be helpful to assure an even smoother upgrade of injector II during one of the next extended shut-down periods. Another important improvement was the replacement of the deceleration voltage safety interlock by a new hardware based solution.



This interlock ensures that beam extraction will be stopped if there is insufficient negative voltage at the deceleration grid to suppress back streaming electrons. The previous software based interlock had been a frequent source of erroneous pulse stops during modulated beam operation. The new interlock performs without these flaws.

In early 2009 a new water-cooled wall shielding in the duct was installed to replace its worn out predecessor. This new shielding is also a design prototype for the corresponding component on W7-X. The 2010 shut-down offered the first opportunity for inspection after one full campaign in use. The only minor problem detected was that a few screw hole plugs on the front surface had come out. This problem could be fixed with graphite glue.

Another W7-X component, a HF transformer, was tested on source 7 (Injector II). Despite a design identical to the transformers in use at AUG the test became necessary because the old cable and ferrite types were no longer available. Whereas the new cable proved suitable, the ferrites did not. At the end of November 2010, NBI went back into operation with all 8 sources fully operational and ready to deliver up to 20 MW of heating power.

#### 6.4 Ion Cyclotron Resonance Heating

In co-operation with IPR, India, one of the ASDEX/W7-AS generators was modified to use an EIMAC 4CK2.500KG tetrode. This type of tetrode is still commercially available, in contrast with the type built into the AUG generators, which is no longer being manufactured. The modification of one of the ASDEX/W7-AS generators allowed testing this tetrode without any risk for the operation of the AUG generators.

Even though the modifications are not completed yet, the modified generator has already achieved one second pulses at 1.1 MW and 1.2 MW for 20 ms. Higher power levels and longer pulse length require a change to the external cooling system to fulfil the different requirements of the new tetrode and the modification of the HV power supply to allow different voltages to be applied to driver and final stage. Since all spare tetrodes of the AUG generators are currently in use, it is essential to modify the generators step by step to accept the EIMAC tetrode.

In AUG, one of the antennas was changed to test some of the guiding principles and calculations according, to which antennas can be optimised to reduce impurity production. The limiters of this antenna were widened (see figure 15) and the antenna straps narrowed. Should the experiment confirm the calculations, more substantial modifications are envisaged for the antenna as the optimisation calculations shows that further significant reduction of the impurity production can be obtained.

The limiters of the other three antennas were replaced from the equatorial plane up to the top of the antenna with limiters of larger depth, in order to provide protection for the new

coils, which have been built into the machine. This increases the distance between the antenna strap and the front of the antenna and will decrease the coupling of the antenna.

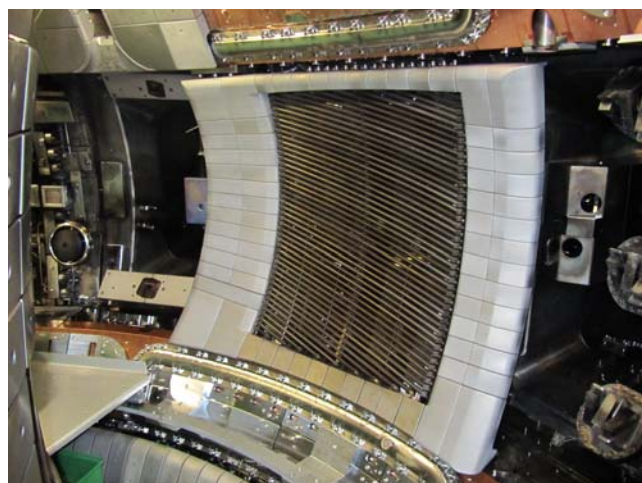


Figure 15: Modified antenna, with wider limiters on both sides, and reduced width antenna central conductors. B-coils are seen above and below the ICRF antenna.

IPP was able to get a steady state generator and coaxial components from the Bayerischer Rundfunk for a symbolic price. This generator has a frequency range of 3.9 MHz to 26.1 MHz, can operate in full steady state at 0.5 MW and at 0.75 MW for one hour and has a modulation bandwidth of 18 kHz. With its lower frequency range and very fast modulation, it provides new experimental options for AUG. Its steady state capability makes it ideal for testing steady state components for ITER or W7-X.

#### 6.5 Electron Cyclotron Resonance Heating

Efforts with respect to ECRH were concentrated on the installation of new gyrotrons in the new ECRH system using the long shutdown. Status at the beginning of the year was one gyrotron absent for repair and one new gyrotron partially in operation but not fully accepted due to problems with the heater contact. In February 2010 the latter gyrotron was operated successfully using a rectifier in the heater supply and was accepted on the basis of an extended guarantee in case of a heater failure. It achieves 0.95 MW (specified: 1 MW) at 140 GHz and 0.85 MW (0.8 MW) at 105 GHz. The repaired gyrotron was delivered in July and accepted in October delivering 0.83 MW (140 GHz) and 0.65 MW (105 GHz), close to its performance before repair. A 3<sup>rd</sup> gyrotron was delivered in October and accepted in December operating at parameters similar to the one accepted in February. With the acceptance of these two gyrotrons, the second stage of the extension of the ECRH systems nears completion. These gyrotrons were financially assisted by EURATOM preferential support. The first stage, which in its contractual structure

leaves more room for development, is not yet completed. The decision if the last gyrotron financed in this framework shall be a 2-frequency or 4-frequency system will be taken in early 2011. The decision depends on independent mechanical stress calculations by KIT, Karlsruhe and IAP, Nizhny Novgorod for the foreseen 4-f operation grooved diamond window, based on the existing samples provided by element-6, Cuijk, the Netherlands. Depending on the risk assessment, a grooved disk will be ordered or an existing flat disk will be used. In the latter case the corresponding 2-f gyrotron is expected to be operational at the end of 2011. A 4-f version with a new grooved disk could be ready in spring 2012. The extension of the new ECRH system in 2010 additionally included the final design of the matching-optics units (MOU) together with IPF Stuttgart.

IPP workshops (ITZ) were heavily involved in MOU production as well as in the completion of the HV-modulators. Further hardware installations concern the holographic reflector plates on the inner heat shield used for O<sub>2</sub>-heating. Together with IPF Stuttgart (see section 9), additional thermocouples have been integrated based on experimental results in 2009. In the 2011 campaign these thermocouples will be used for a real-time safety system, ensuring that the microwave beam either stays on the plate or is switched off. The beam moves owing to variations of the refractive index, which in turn depends on the electron density profile. Another major hardware system installed in the new part of the AUG-ECRH is the FADIS system developed at IPF, Stuttgart and TNO, Delft and tested in the ECRH installation of W7-X. The system allows switching power between two outputs either by mechanical tuning of the interference setup or by variation of the gyrotron frequency. An application foreseen for 2011 is to combine NTM stabilisation by a modulated beam (O-point heating) with central heating of the plasma. Such applications are especially interesting for devices with more beam lines than gyrotrons, as planned for ITER.

## 6.6 Data acquisition and computer infrastructure

The data acquisition and discharge control system was routinely operated. Two special topics are highlighted below.

### - The Video Real-time Safety System (VRT)

The VRT for machine protection is based on analogue CCD/CMOS cameras installed in different ports covering nearly the whole in-vessel surface. All these cameras are recorded and archived as MPEG streams, some of them are used to detect possible overheating of built-in components and movable probes in real-time. The system is in standard operation for all discharges. A principal scheme of the realisation and implementation of the system is illustrated in figure 16. The connection to the discharge control system is implemented via a status signal, reporting periodically (40 ms) if local overheating of parts of the divertor is detected or if one of the inspected manipulators is glowing in the

pre-defined region of interest. If that occurs the discharge is terminated by a soft pulse stop. This happened for 2 % of the plasma discharges within the last campaign.

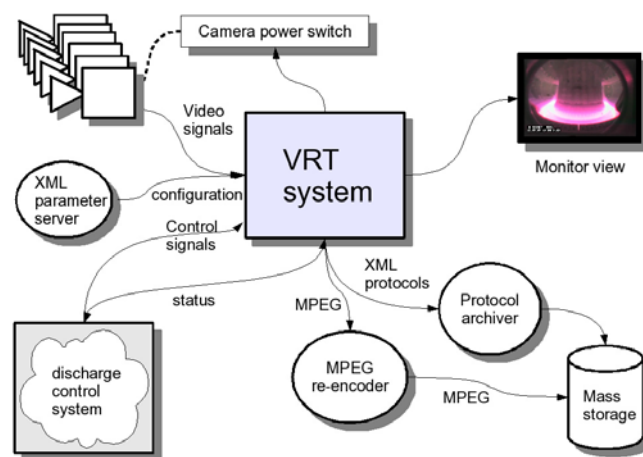


Figure 16: Data flow diagram of the real time video system.

### - Infiniband for Real-time Feedback

Benchmarking MPI (Message Passing Interface) as a means to run data analysis codes in parallel on multiple computing nodes, has verified that this concept seems a promising way to speed up physics calculations and extend the normal size of control codes for real-time feedback. However, the communication latency over Ethernet was identified as a main bottleneck when trying to tune this sort of cluster applications for an integrated diagnostics and control environment. This led to setting-up a small Infiniband computing cluster to test possible advantages of this high-speed communication method over Ethernet. The tested cluster consists of two Solaris X86 eight-core nodes, a Sun Infiniband switch, and the Sun HPC implementation of the MPI software suite for Solaris. The overall communication latency for data buffer sizes varying from 64 to 8096 bytes over Ethernet was found to be 180 to 700  $\mu$ s. In contrast latencies found with the same benchmark code just replacing Ethernet by Infiniband were 22 to 140  $\mu$ s. This improvement in latency will allow real-time criteria to be better satisfied.

## 7 Core Plasma Physics

### 7.1 Energetic Particle Losses Induced by Alfvén Eigenmodes

Convective and diffusive energetic particle losses induced by shear Alfvén Eigenmodes (AE) have been recently observed in the AUG tokamak. Simulations with the full orbit code GOURDON and the guiding center drift orbit code HAGIS have been performed to better understand the orbit topology of the escaping ions and the nature of their interactions with the AE wave fields. Figure 17 shows the typical trajectory of a lost ion in the presence of AE.

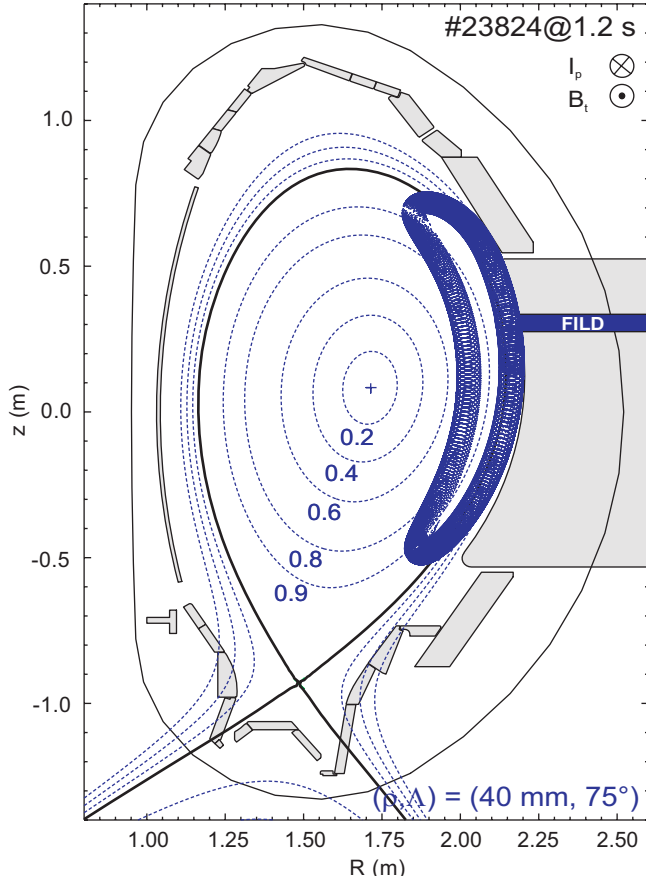


Figure 17: Typical trajectory of an escaping ion in the presence of AE.

## 7.2 Sawteeth Destabilisation of Fast Particle Stabilised Sawteeth with ECCD

It is often observed that large sawteeth trigger neoclassical tearing modes (NTM) well below the usual threshold for this instability. At the same time, fast particles in the plasma core stabilise sawteeth and make large crashes possible.

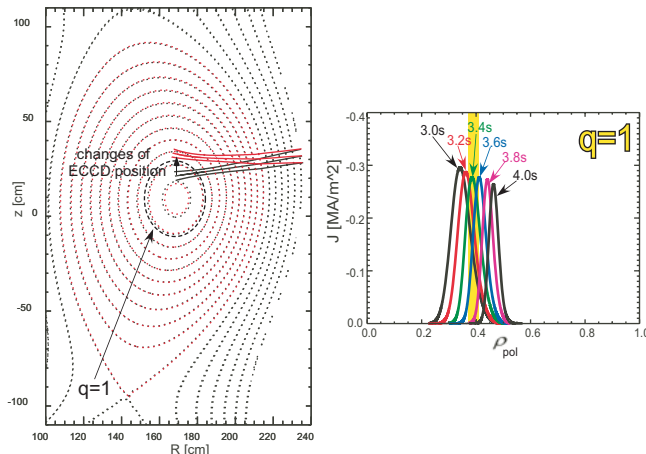


Figure 18: Changes of the electron cyclotron current drive position and shapes of the current related profiles.

This fast particle stabilisation effect will be much more important in ITER. The flexible heating system of AUG allows an ITER relevant demonstration of fast particle (NBI+ICRH) sawtooth stabilisation. Such sawteeth can then be destabilised by electron cyclotron current drive (ECCD) as foreseen in ITER. Results of first experiments show that moderate ECCD from a single gyrotron is able to destabilise the fast particle stabilised sawteeth. A reduction in sawtooth period by about 40 % was achieved in these experiments. The predicted sawtooth amplitude in ITER is about the critical size to trigger NTM. Thus, a 40 % reduction of the sawtooth period could be sufficient to avoid such triggering. Further experiments are planned to provide a solid basis for extrapolating to ITER conditions.

## 7.3 Hollow Central SXR Profiles and Inverse Crashes

Hollow soft X-ray radiation (SXR) profiles and repeated inverse crashes (IC), where profiles relax from hollow to flat, have been observed in H-mode discharges with central ECRH (see figure 19). As in the case of sawtooth crashes (SC),  $T_e$  profiles are flattened during IC with the inversion radius close to  $q=1$ . Both types of crashes have (1,1) precursors. Therefore, it is assumed that IC are plain SC with initially hollow SXR profiles. Since central  $n_e$  and  $T_e$  profiles are peaked, impurity densities must be hollow. The related central (unfolded) radiation can be up to 5 times lower than the maximum.  $Z_{eff}$  can hardly account for this variation, so hollow tungsten profiles must be assumed. Neither effects of plasma rotation nor turbulent transport with increased  $T_e$  gradients can account for the hollowness. The  $q=1$  modes are observed with hollow SXR profiles and a radiation peak close to  $q=1$ . However, W snakes are not observed. In many discharges (also without ECRH) several (1,1) modes with different frequencies simultaneously at the same position. SXR profiles are hollow only when a (1,1) mode with lower frequency is dominant.

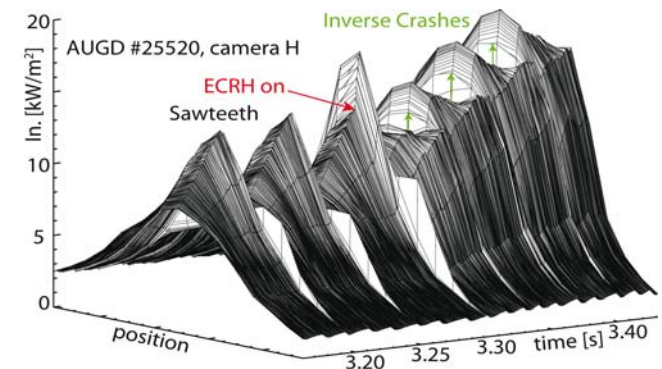


Figure 19: Line integrated SXR profiles changing from peaked to hollow before the crashes when ECRH is switched on.



#### 7.4 ECCD Based NTM Control Using Real-time Computers

Advanced scenarios of tokamak operation are considered key to achieving efficient fusion power. These scenarios are prone to the occurrence of so-called magneto-hydrodynamic modes, which form magnetic islands. Neoclassical Tearing Modes (NTM) deteriorate the plasma confinement substantially. The method of choice for controlling and avoiding NTM is deposition of ECCD inside the magnetic island for stabilisation. In the newest approach, the ECCD deposition is controlled by a moveable mirror, which directs the ECRH beam. The magnetic equilibrium determines the location of rational surfaces where an instability may develop (usually  $m=2$ ,  $n=1$  or  $m=3$ ,  $n=2$ ) even before the island appears in the plasma. ECE measurements can make use of correlation analysis ( $T_e$  fluctuations and magnetic signals) to determine the actual mode location, when it is present. Both methods are compatible with real-time (RT) control.

The ECCD deposition location can be attained from correlating ECE signals by using a modulated ECRH beam, but for predictive calculation of the deposition, a real-time version of the TORBEAM code is used. RT-enabled diagnostics provide the input data to TORBEAM (equilibrium, electron temperature and density and actual mirror angle).

A proof of principle discharge with pre-programmed (feed-forward) mirror positions and sufficient heating to trigger an  $m=3$ ,  $n=2$  NTM was run successfully in December. Data analysis shows that the movement of the ECCD deposition by means of tilting the mirror was indeed the key parameter to stabilise the magnetic island, which was unaffected by the ECCD until the correct mirror angle was set by the control system. It was shown that an NTM could be stabilised by ECCD current drive. This is the first time at AUG, where this was achieved by moving the ECRH mirror instead of changing the ECRH resonance by ramping the magnetic field. Experiments closing the now possible control loop and thus demonstrating active control of NTMs by ECCD are planned for 2011.

#### 7.5 $Z_{\text{eff}}$ Profile Analysis

Effective ion charge  $Z_{\text{eff}}$  profiles are routinely analysed from the combined analysis of CXRS- and bremsstrahlung diagnostics applying the concept of Integrated Data Analysis (IDA) within the framework of Bayesian probability theory. The robust estimation technique applied to the complementary and redundant data allows one to resolve and mitigate data inconsistencies due to wall reflections, gas fuelling, passive or active line distortion of the bremsstrahlung background, and transient distortions. The estimation of  $Z_{\text{eff}}$  profiles relies on the knowledge of the electron density and temperature profiles, which are themselves obtained from an integrated analysis of the lithium beam, interferometry, and ECE diagnostics. The results are validated with low-impurity ( $Z_{\text{eff}} \approx 1.0$ ) and helium discharges ( $Z_{\text{eff}} \approx 2.0$ ).

With a temporal resolution of 50 ms, the correlation of the improved plasma confinement induced by nitrogen seeding with the increase of  $Z_{\text{eff}}$  can be studied. The enhancement of  $Z_{\text{eff}}$  with nitrogen seeding is stronger at the edge than in the core (see figure 20). According to the peeling-ballooning limit of the electron transport barrier an increased  $Z_{\text{eff}}$  at the edge results in an increased electron temperature due to the deuterium dilution. Profile stiffness results accordingly in an increased H-factor.

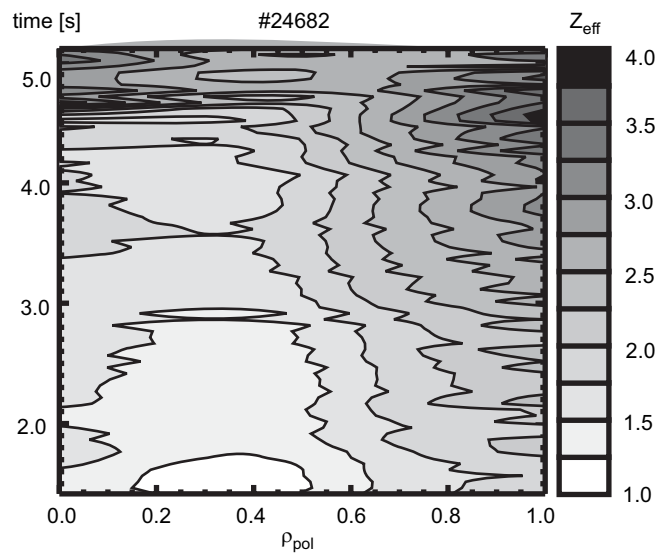


Figure 20: Temporal evolution of the  $Z_{\text{eff}}$  profile with nitrogen seeding starting at 1.7 s. Tungsten starts to accumulate at 4.6 s.

#### 7.6 Disruption Analysis and Mitigation

The main achievements of the last year in the field of disruption studies can be summarised as follows:

- (1) The halo current can reach 50 % of the plasma current, independently of the disruption type, but this maximum value lasts a fraction of a ms. The question whether 2D MHD transport codes like DINA and TSC can reproduce this maximum is under investigation. Preliminary results are positive.
- (2) The toroidal halo current asymmetry is typically caused by a large magnetic perturbation with a toroidal mode number  $n=1$  and appears at the maximum of the vertical displacement during the current quench. This perturbation lasts one millisecond. Long-life asymmetries are an exception in AUG. They neither exhibit a regular periodic structure nor are locked. Large horizontal forces on the vessel have not been observed.
- (3) A preliminary classification of disruption groups based on their physical cause, permits the application of discriminant analysis to find functions describing the boundary between each disruption group and the safe plasma states. Disruptions caused by edge cooling can be predicted by a simple linear or quadratic function of 3 to 5 plasma variables.

Disruptions following  $\beta$ -limit and impurity accumulation are more unpredictable and additional precursors (MHD for example) must be used for their forecast.

- (4) The attainment of the critical density in our medium size tokamak seems to be technically and physically possible. Therefore a fast valve was designed, built and installed on the high field side. It is scheduled to go into operation at the beginning of 2011. The use of multiple valves is expected to favor the redistribution of the injected impurities around the torus, which would otherwise be prevented by the low ion temperature and mobility.

### 7.7 A Real-time Grad-Shafranov Solver

The magnetic equilibrium for a tokamak is described by the Grad-Shafranov equation in the poloidal flux,  $\Psi$ . The algorithm for the solution of Poisson's equation in cylindrical coordinates using discrete sine transforms, DST, along the Z axis and a tridiagonal solver has been adapted for solving this equation in real-time. This algorithm is an alternative to the commonly used cyclic reduction algorithm.

The  $\Psi$  generated by the external poloidal field coils is realised as a matrix-vector multiplication using pre-calculated factors from the Green's function for a current in a circular hoop. A calibration procedure involving the measurement responses to current in each poloidal field coil in the absence of plasma ensures that the probe positions and calibration factors were as accurate as possible.

The first step of the solver has zero as boundary conditions on the edges of the grid. For this solver step it is only necessary to compute those elements at grid point neighbors to the boundary. A special inverse DST can then be used to calculate only the needed elements of the grid rather than the inverse DST for the whole grid. The second step of the solver is carried out with boundary conditions from the first solver step but without current source terms on the right hand side of the Grad-Shafranov equation. Only the first and last elements of each row are non-zero so that a special DST that is significantly faster than the full DST can be used. The tridiagonal solver is applied to this second solver step and the results of the first and second solver steps are added. The solution of the Grad-Shafranov equation is then calculated by an inverse DST, realised as a matrix-matrix multiplication with pre-calculated factors. A weighted least squares fit to the magnetic probe and flux loop difference response yields three coefficients that scale the current profile form factors to give the current profile that is consistent with these measurements. The real-time Grad-Shafranov solver runs with a cycle time of 0.63 ms.

### 7.8 Magnetic Field Dependence of Pellet Injection

Cryogenic hydrogen isotope pellet injection is an effective particle refuelling method and, in addition, an established ELM control method at present fusion devices, foreseen for

ITER as well. In both cases, the penetration depth of the pellet is a key parameter as the large fuelling pellets have to penetrate beyond the pedestal region for effective core fuelling, whereas small ELM pacing pellets have to reach far into the pedestal area for the prompt ELM triggering mechanism to take place.

At AUG an empirical penetration depth scaling had been established based on statistical model selection methods to determine the statistically important variables in pellet ablation based on the HFS-PAD pellet ablation data base. The scaling showed reasonable agreement with ablation theories, the neutral gas shielding model and the hybrid pellet ablation model regarding the electron temperature, pellet mass and velocity. The empirical scaling however indicated negative magnetic field dependence with an exponent of  $-0.41(\pm 0.08)$  that was in strong disagreement (even regarding its sign) with our present theoretical understanding. This may play a significant role in ITER, as its foreseen toroidal magnetic field is 5.3 T compared to about 2.5 T of the measured depths in our data base. In order to resolve this discrepancy, dedicated experiments have to be carried out at AUG to investigate the magnetic field dependence in a single parameter scan especially covering higher toroidal magnetic fields. Recent experiments indicate a magnetic field dependence with exponent of  $-0.63(\pm 0.2)$  in agreement with the prior empirical scaling.

## 8 Edge and Divertor Physics

### 8.1 Characterisation of the Pedestal Width

The analysis of the edge pedestal relies on an accuracy, which is near the limits of plasma diagnostics. Therefore, it is important to eliminate all other sources of uncertainties. Pedestal information from different machines is often derived with different analysis codes, which may lead to small systematic deviations. In cross machine comparisons of pedestal parameters even such relative small deviations can result in unexpected discrepancies. An initial comparison of the AUG pedestal width with literature values from DIII-D showed systematically larger pedestal widths for AUG. This discrepancy could be resolved by analyzing data from both devices with the same code for pedestal characterisation. A two-line analysis yielded pedestal widths of the electron temperature  $w_{Te} \sim 1.8 \pm 0.3$  cm and of the density  $w_{ne} \sim 1.5 \pm 0.3$  cm for both devices without significant deviations throughout the whole dataset.

### 8.2 Modelling of Divertor Detachment

The multi-fluid plasma edge code package coupled to a Monte-Carlo transport code for neutrals, SOLPS5.0, is used to simulate the SOL and divertor of AUG. The code validation effort against experimental data of Ohmic and L-mode discharges for He in forward only and for D fuelled in forward

and reversed  $B_t$  in lower single null configurations has been continued. As long as one of the two divertors is not strongly recombining and the other is at most in a medium recycling regime, satisfactory agreement between the results from simulations and experimental data can be achieved. Neither the experimentally observed high particle fluxes and densities in the far SOL of the inner divertor target at medium to high line averaged densities, nor the strong detachment along the inner vertical target plate, nor the ion flux densities close to the detachment threshold of the outer target can be simulated numerically.

### 8.3 ELM Resolved Edge Profiles

Profiles of the radial electric field in-between ELMs are inferred by analyzing the HeII line radiation at the plasma edge. First results are in agreement with neoclassical expectations. With dedicated edge diagnostics it is found that during the ELM crash the electron density ( $n_e$ ) and temperature ( $T_e$ ) profiles flatten and that the re-steepening of the  $T_e$  profile stagnates when the  $n_e$  profile starts to steepen. After the  $n_e$  and  $T_e$  profiles have gained their pre-ELM shape, no ELM appears then, but large scale fluctuations are observed. It cannot be confirmed that the delay in the recovery of the edge current density due to current diffusion sets the time for the next ELM.

### 8.4 Ion Temperatures in the Scrape Off Layer

Using the Retarding Field Analyser (RFA) technique, ion energies carried by ELM filaments have been measured for the first time in the far scrape-off layer (SOL). Energies, exceeding 160 eV have been found 5-6 cm outside the separatrix, with a decay length of about 2 cm. The measured ELM ion temperature ( $T_i$ ) in the far SOL is in the range 50-80 eV, in good agreement with the predictions from two simple collisionless models of ELM parallel transport. In between ELMs,  $T_i \approx T_e \approx 10$  eV is observed in the far SOL, consistent with relatively strong ion-electron thermal coupling in this region.

### 8.5 ELM Characteristics in Helium Discharges

To achieve sufficient confidence on the predictions for ITER on ELM behaviour and mitigation techniques it is important to compare the ELMs in He and D plasmas in present day experiments. In AUG helium H-mode discharges a similar ELM phenomenology as in deuterium is observed, showing both type-I and type-III like behaviour. A somewhat larger heating power in He than in D seems to be needed to enter reliably the type-I regime. The fraction of ELM energy losses ( $W_{\text{loss}}/W_{\text{MHD}}$ ) lies in the same range as in D and scales similarly with confinement and ELM frequency (see figure 21). About 50 % of the energy loss reaches the targets. These first results indicate that the type-I ELM regime in helium is reached with  $P_{\text{tot}}/P_{\text{thr}}(\text{He}) \geq 1.5$ . Assuming for ITER about

70-80 MW available for heating and the predicted  $P_{\text{thr}}(\text{D})=53$  MW, type-I ELM may be reached only if  $P_{\text{thr}}(\text{He}) \approx P_{\text{thr}}(\text{D})$  as observed at AUG. If the L-H power threshold is considerably higher as for example found in JET, type-I ELM in helium may be still obtained at reduced plasma current.

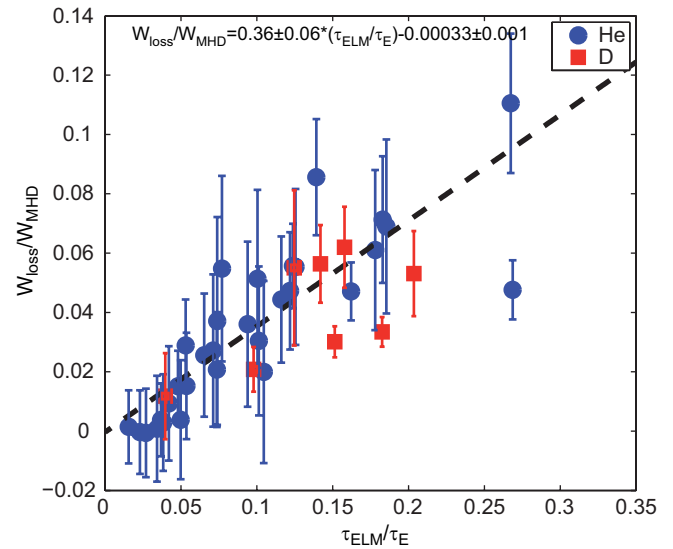


Figure 21: Energy loss fraction as a function of ELM period normalised to the energy confinement time for discharges with  $\delta > 0.2$ . The linear fit is shown with a dashed black line.

### 8.6 Type-II ELM Experiments

Edge localised modes with high frequency and low power (type-II ELMs) occur at high triangularity and close to double null in AUG with full tungsten plasma facing components. The transition from type-I to type-II ELMs was shown to occur above a collisionality threshold. For the first time a characteristic MHD feature around 40 kHz has been localised. The fluctuations are observed in a wide region from the pedestal inwards. Their amplitudes on the low field side of the plasma exhibit maxima above and below the mid-plane. The fluctuations move in the electron drift direction and lead to reduced edge electron temperature gradients. The reduction in edge pressure gradients is connected with these MHD fluctuations, which affect the  $T_e$  but not the  $n_e$  profiles.

### 8.7 Results on Impurity Seeded Discharges

Radiative cooling has been applied in a large variety of plasmas ranging from improved H-modes at intermediate density and heating power to discharges with very high heating power ( $P_{\text{aux}} \approx 20$  MW) or high density and radiation fraction exploring the type-III ELM regime. Generally, the radiated power from the X-point and divertor region increased in  $N_2$  seeded discharges by more than a factor of two, but the core radiation is almost unchanged.

In type I ELMy H-modes the ELM averaged radiation level increased from about 60 % of the input power in unseeded discharges and raises to 80 % in nitrogen seeded discharges. This increase is mainly in between ELMs, whereas the absolute value of the additional radiation during ELMs is nearly the same for both seeded and unseeded discharges. About 20-25 % of the ELM energy is found as radiation in unseeded discharges and 30-40 % in nitrogen seeded discharges, due to the smaller ELM size (see figure 22).

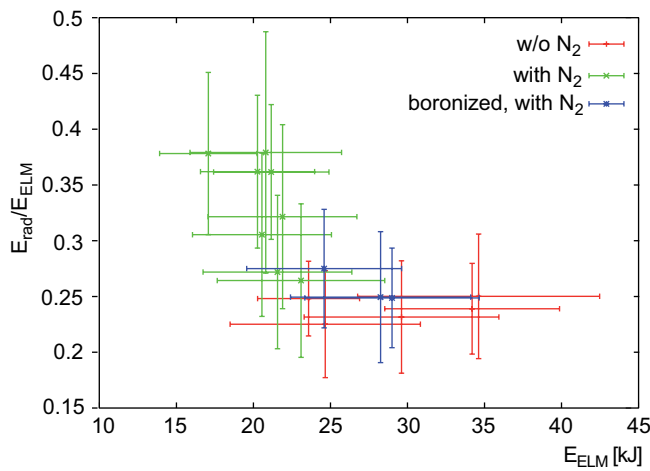


Figure 22: Normalised ELM radiation  $E_{\text{rad}}/E_{\text{ELM}}$  versus ELM energy  $E_{\text{ELM}}$  in unseeded and  $N_2$  seeded (unboronised/boronised) discharges.

This value is comparable to the values found in former campaigns with mixed carbon and tungsten PFCs. Consequently, the power load to the divertor targets during and in between type-I ELMs drops significantly with nitrogen seeding. Even for discharges at highest heating power, good energy confinement could be obtained simultaneously with a low impurity content of the core plasma and efficient power control in the divertor. In seeded type-III ELMy discharges a strong increase of the confinement with plasma pressure was observed. In parallel, a very moderate power flux in the outer divertor and a strong suppression of the W influx could be achieved. Investigations using a mixture  $N_2/\text{Ar}$  as seeding gas revealed a change in central particle transport compared to discharges with  $N_2$  seeding only.

### 8.8 Tungsten Sputtering during ICRH

ICRF operational experience with increasing coverage of the wall with W-coated PFCs is confirmed by the analysis of the rise of W concentration  $c_w$  during RF power application. Although such components as the upper PSL and the divertor horizontal plate, which connect to active antennas along magnetic field lines are non-negligible W sources, the antenna limiters are mostly responsible for the  $c_w$  rise. In recent experiments with rearranged antenna pairs a discrete operation of neighbouring antennas in a wide range of plasma

parameters could be performed. They revealed that the connection length of flux tubes starting at limiters can undergo a step-like change, which correlates to dramatic changes of the W sputtering patterns measured spectroscopically. This indicates that the local magnetic geometry is at least as important for the W sputtering as the distribution of RF near-fields at the antenna. The sputtering is also likely to be influenced by  $E \times B$  density convection in front of the antenna, which is implied from the experiments comparing discharges with normal vs. reversed toroidal field. A modified ICRF antenna, which aims at reduction of the W sputtering has been installed in sector 12. The first results of antenna comparison are anticipated early 2011.

### 8.9 Transport of Tungsten in the Plasma Edge

The transport of tungsten in the plasma edge was investigated by the use of a modulated W-source at the low-field side. It was possible to observe the phase of the W-modulation at three radial positions ( $\rho_{\text{pol}} = 0.7, 0.9, 0.97$ ) and the amplitude of  $c_w$  at one position ( $\rho_{\text{pol}} = 0.7$ ). Additionally, a scan in upper triangularity and gas puffing was performed. A 1-D model (STRAHL) predicted changes in phase shifts in case of changed radial transport parameters. However, the observed phase shifts showed no correlation with neither triangularity nor gas puff. Therefore, radial transport appears to be unaltered by the scanned parameters. On the other hand, changed parallel transport in the SOL and prompt W-redeposition could explain the strong dependence of W-concentration on gas puffing observed in the experiments.

The transport in the edge transport barrier (ETB) is dominated by the effect of Coulomb collisions. W has an even higher collisional diffusion coefficient than the light elements, for which an agreement with purely collisional transport could be deduced from direct measurements. The collisional transport produces a strong inward pinch and a respective peaking of tungsten, which is relaxed during an ELM. When modelling the edge transport with the STRAHL code that treats the parallel losses in the SOL with volume loss rates, the impurity confinement time shows a strong decrease with increasing ELM frequency as experimentally observed. However, there is an equally strong dependence on the characteristic parallel loss time in the SOL, which is at present not well known and requires further measurements to restrict this parameter in the model (see above). The dependence on the diffusion coefficient in the SOL is very weak. In the ETB of ITER, the collisional impurity transport coefficients are about a factor of 20 smaller than in AUG. Thus the time to build up a strong edge gradient is substantially longer. In addition, the ELM frequency has to be kept high (around 20-30 Hz) in order to achieve small ELMs. Thus, the average edge gradient will be quite small, provided that the ELMs do not lead to a much smaller increase of the effective diffusion coefficient than used in the model (see figure 23).



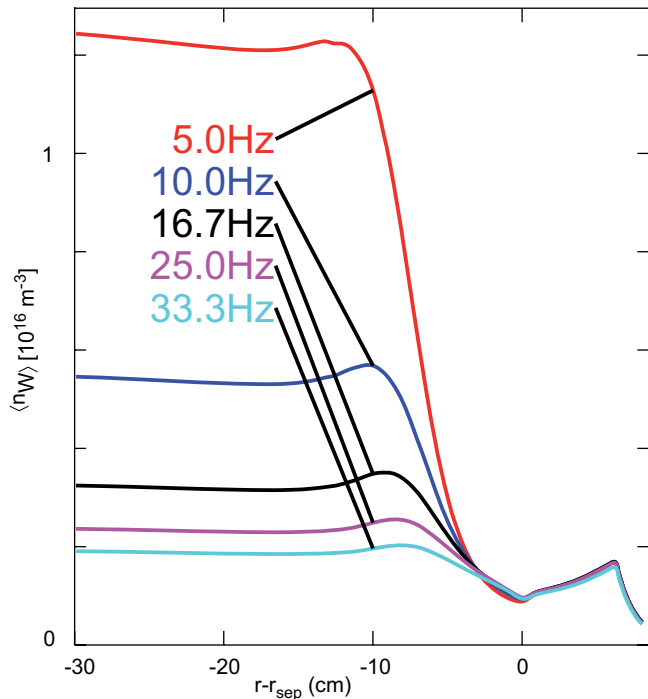


Figure 23: Modelled tungsten profiles in the ITER edge averaged over one ELM cycle. The profiles were calculated for different ELM frequencies and are normalised to the same effective source rate.

### 8.10 Characterisation of Arcs

The arcs observed in AUG can be categorised in arcs ignited at components in contact to the main/SOL plasma and arcs in remote areas, i.e. areas without field line contact to the main plasma. A systematic investigation of localised glow/arc events detected by the video system identified a preferential region above the upper PSL. Events at this position are found in discharges with plasma currents above 0.9 MA, mostly during phases with decreasing plasma stored energy. It turned out, that the events themselves are not the reason for the decay of the plasma stored energy, but a correlation with the ECR-sniffer probe reveals that they are due to a local cut-off for ECRH absorption. The resulting stray radiation is absorbed by PEEK insulators nearby resulting in local electrical fields and overheating. Detailed investigations were performed on the plasma induced, monopolar arcs. High resolution, fast camera observations show single arcing events and identify ELMs as possible initiating process of arcing.

As high Z PFCs show low physical sputtering other erosion mechanisms as for example arcing have to be taken into account to get the total erosion. Arc traces are observed locally in AUG, especially at the inner baffle region. The typical width of the arc tracks in the order of 10  $\mu\text{m}$  requires the combination of different analysis techniques to yield the total erosion. High resolution photographs from complete tiles were taken to derive the total area affected by arcs.

A confocal laser scanning microscopy allowed measuring the erosion by single arcs and their details were studied by SEM. Strong erosion by arcing was always found if the surface conductance is poor, i.e. in deposition dominated regions, whereas at pure tungsten surfaces almost no erosion by arcing was determined.

### 8.11 Dust Investigations

2D dust particle trajectories were extracted from fast framing camera videos by a new time- and resource-efficient code developed at University Nancy. Using hybrid global and local intensity thresholding and linear trajectory extrapolation individual particles could be tracked up to 80 ms even under challenging conditions such as high particle density and strong vacuum vessel illumination. In parallel, dust has been trapped on five strategically positioned silicon wafer collectors. Characterisation of the outer morphology and determination of the elemental composition of  $5 \cdot 10^4$  particles were performed via automated SEM-EDX analysis resulting in the definition of a first preliminary dust classification scheme linking several classes to their most probable production sites.

### 8.12 Gas Balance Investigations

Gas balance measurements were repeated with extended discharge length, yielding to steady state phases up to 3.1 s, during which the gas inlet equals the amount of gas pumped. A series of equal discharges with different gas puffing levels confirms the importance of the amount of gas retained in the wall to reach this steady state phase. Obviously, the gas balance is dominated by dynamic wall loading and out-gassing after the discharge. To investigate the out-gassing in detail, special discharges without active pumping and low gas puff rate were performed. In these discharges three components with a gas release on different time scales could be identified. The investigations show high relative gas retention similar to that reported from ALCATOR C-mod, but the absolute amount of gas retained is almost the same as in high density scenarios. This confirms the earlier observation of an absolute amount of gas loading necessary for dynamic wall saturation.

## 9 University of Stuttgart

### 9.1 Simulations on ECRH Propagation

The fullwave code IPF-FD3D was used to investigate the impact of fluctuations on ECRH beam quality. Several density profiles were taken from the shot database and were overlaid with random fluctuations or single blob structures at various radial positions. An ECRH beam in the standard central heating scenario was injected and its position and mode composition at the resonance layer was analysed. It was found that extreme fluctuation strengths or blob densities

lead to significant broadening and spatial deviation of the beam. In addition, the beam quality was seriously degraded by the appearance of higher Gaussian modes and a strong divergence. A given density blob's influence on the beam degradation depended only weakly on its radial position but strongly on its size and density. It is planned to incorporate experimental knowledge of fluctuation levels into the simulation to assess if there is any significant impact on ECRH in actual operations.

### 9.2 Langmuir Probe Enhancement

Electronic problems have been discovered in the probe system of the midplane manipulator. Investigations of plasma turbulence and intermittent density filaments in the scrape-off layer have sometimes been dominated by cross-talking cables, electro-magnetic pickup and circuit oscillations. The cross talk amplitudes were reduced by more than three orders of magnitude after reconnection of the coaxial cables outer conductors at the manipulator exit. Furthermore, a reduction of electro-magnetic pick-up from the torus hall is expected. Cable low-pass characteristics and non-linear resonances in  $\phi_{\text{float}}$  measurements could be suppressed by impedance transformation close to the probe tips. A newly designed passive filter will be available to suppress aliasing in future experiments. Some former physics results might need to be reviewed if they were based on fast measurements with the old probe setup to rule out systematic errors.

### 9.3 Holographic Mirrors for O2-mode Heating

In the last years, electron cyclotron heating scenarios were developed in order to overcome the X2-mode cutoff in ITER-like plasmas at high confinement and densities near the Greenwald limit in AUG. The O2 mode, which has twice the cutoff density of the X2 mode is one option, but suffers from incomplete absorption. To increase the absorption of this mode to non critical values, the shine through beam is reflected at two holographic mirrors, mounted at the inner wall, to ensure a second pass through the plasma core. For safety issues in these reflectors additional thermocouples have been integrated. In the 2011 campaign these thermocouples will be used for a real-time feedback system, ensuring that the microwave beam either stays on the plate or is switched off, as it moves due to variations of the refractive index depending on the density profile.

## 10 International & European Cooperations

### 10.1 IEA Implementing Agreement

The IEA Implementing Agreement on 'Cooperation of Tokamak Programs (CTP)' was created from a merger of the IEA Large Tokamak Agreement and IEA Poloidal Divertor Agreement, which formally, after five years of discussion, was accomplished in June 2010. The objective of this

Agreement is to advance toroidal plasma physics and technologies by strengthening cooperation among tokamak programmes. The signatories of the agreement are EURATOM, Japan, Republic of Korea, and the United States. Both China and the Russian Federation have been invited to join the agreement. The exchange of information between parties comprises almost all experimental, theoretical and technical areas of fusion-oriented research. For IPP most important is that assignments of scientists, engineers and other technical experts to work at the facilities of the other contracting parties are covered by this agreement. In 2010 several of such visits took place and are reported in the following.

A multi-weeks stay of an IPP scientist at the Plasma Science & Fusion Centre at MIT, Cambridge, US gave an opportunity to exchange the experiences on plasma wall interaction physics and edge plasma physics. This included radiative cooling by impurity seeding, pedestal physics, plasma wall interaction in a high-Z environment during ICRF heating, operational limits of the I-mode, pedestal rotation signatures and charge-exchange with background deuterium. Special focus was put onto the active charge exchange spectroscopy system using a simple deuterium gas puff, which is operational at the inboard and outboard side of Alcator C-Mod. A similar system has been designed for AUG and design assumptions could be verified by a comparison. Using this system at Alcator C-Mod, the impurity transport at the H-mode pedestal was investigated. The discharges of interest were the enhanced  $D_{\alpha}$  H-modes. First indications of the analysis confirm the observations from AUG that the impurity transport at the edge pedestal exhibits a strong inward convection.

The analysis of the edge pedestal relies on an accuracy, which is near the limits of plasma diagnosis. In particular, cross machine comparisons of pedestal parameters may suffer from small deviations resulting in unexpected discrepancies. An initial comparison of the AUG pedestal width with literature values from DIII-D showed systematically larger pedestal widths for AUG. By sending an IPP scientist to GA, this discrepancy could be resolved by analyzing data from both devices with the same code for pedestal characterisation (see section 8.1).

The understanding of apparent inconsistencies between the calculated distribution of neutral beam current density and measured changes in q-profile is important for predictions of q-profile evolution in future devices. In 2008, a series of plasmas have been done on JT60-U (JAEA, Naka, Japan) to better understand the localisation of NBCD. Those plasmas had 3 different phases, first an on-axis NBI phase to create a target plasma with a stable density and energy content. In the second phase, some of the on-axis NBI was replaced by off-axis injection to change the equilibrium q-profile by NBCD. The third phase served as a reference for the first one. As many parameters as possible were kept constant



during the experiment so that the MSE measurement only detects q-profile changes caused by off-axis NBCD. During a stay in Naka, Japan, an IPP scientist compared these JT60-U pulses with ASTRA simulations. The time dependence of MSE angles calculated with ASTRA does not agree with the time evolution measured with the MSE diagnostic. At the moment there is no apparent explanation for this discrepancy and further analysis will be necessary before conclusions on the localisation of off-axis NBCD in JT60-U can be drawn. The next step in the process to improve the understanding of off-axis NBCD will be joint JAEA - IPP experiments on AUG in 2011.

## 10.2 EURATOM Associations

2010 was a year devoted to analysis of experiments conducted in previous campaigns. 25 out of 70 AUG-related publications in refereed journals were written by external first-authors. Thus, the fraction of publications with an external first-author stayed at 35 % as in previous years since the AUG programme was opened, in particular to the EU fusion community. In the case of contributions to conferences this fractions reached even 42 %.

In 2010, also a call for participation in the 2010/11 AUG campaigns was launched. This call was answered with 208 experimental proposals requesting almost 2.300 discharges. Again 35% of these proposals were submitted by non-IPP scientists from 13 EU Associates: CCFE, CEA, CIEMAT, ENEA, FOM, FZ-J, GREECE, HAS, IPP-CZ, IST, ÖAW, RISØ and TEKES. In addition, we received proposals from IPP Greifswald, University of Stuttgart and from international labs like GA, ITER-IO, JAEA and PPPL. After appropriate discussion with the AUG team a prioritised programme was compiled and finally approved by the AUG Programme committee, which met in July 2010. The experiments will be conducted by 5 Task Forces (TF) mainly in the first half of 2011. Also for the period 2010/11 one TF will be led by another EU Associate. The TF IV “*MHD instabilities and their active control*” will be managed by a scientist from FZ-J. In the following, short reports are given for the 2010 contributions of a selection of EU Associates. Due to limitation in space such reports were not possible for all EU Associates involved in the 2010 AUG Programme. However, their contributions are documented in the staff list below and the section ‘Publications’.

### DCU – University College Cork

Progress made during 2010 in the context of the ongoing collaboration between IPP and University College Cork is summarised as follows: The FORTRAN 90 version of the CLISTE equilibrium code is now used for routine post-discharge equilibrium reconstruction. Processing of magnetic data within the code has been made machine-independent, and magnetic probe, PF coil and vacuum vessel geometry

data is now read in from the AUG Machine Description file. Work to remove AUG-specific data associated with non-magnetic diagnostics from the code is underway.

Work continued on the investigation of  $\beta$ -induced Alfvén eigenmodes (BAEs) using the CLISTE equilibrium code and a numerical solver for the kinetic ballooning mode dispersion relation. The effects of electron temperature gradient variations during the sawtooth cycle on the mode frequency evolution were studied. This work has been further expanded to include the effects of trapped particles on the frequency evolution of these modes.

Work has also begun on an investigation of reversed-shear Alfvén-eigenmodes (RSAEs) or chirping modes, so named because they often exhibit pronounced upward frequency chirping towards the end of the sawtooth cycle. The work in this area focused on how q-profile evolution near the magnetic axis can affect the behaviour of these modes.

Work commenced on an analysis of the evolution of the loop voltage profile during the ELM recovery cycle using the CLISTE code and high resolution edge kinetic data mapped to ELM phase.

### FOM

ECE-Imaging diagnostic installed at AUG by FOM staff, provides a local, 2D measurement of the electron temperature and its dynamics. It measures the temperature in a 2D array of 8 (horizontal) by 16 (vertical) positions (128 channels total) in the poloidal plane, covering an area of 13 by 40 cm at a sampling rate up to 1 MHz.

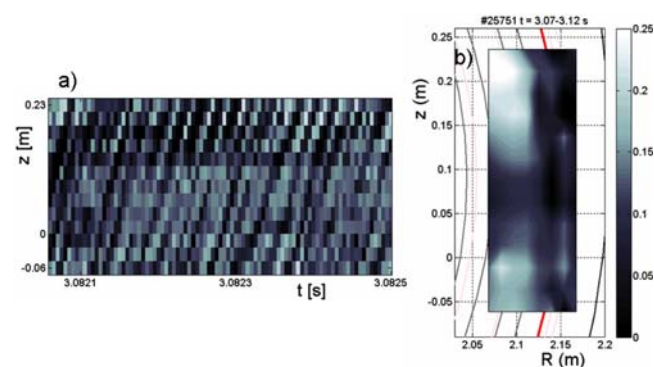


Figure 24: Type-II ELMs. a) Poloidal mode structure (radially averaged) versus time. b) 2D averaged mode amplitude.

As an example of data analysis performed in 2010, figure 24 shows data on type-II ELMs. Characteristic for this ELM regime is the appearance of a broad fluctuation band between 20 and 50 kHz. In figure a), the poloidal structure (at the low field side, averaged over the 8 radial ECE-Imaging channels) of this fluctuation is shown versus time, showing it's (upward) poloidal propagation and irregular frequency. In figure b), the averaged fluctuation amplitude is shown in 2D.

It shows that the fluctuations are localised just inside the separatrix, and that an unexpected poloidal asymmetry is present; the mode is strongest on the channels above and below the midplane. The interpretation of this effect is still ongoing (see also section 8.6).

#### HAS – KFKI RMKI, Budapest

The ongoing collaboration between IPP and EURATOM HAS resulted in the following main advances in 2010: The hardware development of the Event Detection Intelligent Camera (EDICAM, maximum frame rate: 100 kHz) for pellet observation was finished in 2010. In order to get a direct view of the AUG interior, two ports have been modified to be able to accommodate the small-sized EDICAM in the plasma facing end of the ports. Port 5Co (radial view) will be used to see the pellet-plasma interaction volume of the cryogenic pellets. Port 1Co (tangential view) will be applied to investigate ELM filament interaction with plasma facing components (typically antenna limiters) of the outboard wall. The first EDICAM was installed to perform pellet tracking using a tangentially viewing image guide, and commissioning was successfully finished in the AUG restart in November 2010.

A major change/upgrade of the optical observation system of the Li-beam diagnostic was started. The new optical setup is necessitated by two factors: The A-coils (to be installed after 2013) will block the existing observation views and therefore new observation optics must be built. An increase of the number of detectable photons for fluctuation measurements is required as well. The new optic head will have 30 channels and the number of detectable photon will increase by one order of magnitude.

Sawtooth precursor activity, namely the interaction of the main kink mode and a lower frequency mode was studied in detail. Both bandpower-correlation and bicoherence analysis indicate a non-linear interaction between the two modes. Wavelet-based methods developed to determine mode numbers of core modes found both spatial structures with a (1,1) characteristic.

#### National Technical University of Athens (NTUA), Greece

A guest from NTUA developed together with members of IPP divisions E1 and TOK a model describing the stabilisation of tearing modes by ECCD through the change in equilibrium current profile in the presence of a magnetic island. This work extends previous work that neglected the island. Implications for NTM stabilisation on AUG are still under discussion and may result in an experimental proposal for the 2011 campaign.

#### IST – Centro de Fusão Nuclear

In 2010 a continuous effort was dedicated to the implementation of the real-time density profiles. Significant progress

was achieved: the acquisition system's functionality and low level system software were completed and fully tested. The new system hardware was commissioned at AUG and Level 0 software integration in the RT AUG network completed. Level-0 RT operation was tested during the 2010 experimental campaign with full operation (low and high-field-side profiles and boundary position time trace at 1 ms intervals) in early 2011. An automatic procedure was developed for measurement validation (e.g. during ELMs) and to give position estimate confidence values. First results give confidence that reflectometry data can be incorporated into the AUG plasma position control loop during ELMy H-modes. Investigations were made to find a non magnetic indicator of the plasma separatrix position from the frequency variance of the FM-CW (Frequency Modulation of a Continuous Wave) signals. Preliminary results are promising but technique validation is ongoing. The planned refurbishment of the FM-CW system was delayed due to funding. Only repairs and minor modifications were undertaken. A major improvement was the implementation of a novel technique to generate reference signals without the in-vessel directional coupler loads, which has led to significant hardening of the HFS channels against excess stray ECRH radiation, thus keeping the unique HFS/LFS capability of the profile system.

The fluctuation channels have been equipped with a new Hotlink/SIO system from IPP enabling to measure density fluctuations up to 1 MHz. Control software has been developed and full operation is expected shortly. Further data analysis tools were developed to improve density profile accuracy, specifically the application of the reassigned spectrogram technique to increase the time-frequency resolution of the classic spectrogram. Excellent progress has been made in integrating the reflectometry data into the IDA package. A forward model has been built using the (partially processed) level-1 group-delay signal as input rather than the raw 'phase' data. The inclusion of the reflectometer data has a major impact on the resulting IDA profile both in terms of pedestal position and edge gradients.

Several plasma physics studies were performed. (i) Fast particle/MHD modes: The radial structure of the AE cascades has been obtained from the cross-correlation of reflectometer, ECEI and SXR signals. Resulting experimental coherence profiles are in good agreement with simulated radial eigenfunction by CASTOR code. Energetic particle modes have also been investigated via SXR and reflectometry correlation. (ii) Edge profile and fluctuation studies: The search for robust filament signatures shows clear reflectometer phase perturbations towards the bottom of the pedestal. Signal correlation with Langmuir probe data will continue in 2011, particularly during edge ergodisation experiments with the RMP coils. (iii) Density profiles and fluctuation measurements from reflectometry have also

contributed to the characterisation of the edge pedestal, analysis of triggering mechanisms of the edge transport barrier formation; characterisation and comparison of the kinetic edge profiles in nitrogen seeded discharges.

Regarding theory and simulation studies, the results obtained with the 2D FDTD code could already support the interpretation of unprecedented reflectometry experiments without reflecting layer where Alfvén cascades located at the plasma centre were detected. Significant progress has been also made on integrating GEMR turbulence simulation data into the 2D FDTD reflectometer code.

#### RISØ

A design for a major upgrade of the collective Thomson scattering (CTS) diagnostic on AUG has been carried out in 2010. Presently, the CTS is coupled to the ECRH transmission line via moveable quasi-optic mirrors located in the matching optics unit located in the gyrotron hall. The new design directly couples to the ECRH waveguides via RF switches designed by RISØ in collaboration with the ECRH group at IPP Greifswald and the plasma research group at the University of Stuttgart. The complete CTS hardware will be relocated to a section of the NBI control room where the waveguides are easily accessible. In addition to a more robust quasi-optic design, one of the many advantages of this upgrade is the added flexibility to easily change the receiver transmission line allowing different scattering geometries. This also enables the CTS to be independent to one particular gyrotron as its probing source. Furthermore, an additional receiver (formally located at TEXTOR) will be installed allowing two simultaneous measurements of the fast ion distribution at different locations in the plasma. The RF switches and the new quasi-optics components are scheduled to be completed in 2011.

#### ÖAW – IAP, TU Vienna

ÖAW supported the enhancement and technical improvement of the AUG lithium beam diagnostic by designing a new observation system and by building up a new data acquisition based on the SIO technology. The new observation head is currently been manufactured and will be installed in AUG during the 2011 shutdown. The SIO data acquisition system was tested and will soon replace the current CAMAC system once all remaining technical problems are solved.

At the end of the year, the restart of the lithium beam diagnostic was cumbersome, mainly caused by aging of many technical components. Finally, we were able to measure the edge electron density profile during the first plasma discharges of the 2010 AUG campaign. Especially, the effect of the new RMP coils, on the edge electron density profile could be studied.

In addition, the preparation of experiments concerning the H-mode pedestal profile evolution following L-H and H-L transitions, proposed for the 2010/11 AUG campaign proceeded. This included the analysis of pedestal profiles close to either the L-H or H-L transition from previous campaigns.

#### TEKES

In 2010, TEKES contributed to the research efforts at IPP on two distinct frontiers: fast ion physics and plasma-wall interactions (PWI). In PWI, SIMS measurements were carried out at VTT, Finland, to determine the deposition profiles from  $^{13}\text{C}$  puffing experiments. RBS, NRA, and also SIMS were used to study erosion of W and Ni in divertor tiles with special marker coatings as well as re-deposition of these two elements. In addition, the poloidal deposition profiles of B, C, and D on different substrate materials were determined on the same tiles.

$^{13}\text{C}$  puffing experiments were also modelled using DIVIMP, ERO and ASCOT-PWI codes and the results were reported in 3 different contributions at the 2010 PSI conference and were published in journals. For this purpose, the ASCOT code, originally used for fast ion physics, was upgraded to include background flows essential for impurity migration. The task of converting CAD drawings of the AUG wall into 3D wall structure usable by ASCOT was also completed. Using this new capability, we were already able to show that  $^{13}\text{C}$  simulations using only a 2D wall representation give misleading results. The new ASCOT-PWI is now capable to perform impurity studies using 3D magnetic and wall geometries. Both the toroidal ripple and 3D wall elements were found to affect the  $^{13}\text{C}$  deposition.

For fast ion physics, ASCOT simulations to determine the potential of an ‘active’ NPA system utilizing neutrals generated from beam-beam interactions were carried out after developing an NBI neutral cloud model for ASCOT. In this context, also the ADAS database was adopted in ASCOT. The simulations indicate that a refurbished NPA could be used to monitor the fast ion population from tangential NBI lines.

In collaboration with IPP’s TOK division, ASCOT was also equipped with a numerical model for NTM-type islands, so that their effect on NBI current drive can be studied. The extension of this model to 3D magnetic fields was started in collaboration with TOK.

## 11 Scientific Staff

**Tokamak Scenario Development (E1):** N. Arden, C. Aubanel, K. Bald-Soliman, R. Bauer, K. Behler, É. Belonohy, N. Berger, H. Blank, J. Boom, A. Buhler, I. Classen, G. D. Conway, R. Drube, M. Ebner, H. Eixenberger, K. Engelhardt, E. Fable, S. Fietz, A. Flaws, J. C. Fuchs, M. García-Muñoz, B. Geiger, L. Giannone, B. Gmeiner, I. Goldstein, E. Grois, O. Gruber, A. Gude, T. Härtl, A. Herrmann, J. Hobirk, M. Huart, V. Igochine, K. Iraschko, C. Jacob, R. Jung, C.-P. Käsemann, A. Kagarmanov, A. Kallenbach, M. Kaufmann, K. Klaster, B. Kleinschwärzer, H. Kroiss, P. T. Lang, P. Leitenstern, F. Leuterer, L. Liu, A. Lohs, K. Mank, M. Maraschek, P. de Marné, R. Merkel, V. Mertens, A. Mlynec, F. Monaco, P. Müller, S. Müller, M. Münich, U. Mszanowski, G. Neu, J. Neumann, H. Nguyen, B. Plöckl, G. Prausner, G. Raitmeir, G. Raupp, M. Reich, M. Rott, F. Ryter, P. Sauter, G. Schall, K.-H. Schuhbeck, J. Schweinzer, G. Sellmair, O. Sigalov, M. Sochor, F. Sommer, R. Stephan, F. Stobbe, J. Stober, B. Streibl, W. Suttrop, G. Tardini, W. Treutinger, T. Vierle, S. Vorbrugg, C. Vorpahl, D. Wagner, R. Wenninger, M. Wolf, D. Zasche, T. Zehetbauer, Y. Zhang, H. Zohm.

**Tokamak Edge and Divertor Physics (E2):** M. Bernert, A. Burckhart, R. Dux, T. Eich, N. Endstrasser, R. Fischer, G. Haas, M. A. Janzer, M. Kocan, B. Kurzan, T. Lunt, C. Maggi, R. McDermott, H. Meister, H. W. Müller, H. D. Murmann, R. Neu, S. Potzel, T. Pütterich, B. Reiter, V. Rohde, W. Sandmann, P. A. Schneider, A. Scarabosio, M. Sertoli, B. Sieglin, U. Stroth, E. Viezzer, A. Weller, B. Wieland, M. Wischmeier, E. Wolfrum.

**Tokamak Physics Division:** C. Angioni, V. Belmondo, A. Bergmann, R. Bilato, A. Bottino, T. Breu, M. Brüdgam, A. Chanin, C.P. Coster, T. Görler, S. Gori, J. Grießhammer, S. Günter, T. Hein, M. Hölzl, F. Jenko, O. Kardaun, H.-J. Klingshirn, C. Konz, M. Kraus, K. Lackner, P. Lauber, O. Maj, P. Martin, P. Merkel, F. Merz, G. Pautasso, G. Pereverzev, E. Poli, M.J. Püschel, T. Ribeiro, W. Schneider, M. Schneller, E. Schwarz, B. Scott, M. Sempf, M. Siccino, G. Strohmayer, E. Strumberger, C. Tichmann, D. Told, C. Wigger, Q. Yu.

**Technology Division:** V. Bobkov, F. Braun, R. D'Inca, H. Faugel, P. Franzen, M. Fröschle, H. Fünfgelder, D. Hangan, B. Heinemann, D. Holtum, C. Hopf, C. Martens, P. McNeely, J.-M. Noterdaeme, S. Obermayer, A. Onyshchenko, Y. Podoba, F. Pompon, R. Riedl, J. Schäffler, E. Speth, A. Stäbler, P. Turba, K. Winkler, E. Würsching.

**Materials Research:** M. Balden, B. Böswirth, H. Greuner, W. Jacob, K. Krieger, S. Lindig, H. Maier, G. Matern, M. Mayer, J. Roth, K. Schmid, K. Sugiyama, U. von Toussaint.

**Garching Computer Centre:** C. Guggenberger, C. Hanke, P. Heimann, J. Maier, H. Reuter, A. Schott, M. Zilker.

**Integrated Technic Center:** F. Ascher, R. Blokker, T. Franke, M. Kircher, J. Lex, G. Lexa, W. Lösch, J. Maier, H. Pirsch, F. Zeus.

**IPP Greifswald:** C. Biedermann, M. Laux, E. Pasch, R. Radtke, R. Reimer, J. Sachtleben, W. Schneider.

**IPF University of Stuttgart:** G. Birkenmeier, H. Höhnle, E. Holzhauer, W. Kasperek, B. Nold.

**Technische Hochschule Wildau:** M. Marx, K. Siemroth.

**CCFE, Culham, Abingdon, United Kingdom:** C. Challis, I. Chapman, P. Coad, P. Jacquet, A. Kirk, Y. Liu, I. Monakhov, A. Widdowson.

**CEA, Cadarache, France:** L. Colas, D. Douai.

**CIEMAT, Madrid, Spain:** T. Happel.

**DCU, University College Cork, Ireland:** P. McCarthy, M. Dunne.

**EFDA-JET, Culham, United Kingdom:** A. C. C. Sips.

**ENEA, C.R. Frascati, Italy:** B. Esposito.

**ENEA, Consorzio RFX, Padua, Italy:** E. Gaio, P. Martin, P. Piovesan, V. Toigo, N. Vianello, A. Zamengo.

**ENEA, IFP, CNR, Milano, Italy:** G. Gorini, G. Granucci, G. Grosso, M. Nocente, M. Tardocchi.

**Etat Belge, ERM/KMS, Brussels, Belgium:** P. Dumortier, D. Grine, A. Lyssoivan, M. Vranken.

**FOM, Rijnhuizen, The Netherlands:** T. Huijser, J. Rapp, G. van Rooij.

**FZ Jülich:** R. Koslowski, V. Phillips.

**EURATOM HAS, Budapest, Hungary:** K. Gál, S. Kálvin, G. Kocsis, G. Por, G. Pokol, G. Papp, T. Szepesi, Sz. Tulipan, G. Veres, S. Zoletnik.

**Hellenic Republic, Athen, Greece:** A. Lazaros.

**IPP, Praha, Czech Republic:** J. Adamek, V. Weinzettl.

**IPPLM, Warsaw, Poland:** P. Gasior, J. Wolowski.

**IPPLM, Warsaw University of Technology, Poland:** E. Fortuna-Zalesna, M. Rosinski.

**IPR, Bath, India:** P. Ajesh, A. Bhardwaj, M. Kushwah, A. Mukherjee, K. Rajnish, R. Singh, N. Sing, G. Suthar.

**IST Lisbon, Portugal:** C. Amador, L. Cupido, S. da Graca, M.-E. Manso, V. Plyusnin, J. Santos, F. Serra, A. Silva, P. Varela, J. Vicente.

**NILPRP, Bucharest, Romania:** C. V. Atanasiu.

**ÖAW, University of Innsbruck, Austria:** C. Ionita, C. Maszl, F. Mehlmann, R. Schrittwieser.

**ÖAW, IAP, TU Wien, Austria:** K. Igenbergs, M. Willensdorfer.

**RISØ, Roskilde, Denmark:** J. H. Holm, M. Jessen, S. B. Korsholm, F. Leipold, F. Meo, D. Moseev, A. H. Nielsen, M. Salewski, M. P. Stejner.

**TEKES, HUT, Espoo, Finland:** L. Aho-Mantila, S. Äkäslompolo, M. Airila, M. Groth, T. Kurki-Suonio.

**TEKES, VTT, Espoo, Finland:** A. H. Hakola, J. Likonen.

**University of Latvia, Riga, Latvia:** O. Dumbrajs.

**VR, Stockholm, Sweden:** P. Brunsell.

**GA, DIII-D, San Diego, USA:** W. W. Heidbrink, D. Rudakov, M. van Zeeland.

**INEEL, Idaho, USA:** P. W. Humrickhouse.

**University of Nancy, France:** S. Bardin, I. L. Briançon, F. Brochard.

**University of Sao Paulo, Brazil:** A. Elfimov.

**University of Strathclyde, Glasgow, United Kingdom:** M. G. O'Mullane, H. P. Summers.



# JET Cooperation

Head: Dr. Josef Schweinzer

## Introduction

During 2010 JET laid the foundations for the next cycle of its exploitation. The current EP2 shutdown for installation of a Be wall and a W divertor is in its final phase. Replacement of the in-vessel components has turned out to be more difficult than expected owing to the large number of in-vessel anomalies encountered. Preparation of the 2011-12 campaigns has also been finalised. The amount of work carried out by the Association staff within the JET Task Forces has been substantial and of high quality. Wide consultation with the JET stakeholders (Associations, EFDA Task Forces and Topical Groups, Fusion for Energy and the ITER Organisation) took place throughout the year, with two General Planning Meetings. More than 15 IPP scientists participated in these meetings. A senior IPP scientist is leading JET Task Force E1, which is responsible for a safe and efficient scientific exploitation of JET with its new wall. Characterisation of the latter will start already with the first plasma during the JET restart in 2011. Such first attempts of plasma operation are envisaged for the end of July 2011.

IPP continued its contributions to several JET enhancement projects. A new project for the installation of two additional IR cameras was launched. At the end of 2010 a kick-off meeting for a Fusion Technology task with the aim of installing AUG-type dust collectors in JET took place. Two IPP scientists attended the JET Session Leader Training and qualified for the practical part of the training during the coming 2011 campaigns.

Seven long-term secondments of IPP staff to the Close Support Unit (2), the JET CODAS group (1) and to the JET Operator (JOC, 4) were active in 2010. IPP staff seconded to JOC has been responsible for visible imaging diagnostics, ECE diagnostics, spectroscopic measurements of impurity influx and maintenance and development of codes for data analysis.

Edge modelling activities were performed in 2010 as well. The CARRE grid generator was extended to create fully orthogonal grids up to the target plates combined with a cut-cell approach at material boundaries. This approach will improve the numerical accuracy of edge modelling codes and will allow automatic creation of field-aligned grids covering the whole in-vessel domain. EDGE2D modelling of JET divertor plasmas were performed to study the effect of neutrals on the power decay length at the outer divertor target plate.

Selected examples of scientific results as well as contributions to JET enhancement activities are given in the following.

JET continued its major shutdown, started in 2009, for installation of the ITER-like wall. This shutdown is the largest modification of JET since installation of the pumped divertor in the early 90s. In parallel, preparation of the 2011-12 campaigns proceeded, with IPP transferring its experience gained with the fully tungsten-clad ASDEX Upgrade to the forthcoming JET operation with beryllium wall and tungsten divertor.

## Fast Particle Physics

During 2010 work with the scintillator probe for fast ion losses in JET (KA3 diagnostic) focussed on two areas: (a) upgrading of specific components, during the ILW shutdown, to improve the time response of the diagnostic, and (b) continuation of its scientific exploitation by analysis of data collected in previous campaigns.

Motivated by the experience obtained on ASDEX Upgrade, IPP contacted a small enhancement project to exchange the scintillator coating of the detector head from P56 ( $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$ , 2ms decay time) to the much faster responding TG-Green ( $\text{SrGa}_2\text{S}_4:\text{Eu}^{2+}$ , 400ns decay time). The task involved remanufacturing key components (plate substrate, a Faraday cable plug and holding structure) and carrying out stopping power computations (SRIM code) for fusion-relevant ion species to determine an adequate scintillator material coating thickness. The plate substrates were coated at Sarnoff Co. (USA) and delivered to JET in October 2010. Vacuum compatibility tests were successfully performed and the new components are envisaged for installation on the probe head, in time for its deployment in the next JET campaigns. The scintillator exchange was supplemented by the recent purchase of a new CCD camera by Princeton Plasma Physics Laboratory. Compared with the CCD camera used so far (~20 Hz frame rate), the new camera (Photon Ultima APX-i2) offers 4000 times faster data acquisition.

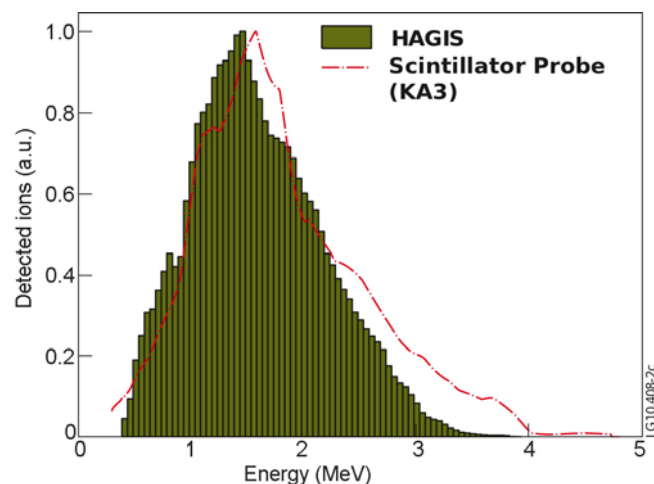


Figure 1: Energy distribution of fast ion losses measured with the KA3 diagnostic and compared with results from HAGIS simulation.

For scientific exploitation of the KA3 diagnostic, a synthetic diagnostic model for simulation of 2D scintillation-type detectors was developed and integrated into the HAGIS drift orbit following code. The model was subsequently tested on a

JET discharge, which exhibited fast ion loss bursts caused by fishbones. Thanks to the improved geometrical treatment within the simulations and to an accurate consideration of the instrument function of the diagnostic, the simulated energy (see figure 1) and pitch angle distributions at the detector are found to be in excellent agreement with the measurements.

### Divertor Heat Loads

The divertor outer target heat flux profiles in JET were analysed with a high-resolution IR camera for 63 deuterium plasmas and 4.383 single ELMs in Type-I ELMy H-mode discharges. The data base includes discharges with plasma currents from 1.0 to 3.5 MA,  $q_{95}=2.8-5.6$ , triangularity of 0.28-0.4 and gas puff scans. The inter-ELM profiles are taken prior to ELM onset in a time window of about 10 ms when the strike line is found to stay constant. The ELM profiles are averaged in time from ELM onset until a value of  $1/e$  after the ELM heat flux peak value ( $\sim 1$  ms) is reached. It was observed that divertor heat flux decay lengths time-averaged over the discharge duration gives too large inter-ELM values due to strike point movements. Two different quantities are employed to characterise the power fall-off length: first, the target power decay length  $\lambda_{\text{target}}$  using the integral value of the heat flux divided by the peak heat flux; second, an e-folding length at the divertor entrance ( $\lambda_{\text{entrance}}$ ), derived from fitting the target heat flux profiles by a convolution of a Gaussian function with an exponential function to take into account diffusive transport into the private-flux region. It is found that  $\lambda_{\text{target}} \approx 2 \cdot \lambda_{\text{entrance}}$  for inter-ELM periods. The inter-ELM scaling reveals an inverse dependence on the plasma current:

$$\lambda_{\text{target}}^{\text{inter-ELM}} \propto B_{\text{tor}}^{0.38 \pm 0.24} \cdot P_{\text{NBI}}^{0.09 \pm 0.12} \cdot I_p^{-0.86 \pm 0.23}$$

The smallest inter-ELM target decay lengths found are in the range of 3 mm when mapped to the midplane for discharges at 3.5 MA and  $q_{95}$  values of 2.8. The inter-ELM exponential decay lengths give smallest values of about 1.5 mm in this case. Largest values for the mapped inter-ELM target decay lengths are  $\sim 7$  mm at 1 MA and  $q_{95}=3.5$ . ELM broadening values (ratio between ELM and inter-ELM values) are found to vary between 1.5 and about 5, systematically increasing with larger ELM loss energies normalised to the plasma stored energy ( $E_{\text{ELM}}$ ). A residual diagnostic artefact arising from co-deposited surface layers cause large scatter for a given normalised ELM loss energy. Neglecting this, we found a scaling for the ELM power profile width  $\lambda_{\text{target}}^{\text{ELM}} \sim B_{\text{tor}}^{0.35} \cdot I_p^{-0.19} \cdot E_{\text{ELM}}^{0.18}$ .

### Contributions to the ITER-like Wall Project

In 2010 installation of the ITER-like wall (ILW) commenced. Tungsten coating of a total of about 1.700 CFC tiles – covering nearly 50 m<sup>2</sup> of JET's first wall – was finished at the 'National Institute for Laser, Plasma and Radiation Physics'

(NILPRP), Bucharest. The main focus at IPP, consequently, was completion of the quality assurance high heat flux tests in GLADIS, which were started in September 2008. After testing of nearly 170 samples, mostly larger divertor tiles, the quality assurance goal of testing a fraction of approximately 10 % of the production was achieved in mid-2010. Marginal defects occurred on only four tiles, which led to an overall failure rate of less than 2.5 %. After six years IPP's involvement in the development and quality assurance of tungsten coatings on CFC tiles for the ILW was successfully completed in 2010. Investigations on another topic were initiated: During operation in JET some tiles will undergo phases of high surface temperature. Carbon from the tiles can then diffuse into the metal coating and convert it into a brittle metal carbide. This will ultimately limit the thermomechanical performance of the coatings. First experiments to investigate the lifetime limits of the coatings were performed in GLADIS by high heat flux testing of coated tiles after dedicated heat treatment. Clear threshold behaviour with respect to the thickness of the carbidised layer was observed, indicating that the effect can be controlled by restricting the peak surface temperatures accordingly.

Specially developed molybdenum/tungsten marker layers for investigation of tungsten erosion and redeposition in the JET divertor were coated on 15 divertor tiles and on 10 lamellas of bulk tungsten tile 5 at the NILPRP in Bucharest (Romania). The thicknesses of the marker layers were determined at IPP using ion beam analysis with incident high-energy protons. The tiles were delivered to JET. In total, two sets of marked tiles were produced in 2009 and 2010: The first set is currently being installed, while the second is envisaged for installation in 2012. Special deposition monitors for measuring material deposition in remote areas of the divertor were manufactured and delivered to JET. Sachet samples for measuring beryllium and tungsten erosion at the inner main chamber wall were coated with tungsten and beryllium marker layers. The initial thicknesses of these marker coatings were measured by ion beam analysis methods, and two sets of these sachet samples were delivered to JET.

### Scientific Staff

**Data Analysis & Campaign Preparation:** E. Belonohy, V. Bobkov, A. Burckhart, R. Dux, T. Eich, J. Hobirk, A. Kallenbach, K. Krieger, P. T. Lang, S. Marsen, H. W. Müller, K. McCormick, R. Neu, M. Reinelt, J. Roth, A. Scarabosio, J. Svensson, H. Thomsen, R. Wenninger.

**Enhancements:** M. Balden, B. Böswirth, H. Braune, M. Garcia-Munoz, H. Greuner, S. Lindig, H. Maier, M. Mayer, J.-M. Noterdaeme, M. Rasinski, A. Stäbler, W. Treutterer, W. Zeidner.

**Modelling:** A. Chanin, D. P. Coster, H. J. Klingenshirn, Ch. Konz, M. Wischmeier.

**CSU:** P. Nieckchen, C. Perez v. Thun.

**JOC & CODAS:** S. Devaux, D. Dodt, C. Hennig, C. Maggi, S. Schmuck.

## Stellarator Research





# Wendelstein 7-X

Heads: Dr. Remmelt Haange, Prof. Dr. Thomas Klinger

## 1 Introduction

In 2009 the organisation of the project Wendelstein 7-X remained mostly fixed. In spring of 2010 the department dealing with the superconducting coils was dissolved and its responsibilities were taken over by the department for the magnet power supplies. In the sub-division for in-vessel components, the tasks of the two departments were redistributed and the departments were correspondingly renamed in “first wall” and “divertor”. Within the Physics sub-division a new department “diagnostics engineering” has been established. This department under the lead of an experienced engineer will support the construction of the W7-X diagnostics. In September 2010 the department head “Quality management” retired and this position was taken over by an experienced engineer from this department. Design and manufacturing of the different components of the basic device have considerably progressed, as described in chapters 2 to 4. The accompanying efforts of the engineering subdivision (chapter 5) and the design and configuration control (chapter 6) are still indispensable. The assembly of

In 2010, considerable progress was achieved in the construction of Wendelstein 7-X. Fabrication of most of the major components has been finished. For the remaining components design and manufacturing continued according to schedule. Assembly of the device progressed very well and by the end of 2010 the first three magnet modules have been installed in their final position in the cryostat module and work is progressing well on all five modules of Wendelstein 7-X.

the stellarator device and the development of the related technologies have made great progress, as described in chapter 7. Diagnostics developments (chapter 8) and the set-up of heating systems (chapter 9) as well as the development of control systems have continued. The Wendelstein 7-X device consists of five identical modules (M1 to M5), each of them consisting of two flip-symmetric half-modules. Assembly started with module 5; the assembly sequence is M5-M1-M4-M2-M3.

## Quality Management

The Quality Management (QM) department reports directly to the project directors via the associate director coordination. The department organises the QM system within the project W7-X and supports the supervision of all external contractors. It has taken over responsibilities for quality assurance during the assembly phase of Wendelstein 7-X. At the end of 2010 the QM system of Wendelstein 7-X has been supervised by the TÜV NORD CERT according to the DIN EN ISO 9001. TÜV NORD CERT certified an improvement of the system, no obligations were given.

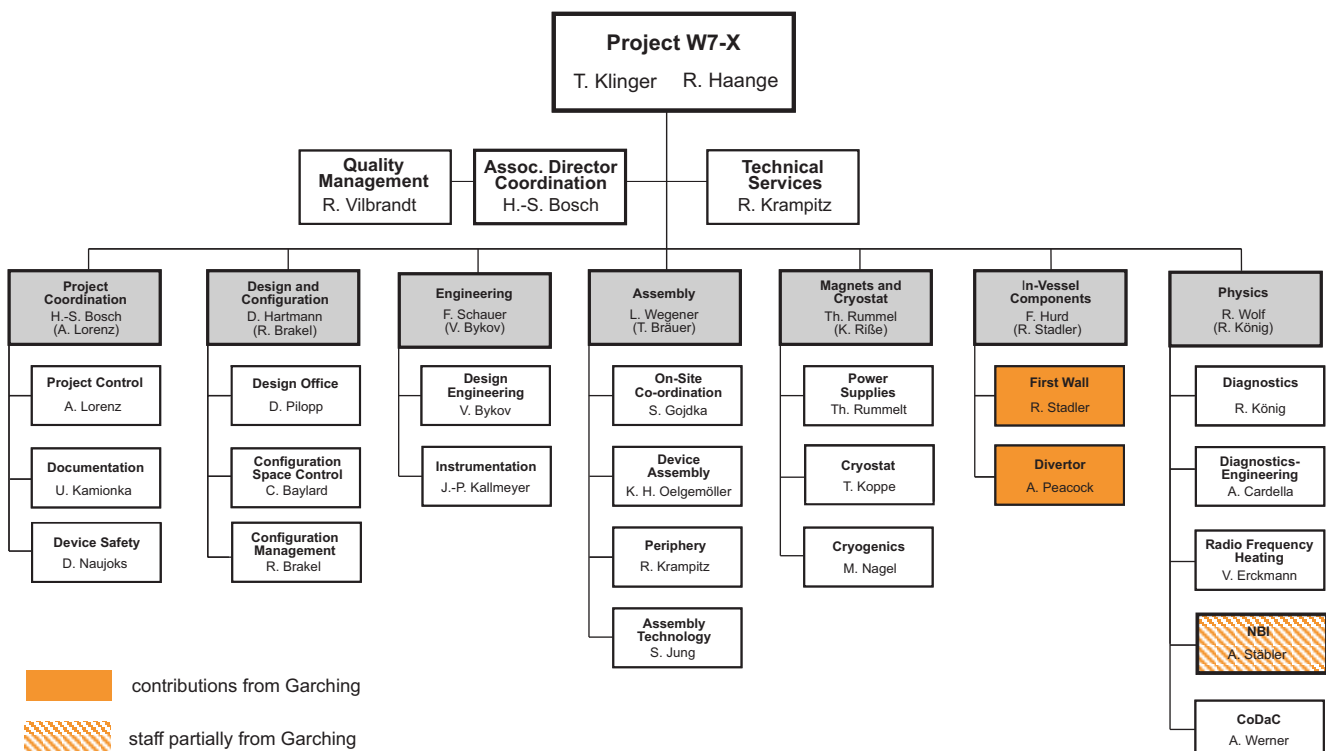


Figure 1: Organigramme of Wendelstein 7-X project as of 31 December, 2010.

### Project Coordination

This subdivision comprises three departments dealing with coordination activities for the project Wendelstein 7-X:

(I) The project control department (PC-PS) is responsible for the financial planning of the project, for the control of the expenditures and for the time planning and coordination of all activities within the project as well as of the external contracts. The department monitors and co-ordinates component delivery and assembly schedules, supports the component responsible officers in the handling of industry contracts; it deals with organisational aspects of the project and is responsible for the reporting to all external supervising bodies, especially the supervising body of the financing institutions (Project Council).

A new Integrated Planning Tool (IPT), based on MS Project 2007, had been developed up to the end of 2009. In 2010 its use within the project Wendelstein 7-X has been enforced and to date the IPT has become a routinely used tool for the responsible officers, their supervisors, but also for the financial reporting to both the management and the supervising bodies. The concept of establishing links between all sub-projects in a stable and reliable way has been implemented. The interlinked processes within the project are now monitored and controlled by a control WBS, which compares the delivery milestones of components with the dates when these components are required for assembly preparation or for other work processes in a different department/sub-division. (II) The documentation department (PC-DO) is responsible for an independent check of all technical drawings and CAD-models and for archiving all documents relevant to the project. An electronic documentation system (agile-PLM) is used for archiving documents and CAD models (in CADD5-format). Because of the increased use of CATIA v5 for design and collision investigations, in 2009 an interface between PLM and CATIA v5 has implemented. In 2010 additional tools have been implemented for this interface to allow a daily automatic export of new models in the archive into a working directory of all W7-X models, the so-called “W7-X assembly”. This allows concurrent engineering within a full W7-X CAD model for all designers and also allows keeping track of changes in the part models via a daily “baseline”. In November 2010 the implementation and test phase of these additional tools was finished and this “CATIA assembly” replaced the former “CADD5 assembly”. With this switch to the CATIA assembly, the change of the main CAD tool (from CADD5 to CATIA v5) was completed. (III) The device safety department (PC-DS) plans, implements and leads the processes that are required to ensure safe operation of the Wendelstein 7-X device with its interacting components and supply systems. In 2010, a number of hazard events (currently 32), which could occur on the W7-X stellarator have been analysed. The way of detecting the events is described as well as the associated technical

and control safety measures; administrative procedures and the resulting actions. Systems and components that are important for personnel or public safety are identified considering their functional importance in the overall plant safety. To each global hazard event, the corresponding reports and references are given.

All control components and systems foreseen for the supervision of W7-X operation have been compiled and assessed regarding their importance for analysis purposes, operation requirements, and for personnel and device safety issues.

The specification of fire protection in the W7-X torus hall has been finalised in 2010 and the realisation of the defined technical measures (amongst them fire detection sensors, a mobile water mist station, and a central high-pressure water mist system) was started.

The successful collaboration with the Lithuanian Institute of Energy (under the EFDA agreement – Association Work Programme) on the topic of Loss of Coolant Accidents (thermo-hydraulic modeling, analysis of the water hammer phenomenon, structural analysis, leak-before-break studies) has been continued.

### Schedule

Also in 2010, the time schedule of the co-called “scenario 3” (developed in fall of 2007) was followed. All five milestones scheduled in 2010, have been achieved in 2010, four of them in (or ahead of) time, the other one with a delay of five weeks. The experiences gained with port assembly in the first module resulted in a planning revision as these processes turned out to require more time than planned before. However, the revised schedule did not introduce any delay to the assembly end date due to a reorganisation of the use of the port assembly ramp. The end of assembly and start of commissioning is still scheduled for August 2014.

By the end of 2010, the first three magnet modules were installed in their respective cryostat vessel modules. In the first module, all ports have been insulated and inserted, welding is under way. In the second module, insertion of the ports is still ongoing. On the last two modules, the busbars and cryo-piping are being installed. The detailed planning of assembly packages for the peripheral installations such as supply systems, diagnostics and heating systems has begun in summer 2010.

## 2 Magnets and Cryostat

### 2.1 Magnet System

#### 2.1.1 Coils

W7-X has a superconducting magnet system consisting of 50 non-planar coils and 20 planar coils. The procurement contracts for the coils were formally closed in spring 2010. Meanwhile all coils are assembled. In addition to the superconducting coils, which will produce the main stellarator

field, normal conductive coils were developed to fine tune the magnetic field and to increase the physical flexibility of the magnetic field configuration. The five trim coils will be located at the outer side of the cryostat and have a size of  $3.6 \text{ m} \times 3.3 \text{ m}$  and  $2.8 \text{ m} \times 2 \text{ m}$ , respectively. In the frame of an international cooperation the US partners Princeton Plasma Physics Laboratory (PPPL), Oak Ridge Laboratories (ORNL) and the Los Alamos National Laboratories (LANL) got a three years DOE funding program to support the stellarator research at IPP. The US partners PPPL and ORNL will contribute the five trim coils within the frame of this support program. The cooperation started in the mid of November 2010. The delivery of the first coil is scheduled for 2012.

### 2.1.2 Coil Support Structure and Cryo Legs

The support of magnet system is composed of the central support ring, the inter coil supports and the cryo legs. The central support ring consists of ten identical sectors (half-modules) with a total weight of 72 t. It is made from steel plates, cast flanges and cast extensions, which are welded together to one half module. The contract was successfully finished in 2009. For the assembly of the modules to a ring, connection elements between the module flange are necessary. These connection elements are composed of several 3-D shims, diamond foils and special bolts. The bolts for all five connections are delivered. Special measurement tools were developed for the fabrication of the shims and the first connection was measured. The associated shims are drawn and the manufacturing process is running according to the schedule.

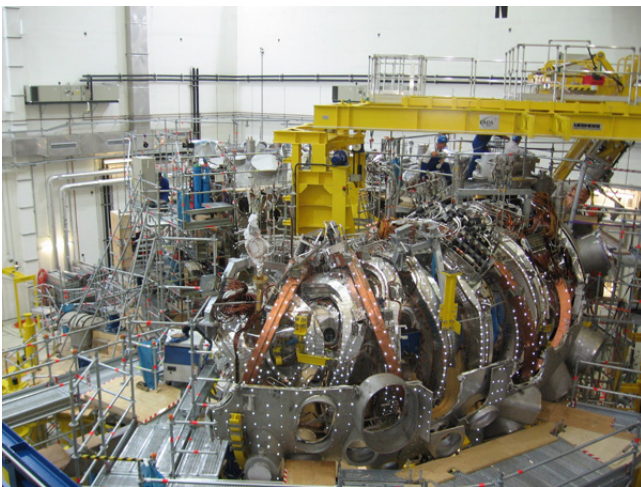


Figure 2: Magnet module 4 inside the lower OV shell.

The coil support structure is vertically supported by ten cryo legs. The delivery of the prototype and the ten regular cryo legs was finished. IPP has reworked the base-plates and installed the instrumentation for measurement of vertical forces.

The cryo legs of three modules have already been installed between central support ring and the W7X-machine base. Also the associated bellows were welded. The remaining cryo legs and bellows will be assembled according to the schedule in 2011.

### 2.1.3 Inter-coil Supports and Connection Elements

Different types of support elements connect the coils with each other. The narrow support elements (NSE) between non-planar coils on the inner side of the torus take up pressure loads while simultaneously allowing sliding and tilting. Meanwhile all NSE were produced and assembled. The welded lateral support elements (LSE) join the non-planar coils on the outer side of the torus. The semi products of all LSE's (with exception of the LSE-D06 at the module separation plane) have been manufactured. The final measurement, custom-machining and assembly were successfully completed. For LSE-D06 a new design was created and a mock-up was successfully tested. The semi-finished parts were specified and delivered in 2010. The new design includes some diamond foils, a call for tender is planned for 2011. For the fabrication of the LSE-D06 mono block a call for tender is running. The connection elements like bolts and super nuts were also delivered in 2010. The planar support elements (PSE) connect the planar coils to the non-planar coils. Two types of the PSE had to be pre machined and afterwards E-beam welded. After the welding the final shape had to be realised after a measurement of the real geometry. Most of the PSE were fabricated and assembled. The remaining PSE-B3 of the fourth module at the module section will be assembled in spring 2011. Two sorts of contact elements (CE) support the non-planar coils at the half-module separation plane and at the module separation plane. They take up pressure loads while simultaneously allowing sliding and tilting. Each contact elements consists of two machined steel blocks, padframes, pads and sliding plates.



Figure 3: CE330



All smaller contact elements (CE 330) were machined, assembled and installed at the half module separation plane. The steel blocks for the module connection (CE 540) are machined and assembled except one part for assembly tests. All the pad frames, pads and sliding plates are prepared. After final measurements of the modules in their final position, the pad frames will be adapted. The first assembly of the pad frame and pads is planned for spring 2011. All bolts, super-nuts, round-nuts, sleeves, spherical washers, shims and wedges for the supports of the magnetic system are listed as connection elements. The shims and wedges are machined after a special measurement by IPP. The contractor Tempelmann and the Swiss subcontractor P & S Vorspannsysteme AG delivered all the different bolts and nuts by the end of 2010.

## 2.2 Vessel, Cryostat and Ports

The plasma is surrounded by the Plasma vessel, which follows the plasma contour and constitutes the first ultra-high-vacuum barrier. The entire superconducting coil system is assembled between the Plasma vessel and the Outer vessel. Their function is to create a cryostat keeping the magnet system at cryogenic temperature and constitute the boundary between the W7-X main device and the external environment. 254 ports give access to the Plasma vessel for diagnostics, additional heating and supply lines. MAN Diesel & Turbo (MAN DT), Germany, is responsible for manufacturing the Plasma vessel, the Outer vessel and the thermal insulation of Plasma vessel, the Outer vessel and ports. Romabau Gerinox (Swiss) was responsible for manufacturing of the ports.

### 2.2.1 Plasma Vessel

The maximum outer diameter of the helical twisted Plasma vessel torus is approximately 12 m; the minimum inner diameter is 8 m. The Plasma vessel is made of the austenitic steel 1.4429 (X2CrNiMoN17-13-3) and has a wall thickness of 17 mm. The openings for the 254 ports are distributed evenly around the Plasma vessel torus. The shape of the Plasma vessel cross-section changes within each module from a triangular to a bean form and back again to a triangular form. The Plasma vessel (PV) is composed of ten half-modules, which are divided into two sectors to allow stringing of the innermost coil during assembly. Manufacture of all ten half-modules was completed in 2005 and installation of the thermal insulation has been nearly finished. In each case two sectors forming the half-modules were welded with very low distortion. The cooling pipe inlet and outlet lines of these four half-modules have been manufactured and assembled. All main brackets of the PV-modules are assembled. All 15 vertical supports of the Plasma vessel were delivered by MAN DT. The vertical supports for the first four modules were welded successfully to the lower

shell of Outer vessel by IPP in 2009 and 2010. The assembly for the last module is planned for middle 2011. For the horizontal support/centering system the design, the calculation of horizontal adjustment (University of Rostock; Germany) and the technical specifications were completed. The standard parts have been manufactured by IPP. The additional brackets to the five ports AEU by TRINOS were welded successfully in 2010.

### 2.2.2 Outer Vessel

The Outer vessel is designed as a torus with an outer diameter of approximately 16 m. The internal diameter of the cross section is 4.4 m. It is made of austenitic steel 1.4429, the same material as the Plasma vessel. The nominal wall thickness of the shell is 25 mm. The Outer vessel is made of five modules; each module is divided into an upper and a lower shell. The Outer vessel is designed to have 524 domes for ports, supply lines, access ports, instrumentation feed through and magnetic diagnostics. All modules passed the works acceptance check and were delivered to IPP. The finalisation of the remaining domes is on track by MAN DT according to the time schedule. Several port elongations especially for the cryo valves were manufactured by the German company Trinos. A further Italian supplier Simic manufactured 20 port elongations for the water pipes of the Plasma vessel and 10 Quench detection and 10 instrumentation port elongations. Romabau reworked nine coil connection domes because of collisions. The upper and lower shells of the first two modules have been welded. In the fourth module, assembly of the thermal insulation is almost finished.

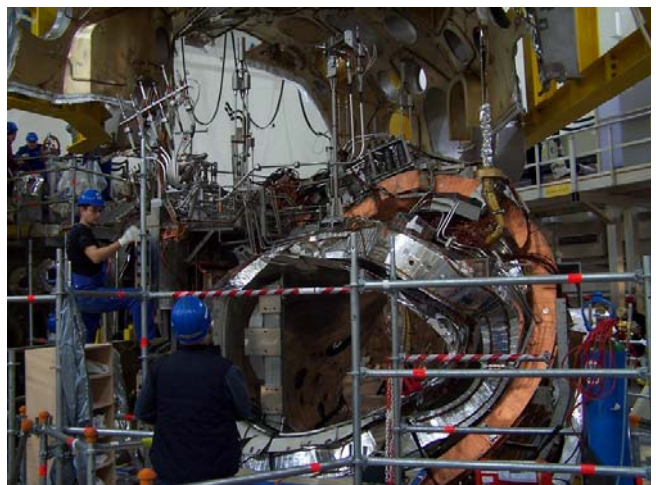


Figure 4: OV upper shell above module 4.

The preassembly and measurement is done. For the last module the insulation is running according to schedule. Further at the first two modules the port elongations for the cryo valves have been welded.

### 2.2.3 Ports

A total of 254 ports will be used to evacuate the Plasma vessel, for plasma diagnostics and heating, as well as for supply lines and sensor cables. The cross sections of the ports range between 100 mm circular up to 400×1000 mm<sup>2</sup> square and are equipped with bellows to compensate deformations and displacements of the Plasma vessel with respect to the Outer vessel. All ports are surrounded by water pipes in the bellow-area to control their temperature. All the ports and their fixing tools were delivered in 2007. Ten ports had to be elongated, and have been successfully reworked by the contractor Trinos. Because of collisions all water pipes at port tubes have to be reworked. At some special ports additional copper stripes between cooling pipes and ports were installed for a better heat transfer. The routing of water pipes in the bellow area has been corrected for the first three modules. Because of misalignment of ports an enlargement of dome plates was partially necessary. The needed additional sickle plates were designed and tested. For the first module all plates have been delivered and assembled. For the second module the manufacturing is on track according to the time schedule. During the assembly preparation of the ports four damaged bellows were found. Romabau in collaboration with the sub-contractor Kompaflex renewed the four bellows in 2010. The two special ports AEK-V2 for the neutral beam injection have to be reworked to allow assembly with the small tolerances required. Therefore a dummy was manufactured to simulate the revision. The rework is on track according to the time schedule. The delivery is planned for April 2011.



Figure 5: Port assembly preparation.

### 2.2.4 Cryo-pipes

The cryo-pipes of W7-X distribute the cold helium within the cryostat with pipe diameters ranging from Ø13×1.1 to Ø50×3. They start at the Helium port in the cryostat and end

in the individual feeders of the cold components, i.e. the coils, the central support structure, the thermal shields, etc.. The very restricted space inside the cryostat resulted in a complex, three dimensional pipe routing. Geometrical problems with the pipes consisting of flexible hoses could be solved. At first, no length change of the flexible hoses was taken into account during the production. This change was caused during pressurizing the pipes after the glow-process. As a consequence the lengths of the flexible hoses were observed carefully during the different manufacturing steps and additional correction steps were implemented. In most cases an accuracy of about +/-10 mm could be achieved for the pipe length. The cryo pipe header located inside the cryostat and the process feed/return-pipes running from the helium refrigerator to the cryostat have to be connected at the helium-port. A design for the connection of both pipe groups was developed and collision checks were carried out to confirm the routing. The very narrow available space required an enlargement of a dome opening, which is located at the module separation plane between the last two modules. After finishing the design of the pipe connection at the helium-port the final pipe routing was sent to Romabau where the modified pipes were manufactured, tested, and finally sent to IPP. The contract with Romabau – Gerinox could be completed in 2010. About 1000 pipes were bent, welded, geometrically checked with a FARO- measuring tool and finally leak tested. About 740 supports made of stainless steel frames and glass-fiber inlays were manufactured and delivered. In the meantime a new assembly concept for the current leads (CL) was developed. This concept required new temporary supports that hit the He-supply pipes for the current leads. Therefore a new pipe routing was required. The design has been developed for four modules. Collision control will be carried out after the fixing box design has been finished. After finalizing the design for all five modules it will be decided whether IPP or an external company will bend and weld the new pipes.

### 2.2.5 Thermal Insulation

The thermal insulation of the Wendelstein 7-X cryostat is fixed at warm cryostat surfaces and protects the cold components against heat loads from the warm surfaces. The thermal insulation consists of multi-layer insulation (MLI) and a thermal shield. The shield is cooled by helium gas flowing in pipes, which are attached to the shields via copper strips or braids.

### Engineering and manufacturing

The preparation of the CAD-models made further progress for the outer vessel insulation. All shield models like outer vessel panels, cooling pipes and dome shields for the last two modules were sent to MAN DT. The manufacturing models were created by MAN DT and finally approved by IPP.



The outer vessel insulation was manufactured for the fourth module and is in work for the last module according to schedule. The CAD-data for the port insulation were sent to MAN DT for the second and third module. All port insulations of the first two modules were manufactured. Additionally 20 port shields were fabricated for the third module. Scans of the ports AEE and AEA in the first three modules showed geometrical deviations that do not fit to the port shield geometry. Individual solutions for each port were elaborated. Wherever possible the outer diameters of the port shields were increased. In some cases the copper strips on the ports had to be removed partially to fulfil the geometrical requirements. It was tried to use the same ports shields for the same port types that are located in different modules starting the procedure from the second module. This required a collision control of a port shield in all relevant modules. Deviations in the as-built geometry of the coils, however, required different cut outs for port shields of the same type that are located in different modules. Finally, a port shield geometry was created that fulfilled all the requirements in the different modules. This procedure reduced the engineering work and the manufacturing documents for the manufacturer. 26 port-types were identified as candidates for this procedure.

### Assembly

The insulation of the outer vessel half shells continued in Lubmin. Meanwhile, the second and the third module have been insulated successfully. The lower half shell of the fourth module was also insulated. Work in the upper shell of Mthis module is in progress. Dome shields and panels are installed.

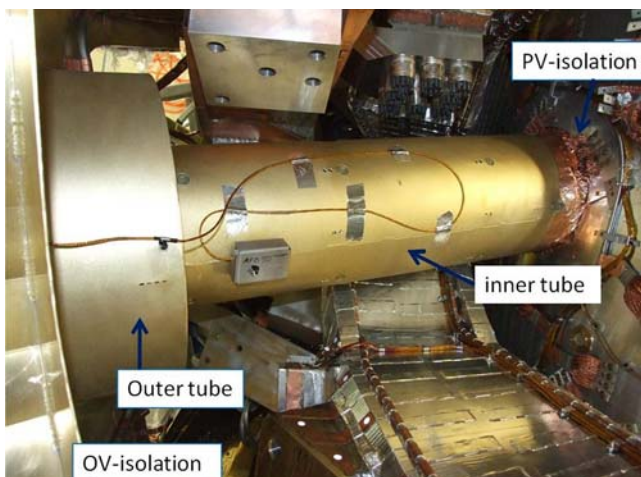


Figure 6: View on a port insulation.

The cooling pipes were adjusted to the panel geometry and welded together. On site welding seams were leak tested. The soldering of the pipes to the copper strips of the panels has been started.

The port insulation generally consists of two major components, the outer tube insulating the bellow area and the inner tube insulating the lower port tube (see figure 5). The inner tube is axially fixed on the PV and is supported on the ports in radial direction with Torlon-pins. The outer tube is welded to the outer vessel (OV) shield. The assembly of the port insulation is closely connected to the port assembly process. In a first step the outer tubes are welded on the OV-shields in the cryostat. Then the inner tube is threaded over the port and fixed. The shields are positioned on the ports with an accuracy of  $\pm 3.5$  mm (including manufacturing and assembly tolerances). Then the port is transported with attached insulation to the cryostat and clamped to the port assembly device. After that the port is threaded with the insulation through the port dome in the OV-shell into the cryostat and inserted in the corresponding whole of the plasma vessel (PV). The port shield is axially positioned with an accuracy of  $\pm 5$  mm compared to the nominal position. The port MLI-layers are connected to the PV-MLI and to the OV-MLI during the threading process. Copper tresses are riveted and soldered to the adjoining shields. The assembly of the port insulation started end of March 2010 with the first module. In October 2010 this process was finished and work on the insulation assembly of the second module has started. 42 ports of the first and 27 ports of the second module have already been insulated. The close interaction between port assembly and port insulation required a very close cooperation of the workers from MAN DT and IPP.

### 2.3 Current Leads

The current leads (CL) are the electrical connection between the superconducting magnet system inside of the cryostat and the power supplies outside of the cryostat, operated at room temperature. The main challenge in W7-X is the so-called upside-down orientation of the CL, i.e. the cold end is on top and the warm end is at the bottom. The development and production is being performed by the Karlsruhe Institute of Technology (KIT). In 2010 significant progress has been achieved in the production as well as in the field of testing. The production of the two current lead prototypes has been finished in spring 2010. In parallel the work for the refurbishment of the TOSKA test facility has been finished, too. The two current leads were installed in the test cryostat and all the instrumentation was connected to investigate the thermal, hydraulic and electrical behaviour of the current leads. The interconnection between the current leads inside the test cryostat, consisting of about one meter of NbTi superconductor of the W7-X type, was connected and pre tested. Then the current lead prototypes were tested in two test campaigns. After a thorough check under room temperature the whole test arrangement was cooled down to cryogenic temperature with a cooling speed of approx 10 K/h. After the hydraulic and thermal stabilisation the current

leads were successfully loaded up to the maximum current of 18.2 kA several times. Also an overload test up to 20 kA was performed to check the margin in terms of the current. A steady state test at 18.2 kA over six hours did not show any problems. Also the test of a loss-of-Helium-flow accident showed sufficient time to de-energise the W7-X magnet system slowly, until a quench will occur. In the test campaigns also the safety margin of the superconducting parts was tested by induced quenches. The margin between the operating conditions and the achieved quench temperature meet the requirements. The necessary helium mass flow rates to operate the current leads fit to the expectations. The high voltage strength of the test arrangement was improved between the two test campaigns to overcome problems observed at higher voltages.

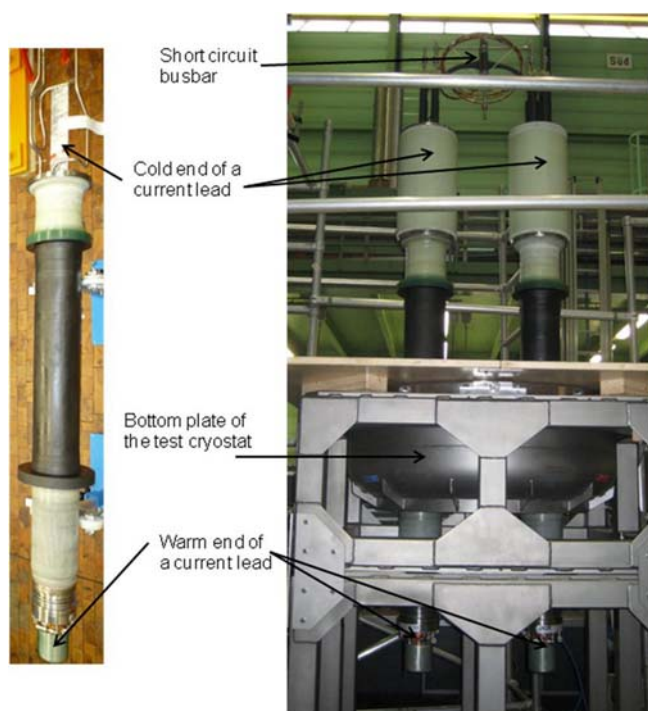


Figure 7: Current lead (left) and current lead prototype test arrangement at KIT.

In parallel to the test at KIT, tests on the mechanical stability of the two GRP-flanges have been finished successfully. Flange test mock-ups were loaded with up to 150 % of the forces and moment, which will be acting during the W7-X operation. The tests were done at room temperature as well as at cryogenic temperature at the test facility of the company IMA in Dresden, Germany. In conclusion of the several tests it can be stated that the development of the current leads was successfully finished and that the worldwide unique upside down operation of current leads is manageable. On the basis of the test results the series production was released by IPP.

In order to make the best use of the knowledge at KIT gained during the development and production of the prototypes it was commonly decided to produce the 14 series current leads at KIT as an in-house fabrication with only a few tasks done externally by a few key sub suppliers. The production has been started in the middle of 2010. Most of the material has been ordered and the production of main components is well advanced. By the end of 2010 the components for the first four current leads have been manufactured and assembly of the first two current leads was underway. The overall schedule for the production and test of the current leads is in agreement with the assembly schedule of Wendelstein 7-X.

### 2.3.1 Current Leads Mechanical Support

Mechanical supports of Current Leads are needed to support the current leads itself at the section between warm and cold side while allowing all the movements coming from the operation. Simultaneously they will be needed to support the bus system up to the central support ring. They consist of two main parts, which will be manufactured in different steps. Firstly the bearing at the central support ring with the connected horizontal rods to join the coil support structure with the fixing box. In the second step, the fixing box itself with the bearings for the current leads and the bellows is built. Because later there is no access possible, the supports and rods have to be installed first. The manufacturing for all bearings and rods is finished. Beside the last module, all the bearings and rods have been assembled in 2010. Because of a reduced access during the assembly of the fixing box, a mock-up was manufactured in 2010, too. With the first results the design was partial reworked and finally finished for the fixing box, the bellows, the bearings for the current leads and the connected bus supports. The first rectangular pipes for the fixing box have been manufactured. A specification for the bellows is finished; a call for tender is prepared. The assembly is on track according to the time schedule.

## 3 Supply Systems

### 3.1 Helium Refrigerator

The helium refrigerator produces and distributes the cold helium mass required to cool the cold components of W7-X. The commissioning of the refrigerator is in progress. The installation and testing of test boxes 1 & 2 containing the main test heaters were completed. The oil heat exchanger was replaced with a bigger type because the maximum oil temperature was exceeded. Wrong bearing material for the pump shafts resulted in scratches on the pump shafts. Although Linde Kryotechnik (LKT) has replaced the bearing materials, the problems persisted; therefore LKT has decided to change these pumps with another type of pumps.

After the mounting of cold machines i.e. cold compressors and cold pumps the commissioning of these machines was started. Both the cold compressors were operated in manual mode, the start-up in automatic mode was carried out for the first one, further work is continuing. The manual start-up of cold pumps is also continuing in parallel. The change of the control program from FUP to PCS7 for all the 3 SPS units was completed; further refrigerator operation was carried out with the new program. The integral leak test of boxes and transfer lines with vacuum enclosures were completed, the leak tests of warm piping are planned for the near future. LKT has announced further delay in completion of commissioning and documentation with a finalisation date of May 2011. Meanwhile, LKT delivered and integrated a fourth cold pump that is needed to run the cryo-vacuum-pumps. Additionally seven spare cartridges were delivered for the seven turbines.

### 3.2 Magnet Power Supply

The superconducting magnet system is divided into seven electrical circuits, containing five circuits with ten non planar coils each and two circuits with 10 planar coils each. Seven independent power supplies provide direct currents of up to 20 kA at voltages of up to 30 V. Fast and reliable discharge of the superconducting magnets in case of quenching or severe faults is realised by fast circuit switches, which short-circuit the coils and dump the magnetic energy into resistors. After the declaration of the acceptance in mid 2007, several test campaigns were performed to train the staff and to identify possible weak points. Over the time the failure rate tends to increase. Intensive negotiations with the main contractor ABB turned out to be necessary to find a common solution in terms of repair, warranty, payment and spare parts. As one result ABB started the repair mid of 2010 with the aim to demonstrate the proper operation of the system in an eight hour steady state test. By end of 2010 several repair measures has been done and most of the spare parts have been delivered.

### 3.3 Quench Detection System

The quench detection system of W7-X will permanently check the differential voltages across the double layers of the coils, all sectors of the bus system and the superconducting part of the current leads. The system has to reliably detect millivolt signals in a broadband noise environment and operate at high voltages during a rapid shutdown of the magnets. In order to provide a redundancy in the quench detection, it was decided to install a back-up quench detection system. It runs in parallel to the original system, but allows as an additional feature to detect symmetric quenches in adjacent double layers of the coils. Due to a slightly different cabling concept the number of necessary units is less than in the original quench detection system. In total 560

quench detection units are necessary. The quench detection units will be put into ten so called subsystems. One subsystem contains up to 64 quench detection units and is equipped with an internal AC/DC power supply combined with an uninterruptible power supply to secure the independent operation of the subsystem. For control and data acquisition an internal controller is installed to evaluate and to transmit the quench signals to the magnet safety system and to allow a fully remote control. The fabrication of the prototype subsystem has been finished in 2010. In a steady state test over several weeks the error free operation was demonstrated. All the components of the subsystem have to withstand the magnetic field strengths. Therefore the components as well as the finished subsystem were tested in a magnetic field up to 30 mT successfully. Due to the good results the prototype subsystem will be used as the first series subsystem. The production of the remaining subsystems has been started in IPP.

## 4 In-vessel Components

The in-vessel components consist of the divertor target plates, baffles, panels and heat shields, control coils, cryo-pumps, port protection and special port liners for the NBI and DNBI and the complex system of cooling water supply lines. Plansee SE is manufacturing the High Heat Flux (HHF) target elements and MAN DT the wall protection panels. The horizontal and vertical target modules of the HHF divertor are designed to withstand power fluxes of up to 10 MW/m<sup>2</sup>. The baffles, which prevent the neutrals from re-entering the main plasma chamber, receive power fluxes of up to 0.5 MW/m<sup>2</sup>. The remaining first wall components are subject to neutral particles and plasma radiation of up to 0.3 MW/m<sup>2</sup>. In 2007 it was decided to start operation of Wendelstein 7-X with a test divertor unit (TDU) without water cooling. The TDU is designed for short pulses of 6.25 seconds at a maximum heating power of 8 MW. The recovery time between pulses at maximum load shall be 20 minutes. The design, manufacture and assembly is managed by the In-vessel component division in Garching. Assembly of the target modules from target elements for both the TDU and HHF divertors, much of the fabrication of the TDU frames and module structures, baffles, heat shields, the cryo-pumps and of the supply lines is performed by the Integrated Technic Center of IPP in Garching or the Technical Services in Greifswald. Specialised companies are used to perform the vacuum brazing, pipe bending, specialist welding processes and machining. All in-vessel components are tested in Garching (geometry, He-leak tests and hydraulic tests) before delivery to Greifswald. For the first operational period with the TDU it is foreseen to operate with a limited number of cooled components. These include the control coils and some special areas close to diagnostics and heating systems.



However, in order to reduce the length of the subsequent shut down, all the other components and their cooling circuits necessary for long pulse operation will be installed. Only the cryo-pump, the HHF divertor and their water supply lines will be omitted for this first operation phase. The input parameters for the cooling requirements during the first operation period are presently assessed in detail and fixed by a working group.

#### 4.1 Target Modules

The ten divertor units of the HHF target are designed to remove 10 MW convective stationary power load. The ten units consist of two main areas: the first, an area of 19 m<sup>2</sup>, which can be loaded up to 10 MW/m<sup>2</sup> and the second with an area of 5.4 m<sup>2</sup>, which can be loaded up to 1 MW/m<sup>2</sup>. Each divertor unit is assembled from 12 separate target modules. The highly loaded target modules are assembled from sets of bar-like target elements, which are supplied with cooling water in parallel and fixed on a common frame. The supports of these modules are adjustable within a range of a few millimetres to allow for compensation of manufacturing and assembly tolerances of the plasma vessel or uneven heat-loading during plasma operation. For the higher-loaded area 890 target elements are required. Their surface closely follows the 3-D shape of the plasma boundary and will be machined before assembly of a module. The decision to introduce the TDU in the first operation period has meant significant additional design and testing. The TDU will have the same surface contour as the HHF divertor. Some of the mounting frames and the intermediate area modules will be the same components to save time and cost. The TDU will use un-cooled fine grain graphite elements and is expected to withstand up to 8 MW/m<sup>2</sup> for 6.25 seconds. A total energy input limit of 50 MJ has been set for the design phase. The detailed design of the TDU including a prototype module test to qualify the design and fine grain graphite material was completed in 2009. During 2010 the 3D machining of the TDU elements, the Vertical support frames and vertical module frames have been completed, contracts for the first sets of horizontal support frames have been placed. The procurement of the divertor modules of the lower loaded area was started in 2010 using a design similar to the Baffles and will be included in the TDU phase. In 2010 the detailed design of the HHF divertor modules has continued. In the HHF divertor 8 mm thick CFC tiles made of SEPCARB® NB31, produced by SNECMA Propulsion Solide, are joined to a water-cooled CuCrZr heat sink. These tests have shown the improvement in the technology by the introduction of a compliant copper layer between the AMC® interlayer and the CuCrZr heat sink. In collaboration with the materials research division in Garching further lifetime and increased power loads have confirmed the robustness of the manufacturing technology. In 2010 a standard element with known

defects has been used to correlate the infrared measurements carried out in the ARGUS facility of Plansee SE with possible defects. With the support of the BMBF a pre-series of long elements is continuing to qualify the end tile and long cooling structure technology.

#### 4.2 Baffle Modules

The baffle modules prevent back-streaming of the neutralised gas from the target plates into the main plasma and protect the water manifolds of the target modules. The design uses graphite tiles, which are clamped onto a cooling structure made of CuCrZr. Water cooling is achieved by stainless steel tubes, which are vacuum brazed to the back-side of the heat sink. The fixing screws for the graphite tiles are made from a molybdenum alloy (TZM). In total there are 170 Baffle modules, 150 of the cooling structures are completed or in manufacture by the IPP workshop in Garching, the ordering of the graphite tiles runs in parallel to the cooling structure manufacture.

#### 4.3. Wall Protection

About 70 m<sup>2</sup> of the plasma vessel surface is covered by double-wall stainless steel panels with integrated water-cooling. In total over 320 panels have been delivered, including panels for the protection of the plasma vessel behind the pumping gap and an additional 50 panels required due to the Scenario 3 changes have been delivered by MAN DT. The majority has been tested and accepted. Additionally other areas of the inner wall of the plasma vessel are protected by heat shields. These heat shields use graphite tiles, which are clamped to a cooling structure using a similar design to the baffles. The design integrates several plasma diagnostic components as well as a NBI beam dump and mirrors for ECR heating. By the end of 2010 a total of 160 of the 162 heat shield cooling structures are completed or in manufacture in the IPP workshops. In 2010 a set of 4 heat shields were installed in a plasma vessel sector in collaboration with the assembly division. The procurement of the graphite tiles runs in parallel to the cooling structure manufacture. During steady state and full power plasma operation, the inner surfaces of the ports need to be protected in the same way as the plasma vessel. For budgetary reasons, the detail design of the port protection panes has been delayed, nevertheless, the qualification of the technology and definition of interfaces has continued. Since the space behind the wall protection is very restricted, all port protection panels will be later supplied with water from outside via port. The NBI ports as well as the port for the diagnostic injector need to be protected against energetic particles by CFC and graphite tiles from the beginning. In 2010 the manufacture of the first assemblies was completed. Due to new data the beam dump area is being re-designed to increase the cooled area and its thermal load capability.

#### 4.4. Cryo-pumps

Ten cryo-pumps are located behind the target plates to increase the pumping capacity for hydrogen and deuterium up to  $75\text{m}^3/\text{s}$  during high-density plasma discharges. The cryo-pumps are composed of a cryo-panel cooled with single phase helium, a Chevron baffle cooled with liquid nitrogen and an additional water cooled baffle. Fabrication of the cryo-pumps is well advanced, however, the cryo-pumps will be installed only after the first operation phase. Due to possible high ECRH stray radiation a special absorbing coating has been developed and tested in MISTRAL.

#### 4.5 Control Coils

Ten control coils will be installed behind the baffle plates. These coils will be used to correct small field errors at the plasma edge, to optimise the position and extent of the islands and dynamically sweep the power across the target plate. The coils have been fabricated by the company BNG. Each coil is made of eight turns of a hollow copper conductor and is water cooled. All control coils have been tested and accepted. All ten control coils have been delivered to Greifswald. During 2010 assembly trials have been carried out in collaboration with the assembly division.

The control coils are supplied by power supplies, which are able to provide direct currents of up to 2500 A and alternating currents up to 625 A with frequencies between one and 20 Hertz in parallel. In 2010 the operation of a power supply together with the associated control coil was performed successfully. The coil was operated up to the maximum direct and alternating current several times to check the electrical and thermal performance. Also the quality of the closed loop controller was checked successfully.

#### 4.6 Water Supply Lines inside the Plasma Vessel

Cooling for the in-vessel components is provided from the main water system through 80 supply ports in the different W7-X modules. The interface between the supply lines and the cooling loops inside the plasma vessel is achieved by so called plug-ins, which are groups of pipes and cables that can be installed as a single assembly with the port flange. The water cooling loops inside the plasma vessel form a very complex network of pipes with a total length of about 4000 m. Routing of the water pipes has to take account of the 3D-shape of the plasma vessel, avoid the diagnostics and heating systems port openings, take into account the restricted space behind the wall protection panels and identify appropriate attachment points. In addition, the design of the cooling circuits has to consider many interfaces with the diagnostics and heating systems. The design was qualified by the installation of a prototype in a sector of the plasma vessel. The design, manufacture, assembly and testing the main cooling circuits is complete. Some cooling circuits have been modified to take account of changes required by

other divisions and this work is progressing. A prototype plug-in, including a special thermal shield required for port protection and the diagnostic cable routing and protection, has been manufactured to qualify the technology and the design of the other seven variants. This has also been tested in MISTRAL to assess ECRH effects on the integrated diagnostic cables.

#### 4.7 Glow Discharge Electrodes

The conditioning of the W7-X plasma vessel will be performed by glow discharges. Ten glow discharge electrodes will be permanently placed inside the vessel. These electrodes are ready and available for installation in W7-X. One prototype was tested in ASDEX Upgrade and was operated successfully for four months. Some small design changes will be made to the fixation of the glow discharge cathode. A second test in 2009 was also successful.

Each glow discharge electrode is supplied by a separate power supply delivering a voltage of up to 3 kV and a current of up to 3 A. The power supplies have to be combined in one system with one central control unit. The contract for the development, production and test of the power supply system was awarded to the company Puls Plasmatechnik Dortmund. The whole system was produced, delivered to IPP and finally tested. In 2010 the test campaigns under different operating conditions were continued.

### 5 Engineering

The sub-division Engineering (EN) provides engineering support to the Wendelstein 7-X project. EN is now organised in two departments: Design Engineering (DE) and Instrumentation (IN). The department Development and Test (DT) was closed on July 9, 2010.

#### 5.1 Design Engineering

##### 5.1.1 Structural Analysis and Design

Design of the “basic machine”, i.e. without in-vessel components, diagnostics and periphery, is largely completed, structural parameters such as bolt preload, initial conditions for contact elements, etc., are defined. Therefore, the focus is shifting towards fast analyses of non-conformities, deformations as input for collision checks, and changes in the assembly procedure. This assembly-related work is expected to continue until commissioning of the machine, however, with decreasing intensity. In parallel the analyses for in-vessel components, diagnostics and periphery, as well as exploration of operational limits of the as-built machine are increasing. In addition, initiation of design activities on a relevant level at least for the mechanical structure and cryostat of a HELIAS stellarator reactor is considered indispensable in order to arrive at a competitive decision base for a DEMO-Reactor.



#### 5.1.1.1 Magnet System Global Analysis

The magnet system global model (GM) encompasses the non-planar and planar coils (NPC and PLC, resp.), the central support structure (CSS), and the inter-coil support structure. The latter comprises the narrow and lateral support elements (NSE and LSE, resp.) between the NPCs, the contact elements (CE) between the half-modules and modules, and the planar support elements (PSE) between NPCs and PLCs. The NSE and part of the PSE as well as the CE basically consist of sliding aluminium bronze pads and corresponding sliding steel counter-faces. The highly loaded interfaces between the CSS and the coils, the so-called central support elements (CSE), comprise the bolted and wedged flange connections, which partially open during operation. Two GM variants are routinely in use: The 36°-GM with flip-symmetric boundary conditions encompasses one half-module for quick simulations of bolt loads, cool-down, and magnetic loads. For loads not in accordance with the stellarator symmetry like gravity and cryo-leg forces, a more involved 72°-GM with cyclic boundary conditions is needed. For loads not complying with the five-fold torus symmetry, like forces from auxiliary supports during assembly, module misalignments, or trim coil fields, a complete 360° model or part of it is required (figure 8).

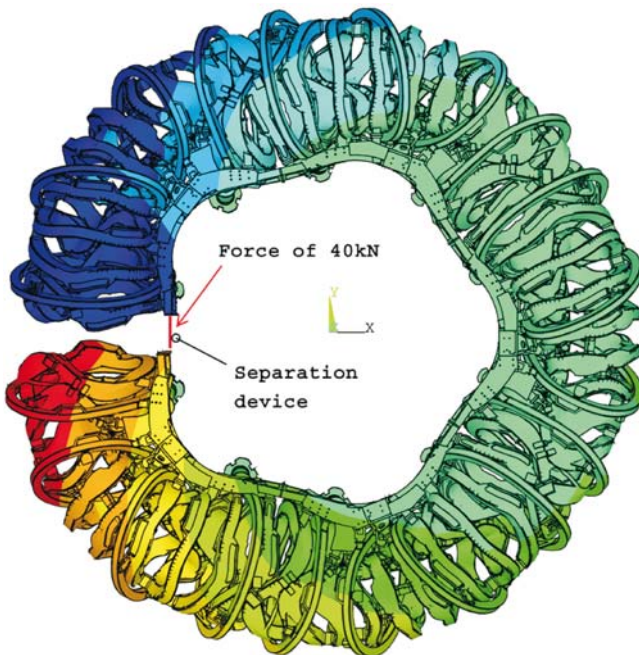


Figure 8: Evaluation of torus spreading of  $2 \times 0.25$  mm for assembly of the last module using the 360° global model. Deformation is shown highly exaggerated, forces are  $\approx 40$  kN.

Due to the non-linearity of the structure, the GM is very sensitive to variations of initial parameters and boundary conditions. For sufficient confidence, at least two independent

global FE-models are indispensable. Actually, three independent FE-GMs were created: The ANSYS GM with fully operational 36° and 72° variants as well as a simplified 360° model, the ABAQUS GM in 36° and 72° variants, and a completely independent and more detailed 36° ADINA GM, which was used to benchmark the other two. Now and in future only the ANSYS and ABAQUS models are in use. Continuous improvements as well as updating corresponding to the as-built geometry and real materials are still ongoing. The 36° and 72° ANSYS models are the workhorses, which are heavily used for all kind of magnet system analyses. The ABAQUS GM 36°- and 72°-variants, originally created by LTC (Italy), are now continuously operated and updated by IPP. They are used for benchmarking, comparative studies of special structural questions, and for tasks, for which ABAQUS is better suited (e.g. dynamic analyses, friction studies of cryo-legs, large deformations, limit analyses, serration effects). Major GM applications during the reporting period are listed in the following:

- Studies concerning operational limits based on as-built NSE gap tolerances have been started. The real gaps are about twice as large as previously assumed, therefore, significantly higher loads, particularly on the CSE and NSE, have now to be taken as design loads. In the worst case some extreme 3 T configurations might not be completely accessible.
- The 36° global models were extended from elastic to ideal elastic-plastic material properties, which yield better load distributions. Limit analyses are now possible resulting in large load scaling factors  $>2$  before collapse of the magnet system.
- The structure concept of a HSR5 reactor with  $\approx 12$  T at the coil was further developed using a simplified 72° FE-model. Figure 9 shows that most of the stress intensity in the double shell inter-coil structure is far below the allowable limits for steel, and that in the next step the structural mass can be greatly reduced. No CSS is required. It was also shown that stress and deformation levels in winding pack components (cable jacket and insulation) are comparable to the ones of ITER.
- Temporary supports at the interfaces between modules impede installation of the current leads. In order to accelerate the W7-X assembly, an early removal of these supports would be advantageous. The corresponding FE-analyses were completed with the result that premature temporary support removal is possible without unacceptable deformations of the magnet system.
- For moving the last module into the gap between the already aligned other four modules, this space has to be widened by 0.25 mm on each side for installation of flange shims with friction-enhancing foils. An assessment using the 360 degree FE GM (figure 8) gave a moderate spreading force of approx. four tons.

- The PLC case is a bolted and pinned structure with some highly loaded pins and surrounding case plate regions. The cyclic behaviour of the PLC case was analysed iteratively with the ABAQUS GM. The conservative analysis showed that even in case of complete breakage of a few pins there is no danger of excessive deformation and overloading of the winding pack.
- Dynamic FE studies were continued and finished for final evaluation of the “MQ-test” performed on a non-planar coil in the course of the acceptance tests at Saclay. The energised coil was hit with different impact energies in order to simulate stick-slip events within the W7-X magnet structure. Aim was to investigate the stability of the superconductor with respect to mechanical disturbances. The experiment and theoretical calculations confirmed that no loss of superconductivity has to be expected due to worst case stick slip events.

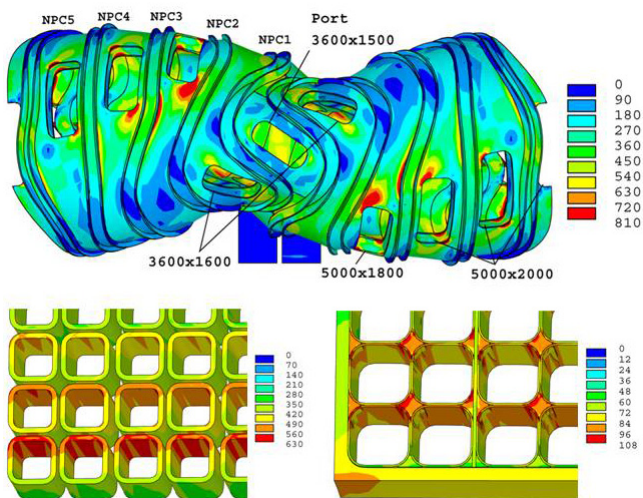


Figure 9: Stress intensity distributions in HELIAS reactor magnet system (top), conductor jackets (bottom left) and WP insulation (bottom right); units: mm and MPa.

#### 5.1.1.2 Detailed Analysis of Magnet System Components

Development, refinement and updating of the numerous local structure models for detailed analyses was done mainly at IPP. Cooperation existed with FZJ (bus system), Warsaw Technical University (CSEs and LSE 5-5), and with LTC (NSE limit analysis). Besides the accompanying calculations for W7-X assembly, other major tasks are listed in the following:

- The parametric FE-models created by WUT for all 14 CSE-connections were re-analysed with updated loads resulting from as-built NSE gaps. Three connections showed critical results and have to be further investigated using a less conservative, more accurate approach. This activity is ongoing.

- Limit analyses were performed by WUT on the CSE coil extension welds based on the updated loads and taking into account serration effects. Three coil extensions require further consideration with a less conservative approach. The most critical extension is currently under analysis.
- The design of the bolted LSE 5-5 was completed as a “mono-block” bridge without wedges but with friction-enhancing foils at the contact surfaces under direct bolt load. The bridge has to be adaptable within a wide range to the finally adjusted module positions. Extreme worst case configurations were confirmed with a 3D FE-model created by WUT.
- FE analyses of the module interfaces comprising adaptable shims and friction-enhancing foils were performed. Tolerances, requirements for flange preparation as well as recommendations for the assembly procedure were derived.
- The updated FE-models of the bus system, provided by FZJ, were checked and bus deformations extracted and prepared for collision control. At the interfaces to coils and current leads some reinforcements and design changes were necessary.
- In preparation of the trim coil specification the loads on the outer vessel as well as deformations were determined.

#### 5.1.1.3 Fracture mechanics

The acceptance criteria for surface cracks in the LSE weld influence zones were re-evaluated using different analysis tools. It was confirmed that the crack tip plastic zone of cracks in the maximally stressed regions are sufficiently small such that the linear-elastic approach is justified. Conservative crack propagation estimates show that the foreseen cycle numbers are by a safety factor of >10 below critical values.

#### 5.1.1.4 Cryo-piping

FE-modelling of the cryo-piping was completed for all five modules. The analyses were performed iteratively hand in hand with the design of the pipes and their supports. Modifications due to non-conformities, re-design of components, re-routing of the pipes, etc., are continuously implemented in FE models and re-analysed.

#### 5.1.1.5 Cryostat

Main application of the ANSYS cryostat GM was to provide input for local analyses, particularly forces/moments in port welds and OV supports, local deformations under Trim coil loads, diagnostic port movements/deformations, etc. The current outer vessel FE model is based on a CAD design, which is outdated by now due to many modifications during manufacture and assembly. Activities were started to collect all changes and assess them in view of implementation in an updated OV model. Evaluation of module 5 is completed.

Sufficient safety factors were taken into account in recent calculations so that no serious consequences due to the inaccuracy of the model geometry concerning strength, deformations and port movements are expected. For analysis of the significantly changed cryo-supply dome a local model was created with the help of IGN comp., Germany.

Further activities in the reporting period are listed in the following:

- Work on the port welds at the PV continued. The new weld design, created by AS in cooperation with EN, was analysed with semi-analytical methods. The majority of the ports could be released for welding with the new standard weld seam, and a few ones required stronger seams. For special ports, and in cases of doubt, laborious 3D FE analyses were initiated, including limit analysis. First results show that the planned welds are adequate with sufficient safety factors.
- PV deformation and port sag after tack welding and removal of supporting assembly tools was evaluated. Deformations and displacements of Type 1 ports are within acceptable limits, the Type 2 ("supply") ports need to be fixed temporarily with simple methods.
- Mainly due to tolerance deviations, several OV dome plates had to be split into two parts, and some plate welds had to be changed during assembly. Based on FE analyses of typical domes these weld seams were defined.
- In order to compensate for weld shrinkage, the OV and PV modules have to be shifted apart by 6 mm before welding. FE analysis showed that sliding back of the cryostat supports to the target positions due to the weld shrinkage is not assured. In order to minimise residual stresses and forces, the supports bottom plates thus have to be moved back separately.
- Analysis of the planned OV leg fixation on the machine base revealed overload of the bolts due to thermal expansion during PV/port baking and consequential heating of the OV. An appropriate re-design was developed in collaboration with Assembly dept.

#### 5.1.1.6 In-vessel Components (KIP) and Diagnostics

Analysis activities supporting the design of KIP components and diagnostics grew considerably, major examples are listed in the following:

- Thermal stresses and deformations of HHF divertor tiles were evaluated for overloads and realistic tolerances as achieved in production.
- The influence of thermal shields of the diamagnetic loops on their measurement signals was analysed. Cuts in the shielding were defined in order to limit signal attenuation.
- Two variants of the support structure of the Thomson radiation diagnostic were dynamically analysed with the conclusion that they are similar with regard to vibration response. For both structures it is expected that damping

measures have to be adopted, depending on the real vibration spectrum of the ground floor during W7-X operation.

- Shielding against plasma radiation in front of some diagnostic ports was analysed resulting in proposals for improvements.
- Thermo-mechanical analyses of retroreflector designs for interferometry and polarimetry was done for several fixation options. The poster presenting these analyses at the SOFT 2010 conference got the "Best Poster Award" in the category "Diagnostics, Data Acquisition and Remote Participation".
- Re-evaluation of all thermal loads within the plasma vessel has been continued.

#### 5.1.2 Magnetic Field Analyses

In order to compensate for the influence of accumulated construction errors on the stellarator field configuration, the module positions have to be corrected accordingly. The corresponding software was developed further. A target function, based on weighted field error components, was defined to be minimised for an optimal module position. The first three modules were placed on such optimised coordinates taking also into account the latest assembly state and measurements of all five modules. It was also shown that the influence of machine base sag during assembly is negligible and further corrections of the already placed modules are not necessary. As a recurrent task, calculations of fields and vector potentials, as well as eddy currents and the consequential mechanical loads were performed on request as design bases for components and diagnostics.

#### 5.1.3 Thermal Stress Analyses

Due to the extremely restricted space, the port cooling/heating (C/H) pipes were removed on all ports except at the large rectangular ones. This deterioration of temperature control was compensated by better C/H of the PV-sided flanges between the port tubes and bellows. On the rectangular ports some of the copper stripes providing the thermal contact between the C/H -pipes and the port walls had to be partially removed due to potential collisions. Thermal FE analyses provided decision bases for all these modifications. Another issue was insufficient thermal contact of the bellows middle section to cooling/heating pipes of the large ports, and insufficient flexibility of these pipes to follow the bellows deformations. Based on FE analyses, necessary design changes for both the pipe routing and reinforcement of thermal coupling were developed. Removal of the C/H pipes cause the port wall temperatures to increase during hot-liner operation in those ports, which contain hot water heating pipes. FE analyses revealed that all wall temperatures stay below the allowable level except in one port. For this a special internal wall shield was proposed and developed in collaboration with KiP dept OV heating during



PV/port baking at 150 °C as well as the corresponding heat flow into the torus hall were analysed (figure 10).

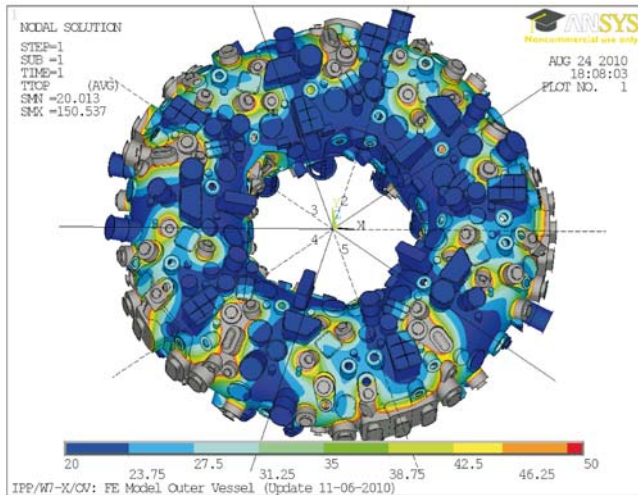


Figure 10: Outer vessel temperature distribution during PV/port baking at 150° C. Gray colour represents regions with temperature above 50° C.

It turned out that the average temperature of the OV body remains below the maximally allowable value of 50°C by natural air convection. However, the heat load on the torus hall becomes up to 200 kW, which has to be taken into account for climate control.

## 5.2 Instrumentation

Main activities were the creation of work instructions for instrumentation applications on the W7-X cold structure and development of signal transfer and processing. Remaining detail development work concerning special applications and clarification of measurement accuracies was completed. Some applied sensors were already used during assembly steps and assembly qualification procedures.

### 5.2.1 Sensors

Application of magnet structure sensors within all five modules of the cryostat is finished to 97 %. These are the strain gauges (SG) on the PSEs, LSEs and CSEs as well as on all highly stressed CSE bolts. The SGs on the bolted LSE 5-5-bridges will be applied after module connection. All cantilevers to monitor the critical CSE flange openings and displacements between the NPCs and PLCs were installed. A solution was found for a SG-based system to monitor the loads on the cryo-legs. The idea is to measure the circumferential compression of the ring-shaped spherical cryo-leg bearing with six SGs (figure 11). FE-analysis showed that the SG signal is almost linear with respect to the cryo-leg load. All bearings are furnished by now at their inside openings with SGs. They are used already for cryo-leg load measurements each time a module is placed onto its

final position. Approximately 20 positions per module are instrumented with electrical contacts to monitor the cold structure for collisions. These sensors, consisting of self adhesive tapes requiring only one signal wire per contact, can easily be adapted to all kinds of component surfaces, even to the surface of multi-layer insulation packs. Modules 5, 1, 4 and 2 are fully instrumented by now, the positions in Module 3 are known and described in a work instruction.



Figure 11: Cryo-leg bearing ring opening instrumented with 6 SGs (left). Instrumentation cable fed through the bearing base plate (right).

### 5.2.2 Signal Transfer and Processing

Much work was devoted to find out the best shielding and grounding system for the instrumentation cables and electronics. Advantage was also taken from experiences gained at ASDEX-Upgrade. A prototype of the whole cryogenic measuring chain consisting of sensor, cryogenic cable, feedthrough, torus hall cable, and cubicle has been built in the lab. Strains and displacements can be simulated under well defined grounding conditions. Investigations using disturbing signal generators and intentionally created power grid disturbances revealed that acceptable signal noise levels can only be achieved with doubly screened cables in a special grounding arrangement. The corresponding cable specification was prepared. A modular cubicle concept was developed. A cubicle consists of the boards with electronics, the power supply module, the line power connection with filter, and the mechanical structure. Based on thermal experiments, a cubicle cooling system was developed using only internal fans and air streams.

### 5.2.3 Extended Instrumentation Group

The extended instrumentation team is composed of members from all divisions and chaired by the EN-IN department head. Its task is to coordinate all instrumentation activities of the project, and it meets at intervals of about six to eight weeks. Main achievement in the reporting period was the final I-Port (cryo-instrumentation feedthrough port) design. A prototype was leak tested, and manufacturing has started. The I-port pinning for Module 1 and 5 has been agreed. The originally planned soldering of the sensor cables to the feedthrough contacts at the cold side was changed to crimping for easier and quicker assembly.

### 5.3 Development and Test

Task of the department EN-DT was development and test of special components of the W7-X magnet system. This work was very successfully completed and EN-DT was closed down in summer 2010. The staff of the department was distributed to EN-DE and the new department Diagnostic Engineering of the sub-division W7-X Physics.

#### 5.3.1 Coil Support Elements

EN-DT helped to prepare and update work instructions for support elements and the CSS, and was heavily involved in evaluating achieved tolerances and non-conformities. Furthermore, MoS<sub>2</sub> layer applications and coil spreading for LSE assembly were supervised. Another routine work was to check and release drawings of connection elements. The systematic NSE MoS<sub>2</sub> layer ageing experiments were finished and summarised in a report. A long time exposure experiment of reference NSEs was started in the torus hall of W7-X in order to allow evaluation of the NSE lubricant layers condition – which are exposed to the torus hall air during the W7-X assembly phase – over the next years.

#### 5.3.2 Module Connections

At the bolted connections of the CSS and the LSE 5-5 high shear forces have to be transmitted. The steel friction factor (FF) has to be significantly increased. Therefore, a qualification program was performed for commercially available friction foils to be inserted between the contact surfaces. After extended test series at room, LN<sub>2</sub>, and LHe temperatures the optimal foil with a FF=0.5 was selected. In addition, cyclic load experiments were performed in LN<sub>2</sub>. The required FF >0.5 was confirmed for the relevant case of dynamic loads without sliding.

#### 5.3.3 Coil Quench Experiment (MQ Test)

Aim of the MQ test was to explore whether dynamic loads originating from stick slips within the magnet structure are able to trigger large enough elastic energy releases within the superconducting cable to cause quenches. The impact loads were applied by a pendulum via a transfer rod to the casing of the cold and energised coil within the test cryostat in Saclay. No quench could be triggered even with the maximal impact energy of about 200 J, corresponding to the worst estimated disturbance within W7-X, and at coil operation conditions with the lowest superconductor stability margin. The data of the successful MQ test were further evaluated and finally documented, the main results were published.

#### 5.3.4 Potential Breaker

The mechanical strength of the potential breakers in the He supply lines for the coil cables is not explicitly specified. They are connected to flexible cryo-pipes, which are not supposed to transmit significant forces, moments and torsions

during W7-X cool-down and operation. However, such loads on moderate levels are unavoidable. Therefore, experiments at ≈85 K were performed to check structural integrity and leak-tightness of the breakers under torsion and tension, and an internal He gas pressure of 10 bar. It was found that the potential breakers withstand, without leaks or mechanical defects, about 10 times the loads expected in W7-X.

#### 5.3.5. Materials

Maintenance and supplementation of the material data base (MDB) was brought to an end. The MDB is a collection of thermal and mechanical property data of all kind of cryogenic materials within W7-X, including all test results from the materials qualification programmes. A summary of the evaluated data was published.

## 6 Design and Configuration

The subdivision “Design & Configuration” is responsible for configuration management of W7-X, for configuration control of the components in the cryostat, the plasma vessel and the components in the experimental area and for providing design solutions and fabrications drawings for many components of W7-X. These tasks are taken care of in the three departments “Configuration Management”, “Configuration Control” and “Design Office”.

### 6.1 Configuration Management

The department Configuration Management (CM) is responsible for providing the complete and up-to-date system identification of all components of W7-X and to ensure proper change and deviation management. This then allows the determination of the present design or implementation status of all components of W7-X and provides detailed information on the history of any design changes. The system identification of all components and documents related to design, installation and operation of W7-X is stored in individual documents, the so called “Ringbuch” documents that either provide the information or refer to the most up-to-date information. Of those, interface documents describe in detail the nature and agreed upon specifics of all interfaces between pairs of components and change notes describe changes in the design that were adopted after the initial design had been released. The product lifecycle management (PLM) system is simultaneously used as a documentation data base, as a navigation platform to the specification of W7-X and its components and for notification on new releases of CM-relevant documents. Permanent control of the various CM processes is supported by specific process data bases, e.g. status and open issues of change requests, quality deviation reports and interface descriptions, are monitored. Well-established procedures are being followed to counteract any delays of in the change note processes or to assist particularly critical issues.



By now the configuration management for system identification, change and deviation management, interface coordination are routinely applied. Currently, 862 design change requests are registered in the change data base. 83 % of the requests have been accepted, 6 % are in the decision process and 11 % have either been rejected, withdrawn or became obsolete by revision. 75 % of the accepted change requests have been closed, i.e. the relevant design and assembly documents, computer aided design (CAD) models and drawings have been revised or created according to the change. Highest priority has been given to changes, which may directly affect the progress of W7-X assembly.

The W7-X interface matrix is currently built up of about 70 components. 192 pairs of them have identified interfaces, which are followed up by the interface coordination process. 51 % of the interface descriptions has been released, 44 % are being processed. For the remaining 5 % the design process of at least one of the components and thus the interface definition is pending. 15 % of the interfaces are fully defined, i.e. the interface descriptions have been released and there are no open issues left.

## 6.2 Configuration Control

The department Configuration Control (CC) is responsible for ensuring collision-free operation of W7-X during all modes of operation and for coordinating the space requests of peripheral components in the torus hall and adjacent buildings. In 2007, tools and procedures were established, to enable detailed and accurate investigations taking into account as-built geometries, in-operation deformation, etc. In 2008, procedures and interfaces with others department were defined or improved and the global strategy for configuration control was defined with the W7-X-board. Due to missing or late information on the deformation of those components and a lack of engineers able to perform the sophisticated investigations, it was necessary to take some risk management decisions: no configuration control for cryopipes was being done, the tolerance chains were reduced (average value instead of worst case). In 2009, the number of engineers in the department was temporarily doubled from 17 to 34 to cope with the workload and deadline of the thermal insulation configuration control. This required a change in the organisation: the group leaders were replaced by a team of projects leaders, and tasks were organised in projects. The department also performed a global check of the first module before the assembly in the outer-vessel. This check was a success: problems (resp. corresponding corrective actions) have been early enough discovered (resp. realised) to ensure the assembly of the module without any problems. It was therefore decided to perform the same check also for the other modules. In 2010, the department performed the global check of the second and the third module. The configuration control of components in cryostat

(thermal insulation, bus system, cable trays, etc.) has been pursued and completed (only a few components still need to be investigated in 2011). Space reservation and design activities in the torus hall have also been pursued, for instance routing of cooling system, vacuum system, space reservation of heating devices, escape paths. The team devoted to this activity was very small during the first semester, but the completion in time (and sometimes ahead of schedule) of the configuration control tasks allowed the department to start to increase the staffing of the team during the second semester. The department "configuration control" continuously improves existing tools and establishes new ones. In 2010, the templates for issuing configuration control reports were further refined to better fit the demands and improve the tracking of changes in the CAD models. Excel tables and databases were implemented to provide complete information on all relevant issues. The CAD database tool Smarteam has been successfully implemented for the group System Layout and specific tools (export, collision reports, etc.) have been developed. The department also played a major role in the change of the assembly procedure of the ports. The first step of this procedure (performed "manually" by AS for the first module) was completely replaced by a new procedure. This new procedure consists in the measurement (scan) of the plasma vessel openings and the computer assisted creation of stencils and requirement sheets. These documents can then be used by AS to perform the cutting and assembly of the port without any additional preparation step. These documents were created for most of ports of module 1. This task required the development of specific tools and procedures inside the department and a lot of common work and coordination with AS.

## 6.3 Design Office

The tasks of the department Design Office are developing design solutions and providing fabrication drawings for components, supports, and tools for W7-X in close cooperation with the responsible officers of other departments. Additional tasks are defining and implementing design guidelines for working with CAD programmes and maintaining a proper structure of the CAD models in the data base. The design office is organised in four groups that focus on different design tasks: The Cryostat group, the Structural Elements group, the Components-In-Plasma-Vessel group and the Diagnostics group. In this way it is possible to coordinate related work packages, to maintain the same standards and design characteristics, to ensure simultaneous engineering, to adopt the design resources quickly to the extent of the design tasks, to effectively train new personnel. Most of the components of W7-X were originally designed using the CAD tool CADD5. In recent years the transition was continued to use the design tool CATIA V5 instead unless the components were already such much

advanced that the conversion to CATIA would have been inefficient. Simultaneous engineering was made feasible by maintaining two identical overall assemblies of all components of W7-X both in CATIA V5 and CADD5 5. The leading assembly for most of the year 2010 was still CADD5 5, since the end of 2010 with the availability of the corresponding data base systems the leading assembly is being maintained in CATIA V5. The group Structural Elements group mainly provided design solutions for various structural components in the cryostat: Here the remaining fabrication drawings for the structural support elements were provided on the basis of measurements of the attachment flanges. Port, outer vessel dome and outer vessel surface models and drawings were modified according to a number of change notes that became necessary to mitigate collisions with the thermal insulation inside of the cryostat or to accommodate the increased space required for in-vessel components. The group Cryostat completed the design of the thermal insulation, of the cryogenic helium supply pipes and of various supports for permanent or temporary use within the cryostat. By now all components inside of the cryostat have been designed. Some modifications, however, are necessary for the cryogenic pipes in the vicinity of the attachment supports of the current leads. The Components-In-Plasma-Vessel group completed the design of the heat shield, of the covers of the diamagnetic loops, of the water cooling pipes and of the wall panels in the plasma vessel based on the design requirements of the initial phase of operation. The Diagnostics group focussed on the design of those diagnostics that need to be installed first or that require the longest time of development and fabrication. The remaining work load is substantial therefore care is being taken to completely specify the design requirements to limit the need for later-on iterations and to monitor the work progress closely in order to receive early warning the predicted completion dates tend to move after the required completion dates.

## 7 Assembly

In 2010 the preparations of assembly equipment and extensive assembly trials have been continued. The fifth and last magnet module passed successfully the mechanical pre-assembly. The first three magnet modules are put into their outer vessel modules on the final positions in the experimental hall. The alignment accuracy achieved is still much better than originally expected. The fourth magnet module was completed with the helium pipe system and the bus-bar system. The bus-bar system is being installed at the last magnet module. Further complex assembly devices for the final assembly (assembly ramps, vessel rigs) were put into operation and optimised. The manufacturing of the bus-bar system (co-operation with FZ Jülich) was accomplished successfully. The manufacturing sit at FZ Jülich was dis-

mantled. All pre-assembly work runs smoothly and without essential problems. The preparation of plasma-vessel (PV) sectors and coils and support structures were finished and the associated assembly equipment dismantled. Both the mechanical preparation of the outer vessel shells (including the complex plasma vessel supports) and the installation work of their thermal insulation still run routinely. The main focus in 2010 was the implementation of the port assembly. With large effort and additional resources this challenging task could be coped with. Indeed the process time needed for the port installation had to be extended noticeably however the schedule could be kept constant through increased work density, optimisation of the technology and restructuring of work packages. Both assembly and welding procedures for special ports were developed to minimise the welding-shrinkage. The assembly sequence and technology for current leads were conceptionally finished with the assistance of the PPPL and ORNL in Princeton and Oak Ridge. A 1:1 mock-up was built to qualify the associated technologies in detail. The challenging assembly process-planning, process documentation and work safety system run reliably.

### 7.1 BUS System

The manufacturing of bus-bars and the associated complex mechanical supports were accomplished. Works on the first four modules are complete; the fifth module was started with. All work inclusive the insulation at the bus-bar joints runs still routinely and without major problems. The process time was shortened accordingly. Development-works for the electrical connection of bus-bars and current leads were continued. A detailed and comprehensive assembly sequence was compiled and reviewed. The technological concepts were developed by the ORNL in Oak Ridge and the PPPL in Princeton. These concepts passed successfully the final design review (FDR). The entire sequence will be tested with dummies in a 1:1 mock-up, which has been built in 2010. First trials showed promising results. The cooperation with IFJ in Krakow was fruitful as in the years before. IFJ provides a major part of the technicians and the responsible line management for the daily works. In conjunction with the decrease of work in this assembly area (no further developments needed) the staff was reduced accordingly.

### 7.2 Vacuum Technology

The work packages of the vacuum technology group in 2010 were continued as in the years before. Main tasks were: leak detection on single components and on the cryo piping of thermal insulation; Paschen tests on coils and on the bus-bar system during the coil preparation and the assembly. Local leak tests with diverse test chambers for superconductor connections and cooling pipes at room temperature and at 77 K (if technically necessary) are routinely used during assembly.

The design of these test-chambers as well as the qualification of the practise was further continued. Design works on the vacuum systems were continued; first components have been ordered. The procurement contract for fast piezo valves for the gas-inlet was finalised.

### 7.3 W7-X Assembly

#### 7.3.1 Component Preparation

The work at the preparation of coils, plasma vessel sectors and support structures has accomplished. Works at the last four outer vessel shells and ports are continued as planned. The preparation work on ports meanwhile runs also routinely. The development and implementation of the detailed procedures required 50% more resources than originally planned. Particularly the precise definition of the 3D cut-contour was very challenging. Moreover, the practical alignment of prepared ports is possible within about 2 mm but the high precision welding procedure requires accuracies of less than 0.5 mm. By rework these discrepancies have to be balanced. The minimisation of this rework through refined preparation processes was one main task in 2010. During the running work the preparation sites were changed to reduce costs. Internal hall space became free since the coil preparation was accomplished and the contracts therefore could be cancelled for external hall space. Despite the more and more optimised technology for the port assembly more process-time was needed than considered in the project schedule. One way out was to omit the trial-assembly of the ports, which lasts about two months per module. With that, the real contour of the PV opening should directly on the port be transferred. Instead, a theoretical procedure was successfully introduced, which bases on metrology data that are converted to a theoretical cut contour through the back office. This process runs completely in advance and in parallel to the practical works on site. A second counter measure was the utilisation of idle times by increasing the work density in the torus hall. Also these improvements were successfully implemented. With all counter measures the original schedule milestones could be kept. First ideas for the preparation of KiP components were developed. Suitable hall space was made up for these works.

#### 7.3.2 Pre-assembly

All magnet modules have been completed mechanically in the pre-assembly. The associated complex assembly equipment was dismantled. The hall space is used now for installing the thermal insulation on ports. The first three modules are positioned onto the machine base in their final co-ordinates. The fourth module is ready for being transported onto its final position. The fifth module gets its bus-bar and helium-pipe system at the moment with all mechanical, electrical and hydraulic connections. These works are running smoothly and routinely and they are slightly in advance of the schedule.

Since here the work load is decreasing and no further qualification and development work is needed, the staff was reduced accordingly.

#### 7.3.3 Final Assembly

In the final assembly the construction work at the first module of W7-X is nearly accomplished. In this module all ports have been installed, welded and leak tested. In the second module the port installation is finalised whereas in the third module these works are just started. The overall accuracy at the port installation is a bit worse than expected but still compatible with the later use of the ports. The implementation of the complex assembly technology was more time and resource consuming than planned (see chapter “component preparation”). Almost all technology resources of the assembly subdivision were allotted to these work packages. Also the assembly bridge and ramps had to be optimised a few times.



Figure 12: The port assembly ramp in operation from the floor.

After ten very work-intensive months in 2010 the technology is now running routinely. Only the highly accurate port AEK-V2, which is used by the ECRH heating still requires the development of a special technology. The precise welding



process particularly is qualified at present. Thanks to a comprehensive qualification in advance the port welding and leak inspection are running without special problems or delays. The quality of these welds is excellent up to now. Six additional welders who are highly qualified were hired from the industry to cover the work system with 88 hours per week. This is another example for the good and long-standing co-operation with our partner firms. The optimisation of the ports assembly is ongoing but with less recourses. The installation of the thermal insulation (TI) in parallel to the port installation runs also very smoothly meanwhile. These works are made by MAN DT. Still open is the issue of harmonizing the different shift systems between IPP and MAN DT. The solution of that issue could save further time and shall be traced again in 2011. The shipment of the fourth module to the experiment hall lies ahead briefly. The insertion into the outer vessel shells is expected to run as smoothly as with the former three modules. Probably these works will start a bit earlier than assumed in our schedule. The preparation of the outer vessel shells for the last module runs without any problems and within the schedule. One main work package in the assembly technology was the further development of the assembly sequence for the module separation plane (MSP). 3D shims (wedges) are used to bridge the gap between neighbouring modules of the magnet structure. The modules of the structure can relative be tilted, shifted and twisted to each other. That result from the final alignment of the individual magnet modules within the W7-X co-ordinate system, which is made independently for every module (minimisation of the resulting field error). Eight shims in total are needed per MSP. Each shim weighs about 20 kg. Every shim must be customised with an accuracy of better than 1/10 mm, which forms a practical limit. Together with the shims diamond-coated friction foils are inserted into the gap between the neighbouring modules. The determination of the gap dimension is made by means of steel-templates and measure machine. The associated procedures were successfully qualified. Another very comprehensive development was made for the lateral supports at the MSP. These supports connect the coils at the adjacent modules. Each support weighs about 50 kg and must be precisely installed through the quite narrow gap between the outer vessel modules. For the positioning and tightening of the bolts the technician must work in the interior of the module in a narrow assembly duct. The support itself represents a complex twisted wedge construction. It must fit into the counter supports at the coil housings with a form-lock better than 1/10 mm. To achieve that accuracy the individual 3D shape of the coil supports is laser scanned. After that the position of two respectively opposite supports is determined with the photogrammetric. Both data sets the scanning and the photogrammetric are then combined forming the base for the manufacturing of an aluminium dummy.

This dummy is trial installed and as long as reworked until the remaining gap is smaller than 5/100 mm. The aluminium dummy is the base for the consecutively manufacturing of the original steel support, which is made from steel 1.4429. This procedure shall be repeated for every support. The soundness of this procedure was proven using several mock-ups and trials. Procedures for the connection of the vessels inclusive its thermal insulation at the MSP were agreed with the company MAN DT. The assembly procedure for the current leads (CL) was the third development work package in 2010 for the final assembly. Much assistance was given by the ORNL in Oak Ridge and the PPPL in Princeton to find conceptional solutions for the various complex details. Particularly a doable solution for the temporary support structure was worked out, which is situated in the interior of the cryostat in the narrow vicinity of coils, pipes, bus-bars and ports. The pair of CL (each weighs 250 kg) will hang at this structure temporarily during the assembly process. The upper end of the CL must be positioned precisely in front of the aligned bus-bar joints to ensure that the electrical connection between CL and joint has got a resistance value of not more than about 10 nOhm. In addition, any misalignment will result in residual stresses, in the associated ends of the bus-bars, their insulation and welds. After the assembly the dead weight of the CL is taken by pivot supports at the bottom side of the CL. The critical step is when the dead weight is being transferred from the temporary support at the upper end on the pivot support at the bottom side. The CL must not inadmissibly tilt or set during this operation to avoid an overstress of the sensitive welds and insulation-connections.

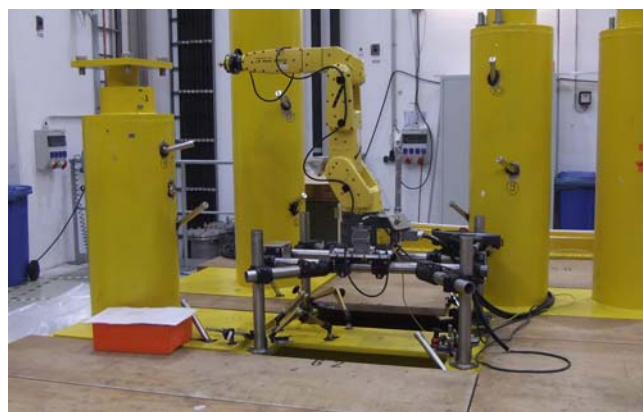


Figure 13: The manipulator during the acceptance test.

A whole set of alignment tools and support was designed and will be tested to realise these requirements. A major tool will be a modified assembly ramp, which is already used during the port assembly. This ramp will allow the precise assembly of the CL but also the associated heavy domes (part of the outer vessel) and pivot supports. In addition this third ramp can be used for the assembly of ports either.

This shall help to minimise idle times. The delivery of this ramp was contracted to the Fantini Company in Italy, which delivered already the first two ramps. For it a comprehensive set of manufacturing-drawings was provided by the ORNL. With the use of the above technologies the five individual modules can be connected with each other and the torus of the base machine of Wendelstein 7-X will be accomplished. According to the present planning the first MSP will be closed in summer 2011. But first part-works have already started.

The co-operation with the KiP division in Garching at the field of conceptual planning of the assembly of the KiP has been continued in 2010. Trial assemblies with wall panels, heat shields and sweep coils have been continued successfully. The system of platforms and cranes for the handling of components was developed further. A manipulator for the precise 3D-alignment of supports and bolts in the interior of the PV was delivered meanwhile. The manufacturing and necessary improvements for achieving the specified accuracies of that system lasted much longer than the supplier and the IPP were expecting. The target co-ordinates for this manipulator are being deduced from the CAD data of the associated models. In the final acceptance test it was proven that the positioning accuracy of the manipulator is approximately within half a millimetre. The technology development in terms of logistics, tooling and procedures is continued as planned.

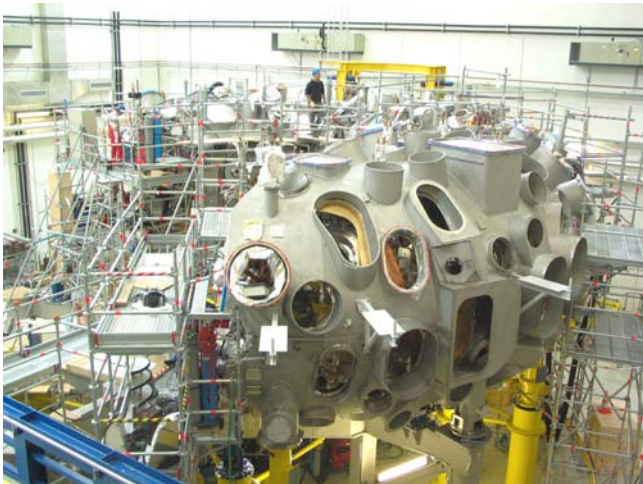


Figure 14: Three out of five modules in the torus hall.

In the periphery, the work on cryo instrumentation in conjunction with the work at the bus-bar systems has been further continued. Installation works of the extension of the low voltage power supply system are continued. The conceptual planning for the realisation of the Electro-Magnetic Compatibility (EMC) during the construction of the periphery was continued. The first construction stage of the cooling system is complete. The planning work on the second stage

is ongoing as planned. The assembly control and the planning work routinely as before. The advanced weekly and 4-weekly plans are used as standardised tools. The preparation of the assembly documentation (QAAP, work and test instructions) is ongoing without any severe problems. In 2010 a further refined resource planning was made. Quality deviations are reliably handled as in the years before. The assembly schedule was slightly updated. The planning for the final periphery (cables, cooling pipes, vacuum lines, and platforms) was further refined. The details here will become a highlight in the year 2011. The commissioning date was kept constant on the middle of 2014 but the work density during the final assembly was increased further. Staff for the assembly was adapted to the changing work packages (mechanics, insulation specialists, welders) with personnel from the industry. More responsible officers took up their employment. Again external staff was included to ensure the partial two-shift-system and extended working times in the assembly. Additional engineering staff started the work for the development and qualification of technologies for the final assembly. The co-operation with engineers and technicians of the Polish Academy of Sciences was continued. Altogether, assembly has reached the planned progress in 2010. Further new assembly technologies were qualified and successfully tested. The preparation of coils, plasma vessels and structural components was accomplished. The same applies to the mechanical pre-assembly of magnet modules. The assembly technologies for the ports were conclusively defined. The device assembly ran continuously and speedily as planned. Resources for engineering tasks and technicians for assembly works were adapted to cope with the changing work packages and needed work capacities. The port assembly technology was completely implemented. The detailed technology for the assembly of module separation planes (magnets, vessels, ports, current leads) was comprehensively developed and complemented. The assembly control with the planning and the documentation of assembly was further refined and works furthermore experienced and reliably. The co-operation with external partners who provide skilled and well-trained technicians and engineers for the realisation of the assembly work on W7-X works stable and smoothly.

## 8 DIAGNOSTICS

### 8.1 Overview

The work concentrates on the “start-up diagnostics” set necessary for safe operation and control of the machine and those diagnostics adapted to and being indispensable during the initial operation phases of the experiment. The diagnostics department consists of three expert groups and a temporary working group, which is developing and testing solutions for ECRH stray radiation shielding of in-vessel components.



The following sections briefly summarise the main activities within the expert groups of the project.

### 8.1.1 Edge/Divertor and Magnetics Configuration Diagnostics

A design optimisation of the flush mounted Langmuir probe array for the Test Divertor Unit (TDU) with respect to manufacturability has been carried out and a new mock-up for testing this design in GLADIS manufactured and assembled. For the first time two of the probe tips were wired and a realistic cable routing implemented. In parallel the electrical connector unit at the end of the divertor module as well as the routing to the plasma vessel and along the vessel wall into the port till the electrical vacuum feed throughs has been completed. The principal design of a resonant piezo step-driver for linearly movable probes required for the pop-up probe array for the actively cooled High Heat Flux (HHF)-divertor has been finished, so that the high-temperature piezo-material can be ordered now. The short prototype of a manometer cannula for W7-X has been successfully tested on WEGA and a number of possible further improvements identified. The mechanical tests of a long prototype showed a small cross-deformation of about 3 mm from bending of the 2.30 m cannula under its own weight, asking for an additional support of the head inside the machine. Using the short prototype the required reduction of the noise with the re-designed digital electronics has been successfully demonstrated on WEGA. The  $H_\alpha$ -diagnostic for W7-X will be installed in all 10 AEF ports, together with the infrared-thermography cameras, for monitoring the divertor plasma in the upper and lower divertor modules with mm-spatial resolution. The design study for a long pulse compatible endoscope system with a cooled entrance pinhole and a mirror system mapping the light from the divertor view onto different detection branches equipped with filters and cameras sensitive for visible and two different IR-regions has been finalised and the specifications for an international call for tender are being prepared. For cost reasons, during the TDU-phase only two such endoscope systems will be installed, while the other eight ports will be equipped with a simple immersion tube system sealed with IR and visible vacuum windows and a shutter for protection during plasma wall conditioning. A cradle containing the IR camera, a visible camera with a wide angle objective equipped with an interference filter (IF) and a third channel for either a further camera system or a fibre optic for spectroscopy, mounts directly behind the window flange to maximise the field of view. The cradle system is at atmosphere and can be unhinged from the immersion tube to service the cameras. With the IFs selection of certain wavelengths bands (e.g.  $H_\alpha$ ,  $H_\gamma$ , C II or C III line radiation) in front of the visible cameras particular physics questions and scenarios will be addressed. Furthermore a third  $H_\alpha$ -diagnostic system employs single-line-of-sight views at various ports collecting the radiation with simple lens systems into fibre-bundles for

spectroscopic investigations. The micro bolometer IR-camera sitting in the cradle has been especially hardened for operation in strong magnetic fields (up to 3 T). The system contains a state-of-the-art infrared detector with  $640 \times 480$  pixels and has a Gigabit Ethernet interface. It features a temperature range of  $0^\circ\text{C}$  to  $1800^\circ\text{C}$ , a special wide-angle lens with FOV of  $116^\circ \times 82^\circ$ , a pneumatically driven shutter and consists of two boxes. The first one includes the sensor housing with parts not sensitive to the magnetic field. The second one is the electronics box, which contains all parts expected to fail in high magnetic fields. Both the sensor housing and the electronics box are sealed to IP54 standard with a rugged housing that holds up well in environments where water and dust resistance is required. Screened cable connections between them provide protection from alien cross-talk and electromagnetic interference. The video diagnostic is being developed by HAS (Budapest, Hungary). A prototype of the video diagnostic system has been manufactured and used for a complete mechanical and thermal in-vacuum test at IPP-Greifswald. Besides the test of the camera docking mechanism the complete system's behavior was tested simulating the different heating scenarios (baking, various plasma operation scenarios) by using an infrared heater. The air cooling (both camera capsule and objective) and the water cooling (pin-hole part) efficiency was found to be sufficient: at the maximum expected temperatures the cooling systems were able to decrease the temperature to an acceptable level in a sufficiently short time span, so that the design of the mechanical part of the diagnostic could be closed. The test of the optics, specially designed for observation through the pinhole, has demonstrated that it performs up to its specifications. The first fully functional control software package (v1.0) for the EDICAM v2.0 fast camera has been completed. The software features all fast camera functionalities, such as a very flexible region of interest (ROI) selection, a wide range of exposure times (25 ns - 100 s), frame rates up to 100 kHz, and triggering capability. The development of the firmware for the intelligent camera operation has been continued in 2010 and the first results are expected in 2011. Reference designs for the in-vessel cabling of the magnetic diagnostics and for the ECR stray radiation shielding of the in-vessel Rogowski and segmented Rogowski coils as well as the diamagnetic loops were chosen. Vacuum tests of outgassing, stray radiation shielding as well as modeling and tests of the electromagnetic behavior, in particular of the effect of eddy currents in the stray radiation shielding, were initiated. The present status of the in-vessel magnetics was reviewed in the framework of a design review in order to identify open points. A concept for the temperature surveillance of the in-vessel Rogowski coils, the segmented Rogowski coils and the diamagnetic loops has been developed. Several material options for the Mirnov coils were considered and first prototypes of these coils been ordered from industry.

The signal cable routing inside the plasma vessel and within the ports was designed for the magnetic diagnostics. The cabling and rack layout in the experimental hall outside the vessel and the definition of the interface to the data acquisition systems has been started.

The design of the manipulators (for the electron gun and the fluorescence rods) and shutters for the flux surface diagnostic made significant progress. The electron gun based on LaB<sub>6</sub> electron emitter material was successfully tested up to a magnetic field strength of 3T in a gyrotron magnet and utilised during magnetic field line visualization experiments on WEGA. In order to provide well defined geometrical reference points inside the W7-X plasma vessel, within the plane of the fluorescence rods, for the AEQ port video observation cameras, copper coated quartz fibres, which will be integrated into the graphite tiles of the wall protecting elements and which can be illuminated from outside the plasma vessel will be used. The ECRH stray radiation compatibility of fibres has been qualified during a test campaign in the MISTRAL chamber. The fibres can be continuously operated at temperatures of up to 700 °C. For the data analysis of the helium beam diagnostic a Bayesian inversion model has been implemented. Simulations for high density and low temperature detached divertor plasma operation show the necessity of an absolute intensity calibration of the detection system to achieve acceptable density measurement errors levels. An application of white light interferometry for in-situ measurement of diagnostic window transmission losses due to plasma deposition in the visible spectral range is being investigated. First Bayesian inversion based simulations suggest the possibility to derive the thickness and absorption coefficient of a coatings building up on the windows from a measured reflection spectrum.

#### 8.1.2 Microwave and Laser Based Diagnostics

The classical microwave and laser diagnostics are being prepared aiming at the measurement of electron density and – temperature in the plasma core, namely Thomson scattering, interferometry, polarimetry, reflectometry, and ECE. The design of most in-vessel components has been finished. For the ECE system the Gaussian in-vessel optics consisting of stainless steel mirrors, with the first mirrors actively being cooled, has been manufactured and alignment tests started in the laboratory. The periphery, control- and data acquisition needs have been defined. For the YAG Thomson scattering system the observation optics for the first port has been delivered and tested successfully and the optics for the second port been ordered. The design of both optics was part of the training program Engineering of Optical Diagnostics for ITER. The design of the laser launching port with its Brewster windows and cooling capabilities is close to completion. Long term tests of the cooled port shutter showed fatigue in the flexible hose for water supply; alternatives

have been found and vacuum tests are now being prepared. Series production and assembly of the 30 polychromator boxes for OP1 has started at the Institute for Nuclear Physics in Krakow (INP, Poland) and runs on schedule. The spectral characteristics of the polychromator filters were measured together with the AUG Thomson scattering group. In the experiment hall a massive support structure in the torus centre will serve as support for the Thomson observation optics as well as for the retro-reflector of the single channel interferometer, which shares its line-of-sight with the Thomson laser, making it ideal for cross calibration. A stability analysis of the support structure has been conducted by the engineering department and a mechanically most robust design for this structure has been selected. The interferometer development was reviewed in the 3<sup>rd</sup> Workshop on Interferometry for Steady State Fusion Devices organised in Greifswald with participants from external cooperation partners and beyond. Issues were options for advanced line average density measurements with improved reliability under high-density steady-state conditions such as dispersion interferometry, polarimetry and high-resolution two coloured interferometry. A modular multichannel Dispersion Interferometer (DI) is being studied by a Post Doc at TEXTOR, Jülich. The system has been delivered by an FZJ contract partner, the Budker-Institute of Nuclear Physics (BINP), Novosibirsk. The four commissioned DI channels are being operated successfully since summer. Improvements with respect to their long-pulse capability are ongoing. Dispersion interferometry allows for a compact optical system without need for a reference line and therefore is intrinsically less prone to vibrations and drifts but also is tolerant against intermittent loss of signal – an advantage in particular for quasi-continuous operation. As a robust fallback solution a classical single-channel two-colour CO<sub>2</sub>-CO interferometer has been set-up, tested and qualified in the laboratory. A fast steady-state phase measurement based on an FPGA has been developed within the framework of a PhD thesis in cooperation with CIEMAT, Madrid. For comparison of both interferometer systems vibration tests were conducted with a piezo controlled retro-reflector. It has been suggested to build both W7-X interferometers – the multichannel interferometer and the single-channel Thomson sightline one – based on Dispersion Interferometry; the final decision on this will be taken by early 2011. In the torus hall mechanically challenging components are the two optical benches for the single- and the multichannel interferometer. Their basic design including laser safety aspects and maximizing mechanical stability has been finished; however, a final decision on the table board material is still missing due to activations risks possibly arising from the desired Granite materials. Granite material composition from different sites is presently being analysed. For long-pulse operation all laser diagnostics need active laser beam position control to

cope with thermal drifts. A first prototype of a system based on a SIEMATIC control unit has been set-up and tested in the laboratory. As a redundant measurement technique for density feedback control of high-density discharges, a feasibility and sensitivity study for a single-channel Cotton-Mouton polarimeter in the specific magnetic geometry of W7-X has been conducted and published together with the Akademia Morska, Szczecin, Poland.

However, due to restricted resources the realisation of this diagnostic has been postponed. The diagnostic group also operates the MICrowave STRay RADIation Launch facility (MISTRAL) together with the diagnostic engineering department and the ECRH group. The MISTRAL chamber is used to qualify diagnostic and other in-vessel components for operation in a high background of 140 GHz microwave stray radiation as expected during O2 and OXB mode ECRH heating of high density plasmas. Suitable diagnostics for 140 GHz stray radiation measurements and its spatial distribution e.g. in W7-X ports, have been specially developed in cooperation with the technical University of Eindhoven. Studies of the spatial distribution and homogeneity of the stray radiation inside the MISTRAL chamber were performed by a trainee (home institution CIEMAT) of the program "Microwave Diagnostics Engineering for ITER", which was part of the European Fusion Training Scheme. Apart from the necessary detection and characterisation of the stray radiation itself, the focus of the work was on the development of stray radiation shields for critical in-vessel components. E.g., the actively cooled radiation shield in front of the cryo-pumps – the so called water chevrons – have been successfully coated with an ECRH absorbing  $\text{Al}_2\text{O}_3$ - $\text{TiO}_2$  ceramic layer at the University of Stuttgart. Another focus has been on the shielding of microwave absorbing cable isolations and entire components, coils, connectors and feedthroughs of the magnetic diagnostics. All in-vessel cables need to be enclosed in Cu tubes. For vacuum pump-down the pipes need to be perforated with a sufficiently large number of holes with diameter significantly smaller than half the wavelength. Finding a suitable compromise between vacuum and ECRH shielding requirements still is an ongoing process.

### 8.1.3 Core Spectroscopy

The construction of the Russian Diagnostic Injector for W7-X (RuDI-X), which is needed for active CXRS and CX-NPA measurements is progressing. The injector tank has almost been completed, with helium leak testing presently ongoing. Furthermore, almost all power supplies have been completed and will next be put through their acceptance tests. The calorimeter is 80 % ready, only the ion source with its sophisticated extraction grid design still requires significant developments during the next months. Two closed-loop cryo-pumps have been delivered to W7-X and tested and presently the S7-control-electronics system is

being set up. The design of the support platform for the RuDI-X in the torus hall has been completed, as well. Numerous tests of vacuum gauges, a mass spectrometer system, a turbo pump system and electronics were successfully performed in the local magnetic field test rig, providing information, on which components can be operated in the permanent magnetic field on W7-X. For the CXRS observation system, the concept and outline design of the immersion tube has been completed. A spectral Motional Stark Effect (MSE) diagnostic has been implemented at ASDEX Upgrade. Data analysis tools have been developed and also used to build a virtual diagnostic. Simulations for Wendelstein 7-X have been performed using predictive transport simulations and pre-calculated equilibria, also properly accounting for partially elliptically polarised light emission due to charge exchange emission and the MSE multiple (supported within the EFDA work program 2010). The general design of the CX-NPA has been finished with exception of its support structure. Presently, the proposed solution with one extension arm for supporting the three analyser is checked by structural analysis calculations. Detailed stability calculations of the support structure and calculations of the load onto the outer vessel in the proximity of the AEN 41 port have been started. Studies of the influence of magnetic stray fields on the performance of the NPAs have been performed on MAST by measuring the outer magnetic field components using a fast 3D-Hall probe during typical discharges. The CAD model for the support structure of the high-efficiency XUV overview spectrometer system (HEXOS) including all set-up modifications due to the special W7-X requirements has been almost designed while the system is still running on TEXTOR-DED (FZ Jülich) for testing purposes. According to a new schedule concerning the preparation of the assembly at W7-X, the HEXOS system should be transferred into the final W7-X support structure in summer 2011 and again mounted to TEXTOR till summer 2012. During this time the control and data acquisition will be adapted to W7-X standards by the ZAT (FZ-Jülich) and the CodaC group (IPP-Greifswald), and in parallel the system will join the scientific program at TEXTOR. In the framework of the cooperation between IPP and University Opole (Poland) the conceptual design of the C/O monitor has been finished and the design work packages fixed during a design review. The TIAP crystal for O VIII has been ordered and for the three MLMs for B V, C VI and N VII the tendering procedure has been started. An appropriate detector foil has been selected and already delivered. For the bulk plasma bolometer system in the triangular plane, a prototype of the shutter system for the horizontal camera in port AEU30 has been manufactured and tested in the laboratory. The design of the vertical camera in port AEV21 has been completed. Manufacturing drawings for a shutter prototype, being different from the one of the

horizontal bolometer camera, have been made. Manufacturing details for the water-cooled detector holder, which needs to be made of highly thermally conducting CuCrZr are presently being discussed with a manufacturer. The impact of non-absorbed 140GHz microwave stray radiation on the bolometer signal has been further investigated in the MISTRAL chamber using a gold-foil type detector. By coating the inner surface of the camera enclosure with  $\text{TiO}_2/\text{Al}_2\text{O}_3$ , an ECRH absorbing ceramic layer, significant damping of the microwave multi-path-reflections has been achieved. In this way the microwave induced signal has been reduced by a factor 10, in line with the expected value deduced from power balance calculations inside the bolometer housing. By installing a suitable metal-mesh ( $d90\mu\text{m}/w236\mu\text{m}$ ) in front of the detector head, it was possible to reduce the microwave impact by a factor 30. By applying both techniques simultaneously a suppression of the impact of the microwave radiation by a factor 300 has been achieved. In this way the microwave induced signal becomes less than 1 % of the expected signal level from plasma radiation ( $50\text{ kW/m}^2$ ). This concept will be adopted in the W7-X bolometer designs. For the in-vessel soft X-ray multi-camera tomography system (XMCTS), the shutter could be improved further to achieve a sufficient long term operation reliability. A prototype multi-channel preamplifier board has been manufactured, tested and remaining signal to noise ratio problems identified. The cooling requirements of the pre-amplifiers in the secondary vacuum were assessed and it was found that a simple contact cooling to the surrounding cooled electronic box is sufficient. The manufacturing of the electronic box made from CuCrZr material, considered for improved cooling, remains a challenge in conjunction with the custom-made multi-pin vacuum feedthroughs. The design was improved further by avoiding weldseams. Different joining technologies for the electrical feedthroughs (glass, ceramics, epoxy) are under consideration and a collaboration with the Köhler Institute in Jena was started. In the scope of the ongoing collaboration with IST/Portugal a feasibility study of support vector machines as method for online tomographic inversion has begun. The design of the pulse height analysis system (PHA) being built by IPPLM Warsaw to monitor the X-radiation emitted from the core plasma has been trimmed to fit into a single beam pipe with the piezo-driven slits, a set of filter-foils and three silicon drift detectors for simultaneous high-efficiency observation in three X-ray energy regions. The PHA detectors and the detector arrays for the multi-filter foil system (MFS) are on order. In collaboration with PTB Braunschweig MCNP modelling of the neutron counters has been started to define their material composition and geometry. The neutron counters are based on the NPL long counter principle (National Physical Laboratory, Teddington, U.K.), but will be equipped with up to five parallel arranged counter tubes.

Some improvements are expected from further optimisation calculations regarding the opening angle and the energy response function of the monitors during the next six months. In addition, first experimental studies with selected counter tubes have been performed. The basic concept for data acquisition system has been worked out taking into account the requirements given by the authorisation agency on one hand and diagnostic purposes on the other.

## 8.2 Collaborations

The diagnostics are being developed in close collaboration with FZ-Jülich. In particular in case of the HEXOS VUV spectrometer and the development of the diagnostic neutral beam FZ-J is heading the projects. The Budker Institute in Novosibirsk, Russia, is developing and constructing the diagnostic neutral beam injection system, EURATOM HAS in Budapest, Hungary, is developing and constructing the video diagnostic systems for W7-X, IPPLM, Warsaw is developing a pulse height analysis (PHA) system and a multi-foil spectroscopy (MFS) system, the university of Opole, Poland is preparing a C/O monitor diagnostic and the Akademia Morska, Szczecin, Poland and the Szczecin University of Technology are investigating the sightline of the Interfero-Polarimeter and different microwave based polarimeter and interferometer methods, CIEMAT investigates potential and components for  $\text{CO}_2$ -Interferometry, IST/CFN, Lisbon participates in developing fast tomographic inversion methods and is developing ADC/DAQ stations being linked to XDV, PTB Braunschweig is working on the development of a Neutron-Counter System for W7-X and IOFFE Institute St. Petersburg, the Culham Centre for Fusion Energy (CCFE) and CIEMAT in Madrid are collaborating in the field of CX-Neutral Particle Analysis and the Technical University of Eindhoven, The Netherlands, is contributing to the development of ECRH stray radiation detectors.

## 9 Heating

### 9.1 Project Microwave Heating for W7-X (PMW)

The 10 MW Electron-Cyclotron-Resonance-Heating (ECRH)-system for W7-X is designed for continuous wave (CW) operation (30 min) at 140 GHz, which is resonant with the W7-X magnetic field of 2.5 T. The total power is generated by ten gyrotrons and is transmitted to the plasma by a low loss quasi-optical transmission line and versatile in-vessel launchers for both, high field side and low field side launch. ECRH will support also W7-X operation at reduced magnetic field, because the gyrotrons can be tuned to 103.6 GHz radiation emission with about half the output power. This is of particular importance during the commissioning phase of W7-X and for confinement studies. The ECRH-system is being developed and built by the “Karlsruher Institut für Technologie” (KIT) as a joint project with IPP and IPF Stuttgart.



The “Project Microwave Heating for W7-X” (PMW) coordinates all engineering and scientific activities in the collaborating laboratories and in industry and is responsible for the entire ECRH system. PMW is strongly involved in advanced and ITER related R&D activities for ECRH and CD-Systems with even higher power, efficiency, and flexibility. This activity is partly organised within the frame of the virtual institute “Advanced ECRH for ITER” (collaboration between IPP Garching and Greifswald, KIT, IPF Stuttgart, IAP Nizhny Novgorod, and IFP Milano), which is supported by the “Helmholtz-Gemeinschaft deutscher Forschungszentren”. The virtual institute was terminated on schedule by end of 2010.

#### 9.1.1 The W7-X Gyrotrons (KIT)

The production of the seven series gyrotrons at THALES started in 2004, the first gyrotron SN1 was delivered and tested successfully in 2005 with an output power of 920 kW for 1800 s. This gyrotron was sealed to keep the warranty, whereas the two prototype gyrotrons were routinely used for experiments and component tests. The reproduction of the SN1 performance turned out to be difficult and the following series gyrotrons failed to meet specifications. A careful analysis indicated, that parasitic oscillations are excited in the beam tunnel region, which lead to an excessive heating of the beam tunnel components, in particular of the absorbing ceramic rings. The inspection of gyrotrons, which were re-opened in the factory after operation showed significant damages due to overheating at the ceramic rings and the brazing of the rings. The series production was put on hold in agreement with THALES and a new beam tunnel was designed, manufactured and validated in experimental high power campaigns with two modular short pulse test gyrotrons in 2009 at KIT. As the main difference to the usual beam tunnel this design features corrugations in the copper rings, which handicap the excitation of parasitic modes. The SN 4 (repair) gyrotron was the first series gyrotron, which was equipped with this improved beam tunnel, and delivered to KIT in early 2010 for Factory Acceptance Test (FAT). During the tests no parasitic oscillations originating from the beam tunnel region were observed and the maximum power could be extended to 820 kW. The gyrotron, however, showed an unstable behaviour and mode loss was limiting the achievable pulse duration to several 10 s of seconds. The limitations could be removed by a careful mechanical adjustment of the gyrotron in the magnet (tilted installation) and by improving the high voltage capability. A reliable operation with up to 870 kW was achieved for 3 min pulses (test stand limit). The thermal power dissipation measured in the beam tunnel, cavity and launcher cooling circuits is as expected with no excessive heat load. The measurement and analysis of the output beam gave a Gaussian content as high as 97 % indicating,

that the mode converter and the internal optics operate as designed. A saturation of the output power on beam current was observed, however, beyond 40 A, which is below the currents observed in previous tubes. The gyrotron will be shipped to IPP for Site Acceptance Test in January 2011, where the activity shall focus on the extension of the pulses and the improvement of the efficiency. The FAT of the SN 3(repair) gyrotron at KIT was performed early 2010 and completed in March. As this gyrotron was still equipped with the old beam tunnel, it was decided to perform the tests at reduced output power, well below the threshold for excitation of the parasitic oscillations. A safe operation of the tube was achieved with an output power  $\ll 700$  kW without oscillations in the beam tunnel. The operation of the gyrotron beyond this limit is usually associated with unstable operation, enhanced stray radiation and an increased amount of absorbed RF power in the beam tunnel region, which may result in a thermal overload. Thermographic measurement and analysis of the output beam gave a TEM00 content of 97 %, which confirms the high quality of the internal converter and mirror system. Long pulses up to 3 minutes were performed during FAT at KIT with 700 kW and an efficiency of 37 % in depressed collector mode for energy recovery. All gyrotrons must pass a reliability test as a standard procedure in consecutive full power, 3 min, pulses.

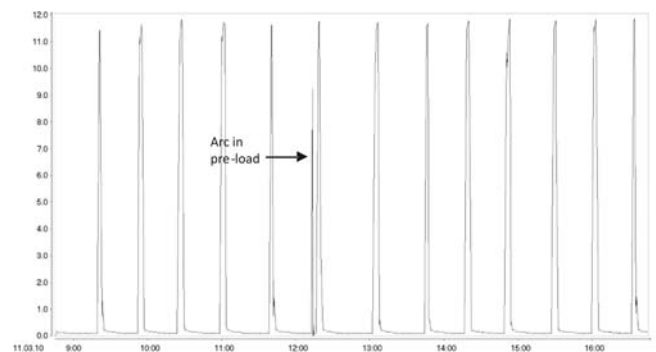


Figure 15: Repetitive operation of the SN3 gyrotron with 3 min pulses at a duty cycle of 10 %. The output power is plotted versus time during one operation day. One short pulse was due to an arc in the pre-load.

Figure 15 shows the repetitive operation during this reliability study for a full day with a duty cycle of 10 % (power supply limit at KIT). All pulses were successful; one pulse was pre-terminated due to an arc in the pre-load. After shipment to Greifswald, the Site Acceptance Test at IPP was performed in parallel to the SN 4 (repair) tests at KIT and completed after only 6 weeks of testing in June 2010 while extending the pulses towards 27 min at the same power. The gyrotron is in regular operation at IPP Greifswald now for tests of advanced ECRH-components.



### 9.1.2 Transmission System (IPF)

The power transmission from the gyrotrons to the plasma is provided by a quasi-optical mirror based system, which operates under atmospheric pressure. It consists of single-beam waveguide and multi-beam waveguide (MBWG) elements. The single-beam lines provide the beam conditioning, i.e. the matching of the gyrotron beams to the parameters of the transmission system, and the adjustment of the polarisation for optimum absorption of the radiation in the plasma. Two symmetrically arranged MBWGs transmit the combined power of all gyrotrons to the experimental hall. At the output planes of the MBWGs situated in the torus hall, two mirror arrays separate the beams again and distribute them via two other mirrors and CVD-diamond vacuum barrier windows to individually movable antennas (launchers) in the torus. The manufacturing and installation of the components of the basic transmission system (112 reflectors for transmission plus 32 reflectors for switching and diagnostics) is completed now. The rf-beam characterisation of the SN 3(repair) gyrotron and the subsequent design and manufacturing of the surfaces of the two matching mirrors for this tube were performed. The beam parameters of the SN 4 (repair) gyrotron, which is presently under test at KIT Karlsruhe have been measured also, the design and manufacture of the related matching mirrors is under way. Standard methods use heat targets, which tolerate only short high-power pulses of a few ms. The W7-X gyrotrons (like others) exhibit, however, a frequency chirp during the first second after switching on, which is caused by the thermal expansion of the cavity, and it is an open question, whether the output beam parameters change significantly during the chirp. We have thus performed measurements on the Maquette gyrotron beam with a thermographically imaged high-temperature Si<sub>3</sub>N<sub>4</sub> target at various locations in front of the CCR load. A noticeable shift of the beam was observed during the pulse of typically 500 ms pulse duration. The target would, in principle, tolerate longer pulses, but the pulse length was limited by arcing at the target surface. A new technique using thin foil beam splitters is now considered. Several materials have been subjected to 100 ms long pulses and a usable material has been identified. Further remaining work includes diagnostics and power measurement of the gyrotron beams. The receivers attributed to the directional couplers on the mirrors M14 have been designed, and are under fabrication; related alignment control is in development. Industrial high power cw dummy loads, which are based on thin absorbing layers on metallic cooling structures shows a long-term destruction of the coating and a related degradation of the power handling capability. This long-term experience has triggered the development of uncoated metallic absorbers. For module 1, a water-cooled version of the ‘Long Load’, which consists of a 22 m long absorbing stainless-steel waveguide, was constructed and

delivered in December 2010. The power distribution along the load shows pronounced minima and maxima due to interference of the propagating modes as seen in figure 16. The load consists of four segments; the first two segments have the same diameter as seen from figure 16 (top) to keep the power loading at an acceptable level. The next segments are connected with linear tapers in areas, where the wall currents and thus the power deposition have a minimum to avoid arcing problems. The total length is chosen to fit into the beam duct at W7-X. The remaining power at the exit of the load is about 25 % of the incident power, which can be easily absorbed and calorimetrically determined. In this arrangement, the Long Load would serve as a calibrated pre-attenuator. Commissioning of this load is scheduled for beginning of 2011.

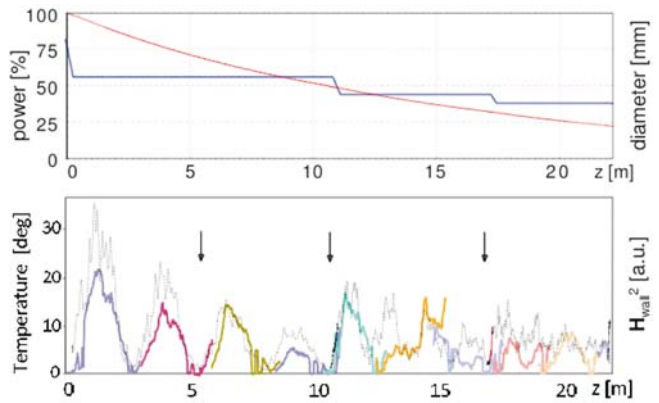


Figure 16: Top: Calculated rf-power and waveguide diameter as a function of the length  $z$ . Bottom: Calculated distribution of the temperature rise and field intensity  $H_{\text{wall}}^2$  as a function of the length  $z$ . The arrows indicate locations of minimum absorption, where the different segments are connected.

In module 5, an industrial compact cylindrical stainless-steel load from GYCOM was installed, and the system of coupling mirrors was upgraded to allow routing of the power beam either to the CCR load or to the GYCOM load. Within the parameters used up to now (700 kW, 15 min), the GYCOM load performs well, further tests are planned.

### 9.1.3 High-field Side Launch with Remote Steering (IPF)

The scientific programme of ECRH and ECCD at W7-X includes confinement studies with high field side launch. Two out of the ten rf-beams can be switched to N-ports, which give access to the plasma from the high field side with a weak gradient of the magnetic field. Front steering launchers as used in the A and E ports will not fit into these narrow ports and thus “remote-steering” launchers (RSL) are foreseen. The further investigation of the RSL-concept is of high importance also in view of future applications of ECRH in radioactive environment e.g. in DEMO. The area of the plasma facing ECRH-launcher front end can be minimised

and movable parts and steering mechanisms are avoided in the hostile environment of a burning plasma. The remote-steering properties are based on multi-mode interference in a square waveguide leading to imaging effects: For a proper length of the waveguide, a microwave beam at the input of the waveguide (with a defined direction set by a mirror system outside of the plasma vacuum) will exit the waveguide (near the plasma) under the same angle as seen from the principle sketch in figure 17. For W7-X, the vacuum window, a vacuum valve as well as a mitre bend must be incorporated into the 4.6 m long waveguide. For the RS-launchers a conceptual design as shown in figure 17 was developed, which is specified for 1 MW, cw, low-loss rf-transmission. The waveguide has corrugated walls and will be fabricated by an electroforming process, thereby integrating the water-cooling channels. In support of the mechanical design, calculations of fields and wall currents at various locations were carried out to estimate the cooling requirements. Also the effect of a bending of the waveguide due to movement of the vacuum vessel and gravitational sag was investigated and found to be uncritical.

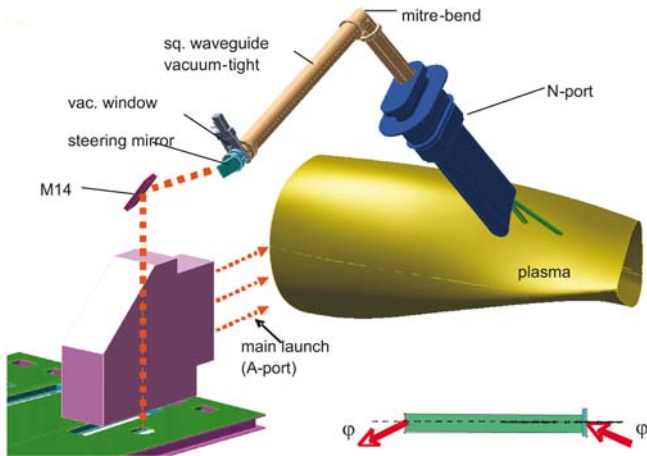


Figure 17: Conceptual design of the remote steering launcher for the Module 5 N-port. The insert at the bottom, right, shows a principle sketch of the remote steering launcher.

To enlarge the steering range, the investigation of small deformations for the basically square corrugated waveguide were continued to find an optimised cross-section. The finite-difference code IPF-FD3D has been adapted to this problem by reducing it to finding the resonance frequency of purely perpendicular modes in the waveguide cross section. This transforms it to a 2D problem, which can be solved with the available computing resources. A number of techniques have been implemented to excite the desired modes in the resonator and find their resonance frequency. As a first result, previous work by a different group was reproduced for an ITER remote steering waveguide, and an

improved (but not yet optimal) waveguide shape was found for W7-X. The results cannot simply be scaled from ITER to W7-X, because the ratio of wavelength to waveguide size, which is relevant here, is different for the two cases. The work will be continued and a suitably deformed waveguide will be built and tested at low power. Furthermore, non-rectangular shapes that ease manufacturing, like rounded instead of sharp corners, will be explored. Preferably the vacuum valve will be shifted from the waveguide entrance towards the mitre bend to increase the angular steering range. Calculations of the losses in the gap needed for installation of the vacuum valve were therefore continued, taking optimised waveguide shapes into account. In conjunction with the optimised waveguide cross-section, a significant reduction of the gap losses especially for larger scanning angles is expected. Low-power experimental investigations on a prototype waveguide have been started at IPF Stuttgart to benchmark the calculations.

#### 9.1.4 In-vessel Beam Control and ECA (IPP, IPF)

Four front steering ECRH-antennas in the outboard mid-plane A- and E-type ports are designed to comply with the different operation scenarios such as plasma start-up, O- and X- mode heating and current drive at 103.6 and 140 GHz. During plasma density ramp-up beyond the X2 cut-off density, a well-controlled transition from the strongly absorbed X2-mode to a multi-pass second harmonic ordinary mode (O2) heating scenario is required. The single pass absorption for O2 is expected to be between 60 and 80% in that case. Therefore the beams must hit specially designed reflector tiles, which are integrated in the heat shield opposite to the ECRH antennas and a reflector liner in between the A- and E-type Ports in two W7-X modules. The reflecting stainless steel liner will be polished for higher microwave reflection.

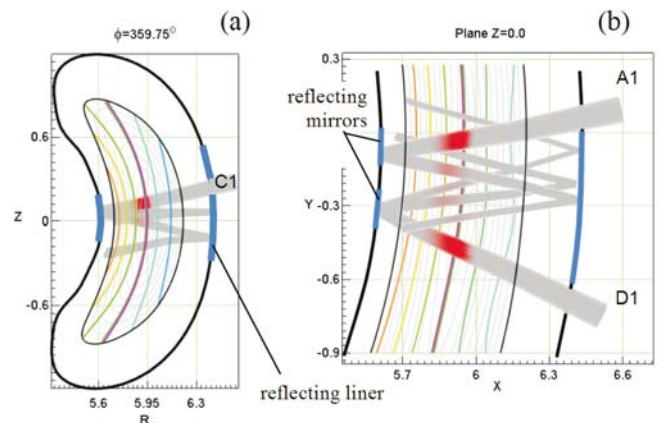


Figure 18: Ray trajectories for multi-pass O2 heating with different ECRH-Beams for the poloidal (a) and toroidal (b) cross section. Three controlled passes can be implemented by reflector tiles at the high field side and a reflector liner at the low field side between the A- and E-type ECRH ports.

Some ray trajectories for the multi-pass heating scheme are shown in figure 18. These sophisticated 10 MW ECRH-scenarios can only operate safely, if the ECRH-launchers are absolutely reliable and precisely controlled. To avoid any possible damage, a set of ECRH-protective diagnostics is being prepared to detect any peculiarity credibly.

The non-absorbed power as well as the beam position and its polarisation at the ECRH heat shield will be measured by an array of altogether 126 small pick-up antennas. This electron cyclotron absorption (ECA) diagnostic consists of circular mono-mode waveguides, which are integrated in the graphite tiles of the heat shield structure. A prototype bundle was successfully test assembled into the heat shield tiles in the W7-X vessel as shown in figure 19. The in-vessel waveguide bundle will be connected with a bundle, which is fed through the B-Port. The four B-Port plug-ins and the vacuum interfaces have been assembled completely and are currently leak-tested.

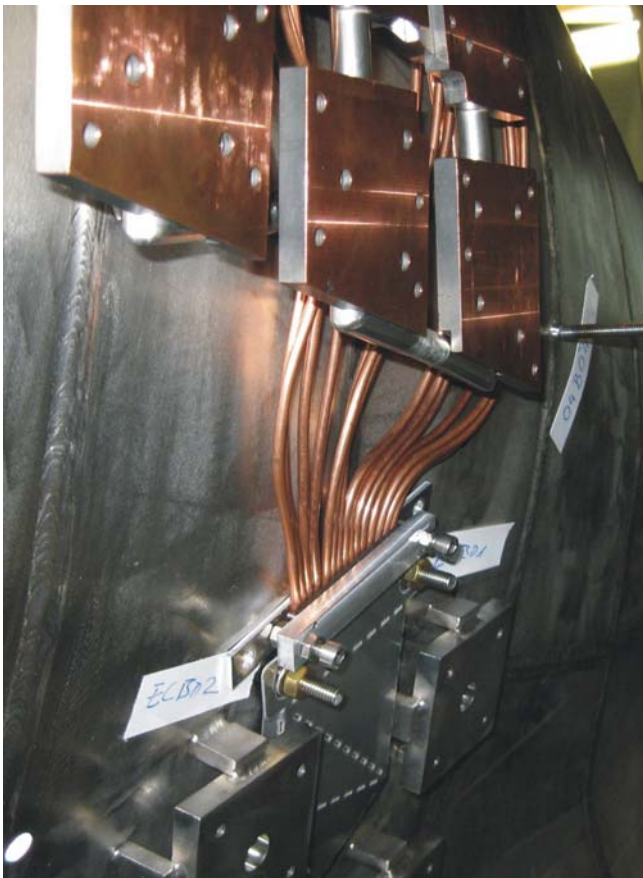


Figure 19: Test assembly of the copper waveguide bundle for the multi-channel ECA-diagnostics in the W7-X vacuum vessel.

The ECA probes allow monitoring the correct adjustment of the launch angle. The motor drives for the front steering mirrors have been installed and tested. The control back-end and the end-point switches of the motor drives have been

put into operation and were used for cyclic tests of the launcher unit within the allowable range. The integration of the launcher control into the central ECRH control is under way. The front steering antennas showed some weakness in the driving mechanism during cyclic fatigue tests and were sent back to TID-DGT (former BTI) at the KIT for enforcement. The first of them was refurbished by end of 2010 and went through intensive mechanical tests successfully. No problems with the bearings were found any more. The launcher was laser tracked and its new dimensions provide the specified clearance of 12 mm on each side with respect to its dedicated port. Finally it passed the vacuum leak test and is presently being mothballed until W7-X assembly completion. The remaining three Launchers will be finished step by step in the next months.

#### 9.1.5 Staff

**Staff at IPP (W7-X-P and ITZ):** B. Berndt, H. Braune, V. Erckmann, F. Hollmann, L. Jonitz, H. P. Laqua, G. Michel, F. Noke, F. Purps, T. Schulz, P. Uhren, M. Weissgerber.

**Staff at KIT (IHM):** K. Baumann, G. Dammertz, J. Flamm, G. Gantenbein, M. Huber, H. Hunger, S. Illy, J. Jin, S. Kern, M. Kupper, R. Lang, W. Leonhardt, M. Losert, D. Mellein, S. Miksch, A. Papenfuß, B. Piosczyk, T. Rzesnicki, A. Samartsev, M. Schmid, W. Spiess, D. Strauss (IMF I), J. Szczesny, M. Thumm, J. Weggen.

**Staff at IPF (Stuttgart University):** P. Brand, H. Höhnle, W. Kasperek, H. Kumric, C. Lechte, F. Müller, R. Munk, B. Plaum, S. Prets, P. Salzmann, K.-H. Schlüter, U. Stroth, A. Zeitler.

#### 9.2. Neutral Beam Injection

The NBI system under construction for Wendelstein 7-X consists of two injectors, positioned close to each other on Module 2. In a first phase of W7-X operation each injector box will be equipped with two beam sources providing a total heating power of up to 7 MW in hydrogen and 10 MW in deuterium, respectively. In a later stage two additional ion sources per injector are planned to double the heating power. The NBI project is supposed to be realised in close co-operation with partners from Polish research institutes. One partner, IPJ Swierk, has got approval and funding from the Polish government at the end of this year to build and provide NBI components like cooling systems, ion deflection magnets, torus valves and injector support structures. The project will be started very soon in the next year and will run over more than 3 years. The second partner, WTP Wroclaw, interested in delivering the cryo-sorption pumps and cryo supply has not yet reached such an advanced state and will submit their proposal for approval by the Polish government in the next year. Discussions have been started meanwhile about alternative fast pumping systems (like cryo-condensation pumps or titanium evaporators) in case this proposal is not being



accepted or not compatible with the required schedule. The procurement of various other components have proceeded as planned during the past year. The assembly of the first ion source flange is being completed, i.e. neutralisers and ion dumps are mounted on its inner side, source valves and beam steering units on its outer side. Figure 20 shows this ion source flange assembled on box 21 with mounted source valves and beam steering units. In addition, the procurement of the calorimeter components is almost finished and the assembly is under way. Design work on the torus adapter unit, consisting of a box exit scraper, assembly bellows and duct protection elements is proceeding. The design of the pipe work and water manifolds for the low pressure cooling cycle is completed, the instrumentation is in house and the manufacturing has been agreed to be done within the W7-X Assembly group in the next year. The magnetic shielding concept to reduce the stellerator stray magnetic field inside the injectors down to an acceptable value has been optimised with respect to minimizing the magnetic material mass. The detail design work on this component is close to completion. Progress has been made in the manufacturing of RF and high voltage cages, which are the first parts of the NBI systems to be installed inside the torus hall as soon as the corresponding space there is not required anymore for machine assembly.



Figure 20: NBI 21 with assembled ion source flange showing source valves and beam steering units on the upper two source positions and a temporary vacuum system on one of the lower source ports.

## Scientific and Technical Staff

### W7-X Subdivisions:

#### Project Coordination

H.-S. Bosch, H.-J. Bramow, J. Dedic, W. Fay, J.-H. Feist, D. Freier, G. Gliege, M. Gottschewsky, D. Grünberg, D. Hagemeister, D. Haus, R. Herrmann, U. Kamionka, T. Kluck, B. Kursinski, A. Lorenz, D. Naujoks, R.-C. Schmidt, M. Schröder, H. Viebke, R. Vilbrandt.

#### Engineering

F. Schauer, T. Andreeva, V. Bykov, C. Caldwell-Nichols\*, A. Dübner, A. Dudek, K. Egorov, J. Fellingner, St. Freundt, K. Hertel, N. Jaksic, J. Kallmeyer, M. Köppen, M. Nitz, F. Scherwenke, T. Schneider, A. Tereshchenko, D. Zacharias, Q. Yang\*, M. Ye.

#### Design and Configuration

D. Hartmann, M. Banduch, Ch. Baylard\*, D. Beiersdorf, A. Bergmann, P. Biedunkiewicz, R. Binder, R. Blumenthal, R. Brakel, T. Broszat, E. Castanos, P. v. Eeten, N. Fuchs, H. Greve, T. Gyulai, N. Hajnal, K. Henkelmann, F. Herold, A. Holtz, C. Klug, J. Knauer, U. Krybus, A. Müller, K. Müller, A. Okkenga-Wolf, D. Pilopp, T. Rajna\*, S. Renard\*, N. Rüter, P. Scholz, K.-U. Seidler, B. Sitkowski, F. Starke, M. Steffen, A. Vorköper, D. Wagner, J. Wendorf, U. Wenzel, K. Zimmermann.

#### Magnets and Cryostat

Th. Rummel, H. Bau, D. Birus, A. Braatz, D. Chauvin\*, C. Dhard, G. Ehrke, A. Friedrich, F. Füllenbach, E. Hahnke, A. Hansen, B. Hein, A. Hölting, M. Ihrke, H. Jenzsch, T. Koppe, R. Krause, B. Missal, St. Mohr, T. Mönnich, M. Nagel, M. Pietsch, K. Riße, M. Schneider, D. Theuerkauf, S. Thiel.

#### Assembly

L. Wegener, J. Ahmels, A. Benndorf, T. Bräuer, E. Chernigov, M. Czerwinski, A. Domscheidt, H. Dutz, S. Gojdka, H. Grote, H. Grunwald, A. Hübschmann, D. Jassmann, H. Jensen\*, A. John, S. Jung, A. Junge, R. Krampitz, F. Kunkel, H. Lentz, H. Modrow, E. Müller, J. Müller, S. Müller, U. Neumann, B. Prieß, D. Rademann, L. Reinke, K. Rummel, D. Schinkel, U. Schultz, E. Schwarzkopf, Ch. von Sehren, O. Volzke, K.-D. Wiegand.

#### Physics

R. Wolf, Y. Altenburg, D. Aßmus, J. Baldzuhn, C. Biedermann, T. Bluhm, H. Braune, R. Burhenn, J. Cantarini\*, A. Cardella, H. Dreier\*, M. Endler, V. Erckmann, H.-J. Hartfuß\*, D. Hathi-ramani, C. Hennig, U. Herbst, D. Hildebrandt, M. Hirsch, L. Jonitz, R. König, P. Kornejev, J. Krom\*, M. Krychowiak, G. Kühner, H. Laqua, H.-P. Laqua, M. Laux, M. Lewerentz, K. Loeckel, G. Michel, I. Müller, U. Neuner, F. Noke, M. Otte\*, E. Pasch, S. Pingel, F. Purps, T. Richert, H. Riemann, J. Schacht,



W. Schneider, R. Schroeder, A. Spring, J. Svensson, H. Thomsen, P. Uhren, S. Valet, A. Werner, D. Zhang, J. Zabochnik.

#### Technical Services (TD)

R. Krampitz, M. Braun, K. Gallowski, M. Haas, M. Hagen, St. Heinrich, M. Marquardt, M. Müller, J. Sachtleben, V. Schwuchow, M. Stöcker, M. Winkler.

#### KIP

F. Hurd\*, A. Cardella\*, M. Czerwinski, G. Ehrke, P. Junghanns, U. Krybus, P. Scholz, A. Vorköper.

**E1:** J. Boscary, A. Eller, C. Li, B. Mendelevitch, A. Peacock\*, B. Petzold, M. Smirnow, R. Stadler, G. Zangl.

**MF:** B. Böswirth, H. Greuner.

**ITZ:** F. Ascher, N. Dekorsy, H. Pirsch, O. Sellmeier, J. Springer, H. Tittes, J. Tretter.

#### Other IPP Divisions

**Stellarator Optimisation:** S. Bozhenkov, P. Drewelov, A. Dinklage, M. Jakubowski, A. Kus, S. Marsen, R. Reimer, T. Stange.

**Experimental Plasma Physics I (E1):** N. Berger, J. Boscary, H. Eixenberger, H. Kroiss, B. Kurzan, H. Murmann, M. Rott, B. Streibl, T. Vierle, S. Vorbrugg.

**Materials Research (MF):** M. Balden, K. Bald-Soliman, B. Böswirth, R. Brüderl, H. Greuner, J. Kißlinger, F. Koch, S. Lindig, G. Matern, M. Mayer, J. Roth, U. v. Toussaint.

**Technology (TE):** H. Faugel, F. Fischer, H. Fünfgelder, B. Heinemann, D. Holtum, C. Martens, P. McNeely, J.-M. Noterdaeme, S. Obermayer, F. Pompon, R. Riedl, N. Rust, G. Siegl, E. Speth, A. Stäbler, P. Turba.

**Computer Center Garching (RZG):** P. Heimann, J. Maier, M. Zilker.

**Integrated Technic Center (ITZ) Garching:** B. Brucker, R. Holzthüm, N. Jaksic, J. Maier, H. Pirsch, H. Tittes, M. Weissgerber, J. Tretter, S. Geißler, T. Franke.

#### Cooperating Research Institutions

**Forschungszentrum Jülich (FZJ), Germany:** W. Behr, G. Bertschinger, W. Biel, A. Charl, J. Collienne, G. Czymek, A. Freund, B. Giesen, D. Harting, H. Jaegers, H. T. Lambertz, M. Lennartz, Ph. Mertens, O. Neubauer, A. Panin, M. Pap, U. A. Pospieszczyk, Reisgen, D. Reiter, J. Remmel, M. Sauer, W. Schalt, L. Scheibl, H. Schmitz, G. Schröder, J. Schruoff, B. Schweer, W. Sergienko, R. Uhlemann, J. Wolters.

**Karlsruher Institut für Technologie (KIT), Germany:** A. Arnold, K. Baumann, K. Boschert, G. Dammertz, S. Drotziger, W. H. Fietz, S. Fink, G. Gantenbein, R. Heidinger, M. Heiduk, R. Heller, M. Huber, H. Hunger, S. Illy, S. Kern, M. Kupper, R. Lang, C. Lange, W. Leonhardt, J. Lietzow, M. Losert, A. Matthäß, D. Mellein, S. Miksch, A. Papenfuß, K. Petry, B. Piosczyk, O. Prinz, A. Samartsev, M. Schmid, W. Spiess, J. Szczesny, M. Thumm, J. Weggen.

**Stuttgart University (IPF):** P. Brand, H. Höhnle, W. Kasperek,

H. Kumric, C. Lechte, F. Müller, R. Munk, B. Plaum, S. Prets, P. Salzmann, K.-H. Schlüter, U. Stroth, A. Zeitler.

**PTB Physikalische Technische Bundesanstalt Braunschweig, Germany:** H. Schumacher, B. Wiegel.

**Culham Centre for Fusion Energy (CCFE), Culham, UK:** M. Turnyanskiy.

**FOM, Amsterdam, Netherlands:** R. Jaspers.

**Technical University Eindhoven, Netherlands:** H. Brand, H. Oosterbeek.

**Commissariat à l'Energie Atomique (CEA), Cadarache, France:** A. Grosman.

**CIEMAT, Madrid, Spain:** A. Cappa, J. M. Climent, T. Estrada, J. Fontdecaba, L. Hernandez, C. Hidalgo, M. Sanchez.

**IST/CFN, Lisbon, Spain:** P. Carvalho.

**RFX Padova, Italy:** M. Zuin.

**CNR Istituto di Fisica del Plasma, Milano, Italy:** M. Romé.

**University of Opole, Poland:** I. Ksiazek, F. Musielok.

**The Henryk Niewodniczanski Institute of Nuclear Physics, Kraków (IFJ PAN):** L. Haiduk, Z. Sulek.

**Institute of Nuclear Physics, Krakow, Poland:** K. Drozdowicz, G. Tracz.

**Maritime University of Szczecin (MUS), Poland:** B. Bieg, Y. Kravtsov.

**Szczecin University of Technology, Szczecin, Poland:** P. Berczynski, I. Kruk.

**IPPLM Institute of Plasma Physics and Laser Microfusion Warsaw, Poland:** A. Galkowski, S. Jablónski, J. Kaczmarczyk, M. Kubkowska, L. Ryc, M. Scholz, J. Wolowski.

**IPJ Swierk, Poland:** J. Jagielski

**Warsaw University of Technology, Poland:** L. Ciupiński, G. Krzesinski, P. Marek.

**IPP Prague, Czech Republic:** J. Preinhaelter, J. Urban.

**Budker Institute of Nuclear Physics, Novosibirsk; Russia:** V. I. Davydenko, A. Ivanov, A. Khilchenko, I. V. Shikhovtsev.

**Efremov Institute, St. Petersburg, Russia:** I. Rodin.

**A.F. Ioffe Physico-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia:** F. Chernyshev, S. Petrov.

**Institute of Applied Physics (IAP), Nizhny Novgorod, Russia:** L. Lubyako, J. Koshurinov.

**Lithuanian Energy Institute, Kaunas:** G. Dundulis, E. Urbonavicius.

**Research Institute for Particle and Nuclear Physics (KFKI-RMKI), Budapest, Hungary:** G. Kocsis, S. Récsei, J. Sárközi, V. Szabó, A. Szappanos, T. Szetefi, Z. Szökefalvi-Nagy, S. Tulipán, S. Zoletnik.

**Princeton Plasma Physics Laboratory (PPPL), USA:** T. Brown, D. Gates, P. Heitzenroeder, S. Lazerson, D. Mikkelsen, H. Neilson, A. Reiman, M. Zarnstorff.

**Oak Ridge National Laboratory (ORNL), USA:** M. Cole, J. H. Harris, A. Lumsdaine, D. A. Spong.

**Kyoto University, Japan:** S. Murakami, Mizuuchi, F. Sano.

**National Institute for Fusion Science (NIFS), Toki, Japan:** T. Funaba, T. Morizaki, M. Shoji, H. Yamada.

# WEGA, VINETA and Further Activities

## WEGA

**Head: Dr. Matthias Otte**

Utilizing a 2D Langmuir probe array turbulence studies in the vicinity of magnetic islands were studied. At minor radii smaller than the island location long range correlations of floating potential fluctuations at about 5 kHz both in toroidal and poloidal direction were found. This correlation appears to be interrupted by the island separatrix. A comparative study at magnetic configurations without major resonances has shown that the potential fluctuations have a toroidal  $m=0$ , and poloidal  $n=0$  mode structure. The magnetic topology was again investigated by flux surface measurements. In general a good agreement with former results was found. Beside an already known  $m=1$  error field component a  $m=4$  component could be detected resulting into magnetic islands. Furthermore, the distortion of the stray field of the transformer coils on the magnetic structure could be qualitatively determined. For the flux surface diagnostic of W7-X a prototype electron gun with a  $\text{LaB}_6$  based electron emitter was successfully tested up to 3.5 T. A highly sensitive magnetic diagnostic including Rogowski-coils, diamagnetic loops as well as compensation coils allowed the detection of a plasma energy of below 1 J and a current of about 5 A during electron Bernstein wave (EBW) heated plasma scenarios at 0.5 T operation. Furthermore, a current of up to 1.2 kA could be measured during lower hybrid (LH) heating scenarios. The characterisation of soft X-ray emission originated by a fast electron component during EBW as well as LH plasma heating experiments was tested with a new silicon drift detector provided by the Garching group "Astrophysics and Laboratory-Plasma-Studies". Perturbative heat transport experiments have been carried out by ECRH power modulation and monitored by a 16-channel fast bolometer (Si-diode array). Furthermore, the electron thermal diffusivity and the two dimensional plasma radiation have been investigated with the bolometer. For EBW emission experiments an optimised steerable quasi-optic antenna system and a corrugated broad band horn antenna were developed. In cooperation with IPP Garching and IPF Stuttgart a new microwave notch filter was developed to suppress the ECRH gyrotron frequency of 28 GHz at minimum damping of other frequencies. During 2010 the experiment control was switched over to the prototype of the W7-X control system. More sophisticated plasma experiments and event detection have been performed.

## International Stellarator/Heliotron Database

The Stellarator/Heliotron database has been maintained within an international collaboration (NIFS, CIEMAT, U-Kyoto, ANU, PPPL, U-Wisconsin, U-Auburn, U-Charkov, U-Stuttgart, and

On WEGA experiments were focused on turbulence studies in the vicinity of magnetic islands, magnetic flux surface measurements and electron Bernstein wave heating. The international Stellarator/Heliotron database and the assessment of ELM control by resonant magnetic perturbations have been continued. The research focus in VINETA has been the kinetic wave damping, turbulent fluctuations, and the plasma profiles in magnetic field inhomogeneities.

IPP). First comparative studies of H-mode (LHD, TJ-II, Heliotron-J, W7-AS) discharges in 3D-devices revealed robust similarities (profile gradients and radial electric field) but also indicate configuration dependencies (e.g. influence of shear and edge iota). First comparative studies of edge fluctuations have been performed also involving tokamak devices (TJ-K, AUG, MAST, URAGAN

3M, HSX, WEGA, W7-AS). The studies were to assess similarities and scaling in fluctuation spectra with regard to blob transport. Discharge documentations for the validation of neoclassical transport models have been started (W7-AS, LHD, TJ-II).

## ELM Control by Resonant Magnetic Perturbations (RMP)

The effect of 3D edge perturbation (RMP) of tokamak magnetic fields has been refined and documented by time resolved infrared imaging (collaboration with GA, San Diego). The beneficial effect of RMPs is due to a significant reduction of power load densities for small ELMs (see figure 1) or elimination of larger ELMs. A similar result was found at the JET tokamak (separate collaboration with EFDA-JET). Moreover, the wetted area increases linearly with deposited power in type-I ELMs without RMPs. This finding partly mitigates concerns for the lifetime of the divertor of ITER.

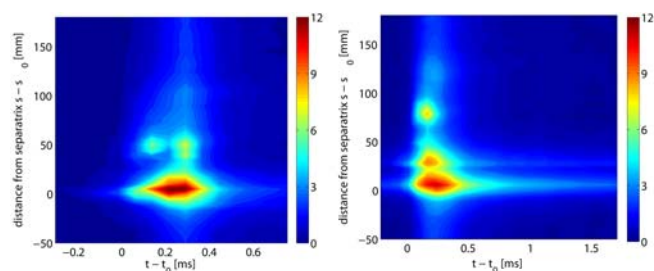


Figure 1: Power loads due to type-I ELMs (in  $\text{MW m}^{-2}$ ) to DIII-D divertor.

## Study of Heat Flux Pattern in Different Beta Discharges

An infrared imaging diagnostic was set up in collaboration with NIFS at LHD. Experiments focused on the time evolution of 2D temperature measurements during comparable discharges at different plasma beta. First results indicate structural changes of observed patterns that could be linked to an altering magnetic edge topology due to the nonlinear interaction with plasma currents.

## Scientific Staff

H. Ahrens, E. Chlechowicz, A. Dinklge, P. Drewelow, M. Glaubitz, M. Jakubowski, A. Kus, H. P. Laqua, S. Marsen, E. Müller, M. Otte, R. Reimer, A. Rodatos, T. Stange, F. Wagner, R. Wolf, D. Zhang.

## VINETA

Head: Prof. Dr. Olaf Grulke

### Wave Dynamics and Turbulent Fluctuations

Electromagnetic wave propagation, particularly for whistler and Alfvén waves, has been a focus of the research at VINETA for several years. The waves have been identified in terms of their respective dispersion relation and its dependency on plasma parameter variation. In high density helicon plasmas those waves are generally dominated by collisional damping. By specific shaping of the plasma profiles kinetic damping, i.e. electron cyclotron and Landau damping, has been studied. For whistler waves excellent agreement has been obtained between the measurements of the critical frequency, at which cyclotron damping represents the dominant damping mechanisms, and linear Vlasov dispersion calculations for a wide range of plasma- $\beta$ , shown in figure 2.

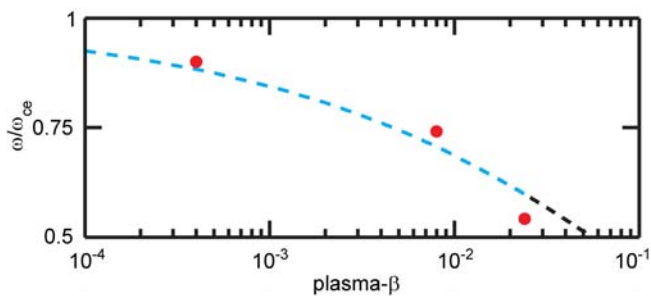


Figure 2: Comparison of measurements of the critical frequency for cyclotron damping of whistler waves (circles) with Vlasov calculation (dashed line).

The observation of a rather complicated whistler wave propagation pattern could be shown to be mainly caused by the wave excitation geometry and the radial plasma density profile, which leads to ducting of the wave energy. Those observations are in good agreement with full wave code calculation specifically tailored to the experimental situations, which were performed in collaboration with the University of Stuttgart. Landau and cyclotron damping of Alfvén waves is observed in axial magnetic field gradients, which cause also axial gradients of the plasma pressure. As for whistler waves the results are in agreement with linear dispersion calculations.

The work on fluctuations and structure propagation in drift wave turbulence has been continued. The experimental results have been compared to fully nonlinear three-dimensional fluid simulation, which are performed in collaboration with the Technical University of Denmark, Risø. In addition to previous results about the radial propagation of turbulent structures, the spatial region of formation of those structures has been shown to correlate with a strong increase of the Reynolds stress in experiment and simulation, suggesting a shear-layer drive of the structure formation.

### Plasma Profiles in Magnetic X-point Configuration

In preparation to investigations in dynamically driven magnetic X-points the evolution of the profiles in rf heated plasmas in a static azimuthally symmetric X-point configuration was studied. In contrast to independent investigations, in which an increased plasma pressure was observed at the X-point and interpreted as either stochastic heating due to ergodisation of particle orbits or increased dissipation of helicon wave energy, the electron temperature is observed to remain flat. However, a local peaking of the plasma density close to the X-point region is observed and could be explained by particle trapping in the strongly inhomogeneous magnetic field. Calculation of the electron density for a capacitive discharge with a hollow radial density source profile due to particle trajectories in the inhomogeneous magnetic field configuration is shown in figure 3.

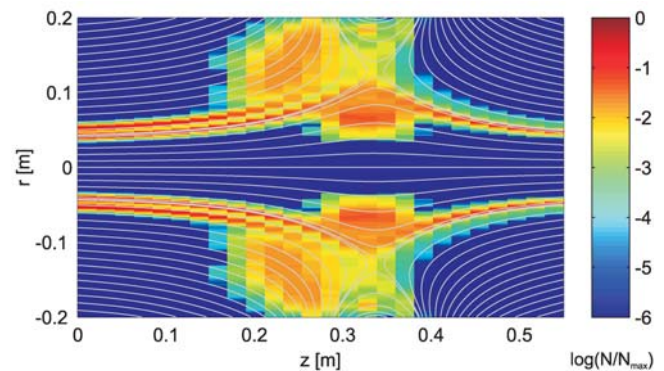


Figure 3: Calculated plasma density in a radial-axial plane for a hollow density source profile (at  $z=0$ ) and an azimuthally symmetric magnetic X-point configuration. The magnetic field lines are superimposed in light gray.

The investigation will be extended from the static to a dynamic investigation during magnetic reconnection. The VINETA setup is currently changed by adding one additional large magnetised vacuum module, which will be used for the reconnection studies. Magnetic reconnection is planned to be driven by a pair of axial conductors carrying a large fluctuating current, which drive reconnection at the X-point in the plasma center. The focus of the studies will be the plasma dynamics and particle kinetics in response to the topological rearrangement of the magnetic field in the presence of boundaries. Finalisation of the setup and diagnostic equipment is envisaged for mid 2011.

### Scientific Staff

H. Bohlin, C. Brandt, F. Braunmüller, J. Brunner, O. Grulke, T. Klinger, D. Niemczyk, K. Rahbrania, C. Rapson, T. Schröder, A. Stark, A. von Stechow, T. Windisch, M. Wisotzky.

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ITER





# ITER Cooperation Project

Head: Dr. Hans Meister

## Introduction

2010 brought major changes to the ITER Project. After controversial discussions, the ITER baseline was accepted in July. In parallel, Osamu Motojima was appointed new director general and proposed a new organisational structure to accompany activities aimed at preventing any further cost increases.

Remmelt Haange was appointed as his deputy and head of the new ITER Project department in November. Fusion for Energy (F4E), the European Domestic Agency, started a restructuring process, too, in order to increase effectiveness and to adapt to the requirements of the ITER baseline. The new budget for ITER has been accepted by the European Commission. However, the European contribution was capped to 6.6 B€ and adoption by the Parliament is still pending. Nonetheless, until end of 2010 procurement contracts worth about 60 % of the European budget have been placed. One visible effect is that construction on the ITER site continued and the first concrete columns rise out of the ground.

The ITER cooperation project at IPP continues its activities along the major topics: The test facility ELISE, a major step on the way to the ITER neutral beam injection system, is being built, R&D on the bolometer diagnostic for ITER continues as does the work on the design of the ITER ICH antenna within the CYCLE consortium. A major R&D task on fast switches for high power microwaves could be finished successfully and on time.

Additionally, IPP is contributing to various heating systems, diagnostics and in particular the preparation of the physics basis through some direct contracts with ITER or F4E and a number of tasks within the EFDA Workprogramme.

## Heating Systems

### Development of RF Driven Negative Hydrogen Ion Sources for ITER

The development of the IPP RF source – being since 2007 the ITER reference source – was ongoing in 2010 with the construction of the new ELISE test facility, the continuation of long pulse experiments at MANITU, basic experiments regarding the magnetic filter field and the influence of the source temperature at BATMAN and with ITER relevant RF experiments at RADI.

ELISE, being supported by a 4 M€ F4E service contract, is an important intermediate step between the small IPP prototype sources and the large ITER source. Therefore ELISE is now an integral part of the F4E and ITER roadmap for the development

The IPP contributes to the ITER Project in a wide range of activities. Tasks range from R&D for heating systems and diagnostics to development of integrated plasma scenarios. In addition, the IPP is playing a leading role in contributing to the ITER physics definition and objectives via contributions to the International Tokamak Physics Activity and by participating in the various Task Forces and Topical Groups of the EFDA Workprogramme.

of the ITER neutral beam system. Most of the components are ordered and in manufacturing; some (source flange, source valve, HV insulator) have been delivered. The assembly is proceeding; a big step was the final assembly of the neutron shield (figure 1). The integrated commissioning with the first pulses is still expected in fall 2011.



Figure 1: View into the L7 experimental hall with the concrete neutron shield assembly for ELISE.

The early operation of ELISE is important for the success of the neutral beam injector test plant (PRIMA) in Padova, Italy, consisting of two test facilities: a full power, 1 MV test facility (MITICA, planned to be operating end of 2016) and a low power, 100 kV ion source test facility (SPIDER, operating end of 2013) as input for the design of the MITICA ion source, which is planned to be frozen in 2013, is essential. Furthermore, IPP continued to contribute to PRIMA in the design of the full size RF source, the RF circuit and the layout of source and beam diagnostics, also by training of PRIMA personnel at the present IPP test facilities. An example is a dedicated material test (thermal parameters, stress) of electro-deposited copper that has been performed in collaboration with RFX Padova. The results of this test went already into the design of the extraction grids of ELISE and PRIMA.

Although long pulses (several 100 seconds) with 80 kW power are now possible at the test facility MANITU, the ITER requirements have not been met yet. The reason is still the increasing electron current during a long pulse. Hence, RF power and extraction voltage are limited in order to avoid damage of the extraction grid. This limitation is even more pronounced in deuterium operation due to the much

larger ratio of co-extracted electrons. Nevertheless, stable deuterium pulses of some hundreds of seconds with an extracted ion current density of 10-15 mA/cm<sup>2</sup> and a co-extracted electron fraction of less than one have been achieved. The homogeneity of the beam – expressed by the beam divergence profile measured by Doppler-shift spectroscopy – does not seem to correlate with the homogeneity of the plasma in front of the plasma grid. That can be explained by the fact that most of the negative hydrogen ions are created at the plasma grid by the conversion of neutrals; the neutral flux, however, onto the plasma grid is not influenced by the filter field and hence homogeneous in the IPP RF driven source.

The experiments at the BATMAN test facility continued on studies of the effects of the magnetic field structure on the source performance, both in hydrogen and deuterium. Two clear correlations of the source performance with magnetic field parameters have been found (figure 2), which are consistent with the present understanding of the processes in the ion source. For ion extraction, the magnetic field strength in front of the plasma grid is the important parameter; a field of some mT in front of the plasma grid for sufficient negative ion extraction is needed, whereas the amount of co-extracted electrons is determined by the integral BdL from the driver to the plasma grid. First experiments in deuterium show similar trends as in hydrogen, the magnetic field at the plasma grid for optimum ion extraction yield and the required integral BdL for sufficient electron suppression, however, are larger than in hydrogen. In order to remove the necessity of an additional heating circuit at 1 MV potential of the ITER neutral beam system, experiments with a reduced source body temperature of 35 °C have been performed and showed no influence of the source performance and the speed of conditioning compared to operation at the standard value of 50 °C.

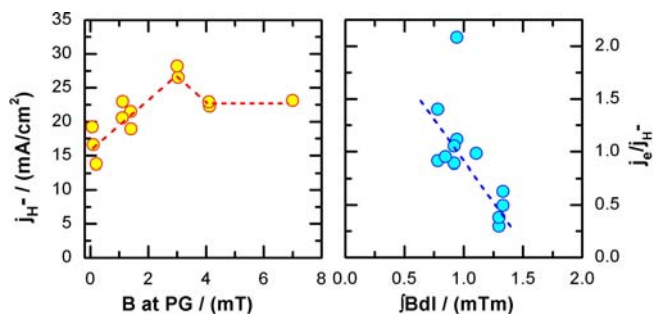


Figure 2: Left: Dependence of the extracted hydrogen current density on the magnetic filter field at the plasma grid; right: dependence of the amount of co-extracted electrons on the integral magnetic field.

The experiments at RADI, equipped with a large scale RF driven ion source, concentrated on stable RF operation of an ITER relevant RF circuit and tests of design choices (e.g. magnetic field configuration) of ELISE and SPIDER.

The experiments are strongly supported by modelling of the processes in the boundary layer near the plasma grid where the negative ions are generated as well as of the distribution of Cesium during and between the plasma pulses, also by basic experiments regarding Cs chemistry, Cs diagnostics and RF efficiency at the University of Augsburg (see chapter 13). The PIC code BACON was applied to investigate the transport of electrons through the magnetic field and the cooling of the electrons correlated to this transport. For the plasma parameters of the IPP ion sources and a small computational domain the electron cooling was reproduced.

### ICRF Antenna Consortium and Design

The CYCLE consortium is progressing well with the design of the ICRF antenna for ITER. In May, a conceptual design review of the ICRF antenna was held in Cadarache. At the end of the year, CYCLE submitted a proposal to an extension of the scope: all tasks are now planned through to the completion of the relevant presentation to the preliminary design review. The duration of the task would be extended from 18 to 24 month. IPP is particularly involved in the mechanical design of the antenna. This design is being developed during four design cycles to provide a design by the Preliminary Design Review that best meets the requirements of the technical specifications. In particular, a CATIA model of the launcher for the integrated antenna showing the sum of all the subsystems and of the component parts will be provided, consistent with the preliminary calculations and computer models.

### ECRH Upper Launcher

In recent years, IPP has coordinated the physics analysis of the ITER ECRH Upper Launcher. Hence, IPP is part of the recently formed consortium between KIT, ITER-NL, FOM, CNR and CRPP that aims at designing this system under an F4E Grant.

### Fast Switches and Diplexers for High Power Microwave Beams

High power diplexers can strongly increase the performance and flexibility of large ECRH systems, and are therefore of potential interest for ITER. To this aim, the research on diplexers for combination of high-power microwave beams and/or switching ("FADIS") on a fast timescale with low loss and without mechanically moving parts, was conducted under the umbrella of the 'Virtual Institute' of the 'Helmholtz-Gemeinschaft deutscher Forschungszentren' (IPP Garching and Greifswald, IAP N.-Novgorod, IPF Stuttgart, KIT Karlsruhe, and IFP Milano) and terminated on schedule by end of 2010.

A major activity were the high-power tests of the compact long-pulse diplexer "Mk II" in the ECRH system of W7-X. It is based on a ring resonator consisting of four mirrors

(figure 3). Coupling to the inputs and outputs is performed by grating beam splitters on two of the resonator mirrors, as well as via matching mirrors and TEM<sub>00</sub>-HE<sub>11</sub> mode converters. This quasi-optical device is compatible with waveguide transmission systems. For the tests, the beams from one or two W7-X gyrotrons was coupled to the input(s), the transmitted power at the two outputs was measured by directional couplers, and finally was dumped into two cw calorimetric loads.

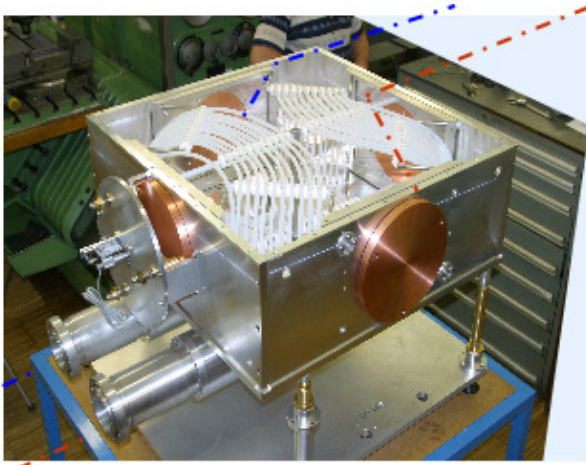


Figure 3: Photograph of the diplexer, which has been investigated using the high power ECRH system for W7-X. At the bottom, one can see the two HE<sub>11</sub>-waveguide outputs. The top plate with the two symmetrical inputs is removed to reveal the resonator geometry and the stray radiation absorbing hoses.

A fast drive for the resonator mirror (developed by TNO in Delft) controlled by the output power signals and an optional real-time frequency measurement allowed tracking of the slope or the peak of the diplexer resonance to the gyrotron frequency on a 20 ms time scale. Several diplexer applications were demonstrated with this arrangement: Slow switching (20 ms timescale) of the power between two output channels (without the need to turn off the gyrotron as is the case for conventional switches) was performed by controlled mirror movement. Fast switching (100 ms timescale) by frequency-shift keying of the gyrotron (using few kV voltage modulation of the body) was performed with optimum contrast.

For the application of resonant diplexers in in-line ECE experiments, where the high-power ECRH gyrotron and the low power ECE signal share a common launcher, tracking of the notch of the diplexer to the gyrotron was demonstrated. This is a necessary prerequisite to guarantee high suppression of possible stray radiation from the gyrotron into the delicate ECE receiver.

The combination of the power from two (or more) gyrotrons may be particularly interesting for large scale ECRH systems, because transmission lines and port space can be saved.

When feeding two gyrotrons to the diplexer, stable power combination with an output contrast of 90 % could be achieved. Encouraged by the good high power performance of the diplexer under test, an HE<sub>11</sub>-resonator diplexer with a new mirror configuration for direct integration into corrugated waveguide was developed and investigated in detail.

The matching and the resonator mirrors are designed as phase-reversing elements for the fields radiated from the HE<sub>11</sub> input waveguides; thus, a perfect image of the input field is obtained on the coupling gratings as well as at the output waveguide. The design is very compact without enhancing the power load on the mirrors, and therefore well suited for integration into large ECRH systems. Owing to the compact design and high mechanical precision, the measured transmission efficiencies were very close to the theoretical limit.

In the non-resonant channel, a transmission efficiency of >99.2 % was reached; the internal resonator round-trip efficiency was 99.1 %. Efficient mode filtering based on the difference in resonance frequencies of higher-order modes was demonstrated. The directivity was typically 60 dB, qualifying it as directional coupler for in-line ECE experiments, where the ECRH launcher is used simultaneously for electron cyclotron emission measurements. This 140-GHz diplexer was designed for integration into the ASDEX Upgrade ECRH system. However, it can be easily scaled to 170 GHz and a waveguide diameter of 63.5 mm. Based on this design, a preliminary proposal and cost estimate on the development of a water-cooled and evacuated version for ITER ECRH has been performed.

### EFDA Tasks

The work on arc detection focussed on the development of an interface between the GUIDAR detector from POLITO and the ICRF transmission line and on the analysis of the frequencies emitted by an arc. The transient behaviour of an arc and its interaction with the ICRF system was analysed using a numerical model. A first draft of the architecture of an arc detection system for ITER was conceived, which took into account the particularities of the operations.

IPP participated in a multi-machine (TEXTOR, Tore Supra, AUG, JET) experiment on wall conditioning with ICRF. The work on AUG concentrated on the simulation of the ICWC scenario at ITER half-field and ICWC discharge optimisation. The results are presented in chapter 1.

Studies showed that local gas injection can substantially increase the ICRF antenna coupling without arcing in the antennas. The distance of the gas inlet valve relative to the ICRF antenna should be kept to minimum to increase the positive effect of gas injection.

Current ramp-up (~1.4 MA/s) assisted by ICRF was achieved only with on-axis  $\omega = \omega_{\text{CH}} @ r/a = -0.1$  ( $f = 36.5$  MHz) and Volt-second consumption similar to  $2\omega_{\text{ce}}$ -assistance.



The use of (ECRF+ICRF)-assistance for plasma initiation reduced the volt-second consumption by  $\sim 10\%$ . With off-axis ICRF,  $dI_p/dt$  degrades due to impurity rise ( $P_{\text{ECRF}}=560\text{--}800\text{ kW}+P_{\text{ICRF}}=100\text{--}540\text{ kW}$ ).

The ECRH-sniffer-probes, which have been installed with EFDA-support were used to characterise the stray-radiation. With respect to their suitability for polarisation control it was found that five percent of the power in the wrong polarisation is the detection limit for X2 heating.

## Diagnostics

### ITER Bolometer Diagnostic

With many years of experience in the development of bolometer detectors IPP proposes to take the lead in a consortium with the Hungarian Association (RMKI) and the Karlsruhe Institute of Technology (KIT) for the full development of the ITER bolometer diagnostic. To this aim a consortium has been set up and the respective contract signed at the beginning of 2010 by all partners. However, the official call for tender by F4E on this topic is still pending. In order to continue the R&D activities started previously in the framework of tasks of the EFDA Technology Workprogramme IPP successfully applied for national funding. 5.7 M€ have been awarded for the period 10/2008 – 03/2012 for detector development, building and testing of prototypes and the development of the diagnostic integration in ITER.

In 2010, results have been achieved in several areas of investigation. The cooperation with IMM (Institut für Mikro-technik Mainz GmbH) on the development of bolometer foils is being continued. A first batch of samples with a  $4.5\text{ }\mu\text{m}$  thick absorber produced by galvanic deposition of Pt onto a thin SiN membrane with Pt meanders on the back-side was characterised in the newly set up high-temperature vacuum test rig at IPP. All parameters relevant for operating the bolometers, resistance  $R$  of the meanders, cooling time constant  $\tau$  and heat capacity  $\kappa$  of the absorber, show a very good linear dependence on the temperature up to values of above  $200\text{ }^\circ\text{C}$  (figure 4). However, from about  $300\text{ }^\circ\text{C}$  onwards a drift in  $R$  can be observed, which differs for each individual detector channel and is still under investigation. The laser trimming of the meanders achieved accuracies in the resistances within one detector channel of  $0.8\%$ . Further optimisation of the trimming parameters will reduce this value. The cooling time constant  $\tau$  of the first samples was in the order of  $420\text{ ms}$ . In order to enhance the response time and to achieve  $\tau$ -values closer to the ones of the detectors currently in use, an additional heat conduction layer was deposited on the absorber side. The subsequent samples featured  $\tau\sim 220\text{ ms}$ . Finally, at the end of 2010 IMM managed to successfully produce a detector featuring a  $12\text{ }\mu\text{m}$  thick Pt absorber. This is the minimum thickness deemed to be

required for the application in ITER. These samples now await their characterisation with respect to temperature dependence, mechanical and irradiation stability.

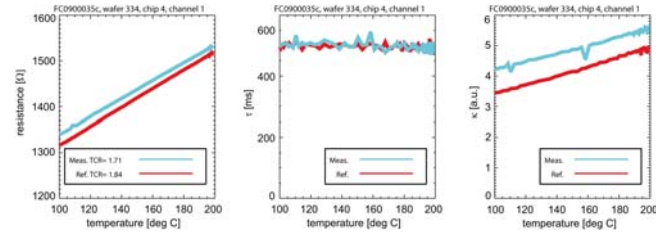


Figure 4: Meander resistance (left), cooling time constant  $\tau$  (middle) and normalised heat capacity  $\kappa$  (right) for measurement (blue) and reference (red) absorber as functions of temperature for a prototype bolometer detector.

During the last year the design of the diagnostic components matured and several prototypes for collimator, mini-camera housing and electrical connectors have been manufactured and tested. For investigating the feasibility of manufacturing collimators with high-precision geometric constraints and to demonstrate a method for in-situ calibration of their geometric function, a light-weight robot has been brought into operation. It is used to illuminate the entrance slits of the collimator from many vertical and horizontal angles using a laser. By simultaneously measuring the response of the bolometer detector the transmission function of the collimator can be determined.

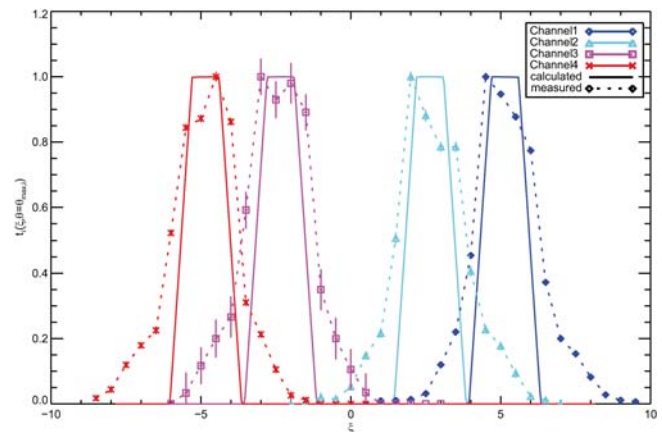


Figure 5: Measured (symbols with dashed lines) and calculated normalised transmission functions of the ITER prototype collimator in the poloidal plane given for each channel at perpendicular incidence.

First measurements (figure 5) proved the viability of this method and demonstrated that the current design of the collimator can be manufactured to the required accuracy of  $0.1^\circ$ , which is also the detection limit of the lab assembly. However, it was also demonstrated that the collimator prototypes suffer severely from stray light, as can be seen in figure 2 by the large deviation of the measured normalised

transmission from the theoretically expected one. Thus, the design of the collimators was changed and additionally, the next prototypes will feature viewing channels coated with  $\text{Al}_2\text{O}_3/\text{TiO}_2$ . This rough, dark gray ceramic can be deposited using plasma spraying. It was initially developed for W7-X and is an efficient absorber of microwaves. A cooperation with the IFKB at the University of Stuttgart has been started to provide the coating for the bolometer collimators.

In cooperation with IPF Stuttgart it could be demonstrated that the top plate designed for the collimators is able to reduce any incoming microwave radiation in the frequency range of 125–220 GHz by at least 70 dB. The complete assembly – collimators, mini-camera housing and connectors – will be tested with respect to their ability to screen the detector from microwaves in the test facility MISTRAL in Greifswald at the beginning of 2011.

Last but not least the finite element analysis of diagnostic components gave useful results. It could be shown that for the current design, if using TZM as main material, maximum temperatures of  $\sim 280^\circ\text{C}$  can be expected at the top of the collimator and that the detectors will remain at  $\sim 200^\circ\text{C}$  with temperature variations below  $0.5^\circ\text{C}$  across the detector chip. The latter is important to prevent temperature drifts in the measurements. Also, the parameters in the simulations having the highest impact on the results have been identified. The simulations will continue by investigating design variants and the impact of electromagnetic forces during disruptions as well as by prototype tests to validate the simulations.

### EFDA Tasks

Plasma diagnostics for present and next generation fusion devices are reviewed with respect to conventional and advanced data analysis and error evaluation techniques. Emphasis was put on forward modelling and synthetic diagnostics capabilities in a probabilistic framework necessary for an Integrated Data Analysis approach.

A development work-flow for synthetic diagnostics has been implemented aiming to support a physical design and optimisation of future instruments or to simulate measuring capabilities. The implementation of a pilot diagnostic (spectral MSE) focused on diagnostic forward models to simulate data. A concept for the validation of the synthetic diagnostic has been developed and tested with experimental data from AUG. The potential of GPUs (graphical processing unit) for real-time analysis and the analysis of large amounts of data was explored for the solution of partial differential equations. For large problem sizes the GPU based solutions showed a better performance. The installation of the necessary diagnostic and computing hardware for the real-time integration of the plasma position reflectometry has been completed. Diagnostic probe signals are collected in a fast FPGA and transferred to a host computer connected to the AUG control system. Separatrix position identification algorithms are being designed.

The visible video diagnostic was upgraded to a video real-time system for machine protection by implementing a fast algorithm for the recognition of hot spots and making use of fast frame grabber cards for video digitalisation and integrating both into the AUG discharge control system.

Additionally, EFDA supported diagnostic hardware upgrades at AUG for some diagnostics. Enhanced time and/or spatial resolution will be used to provide essential data for the analysis of various plasma scenarios in view of ITER to study e.g. fluctuations, disruptions and transport.

## ITER Support

### Contracts with F4E and ITER

IPP conducts several tasks, which are financially supported by contracts with either ITER or F4E. The results and activities of the most prominent among those have been presented in previous sections of this chapter (NNBI and ITER ICH antenna design). Additionally, the following activities were active in 2010.

In order to assess the tritium removal as currently suggested for ITER (wall baking at  $240^\circ\text{C}$  for the main chamber, and  $350^\circ\text{C}$  for the divertor), D retention and release behaviour of Be-containing materials were investigated in a contract with F4E. Pure Be, as well as Be/W/C intermixed and  $\text{Be}_{12}\text{W}$  and  $\text{Be}_2\text{C}$  compound layers were fabricated in collaboration with MEdC, Budapest. In pure Be, D is predominantly released around  $150\text{--}200^\circ\text{C}$  within a relatively sharp desorption peak. The efficiency of tritium removal is reduced for compounds and intermixed Be-W/Be-C layers. At  $350^\circ\text{C}$  Be-W mixtures release still around 80 % of the retained hydrogen. However, in the case of Be-C deposition with C concentrations above 50 % only 10 % of the retained D is released at  $350^\circ\text{C}$ . In consequence, best performance of the wall baking can be expected for tritium removal from high purity Be layers deposited on the main chamber wall under the assumption that the temperature of main chamber wall surface remains below  $\sim 160^\circ\text{C}$ . Under these conditions out-gassing temperatures of  $240^\circ\text{C}$  may be sufficient. Two Grants by F4E have been awarded in mid-2010. One aims at the determination of the three-dimensional distribution of power and particle fluxes during ELM control schemes using in-vessel coils. Another shall investigate the viability of a capacitive diaphragm monitor prototype for the quantitative measurement of dust inside a tokamak.

### Physics Integration

Most of the experimental programme of ASDEX Upgrade is oriented towards the investigation of plasma scenarios required for the operation of ITER. These results are presented in chapter 1. In this section, the results of some specific investigations are presented, which are conducted within the framework of the EFDA Workprogramme.

Simulations of AUG VDEs and centred disruptions have been performed with the MHD-transport code DINA. This code relies on a 2D self-consistent model (from the electromagnetic point of view) of the plasma and surrounding conductors and can predict the evolution of the halo current if the halo region properties (width and temperature) are given.

For the measurement of electromagnetic forces an optical strain measurement system for internal components of ASDEX Upgrade has been installed by laser welding on the PSL. Its 38 sensors routinely collect data since the restart of the campaign.

The development of the edge kinetic profiles after an LH transition was studied and a dependence on the neutral gas inventory was found. In type-I ELMy H-modes the pedestal widths showed a weak correlation with poloidal beta when analysed in real space.

With the upgrade of the installed ECRH power (see chapter 1), the effect of the heating mix (NBI vs. ECRH) on transport will be analysed in the frame work of a PhD work in the 2011 campaign.

The optics of the core CXRS system were redesigned to increase the throughput of light and the number of lines of sight imaging the plasma. These upgrades significantly improve both the temporal and radial resolution of rotation measurements on AUG.

### PWI Task Force

The prediction of erosion and co-deposition processes for ITER is necessary for the design and material choice for the first wall. In particular the formation of co-deposited layers determines the T retention during the nuclear phase. A novel global erosion/deposition model was developed, allowing to calculate the time and poloidal position resolved surface compositions and impurity influxes into the plasma in a self consistent way. From this information the growth rate of Be/C/W mixed layers can be calculated. Using the local plasma parameters to estimate particle energies and surface temperatures the scaling laws from PISCES, San Diego, are used to predict the fuel retention.

### Trainee Programmes

The very successful ENTICE programme is winding down. Eight trainees were trained, out of the 8, 6 have initially found a position in the fusion programme at different fusion associations or at ITER, some of them permanent. One of those has moved to a position outside of fusion.

The ICRF group is also participating in the LITE programme, and numerous trainees from the LITE programme have spent part of their traineeship in the ICRF group. The NIPEE (Negative Ion Physics and Engineering Expertise) programme has started in the last year; it includes one trainee employed by IPP and another five employed by RFX Padua and KIT Karlsruhe.

### Scientific Staff

**ITERBolo:** H. Meister, L. Giannone, M. Kannamüller, A. Kling, J. Koll, K. Machani, F. Penzel, N. Rettner, T. Trauttmann, H. Wolf, W. Zeidner; G. Grunda, S. Kalvin, G. Veres (RMKI); P. Detemple, S. Schmitt (IMM); J. Klammer, H. Langer, C. Zauner (KRP Mechatec).

**NNBI:** H. Falter, U. Fantz, P. Franzen, R. Friedl, M. Fröschle, R. Gutser, B. Heinemann, A. Herttrich, D. Holtum, C. Hopf, W. Kraus, C. Martens, P. McNeely, R. Nocentini, S. Obermayer, R. Riedl, A. Röder, B. Ruf, L. Schiesko, A. Stäbler, E. Speth, P. Turba, D. Wunderlich.

**ICRF:** V. Bobkov, F. Braun, R. D’Inca, H. Faugel, H. Fünfgelder, D. Hangan, L. Liu, J.-M. Noterdaeme, A. Onyshchenko, Y. Podoba, K. Polozhiy, F. Pompon, K. Winkler, E. Würsching, I. Zammuto.

**ECRH Upper Launcher:** E. Poli, H. Zohm.

**ECRH Fast Switches:** B. Berndt, H. Braune, V. Erckmann, F. Hollmann, L. Jonitz, H. P. Laqua, G. Michel, F. Noke, F. Purps, T. Schulz, P. Uhren, M. Weissgerber.; P. Brand, H. Höhnle, W. Kasperek, H. Kumric, C. Lechte, F. Müller, R. Munk, B. Plaum, S. Prets, P. Salzmann, K. H. Schlüter, U. Stroth, A. Zeitler (IPF Stuttgart).

**EFDA Tasks Heating:** V. Bobkov, F. Braun, R. D’Inca, B. Eckert, H. Faugel, H. Fünfgelder, M. Garcia-Munoz, F. Leuterer, F. Monaco, K. Polozhiy, D. Schmid-Lorch, H. Schütz, G. Siegl, J. Stober, D. Wagner; A. Lyssoivan, M. Vrancken (ERM/KMS); P. Jacquet, M.-L. Mayoral, I. Monakhov (CCFE).

**EFDA Tasks Diagnostics:** K. Behler, G. Conway, A. Dinklge, R. Drube, R. Fischer, A. Kus, T. Lunt, M. Rampp, G. Raupp, R. Reimer, U. von Toussaint, W. Treutterer, R. Wolf, M. Zilker; J. Santos (IST); J. Albert, A. Bode, H. Hacker, I. Zhukov (TUM).

**EFDA Tasks Physics Integration:** C. Angioni, R. Dux, B. Geiger, A. Mayer, R. McDermott, G. Pautasso, T. Pütterich, F. Ryter, F. Sommer, J. Stober, E. Wolfrum; V. E. Lukash, R. R. Khayrutdinov, A. A. Kavin (TUAP, St. Petersburg, Russia).

**Contracts with ITER and F4E:** H. Eixenberger, N. Endstrasser, L. Kammerloher, A. Lohs, T. Lunt, B. Reiter, V. Rohde, W. Zeidner.

**PWI-TF:** J. Roth, K. Schmid, M. Reinelt, K. Sugiyama, K. Krieger.

**Trainees:** Y. Altenburg, D. Grine, F. Pompon (LITE); D. Hangan, D. Hancock, A. Krivska, I. Zammuto (EnTicE); R. Nocentini (NIPEE).

## Plasma-wall-interactions and Materials





# Plasma-facing Materials and Components

Head: Dr. Joachim Roth

## Surface Processes on Plasma-Exposed Materials

### Chemical Phase Formation of Beryllium with Tungsten and Oxygen

Interaction of the plasma with first wall materials will lead to formation of mixed materials due to erosion, transport and redeposition. In this study the chemistry of the beryllium-tungsten alloy

Be<sub>2</sub>W is investigated under the influence of energetic oxygen ions by depth-resolved X-ray photoelectron spectroscopy (XPS) at the synchrotron radiation facility HZB-BESSY II. The sample is prepared in-situ in our preparation chamber 'LAICA', which is directly connected to the analysis chamber 'SurICat'. A layered system is prepared by physical vapour deposition of approx. 4 nm tungsten on a beryllium substrate. By heating to 900 K for 60 min the alloy Be<sub>2</sub>W is formed. The oxygen implantation energies are chosen such that the implantation profile is within the accessible information depths of XPS at the selectable photon energies from the synchrotron. According to simulations with SDTrim.SP implantation energies of 500 and 1000 eV satisfy the experimental requirements for oxygen fluences of  $5 \times 10^{14} \text{ cm}^{-2}$ . Between the individual implantation steps the sample is annealed to 600 K. Photoelectron spectra are taken at up to six different information depths for each involved element. This is achieved by varying the X-ray excitation energy, resulting in estimated information depths of 1.2, 1.8, 2.4, 2.9, 3.5 and 4.5 nm. In addition, survey scans are performed at two different photon energies for quantitative compositional analysis. After implantation of energetic O ions the formation of ternary compounds of Be, W and O is observed and investigated at room temperature (RT) and after annealing. Also the influence of different implantation energies on the depth distribution of involved chemical species is investigated.

The W 4f and Be 1s spectra reveal formation of beryllium tungstate BeWO<sub>4</sub> already at RT in significant amounts due to the energy deposition of implanted oxygen ions. For comparison, in thermal annealing experiments this is the case above 600 K. The spectra of the W 4f region show formation of BeWO<sub>4</sub> mainly near the surface. This depth distribution is in qualitative compliance with the simulated implantation depth profiles. No indication for oxygen diffusion at RT is observed. In previous experiments BeWO<sub>4</sub> has proven to be stable at temperatures up to 1100 K in a Be-poor environment. In contrast to these results, annealing of the implanted sample at 600 K leads to a decomposition of BeWO<sub>4</sub>. This decrease of decomposition temperature is attributed to the excessive amount of Be. The implanted oxygen remains in the sample after annealing, bound in BeO.

Within the project "Plasma-facing Materials and Components" the areas of plasma-wall interaction studies, material modification under plasma exposure, development of new plasma-facing materials and their characterisation have been merged to form a field of competence at IPP. The work supports exploration and further development of the fusion devices of IPP and also generates basic expertise with regard to PFC-related questions in ITER and fusion reactors.

### Properties of Nitrogen-implanted Beryllium and its Interaction with Energetic Deuterium

Recent successful experiments with nitrogen as seeding gas in fusion plasma devices, together with the decision to use beryllium as an armour material in the international fusion experiment ITER, have triggered interest in interactions of energetic N ions with Be and the influence of

possible compound formation on parameters relevant to reactor operation and safety. Laboratory experiments are performed to investigate the properties of the 'mixed material' formed upon bombardment of bulk Be with energetic (keV) nitrogen ions. The formation of beryllium nitride within the implantation zone of a few nanometres is observed by X-ray photoelectron spectroscopy and Rutherford backscattering spectrometry. Upon implantation of N at 1.5 keV per atom, saturation of the Be surface with N occurs at a fluence of  $2 \times 10^{18} \text{ Ncm}^{-2}$  and a retained areal density of approximately  $4 \times 10^{16} \text{ Ncm}^{-2}$ . The nitride undergoes an ordering process upon annealing, but does not decompose at temperatures up to 1000 K. The influence of such nitride layers on the retention and release of D implanted with different fluences is investigated by nuclear reaction analysis and temperature-programmed desorption. The nitride layer does not act as diffusion barrier for out-diffusing hydrogen isotopes. A partial sputter yield of 0.013 N/D as a lower limit is measured upon bombardment of the nitride layer with D at 2 keV. These erosion measurements are influenced by the strong tendency of the nitride to oxidise.

### Blistering due to Hydrogen Implantation into Tungsten

On hot-rolled, polished and stress-relieved polycrystalline tungsten (W) a large number of spherical blisters appeared after exposure to a deuterium plasma. The implantations were performed with an ion energy of 38 eV/D, a flux of  $1 \times 10^{20} \text{ D/m}^2\text{s}$  and fluences between  $3 \times 10^{23}$  and  $6 \times 10^{24} \text{ D/m}^2$ . The sample temperature was stabilised at 300 K during plasma exposure. The diameter of the blisters was between 1 and 20  $\mu\text{m}$ , their height reached up to 0.2  $\mu\text{m}$ . At the larger fluences the blister areal density reached  $3 \times 10^9 \text{ blister/m}^2$ , which corresponds to a surface coverage of  $\sim 30 \%$ . After removing all deuterium from the sample by thermal desorption spectroscopy (TDS) at temperatures up to 1200 K,  $\sim 75 \%$  of the blisters had completely relaxed. Markers cut into the sample surface with the focussed ion beam (FIB) of a dual-beam scanning electron microscope (SEM) prior to the implantation allowed a direct comparison of identical surface areas before and after TDS.

To verify whether the relaxation of the blisters was due to the removal of high pressure gas inside the blisters or due to a thermal relaxation effect, the cap of several medium-sized blisters was punctured by FIB. During this procedure, the blister was periodically observed by SEM. After a milling depth of  $\sim 1 \mu\text{m}$ , complete elastic relaxation of the blister was reproducibly observed (see figure 1). This supports the assumption of a high pressure gas filling. Subsequent FIB cross-sectioning revealed a fine crack system running along grain boundaries in a depth of  $\sim 1 \mu\text{m}$  that intersected with the previously milled crater. Using typical values for blister diameter ( $10 \mu\text{m}$ ), height ( $0.15 \mu\text{m}$ ), and cap thickness ( $1 \mu\text{m}$ ) together with the knowledge of a gas-driven and purely elastic deformation, a first rough estimate for the gas pressure was made using Kirchhoff's plate theory. Accordingly, the gas pressure necessary to cause the observed deformations is of the order of 0.7 GPa.

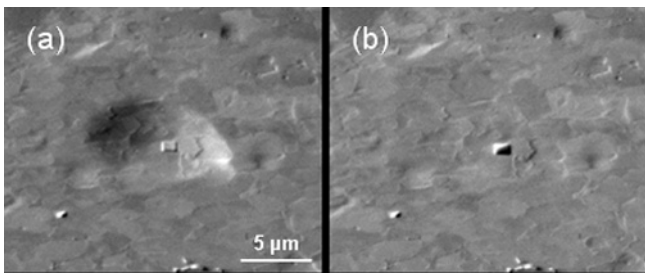


Figure 1: Fully elastic blister on stress-relieved tungsten implanted with deuterium with 38 eV/D at 300 K at the beginning of FIB milling (a) and after penetration of the blister cap (b).

For direct observation of the escaping  $\text{D}_2$  gas puff due to the puncturing of the cap, a residual gas analyser was attached to the specimen chamber of the SEM/FIB. The amount of  $\text{D}_2$  molecules inside such an elastic blister proved to be below the detection limit. However, much larger blisters (diameter up to several  $100 \mu\text{m}$ ) were found on a sample that had not been stress-relieved. This sample had been exposed to a deuterium fluence of  $8 \times 10^{24} \text{ D/m}^2$  with an energy of 200 eV/D and at a specimen temperature of 500 K. When the cap of one of these blisters was opened by FIB, a strong  $\text{D}_2$  gas burst was detected by the residual gas analyser. A quantitative measurement of the gas pressure inside blisters is currently being prepared.

### Migration of Materials in Fusion Devices

Additional contributions to material migration in ASDEX Upgrade (e.g., W melt experiment and dust classification) and JET (ITER-like Wall project and marker layers) are reported in the respective sections of this annual report.

### Tungsten Erosion on Rough Surfaces in ASDEX Upgrade

Global erosion, re-deposition and transport of first-wall materials have been studied extensively in ASDEX Upgrade (AUG).

W-coated C tiles from the outer divertor of AUG were analysed post mortem after the 2007 campaign by ion beam analysis methods and scanning electron microscopy (SEM). The SEM images revealed a very inhomogeneous W erosion pattern. Areas on the  $\mu\text{m}$  rough surface that were inclined towards the magnetic field (=‘leading’ surfaces) were fully eroded down to the C substrate. In contrast, the parts of the rough surface facing away from the magnetic field (=‘shadowed’ surfaces) showed less erosion. In some cases even indications of W deposition in these shadowed areas were found. A very similar result was already observed in the AUG divertor after the 2004-2005 campaign and the same effect was observed with W marker stripes in the outer divertor of JET. The presence of these inhomogeneous erosion patterns puts constraints on the minimal W coating thickness required to avoid exposure of the C substrate to the boundary plasma during an experimental campaign in a fusion experiment. Therefore, an understanding of the underlying processes leading to these patterns is desirable. These patterns cannot be explained by the pure gyro motion of the impinging ions, since the gyro radius is much larger than the surface roughness, which should lead to a homogenous flux and consequently also erosion distribution. Therefore, a new model was developed that explains the erosion patterns by calculating the flux distribution of ions impinging on a rough surface by tracing the path of the ions from the gyro motion in the boundary plasma through the  $\text{E} \times \text{B}$  drift in the sheath region until impact on the surface. The rough surface topography data used in the calculations were taken directly from an atomic force microscope (AFM) scan of a small sample cut from a W-coated carbon tile taken from the outer divertor of AUG. The calculated erosion patterns were compared to SEM images taken at the exactly same location as the AFM image and showed very good agreement both in shape and magnitude.

These model calculations show that the trajectories of particles arriving at the Debye sheath edge on gyro orbits from the boundary plasma are affected by the strong electric fields in the Debye sheath, leading to oblique impact angles, which in turn result in an inhomogeneous flux and erosion distribution. In contrast, promptly re-deposited W that is ionised within the magnetic pre-sheath after being sputtered from the surface has a very different impact angle distribution compared with ions arriving from the boundary plasma. Promptly re-deposited W impinges almost perpendicular to the surface, resulting in an essentially homogeneous flux distribution.

This difference in the flux distribution between promptly re-deposited W and particles from the boundary plasma explains the erosion on leading surfaces and deposition of W on the shadowed surface areas: The local net effect depends on the balance between deposition and erosion. On leading surfaces the homogeneous W redeposition is overcompensated by W erosion mainly due to impurity ions arriving

from the boundary plasma. In shadowed areas sputtering is strongly reduced so that even net deposition can occur. Redeposited tungsten layers have a spongy, foam-like structure, the pore diameters range from a few to a few ten nm. These layers incorporate also impurities, especially B, C, and N.

### Modelling the Beryllium Transport in JET

The new code WALLDYN was developed to simulate the global long-term re-distribution of wall materials in tokamak fusion experiments. It includes parameterised kinetic and thermodynamic wall processes such as physical sputtering, chemical erosion, chemical phase formation and sublimation. Based on these principal processes the code computes the time evolution of the first wall surface concentrations along a two-dimensional discrete representation of the tokamak first wall for an arbitrary number of chemical phases (e.g. Be, C, W, Be<sub>2</sub>C, BeO, WC, Be<sub>2</sub>W,...) under constant plasma contact. The local plasma thereby erodes wall material from the surface, which is transported as impurities to other surface areas along the first wall. The kinetic energy at the impact point of the impurity atoms can again lead to sputtering of wall material. Hence, also impurity- and self-sputtering are included, which is of particular importance for the correct description of W plasma-facing components. Transport through the plasma is assumed instantaneous on the time scale of wall evolution and represented in the code by redistribution matrices, which are pre-computed using, e.g., the DIVIMP code. Each column of such a matrix represents the spatial probability function for redeposition of an

eroded species from a particular wall element to the entire wall. The wall evolution processes in WALLDYN are described by a set of self-consistent coupled algebraic differential equations, which are solved numerically. The background plasma required for modelling of plasma impurity transport is provided by the OEDGE or SOLPS codes based on measured  $T_e$  and  $n_e$  profiles. Chemical surface reactions, such as carbide formation, oxidation or alloy formation, are implemented using parameterised XPS experimental data. The code was benchmarked with experiments performed at JET in 2009, where Be erosion was measured spectroscopically over 800 s total plasma time (identical L-mode discharges) after initial heavy Be evaporation (figure 2). Both the magnitude of the measured erosion flux and typical relaxation time constants towards steady state could be reproduced. Matching the experimental data required the use of a newly developed computational grid for DIVIMP, which extends right to the main chamber wall. Furthermore, the simulations suggest that cross-field diffusivity is a key parameter for the observed relaxation time constants.

### Tritium Inventory – Understanding and Control

Many of the project activities devoted to the understanding and control of the tritium inventory are reported in section “Helmholtz-Russia Joint Research Group: Hydrogen Isotopes Retention in First-Wall Materials” at the end of this chapter.

### Removal of Deuterium from Deposited Layers Containing Beryllium

In order to assess the tritium removal operation currently suggested for ITER (wall baking at 513 K (240 °C) for the main chamber, and 623 K (350 °C) for the divertor), deuterium retention and release behaviour of beryllium-containing materials were investigated. Be<sub>12</sub>W and Be<sub>2</sub>C compound layers were fabricated by thermally treating deposited C or W layers on Be substrates. Pure Beryllium depositions were done by means of Thermionic Vacuum Arc (TVA) deposition method in MEdC, Budapest. Intermixed layers were prepared by simultaneous Be-W or Be-C deposition by means of multiple Thermionic Vacuum Arc (TVA) deposition, resulting in fabrication of Be-W or Be-C layers with different Be/W or Be/C ratios.

In pure Be, D is predominantly released around 420-470 K within a relatively sharp desorption peak. Operation at elevated temperatures reduces the amount of retained D, but the remaining D is less efficiently outgassed at 623 K. Admixture of tungsten or carbon to Be changes the D release behaviour resulting in less efficient D removal by the baking procedure. Especially, the C concentration in Be affects D release behaviour significantly causing it to become difficult to remove by baking at 623 K.

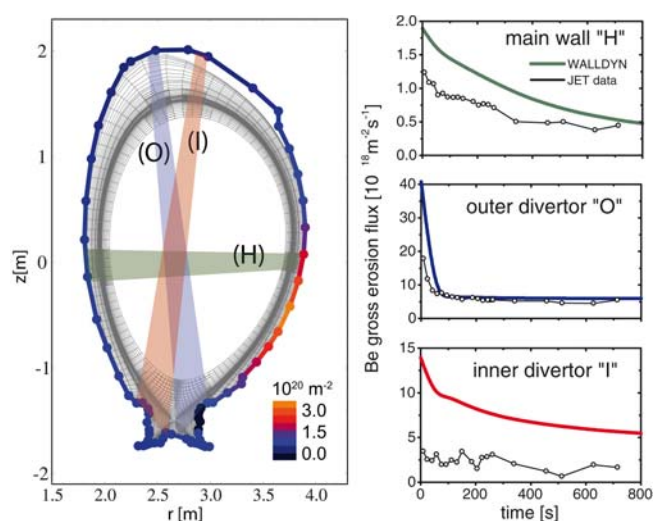


Figure 2: Measured and simulated Be gross erosion fluxes during 800 s L-mode discharges after heavy Be evaporation at JET (right hand side). The schematic view of the JET poloidal cross-section on the left hand side shows the respective spectroscopic viewing chords for main wall (H), inner (I) and outer divertor (O) respectively and the initial Be areal density. The WALLDYN simulations were performed with impurity transport computed by DIVIMP using a computational grid extending to the vessel wall.



Based on the results, the performance expected for the ITER wall baking scenario can be discussed as follows:

- Best performance of the wall baking would be expected for tritium removal from high purity Be layers deposited on the main chamber wall under the assumption that the temperature of main chamber wall surface remains below  $\sim 430$  K.
- Tritium cannot be removed from plasma-facing surfaces where the temperature during implantation is higher than the planned baking temperature. Even for an implantation temperature of 423 K, only about 50 % is released at 623 K. Low operation temperatures are preferable and require the lowest outgassing temperatures. Under these conditions outgassing temperatures of 500 K may be sufficient. On the other hand, the amount of primarily retained tritium decreases with increasing implantation temperature.
- Mixed material deposition is expected to occur mainly in the divertor. The efficiency of tritium removal will be limited for compounds and Be-W/Be-C simultaneously deposited layers as summarised in figure 3. Be-W mixtures release at 623 K between 80 and 90 % of the retained hydrogen related to pure Be co-deposits. The formation of a stoichiometric  $\text{Be}_{12}\text{W}$  phase reduces D desorption even further.
- Mixing of C into Be results in a significant change of hydrogen desorption behaviour. In the case of C-rich Be-C deposition, hydrogen is difficult to remove by a baking at 623 K even if the deposit is formed under low temperature conditions. For such cases, one has to consider the application of other removal methods such as laser/flash heating or oxygen glow discharge cleaning. An exchange of the divertor cassettes as foreseen several times during ITER operation may alleviate this problem.

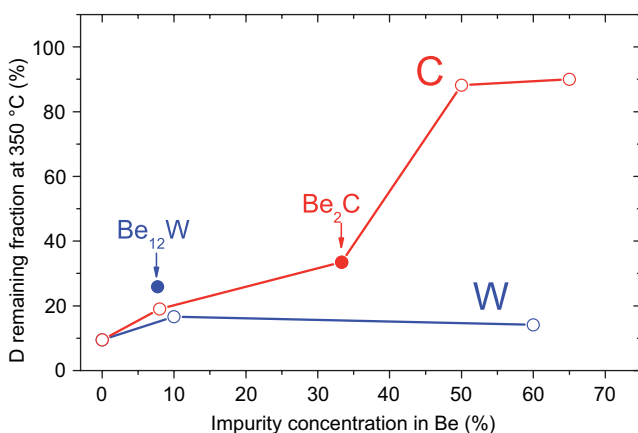


Figure 3: D remaining fraction after outgassing at 623 K for 20 min in Be-containing samples as a function of (W or C) concentration in Be. The data are normalised to the retention in pure Be.

Further measurements should extend the present investigations to thicker deposited layers (mm rather than nm), which requires a proper simulation of D co-deposition during film

deposition. More temperature steps and longer temperature holding times (hours rather than mins) will make the extrapolation to ITER more reliable.

### Influence of the Tungsten Microstructure on the Deuterium Retention

A very important factor determining the retention of hydrogen isotopes in tungsten is the microstructure of tungsten. Since the solubility in a perfect tungsten lattice is extremely low the deuterium inventory after plasma exposure is correlated with the density of defects that can serve as binding sites for the deuterium. In order to elucidate this correlation, hot-rolled tungsten samples (99.97 wt.% purity) from a single manufacturing batch were heat treated after high-quality mechanical polishing in order to systematically modify the grain structure and dislocation density. The samples were then thoroughly characterised by scanning electron and scanning transmission electron microscopy (SEM/STEM). Samples that were degassed and stress relieved at 1200 K for 1 hour did not significantly change their microstructure compared to the initial material. They had small grains with a typical size of approximately 1  $\mu\text{m}$  and a high density of dislocations. Samples annealed at 1700 and 2000 K for 30 minutes were fully recrystallised and also showed grain growth, whereas the typical grain size was smaller for 1700 K (5-20  $\mu\text{m}$  compared to 10-50  $\mu\text{m}$  for 2000 K). The dislocation density was extremely low in both cases.

Well-characterised samples were irradiated in a fully quantified plasma source at a sample temperature of 300 K. The ion energy was 38 eV/D at a flux of  $10^{20}$  D/m<sup>2</sup>s. Rolled and stress-relieved samples were exposed to fluences between  $3 \times 10^{23}$  and  $6 \times 10^{24}$  D/m<sup>2</sup>. Recrystallised samples were exposed to  $6 \times 10^{24}$  D/m<sup>2</sup> simultaneously with the corresponding stress-relieved samples.

Depth profiling by nuclear reaction analysis (NRA) revealed significant diffusion of D up to large depths of several  $\mu\text{m}$  below the implanted surface. In contrast, the implantation range of the ions is only a few nm. A high and narrow surface maximum was typically followed by a local concentration minimum and a secondary maximum. The shape of the depth profile was strongly affected by the microstructure of the sample. The total amount of deuterium in the accessible range of about 8  $\mu\text{m}$  increased with fluence for the stress-relieved samples and showed a beginning saturation for the higher fluences. The samples recrystallised at 1700 K had approximately the same deuterium inventory as the stress-relieved sample exposed to the same fluence, whereas the inventory of the sample recrystallised at 2000 K was by a factor of 2 lower. Temperature programmed desorption (TPD) showed the same relative behaviour of the total inventory as the NRA analysis. The D<sub>2</sub> release spectra (figure 4) were strongly affected by the microstructure.

The stress-relieved sample showed a clear two-peak structure, as opposed to a single broad peak for the samples recrystallised at 1700 K and a much smaller, narrow peak with broad shoulders for the samples recrystallised at 2000 K.

Under the irradiation conditions in these experiments a large number of spherical blisters with a diameter of up to 20  $\mu\text{m}$  and a height of up to 200 nm appeared on the stress-relieved samples, whereas the recrystallised samples showed no signs of blistering.

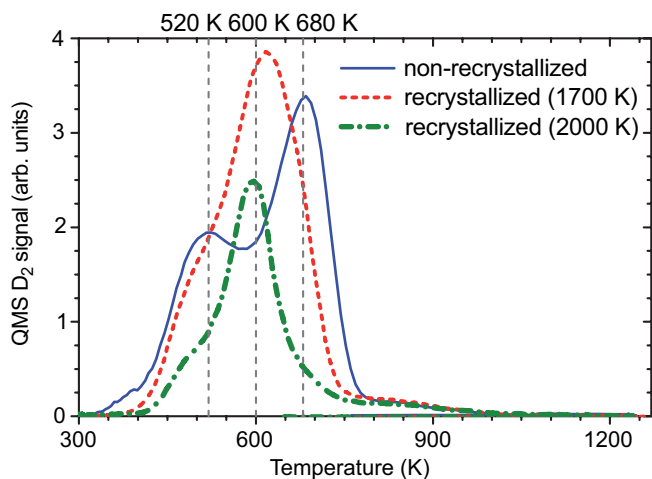


Figure 4:  $D_2$  release spectra from rolled and recrystallised tungsten samples exposed at a fluence of  $6 \times 10^{24} \text{ D/m}^2$ . The heating rate was 1.2 K/s for each sample.

## Materials and Components

### Tungsten Wire-reinforced Tungsten Composites for Toughness Enhancement

Inherent brittleness and further embrittlement by neutron irradiation are two of the most critical issues in the application of tungsten for plasma-facing components. Recently, we proposed an innovative novel toughening method for tungsten, which does not necessarily rely on physical ductility i.e. plasticity. To this end, we utilised tungsten wires as reinforcement with an engineered fibre/matrix interface. The idea is based on incremental dissipation of strain energy by controlled debonding and subsequent frictional sliding at the engineered interfaces. When a propagating matrix crack meets an array of fibres standing perpendicular to the crack front, it deflects along the interfaces, provided that a specific fracture mechanical condition is fulfilled. Then the strong fibres collectively bridge the primary crack, suppressing its dynamic extension and leading to stress redistribution over a finite volume. The total amount of the absorbed energy is a measure of apparent ductility or pseudo toughness. Here, fracture mechanical properties of the interface are the key factors. In order to achieve maximal toughness, the interfaces

need to be optimised in terms of fracture behaviour. To this end, we coated the interfaces with thin films. As a preparatory study, we fabricated a number of single-filament composite specimens with various kinds of interface coatings using PVD and CVD processes. We evaluated their interfacial parameters such as shear strength or debonding energy by means of fibre push-out test together with theoretical models. The measured parameters satisfy the criterion for crack deflection. The mechanism of wire bridging was also demonstrated by miniaturised 3-point bending tests under in-situ SEM using a dedicated specimen design (figure 5). The present results confirm the basic feasibility of significant enhancement of tungsten toughness.

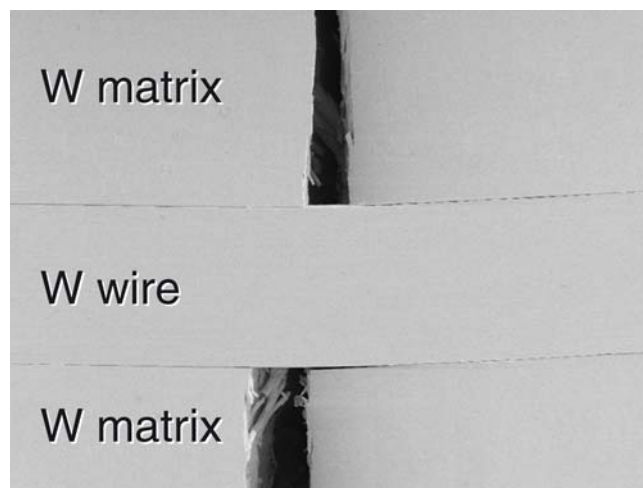


Figure 5: Crack bridging of the tungsten wire under bending load.

### Microstructure-based Finite Element Analysis of Heterogeneous Materials

The image-based finite element analysis (FEA) is a numerical technique, which utilises the realistic micrographic images of a heterogeneous material. The image-based FEA allows one to take the characteristic features of the actual microstructure into account for simulating thermal and mechanical processes on a mesoscopic scale. We applied both of these techniques successfully to two sorts of heterogeneous materials considered for the plasma-facing components of next generation fusion reactors, namely, infiltrated particulate W/CuCrZr composites and plasma-sprayed porous tungsten coatings (PS-W). The aim of the study was to elucidate the effect of microstructure morphology on the local damage evolution and failure. To this end the representative volume elements (RVE) were used as a modelling domain.

For the W/CuCrZr composites with different chemical compositions plastic deformation and ductile rupture behaviour under tensile loads were simulated using plane RVE models created from scanning electron micrographs. A continuum damage evolution law was applied to the Cu matrix.

The predicted feature of meso-scale failure was the spontaneous formation of several plastic strain bands oriented to the loading direction at about  $45^\circ$  where ductile damage preferentially accumulated leading to fracture.

For validation the simulated tensile stress-strain curves were compared with the experimental data at RT, 300 and 550 °C considering the contribution of thermal stresses. They exhibited a remarkable agreement even for the final rupture stage. The findings of fractographical inspection also supported the predicted failure mechanism.

Stereographic mapping of the porous microstructure of the PS-W coating with a W/Fe interlayer was conducted using the synchrotron micro-tomography images with a detector resolution of  $1.4 \mu\text{m}/\text{voxel}$ . The reconstructed 3D microstructure image (figure 6) was implemented into a FEA model for further stress analysis. By comparing the computed stress fields of the 3D model with those of a planar model we could estimate the effect of dimensionality in meso-scale modelling. In addition the consequence of loss of geometric information about the defect fine structures was assessed.

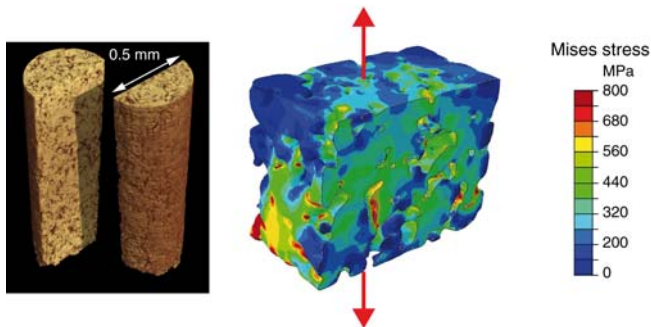


Figure 6: Micro-tomography image of porous tungsten coating (left) and 3D finite element analysis of local stress field (right).

Additional contributions to component behaviour are reported in the section JET cooperation of this annual report.

### High Heat Flux Test Facility GLADIS

The high heat flux (HHF) test facility GLADIS offers testing of large water-cooled plasma-facing components (PFCs) as well as small samples with heat and particle loads similar to the expected operating conditions in current and future fusion experiments. The facility is equipped with two neutral beam sources, each up to 1 MW power. The commissioning of the second source in 2010 considerably enhances the experimental capabilities to study the behaviour of plasma facing materials subjected to hydrogen or helium particles. The completely independent operation of the sources provides a unique capability for operation with H, He or mixed H/He neutral beams, as well as different thermal load profiles.

The continuation of high heat flux testing of the actively water-cooled divertor targets for W7-X was the main task in 2010.

Different types of tungsten as plasma facing material were investigated with power loads exceeding  $20 \text{ MW}/\text{m}^2$  in hydrogen and helium beams. Further, W coatings on CFC for the JET ITER-like Wall Project (see section “JET cooperation”), powder metallurgy fabricated W components for the ASDEX Upgrade divertor (see section “ASDEX Upgrade, technical systems”) and newly developed divertor materials in the frame of the EFDA topical group “W&W alloys” in collaboration with the Karlsruhe Institute of Technology were investigated.

Tests of pre-series IV targets for the W7-X divertor with power loads exceeding the design value by a factor of three were performed to study overload situations for the W7-X long pulse divertor. A sequence of 24 pulses with 30 s duration at 30 to  $33 \text{ MW}/\text{m}^2$  did not cause significant failures in the CFC/Cu bonding and the integrity of the component was not affected. Only strong erosion of the CFC was observed due to the surface temperature of more than  $2200^\circ\text{C}$  reached during high-heat-flux loading. After reduction of the cooling water velocity from 10 m/s to 8 m/s a partial melting of the CFC/Cu interface occurred. Nevertheless, a loss of the CFC tiles did not occur due to the strong graphite evaporation. This overloading test series demonstrates the maturity of the target component design for W7-X.

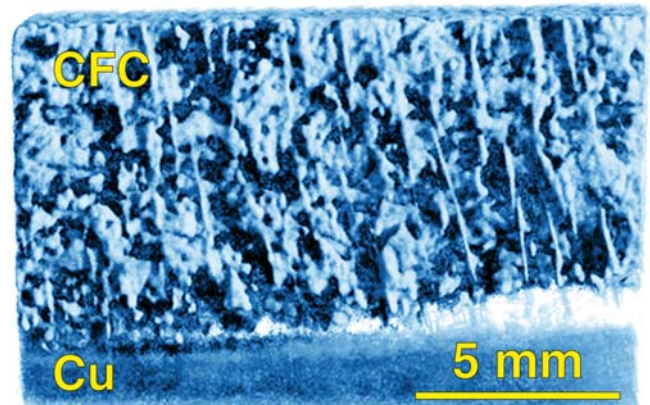


Figure 7: Example of a computed 3D tomogram of a 8 mm high CFC tile bonded onto a copper structure. The thickness of the sample (perpendicular to the plane of view) is 5 mm. More than 2000 individual images were reconstructed to generate the image. The sample was infiltrated with a contrast agent (gadolinium). Bright areas represent the open porosity of the CFC material, which is filled with the contrast agent thus revealing the structure of the CFC matrix. This sample was cut from a methodically overloaded component. The overloading caused delamination of the CFC from the copper substrate. The delaminated region between CFC and Cu is visible on the lower right. It extends over the whole sample thickness of 5 mm and is therefore much brighter than the CFC porosity. Image: IPP and TUM.

For the investigation of the CFC/Cu interface crack mechanisms extensive metallographic and micro-chemical post-exposure examinations were conducted to analyse changes

of the CFC structure and of the CFC/Cu interface. All these analyses are based on two-dimensional investigations. An insight into the spatial distribution of structural material modifications and of interface failures is therefore limited. Neutron tomography opens up the possibility to analyse such structures on centimetre-sized samples non-destructively with a high spatial resolution. In the frame of the FEMaS project (see below) the ANTARES facility at FRM II was used to perform neutron radiography and tomography on samples of W7-X targets. The applicability of the method was successfully demonstrated and further improved by vacuum infiltration with a gadolinium agent as neutron absorption fluid. A spatial resolution of about 25  $\mu\text{m}$  was achieved. The comparative analysis of an unloaded and a thermally cycled sample showed distinct differences at the CFC/Cu interface, but no changes of the CFC material. It is concluded that the slight surface temperature increase during loading up to 10,000 cycles at 10 MW/m<sup>2</sup> is based on a number of micro cracks in the CFC/Cu interface.

### Integration of and Collaboration in EU Programmes

#### EU Task Force on Plasma-Wall Interaction

The contribution of the project to the EU PWI Task force has further intensified in 2010 with the TF leader, the new leader of the Gas Balance and Fuel Retention expert group and the leader of the Mixed Materials expert group from the PFMC project at IPP. In addition to leadership activities, PWI research within the PFMC programme is characterised by cooperation based on joint experiments (e.g. the ITER-like Wall experiment at JET, the joint impurity migration modelling efforts for ASDEX Upgrade, JET and ITER), which is the basis for several priority tasks assigned by EFDA. Consequently, strong contributions were made to all topics of the Task Force, amounting to 4.1 ppy Priority Support and 12.3 ppy Baseline Support. Within the EFDA Fusion Programme the Project provides two mid-size facilities: The High-Heat-Flux Test Facility GLADIS and the Integrated PWI Facility.

#### ExtreMat – New Materials for Extreme Environments (an EU Integrated Project in FP6)

The European research project ExtreMat is coordinated by IPP and brings together 37 European partners from industry, research centres and universities with the aim to develop new materials for very demanding applications. Application fields besides fusion are advanced fission, electronics and space applications, as well as gas turbine compounds, brake systems, X-ray generators etc. as spin-off applications. Common requirements are the basis for the development of self-passivating protection materials, new heat sinks, radiation-resistant materials and of compounds integrating these materials with their favourable properties. The project, started

end of 2004, was terminated successfully in September 2010. The final task was the termination of the neutron irradiation campaign, which for the first time enabled material scientists from many institutions to test their materials in a nuclear environment. Overall, the project was very successful, both in developing new materials concepts in the targeted applications fields, and in its integrative character. Several new lasting collaborations were initiated and a number of follow-up projects between ExtreMat partners are already running. ExtreMat was nominated as “FP6 Success Story” by the EU project officer.

#### FEMaS – Fusion Energy Materials Science (an EU Coordination Action in FP7)

The FP7 EU Coordination Action “Fusion Energy Materials Science (coordinated by IPP) aims to foster the integration of universities, research centres and in particular large-scale research facilities like synchrotrons and neutron sources into the fusion materials community. 27 participants from universities, research centres and large-scale facilities like ESRF, FRM II and HZB-BESSY II collaborate in training activities, summer schools and bilateral exchange of researchers. In 2010, the 2<sup>nd</sup> FEMaS Workshop was organised, presenting an overview of the fusion materials science activities in ~50 presentations.

### Scientific Staff

Ch. Adelhelm, J. Albert, V. Alimov, A. Anghel, U. Auzmendi Arrondo, M. Balden, I. Bizyukov, B. Böswirth, A. Brendel, J. Brinkmann, R. Brüderl, T. Chikada, A. Detloff, T. Dittmar, K. Dobes, J. Dorner, J. Du, T. Dürbeck, N. Drescher, A. Eggeling, M. Elloriaga Rico, N. Endstrasser, K. Ertl, M. Fusseder, Y. Gasparyan, A. Golczewski, H. Greuner, R. t’Hoen, A. Hakola, D. Harangozo, Al. Herrmann, M. Hinterhofer, J. Hirdes, C. Höschen, T. Höschen, R. Hoffmann, W. Hohlenburger, A. Holzer, E. Huber, W. Jacob, S. Jong, W. Junghans, S. Kimmig, J. Kisslinger, M. Köppen, F. Koch, K. Krieger, R. Lang, H. Langhuth, M. Laux, H. T. Lee, P. Leitenstern, S. Lindig, Ch. Linsmeier, A. Luo, T. Makkonen, H. Maier, A. Manhard, E. Markina, A. Markin, P. Maya, G. Matern, P. Matern, M. Mayer, M. Mezger, K. Moshkunov, E. Neitzert, R. Neu, M. Oberkofler, S. Olmenchenko, O. Ogorodnikova, V. Paffenholz, R. Piechoczek, M. Pietzka, T. Phan, C. Porosnicu, M. Rasinski, M. Reinelt, J. Riesch, V. Rohde, D. de Rooij, M. Roppelt, J. Roth, P. A. Sauter, J. Schäftner, S. Schindler, K. Schmid, T. Schwarz-Selinger, M. Sode, R. Strasser, G. St. Aubin-Haker, K. Sugiyama, K. Tichmann, B. Tyburska, U. von Toussaint, S. Vorbrugg, P. Wang, A. Weghorn, M. Werkstetter, W. Yao, J.-H. You, Y. Yuan, A. Zivelonghi, P. Zeijlmans van Emmichoven, I. Zhukov.



### Helmholtz-Russia Joint Research Group “Hydrogen Isotopes Retention in First-Wall Materials”

**Heads:** Dr. Matej Mayer (IPP), Dr. Anna Golubeva (Kurchatov Institute)

This joint research group comprises scientists from the IPP, from the Moscow Engineering and Physics Institute (MEPhI), and from the Kurchatov Institute (both located in Moscow, RU). The research group is funded by the Helmholtz Association.

### Deuterium Retention in Polycrystalline Tungsten and Tungsten Coatings

Deuterium retention in polycrystalline tungsten and tungsten coatings exposed to low-energy pure and helium-seeded deuterium plasmas was investigated. ITER-grade W and two W coatings with 200  $\mu\text{m}$  and 10  $\mu\text{m}$  thicknesses were used. Seeding of helium into D plasmas with a helium ion flux fraction of 10 % reduces the deuterium retention for all tungsten grades. A more significant reduction was observed for ITER-grade W, a less significant effect was found for W coatings. From thermal desorption spectroscopy measurements we conclude that the presence of He modifies the density of existing deuterium traps, but does not modify the nature of the traps. The maximum effect of deuterium retention reduction was observed at around 500 K.

### Deuterium Retention in Damaged Tungsten

The effects of fast neutron damage on deuterium retention in W were simulated using fast charged particles. W samples were damaged by 5-20 MeV W ions and subsequently exposed to deuterium plasmas at different exposure temperatures. The D retention in damaged W correlates with the calculated damage level. Self-implantation of W results in D trapping in radiation damage (vacancies and vacancy clusters), thus increasing the D inventory. A diffusion model with dynamic trap formation during irradiation was validated by comparison with experiments. The model was applied for the calculation of hydrogen isotope retention in ITER in the presence of neutron irradiation. Calculations show that T retention does not reach the limit of 700 g until the end of the ITER lifetime.

### Deuterium Retention in Co-deposited Mixed C-W-D Films

Co-deposition of tritium with eroded wall material in remote areas is considered as the main channel of tritium accumulation in fusion devices with a carbon wall. A divertor consisting of carbon and tungsten is planned for ITER, thus resulting in the formation of mixed C-W-D redeposited layers. Deuterium retention in C-W-D films co-deposited during a deuterium magnetron discharge with a mixed C-W cathode was investigated. Morphology and composition of deposited films were analysed by secondary electron microscopy, ion beam analysis, and thermal desorption spectroscopy. The films were carbon dominated with a maximal concentration of tungsten of 50 at.%. Deuterium retention in these films was comparable to C-D films and was still at a level of tens of percents at temperatures below 100 °C.

### Deuterium Permeation through Carbon-coated Tungsten during Ion Bombardment

Ion-driven D permeation through tungsten membranes coated by amorphous carbon films was investigated and compared with the permeation through bare W at a temperature of 873 K. The initial thicknesses of the carbon films were 120-170 nm, detailed characterisations of these films were performed using AFM, NRA, RBS, FIB/SEM and XPS. The influence of the carbon films on permeation was strong ion energies, but different for each energy. In the case of 200 eV/D ions, the film was completely removed by the end of permeation due to intensive chemical sputtering, the lag time of permeation was much longer than for the bare membrane, and the permeation rate rose to a maximum value close to the bare membrane and then decreased to lower values. In the case of 1200 eV/D, the films were sputtered only very slowly, the lag time was much longer than in the case of the bare membrane but shorter than at 200 eV/D, and the permeation rate increased steadily up to several percents of the incident flux.

### Simultaneous Depth Profiling of Hydrogen Isotopes and Helium

It is expected that helium implantation has a strong effect on the permeation of D through W. For the simultaneous detection of hydrogen isotopes and helium in tungsten after exposure to He seeded D plasmas the elastic recoil detection method using medium heavy ions (MI-ERDA) was further developed for 15 MeV oxygen ions. The recoil cross-sections for H, D and He were derived from backscattering cross-sections available from the IBANDL data base using kinematic transformations. A depth resolution of 25-30 nm at the surface is achieved.

### Permeation of D Gas through Coated Carbon Materials

Hydrogen gas driven permeation through graphite coated with different types of tungsten coatings (magnetron-sputtered, VPS) with thicknesses up to 200  $\mu\text{m}$  has been investigated. The gas-driven permeation occurs through the carbon base-materials by hydrogen molecular gas flow through the internal porosity network rather than hydrogen atom diffusion through the graphite lattice. It was found that W coatings with thicknesses up to 3  $\mu\text{m}$  are transparent for hydrogen gas penetration and do not influence the permeability of coated fine-grain graphite, because the open porosity system of graphite remains open. Even a 200  $\mu\text{m}$  thick layer of VPS-W has an open system of connected pores, which connects the front and rear surfaces of the deposited layer.

### Scientific Staff

**IPP:** E. Markina, M. Mayer, O. Ogorodnikova.

**MEPhI:** V. Efimov, Y. Gasparyan, S. Krat, V. Kurnaev, N. Mamedov, E. Marenkov, K. Moshkunov, A. Pisarev, D. Sinelnikov.

**Kurchatov Institute:** A. Golubeva, A. Spitsyn.

## Plasma Theory



# Theoretical Plasma Physics

Heads: Prof. Dr. Sibylle Günter, Prof. Dr. Per Helander

## Tokamak Physics Division

Head: Prof. Dr. Sibylle Günter

### Tokamak Edge Physics Group

The neoclassical transport code NEOART by A. Peeters has been integrated as a module into the B2.5 code and tested on an ASDEX Upgrade discharge. Development of the SOLPS6-B2.6 project (which introduces a solution-adaptive finite volume scheme to the B2 code) has continued. The main focus was on preparing the B2.6-structured branch of the code for production use and dissemination to users. A major milestone in this process was the implementation of a regression testing framework to ensure reproducibility of results between different versions of the B2 code. Further, development of the B2.6-unstructured code has progressed, and the associated grid generation tools were improved with the aim of enabling use of fully orthogonal grids close to the target plates. A test version of the kinetic module for the B2 fluid code has been completed. It combines a fast scheme for parallel electron propagation (“free-streaming”), a fully implicit scheme for the non-linear Coulomb collision operator for electron-electron collisions, an implicit scheme describing the parallel electric force on the plasma, and the Debye sheath. First tests revealed a good match with parallel electron transport coefficients in regimes of strong collisionality. The first SOLPS developers’ meeting was held at IPP and included participants from IPP, Russia (State Polytechnical University of St Petersburg), France (CNRS-Paris), FZJ, and the Netherlands (FOM). Current developments of the code were presented and discussed.

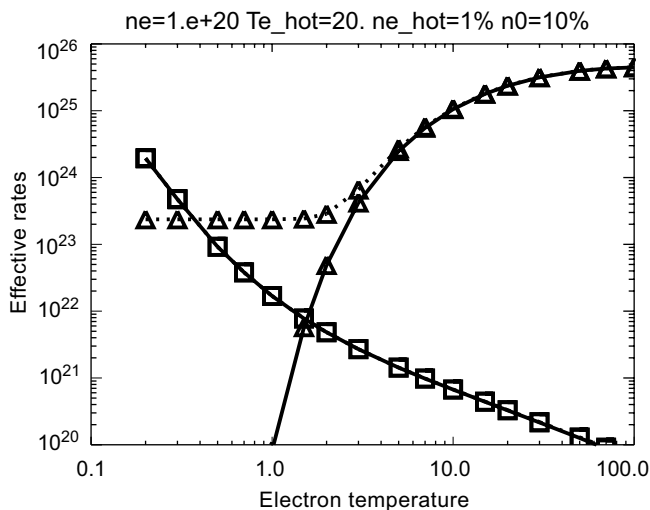


Figure 1: Rates for ionisation (triangles) and recombination (squares) without fast particles (solid lines) and with a 1 % 20 eV electron population (dotted line).

The project “Theoretical Plasma Physics” is devoted to first-principle based model developments and combines the corresponding efforts of the divisions Tokamak and Stellarator Theory, of two independent Junior Research Groups, and of the HLST Core Team of the EFDA HPC initiative. To exploit synergies between astrophysical and fusion plasmas, a collaboration between IPP and the Max-Planck-Institute for Solar System Research (MPS) has been started.

ITER has been designed to operate in the semi-detached regime on the basis of SOLPS calculations, but simulations of detachment on present machines are not always successful – with the main problem of the asymmetry in detachment between inner and outer target. A study was performed with SOLPS to identify physics mechanisms affecting the asymmetry. This asymmetry was large-

ly unaffected by: divertor geometry (vertical or horizontal target); fluid or kinetic neutrals; input heating power; varying the transport coefficients with upstream separatrix density; the presence or absence of impurities (C); or the presence of ELMs (the “standard” knobs used in the code). Including drift effects in SOLPS though had some impact on the asymmetry. A small (1 %) background of hot (20 eV) electrons in the divertor region had a significant effect on the ionisation rates at lower divertor temperatures, while leaving the recombination rate largely unaffected (see figure 1). This introduced a new loss mechanism into the simulations, which increased the small asymmetry between the inner and outer divertors substantially (see figure 2).

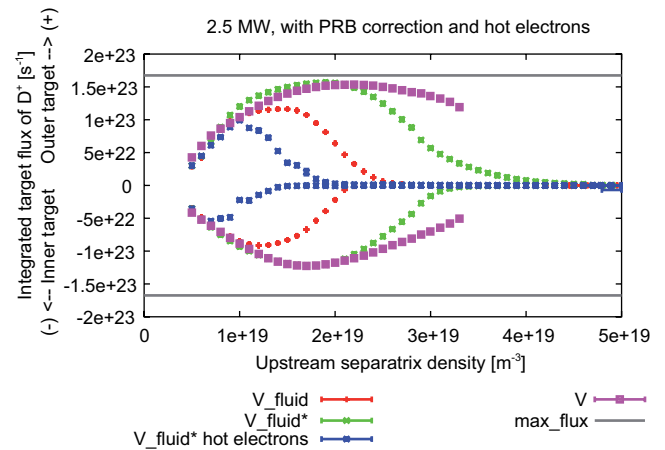


Figure 2: Integral particle fluxes to the outer (positive) and inner (negative) divertor plates as a function of the outer midplane separatrix density where the hot electron results are compared with the other vertical target results.

## MHD Theory Group

### Linear Stability Studies in the Presence of 3D Wall Structures

The three-dimensional, linear MHD codes CAS3DN and STARWALL in combination with the feedback optimisation code OPTIM have been used to perform stability studies investigating the stabilisation properties of various AUG wall designs with respect to ideal external kink modes. A model plasma based on AUG #20993 has been used to determine the ideal wall beta limit for several wall designs consisting of multiply-connected wall elements and ICRH antennas.



First results of this study show that Faraday screens connected to the wall increase the beta limit noticeably, while ICRH antennas (Faraday screen plus antenna box) that are not connected to the wall are less effective. However, the latter also contribute to the mode stabilisation.

However, damping mechanisms, such as plasma toroidal flow and drift kinetic resonances, play also an important role for the stabilisation of RWMs. Since these effects are not included in the above mentioned code package, the vacuum solution of the STARWALL code for given unit perturbations and 3D wall geometry has been coupled to the resistive, linear MHD code CASTOR\_flow. This code already includes plasma rotation, resistivity, and viscosity. Furthermore, the CASTOR\_flow code has been extended. The new code version, called CASTOR\_3DW, includes eigenvalue splitting and toroidal mode coupling. Both effects are caused by the symmetry breaking 3D wall structures.

#### Kinetic MHD and Fast Particle Physics

Due to their importance with respect to energetic particle transport, the physics of BAE (beta induced Alfvén eigenmodes) modes has been further investigated. First, the frequency splitting of BAE modes with different poloidal mode numbers as predicted by an extended dispersion relation has been confirmed experimentally by dedicated ASDEX Upgrade discharges. Furthermore, the evolution of the mode frequencies during a sawtooth cycle has been explained by a detailed analysis: diamagnetic effects, finite  $k_{\parallel}$  corrections and trapped particle contributions all play a significant role and therefore stress the importance of a fully kinetic treatment of modes at and below the BAE resp. GAM (geodesic acoustic) frequency. The analysis for modes at even lower frequencies  $\omega_{\text{BAE}}/2$ , as seen in many ASDEX Upgrade discharges has been started. Finally, fully kinetic electromagnetic BAE eigenfunctions were calculated for the first time with the LIGKA code. The modes exist in the BAE gap, but can also move into the continuum depending on the background temperature gradients. Steep thermal gradients also destabilise the mode. Therefore, despite increased ion Landau damping and coupling to sound waves, the modes can easily be destabilised by energetic particles, as seen experimentally.

Non-linear multi-mode runs were carried out to understand the complex interplay of Alfvén modes with different frequencies and radial localisations and their impact on the overall fast particle transport.

#### Linear MHD Stability Analysis

As part of the linear MHD stability chain workflow, the high resolution fixed boundary equilibrium module HELENA and the linear MHD stability module ILSA have been coupled to the free boundary equilibrium reconstruction module EQUAL. The workflow has been successfully applied in tests to JET and ASDEX Upgrade discharges and will now

enter the production stage. An effort to parallelise the eigenvalue solver of ILSA using cyclic reductions in a hybrid OpenMP/MPI algorithm has been started. The parallel version of ILSA will allow studying the effects of toroidal plasma rotation and edge resistivity on the linear MHD edge stability of tokamak discharges ( $j$ - $\alpha$  studies).

#### Stability Analysis of Vertical Displacement Events

The development of a non-linear resistive MHD code has been continued. The code is able to predict growth rates and non-linear behaviour of the generalised positional instability of a plasma in the presence of finite resistivity structures like the passive stabilizing loops (PSL) of ASDEX Upgrade. The implementation of projection boundary conditions eliminates the artificial stabilizing effect of the computational domain boundary. First comparisons of growth rates observed in experimental plasmas and obtained as result of the developed code (using CLISTE equilibria) show good agreement.

#### Non-linear MHD Studies

a) Three-dimensional non-linear reduced MHD Simulations  
Work on the three-dimensional non-linear reduced MHD simulation code JOREK (in collaboration with CEA/Cadarache) has continued comprising improved documentation, debugging and code cleanup, as well as handling on Linux-cluster and IBM-architectures. As additional functionality implemented in JOREK, an interface for ASDEX Upgrade data was realised that allows using specific experimental snapshots as initial data for simulation runs. Resistive wall boundary conditions that are necessary, e.g., for simulations of vertical disruption events or resistive wall modes are currently implemented by coupling JOREK with the STARWALL code. First simulations of edge localised modes in realistic ASDEX Upgrade geometry have been started.

b) Linear and non-linear stability of drift-tearing modes  
The drift-tearing mode was investigated using two fluid equations in the large aspect ratio and cold ion approximation. For experimental data as input, the drift-tearing mode can be driven unstable by the electron temperature gradient if the classical perpendicular electron heat conductivity is taken into account, providing a possible explanation for the spontaneous growing tearing mode in experiments. In the non-linear phase, two saturation regimes are found: the small magnetic island regime and the neoclassical tearing mode (NTM) regime. For a low electron diamagnetic drift frequency and/or a high fraction of the bootstrap current density, the modes turn into large amplitude NTMs. In the opposite case, the saturated island width is small, being about the critical island width for flattening the local electron temperature profile, and the diamagnetic drift (ion polarisation current) dominates the non-linear saturation. A sufficiently large external trigger extends the NTM regime to the region with a lower bootstrap current fraction or a higher electron diamagnetic drift frequency.

c) Plasma response to externally applied resonant magnetic perturbations

The plasma response to resonant magnetic perturbations (RMPs), studied numerically by using non-linear two fluid equations, is affected by the plasma rotation direction and frequency, the RMP amplitude, and the particle, heat, and momentum transport coefficients: (1) In the case of a sufficiently high value of  $S^2/(\mu\tau_R/a^2)$ , the change of the plasma rotation frequency is more significant than that of the local electron pressure gradient (or electron diamagnetic drift frequency), where  $S=\tau_R/\tau_A$ ,  $\tau_R=a^2/\eta$  is the resistive time,  $\tau_A=a/V_A$  the toroidal Alfvén time,  $\mu$  the plasma viscosity, and  $a$  the plasma minor radius. The RMP can either speed up or slow down the plasma rotation or even change the rotation direction, depending on the original equilibrium plasma rotation frequency and direction. (2) In case of a sufficiently low value of  $S^2/(\mu\tau_R/a^2)$ , the change of the local electron density gradient can be significant, especially for plasmas with higher rotation speed or smaller perpendicular particle diffusivity at the resonant surface. The RMP can either increase or decrease the local electron density gradient, depending on the original equilibrium plasma rotation frequency and direction. The electron temperature changes in a similar way to the electron density, if the local parallel heat diffusivity and the island width are not too large. In the opposite limit the local electron temperature profile flattens, which enhances the change in the local electron density gradient.

#### MHD/Gyrofluid Ballooning Mode Analysis

A comparison between the gyrofluid fluxtube code GEM and the linear MHD solver ILSA for a ballooning unstable equilibrium yielded good agreement for the growth rates and the toroidal mode numbers during the initial linear phase of the instability. The circular equilibrium was based on an s- $\alpha$  model

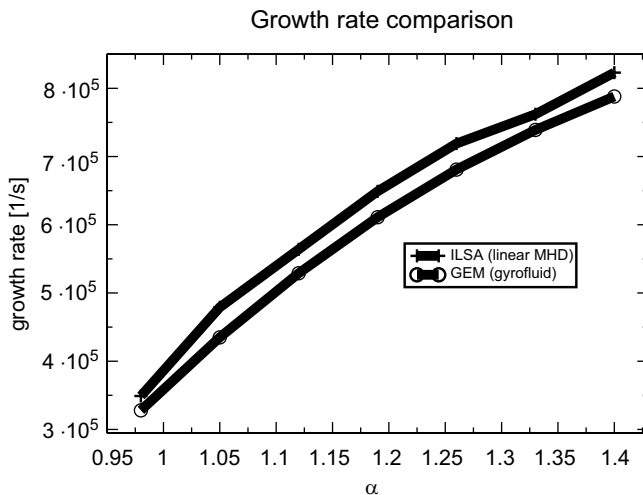


Figure 3: Comparison of the growth rates  $\gamma$  for several normalised pressure gradients  $\alpha = -2\mu_0 R q^2 / B^2 \frac{dp}{dr}$ .

with analytical profiles where the edge current density was chosen artificially low to suppress peeling modes. The shape of the pressure profile was similar to an L-mode profile.

#### Transport Analysis Group

In the field of particle transport, theoretical research has been dedicated to electromagnetic effects in electron transport, by both analytical and numerical linear and non-linear gyrokinetic calculations. In ion temperature gradient turbulence, the loss of adiabaticity of passing electrons produced by the fluctuating perpendicular magnetic field provides an outward directed convective contribution to the particle flux, which decreases significantly the logarithmic density gradient at zero particle flux with increasing  $\beta$ . However, if the increase in pressure is mainly obtained by increased beam heating, the concurrent increase of beam fuelling can balance this effect, leading to the prediction of logarithmic density gradients, which can also moderately increase with increasing  $\beta$ . Gyrokinetic modelling of particle and impurity transport has been applied to explain the observation of increasing density peaking of both electrons and boron with increasing central ECH power, in low current NBI heated H-modes in AUG (see ASDEX Upgrade, section particle and impurity transport). The logarithmic electron density gradients have been determined by the condition of matching the experimental particle to heat flux ratio, evaluated by particle and power balance analyses, while the boron logarithmic density gradients have been determined by the condition of zero impurity flux. The quantitative agreement with the experimental results has confirmed the role of ion temperature gradient and trapped electron mode turbulence in governing the response of the electron density profile to central electron heating, and has indicated the non-negligible role of roto-diffusion in the modelling of impurity transport. Finally, research has been dedicated to the experimental characterisation and the theoretical modelling of plasmas during current ramps in AUG. The energy confinement time is observed to increase with increasing current during the ramp-up, while it remains rather constant during the ramp-down. Electron temperature and density profiles are more peaked at low currents, and the peaking of the density profile requires a turbulent pinch. Theory based transport modelling (GLF23) becomes unreliable at low currents, where a large portion of the minor radius is found to exhibit edge like parameters, at which usual core transport models become non-applicable. First gyrokinetic linear and non-linear calculations reveal that the dominant turbulence is usually TEM at low currents and moves to ITG when the current is increased.

#### Kinetic Theory and Wave Physics Group

The beam tracing method has been employed to investigate the possibility of a diagnostics based on the deformation of the beam cross section during its propagation in the plasma.

Under cut-off conditions, a wave beam is found to be strongly distorted in the direction of the magnetic field at the reflection point, confirming previous ray tracing results, so that the return footprint can be used to measure the magnetic pitch. This measure is shown to be impossible in transmission, but a density measurement based on the rotation of the beam cross section after propagation in the plasma appears to be feasible. Algorithms for the evaluation of the orbit-averaged quasi-linear operator describing the cyclotron ion heating in a general axisymmetric configuration have been developed and the corresponding numerical implementation has been performed. Particular attention has been devoted to the calculation of the resonant kernel of the wave-particle interaction, the algorithm being capable of dealing with all the possible positions of the resonance along the particle orbit.

The TORIC-SSFPQL package for the propagation and absorption of ICRF waves has been augmented with the beamlets code SINBAD in order to calculate the ionisation profile from neutral particle beams (NBI). This is used as an NBI source in the Fokker-Planck solver SSFPQL. With this addition, the package allows a self-contained simulation of simultaneous ICRF and NBI heating including possible synergies. Within an international benchmark activity of ICRF codes, TORIC has shown good agreement with the most developed codes in the field.

Neoclassical physics in a transport barrier like in the H-mode pedestal (with density and temperature gradient lengths of about a poloidal gyroradius and a strong electric field) has been studied with the delta- $f$  code HAGIS. Due to the strong peaking of the electric field and the realistic aspect ratio, the effect of the orbit squeezing by the electric-field gradient on the plasma flow and on the bootstrap current is strongly reduced with respect to the usual large-aspect-ratio theory. The density of trapped ions decreases due to a shift of the trapping region in velocity space caused by the electric field. This leads to a reduction of the ion heat flux. The bootstrap current, however, depending on the fraction of trapped electrons, is close to the usual value without orbit squeezing.

The flux-tube gyrokinetic spectral code GKW has been employed to compute the electrostatic potential connected with the rotation of a magnetic island, allowing for finite-Larmor-radius effects and plasma toroidicity. In the limit of small islands, which cannot be treated with existing analytic techniques, the ion response becomes more and more adiabatic. The corresponding density perturbation is shown to lead to a flattening for the case of island rotation in the ion diamagnetic direction and to a steepening in the opposite case. This confirms previous drift-kinetic results obtained without a self-consistent calculation of the electrostatic potential.

Gyrokinetic turbulence simulations including the island geometry in both ion and electron response show the formation of a time-dependent potential vortex with the wavelength of the island. The associated  $E \times B$  velocity is found to impact

the transport across the rational surface where the island is located and its shearing reduces drastically the transport across the island separatrix. Self-consistent electromagnetic gyrofluid simulations demonstrate that the non-linear coupling between turbulence and island scales contributes to the island stability under realistic tokamak conditions.

### Turbulence Theory Group

Progress was made on a wide front in both analytical and computational efforts. A solution was given for the momentum conservation controversy in global gyrokinetic theory. Global gyrokinetic electromagnetic turbulence simulations with a particle in cell (PIC) model were carried to the high performance tokamak regime. A self-consistent bootstrap current was captured by total- $f$  gyrokinetic computations. Full flux-surface edge turbulence computations explored the connection to a self-consistently generated MHD component. Other elements including non-linear collisionless magnetic reconnection are also reported.

### Fundamental Theory

A major controversy involving gyrokinetic theory was addressed. It was asserted that the theory as currently known was inadequate to determine the radial electric field of a magnetised plasma because the part of the theory governing the establishment of self-consistent fields was not developed to high enough order in the ion gyroradius or fluctuation amplitude. In general however the theory as we know it today is a Hamiltonian field theory supported by general theorems governing the conservation laws. Since circa 1983 gyrokinetic theory is no longer a gyrokinetic equation governing particle motion but a self-consistent system of equations governing the collective responses of both particles and fields. And since circa 2000 it is known as a field theory supported by the Noether theorem. We addressed the question of momentum conservation and transport in detail for general systems subject to any ordering scheme. The problem was addressed in terms of functional form by transforming the gyrokinetic Lagrangian for the particles into a form, in which the dynamical fields enter only in the Hamiltonian. Conservation laws then result from the symmetries in the coordinate-space components of the Lagrangian (for gyrokinetic motion these components are the gyrocenter positions in 3D plus the two variables governing parallel and perpendicular dimensions of velocity space). Energy conservation is well known and was used as an example. Momentum conservation is more involved because the Noether theorem gives the canonical momentum as the globally conserved quantity. To show the actual plasma motion is conserved it is necessary to use the (ambipolar/quasineutral) charge conservation equation, which then obtains the parallel and  $E$ -cross- $B$  components of the toroidal plasma momentum. We then examined the local form of momentum conservation, that is,

the equation of momentum transport. Conversion of canonical to plasma momentum is done by using the radial component of the charge conservation, which is one and the same with the statement that the flux surface average of the radial current is zero. We therefore proved that not only canonical but also plasma momentum is conserved both locally and globally by modern gyrokinetic field theory. The sole necessity is to start from an energetically consistent form, which is guaranteed by the use of the canonical version of the Lagrangian. Currently used global codes such as FEFI, ORB/NEMORB, Gysela, and GTC were shown to satisfy these conditions at least at the level of the coded equations.

#### Gyrokinetic Study of Core Turbulence

Work was done to understand the high performance tokamak regime, similar to expectations for the ITER core, in which electron drift-Alfvén transients control saturation and therefore transport scaling. The particle pushing algorithm was rebuilt around equations with explicit Hamiltonian support following the above-mentioned work on energetic consistency.

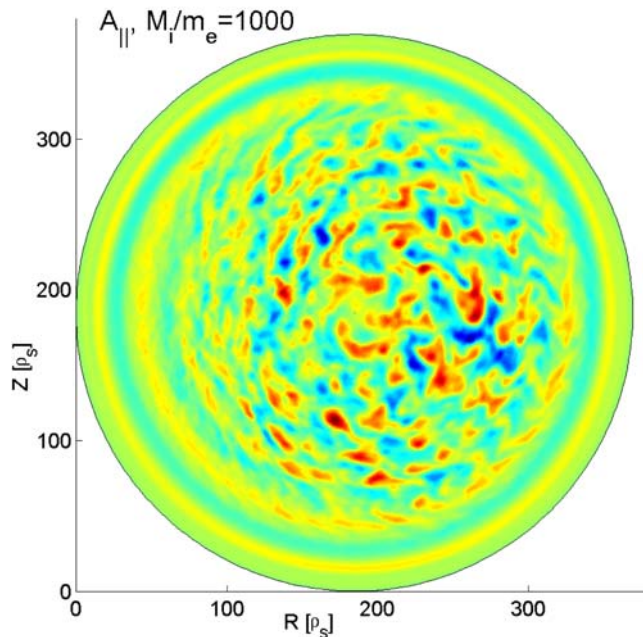


Figure 4: Morphology of the parallel component of the magnetic vector potential in the poloidal plane. The toroidal symmetry axis is to the left near  $R = -350$  in the units of the plot.

#### Gyrokinetic/Fluid Edge Studies

A series of edge turbulence parameter scalings run with the fluxtube delta-f gyrokinetic model delta-FEFI uncovered a long-wavelength electromagnetic component, which controls saturation and therefore scaling. A scaling campaign in computational domains commensurate with the entire flux surface in terms of perpendicular scale, about 1500 ion gyroradii in the electron drift direction while still following the narrow

edge channel was carried out. The spectrum was found to peak in the long-wavelength MHD regime, while companion linear scaling runs showed instabilities only at wavelengths of 10 to 20 gyroradii. The scalings were also very different, underpinning the need for a non-linear perspective in the central role and not as an afterthought for instability studies. The total-f gyrokinetic model FEFI was employed in a 4D axisymmetric form (2-space 2-velocity) to study the neoclassical equilibrium. Collisions were incorporated in the isotropic field particles model of Brizard, a non-linear treatment with exact conservation properties. FEFI was demonstrated to conserve momentum as well as energy with and without collisions. The basic neoclassical control case of no transport and no bootstrap current was found for the collisionless case, while a bootstrap current emerged self consistently in the collisional cases. In all cases radial force balance and Pfirsch-Schlüter balances in currents, flows, and heat fluxes were found. The introduction of global conformal coordinates allows closed field line computations to go arbitrarily close to the X-point of a diverted tokamak geometry. The FEFI code is being re-written to use this representation.

In collaboration with IPFN (Lisbon, Portugal) the GEMR model is used together with the full-wave reflectometry simulation model REFMUL as a synthetic diagnostic for detailed comparisons to experimental signals. A time trace is constructed using 2000 temporal realisations of the GEMR turbulence. The effects of various flux surface shapings are being explored.

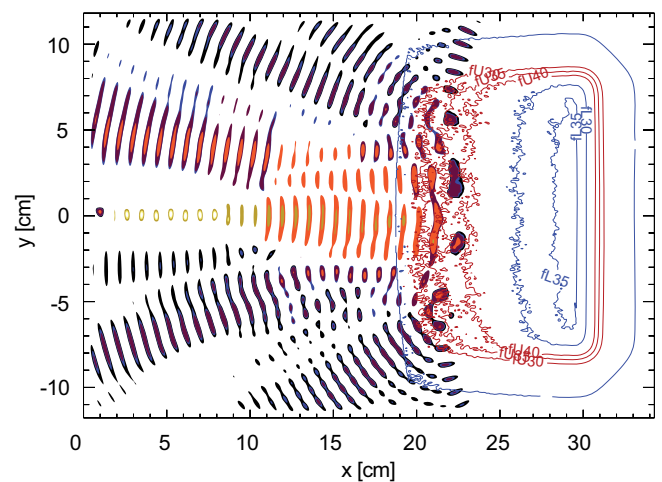


Figure 5: Snapshot of the EM field contour of an LFS X-mode reflectometry simulation (REFMULX code) in a poloidal plane of the electron density given by GEMR.

#### Other Topics

Our study of collisionless magnetic reconnection under the IPP/MPS astro/spaceplasmas project focused on non-linear acceleration in 3D Harris-pinch cases. A complicated non-linear evolution is found en route to saturation.



Unlike 2D cases, which simply grow a coherent magnetic island structure and then saturate, 3D cases generate their own set of both subsidiary islands as well as self generated turbulence. Both effects produce acceleration of the original linear growth rate by a factor of a bit less than one order of magnitude. A full battery of convergence tests against detailed energetic diagnostics was undertaken before the result could be verified.

An analytical study of drift wave turbulence produced a model, which could correctly predict the non adiabatic density spectrum in the simplified 2D Hasegawa-Wakatani model. An attempt to calculate rotation effects of edge/SOL coupling through turbulence, which exists mostly on the outboard side of the torus was started. A PhD project studying the mathematical underpinning of the gyrokinetic Lagrangian in terms of differential forms was started. A possible aim is to find whether coordinate-free discrete systems satisfying an approximate Lagrangian but with exactly symplectic properties can be a possible basis for improved numerical models.

#### **EFDA Task Forces, Topical Groups, and Other Activities** **Integrated Tokamak Modelling (ITM)**

IPP continues to play an important role within the ITM (<http://www.efda-itm.eu/>), providing two Integrated Modelling Project Leaders (IMP3 and IMP4), two deputy leaders (IMP12 and IMP3), and, from September 2010, a deputy task force leader. In addition, the following physics contributions have been made: The neoclassical transport code NEOART has been converted from a standalone code into a transport module complying with the ITM standards for data structures. Based on previous work by J. Storrs at CCFE a new web publishing system based on XML was developed and applied for the ITM Task Force. The first production workflows for the linear MHD stability analysis chain have been developed using the EQUAL, HELENA, and ILSA actors. To support the use of the ITM general grid description, a multi-language library is being developed, which allows generic grid manipulation and plotting. Based on these tools, integration of the SOLPS package into the ITM structure has started.

#### **Transport Topical Group (TTG)**

IPP has contributed to research activities within the EFDA Transport Topical Group. An IPP scientist has been directly involved as Topical Group Vice Chair, and is at present Chair of this Topical Group. Scientific contributions are provided in the fields of the L-H transition, with investigations on the role of fluctuating and mean fields in the H-mode trigger, and on the physics governing the pedestal width, on electron heat transport, with particular focus on measurements and simulations of high wave number fluctuations, on core impurity transport, as well as on edge and SOL turbulence.

#### **EFDA Goal Oriented Training in Theory (GOTiT)**

IPP continued as coordinator of GOTiT (<http://solps-mndsplus.aug.ipp.mpg.de/GOTiT/>), as well as leader of WP2 (High Level Courses). Three high level courses (“Anomalous Transport in Fusion Plasmas” at ULB Bruxelles, “Transport in Tokamaks” at CCFE Culham, and “Modern Programming and Visualization Techniques” at IPP Garching) have been organised by IPP. The web pages for the GOTiT project have been extended.

#### **ITPA Group on Energetic Particles**

A world-wide benchmark of codes concerning the damping rates of low- $n$  TAE modes ( $n=3$ ) was carried out. In general, good agreement among the codes and reasonable agreement with experimental measurements were found. The results of the LIGKA code allowed to relate the different damping mechanisms to radial locations and therefore facilitated a detailed distinction between local and non-local damping mechanisms.

#### **EUFORIA and MAPPER**

IPP continued to contribute to the EU FP7 project EUFORIA (<http://www.euforia-project.eu/>), providing leadership (deputy coordinator) as well as input in the area of workflows. The EUFORIA project came to an end at the end of 2010.

IPP is also taking part in the FP7 project MAPPER (<http://www.mapper-project.eu/>) on “Multiscale Applications on European e-Infrastructures”, which started in October, 2010.

#### **Scientific Staff**

C. Angioni, A. Bergmann, V. Belmondo, A. Biancalani, R. Bilato, A. Bottino, T. Breu, M. Brüdgam, A. Chankin, D. Coster, A. Dodhy-Würsching, S. Gori, J. Griebhammer, S. Günter, T. Hein, M. Hölzl, O. Kardaun, H.-J. Klingshirn, C. Konz, M. Kraus, K. Lackner, P. Lauber, O. Maj, P. Martin, P. Merkel, G. Pautasso, G. Pereverzev, E. Poli, J. Pratt, M. Püschel, T. Ribeiro, W. Schneider, M. Schneller, E. Schwarz, B. Scott, M. Sempf, M. Siccino, T. Stoltzfus-Dueck, G. Strohmayer, E. Strumberger, C. Tichmann, C. Wigger, Q. Yu, R. Zille.

#### **Guests**

C. V. Atanasiu, Inst. of Atomic Physics, Bukarest, RO; D. Curran, Univ. College, Cork, IR; E. Havlickova, JET, Culham, UK; P. McCarthy, Univ. College, Cork, IR; G. Poulipoulis, Univ. of Ioannina, Ioannina, GR; V. Rozhansky, Techn. Univ., St. Petersburg, RU; A. Snicker, TKK, Espoo, FIN; G. N. Throumoulopoulos, Univ. of Ioannina, GR; C. Tsironis, National Techn. Univ. of Athens, Athens, GR; S. Voskoboynikov, Techn. Univ., St. Petersburg, RU.

## Stellarator Theory Division

Head: Prof. Dr. Per Helander

### Stellarator Optimisation

Looking beyond W7-X and towards a reactor, it is important to establish whether suitable quasi-isodynamic configurations exist. Such configurations with four periods, very good alpha-particle confinement, low neoclassical transport, and negligible bootstrap current have been investigated in collaboration with the Kurchatov Institute in Moscow.

In theory, it should be possible to construct magnetic configurations that are exactly quasisymmetric on one flux surface. A quasi-helical configuration has been found through computational optimisation that satisfies this requirement to a high degree of accuracy and has benign neoclassical properties throughout the plasma volume.

In collaboration with the University of Nancy, a low aspect ratio, low-beta, quasi-axisymmetric stellarator has been designed. The aim is to produce a device that can confine a plasma with beta up to 0.5 % having very good neoclassical transport properties, which is achieved in a configuration with two periods and an aspect ratio of 5. The magnetic field is produced by 20 modular coils of five different types. Because of the modest beta requirement, the rotational transform is limited to about  $\frac{1}{4}$  and can be produced with relatively simple magnetic field coils.

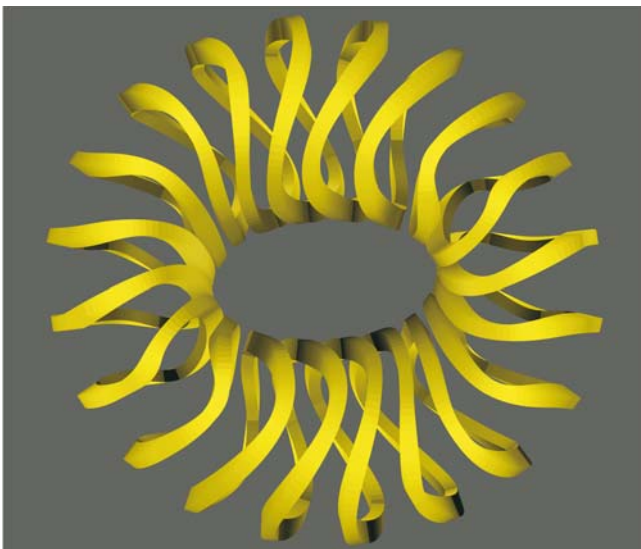


Figure 6: Top view of the coil system of the quasi-axisymmetric stellarator.

### Gyrokinetic Simulations

#### Zonal Flows

Zonal flows are believed to be important for regulating the level of turbulence driven by ion-temperature-gradient modes, both in tokamaks and stellarators. To understand these flows better, the linear response of a collisionless stellarator plasma to an applied radial electric field has been calculated, both analytically and numerically. Unlike in a tokamak, the electric

field and associated zonal flow develop oscillations before settling down to a stationary state, the so-called Rosenbluth-Hinton flow residual. These oscillations are caused by locally trapped particles with radially drifting bounce orbits and were first predicted in 2008. The prediction has now been confirmed by gyrokinetic simulations, both in local (flux-tube) and global geometry, using two independent gyrokinetic codes, GENE and EUTERPE. It has also been established that the oscillations are subject to a kind of Landau damping that depends sensitively on the magnetic configuration. The relative importance of geodesic acoustic modes and zonal flow oscillations therefore varies among different stellarators and it is expected that both could be instrumental in regulating the turbulence level.

### Benchmarking of Gyrokinetic Codes

In collaboration with PPPL, a thorough linear benchmark of the codes GS2 vs. GENE was accomplished in several stellarator configurations. The code GIST was used for both codes, which predicted similar linear ion-temperature-gradient (ITG) instability growth rates and frequencies within a few percent. In collaboration with NIFS, the Japanese code GKV has also been benchmarked with GENE, producing a non-linear ITG comparison for LHD geometry, demonstrating an excellent statistical agreement. In both cases, the electrons were taken to be adiabatic, since the computational cost (especially for the non-linear comparison) of the full gyrokinetic system is very high.

### Turbulence Optimisation for Stellarators

The GIST code, which is able to produce geometrical elements relevant to gyrokinetic simulations, was included in the stellarator optimisation code STELLOPT, together with the introduction of a new target function peculiar to the ITG instability, stemming from a linear response analysis. Initial studies concerned the NCSX configuration, where it was shown that a new configuration can be created with significantly reduced ITG transport levels. This new configuration is characterised by surfaces shifted outwards, similar to a Shafranov shift, thus creating an improved magnetic well.

### Statistical Analysis of Drift-Wave Turbulence

A first attempt for a theoretical interpretation of numerically generated probability density functions of intermittent plasma transport events was carried out. In particular, GENE simulations of ITG turbulence with adiabatic electrons for a simple circular large-aspect-ratio tokamak were performed, and the resulting radial heat flux was treated as a time series allowing for statistical analysis. It was demonstrated that, after the removal of autocorrelations via a specific numerical technique (Box-Jenkins modeling), the probability distribution function of the heat flux can be matched with predictions from a fluid theoretical setup, based on the instanton method. This result points to a universality in the modeling of intermittent stochastic processes, offering predictive capability.

### Collisions

The global three-dimensional gyrokinetic PIC code EUTERPE includes a pitch angle scattering operator. As an application, the stabilising influence of collisions on ITG instabilities in various geometries (cylinder, tokamak, LHD) has been investigated. The strongest reduction of the growth was found for the cylinder and the weakest for a tokamak, while the stellarator case was intermediate. To further benchmark the neoclassical capabilities of the code, the particle transport for an LHD configuration was simulated and compared with DKES calculations. Including collisions in a  $\delta f$  Monte Carlo algorithm requires a two-weight scheme. Unfortunately, this scheme leads to so-called weight spreading. Using the Ornstein-Uhlenbeck diffusion as a model problem, it has been demonstrated that the statistical error resulting from this scheme increases linearly with time, so that the error for a  $\delta f$  simulation can exceed that of a full- $f$  simulation. However, by exploiting an enhanced control variate, where a free parameter is used to minimise the variance of the solution, an improved algorithm has been developed and applied to the Ornstein-Uhlenbeck diffusion. The error of the new scheme behaves much better: it no longer increases but is bounded by the error of the full- $f$  scheme. The enhanced control variate can also be used to ensure the conservation of certain moments of the distribution function. Using the TORB code this has been demonstrated for the particle number, which, with the new scheme, stays constant instead of increasing as for the standard  $\delta f$  scheme.

### International Collaboration on Neoclassical Transport

Over the past ten years, the International Collaboration on Neoclassical Transport in Stellarators has undertaken an extensive benchmarking activity of various computer codes used within the stellarator community to determine the three mono-energetic transport coefficients required for a complete neoclassical description of stellarator plasmas. This activity was concluded during 2010 and the results obtained for twelve different magnetic configurations have been thoroughly documented in a report, which has been submitted for publication.

### DKES Analysis of W7-X Configurations

The Drift-Kinetic Equation Solver (DKES) has been used to analyse the neoclassical transport and the bootstrap current in various W7-X configurations. In particular, the bootstrap current has been found to be rather large in all low- $\iota$  configurations and smaller (even negative) at high  $\iota$  and high mirror ratio. For nearly all configurations under investigation, higher  $\beta$  increases the bootstrap current. Minimum bootstrap current is only found in configurations with relatively large neoclassical transport.

### Collision Operators with Momentum Source Correction

Several linearised collision operator models with parallel momentum conservation enforced by source functions are benchmarked against the correct collision operator based on

Rosenbluth potentials. The benchmarking is performed both for the parallel conductivity with the ions assumed at rest and for the bootstrap current, where ion and electron flows are collisionally coupled. The accuracy of the results obtained with the operators varies from rather poor in the case of the simplest mono-energetic model to quite satisfactory for the models employing an energy-weighted parallel momentum source function.

### Predictive Transport Modelling

Minimisation of neoclassical transport is a key element in the design of economic fusion reactors based on the stellarator concept. In the long mean free path regime, the neoclassical transport has a very unfavourable temperature dependence, in particular in the  $1/\nu$ -regime where the neoclassical heat diffusivity for electrons scales as  $T^{7/2}$ . To study the impact of the neoclassical optimisation on the confinement, predictive energy transport calculations have been carried out for the optimised magnetic configuration of LHD and for the “standard” configurations of TJ-II, W7-AS and W7-X. These stellarators exhibit very different magnetic field structures, and their transport coefficients in the  $1/\nu$ -regime differ by more than one order of magnitude. The energy confinement times  $\tau_E$  from these simulations are compared with the ISS04 scaling based on experimental results of quite different stellarators. Good agreement is found, supporting the conclusion that high-performance stellarator discharges with sufficiently high temperatures are governed by neoclassical transport in the bulk of the plasma and that anomalous transport is only dominant at outer radii. A direct comparison of the impact of neoclassical confinement optimisation on the achievable  $\langle\beta\rangle$  and  $\tau_E$  has been performed with the LHD and the TJ-II configurations scaled in plasma volume to the W7-X “standard” configuration while holding the aspect ratio fixed. The neoclassical transport coefficients for scaled configurations are derived from the database for the original device. For the same density and magnetic field strength, the volume averaged  $\langle\beta\rangle$  as well as  $\tau_E$  normalised to the ISS04 scaling are calculated in a heating power scan. It is found that the impact of the quite different neoclassical optimisations on the confinement is not as strong as would be expected from the ratio of their transport coefficients in the  $1/\nu$ -regime, which scale as  $\varepsilon_{eff}^{3/2} / R^2$ . The reason is that the high non-linearity of the thermal transport coefficients with respect to temperature and electric field diminishes the large difference in transport implied by a “pure”  $1/\nu$ -regime. For fixed heating power,  $\langle\beta\rangle$  is highest for the W7-X configuration, reduced by a factor of two for the LHD case, and further reduced by the same factor for the TJ-II configuration. The required power to achieve a given  $\langle\beta\rangle$  reflects directly the degree of neoclassical confinement optimisation. Whereas for the W7-X configuration  $\langle\beta\rangle=2.6\%$  is obtained at 5 MW, the required power to reach this  $\langle\beta\rangle$  in the optimised LHD is 15 MW, and even  $\langle\beta\rangle=2\%$  cannot be achieved in TJ-II.

It should be borne in mind that these results are “best-case” scenarios obtained by assuming that turbulence is only important at the plasma edge. Finally, the impact of the device size on the neoclassical confinement is studied; the results are consistent with the ISS04 scaling where  $\tau_E$  roughly scales with the plasma volume. It is found that while the electron heat transport is significantly decreased in the  $1/\nu$ -regime when the device is made larger, the ion heat transport is amplified. Increasing the magnetic field strength to reduce the neoclassical transport leads to much greater forces on the coils and correspondingly greater demand on the support structure. Increasing only the size of a device does not help without increasing significantly the heating power. Therefore, neoclassical optimisation is essential to allow for a reasonable reactor perspective of stellarators.

### Steady-State Scenarios for W7-X

The prospects for W7-X to create high-performance plasmas under steady-state conditions have been investigated with respect to the properties of equilibrium, transport and fast-particle confinement. Equilibria of different configurations with varying toroidal mirror ratio and  $\iota$ -values have been calculated and were investigated with a 1-D transport code under optimistic confinement assumptions (anomalous transport only relevant at the plasma boundary). Most critical for reaching steady-state discharge conditions is the combination of good confinement and minimised bootstrap current. Since the bootstrap current evolves on an L/R-time (some tens of seconds), the net plasma current needs to be minimised to keep the boundary-value of  $\iota$  constant for proper island divertor operation. In some configurations electron cyclotron current drive offers the possibility to counteract the bootstrap current, usually at the expense of a deformed  $\iota$ -profile. A conservative approach to steady-state is offered by the high-mirror configuration, which has a very small bootstrap current, but somewhat greater neoclassical transport than the optimum. To extend the reliability of the transport modelling, turbulent transport is investigated using gyro-kinetic turbulence codes. First results investigating ITG-modes using the GENE-code for an NBI-scenario maximizing the ion temperature gradient show instability of these modes over the outer 40 % of the minor radius where the gradients are steep. However, the strong radial electric field shear, which is expected in this scenario from neoclassical considerations and which has not been considered in the simulations should reduce the linear growth rates as well as the turbulent transport level.

### Benchmarking of 3D-equilibrium MHD Codes

The 3D equilibrium codes HINT2 and PIES have been benchmarked in collaboration with NIFS and PPPL. A new version of HINT2 using a rectangular cylindrical grid has replaced the previous version using a helically rotating one.

The new grid is advantageous with respect to the simplicity of the metric and therefore for the accuracy of splines and differentials. Beta-sequences for the selected reference configurations of W7-X and LHD have been generated with both codes up to  $\langle\beta\rangle$ -values of 5 % for W7-X and of 2 % for LHD.

### Ideal MHD

The CAS3D code has been used to assess the impact of error fields on stellarator equilibria. To this end, the code was further developed along its perturbed equilibrium line and, as a first step, proved to reliably determine the effect of a periodicity preserving perturbation causing an inward shift of the W7-X plasma.

### Fast Equilibrium Recovery by Function Parametrisation

Function parametrisation (FP) has been implemented in Java for recovering the flux surface geometry and the magnetic field strength from pressure and toroidal current profiles. The implementation allows the use of FP as an XML/SOAP web-service with response times on the order of milliseconds.

### Monte Carlo Simulations of Fast Particles

The ANTS (plasma simulation with drift and collisionS) code has been used to investigate NBI particle losses in all standard configurations of the magnetic field for both injection systems on W7-X, at different plasma densities. Several regions requiring power flux mitigation were identified. The ANTS code was also used to investigate the ability of W7-X to confine fast particles. Recent calculations had shown that small design changes have degraded fast-particle confinement at finite beta. Various optimisation strategies have yielded configurations of coil currents resulting in a significant improvement of pressure-induced fast-particle confinement.

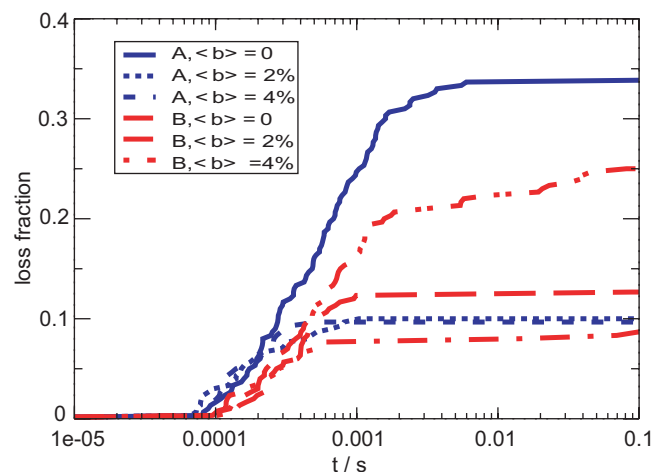


Figure 7: Fast Particle loss fraction over time for collisionless 60 keV protons initiated isotropically at  $r/a = 1/4$  for two different optimised W7-X configurations of the coil currents and for different values of beta.



### Global Particle-in-cell Simulations of Electromagnetic Modes

The effect of plasma pressure on Alfvénic modes has been studied. Global electromagnetic gyrokinetic simulations in realistic tokamak geometry have been performed using the particle-in-cell codes GYGLES and EUTERPE. The simulations have demonstrated that the fast-particle pressure can considerably affect the shear Alfvén wave continuum structure and hence the toroidicity induced gap in the continuum. It has further been found that energetic ions can substantially reduce the growth rate of ballooning modes. It has also been shown that the diamagnetic effects associated with the bulk-plasma temperature and density gradients can modify the Toroidal Alfvén Eigenmodes (TAE) in a large-aspect ratio tokamak, even at moderate mode numbers, since it is relatively easy to match the TAE frequency to the diamagnetic one, if the aspect ratio is large enough. The BSPLINES package developed at CRPP Lausanne has been integrated into the GYGLES code, making computations with non-equidistant grids possible. This can be very useful when studying global modes, such as the kink or tearing modes, which can develop extremely fine scales at resonant surfaces. In collaboration with CIEMAT, calculations for energetic particle driven Alfvén modes using CAS3D, CONTI and a local model for growth rates have been made for a recent campaign of TJ-II.

### Kinetic MHD

The three-dimensional particle-in-cell code EUTERPE has been successfully coupled with a linear reduced MHD model implemented in the CKA code to investigate the influence of fast particles on Alfvén modes. In the present status, EUTERPE calculates the linear growth rates from

the energy transfer between the waves and the particle population using the MHD eigenfunctions and particle orbits, which are not influenced by the wave. The resulting CKA/EUTERPE MHD/gyro-kinetic hybrid model has been benchmarked against several other codes for tokamaks where good agreement has been found. As an example, the comparison with GYGLES and CAS3D-K is shown in figure 8. The new hybrid code includes effects of the full particle orbits and finite Larmor radius (FLR), and can therefore replace the older CAS3D-K, which does not account for these effects. Consequently, the benchmark results (see figure) agree with those of the fully kinetic code GYGLES and deviate from those of CAS3D-K for higher fast particle energies where the size of the orbits or the FLR effects are important. The extension to three-dimensional stellarator geometry is in progress.

### ECCD Calculations with Parallel Momentum Conservation and Finite Collisionality Effects

Various computational codes and the approximations that are used in them have been compared and developed to describe various scenarios of electron cyclotron resonance heating and current drive (ECRH/ECCD). It was found that in high temperature (relativistic) plasmas where the low-collisionality limit is valid, it is important to account for parallel momentum conservation in electron-electron collisions. In ITER scenarios it was found that the usual high-speed limit model underestimates the current drive efficiency by 10 %-30 %. In addition, effects of finite collisionality are investigated in collaboration with TU Graz. The solution of the generalised Spitzer problem from the NEO-2 code was applied for calculation of the local ECCD efficiency, and for dense plasmas with moderate temperatures finite-collisionality effects were found to be significant.

### Edge/Divertor Physics

#### Comparison between Stellarator and Tokamak Divertor Transport

The essential divertor transport features of the non-axisymmetric divertors currently investigated on helical devices have been compared with those of the typical poloidal tokamak divertor, surveying the fundamental similarities and differences in divertor concept and geometry and their consequences for the divertor functionality. In particular, the importance of the various physics terms governing axisymmetric and helical scrape-off-layers (SOLs) was examined, with special attention being paid to energy, momentum, and impurity transport. Several of the main features of tokamak and stellarator SOLs can be understood from a few geometric parameters governing the relative importance of various physical effects, which makes it possible to assess these by simple models and estimates. More quantitative assessments must nevertheless rely on numerical modeling. The theoretical results correlated closely with experimental observations.

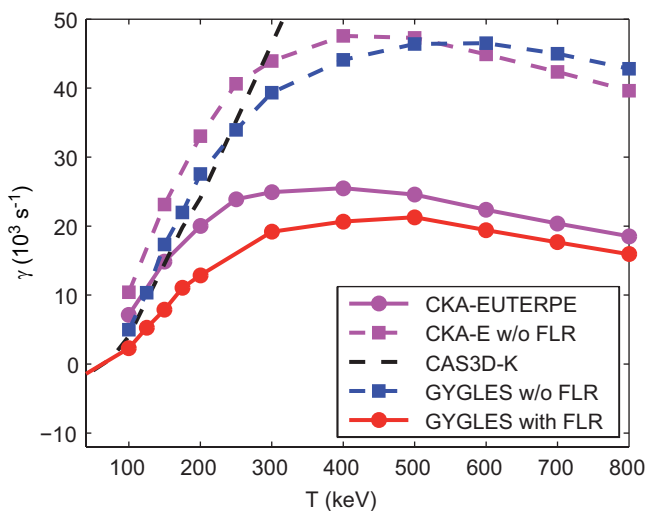


Figure 8: The figure compares results for the growth rate of an  $n=-6$  TAE mode in a circular tokamak driven by energetic ions. The radial extent of the orbits, which is not included in CAS3D-K, causes deviations from GYGLES and EUTERPE for higher energies. The fully kinetic GYGLES model and the CKA/EUTERPE model agree quite well.

### EMC3-EIRENE Optimisation for Large Tokamak Application

Several numerical improvements have been made in the EMC3-EIRENE code to enhance its computational efficiency for large tokamaks. A flexible mesh structure is now possible, where the computational domain can be resolved into arbitrary sub-domains to better match the local field geometry and the local physics requirements. A particle splitting technique is developed and implemented for improving the overall Monte Carlo statistics of the calculated plasma parameters, which, with increasing size of the device and the computational domain, can vary by several orders of magnitude. The new code version has been implemented at ASDEX-Upgrade and ITER.

### Kinetic Transport Modelling

Hydrodynamics is widely used to model transport phenomena at the edge of fusion devices. However, it is well known that under typical conditions the mean free path is not short enough to justify local transport coefficients. Over the years, several attempts have been made to improve the situation within the framework of hydrodynamics. The opposite strategy has been followed here, trying a kinetic model with simplified collision operator that however obeys the correct conservation laws exactly. The penalty is an error of up to 25 % in the resulting transport coefficients. The 1D kinetic and corresponding “reference” fluid models have been implemented numerically; their benchmarking shows that the error lies within the theoretically predicted range. Significant efforts have also been made to parallelise the kinetic code. Currently, the algorithm requires computers with shared memory, which limits its capacity.

### Runaway Energy Amplification in Vertical Disruptions

In a tokamak disruption, a substantial fraction of the plasma current can be converted into runaway electrons. Although these are usually highly relativistic, their total energy is initially much smaller than that of the pre-disruption plasma. However, through numerical simulation, it has been shown that as the post-disruption plasma drifts toward the first wall, a large part of the energy contained in the poloidal magnetic field can be converted into kinetic energy of the runaway electrons. In ITER, an energy of order 100 MJ can be channelled into runaway electrons by this mechanism. The model was implemented and solved using the finite-volume transport code BoRiS.

### Effect of Toroidal Currents on $\iota$ in W7-X

The effect of positive and negative toroidal currents (of the order of several [kA]) on the beta-profile has been investigated by using the VMEC/MFBE code package. Results for  $\beta=4\%$  are shown in the figure 9: fn corresponds to -15 [kA], fp corresponds to +15 [kA].

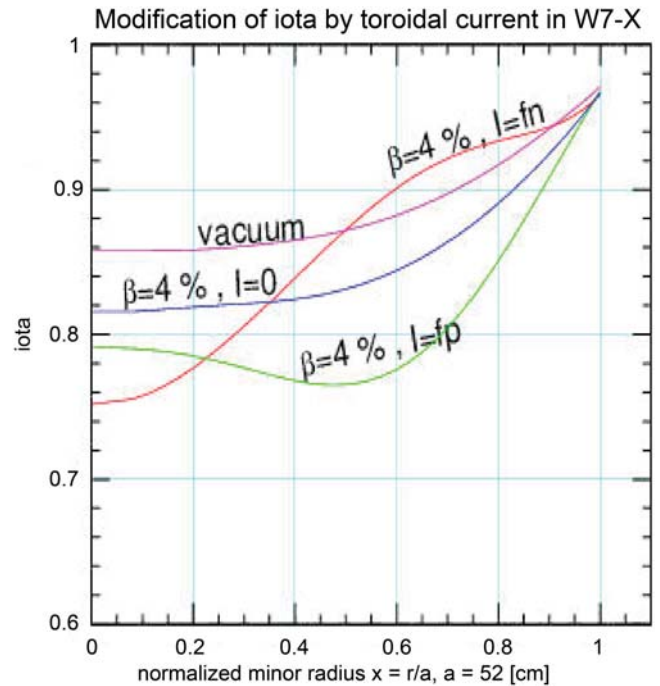


Figure 9: Effect of toroidal currents on  $\iota$  in W7-X for  $\beta=4\%$ .

### Scientific Staff

J. Andersson, C. D. Beidler, M. Borchardt, S. Braun, M. Drevlak, T. Feher, Y. Feng, J. Geiger, P. Helander, K. Kauffmann, R. Kleiber, A. Könies, H. Maaßberg, N. Marushchenko, A. Mishchenko, C. Nührenberg, J. Nührenberg, J. Prohl, J. Regaña, J. Riemann, A. Runov, F. Sardei, Yu. Turkin, P. Xanthopoulos, O. Zacharias.

### Guests

J. Baumgaertel (PPPL), N. Bertelli (FOM Rijnhuizen), J. Betram (Australian National University Canberra), A. Boozer (Columbia University New York), P. Catto (MIT Cambridge), J. Connor (UKAEA, Culham), B. Dudson (University of York), A. L. Fraguas (CIEMAT Madrid), T. Fülöp (TU Chalmers Göteborg), J. Garasa (CIEMAT Madrid), J. Hanson (Auburn University), S. Hirshman (ORNL Oak Ridge), M. Isaev (Kurchatov Institute Moscow), S. Kasilov (University Graz), W. Kernbichler (University Graz), Y. Kolesnichenko (Institute for Nuclear Research Kyiv), M. Landreman (MIT Boston), X. Le (University Beijing), E. Leeb-Lundberg (TU Chalmers Göteborg), G. H. Lu (University Beijing), P. Manz (University Stuttgart), B. McMillan (CRPP&EPFL Lausanne), M. Mikhailov (Kurchatov Institute Moscow), D. Mikkelsen (PPPL), S. Murakami (NIFS Toki), A. Nikonov (University Munich), G. Papp (University of Budapest), V. Tribaldos (University Carlos III Madrid), N. Tronko (University Marseille), X. Zha (University Shanghai), K. Zhu (University Beijing).

### Helmholtz University Research Group “Theory and Ab Initio Simulation of Plasma Turbulence”

**Head: Prof. Dr. Frank Jenko**

The main goal of our research is to better understand the important unsolved problem of plasma turbulence. Spanning a wide range of approaches, from simple analytical models to simulations on massively parallel computers, we address both fundamental issues as well as applications to specific experiments. Beyond this, we hope that our research helps to improve the general dialogue and cross fertilisation between plasma physics and neighbouring fields of science. Below, three examples of current projects are described briefly.

#### Global GENE Simulations: Finite Size Effects

One of the important open questions concerning turbulent transport in magnetised fusion plasmas is its scaling with the system size. This issue has been addressed recently by means of numerical simulations with the gyrokinetic GENE code (see [gene.rzg.mpg.de](http://gene.rzg.mpg.de)). GENE is physically comprehensive (including e.g. multiple particle species, electromagnetic effects, and collisions), well benchmarked, and scalable up to more than 100,000 cores. It can be run either as a radially local (flux-tube) or global (full-torus) code. Moreover, it can be interfaced with MHD equilibrium codes for both tokamak and stellarator geometry. By means of global GENE simulations of ion temperature gradient (ITG) driven turbulence for values of the ratio  $\rho^*$  of the thermal ion gyroradius and the minor radius between 1/140 and 1/1000 (corresponding to ITER), it was shown that radial heat flux avalanches, which are often considered as candidates for breaking the standard (“gyro-Bohm”) scaling of turbulent transport are meso-scale phenomena (extending typically for 20–40 ion gyroradii radially), but are linked to the ion gyroradius, not to the system size. Moreover, avalanches with the same properties can also be observed in local simulations, in which the average gradients are held fixed, but the (radially) local gradients may vary. In this context, it could also be shown that increasing the physics realism and adding effects due to turbulence drive by trapped electron modes, the influence of avalanches is further reduced. In summary, the present studies demonstrate that avalanches are unlikely to contribute to the breaking of the gyro-Bohm transport scaling, which is sometimes observed experimentally.

#### Global GENE Simulations: Transport Barriers

By means of both the local and global versions of GENE, we addressed important aspects of the nature of electron internal transport barriers in the TCV tokamak. Using the experimentally determined temperature and density profiles as well as realistic MHD equilibria, it could first be shown by local runs that the low levels of cross-field particle transport are likely due to a competition between ITG and trapped electron modes, as also suggested by simple quasilinear models.

Preliminary global GENE simulations (see the figure below), on the other hand, were able to confirm that the heat transport tends to be strongly dominated by the electron channel, and that small-scale electron temperature gradient (ETG) driven turbulence seems to play a role in the steep gradient (barrier) region. Further investigations along these lines are underway.

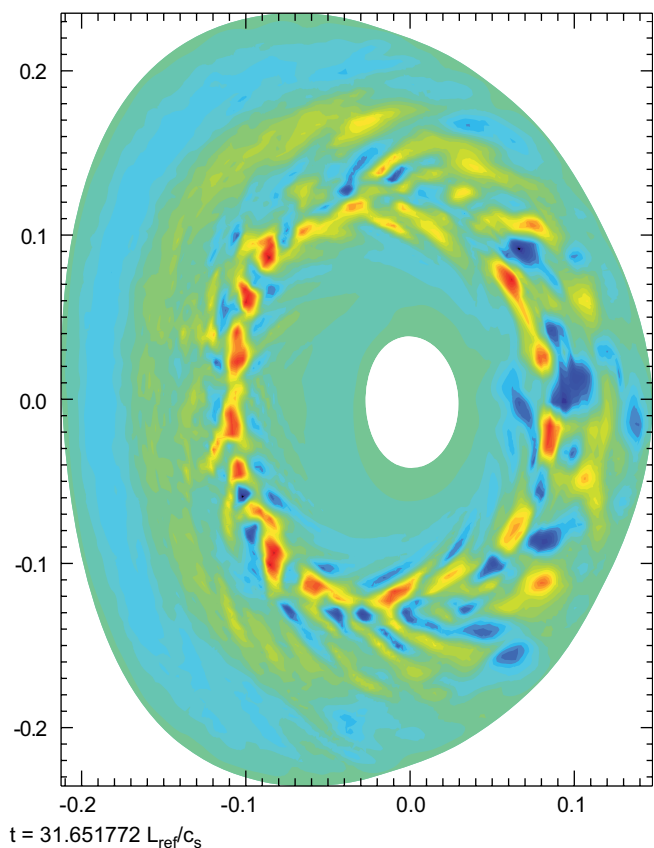


Figure 10: Snapshot of a global gyrokinetic turbulence simulation for an electron internal transport barrier in the TCV tokamak using GENE.

#### Turbulent Transport of Cosmic Rays

Recently, a newly developed scaling theory describing the turbulent transport of energetic particles in tokamaks could be extended to astrophysical problems like the propagation of cosmic rays in magnetic turbulence. Based on the well-known Taylor theorem, expressing an exact analytical relation between the Lagrangian velocity autocorrelation function of the test particles and the running (time-dependent) diffusion coefficient, the energy dependence of the cross-field diffusivity could be worked out both non-relativistically and relativistically.

#### Scientific Staff

H. Doerk, T. Görler, A. Limone, P. Marcus, F. Merz, M. J. Püschel, D. Told.

## EURYI Research Group “Zonal Flows”

**Head: Priv.-Doz. Dr. Klaus Hallatschek**

The group focuses on the properties and interaction of large scale flows, a critical agent determining the level and deleteriousness of turbulence. In toroidal systems, the curvature induced coupling of the flows perpendicular to the magnetic field to pressure fluctuations and parallel flows results in two branches, the oscillating geodesic acoustic modes (GAMs), and the stationary zonal flows (ZF) with a dominant parallel flow component.

### Geodesic Acoustic Mode Studies: Radial Propagation and Geometry Effects

To search for global eigenmodes of the GAMs and their potential non-local excitation, it is necessary to study how and when they can propagate radially. Following the successful discovery of a useful and physically meaningful way to express the linear propagation terms in terms of fluctuation Poynting fluxes, which leads itself to straightforward estimation even for asymmetric flux surface shapes, we have begun studying the non-linear, i.e., turbulence induced propagation of GAMs. Since for that purpose the turbulence naturally must not be influenced, the numerical investigation of the non-linear transfer involves full turbulence computations. Clear evidence for the effect has been obtained in Non-Boussinesq (i.e. global) NLET code runs of high-gradient ITG turbulence pertaining to the tokamak edge region. Using a frequency filter, the turbulence modified radial eigenmode structure can be extracted from the flow oscillations. The associated radial propagation velocities depend on the turbulence parameters. The non-linear, turbulent contribution typically dominates the linear one by an order of magnitude.

Even discounting the dispersive effects associated with the radial propagation, the turbulence must be included in the description of GAMs for shaped flux-surfaces, since there

are several linear flow modes with different frequencies, and the one(s) actually realised are selected by the turbulence. To test our understanding of the geometry dependence of GAM frequencies against observations in present tokamak experiments (specifically ASDEX Upgrade and NSTX), we have developed a method to reinterpolate the flux functions delivered by the respective tools for the flux surface geometry to the needs of the turbulence codes, including, in particular, well converging second derivatives of the interpolating function, which enter in the magnetic curvature terms. The ensuing turbulence runs have resulted in GAMs with frequencies consistent (NSTX) or rather well agreeing (ASDEX Upgrade) with the observations.

### Zonal Flow Studies: Reynolds Stress Functional

The Reynolds stress response to ZFs determines the evolution and flow structures in tokamak core turbulence. Its functional form is restricted by symmetry, the flow saturation level, and the observed existence of a preferred wavelength. Having traced back an acceptable approximation of the perpendicular stress to the form

$$R_{\rho\theta} = Q(\alpha u(1 - \beta u^2) - \gamma \partial_\rho^2 u - \delta \partial_\rho^4 u),$$

with  $u = \partial_\rho v_\theta$  dependent on the heat flux  $Q$  and the poloidal flow velocity  $v_\theta$ , the actual numerical coefficients, in particular, the existence and positive signs of  $\gamma, \beta$  have been reliably determined from extensive computer studies of ITG turbulence with varying flow profiles using a novel optimal filter algorithm. A qualitatively identical functional has been found for the parallel stress.

### Scientific Staff

N. Gürtler, R. Hager, A. Kammel.

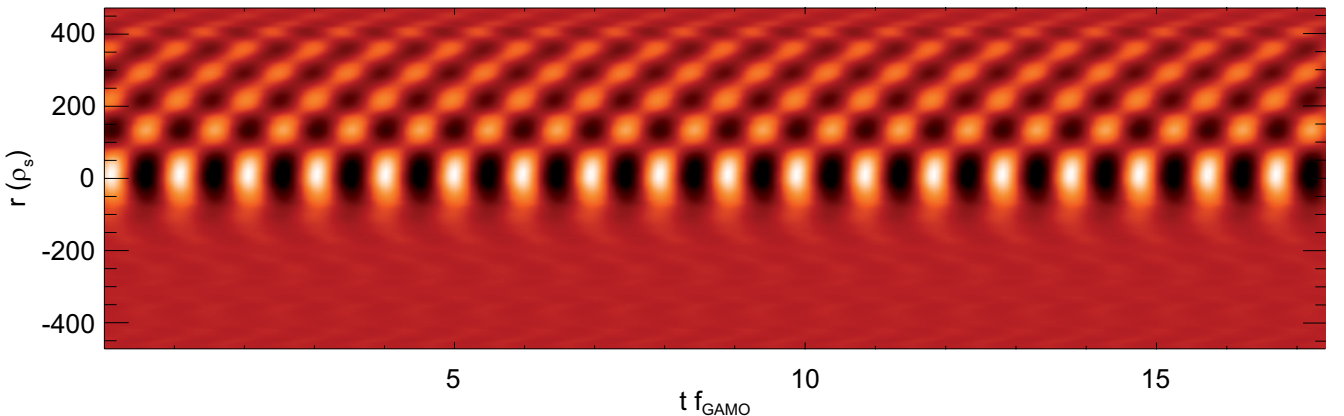


Figure 11: Global GAM Eigenmode caused by non-linear dispersion due to background turbulence in an NLET code computation. The plot shows the flux surface averaged poloidal flow velocity versus minor radius and time.



## High Performance Computer for Fusion Applications – High Level Support Core Team

Head: Dr. Roman Hatzky

### Tasks of the High Level Support Team

The High Level Support Team (HLST) provides support to scientists from all Associates of the European Fusion Development Agreement (EFDA) for the development and optimisation of codes to be used on the dedicated High Performance Computer for Fusion (HPC-FF) supercomputer located in the Forschungszentrum Jülich Supercomputing Centre (JSC). The HLST consists of a core team based at IPP Garching and of high level support staff provided by the Associates. At present the core team has five members and the high level support staff contributes additional seven scientists. This year the HLST core team was involved in nine different projects submitted by scientists from all over Europe. Exemplarily, we present here the work being done for three projects with IPP participation.

### GYNVIZ Project

The aim of the GYNVIZ project is to unify and to provide support for the whole hardware and software chain concerned with the visualization process of large datasets being produced by major European gyrokinetic codes.

Three main components can be identified. The first one consists of a uniform data format, namely XDMF. It has been decided to use this format as standard because a wide spectrum of data types can be expressed and its design is very flexible implying rather low effort on the code developer side. A collaboration with the XDMF team in the U.S. has been set up to improve parts of the implementation for our needs.

The second component consists of a set of post-processing software. The main part is intended to turn 3D time-varying datasets in 4D compressed ones to explore them with 4D visualization. The 4D compression and visualization are technologies transferred from a former EUFORIA (EU Fusion FOR Iter Applications) project while the post-processing tool is a genuine development within the GYNVIZ project. Finally, network and computing infrastructures hosted by the computer centres, Rechenzentrum Garching (RZG) and JSC are the third component. In close collaboration with RZG, a DEISA (Distributed European Infrastructure for Supercomputing Applications) project involving JSC has been established. As a result, data generated by HPC-FF can be easily and efficiently transferred from JSC to RZG via the DEISA file system. Subsequently, a remote visualization session can be started on the newly built visualization cluster at RZG to explore the transferred data.

### EUTERPE Project

The EUTERPE code is a global gyrokinetic particle-in-cell code aimed at simulating turbulence in fully 3D stellarator

geometry. It was created at the Centre de Recherches en Physique des Plasmas (CRPP) and afterwards developed further at IPP. Beside these institutions it is currently used at the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) in Madrid as well.

The focus lay on the performance improvement of the EUTERPE code by making use of the Single Instruction, Multiple Data (SIMD) capabilities of the Intel Nehalem processor also known under the term of vectorization. Such SIMD capabilities will be further extended in future CPU design and are in line with the Single Instruction, Multiple Thread (SIMT) concept of Graphics Processing Units (GPUs). The two main particle loops of EUTERPE had to be restructured for vectorization. In addition, it was necessary to get detailed information of the performance of the vector registers. Corresponding results were achieved with a self programmed test bed of common intrinsic functions on both, Intel's Nehalem and IBM's POWER6. Detailed results of these tests are published in the HLST report "*Performance Tuning Using Vectorization*" as a contribution for training young scientists to the use of upcoming new computer architectures. Unfortunately, in the special case of the EUTERPE code, the performance improvement due to vectorization was cancelled by its own overhead so that the overall performance did not change significantly. However, the new code structure made a more detailed performance analysis possible, which revealed further potential for performance improvement.

### MGEDGE Project

Work was done on the efficient implementation of the multigrid method in the GEMZ (Gyrofluid ElectroMagnetic) code of B. Scott, which solves non-linear gyrofluid equations for electrons and one or more ion species in tokamak geometry. Starting from an already existing implementation of the multigrid method we amended the intergrid transfer operators and the linear solver. We further continued with detailed adaptation and testing of the implemented multigrid algorithm on the HPC-FF machine at JSC and the VIP machine at RZG. Overall, we proved that our implementation of the multigrid method using the conjugated gradient method as a "lowest level" solver and first-order intergrid transfer operators has very good strong and weak scaling properties up to 2048 cores. Thus, it is suitable for usage on massively parallel machines like HPC-FF. For details please see the HLST report "*Parallelization of the Multigrid Method on High Performance Computers*", which has been published as IPP report 5/123.

### Scientific Staff

M. Haeefe, N. J. Hammer, N. Hariharan, K. S. Kang.

## Supercomputing and other Research Fields



# Computer Center Garching

Head: Dipl.-Inf. Stefan Heinzel

## Introduction

The Rechenzentrum Garching (RZG) traditionally provides supercomputing and archival services for the IPP and other Max Planck Institutes throughout Germany. Besides operation of the systems, application support is given to Max Planck Institutes with high-end computing needs in fusion research, materials science, astrophysics, and other fields. Large amounts of experimental data from the fusion devices of the IPP, satellite data of the MPI for Extraterrestrial Physics (MPE), also data from institutes outside Garching, and supercomputer simulation data are administered and stored with high lifetimes. In addition, the RZG provides network and standard services for the IPP and part of the other MPIs at the Garching site. The experimental data acquisition software development group XDV for both the W7-X fusion experiment and the current ASDEX Upgrade fusion experiment operates as part of the RZG. Furthermore, the RZG is engaged in several large MPG, national and international projects in collaboration with other scientific institutions.

## Major Hardware Changes

The RZG operates a supercomputer complex with two system parts, an IBM Power6 system with 6624 processors and a fast 8-plane-InfiniBand communication network yielding a peak performance of 120 TFlop/s; and an IBM Blue Gene/P system with 16 384 PowerPC@850MHz-based cores corresponding to a peak performance of 55 TFlop/s. Furthermore, an IBM p575-based cluster of 8-way nodes and a series of Linux clusters with Intel Xeon and AMD Opteron processors are operated. Dedicated compute servers are operated and maintained for an ever increasing number of MPIs. They mostly consist of modern Intel-processor based nodes in blade technology with Infiniband interconnect. The largest system has around 4500 processor cores, 54 TF peak performance and 18 TB of main memory. In December 2010, the RZG has upgraded an existing system for developing and testing GPGPU (General purpose Graphics Processing Unit) computing applications. The system now comprises an additional NVidia S2050 unit with four GPUs of the latest “Fermi” generation, which feature significantly enhanced performance for double-precision arithmetic and are equipped with error-correcting (ECC) memory. In order to provide interactive remote-visualization services to scientists of the Max Planck Society a Linux cluster with powerful graphics hardware was installed in the computing centre. The production phase started in October, 2010.

A major task has been the optimisation of complex applications from plasma physics, materials science and other disciplines. Based on the tests on WEGA all major components of the control and data acquisition system for W7-X were reviewed for adjustments. The RZG has continued its engagement in several large MPG, national and international projects in collaboration with other scientific institutions.

The new cluster (delivered by Hewlett Packard) comprises a login node and 6 visualization nodes. Each of the latter nodes contains two NVidia FX5800 GPUs. Five of these nodes are equipped with 2 Intel “Nehalem” quad-core CPUs and 144 GB RAM. For especially demanding tasks, a large node with 4 Intel hexa-core CPUs and 256 GB

RAM is available. The nodes are connected with a fast InfiniBand network. A 30 TB scratch file system is dedicated to the cluster. In addition, the scratch file system of the Power6 supercomputer and the DEISA file system are accessible from the visualization nodes. Thereby, HPC users can investigate their simulation results directly without having to transfer raw data to their sites.

## Developments for High-End Computing

The application group of the RZG gives support in the field of high-performance computing. This includes supervising the start-up of new parallel codes, giving advice in case of software and performance problems as well as providing development software for the different platforms. One of the major tasks, however, is the optimisation of complex codes from plasma physics, materials sciences and other disciplines on the respective, in general parallel high-performance target architecture. This requires a deep understanding and algorithmic knowledge and is usually done in close collaboration with the authors from the respective disciplines. In what follows selected optimization projects are presented in more detail.

### ASDEX Upgrade Real-time Solver

To control the plasma discharge of the fusion experiment ASDEX Upgrade, the discretised Grad-Shafranov differential equation has to be solved numerically within the control cycle of the experiment, which is 1.5 ms. In order to achieve the necessary computational performance a new algorithm based on Fourier analysis has been implemented, which is significantly faster than the previously employed cyclic reduction method and allows straightforward parallelization. At RZG the program has been parallelised and optimised for multi-core x86 (Intel or AMD) servers. On an up-to-date Intel platform with 8 cores running at 2.5 GHz the latest version of the program requires less than 0.3 ms for a complete equilibrium cycle when using a numerical resolution of  $128 \times 64$  zones.

In parallel, the suitability of this algorithm for GPGPU computing was assessed in the context of a master thesis, which was jointly supervised by IPP, RZG and LRZ/TUM.



For standard resolution sizes ( $128 \times 64$  zones) it turned out that it was not possible to outperform the latest CPU version, which is mostly due to relatively large overheads for data transfer between the GPU and its host server. At the same time it was shown that GPUs could in principle serve as an attractive alternative hardware platform for this type of application, when significantly larger numerical resolution and/or next-generation GPU hardware is employed.

### GENE Code

An important tool for the simulation of gyro-kinetic turbulence in fusion plasmas is the GENE code, which is used for many years now on various architectures and is under continuous development both under physical and under computational aspects. The latest version of the GENE code was optimised to the effect that large runs within the framework of PRACE became possible (50 million CPU hours on the Blue Gene/P at the FZ Jülich). Especially by switching from full matrices to sparse ones and by skilful exploitation of the shared memory on the node for large data structures needed by all MPI tasks running on the node, the memory consumption of the code could be reduced and the scalability increased. Scalability benchmarks on the Blue Gene/P in Jülich proved a good scaling up to 256 000 cores for larger problems.

### FHI-aims Code

The FHI-aims code is a new quantum-chemical code developed at the FHI on basis of the density-functional theory. The RZG continued to support the developers in optimizing the code for three different architectures with corresponding software environments: for IBM Blue Gene/P, IBM Power6 and Intel Xeon (Nehalem) based compute nodes with Infiniband interconnect. The work was concentrated on the performance of the direct eigenvalue solver for symmetric matrices. In the framework of the BMBF project ELPA, which is carried out together with the FHI and the MPI for Mathematics in the Sciences as well as with the University of Wuppertal and the TU Munich, a new, two-stage algorithm was developed, which has meanwhile reached production state. Compared to the former one-stage algorithm this new two-stage method is superior in scalability, especially for the case that a large fraction of all eigenvectors is needed. The efficiency of the new solver was successfully tested on up to 65 536 processor cores on the Blue Gene/P and on up to 4096 Intel Xeon cores, the results have been submitted for publication.

### Scientific Visualization

In 2010, a Linux cluster was installed at the RZG which is dedicated to quantitative analysis and visualization of simulation data from scientists of the IPP and the Max Planck Society.

It is comprised of a dedicated file system and 6 visualization nodes which are equipped with large main memory and two powerful graphics processing units (GPUs) each. The cluster enables scientists to efficiently perform remote visualization of large data sets, in particular without the need to transfer the data to their local workstations. On the cluster, state-of-the-art visualization applications for various purposes are available.

In addition to providing a hardware and software platform, the RZG offers support in the selection and usage of visualization and data analysis tools and in the instrumentation of simulation codes. A close cooperation with the High Level Support Team (HLST) takes place, in particular in the framework of the GYNVIZ project. Moreover, the visualization staff at the RZG has recently supported a number of particularly challenging visualization projects directly. In these cases, either the complexity or size of the simulation data, or specific visualization goals required expert knowledge of existing visualization methods or even the development of tailored software solutions. Examples include projects from plasma physics (IPP), materials research (FHI) and astrophysics (MPA, MPE).

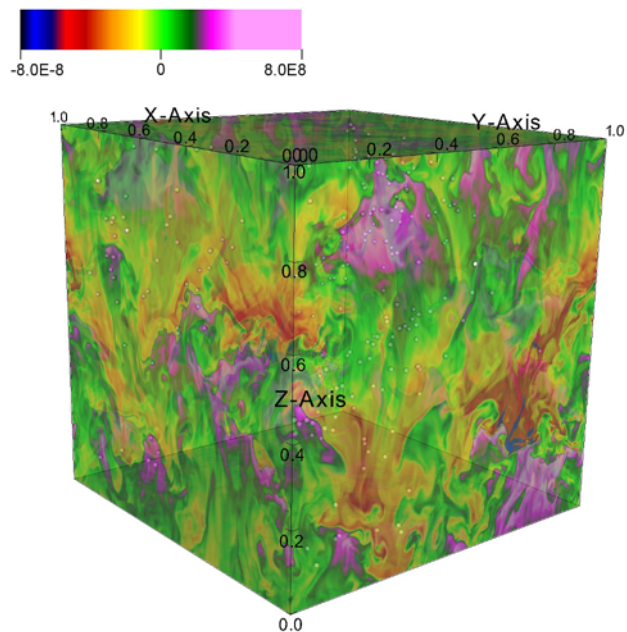


Figure 1: Visualization of temperature fluctuations and Lagrangian tracer particles in a direct numerical simulation of turbulent magneto-hydrodynamic Boussinesq convection. Simulation: J. Pratt, W.-C. Müller (IPP), Visualization: J. Pratt, K. Reuter (RZG).

As a recent example for a successful collaboration between visualization experts and computational plasma physicists we cite visualizations of fluctuations and Lagrangian tracer particles in simulations of turbulent magneto-hydrodynamic (MHD) Boussinesq convection. The simulations are

performed by J. Pratt and W.-C. Müller (IPP) to study magnetic field generation (dynamo action) in the solar convection zone. An amplitude-dependent colour coding of the fluctuations allows the identification of structures in the turbulent fields that extend over large spatial scales. Simultaneously, massless Lagrangian test particles are shown which are advected by the turbulent flow. Following such particles individually or in pairs provides insight into the statistics of turbulent transport mechanisms, field-line stretching, and large-scale magnetic structure formation. Figure 1 shows a snapshot of the temporal evolution of temperature fluctuations and tracer particles from an MHD convection simulation.

### Projects in Collaboration

#### The Munich-ATLAS-Tier2 Project

As part of an active research program the MPI for Physics (MPP) participates in the ATLAS experiment, which is located at the Large Hadron Collider (LHC) in CERN Geneva. To overcome the computing challenges associated with enabling thousands of users to access and analyse the petabytes of data which will be produced by ATLAS the collaboration has turned to grid computing. A multi-tiered computing grid has been formed and extensively tested during the last decade as the LHC experiments have prepared for their long-awaited data taking phase. In Munich a Tier2 centre is supported by collaboration from RZG/MPP and the LRZ/LMU. One half of this federated centre is hosted at the RZG with the other half being hosted at the LRZ. During the past 12 months the Tier-2 centre has been continuously used for the production of simulated data and, more importantly, the analysis of real data from the ATLAS experiment. In addition to the role of a standard Tier2 the Munich Tier2 acts as one of three centres which will perform a special role as a Muon Calibration centre. This activity requires an extremely quick cycle of data import from CERN, analysis of the data and the subsequent return of important calibration data to CERN. New hardware purchased in 2010 more than doubles the compute and storage capacity of the Tier-2 centre. During 2011 the Tier-2 system will be re-optimised to incorporate the new hardware and fit to the changing needs of the ATLAS community. Additionally, upgrades of several core services are expected to follow the evolution of the gLite middleware.

#### The DEISA2 Project

The DEISA Consortium has continued to support and further develop the *Distributed European Infrastructure for Supercomputing Applications* as an EU FP7 project from 2008 to 2011, coordinated by RZG/IPP. Activities and services relevant for Applications Enabling, Operation, and Technologies have been continued and further enhanced.

The very successful DEISA Extreme Computing Initiative (DECI) with annual calls for Europe's most challenging computational science projects has also been continued. In meantime, scientists from more than 180 universities or research institutes from 25 European countries with collaborators from four other continents have already benefitted from DECI. In addition, DEISA has started support for science communities as a whole, among them from fusion energy research, climate research, astro sciences, and life sciences. DEISA services will be continued at European level by PRACE after the end of the DEISA2 project in 2011.

#### HLST Project

The High-Level Support Team (HLST) was set up with support of the EU to ensure support for HPC applications in the European fusion community. With the help of the RZG the core team has been established at the IPP, with the other partners residing at different other EFDA sites. The team consists of HPC experts with experiences in scientific computing, having especially a deep knowledge in the fields of numerical algorithms and visualization. The scope of tasks reaches from technical advice, training, all sorts of optimization and visualization of large data sets to the challenging task of increasing the scalability of existing parallel applications.

#### Bioinformatics/Computational Biology

Initiated several years ago in the context of the MIGenAS project, the RZG maintains a dedicated hardware and software infrastructure for computational biology applications and offers high-level application support for all kinds of bioinformatics projects of the Max Planck Society. Among others, a number of prominent genome projects were completed with the help of this infrastructure in the course of 2010. Specifically, RZG staff participated in the bioinformatics analysis of two economically and biologically particularly relevant microbial genomes, namely *Halomonas elongata* and *Haloferax volcanii*.

#### MPGAAI – An MPG-wide Authentication-and-authorization Infrastructure

MPGAAI is a joint project of MPDL, GWDG and RZG to establish an MPG-wide corporate and federal infrastructure for authentication (“who am I”) and authorization (“what am I entitled to”) on the Web. Via this authentication-and-authorization infrastructure (AAI), based on the Shibboleth Framework (<http://shibboleth.internet2.edu/about.html>) and SAML protocol (<http://saml.xml.org/about-saml>), scientists and staff of the MPG can login directly with their local user accounts at their home institute (Identity Provider), and in doing so obtain access (Single Sign On) to online resources of all Service Providers within the so-called AAI Federation.

Thus, users can have easy and secure access to participating publisher's protected online contents like articles, publications, databases and other services, also and especially from outside the home institute's intranet, when at home or away on business. Pilot service with several MPIs has started.

### Videoconferencing (VC)

The VC infrastructure based on the Open Source GnuGK gatekeeper with integrated phonebook application worked reliable without downtime (99.99 % availability) in 2010. The gatekeeper was migrated to new hardware with higher performance to manage the increasing load of HD videoconferencing connections. To meet future requirements H460 and URI support were enabled. Currently 466 VC systems are registered at the gatekeeper. After an update, the Codian MCUs of the DFN service manage connections with Full-HD resolution (1080p). The booking system supported by the VC group worked also with highest availability. Until today 44 000+ bookings were executed. Solutions for a protocol-independent, but commercial videoconferencing infrastructure were successfully evaluated.

### Data Network

The data network is based on the concept of a "collapsed backbone" consisting of high-level switches at a few central locations which directly connect to all endpoints via links based on copper or fibre – eliminating the need of aggregating and limiting switches at workgroup or story level. This structure greatly enhances overall network performance, for most of the connections between the backbone routers/switches are at a speed of 1 Gigabit/s (Gigabit Ethernet technology) and a few have even been raised to 10 Gigabit/s on demand, numbers increasing. With this structure security and integrity of data have also been improved because eavesdropping is almost impossible.

Due to various reasons within the compute and data centre the concept of fat trees with high flexibility and performance, but very expensive routers/switches will probably be ruled out by small standard-based switches which are clustered by specific software to form a "virtual chassis". To adopt this rather innovative technique, all new network devices have to be checked against this functionality.

For logical security based on the functionality of the internet protocol suite TCP/IP a packet filter firewall combined with stateful inspection at the access point to the internet (a Cisco 6509 router with hardware-based firewall module) is implemented, where all the incoming/outgoing packets are checked against a set of blocking or granting rules. Additionally, all incoming electronic mail is scanned for viruses and only clean and unobjectionable data (based on known problems) will be passed to the internal network, the rest gets quarantined.

To relocate part of this procedure, a security appliance (from Ironport) was successfully tested and will be adopted in the future. Spam mail marking is also active. Based on a level of probability users can define and set filter threshold values at their PC's email client. In addition, the individual activation of "greylisting" drastically reduces the incoming of unwanted emails.

In the beginning of the year Internet connectivity via DFN was upgraded to a capacity of 4 Gbps to keep pace with the ever growing bandwidth demand. The RZG participates in the eduroam initiative via DFNRoaming. This allows users to make use of the wireless networks of other institutions also participating in eduroam. A controller-based Wireless LAN solution from Trapeze consisting of 23 access points (802.11n-devices) has been installed in the buildings D2/D2A/D2B. Various profiles for employees, guests and eduroam users implement specific security rules.

### Data Acquisition and Data Bases for Plasma Fusion Experiments

The XDV group at the RZG is responsible for the development of the data acquisition and data storage system of the W7-X experiment in Greifswald. These components, together with the control components developed by the control group of W7-X were successfully tested as a complete integrated system on the smaller machine WEGA. Following these tests the opportunity was taken to review all major components of the system internally. The review based on the results of the tests showed where minor corrections of the component structures are necessary and where some improvements must be developed. The next step will be the installation of the components needed for the operation of W7-X in the near future.

### Scientific Staff

A. Altbauer, V. Bludov, G. Bronold, T. Dannert, C. della Fratte, K. Desinger, R. Dohmen, M. Egger, R. Eisert\*, C. Falls-Rodriguez, S. Groß\*, K. Gross, C. Guggenberger, A. Hackl, C. Hanke, S. Heinzl, F. Hinterland, J. Kennedy, R. Klatt\*, M. Kölbl, G. Kühner\*, H. Lederer, K. Lehnberger, A. Marek, K. Näckel\*, W. Nagel, M. Panea-Doblado, F. Paulus, A. Porter-Sborowski, R. Preuss, M. Rampp, J. Reetz, H. Reuter, K. Reuter, K. Ritter, S. Sagawe\*, A. Schmidt, A. Schott, H. Schürmann\*, J. Schuster, U. Schwenn, S. Valet\*, S. Wangnett, I. Weidl, K. Zilker.

**Data Acquisition Group:** T. Bluhm\*, P. Heimann, C. Hennig\*, J. Krom\*, G. Kühner\*, H. Riemann\*, J. Maier, A. Werner\*, M. Zilker.

\* IPP Greifswald

# Energy and System Studies

Head: Dr. Pascal Mühlich (Prof. Dr. Thomas Hamacher till March 2010)

## Fusion Power Plant Models

### System Code Studies

At the beginning of this year we started to develop a systems code for 0D tokamak power plant system analysis. The objective is to assess the impact of physics and technology improvements on fusion power plants in a multi-parametric space. The systems code is composed of different modules, which operate on a central data structure. Most of the work was done in the physics module, which consists of balances for particles, power and current in the plasma.

### Dual Use in Fusion and Industry

On the way to solutions for the complex requirements of a fusion reactor, researchers are developing new manufacturing processes, constructions, materials, theories etc., to overcome this challenge. At the same time this know-how may refine products and technologies in other applications and thus deliver the industry already today a significant benefit for the high-tech sector and qualify the industrial partners for future tasks. The outline of these multiple-use scenarios and the promotion of cooperations between industry and research is the scope of a project with the TU München and the Siemens AG.

### Sustainability Analysis of Fusion

Sustainability requires a new look on any kind of material use. Either materials are abundant relative to their current use or the material cycles need to be closed by recycling technologies. This rule should be followed right from the beginning for fusion. A first analysis of this kind was performed for lithium, which is a key material for the construction of fusion blankets and which plays a central role in the fuel cycle. Problems are also expected for a number of other materials like beryllium and helium.

### Fusion Economics

Assessments on the economic prospects of nuclear fusion are usually performed on the basis of cost competitiveness; It is common to compare the expected cost of fusion power electricity to the projected cost of other technologies and conclude on the profitability of a fusion investment. While the merits of this method, especially its low complexity, are evident, there are several shortcomings: The differences of investor's decision fields are neglected; also, in absence of support schemes, intermittency penalties can negatively impact the relative profitability of alternative energy sources, and slight variations of technological and economic parameters can produce very different results. Our review of several prominent cost and technology scenarios shows that it is not possible to draw reliable conclusions from cost comparisons alone. Especially when expressed

The financial crisis has once more demonstrated the strong correlation between economic growth and energy, especially electricity demand. The restless search for new energy and material resources leads on the one hand to new opportunities like shale gas in the US, but also to catastrophes like the oil spill in the Mexican sea. New, sustainable energy sources need to be brought on-line as fast as possible, fusion being one of them.

in single values instead of ranges, cost projections must be treated with caution. Therefore we develop an improved framework for the valuation of fusion power that takes into account the important parameters and limitations of a potential investor's decision as well as the effect of fusion investments on the power system.

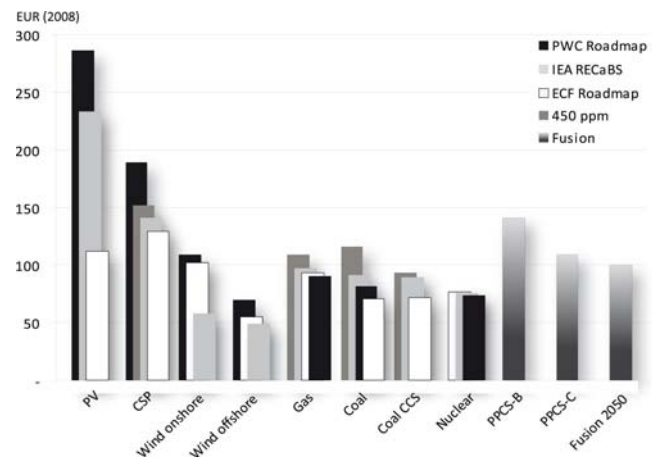


Figure 1: Levelised unit cost of electricity projections. References: ECF Roadmap 2050, PWC Roadmap 2050, IEA, RECaBS (2025), PPCS, Ward, IEA World Energy Outlook 2009.

## Global Energy Models

### EFDA-TIMES Model

The IPP participates in the development of the global energy system model EFDA-TIMES, concentrating on the evaluation of future pathways for the integration of fusion power in the electricity market of the 21<sup>st</sup> century. Recent scenario results ascertain that substantial market shares can be expected for fusion power, premising serious political efforts on climate change mitigation. Furthermore, a strong interdependence to the nuclear fission sector was figured out. Consequently, the current work focuses on an enhanced model of the nuclear fuel cycle and extended climate equations to advance the model's scope and significance.

### European Supergrid

The integration of variable renewable energies (VRE), such as wind and solar PV energy challenges the energy system. We analyse the medium and long term implications of VRE integration in Europe, with a regionally resolved energy system model based on linear optimisation. Special focus lies on the role of transmission grid extensions – i.e. building a “supergrid” in Europe. We find that VRE strongly influence the price dynamics at the electricity spot markets. While today, electricity prices



are demand driven, they may in near future be driven by the VRE supply, as due to increased investments in wind and solar power, the VRE contribution may reach total demand in several hours. This oversupply drives electricity prices. These stochastic price dynamics imposed by VRE contribution can partially be alleviated through extensions of the interregional transmission grid capacities. In the long term, major structural changes of the European power supply system are needed to integrate high shares of VRE. Grid extensions facilitate VRE integration: they lower the impacts of VRE to the power system and the total system costs. We quantify necessary grid extensions for varying VRE shares and mixes between wind and solar energy. The costs for grid extensions remain below 20 % of the investments in the VRE capacities themselves.

## Energy and Cities

### PACT and Timebudget-microsimulation

The PACT (Pathways for Carbon Transition) project is now already in the second half of its duration. The project is under the leadership of ENERDATA. The aim of the project is to show pathways of society in the long run (2050 and beyond) and its implications especially for the energy demand. The mid-term reports are meanwhile available. One of the key factors is how time is spent in daily life. To improve the understanding of this aspect and the resulting demand of energy, a micro simulation linked with a geographic information system is currently built up at city level.

### Greifswald

In cooperation with three partners the working group developed an integrated climate protection concept for the city of Greifswald, funded by a program of the Federal Ministry for Environment. The concept consists of five parts: a CO<sub>2</sub>-inventory, CO<sub>2</sub>-saving measures for the transport sector and for energy supply and demand, civic participation in transport sector and



Figure 2: GIS based building database for the city of Greifswald and power supply networks for Gas and district heating-buildings are coloured in green for less energy demand to red for high energy demand.

energy usage. The main results are two scenarios for saving CO<sub>2</sub>. A first scenario shows how to reach a self-imposed goal reducing the CO<sub>2</sub> emissions of 2005 by at least 14 % until 2020. A second scenario in the climate protection concept even shows the opportunity to achieve a 24 % reduction. The working group was responsible for the CO<sub>2</sub>-inventory, analysed the energy system and developed a CO<sub>2</sub>-saving action plan in the energy sector. A linear optimisation model of the energy system and a GIS-based building database were the main working instruments. On 27<sup>th</sup> September 2010, the city council of Greifswald passed the concept. A first measure of the concept, a local district heating act, was established only a few weeks later.

### Salzburg

The project was finished in October 2010 and provided reliable results for the energy infrastructure in Salzburg. The first challenge was to set up a good physical description of the building stock. Working on single objects, the energy models can be set up in a high geographical resolution. The localisation of the heat demand dependent on refurbishment and energy prices was therefore possible. On that base, optimal supply structures were analysed. Furthermore, the influence of specific climate on the city's energy system structure is considered.

### Oldenburg

The project "energy efficient city of Oldenburg", concerning all energy demand sectors was finished and the suggested decrease of CO<sub>2</sub>-emissions of 40 % until 2020 based on 1990 was decided by the city council. In a second project, a geo-referenced building database containing the whole city area and characteristic information like construction date, size, usage and inhabitants of every building was completed. With this database heat demand and cost-effectiveness of refurbishment measurements could be calculated depending on expected heat price development.

### St. Roman

The subject of this project is to develop methods which enable an understanding of drivers, quantities and qualities of transport in rural areas. Spatial methods of data processing and visualization using geographic information systems (GIS) are the centre stage of the project. Mobility images and indicators are developed and contribute to a better understanding of the transport system. Furthermore, first approaches for the integration of mobility into the energy system modelling are aimed for. The project was financially supported by the Friedrich Schiedel Foundation for Energy Technology.

## Scientific Staff

M. Bartelt, P. Böhme, F. Botzenhart, S. Braun, M. Busch, T. Eder, T. Hamacher, T. Hartmann, N. Heitmann, P. Henne-mann, J. Herrmann, D. Köther, P. Kurz, C. Linder, P. Mühlich, G. Pitl, K. Schaber, I. Schardinger, M. Sommerer.

# Electron Spectroscopy

Head: Dr. Uwe Hergenhahn

## Electron Spectroscopy Using Synchrotron Radiation

Arguably electron spectroscopy is the most powerful method for studying the electronic structure of materials. In order to carry out such studies with a defined, intense and tuneable excitation source the group uses synchrotron radiation from the storage ring BESSY (Berlin), and, for experiments on ultra-dilute targets, the Free Electron Laser FLASH (Hamburg). Topics covered in 2010 were the investigation of excited state dynamics by electron spectroscopy and experiments on ionization of a free, fast moving ion beam. For the former project, a major upgrade of our experimental apparatus was undertaken in 2009, which has led to a series of interesting results in the last twelve months. Some of these are described below.

Electronically excited states in weakly bonded aggregates, e.g. water, can decay in a number of fundamentally different ways: Fluorescence and dissociation are well known, and more involved phenomena such as transitions to other electronic states via conical intersections have been intensively studied in the last two decades. In 2003, the electron spectroscopy group first demonstrated experimentally the importance of another decay mechanism, namely, a low energy autoionization process, which involves a concerted transition at two, or even three adjacent sites in the aggregate. The existence of this process had been predicted several years before the experiment by the theory group of L. S. Cederbaum (Heidelberg), who termed it Intermolecular Coulombic Decay (ICD).

## Autoionization: Charge Transfer vs. Energy Transfer

Intermolecular Coulombic Decay has since been found in a number of systems, both by the IPP group and by several other teams. Examples are clusters of Ne and, more recently, water clusters (see Annual Report 2008). In our ICD experiments, a vacancy in the valence charge cloud of a free cluster is produced by photoionization, and the filling of this vacancy is monitored by detection of a low kinetic energy electron, which is liberated by the excess energy. The effect is thought to occur generally in weakly bonded systems, and for any excitation source with sufficiently high energy transfer. An apparatus dedicated to the flexible production of cluster beams of various materials, and to the efficient detection of their photoelectron spectra, was commissioned by the electron spectroscopy group in 2009. For studies of ICD, the coincident detection of the primary photoelectron, and of the low kinetic energy electron produced by autoionization, is crucial in order to reliably show the signature of the process. Towards this end, we now use electron spectrometers additionally equipped with magnetic guiding fields ('magnetic bottle' spectrometer).

The electron spectroscopy group at IPP is internationally known for its studies of excited state relaxation in free nanoparticles. Further, the group plays a leading role in the development of electron co-incidence spectroscopy, which is of possible future technological relevance. Highlight of its research in 2010 was the spectroscopic proof of ultra-fast charge transfer processes in mixed rare gas clusters.

As the spectrometer detects electrons in a large interval of kinetic energies with almost  $4\pi$  sR solid angle, the electron pairs can be easily distinguished from any background processes, e.g. from inelastic electron scattering. Examples of ICD spectra recorded by a magnetic bottle spectrometer have been shown in the Annual Reports 2008 and 2009.

In Intermolecular Coulombic Decay, a vacancy in the valence shell at a site "A" is filled by an even less strongly bound electron, and the energy released in this transition is transferred to a neighbouring site "B". There, a low kinetic energy electron is ejected by the excess energy. Electron correlation is responsible for this process, which can take place in some tens of femtoseconds. In principle, a similar process can occur involving electron transfer instead of energy transfer between the two participating sites A and B, i.e. a vacancy is created at site A, then filled by electron transfer from site B, and another electron is ejected by the excess energy also at site B, or a third site B'. Indeed, the theoretical prediction of these processes is almost as old as that for ICD, and such transitions were termed 'Electron Transfer Mediated Decay' (ETMD).

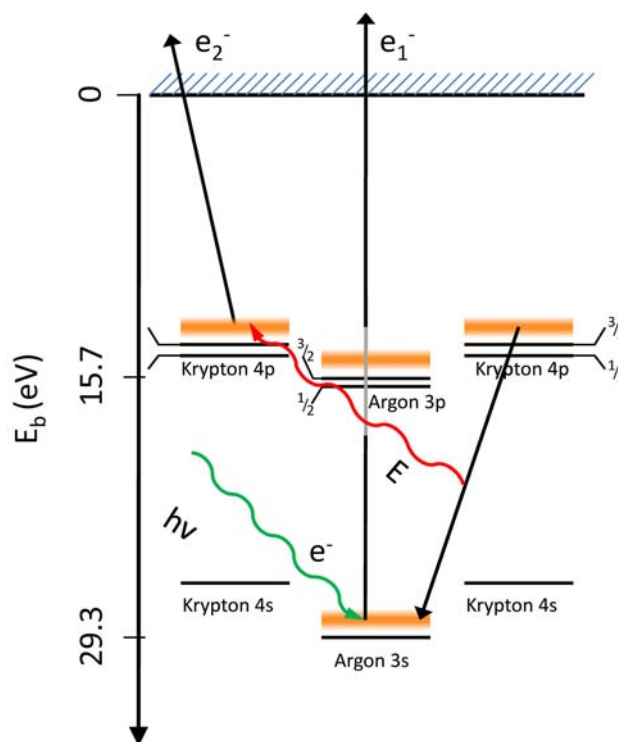


Figure 1: Scheme of a non-local autoionization process mediated by charge transfer, ETMD (3), in a Kr-Ar-Kr cluster. The first experimental demonstration of these processes was made this year by the IPP electron spectroscopy group (see text for details).

As we are considering autoionization processes in weakly bonded clusters, the dependence of the decay rates on bond length  $R$  is critical. For ICD, an algebraic dependence by an  $R^{-6}$  power law was shown. In ETMD, however, an electron has to be transferred between the two participating sites. An exponential dependence on  $R$  would therefore be expected. As a consequence, ETMD has never been observed in competition with ICD. In mixed systems however, cases exist where the energy levels are arranged such that only ETMD, but not ICD is energetically viable. Mixed clusters of Ar and Kr represent one such system. Here, a vacancy in the Ar 3s shell created by photoionization can relax by autoionization, but only into a state where two outer valence vacancies are located at two different Kr atoms (figure 1). The decay to any state involving Ar vacancies is ruled out, as these states would be too high in energy.

We have performed an experiment, in which the ETMD process sketched in figure 1 has been shown in larger, mixed Ar-Kr systems. Generally, noble gas clusters can be produced by expansion of the gas through a small, conical nozzle under a high pressure into vacuum. Clusters form by three-body collisions and subsequent aggregation in the nozzle. Under suitable conditions, expansion of a gas mixture, so-called co-expansion, leads to formation of mixed clusters. For Ar-Kr mixtures, these consist of a Kr core, which is covered by one or a few outer layers of Ar. The electron-electron coincidence spectrum from Ar-Kr mixed clusters after photoionization with a photon energy of 32 eV is shown in figure 2. At this photon energy, the majority of photoionization events lead to emission of only one outer valence electron, from the Kr 4p or Ar 3p shell. In figure 2 this part of the spectrum does not show up, as we consider only the detected *electron pairs*. Electron Transfer Mediated Decay is one of the processes, which contribute to electron pair emission. The Figure shows a clear increase in the number of secondary electrons recorded when the energy of the primary electron corresponds to that of Ar 3s photoemission. We attribute this to ETMD (Förstel et al, Phys. Rev. Lett. **106**, 033402 (2011), which so far has only been predicted theoretically. In a control experiment on pure Ar clusters, no emission of secondary electrons related to 3s photoionization has been observed. Charge transfer processes in chemistry conventionally are thought to arise when fluctuations in the nuclear coordinates make Franck-Condon like transitions between two different configurations possible, or when tunneling, called ‘hopping’ in this context, occurs. ETMD is a charge transfer process produced solely by electron correlation, and its discovery may lead to a change in paradigm.

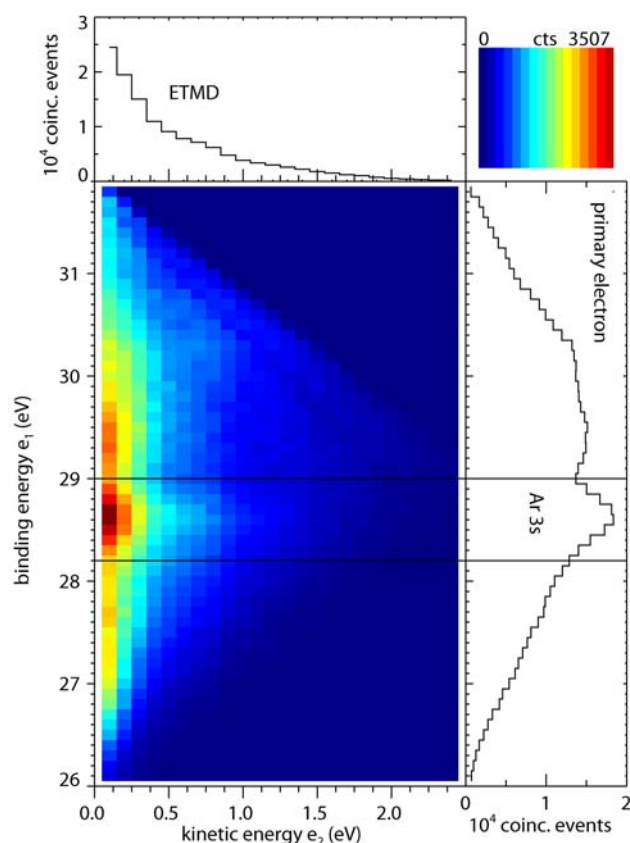


Figure 2: Color-coded map showing the intensity of electron pairs vs. binding energy of the primary electron  $e_1$  and vs. kinetic energy of the secondary electron  $e_2$  (central panel). The region between the two bars corresponds to primary photoelectrons from the Ar 3s shell. The energy spectrum of the primary electrons can be obtained by summation of the intensity along the  $e_2$  axis. It is plotted in the right hand panel, where the 3s photoline from Ar clusters is observed. An increased yield of electron pairs with a 3s primary electron, and a secondary electron of very low kinetic energy, can be seen in the central panel. The energy spectrum of the secondary electron in the region marked by the two horizontal bars can be obtained by summation of the intensity along the  $e_1$  axis, and is plotted in the right hand panel.

### Other Studies

Several other projects have been carried out successfully, but cannot be covered in detail here. Briefly, for water clusters we have investigated the dependence of the ICD energy spectrum on cluster size. First information on the interplay of ICD with the nuclear dynamics in larger clusters was gathered by a comparison of water to deuterated water clusters. Non-local autoionization (ICD and ETMD) was also shown in two other types of mixed noble gas clusters, ArXe and NeKr. Photoionization of hydrogen still continues to be a benchmark for theory. Surprisingly, this photoelectron spectrum has never been recorded with vibrational resolution over an extended range of energies. We have measured the pertaining spectra using our magnetic bottle set-up. Finally, as a test for our FEL experiments we have qualified our spectrometer by recording photoelectrons from a negatively charged ion beam using an optical laser for excitation.

### Scientific Staff

T. Arion, M. Förstel, M. Mucke, H.-P. Rust, A. M. Bradshaw, U. Hergenhahn.



# Astrophysics and Laboratory Plasma Studies (ALPS)

Heads: Prof. Dr. Günther Hasinger, Dr. Mara Salvato

## Laboratory Experiments

During experiments at the WEGA stellarator in Greifswald, high energy emission was originally detected outside the torus by X-Ray dosimeters. The quantity of this emission was significant during a) OXB-mode conversion experiments with the 28 GHz ECRH and b) lower hybrid heating scenarios with an additional non-resonant 2.45 GHz heating system. Using the Silicon Drift Diode (SDD) sensors, which we originally had tested on ASDEX Upgrade (provided by the HLL and the PNSensor and PNDetector companies), we have been able to study and quantify this emission in detail. Two detectors were used: first a 450  $\mu\text{m}$  thick SDD with Al-coated entrance window behind an 11  $\mu\text{m}$  beryllium filter suitable for the detection of soft X-Rays (0.8 keV to 30 keV) placed inside the WEGA vacuum chamber. The spectrum obtained with this detector while applying OXB-mode ECRH (see figure 1, top) showed a continuum together with line emission from Ar, Cr, Fe, Cl and S.

The “Astrophysics and Laboratory Plasma Studies” (ALPS) was established in November 2009. Half of the group is currently testing X-ray detectors conventionally used in X-ray space astronomy while the other half is occupied in studying the properties of galaxies hosting an Active Galactic Nuclei (AGN), one of the most powerful sources of X-ray emission in the Universe. Our work is done in close collaboration with the HLL and MPE.

Assuming a thermal Bremsstrahlung continuum, an electron temperature of 10.8 keV could be derived. However, a simple power law is an even better description of the spectrum. Since the bulk temperature of the electrons in the WEGA is only of the order of a few 10 eV, it is immediately clear that this high-energy emission has to originate from a supra-

thermal population of electrons. The emission lines are produced by impurities originated from the steel parts inside the vessel (Cr, Fe), from rest gas of other discharges (Ar) and possibly the cleansing of the vessel (Cl, S). For the detection of Hard X-Rays (20 keV to few 100 keV) a second sensor consisting of a cylindrical CsI(Tl) scintillator crystal (5 mm height, 5 mm diameter) coupled to a Silicon Drift Diode was used outside the WEGA vacuum vessel. During lower hybrid heating scenarios in helium plasma discharges an emission of up to several 100 keV was detected (see figure 1, bottom). The spectral shape of this emission could not be determined in more detail due to the large soft X-ray absorption of the setup. However, more tests with an advanced imaging hard X-ray detector inside the vessel are planned for the future. In addition, we are currently planning a set of experiments using the new detector for particle induced X-ray (PIXE) and gamma-ray (PIGE) analysis at the 3MeV tandem accelerator in Garching.

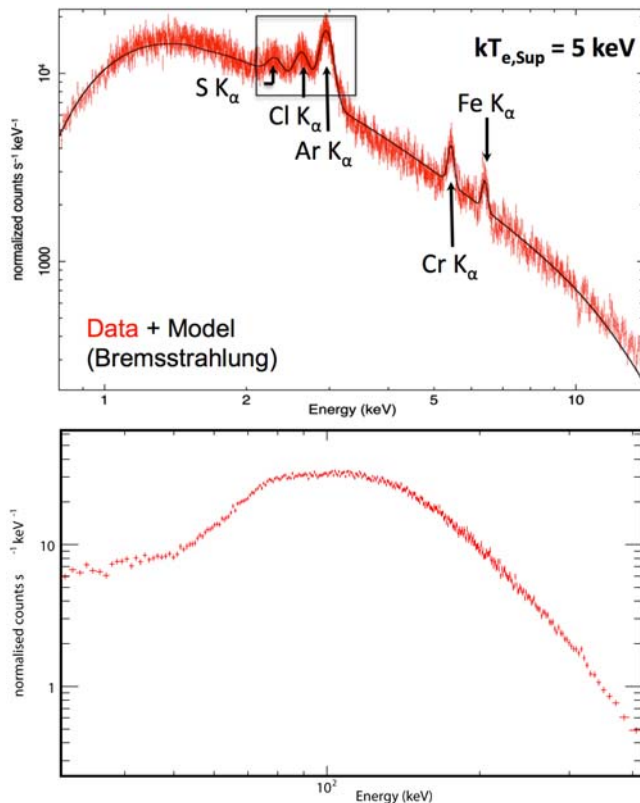


Figure 1: Confirmation of the super-thermal electrons during the LH heating (#35609) at WEGA, Greifswald, observed with new X-ray SDD PHA system developed at ASDEX Upgrade. The emission lines produced by the impurities are also indicated (top). Hard X-ray spectrum obtained at WEGA with the new SDD detector (bottom).

## Astrophysics

In the recent years it has become obvious that AGN are a key, possibly recursive, phase of the evolution of almost every galaxy. AGN trace the growth of supermassive black holes in the nuclei and provide important energetic feedback to their hosts and the intergalactic medium. Thus, the complete census of AGN and the detailed characterisation of their properties is of paramount importance to improve our understanding of the evolution of the Universe. In particular, the actual distance (redshift) of the AGN is extremely important and at the same time very time consuming to be directly obtained at the telescope via spectroscopy, as the majority of the galaxies hosting an AGN is very distant and thus faint. Our group is involved in improving the determination of the distance using a secondary method called “Photometric Redshift” fitting precise multiband photometry to the spectral energy distribution (SED) of known sources hosting AGN. We successfully managed to obtain photometric redshifts with a precision competitive with very low resolution spectroscopy (see figure 2). This was obtained also by taking into account the AGN variability and carefully selecting the templates used for the comparison.



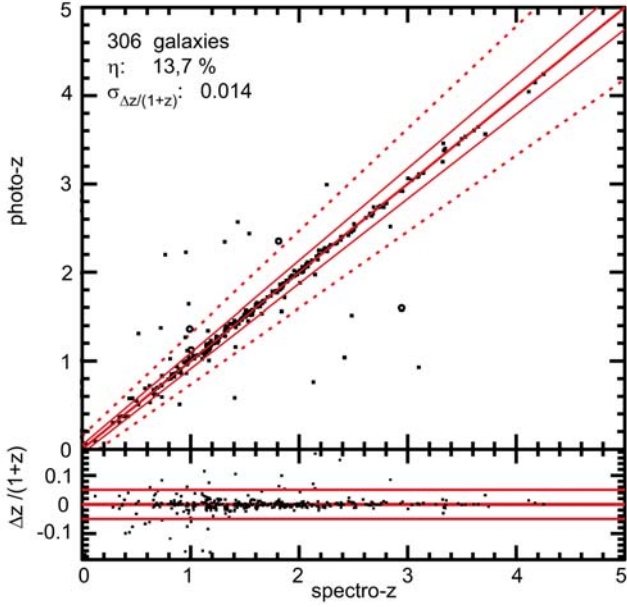


Figure 2: Comparison between photometric redshift and actual (spectroscopic) redshift for a sample of AGN. The number of sources, the fraction of outliers ( $\eta$ ) and the accuracy ( $\sigma$ ) are indicated. From Salvato et al. (2011), submitted.

The method is at the moment applied to the CHANDRA-COSMOS and Lockman Hole surveys, which are among the best-studied sky fields at any wavelength. When an accurate redshift is known, it is possible to use the spatial clustering of AGN to put constraints on how the AGN are triggered and fuelled and to understand how galaxies and AGN co-evolve.

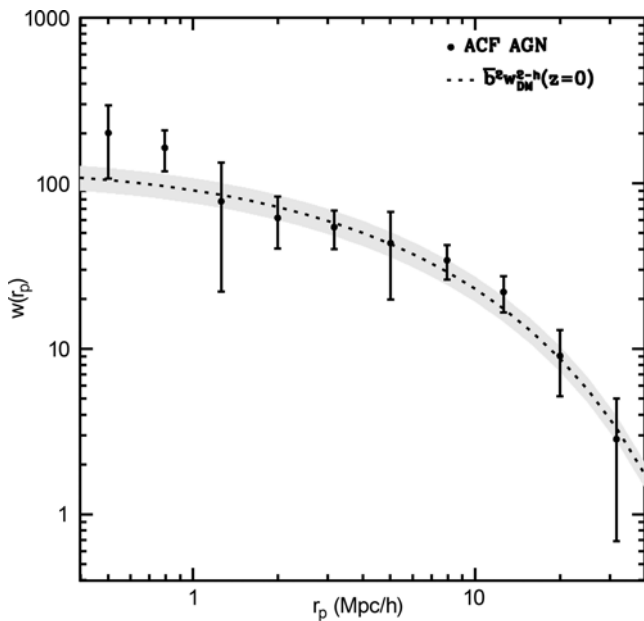


Figure 3: Projected AGN correlation function  $w_p(r_p)$  (black circles) compared to the projected 2-halo term  $b_{\text{AGN}}^{-2} w_{\text{DM}}^{-2} h(r_p)$  (grey region), where  $b_{\text{AGN}}$  is the AGN bias respect to the DM distribution and is the DM 2-halo term evaluated at  $z=0$ . From Allevato et al. (2011), submitted.

The statistics commonly used to measure the clustering properties of AGN is the two-point projected correlation function (see figure 3), which relates clustering properties of AGN to typical mass of dark matter (DM) halos, in which they reside and allow various types of AGN to be placed in a cosmological context. Modeling the AGN correlation function with the 2-halo term, we studied the redshift evolution of the projected correlation function of 593 X-ray selected AGN extracted from the 0.5-2 keV X-ray mosaic of the XMM-COSMOS survey. We found evidence of a redshift evolution of the bias factor for X-ray selected AGN up to  $z < 2$  with an average mass of the DM hosting halos that remains constant over time. Another line of investigation is aimed at global, statistically significant characterisations of the physical properties of AGN hosts in the COSMOS field.

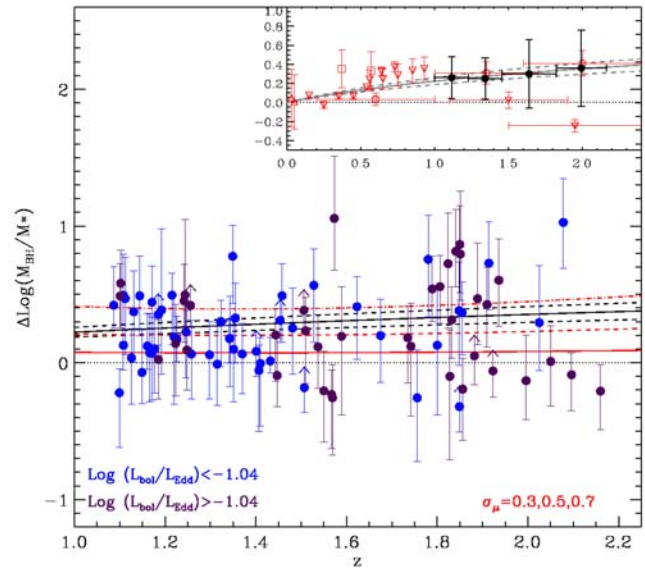


Figure 4: Redshift evolution of the offset measured for  $z$ COSMOS type 1 AGN from the local MBH- $M^*$  relation. Black lines show the best fit obtained assuming an evolution of the form  $\Delta \text{Log}(\text{MBH}/M^*)(z) = (0.68 \pm 0.12) \text{Log}(1+z)$ . Red lines show the bias due to the intrinsic scatter in the scaling relations to be expected even if they are universal. In the inset, we show a comparison of our data (black circles) with data from the literature. From Merloni et al. (2010).

For the sub-sample of broad-line AGN, for which black hole masses can be estimated through the measure of the broad lines width, we show that the local scaling relation between BH and host stellar masses must have evolved at  $1 < z < 2$ , either in normalisation or in intrinsic scatter. At the observed growth rates, the requirement that high redshift QSOs will evolve onto the locally observed scaling relations put additional constraints on the lifetimes and duty cycles of quasar activity.

#### Scientific Staff

V. Allevato, J. Belapure, S. Fotopoulou, G. Hasinger, B. Huber, A. Merloni, M. Salvato.

## University Contributions to IPP Programme



# Cooperation with Universities

Author: Dr. Udo v. Toussaint

## Teaching and Mentoring

Teaching plasma physics at various universities has a long tradition at IPP. Since fusion-relevant physics and engineering are not the most prevalent subjects in Germany's academic landscape, IPP is interested in sparking students' interest in high-energy plasma physics and other fusion-relevant fields. In 2010, 22 members of IPP taught at 9 universities or universities of applied sciences: Many members of the IPP staff are Honorary Professors, Adjunct Professors or Guest Lecturers at various universities and give lectures on theoretical and experimental plasma physics, fusion research, data analysis and materials science. The table gives an overview.

University	Members of IPP staff
University of Greifswald	Dr. Hans-Stephan Bosch Dr. Andreas Dinklage Prof. Olaf Grulke Prof. Per Helander Prof. Thomas Klinger Dr. Heinrich Laqua
Technical University of Munich	Prof. Sibylle Günter Dr. Klaus Hallatschek Prof. Thomas Hamacher Prof. Günther Hasinger
University of Munich	Dr. Jörg Stober Prof. Hartmut Zohm
University of Augsburg	Dr. Ralph Dux Prof. Ursel Fantz
University of Ulm	Dr. Emanuele Poli Dr. Frank Jenko Dr. Jeong-Ha You
Technical University of Graz	Dr. Udo v. Toussaint
University of Tübingen	Dr. Rudolf Neu
University of Bayreuth	Dr. Wolf-Christian Müller-Nutzinger Dr. Wolfgang Suttrop
University of Gent	Prof. Jean-Marie Noterdaeme

Table: IPP staff who taught courses at universities in 2010.

The teaching programme has been highly successful over the years and many students who first came into contact with plasma physics through lectures given by IPP staff have later done thesis work and even taken up a career in the fusion research. Lecturing at and cooperation with universities are supplemented by IPP's Summer University in Plasma Physics: one week of

Many important goals in plasma physics, technology and materials science have to be attained on the way to a fusion power plant. Since this process will last another generation, IPP attaches great importance to training young scientists. Close interaction with universities in teaching and research is therefore an important part of IPP's mission. Moreover, joint projects with several universities form an integral part of IPP's research programme.

lectures given by IPP staff and lecturers from partner institutes providing detailed tuition in nuclear fusion – in 2010 for the 25<sup>th</sup> time at Garching. Most of the participants were from Europe but the number of participants from abroad is steadily increasing. Some of them are taking part in the “European Doctorate in Fusion” programme. A “European Doctorate” title is awarded to

PhD students in parallel to a conventional one. This requires spending a significant part of the work on their subject at another European university or research centre. The European Doctorate in Fusion was initiated three years ago. At present institutions in Germany, Italy (EURATOM Association Consorzio RFX Padova and the University of Padua), and Portugal (EURATOM Association IST) are supporting this programme.

The international character of fusion research is also reflected in the countries of origin of graduate students at IPP: one-fifth of the postgraduates and approximately two-thirds of the postdocs are from abroad. In the year 2010 a total of 60 postgraduates were supervised, 12 of them successfully completing their theses.

## Joint Appointments, Grown and Growing Cooperation

IPP cooperates closely with some universities in the form of joint appointments. In 2010 there was a joint appointment with the Technical University of Berlin of Prof. Wolf in the field of plasma physics/stellarator optimisation.

A second W2-appointment in the field of plasma astrophysics is expected to take place in 2011.

In December 2009, IPP and the Technical University of Munich contracted to intensify cooperation: Three joint professorships were agreed on fusion-relevant research fields of plasma edge and divertor physics, plasma-wall interactions, and numerical methods in plasma physics. The appointment process is actively pursued.

Another example of very close cooperation with universities is that with Stuttgart University by virtue of its essential contributions to the development of heating systems for W7-X as well as for ITER within the Helmholtz Virtual Institute, Advanced ECRH for ITER. The development of a negative-ion source for the neutral-beam injection – selected as reference source for ITER – is being continued with Augsburg University. The collaboration, even in lecturing and practical courses, has a sound tradition.



### Networking

In addition, IPP uses specific instruments developed by the Max Planck Society, the Helmholtz Association, Deutsche Forschungsgemeinschaft (DFG), Leibniz-Gemeinschaft or the German government for more intensive networking with universities on a constitutional basis – partly in conjunction with non-university research partners and industrial partners.

Organisation of or participation in graduate schools:

- the International Max Planck Research School on Bounded Plasmas at Greifswald in cooperation with Greifswald University,
- the International Leibniz Graduate School for Gravity Waves and Turbulence in the Atmosphere and Ocean started 2008 in cooperation with Leibniz Institute of Atmospheric Physics, Kühlungsborn, Leibniz Institute for Baltic Sea Research, Warnemünde, and Rostock University.

Young investigators groups:

- Helmholtz Young Investigators Group, Theory and Ab Initio Simulation of Plasma Turbulence, headed by Dr. Frank Jenko, in cooperation with Münster University,
- European Young Investigator Award Group, Zonal Flows, headed by Dr. Klaus Hallatschek,
- Helmholtz Russia Joint Research Group, Hydrogen Behaviour in Advanced and radiation damaged materials for fusion applications, headed by Dr. Matej Mayer as Helmholtz Principle Investigator and Dr. Alexander V. Spitsyn, RSC Kurtschatov Institute.

Research partnerships:

- participation in the DFG Collaborative Research Centre Transregio 24, Fundamentals of Complex Plasmas, together with Greifswald University, Kiel University and Leibniz Institute for Plasma Science and Technology, Greifswald,
- Helmholtz Virtual Institute, Advanced ECRH for ITER, together with the University of Stuttgart and Karlsruhe Institute of Technology (merging of the former and Karlsruhe Research Centre and University of Karlsruhe).

Participation in Clusters of Excellence in the context of the German government's Excellence Initiative in cooperation with Ludwig Maximilian's University and Technical University Munich:

- Munich Centre for Advanced Photonics, together with Universität der Bundeswehr München, Max Planck Institute of Quantum Optics, Max Planck Institute for Extraterrestrial Physics, Semiconductor Laboratory and Max Planck Institute of Biochemistry as scientific partners and Siemens AG/Healthcare as industrial partner,
- Origin and Structure of the Universe, together with Max Planck Institute for Astrophysics, Max Planck Institute for

Extraterrestrial Physics, Semiconductor Laboratory and Max Planck Institute for Physics and the European Southern Observatory.

A few years after its formation IPP joined the European Fusion Development Agreement as a EURATOM Association. When the decision was made to build ITER, it became clear that training of young scientists and engineers had to be intensified. A European Fusion Education Network (FUSENET) was therefore formed in FP7. FUSENET consists of 14 EURATOM associations – one of them IPP – and 22 universities from 18 European countries. FUSENET provides education material and training opportunities in fusion science and technology covering all education levels, from secondary school through Bachelor and Master level to PhD.

# University of Augsburg Lehrstuhl für Experimentelle Plasmaphysik

Head: Prof. Dr.-Ing. Ursel Fantz (acting)

## Low Temperature Plasmas

Helicon-like discharges (rf frequency 13.56 MHz, Helmholtz coils with an axial magnetic field up to 150 mT) in hydrogen and deuterium have been established to explore their feasibility as plasma driver in ion sources for negative hydrogen ions. They could replace the inductive rf-coupling used in the IPP prototype ion source for the ITER neutral beam systems promising higher rf-power efficiency as well as higher atomic hydrogen and positive hydrogen ion densities. In contrast to classical helicon discharges, which operate in rare gases using long and thin vessels, the helicon mode must be achieved in hydrogen and deuterium using an aspect ratio close to one. Figure 1 compares the axial averaged density ratio of atoms to molecules in  $H_2$  and  $D_2$  plasmas (vessel: 10 cm diameter, 40 cm length) obtained by emission spectroscopy. Obviously, a higher dissociation is achieved in deuterium than in hydrogen and a peak at low magnetic field is obtained followed by an almost linear increase. The peak in  $D_2$  becomes even more pronounced with increasing power and is also observed in the vibrational and gas temperature as well as in the total plasma emission. In comparison to the standard ICP configuration the density ratio is typically increased by a factor of five, which demonstrates the high potential for the usage of this kind of discharge as driver in ion sources. Further investigations will follow subsequent to this diploma thesis in the framework of a PhD thesis.

A planar coupled ICP experiment at a frequency of 27.12 MHz and up to 600 W power is used for systematic investigations on hydrogen and deuterium plasmas in a pressure range of 0.5 to 20 Pa. Helium is routinely added to actively change the plasma parameters. Profiles of electron density and temperature are

The research at the University of Augsburg is concentrated on diagnostics of molecular low temperature plasmas, on investigations of plasma chemistry and on plasma surface interaction studies. For that purpose several different low pressure plasma experiments are available. Focus is laid on the development and application of diagnostic methods for negative hydrogen ion sources, which is carried out in close collaboration with the Technology Division of IPP.

obtained with a Langmuir probe system. Atomic and molecular hydrogen densities as well as rotational and vibrational temperatures are obtained from atomic and molecular hydrogen lines; the CR models for H and  $H_2$  are continuously updated. The plasma characterisation is being completed by an energy resolved mass spectrometer for measuring densities of neutrals and ions as well

as ion energies. The densities of hydrogen ion species in a hydrogen/helium mixture are compared to results from a 0-dim dissociation and ionisation model using the flexible solver Yacora. In some cases a good agreement is observed, however in other cases not. Based on such measurements, the model will be further improved and benchmarked in order to receive reliable predictions of the positive ion distribution in hydrogen ion sources. The CR model for molecular nitrogen (see Annual Report 2009) has been improved. To reflect the measured emission from the 1<sup>st</sup> positive system of nitrogen ( $B^3\Pi_g \rightarrow A^3\Sigma_u^+$ ) in argon low-pressure arc discharges a collision induced transition from the A- to the B-state had to be considered, where the inducing collision-partner can either be a nitrogen molecule or an argon atom:  $N_2(A) + M \leftrightarrow N_2(B) + M$  ( $M = N_2, Ar$ ). Using this modified CR model and experimentally determined plasma parameters the intensity of the molecular nitrogen emission can now be simulated for a wide parameter space of gas mixture (0.1 %  $N_2$  in Ar to 100 %  $N_2$ ), absolute pressure ( $10^{-1}$ – $10^2$  mbar) and discharge current (100–500 mA).

## Diagnostics for Negative Hydrogen Ion Sources

Experimental campaigns at the IPP test facilities for negative hydrogen ions (see ITER contributions) showed a high relevance of the caesium dynamics for the ion source performance. Key issues are the routine achievement of high, uniform and stable negative ion current densities accompanied by a low co-extracted electron current. Caesium is used for an effective conversion of atoms and positive hydrogen ions into negative ions at surfaces close to the extraction system. The control and monitoring of caesium dynamics is strongly supported by basic investigations in the lab.

As reported last year, a diode laser absorption system on the cesium  $D_2$  transition (852 nm) for monitoring Cs densities has been validated at EPP. The benefit of such a system is – besides its perfect suitable dynamic range – the fact that it is applicable during both plasma and vacuum operation. This system has been transferred to the BATMAN test facility and implemented as a routine on-line diagnostic method. First very interesting results have been obtained already giving an insight into the Cs dynamics.

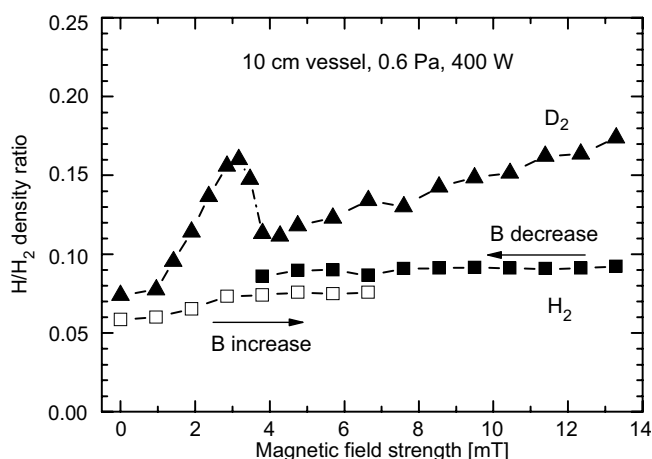


Figure 1: Atomic to molecular hydrogen density ratio in hydrogen and deuterium plasmas using a Helicon-like discharge (ICP with magnetic field).

Figure 2 shows a typical time trace of the neutral Cs density in a line-of-sight parallel to the convertor surface at a distance of 2 cm. The signal of the Cs line emission is shown for comparison (plasma only). Three phases are to be seen: (i) the vacuum phase before the plasma pulse reflects a stable neutral Cs density, (ii) the plasma phase, in which the neutral Cs density stays at the same level although more than 90 % of the Cs is singly ionised, which means that a huge amount of Cs is released from the surfaces by the plasma and (iii) the vacuum phase after the plasma pulse, which implies the recombination of the ions and the time constant for transport and sticking of Cs at the surfaces. During Cs conditioning of the source a steady increase of the Cs density is measured until a saturation level is achieved. The saturation seems to be correlated with a high source performance. In-detail studies of the Cs dynamics by laser absorption are one of the high priorities for the next experimental campaign at BATMAN.

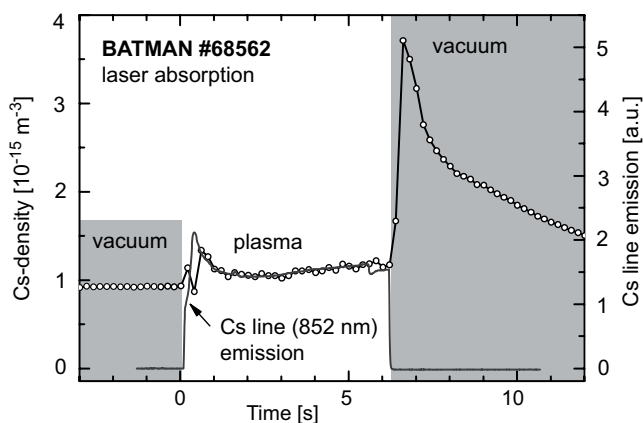


Figure 2: Temporal evolution of the neutral caesium density before, during and after a hydrogen discharge in the IPP prototype ion source (BATMAN test facility) as measured by the laser absorption spectroscopy technique.

To monitor the evaporation rate of the currently used liquid caesium ovens, a surface ionisation detector (SID) mounted directly in front of the oven nozzle (therefore called oven SID) was investigated. Showing good agreement with absorption spectroscopy and an established local SID, this oven SID gives the opportunity for a feed-back-controlled evaporation. In order to overcome the prevailing issues arising from the high reactivity of the pure caesium with impurities of the background gas in the liquid Cs ovens at IPP, Cs compound dispensers were investigated. Besides the well-known chromate dispensers new alloy dispensers have been tested showing a better stability and a reproducible evaporation.

Subsequent to the successful realisation of the laser photo-detachment diagnostic in an ECR plasma experiment, the volume process of negative ion production has been systematically investigated. In order to reduce the destruction of negative ions the hot plasma region is separated by a meshed grid from the cold part, in which the measurements take place.

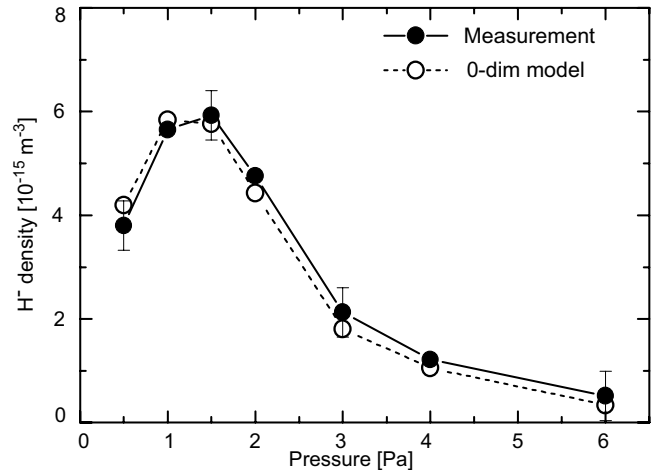


Figure 3: Negative hydrogen ion density measured by laser detachment in an ECR discharge compared to results from a 0-dim particle balance model.

As shown in figure 3 a strong pressure dependency of the  $H^-$  density is obtained; the maximum at about 1.5 Pa represents a ratio of negative ions to electrons of about 16 %. Using the general plasma parameters measured by means of a Langmuir probe and OES, a particle balance for ion production and destruction has been established. The excellent agreement with the measurements allows for an analysis of potential improvements of the volume generation process in this experiment. Further steps will be the quantitative investigation of the enhancement of negative ion production by different surfaces at relevant ion source parameters to investigate alternatives to caesium.

### Diploma and PhD Theses

- R. Gutser: Experiments and Simulations for the Dynamics of Cesium in Negative Hydrogen Ion Sources for ITER N-NBI. (PhD Thesis)
- S. Dietrich: Verifikation von optischen Diagnostikmethoden an  $H_2/D_2$ -Plasmen. (PhD Thesis)
- P. Schmidt: Verdampfung von Cäsium und dessen Einflüsse auf Austrittsarbeiten von Oberflächen und Wasserstoffplasmen zur Optimierung von negativen Ionenquellen. (Diploma Thesis)
- C. Wimmer: Laserabsorptionsspektroskopie zur Quantifizierung von Cäsium. (Diploma Thesis)
- D. Ertle: Teilchendichten in HF-angeregten Wasserstoff- und Deuteriumplasmen. (Diploma Thesis)
- B. Ruf: Cäsium- und Plasmahomogenität in großflächigen Quellen zur Erzeugung von negativen Wasserstoffionen. (Diploma Thesis)

### Scientific Staff

U. Fantz, S. Briefi, W. Böhm, D. Ertle, R. Friedl, T. Maier, P. Schmidt, F. Vogel, C. Wimmer.

# University of Bayreuth

## Lehrstuhl für Theoretische Physik V

Head: Prof. Dr. Arthur G. Peeters

### Cooperation

In June 2010 the University of Bayreuth opened a new Chair researching the physics of high temperature plasmas. The Chair is financially supported by the University, the ‘Volkswagen-Stiftung’, through a Lichtenberg Professorship for Prof. A. G. Peeters, and the IPP. Through this Chair the University and the IPP continue and strengthen their long term collaboration, in particular in the areas of nonlinear dynamics and computational physics. Both these areas are central in the research at the IPP and the close collaboration will also give input to the research conducted in Bayreuth. The dedication to the collaboration is clearly expressed through the involvement of two IPP employees, PD Dr. W. Suttrop and PD Dr. W.-C. Müller, in the teaching at the University. It is also evident from the multiple collaborative projects between the University and the IPP. In 2010 these projects resulted in six publications with shared co-authorship. Two examples, the turbulent dynamics around a magnetic island and the influence of the centrifugal force on plasma turbulence, are discussed in some detail below. Other, equally successful projects exist, like the study of electro-magnetic effects within the global plasma description, and the study of toroidal momentum transport, but are not reviewed here.

### Island Dynamics

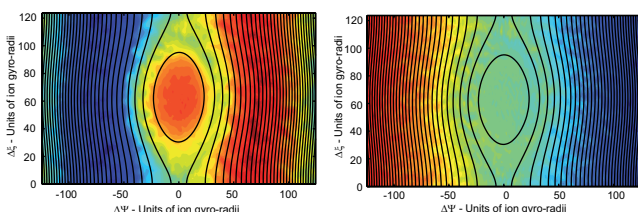


Figure 1: Electro-static potential (left) and total density (right) in the radial-biormal plane. The dashed line gives the (stationary) island.

Magnetic island formation plays an important role in fusion plasmas. One of the long outstanding questions is the interaction between small scale turbulence and meso-scale magnetic islands. Turbulence around a static magnetic island has been computed including, for the first time, the effect of kinetic electrons. The consistent physics description of the electrons allows electro-static perturbations to develop that are constant on the perturbed magnetic flux surfaces. Indeed, as shown in figure 1, large scale potential structures develop that coincide with the island structure. These structures are similar to the zonal flows found in plasmas without islands. However, the potential structures in the case with an island have a finite toroidal wave number

In the frame of the collaboration between IPP and the University of Bayreuth, research projects on nonlinear dynamics and computational physics are carried out. They include the study of turbulent dynamics around a magnetic island, of the influence of the centrifugal force on plasma turbulence, of electromagnetic effects within the global plasma description and of toroidal momentum transport.

and, consequently, lead to radial transport of particles and energy. The potential structure inside the island leads to an enhanced radial transport across the island, which can compete with the transport along the perturbed magnetic field. The potential structures show a complex behaviour, being non stationary in time.

### High Mach Number

At high Mach number the centrifugal force must be retained in the description of instabilities and turbulence. The force enhances the mirror force, modifies the trapping condition as shown in figure 2, and redistributes the density over the flux surface. At intermediate scales the enhanced trapping can result in the promotion of the trapped electron mode over the ion temperature gradient (ITG) mode. The increased fraction of slow trapped electrons enhances the convective particle pinch, leading to an increase in the steady state density gradient. Linear ITG mode results show an increased pinch of heavy trace impurities due to their strong centrifugal trapping.

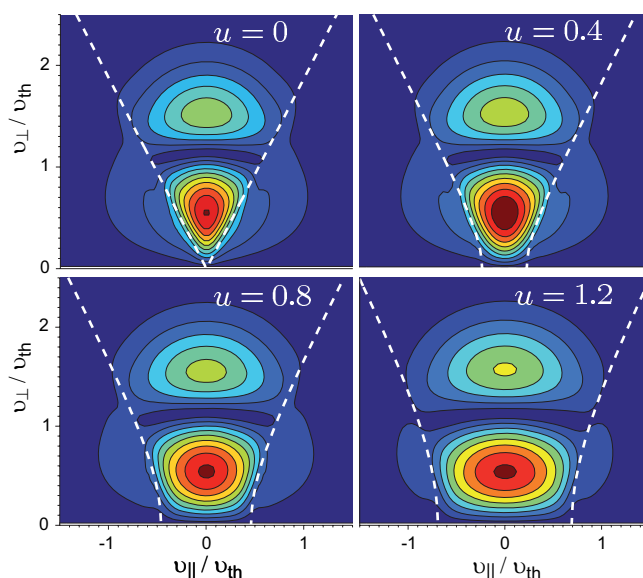


Figure 2: The perturbed electron distribution in velocity space for a trapped electron mode at the outboard midplane with increasing toroidal Mach number. The trapped-passing boundary is shown as a dashed line.

### Scientific Staff

C. Angioni, A. Bottino, F. J. Casson, T. Hein, W. A. Hornsby, W.-C. Müller, E. Poli, T. Ribeiro, B. D. Scott, M. Siccino, D. Strintzi, W. Suttrop, G. Tardini, C. Veth.





# Ernst-Moritz-Arndt University of Greifswald

## IMPRS "Bounded Plasmas"

**Head: Prof. Dr. Thomas Klinger**

The International Max-Planck-Research School "Bounded Plasmas", jointly run since 2001 by IPP, the Institute for Physics of the Ernst-Moritz-Arndt University (IfP) and since 2003 also the Institute for Low-Temperature Plasma Physics (INP), provides an international framework for education and research of highly qualified PhD students in the field of plasma physics. Currently, 24 PhD students are member of the IMPRS. As shown in figure 1 the members are generally equally distributed over IPP and the other two institutions with a total fraction of non-German students of 44 %. Research results are communicated in a weekly graduate colloquium, which also fosters collaborations across the individual PhD projects. In addition to the university curriculum advanced education in specialised plasma physics fields is provided by guest lecturers. In total 47 guest lectures have been realised, two in 2010. The excellent research conditions are also expressed in the average duration of the PhD projects of 3.2 years, which is well below the German university average.

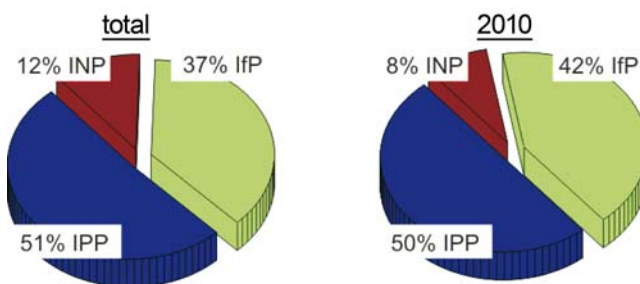


Figure 1: Distribution of PhD students over institution for the total period (left) and for the year (right).

## Particle Modelling of Plasma Thrusters

**Head: Prof. Dr. Ralf Schneider**

Within the DLR project 50RS0804 particle-in-cell models, originally developed for fusion applications, are applied to ion propulsion systems in collaboration with Prof. Dr. Ralf Schneider at the Ernst-Moritz-Arndt University in Greifswald. Ion propulsion gets more and more attractive for satellites due to the larger exit velocity compared with chemical propulsion allowing weight reductions of some 100 kg. Developments of ion propulsion systems are dominated by empirical testing of prototypes. Advances in the physics models for plasmas in contact with walls and in computing create new chances for numerical optimisation and cost reduction by a smaller number of prototypes. The interaction of the plasma with the walls and

The key element of the cooperation with the Ernst-Moritz-Arndt University Greifswald is the education within the framework of the "International Max-Planck Research School", successfully operated since 2001. Another scientific collaboration is performed in the field of plasma propulsion, where dedicated particle-in-cell simulations are performed. This is considered as an important plasma science spin-off.

its influence on the performance as well as fluctuation-induced transport processes are key elements for a better physics understanding, as also in fusion plasmas. The DLR project is realised in close collaboration with Thales Electron Devices GmbH Ulm to develop and validate a modular Particle-in-Cell (PIC) code for the simulation of so-called HEMP-Ts (high efficiency multistage plasma thrusters).

The 2d3v RZ PIC code was used to study and compare two different thruster concepts – Hall effect thruster (HET) and HEMP-T. The simulations demonstrated that in the HEMP thruster the plasma contact to the wall is limited only to small areas of the magnetic field cusps, which results in much smaller ion energy flux to the thruster channel surface as compared to HET.

The erosion yields for dielectric discharge channel walls of HET and HEMP thrusters were calculated with the binary collision code SDTrimSP. For the HET the erosion rate on level of 1 mm of sputtered material per 1000 hours was observed. For HEMP thruster the simulations have shown that there is no erosion inside the dielectric discharge channel.

The electron current in the thrusters with a strong magnetic field is defined by fluctuations driven anomalous transport. The electron transport model based on Bohm-like diffusion was developed and tested in collaboration with PPPL. The model results have shown a good agreement with measurements for PPPL 100 W cylindrical hall thruster (CHT).

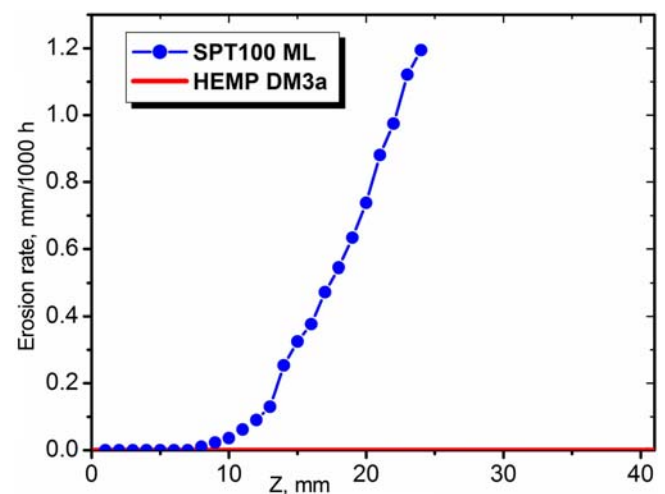


Figure 2: The erosion rate for the dielectric discharge channel wall of the HEMP DM3a thruster and for the inner wall of HET (SPT100 ML) as calculated with SDTrimSP.

## Scientific Staff

O. Kalentev, K. Matyash, A. Rai, R. Schneider, G. Stoppa, R. Warmbier.



# Technical University of Munich Lehrstuhl für Messsystem- und Sensortechnik

Head: Prof. Dr.-Ing. Dr. h.c. Alexander W. Koch

## Introduction

Speckle interferometry (SI) is a powerful tool that can be used for fast, robust and noncontact measurement of deformation, vibration, roughness or shape and derivable quantities. In each case the accuracy of measurement is depending on the measurement setup and its components, the environmental conditions while performing the measurement and the device under test itself. Most applications in the field of SI aim at measurements of a single quantity (e.g. shape): influences on the measurement result due to vibrations or material property of the surface under test are reduced or compensated by vibration-cushioned design, algorithms or a specific choice of measurement setup and components. Our approach is not to eliminate these influences but to acquire as much information about the surface under test as possible and to increase the measurement performance by applying data fusion algorithms. Hereby, both shape and surface roughness may be measured at the same time.

## Surface Shape Measurement

Both measurement of shape and surface roughness using SI depend on the used wavelengths. In case of shape measurement at least two interferograms are recorded at different wavelengths (or different angles of observation, respectively). When two wavelengths  $\lambda_1$  and  $\lambda_2$  are used, the obtained sensitivity is determined by the synthetic (or effective) wavelength  $\Lambda$ :

$$\Lambda = \frac{\lambda_1 \lambda_2}{2|\lambda_1 - \lambda_2|}$$

On the one hand,  $\Lambda$  is equal to the sensitivity of the measurement system due to separation between two adjacent fringes in the resulting phase image. On the other hand,  $\Lambda$  is linked to the height resolution in relation to the surface roughness  $\sigma$ : an increasing roughness leads to a decrease of fringe visibility. Here, a limit is given by [1]:

$$8\sigma < \Lambda$$

If  $\Lambda$  is chosen too small, a second effect appears: high frequency fringes appear in the phase image resulting in a misleading wrong interpretation of the phase map [2]. The origin of these additional fringes is the term of the synthetic wavelength:

There has been a continuous cooperation of IPP and Technische Universität München in the past. Next to thermography measurement techniques and thin film interferometry, speckle interferometry has always been a shared field of research. Speckle measurement techniques can be used to detect arc traces, deformation, erosion, surface roughness, surface structure and surface contour of the inner wall and the divertor region of experimental fusion devices.

it is only valid as long as both wavelength  $\lambda_1$  and  $\lambda_2$  are nearly equal. Figure 1 shows four different phase images, each produced by a speckle simulation tool [3] modeling a Mach-Zehnder speckle interferometer with a plane measurement surface (with a given roughness  $\sigma$ ) tilted with respect to a reference mirror.

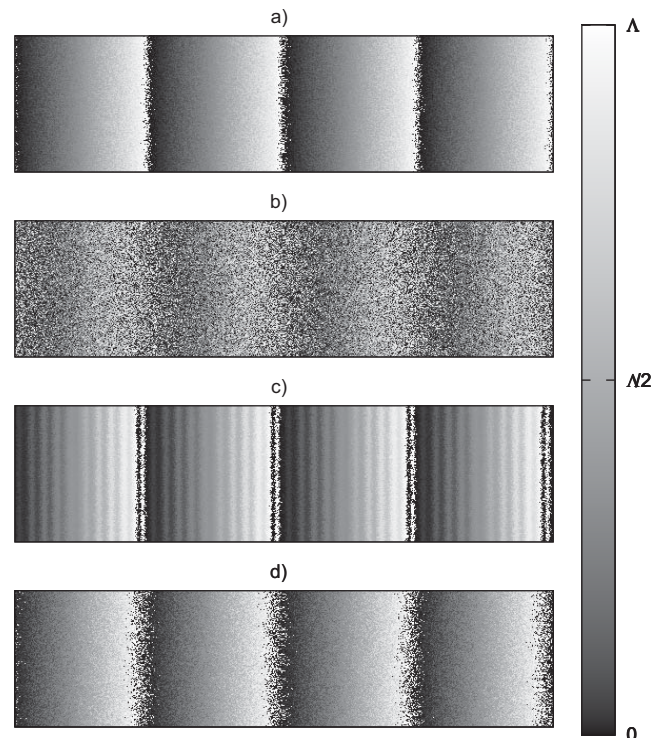


Figure 1: Results of four simulations with the following parameters: a)  $\Lambda=100 \mu\text{m}$ ,  $\sigma=1 \mu\text{m}$ , b)  $\Lambda=100 \mu\text{m}$ ,  $\sigma=10 \mu\text{m}$ , c)  $\Lambda=2.4 \mu\text{m}$ ,  $\sigma=0.01 \mu\text{m}$ , d)  $\Lambda=2.4 \mu\text{m}$ ,  $\sigma=0.05 \mu\text{m}$ . Each phase image is illustrating a plane tilted surface with respect to a reference plane. The tilt angle is chosen to show the same four fringes in each image. Due to different synthetic wavelengths and roughnesses the images have different qualities.

The simulation results are in good agreement with theory showing fringe visibility where  $8\sigma \ll \Lambda$  (figures 1a and 1c) and almost no visibility where  $8\sigma \approx \Lambda$  (figure 1b). Figure 1c shows the mentioned high frequency fringes that would lead to assume a rippled instead of a flat surface under test in this case. These additional fringes are only visible, if the surface under test is smooth. If the roughness exceeds a certain limit, fringes cannot be observed. Nevertheless, the quality of the result is still worse compared to a measurement where a small difference in wavelength was used.



## Surface Roughness Measurement

There are several techniques for roughness measurement using SI: in case of surface roughness  $\sigma < \lambda/4$  speckle contrast can be used to determine the roughness. If  $\sigma$  is above this limit the speckle contrast method cannot be applied due to fully developed speckles. A second method is angular speckle correlation (ASC). Two images of the surface under test are acquired while the angles of observation and illumination, respectively, are changed.

As mentioned above, roughness measurement using SI is also depending on the used wavelengths. A well known technique for roughness measurement using SI is the spectral speckle correlation (SSC). A camera is used to acquire at least two speckle interferograms, each using a different illumination wavelength. The correlation coefficient  $\rho$  of two acquired speckle images is an indicator for the surface roughness. A simple equation describing the relation between the correlation coefficient  $\rho$  and the surface roughness  $\sigma$  can be found if a certain measurement setup is used [4]:

$$\rho = e^{-(2\pi \cos(\alpha) \sigma \frac{1}{\lambda})}$$

The following figure includes three plots for three different sets of wavelengths.

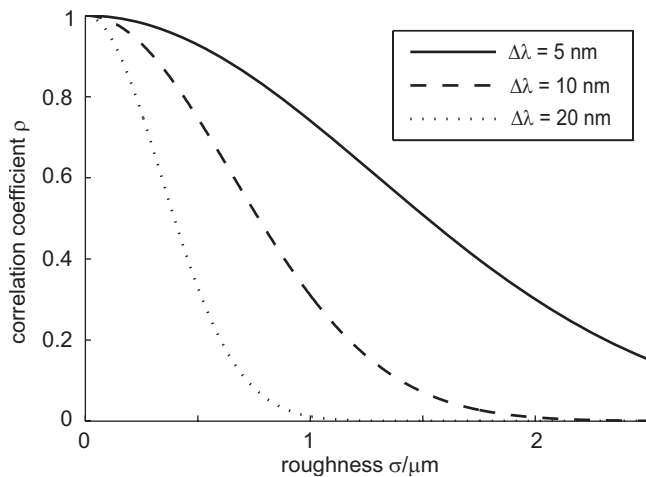


Figure 2: Relation between the correlation coefficient  $\rho$  of two acquired speckle interferograms and the surface roughness  $\sigma$ . The slope of this relation differs depending on the used set of wavelengths.

It is obvious that certain sets of wavelengths are more appropriate for specific regions of roughness: large differences in wavelength lead to a small region of sensitivity. In this case, the sensitivity itself is higher compared to a region with small differences in wavelength, where the slope of the function  $\rho(\sigma)$  is much lower.

## Data Fusion

Both measurement techniques feature a high dependency of roughness and wavelength. To our knowledge there is no system that is able to measure shape as well as surface roughness at the same time using the SI method. The performance of such a system can be increased by applying data fusion. By adding a third wavelength to the procedure, the roughness measurement can be divided into three single measurements with the wavelength sets  $(\lambda_1, \lambda_2)$ ,  $(\lambda_1, \lambda_3)$  and  $(\lambda_2, \lambda_3)$ . The obtained correlation coefficients  $\rho_{12}$ ,  $\rho_{13}$  and  $\rho_{23}$  can be merged with the following equation

$$\rho = c_{12}\rho_{12} + c_{13}\rho_{13} + c_{23}\rho_{23}$$

where the coefficients  $c_{ij}$  are calculated by scaling the derivation of  $\rho_{ij}$  with respect to  $\sigma_{ij}$ . Using this method enables an enhanced region of sensitivity, and more reliable results. Further improvement can be achieved by taking into account the speckle interferograms and phase images from the shape measurement: the fringe contrast in SI shape measurement is an indicator for surface roughness. If the object under test features a very smooth surface ( $\sigma \ll \lambda$ ) it is also possible to take into account the speckle contrast of each interferogram. The principle of data fusion is not only applicable to improve the results of roughness measurement but also the ones of shape measurement. Without any knowledge of the surface finish of the object under test, it is often not possible to discriminate measurement errors from a decline of quality in the phase image due to roughness effects. Sources for such errors can be decalibration of the setup or vibrations during measurement. Since the presented proposal improves both shape and roughness measurement using SI according simulations and measurements will be presented in near future.

## References

- [1] R. Jones, and C. Wykes: Holographic and speckle interferometry. Cambridge University Press, Cambridge, pp. 589-628 (1989).
- [2] T. Bodendorfer, and A. W. Koch: Resolution limit of Mach-Zehnder two-wavelength phase-shifting speckle interferometer. Proceedings of SPIE, p. 73870X (2010).
- [3] P. Evanschitzky: Simulationsgestützte Oberflächen-diagnostik mittels Speckle-Interferometrie. Technische Universität München, PhD Thesis (2002).
- [4] A. W. Koch, M. W. Ruprecht, O. Toedter, and G. Häusler: Optische Meßtechnik an technischen Oberflächen. Expert-Verlag (1998).

## Scientific Staff

T. Bodendorfer, M. Jakobi.

# University of Stuttgart Institut für Plasmaforschung (IPF)

Head: Prof. Dr. Ulrich Stroth

## ECRH in Over-dense Plasmas

In 2010, the microwave heating system of TJ-K was upgraded. The old magnetron operating at 2.45 GHz was replaced with a magnetron, whose power can be modulated with frequencies of  $50 \text{ Hz} \leq f_{\text{mod}} \leq 25 \text{ kHz}$ . In power modulation experiments, magnetic diagnostics revealed an energy content of 20 mJ and a plasma- $\beta$  of  $1.4\text{--}7.2 \cdot 10^{-5}$  in low-field discharges ( $B_0 = 72 \text{ mT}$ ). Furthermore, a parametric decay instability was found in the low-field discharges, where the injected wave decays into upper hybrid oscillations and ion-acoustic and lower-hybrid waves. Figure 1a shows the spectrum in the vicinity of the heating frequency  $f_0$ . A sideband with a continuous decay down to  $f_1 \approx 2.4 \text{ GHz}$  can be recognised. The corresponding low-frequency component  $f_2 = f_0 - f_1$  is found in the spectrum shown in figure 1b.

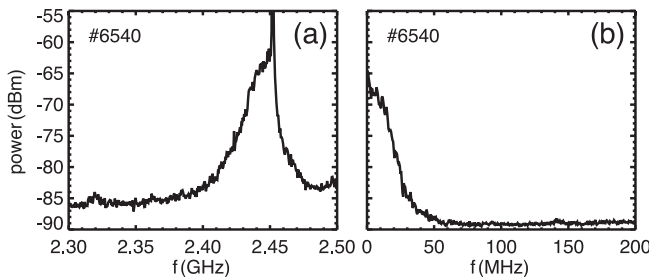


Figure 1: (a) Frequency spectrum in the vicinity of injected microwave, (b) frequency spectrum showing the corresponding low-frequency component.

The old microwave system operating at 7.9–8.4 GHz has a maximum power of 1 kW. It turned out that the achieved plasma density is too low to allow for efficient O-X-B mode conversion. Therefore, a new microwave system was bought with an increased power of 3 kW. A crucial parameter for mode conversion is the injection angle of the microwave beam with respect to the background magnetic field. In first experiment, indications for successful mode conversion at the optimum injection angle were found.

TJ-K was furthermore equipped with a new microwave heating system operating in the frequency range of 13.75–14.5 GHz. It consists of three klystrons, each capable of a maximum power output of 2.5 kW. The design process of the transmission line was completed in 2010 and its components are currently manufactured in the mechanical workshop of IPF. An optimisation and feasibility study of the O-X-B mode conversion heating scenario has been started in 2010 for the Pegasus Toroidal Experiment with the full-wave code IPF-FDMC. This study is performed in preparation of heating experiments and will be continued in 2011.

The joint program between IPF and IPP on ECRH systems for AUG, W7-X, and ITER as well as contributions to the experimental program of AUG can be found on the respective pages of this report. Here is summarised the part of the program carried out at IPF: the development of new mm-wave components, investigations of plasma waves and turbulent transport. Experiments are carried out on the torsatron TJ-K, which is operated with a magnetically confined low-temperature plasma.

## Global Turbulence and Confinement Studies

Studies from 2009 on drift-wave (DW)/zonal-flow (ZF) interactions were continued. Further analyses of data from the poloidal 128-pin Reynolds stress probe array showed an increase in the drive of kinetic ZF energy, when background flows are imposed externally by plasma biasing.

This suggests that sheared background seed flows could serve as a trigger mechanism of turbulence generated ZFs. The temporal behaviour of DW and ZF enstrophy showed that the interplay between small-scale DW turbulence and large-scale ZFs follows a predator-prey mechanism. First indications for spontaneously driven ZFs in TJ-K were observed in limited discharges.

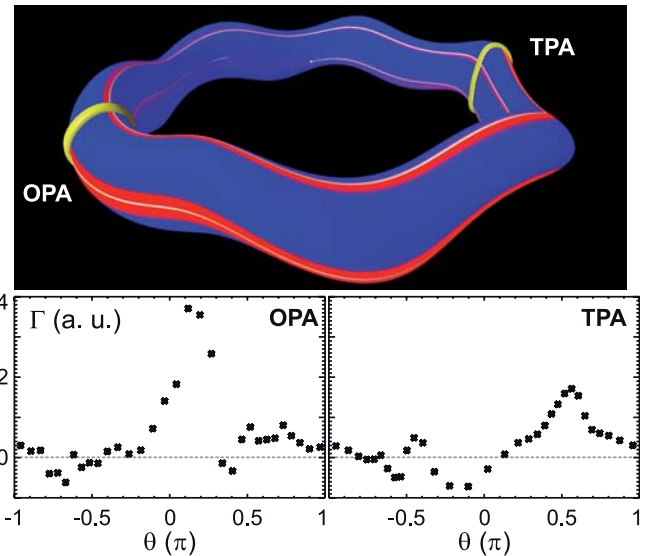


Figure 2: Top: 3D turbulent structure mapped onto a flux surface. Bottom: Turbulent transport measured with poloidal outer (OPA) and top port array (TPA).

The 3D structure of DW turbulence was studied with a pair of poloidal probe arrays set up at variable toroidal positions. Correlation analyses between these positions revealed that the structure is aligned with the field lines with a length of  $L_{\parallel} \approx 3 \text{ m}$  and a speed  $v_{\parallel} \approx 500 \text{ km/s}$  between ion-sound and Alfvén velocity. Poloidally it forms an  $m=4$  mode corresponding to  $\approx 1/4$ . The perpendicular dynamics was found to agree with first results from fast imaging. Local maxima in the turbulent transport were found in unstable regions of negative normal curvature, which in TJ-K is wound helically (figure 2, bottom). They agree with locations of maximum linear growth rates calculated in TJ-K geometry using the new magnetic configuration code.

Ion temperatures of up to 1 eV were measured by LIF and passive spectroscopy. An ion-power balance was set up. Evidence for turbulent heat transfer from electrons to the ions was found. To measure the emitted radiative power, an 8-channel bolometer was put into operation. The numerical reconstruction of radial emission profiles from the line-integrated signals is in progress.

### Simulations of a Plasma-filled Horn Antenna

The investigation of metamaterials in physics, electromagnetics and optics in the last years resulted in many improvements of different devices. In the field of microwave antennas, the phenomenon of gain increase of a shortened horn antenna by embedding a wire-medium-based slab was reported in several papers. The simulation of the wire-media with a homogenised model (ENZ slab, described with Drude dispersion) showed that it is feasible to replace the wire media with a cold plasma inside the horn. Whereas the plasma frequency of the wire media is determined with the diameter of the wires and their distances, the resonant frequency of the plasma can be controlled with the plasma density. This opens new possibilities for optimisation of the horn properties for different frequencies, due to the simultaneous tuning of the plasma density. The numerical investigation of electromagnetic wave propagation in plasma filled horn and the influence of the plasma properties on the radiated field distribution is shown in figure 3. Without plasma (top), the beam divergence is large and the phase fronts are strongly curved. With a homogenous plasma (bottom) at 95 % cut-off density, the phase fronts are nearly planar and the beam is much more narrow.

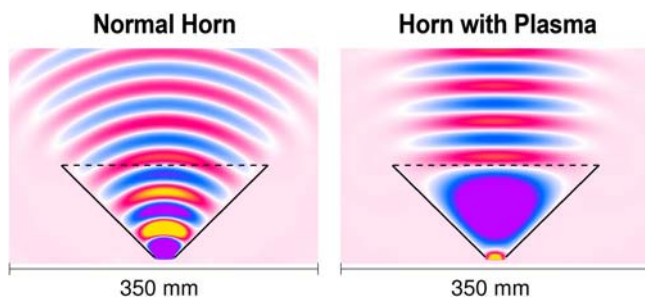


Figure 3: Electric field  $E_x$  of the horn antenna in vacuum (top) and filled with a plasma near the cut-off density of the wave (bottom).

### Reflectometry Simulations with IPF-FD3D

The finite-difference code IPF-FD3D is a fullwave code that solves Maxwell's equations and the electron equations of motion in a cold plasma. It is used for a variety of applications, including the plasma-filled horn antenna, Doppler reflectometry, and remote steering optimisation. It is continually enhanced and upgraded. In a diploma thesis, a set of new solvers for the plasma currents in the presence of a magnetic background field was implemented and tested.

The most useful algorithm was determined to be the Crank-Nicolson solver. Its advantages over the previously used symplectic solver are improved stability in the transition region from vacuum to plasma, and in the presence of strong fluctuation gradients. It is also more accurate than the symplectic, in that it does not introduce a small anisotropy in the current components. Furthermore, the computational requirements are only moderately increased over the symplectic solver.

There are ongoing benchmarking efforts within the European Reflectometry Code Consortiums (ERCC) to prove the correctness of the codes that are in use within the ERCC. Figure 4 shows the result for O mode of ERCC benchmark scenario "Case 1", where a microwave beam hits a plasma with an embedded sinusoidal density fluctuation whose phase is varied from 0 to  $2\pi$ . Comparisons between the codes used by ERCC members show some agreement and some disagreement, and it is currently being discussed how the different simulation methods used within the various codes effect these differences. Activities within the Integrated Tokamak Modeling (ITM) task force under ID WP10-ITM-EDRG-ACT6 have been continued. The European 3D reflectometer code for use on ITER is to be ported to the ITM computers. Work has commenced on integrating the CPO interface (consistent physical objects), which ensure compatibility between the diverse ITM codes written in a number of different programming languages.

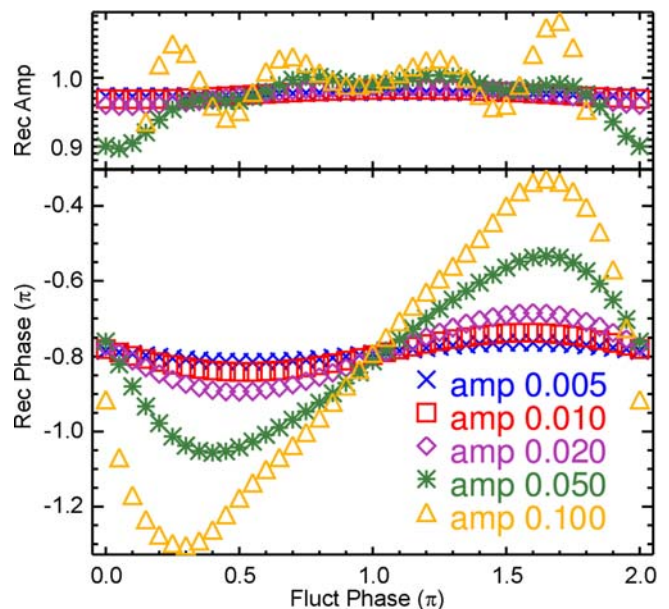


Figure 4: Amplitude and phase of the received signal as a function of the position of the fluctuation ("Case 1" ERCC benchmark scenario using IPF-FD3D).

### Scientific Staff

P. Brand, G. Birkenmeier, S. Enge, G. Fuchert, E. Holzhauer, H. Höhnle, W. Kasperek, A. Köhn, H. Kumric, C. Lechte, P. Manz, B. Nold, B. Plaum, M. Ramisch, U. Stroth.

## Publications





# Publications

## Articles, Books and Inbooks

- Adamek, J., J. Horacek, H. W. Müller, V. Rohde, C. Ionita, R. Schrittwieser, F. Mehlmann, B. Kurzan, J. Stöckel, R. Dejarnac, V. Weinzettl, J. Seidl, M. Peterka and ASDEX Upgrade Team:* Ball-pen probe measurements in L-mode and H-mode on ASDEX Upgrade. *Contributions to Plasma Physics* **50**, 854-859 (2010).
- Aho-Mantila, L., M. Wischmeier, M. I. Airila, A. V. Chankin, D. P. Coster, Ch. Fuchs, M. Groth, A. Kirschner, K. Krieger, H. W. Müller, E. Wolfrum and ASDEX Upgrade Team:* Modeling of Carbon Transport in the Outer Divertor Plasma of ASDEX Upgrade. *Contributions to Plasma Physics* **50**, 439-444 (2010).
- Akiyama, T., M. Hirsch, T. Estrada, C. Hidalgo and T. Mizuuchi:* Status of a Stellarator/Heliotron H-mode Database. *Contributions to Plasma Physics* **50**, 590-593 (2010).
- Alimov, V. K., J. Roth, W. M. Shu, D. A. Komarov, K. Isobe and T. Yamanishi:* Deuterium trapping in tungsten deposition layers formed by deuterium plasma sputtering. *Journal of Nuclear Materials* **399**, 225-230 (2010).
- Allevato, V., C. Pinto, M. Paolillo, I. Papadakis, P. Ranalli, A. Comastri and K. Iwasawa:* Probing BH mass and accretion through X-ray variability in the CDFS. *Proceedings of the International Conference on X-ray Astronomy 2009. Present Status, Multi-Wavelength Approach and Future Perspectives.* (Eds.) A. Comastri, L. Angelini, M. Cappi. *AIP Conference Proceedings* **1248**. American Institute of Physics, Melville, NY (2010) 491-492.
- Allouche, A., M. Oberkofler, M. Reinelt and Ch. Linsmeier:* Quantum Modeling of Hydrogen Retention in Beryllium Bulk and Vacancies. *Journal of Physical Chemistry C* **114**, 3588-3598 (2010).
- Anderson, J. and Eun-jin Kim:* Predicting PDF tails of flux in plasma sheath region. *Plasma Physics and Controlled Fusion* **52**, 012001 (2010).
- Anderson, J. and Eun-jin Kim:* Predicting PDF tails in systems with logarithmic non-linearity. *Physics Letters A* **374**, 1621-1624 (2010).
- Anderson, J. and P. Xanthopoulos:* Signature of a universal statistical description for drift-wave plasma turbulence. *Physics of Plasmas* **17**, 110702 (2010).
- Antar, G., G. Assass, S. Bobkov, V. Noterdaeme, E. Wolfrum, A. Herrmann, V. Rohde and ASDEX Upgrade Team:* Convective Transport Suppression in the Scrape-off Layer Using Ion Cyclotron Resonance Heating on the ASDEX Upgrade Tokamak. *Physical Review Letters* **105**, 165001 (2010).
- Aravena, M., F. Bertoldi, C. Carilli, E. Schinnerer, H. J. McCracken, M. Salvato, D. Riechers, K. Sheth, V. Smolcic, P. Capak, A. M. Koekemoer and K. M. Menten:* Environment of MAMBO Galaxies in the COSMOS Field. *The Astrophysical Journal Letters* **708**, 36-41 (2010).
- Badini, C., M. Busse, K. Kayvantash, D. Lehmhus and Ch. Linsmeier (Eds.):* Advanced Materials in Transportation. *Advanced Engineering Materials* **12**, 7. WILEY-VCH, Weinheim, 554-652 (2010).
- Barnes, M., I. G. Abel, W. Dorland, T. Görler, G. W. Hammett and F. Jenko:* Direct multiscale coupling of a transport code to gyrokinetic turbulence codes (invited). *Physics of Plasmas* **17**, 056109 (2010).
- Barradas, N. P., M. Mayer and M. Thompson:* A new ion beam analysis data format. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **268**, 1824-1828 (2010).
- Behler, K., H. Blank, A. Buhler, R. Cole, R. Drube, K. Engelhardt, H. Eixenberger, N. K. Hicks, A. Lohs, K. Lüdtke, A. Mlynec, U. Mszanowski, R. Merkel, G. Neu, G. Raupp, A. Reich, W. Suttrop, W. Treutterer, M. Zilker and ASDEX Upgrade Team:* Real-time standard diagnostic for ASDEX Upgrade. *Fusion Engineering and Design* **85**, 313-320 (2010).
- Behrisch, R.:* Plasma-Facing Materials for Fusion Devices. *Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques* **4**, 549-562 (2010).
- Belmondo, V., R. Bilato, M. Brambilla and O. Maj:* Orbit-averaged quasilinear diffusion operator in the ion-cyclotron range of frequencies. *Journal of Physics: Conference Series* **260**, 012001 (2010).
- Bhattacharya, B., A. Noriega-Crespo, B. E. Penprase, V. S. Meadows, M. Salvato, H. Aussel, D. Frayer, O. Ilbert, E. Le Floc'h, D. Looper, J. Surace, P. Capak, J. D. Giorgini, M. Granvik, C. Grillmair, A. Hagen, G. Helou, W. T. Reach, L. M. Rebull, D. B. Sanders, N. Scoville, K. Sheth and L. Yan:* Mid-infrared Photometric Analysis of Main Belt Asteroids: A Technique for Color-Color Differentiation from Background Astrophysical Sources. *The Astrophysical Journal* **720**, 114-129 (2010).
- Biancalani, A., L. Chen, F. Pegoraro and F. Zonca:* Continuous Spectrum of Shear Alfvén Waves within Magnetic Islands. *Physical Review Letters* **105**, 095002 (2010).

- Biancalani, A., L. Chen, F. Pegoraro and F. Zonca: Shear Alfvén wave continuous spectrum within magnetic islands. *Physics of Plasmas* **17**, 122106 (2010).
- Biancalani, A. and F. Pegoraro: Cherenkov emission of electron-cyclotron waves by a magnetized satellite orbiting the ionosphere. *Journal of Geophysical Research – Space Physics* **115**, A09330 (2010).
- Biancalani, A. and F. Pegoraro: Radiation of plasma waves by a conducting body moving through a magnetized plasma. *Journal of Geophysical Research* **115**, A03302 (2010).
- Bizyukov, I., A. Mutzke, R. Schneider and J. Davis: Evolution of the 2D surface structure of a silicon pitch grating under argon ion bombardment: experiment and modeling. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **268**, 2631-2638 (2010).
- Bluhm, T., S. Jacob, A. Werner, P. Heimann, C. Hennig, G. Kühner, H. Kroiss, H. Laqua, M. Lewerentz, J. Maier, H. Riemann, J. Schacht, A. Spring and M. Zilker: A service based interface for scientific data retrieval. *Fusion Engineering and Design* **85**, 579-582 (2010).
- Bobkov, V. V., F. Braun, R. Dux, A. Herrmann, L. Giannone, A. Kallenbach, A. Krivska, H. W. Müller, R. Neu, J.-M. Noterdaeme, T. Pütterich, V. Rohde, J. Schweinzer, A. Sips, I. Zammuto and ASDEX Upgrade Team: Assessment of compatibility of ICRF antenna operation with full W wall in ASDEX Upgrade. *Nuclear Fusion* **50**, 035004 (2010).
- Bolzonella, M., K. Kovac, L. Pozzetti, E. Zucca, O. Cucciati, S. J. Lilly, Y. Peng, A. Iovino, G. Zamorani, D. Vergani, L. A. M. Tasca, F. Lamareille, P. Oesch, K. Caputi, P. Kampczyk, S. Bardelli, C. Maier, U. Abbas, C. Knobel, M. Scodeggio, C. M. Carollo, T. Contini, J.-P. Kneib, O. Le Fèvre, V. Mainieri, A. Renzini, A. Bongiorno, G. Coppa, S. de la Torre, L. de Revel, P. Franzetti, B. Garilli, J.-F. Le Borgne, V. Le Brun, M. Mignoli, R. Pelló, E. Perez-Montero, E. Ricciardelli, J. D. Silverman, M. Tanaka, L. Tresse, D. Bottini, A. Cappi, P. Cassata, A. Cimatti, L. Guzzo, A. M. Koekemoer, A. Leauthaud, D. Maccagni, C. Marioni, H. J. McCracken, P. Memeo, B. Meneux, C. Porciani, R. Scaramella, H. Aussel, P. Capak, C. Halliday, O. Ilbert, J. Kartaltepe, M. Salvato, D. Sanders, C. Scarlata, N. Scoville, Y. Taniguchi and D. Thompson: Tracking the impact of environment on the galaxy stellar mass function up to  $z \sim 1$  in the 10 k zCOSMOS sample. *Astronomy & Astrophysics* **524**, A76 (2010).
- Bongiorno, A., M. Mignoli, G. Zamorani, F. Lamareille, G. Lanzuisi, T. Miyaji, M. Bolzonella, C. M. Carollo, T. Contini, J. P. Kneib, O. Le Fèvre, S. J. Lilly, V. Mainieri, A. Renzini, M. Scodeggio, S. Bardelli, M. Brusa, K. Caputi, F. Civano, G. Coppa, O. Cucciati, S. de la Torre, L. de Ravel, P. Franzetti, B. Garilli, C. Halliday, G. Hasinger, A. M. Koekemoer, A. Iovino, P. Kampczyk, C. Knobel, K. Kovac, J.-F. Le Borgne, V. Le Brun, C. Maier, A. Merloni, P. Nair, R. Pello, Y. Peng, E. Perez Montero, E. Ricciardelli, M. Salvato, J. Silverman, M. Tanaka, L. Tasca, L. Tresse, D. Vergani, E. Zucca, U. Abbas, D. Bottini, A. Cappi, P. Cassata, A. Cimatti, L. Guzzo, A. Leauthaud, D. Maccagni, C. Marinoni, H. J. McCracken, P. Memeo, B. Meneux, P. Oesch, C. Porciani, L. Pozzetti and R. Scaramella: The [O III] emission line luminosity function of optically selected type-2 AGN from zCOSMOS. *Astronomy & Astrophysics* **510**, A56 (2010).
- Bosch, H.-S., A. Dinklage, T. Klinger, R. Wolf and Wendelstein 7-X Team: Physics Programme for Initial Operation of Wendelstein 7-X. *Contributions to Plasma Physics* **50**, 687-694 (2010).
- Bosch, H.-S., V. Erckmann, R. W. T. König, F. Schauer, R. J. Stadler and A. Werner: Construction of Wendelstein 7-X – Engineering a Steady-State Stellarator. *IEEE Transactions on Plasma Science* **38**, 265-273 (2010).
- Bosch, H.-S. and Wendelstein 7-X Team: Wendelstein 7-X – a Technology Step towards Demo. *Plasma and Fusion Research* **5**, S1002 (2010).
- Bottino, A., B. Scott, S. Brunner, B. F. McMillan, T. M. Tran, T. Vernay, L. Villard, S. Jolliet, R. Hatzky and A. G. Peeters: Global Nonlinear Electromagnetic Simulations of Tokamak Turbulence. *IEEE Transactions on Plasma Science* **38**, 2129-2135 (2010).
- Brakel, R., C. Baylard, D. Hartmann, D. Pilopp, H. Greve, F. Herold and P. van Eeten: Component Design in Tight Areas in the Cryostat of W7-X – Configuration Management and Control. *IEEE Transactions on Plasma Science* **38**, 346-351 (2010).
- Brandt, C., O. Grulke and T. Klinger: Comparison of electrostatic and electromagnetic synchronization of drift waves and suppression of drift wave turbulence in a linear device. *Plasma Physics and Controlled Fusion* **52**, 055009 (2010).
- Brandt, C., O. Grulke and T. Klinger: Nonlinear interaction of drift waves with driven plasma currents. *Physics of Plasmas* **17**, 032304 (2010).
- Braun, S. and P. Helander: Pfirsch-Schlüter impurity transport in stellarators. *Physics of Plasmas* **17**, 072514 (2010).
- Braun, S. and P. Helander: Pfirsch-Schlüter impurity transport in stellarator edge plasmas with large radial gradients. *Journal of Physics: Conference Series* **260**, 012004 (2010).

- Bridge, C. R., H. I. Teplitz, B. Siana, C. Scarlata, C. J. Conselice, H. C. Ferguson, T. M. Brown, M. Salvato, G. C. Rudie, D. F. de Mello, J. Colbert, J. P. Gardner, M. Giavalisco and L. Armus: A spectroscopic search for leaking Lyman continuum  $z \sim 0.7$ . *The Astrophysical Journal* **720**, 465-479 (2010).
- Brix, M., D. Dodt, A. Korotkov, P. Morgan, D. Dunai, R. Fischer, A. Meigs, I. S. Nedzelskiy, J. Schweinzer, J. Vince, S. Zoletnik and JET-EFDA Contributors: Upgrade of the lithium beam diagnostic at JET. *Review of Scientific Instruments* **81**, 10D733 (2010).
- Brusa, M., F. Civano, A. Comastri, T. Miyaji, M. Salvato, G. Zamorani, N. Cappelluti, F. Fiore, G. Hasinger, V. Mainieri, A. Merloni, A. Bongiorno, P. Capak, M. Elvis, R. Gilli, H. Hao, K. Jahnke, A. M. Koekemoer, O. Ilbert, E. Le Floch, E. Lusso, M. Mignoli, E. Schinnerer, J. D. Silverman, E. Treiste, J. D. Trump, C. Vignali, M. Zamojski, T. Aldcroft, H. Aussel, S. Bardelli, M. Bolzonella, A. Cappi, K. Caputi, T. Contini, A. Finoguenov, A. Fruscione, B. Garilli, C. D. Impey, A. Iovino, K. Iwasawa, P. Kampczyk, J. Kartaltepe, J. P. Kneib, C. Knobel, K. Kovac, F. Lamareille, J.-F. Leborgne, V. Le Brun, O. Le Fevre, S. J. Lilly, C. Maier, H. J. McCracken, R. Pello, Y.-J. Peng, E. Perez-Montero, L. de Ravel, D. Sanders, M. Scodeggio, N. Z. Scoville, M. Tanaka, Y. Taniguchi, L. Tasca, S. de la Torre, L. Tresse, D. Vergani and E. Zucca: The XMM-Newton wide-field survey in the COSMOS field (XMM-COSMOS): demography and multiwavelength properties of obscured and unobscured luminous active galactic nuclei. *The Astrophysical Journal* **716**, 348-369 (2010).
- Bruschi, A., V. Erckmann, W. Kasperek, M. I. Petelin, M. Thumm, W. Bin, S. Cirant, O. D'Arcangelo, F. Hollmann, L. Lubiako, F. Noke, B. Plaum, F. Purps, H. Zohm and ECRH Team at IPP Greifswald: Diplexers for Power Combination and Switching in High Power ECRH Systems. *IEEE Transactions on Plasma Science* **38**, 1427-1438 (2010).
- Bundy, K., C. Scarlata, C. M. Carollo, R. S. Ellis, N. Drory, P. Hopkins, M. Salvato, A. Leauthaud, A. M. Koekemoer, N. Murray, O. Ilbert, P. Oesch, C.-P. Ma, P. Capak, L. Pozzetti and N. Scoville: The rise and fall of passive disk galaxies: morphological evolution along the red sequence revealed by COSMOS. *The Astrophysical Journal* **719**, 1969-1983 (2010).
- Burckel, A., O. Sauter, C. Angioni, J. Candy, E. Fable and X. Lapillonne: On the effects of the equilibrium model in gyrokinetic simulations: from  $s\text{-}\alpha$  to diverted MHD equilibrium. *Journal of Physics: Conference Series* **260**, 012006 (2010).
- Burckhart, A., E. Wolfrum, R. Fischer, K. Lackner, H. Zohm and ASDEX Upgrade Team: Inter-ELM behaviour of the electron density and temperature pedestal in ASDEX Upgrade. *Plasma Physics and Controlled Fusion* **52**, 105010 (2010).
- Cameron, E., C. M. Carollo, P. Oesch, M. C. Aller, T. Bschorr, P. Cerulo, H. Aussel, P. Capak, E. Le Floch, O. Ilbert, J.-P. Kneib, A. Koekemoer, A. Leauthaud, S. J. Lilly, R. Massey, H. J. McCracken, J. Rhodes, M. Salvato, D. B. Sanders, N. Scoville, K. Sheth, Y. Taniguchi and D. Thompson: Bars in early- and late-type discs in COSMOS. *Monthly Notices of the Royal Astronomical Society* **4009**, 346-354 (2010).
- Cannas, B., A. Fanni, G. Pautasso, G. Sias and P. Sonato: An adaptive real-time disruption predictor for ASDEX Upgrade. *Nuclear Fusion* **50**, 075004 (2010).
- Carvalho, P. J., H. Thomsen, R. Coelho, P. Duarte, C. Silva and H. Fernandes: ISTTOK plasma control with the tomography diagnostic. *Fusion Engineering and Design* **85**, 266-271 (2010).
- Casson, F. J., A. G. Peeters, C. Angioni, Y. Camenen, W. A. Hornsby, A. P. Snodin and G. Szepesi: Gyrokinetic simulations including the centrifugal force in a rotating tokamak plasma. *Physics of Plasmas* **17**, 102305 (2010).
- Chapman, I. T., R. J. Buttery, S. Coda, S. Gerhardt, J. P. Graves, D. F. Howell, A. Isayama, R. J. La Haye, Y. Liu, P. Maget, M. Maraschek, S. Sabbagh, O. Sauter, ASDEX Upgrade Team, DIII-D Team, HL-2A Team, JT-60U Team, MAST Team, NSTX Team, TCV Team, Tore Supra Team and JET-EFDA Contributors: Empirical scaling of sawtooth period for onset of neoclassical tearing modes. *Nuclear Fusion* **50**, 102001 (2010).
- Chaudhary, P., M. Brusa, G. Hasinger, A. Merloni and A. Comastri: Properties of the integrated spectrum of serendipitous 2XMM catalog sources. *Astronomy & Astrophysics* **518**, A 58 (2010).
- Civano, F., M. Elvis, G. Lanzuisi, G. Zamorani, L. Blecha, A. Bongiorno, M. Brusa, A. Comastri, H. Hao, A. Leauthaud, A. Loeb, V. Mainieri, E. Piconcelli, M. Salvato, N. Scoville, J. Trump, C. Vignali, T. Aldcroft, M. Bolzonella, E. Bressert, A. Finoguenov, A. Fruscione, A. M. Koekemoer, N. Cappelluti, F. Fiore, S. Giodini, R. Gilli, C. D. Impey, S. J. Lilly, E. Lusso, S. Puccetti, J. D. Silverman, H. Aussel, P. Capak, D. Frayer, E. Le Floch, H. J. McCracken, D. Sanders, D. Schiminovich and Y. Taniguchi: A Runaway Black Hole in COSMOS: Gravitational Wave or Slingshot Recoil? *The Astrophysical Journal* **717**, 209-222 (2010).
- Classen, I. G. J., J. E. Boom, W. Suttrop, E. Schmid, B. Tobias, C. W. Dormier, N. C. Luhmann, A. J. H. Donné, R. J. E. Jaspers, P. C. de Vries, H. K. Park, T. Munsat, M. Garcia-Munoz and P. A. Schneider: 2D electron cyclotron emission imaging at ASDEX Upgrade (invited). *Review of Scientific Instruments* **81**, 10D929 (2010).



- Conway, G. D., E. Poli, T. Happel and ASDEX Upgrade Team: Interaction of Mean and Oscillating Plasma Flows across Confinement Mode Transitions. *Plasma and Fusion Research* **5**, S2005 (2010).
- Coster, D. P., V. Basiuk, G. Pereverzev, D. Kalupin, R. Zagorksi, R. Stankiewicz, P. Huynh and F. Imbeaux: The European Transport Solver. *IEEE Transactions on Plasma Science* **38**, 2085-2092 (2010).
- Coster, D. P., P. Strand and Contributors to the EUFORIA: EUFORIA: Exploring E-Science for Fusion. *Parallel Computing: From Multicores and GPU's to Petascale*. (Eds.) B. Chapman, F. Desprez, G. H. Joubert, A. Lichnewsky, F. Peters, T. Priol. *Advances in Parallel Computing* **19**. IOS Press, Amsterdam, 520-529 (2010).
- Coveney, P. V., G. Giupponi, S. Jha, S. Manos, J. MacLaren, S. M. Pickles, R. S. Saksena, T. Soddemann, J. L. Suter, M. Thyveetil and S. J. Zasada: Large scale computational science on federated international grids: The role of switched optical networks. *Future Generation Computer Systems* **26**, 99-110 (2010).
- Craciunescu, T., A. Murari, A. Alonso, P. T. Lang, G. Kocsis, I. Tiseanu, V. Zoita and JET EFDA Contributors: Application of optical flow method for imaging diagnostic in JET. *Journal of Nuclear Materials* **400**, 205-212 (2010).
- Dänner, W., D. Hathiramani, F. Schauer and S. Freundt: Cryogenic Materials Data Base for the W7-X Magnet System. *Cryogenics* **50**, 728-736 (2010).
- Da Silva, F., S. da Graca, S. Heuraux, G. D. Conway and ASDEX Upgrade Team: Simulation of reflectometry Bragg backscattering spectral responses in the absence of a cutoff layer. *Review of Scientific Instruments* **81**, 10D927 (2010).
- Dittmann, K., K. Matyash, S. Nemschokmichal, J. Meichsner and R. Schneider: Excitation Mechanisms and Sheath Dynamics in Capacitively Coupled Radio-Frequency Oxygen Plasmas. *Contributions to Plasma Physics* **50**, 942-953 (2010).
- Dodson, T., C. Baylard, D. Hartmann, H. Greve and F. Herold: Configuration Space Control for Wendelstein 7-X. *Contributions to Plasma Physics* **50**, 756-760 (2010).
- Dodt, D., A. Dinklage, K. Bartschat and O. Zatsarinny: Validation of atomic data using a plasma discharge. *New Journal of Physics* **12**, 073018 (2010).  
<http://iopscience.iop.org/1367-2630/12/7/073018/>
- Doerk, H., Z. Idziaszek and T. Calarco: Atom-ion quantum gate. *Physical Review A* **81**, 012708 (2010).
- Domesle, C., B. Jordon-Thaden, L. Lammich, M. Förstel, U. Hergenbahn, A. Wolf and H. B. Pedersen: Photoelectron spectroscopy of O<sup>-</sup> at 266 nm: ratio of ground and excited atomic oxygen production and channel resolved photoelectron anisotropy parameters. *Physical Review A* **82**, 033402 (2010).
- Du, J., T. Höschen, M. Rasinski, S. Wurster, W. Grosinger and J. H. You: Feasibility study of a tungsten wire-reinforced tungsten matrix composite with ZrO<sub>x</sub> interfacial coatings. *Composites Science and Technology* **70**, 1482-1489 (2010).
- Du, J., T. Höschen, M. Rasinski and J. H. You: Interfacial Fracture Behavior of Tungsten Wire/Tungsten Matrix Composites with Copper-Coated Interfaces. *Materials Science and Engineering A* **527**, 1623-1629 (2010).
- Dumbrajs, O., V. Igoshine, A. Gude, M. Maraschek, H. Zohm and ASDEX Upgrade Team: Temporal evolution of neoclassical tearing modes in the frequently interrupted regime. *Physics of Plasmas* **17**, 042118 (2010).
- Eremin, D. Y. and A. Könies: Beta-induced Alfvén-acoustic eigenmodes in stellarator plasmas with low shear. *Physics of Plasmas* **17**, 012108 (2010).
- Esteban, L., M. Sanchez, J. Sanchez, P. Kornejew, M. Hirsch, A. Lopez, A. Fernandez and O. Nieto-Taladriz: Continuous Phase Measurement in the W7-X Infrared Interferometer by Means of a FPGA and High-Speed ADCs. *Fusion Science and Technology* **58**, 771-777 (2010).
- Fable, E., C. Angioni, S. Fietz, J. Hobirk, G. Pereverzev and ASDEX Upgrade Team: Transport physics of ASDEX Upgrade current ramps: experiment and theory. *Journal of Physics: Conference Series* **260**, 012009 (2010).
- Fable, E., C. Angioni and O. Sauter: The role of ion and electron electrostatic turbulence in characterizing stationary particle transport in the core of tokamak plasmas. *Plasma Physics and Controlled Fusion* **52**, 015007 (2010).
- Fantz, U., R. Gutser and C. Wimmer: Fundamental experiments on evaporation of caesium in ion sources. *Review of Scientific Instruments* **81**, 02B102 (2010).
- Fernández-Menchero, L. and S. Otranto: Single ionization of CH<sub>4</sub> by bare ions: Fully differential cross sections. *Physical Review A* **82**, 022712 (2010).
- Feruglio, C., H. Aussel, E. Le Floc'h, O. Ilbert, M. Salvato, P. Capak, F. Fiore, J. Kartaltepe, D. Sanders, N. Scoville, A. M. Koekemoer and Y. Ideue: Obscured Star Formation

and Environment in the COSMOS Field. *The Astrophysical Journal* **721**, 607-614 (2010).

*Fischer, R., C. J. Fuchs, B. Kurzan, W. Suttrop, E. Wolfrum and ASDEX Upgrade Team*: Integrated Data Analysis of Profile Diagnostics at ASDEX Upgrade. *Fusion Science and Technology* **58**, 675-684 (2010).

*Fisher, R. K., D. C. Pace, M. Garcia-Munoz, W. W. Heidbrink, C. M. Muscatello, M. A. Van Zeeland and Y. B. Zhu*: Scintillator-based diagnostic for fast ion loss measurements on DIII-D. *Review of Scientific Instruments* **81**, 10D307 (2010).

*Förstel, M., M. Mucke, T. Arion, T. Lischke, S. Barth, V. Ulrich, G. Öhrwall, O. Björneholm, U. Hergenroth and A. M. Bradshaw*: Observation of electronic energy bands in argon clusters. *Physical Review B* **82**, 125450 (2010).

*Frerichs, H., D. Reiter, Y. Feng, D. Harting and O. Schmitz*: Block-structured grids in Lagrangian 3D edge plasma transport simulations. *Computer Physics Communications* **181**, 61-70 (2010).

*Frerichs, H., D. Reiter, O. Schmitz, T. Evans and Y. Feng*: Three-dimensional edge transport simulations for DIII-D plasmas with resonant magnetic perturbations. *Nuclear Fusion* **50**, 034004 (2010).

*Fülöp, T., S. Braun and I. Pusztai*: Impurity transport driven by ion temperature gradient turbulence in tokamak plasmas. *Physics of Plasmas* **17**, 062501 (2010).

*Fu, H., L. Yan, N. Z. Scoville, P. Capak, H. Aussel, E. Le Floch, O. Ilbert, M. Salvato, J. S. Kartaltepe, D. T. Frayer, D. B. Sanders, K. Sheth and Y. Taniguchi*: Decomposing Star Formation and Active Galactic Nucleus with Spitzer Mid-infrared Spectra: Luminosity Functions and Co-evolution. *The Astrophysical Journal* **722**, 653-667 (2010).

*Galloway, R., P. Helander, A. MacKinnon and J. Brown*: Thermalisation and hard X-ray bremsstrahlung efficiency of self-interacting solar flare fast electrons. *Astronomy & Astrophysics* **520**, A72 (2010).

*Garcia-Munoz, M., N. Hicks, R. van Voornveld, I. G. J. Classen, R. Bilato, V. Bobkov, M. Brambilla, M. Bruedgam, H.-U. Fahrbach, V. Igochine, S. Jaemsae, M. Maraschek, K. Sassenberg and ASDEX Upgrade Team*: Fast-ion losses induced by ACs and TAEs in the ASDEX Upgrade tokamak. *Nuclear Fusion* **50**, 084004 (2010).

*Garcia-Munoz, M., N. Hicks, R. van Voornveld, I. G. J. Classen, R. Bilato, V. Bobkov, M. Brüdgam, H.-U. Fahrbach, V. Igochine,*

*S. Jämsä, M. Maraschek, K. Sassenberg and ASDEX Upgrade Team*: Convective and Diffusive Energetic Particles Losses Induced by Shear Alfvén Waves in the ASDEX Upgrade Tokamak. *Physical Review Letters* **104**, 185002 (2010).

*Garcia-Regana, J., F. Castejon, A. Cappa, N. Marushchenko and M. Tereshchenko*: Comparison of different models for EBCD calculation in the TJ-II Stellarator. *Plasma Physics and Controlled Fusion* **52**, 065007 (2010).

*Geiger, J., G. Beidler, M. Drevlak, H. Maaßberg, C. Nührenberg, Y. Suzuki and Y. Turkin*: Effects of Net Currents on the Magnetic Configuration of W7-X. *Contributions to Plasma Physics* **50**, 770-774 (2010).

*Geiger, J., M. Endler and A. Werner*: Magnetic Diagnostics for Equilibrium Reconstruction at W7-X. *Contributions to Plasma Physics* **50**, 736-740 (2010).

*Gentzsch, W. and H. Lederer*: DEISA Mini-Symposium on Extreme Computing in an Advanced Supercomputing Environment. *Parallel Computing: From Multicores and GPU's to Petascale*. (Eds.) B. Chapman, F. Desprez, G. H. Joubert, A. Lichnewsky, F. Peters, T. Priol. *Advances in Parallel Computing* **19**. IOS Press, Amsterdam, 477-481 (2010).

*Giannone, L., M. Cerna, R. Cole, M. Fitzek, A. Kallenbach, K. Lüdtke, P. J. McCarthy, A. Scarabosio, W. Schneider, A. C. C. Sips, W. Treutterer, A. Vrancic, L. Wenzel, H. Yi, K. Behler, T. Eich, H. Eixenberger, J. C. Fuchs, G. Haas, G. Lexa, M. Marquardt, A. Mlynek, G. Neu, G. Raupp, M. Reich, J. Sachtleben, K. H. Schuhbeck, T. Zehetbauer, S. Concezzi, T. Debelle, B. Marker, M. Munroe, N. Petersen, D. Schmidt and ASDEX Upgrade Team*: Data acquisition and real time signal processing of plasma diagnostics on ASDEX Upgrade using LabVIEW RT. *Fusion Engineering and Design* **85**, 301-307 (2010).

*Giodini, S., V. Smolic, A. Finoguenov, H. Boehringer, L. Birzan, G. Zamorani, A. Oklopčić, D. Pierini, G. W. Pratt, E. Schinnerer, R. Massey, A. M. Koekemoer, M. Salvato, D. B. Sanders, J. S. Kartaltepe and D. Thompson*: Radio galaxy feedback in x-ray-selected groups from COSMOS: the effect on the intra-cluster medium. *The Astrophysical Journal* **714**, 218-228 (2010).

*Görler, T., X. Lapillonne, S. Brunner, J. Chowdhury, T. Dannert, F. Jenko, B. F. McMillan, F. Merz, D. Told and L. Villard*: Non-local effects in gyrokinetic turbulence simulations using GENE. *Journal of Physics: Conference Series* **260**, 012011 (2010).

*Goniche, M., L. Amicucci, Y. Baranov, V. Basiuk, G. Calabro, A. Cardinali, C. Castaldo, R. Cesario, J. Decker, D. Dodt,*

- A. Ekedahl, L. Figini, J. Garcia, G. Giruzzi, J. Hillairet, G. T. Hoang, A. Hubbard, E. Joffrin, K. Kirov, X. Litaudon, J. Mailloux, T. Oosako, R. Parker, V. Pericoli Ridolfini, Y. Peysson, P. Platania, F. Rimini, P. K. Sharma, C. Sozzi and G. Wallace:* Lower hybrid current drive for the steady-state scenario (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124031 (2010).
- Goold, J., H. Doerk, Z. Idziaszek, T. Calarco and Th. Busch:* Ion-induced density bubble in a strongly correlated one-dimensional gas. *Physical Review A* **81**, 041601(R) (2010).
- Grappin, R. and W.-C. Müller:* Scaling and anisotropy in magnetohydrodynamic turbulence in a strong mean magnetic field. *Physical Review E* **82**, 026406 (2010).
- Günter, S. and K. Lackner:* Unterwegs zum numerischen Tokamak. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 28-33 (2010).
- Gutser, R., U. Fantz and D. Wunderlich:* Simulation of cesium injection and distribution in rf-driven ion sources for negative hydrogen ion generation. *Review of Scientific Instruments* **81**, 02A706 (2010).
- Gutser, R., D. Wunderlich, U. Fantz and NNBI Team:* Transport of negative hydrogen and deuterium ions in RF-driven ion sources. *Plasma Physics and Controlled Fusion* **52**, 045017 (2010).
- Hager, R. and K. Hallatschek:* Radial propagation of geodesic acoustic modes in up-down asymmetric magnetic geometries. *Physics of Plasmas* **17**, 032112 (2010).
- Hakola, A., J. Likonon, L. Aho-Mantila, M. Groth, S. Koivuranta, K. Krieger, T. Kurki-Suonio, T. Makkonen, M. Mayer, H. W. Müller, R. Neu, V. Rohde and ASDEX Upgrade Team:* Migration and deposition of  $^{13}\text{C}$  in the full-tungsten ASDEX Upgrade tokamak. *Plasma Physics and Controlled Fusion* **52**, 6, 065006 (2010).
- Hao, H., M. Elvis, F. Civano, G. Lanzuisi, M. Brusa, E. Lusso, G. Zamorani, A. Comastri, A. Bongiorno, C. Impey, A. M. Koekemoer, E. Le Floch, M. Salvato, D. Sanders, J. Trump and C. Vignali:* Hot-dust-poor Type 1 Active Galactic Nuclei in the COSMOS Survey. *The Astrophysical Journal Letters* **724**, L59-L63 (2010).
- Hartmann, D. A.:* Stellarators. *Fusion Science and Technology* **57**, 2T, 46-58 (2010).
- Hasinger, G.:* Ideal für die Grundlast. *Focus*, 14, 68-69 (2010).
- Hasinger, G.:* Der Weg zum Fusionskraftwerk. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 4-5 (2010).
- Hasinger, G., C. Jones, H. Okuda, J. Braga, N. Brosch, T. de Graauw, L. Gurvits, G. Helou, I. Howarth, H. Kunieda, T. Montmerle, M. Salvati and K. P. Singh:* Division Xi: Space & High-Energy Astrophysics. *Proceedings of the International Astronomical Union* **6**, T27B, 248-248 (2010).
- Hathiramani, D., T. Bergmann, V. Bykov, P. Chen, W. Dänner, A. Dudek, J. Fellingner, S. Freundt, L. Genini, K. Höchl, J. Kallmeyer, J. Lingertat, H. Viebke, S. Weber and F. Schauer:* Stability Test of a Superconducting W7-X Coil with Respect to Mechanical Disturbances. *IEEE Transactions on Applied Superconductivity* **20**, 543-546 (2010).
- Hauff, T., F. Jenko, A. Shalchi and R. Schlickeiser:* Scaling Theory for Cross-Field Transport of Cosmic Rays in Turbulent Fields. *Astrophysical Journal* **711**, 997-1007 (2010).
- Hein, T. and C. Angioni:* Electromagnetic effects on trace impurity transport in tokamak plasmas. *Physics of Plasmas* **17**, 012307 (2010).
- Hein, T., C. Angioni, E. Fable and J. Candy:* Gyrokinetic study of the role of  $\beta$  on electron particle transport in tokamaks. *Physics of Plasmas* **17**, 102309 (2010).
- Helander, P. and A. Simakov:* Gyrokinetic Theory of Rotation in Stellarators. *Contributions to Plasma Physics* **50**, 695-700 (2010).
- Henry, J. P., M. Salvato, A. Finoguenov, N. Bouche, H. Brunner, V. Burwitz, P. Buschkamp, E. Egami, N. Förster-Schreiber, S. Fotopoulou, R. Genzel, G. Hasinger, V. Mainieri, M. Rovilos and G. Szokoly:* An X-ray-selected Galaxy Cluster in the Lockman Hole at Redshift 1.753. *The Astrophysical Journal* **725**, 615-624 (2010).
- Hertel, K., H. Viebke, C. Heenemann, J. Baldzuhn, H. Ehmler, G. Croari, M. Bensouda-Korachi, L. Genini, B. Renard and L. Vieillard:* Test of Superconducting Coils for the Wendelstein 7-X Stellarator Experiment. *IEEE Transactions on Applied Superconductivity* **20**, 534-537 (2010).
- Hicks, N. K., W. Suttrop, K. Behler, M. Garcia-Munoz, L. Giannone, M. Maraschek, G. Raupp, M. Reich, A. C. C. Sips, J. Stober, W. Treutterer, V. Volpe, ASDEX Upgrade Team, S. Cirant and G. D'Antona:* Fast Sampling Upgrade and Real Time NTM Control Application of the ECE Radiometer on ASDEX Upgrade. *Fusion Science and Technology* **57**, 1-9 (2010).

- Hirsch, M.: Overview of L-H Transition Experiments in Helical Devices. *Contributions to Plasma Physics* **50**, 487-492 (2010).
- Hole, M. J., G. von Nessi, D. Pretty, J. Howard, B. Blackwell, J. Svensson and L. C. Appel: The use of Bayesian inversion to resolve plasma equilibrium. *Review of Scientific Instruments* **81**, 10E127 (2010).
- Hong, S.-H., C. Grisolia, V. Rohde, P. Monier-Garbet, Tore Supra Team and ASDEX Upgrade Team: Temporal evolution and spatial distribution of dust creation events in Tore Supra and in ASDEX Upgrade studied by CCD image analysis. *Nuclear Fusion* **50**, 035002 (2010).
- Horacek, J., J. Adamek, H. W. Müller, J. Seidl, A. H. Nielsen, V. Rohde, F. Mehlmann, C. Ionita, E. Havlickova and ASDEX Upgrade Team: Interpretation of fast measurements of plasma potential, temperature and density in SOL of ASDEX Upgrade. *Nuclear Fusion* **50**, 105001 (2010).
- Hornsby, W. A., A. G. Peeters, E. Poli, M. Siccino, A. P. Snodin, F. J. Casson, Y. Camenen and G. Szepesi: On the nonlinear coupling between micro turbulence and mesoscale magnetic islands in a plasma. *Europhysics Letters* **91**, 45001 (2010).
- Hornsby, W. A., A. G. Peeters, A. P. Snodin, F. J. Casson, Y. Camenen, G. Szepesi, M. Siccino and E. Poli: The nonlinear coupling between gyroradius scale turbulence and mesoscale magnetic islands in fusion plasmas. *Physics of Plasmas* **17**, 092301 (2010).
- Igochine, V., J. Boom, I. Classen, O. Dumbrajs, S. Günter, K. Lackner, G. Pereverzev, H. Zohm and ASDEX Upgrade Team: Structure and dynamics of sawteeth crashes in ASDEX Upgrade. *Physics of Plasmas* **17**, 122506 (2010).
- Ikkurthi, V. R., K. Matyash, A. Melzer and R. Schneider: Computation of charge and ion drag force on multiple static spherical dust grains immersed in rf discharges. *Physics of Plasmas* **17**, 103712 (2010).
- Ilbert, O., M. Salvato, E. Le Floch, H. Aussel, P. Capak, H. J. McCracken, B. Mobasher, J. Kartaltepe, N. Scoville, D. B. Sanders, S. Arnouts, K. Bundy, P. Cassata, J.-P. Kneib, A. Koekemoer, O. Le Fèvre, S. Lilly, J. Surace, Y. Taniguchi, L. Tasca, D. Thompson, L. Tresse, M. Zamojski, G. Zamorani and E. Zucca: Galaxy Stellar Mass Assembly between  $0.2 < z < 2$  from the S-COSMOS Survey. *The Astrophysical Journal* **709**, 644-663 (2010).
- Imbeaux, F., J. B. Lister, W. Zwingmann, M. Airaja, L. Appel, V. Basiuk, D. Coster, L.-G. Eriksson, B. Guillerminet, D. Kalupin, C. Konz, G. Manduchi, M. Ottavian, G. Pereverzev, Y. Peysson, O. Sauter, J. Signoret, P. Strand and ITM-TF Work Programme Contributors: A generic data structure for integrated modelling of tokamak physics and subsystems. *Computer Physics Communications* **181**, 987-998 (2010).
- Ishida, M., K. Maeki, R. Hiwatari, X. Bonnin, S. Zhu, A. Hatayama, R. Schneider and D. Coster: Numerical Analysis of Divertor Plasma for Demo-CREST. *Contributions to Plasma Physics* **50**, 362-367 (2010).
- Jakubowski, M. W., T. E. Evans, M. E. Fenstermacher, C. J. Lasnier, O. Schmitz, R. C. Wolf, L. R. Baylor, J. A. Boedo, K. H. Burrell, H. Frerichs, J. S. de Grassie, P. Gohil, S. Mordijck, R. A. Moyer, A. W. Leonard, D. Reiter, U. Samm, M. J. Schaffer, T. H. Osborne, E. A. Unterberg and J. G. Watkins: Influence of the Resonant Magnetic Perturbation on the Plasma Boundary in DIII-D. *Contributions to Plasma Physics* **50**, 701-707 (2010).
- Kaliatka, A., T. Kacegavicius and D. Naujoks: Analysis of the processes in the target cooling system of the W7-X fusion experiment. *Kerntechnik* **75**, 255-262 (2010).
- Kallenbach, A., R. Dux, J. C. Fuchs, R. Fischer, B. Geiger, L. Giannone, A. Herrmann, T. Lunt, V. Mertens, R. McDermott, R. Neu, T. Pütterich, S. Rathgeber, V. Rohde, K. Schmid, J. Schweinzer, W. Treutterer and ASDEX Upgrade Team: Divertor power load feedback with nitrogen seeding in ASDEX Upgrade. *Plasma Physics and Controlled Fusion* **52**, 055002 (2010).
- Kartaltepe, J. S., D. B. Sanders, E. Le Floch, D. T. Frayer, H. Aussel, S. Arnouts, O. Ilbert, M. Salvato, N. Z. Scoville, J. Surace, L. Yan, M. Brusa, P. Capak, K. Caputi, C. M. Carollo, F. Civano, M. Elvis, C. Faure, G. Hasinger, A. M. Koekemoer, N. Lee, S. Lilly, C. T. Liu, H. J. McCracken, E. Schinnerer, V. Smolcic, Y. Taniguchi, D. J. Thompson and J. Trump: A Multiwavelength Study of a Sample of 70 micron Selected Galaxies in the COSMOS Field I: Spectral Energy Distributions and Luminosities. *The Astrophysical Journal* **709**, 572-596 (2010).
- Kartaltepe, J. S., D. B. Sanders, E. Le Floch, D. T. Frayer, H. Aussel, S. Arnouts, O. Ilbert, M. Salvato, N. Z. Scoville, J. Surace, L. Yan, P. Capak, K. Caputi, C. M. Carollo, P. Cassata, F. Civano, G. Hasinger, A. M. Koekemoer, O. Le Fèvre, S. Lilly, C. T. Liu, H. J. McCracken, E. Schinnerer, C. Smolcic, Y. Taniguchi, D. J. Thompson, J. Trump, V. F. Baldassare and S. L. Fiorenza: A Multiwavelength Study of a Sample of 70  $\mu$ m Selected Galaxies in the COSMOS Field. II. The Role of Mergers in Galaxy Evolution. *The Astrophysical Journal* **721**, 98-123 (2010).



- Kauffmann, K., R. Kleiber, R. Hatzky and M. Borchardt:* Global linear gyrokinetic simulations for LHD including collisions. *Journal of Physics: Conference Series* **260**, 012014 (2010).
- Kendl, A., B. D. Scott and T. T. Ribeiro:* Nonlinear gyrofluid computation of edge localized ideal ballooning modes. *Physics of Plasmas* **17**, 072302 (2010).
- Kennedy, A. and H. Lederer:* DEISA Extreme Computing Initiative (DECI) and Science Community Support. Parallel Computing: From Multicores and GPU's to Petascale. (Eds.) B. Chapman, F. Desprez, G. H. Joubert, A. Lichniewsky, F. Peters, T. Priol. *Advances in Parallel Computing* **19**. IOS Press, Amsterdam, 482-491 (2010).
- Kernbichler, W., S. Kasilov, G. Leitold, V. Nemov and N. Marushchenko:* Generalized Spitzer function with finite collisionality in toroidal plasmas. *Contributions to Plasma Physics* **50**, 761-765 (2010).
- Kim, K. M., Y.-S. Na, S. H. Hong, P. T. Lang, B. Alper and JET-EFDA Contributors:* Transport simulation of ELM pacing by pellet injection in tokamak plasmas. *Nuclear Fusion* **50**, 055002 (2010).
- Kleiber, R., R. Hatzky and A. Mishchenko:* Simulation of Residual Zonal Flow Levels in Stellarators Including a Radial Electric Field. *Contributions to Plasma Physics* **50**, 766-769 (2010).
- Klinger, T.:* Von Wendelstein 1-A zu Wendelstein 7-X. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 12-17 (2010).
- Kobayashi, M., Y. Feng, S. Morita, S. Masuzaki, N. Ezumi, T. Kobayashi, M. Chowdhuri, H. Yamada, T. Morisaki, N. Ohyabu, M. Goto, I. Yamada, K. Narihara, A. Komori, O. Motojima and LHD Experiment Group:* Transport Characteristics in the Stochastic Magnetic Boundary of LHD: Magnetic Field Topology and its Impact on Divertor Physics and Impurity Transport. *Fusion Science and Technology* **58**, 220-231 (2010).
- Kobayashi, M., S. Masuzaki, I. Yamada, N. Tamura, Y. Feng, K. Sato, M. Goto, Y. Narushima, T. Akiyama, J. Miyazawa, M. Shoji, S. Morita, B. Peterson, H. Funaba, N. Ohyabu, K. Narihara, T. Morisaki, H. Yamada, A. Komori and D. Reiter:* Detachment stabilization with  $n/m=1/1$  resonant magnetic perturbation field applied to the stochastic magnetic boundary of the Large Helical Device (invited). *Physics of Plasmas* **17**, 056111 (2010).
- Kocan, M. and J. P. Gunn:* Comparison of scrape-off layer profiles in outboard-versus inboard-limited plasmas in Tore Supra. *Plasma Physics and Controlled Fusion* **52**, 045010 (2010).
- Kocan, M., J. P. Gunn, J.-Y. Pascal and E. Guthier:* Ion temperature measurements in the Tore Supra scrape-off layer using a retarding field analyzer. *Contributions to Plasma Physics* **50**, 836-840 (2010).
- Könies, A. and D. Eremin:* Coupling of Alfvén and sound waves in stellarator plasmas. *Physics of Plasmas* **17**, 012107 (2010).
- König, R., J. Baldzuhn, W. Biel, C. Biedermann, R. Burhenn, S. Bozhnikov, J. Cantarini, H. Dreier, M. Endler, H.-J. Hartfuß, D. Hildebrandt, M. Hirsch, M. Jakubowski, R. Jimenez-Gomez, G. Kocsis, P. Kornejew, M. Krychowiak, H. P. Laqua, M. Laux, J. W. Oosterbeek, E. Pasch, T. Richert, W. Schneider, B. Schweer, J. Svensson, H. Thomsen, A. Weller, A. Werner, R. C. Wolf, D. Zhang and S. Zoletnik:* Diagnostics design for steady-state operation of the Wendelstein 7-X stellarator. *Review of Scientific Instruments* **81**, 10E133 (2010).
- Kolesnichenko, Y. I., Y. V. Yakovenko, V. V. Lutsenko, R. B. White and A. Weller:* Effects of energetic-ion-driven instabilities on plasma heating, transport and rotation in toroidal systems. *Nuclear Fusion* **50**, 084011 (2010).
- Kotov, V., D. Reiter, D.P. Coster and A.S. Kukushkin:* Verification of the 2D Tokamak Edge Modelling Codes for Conditions of Detached Divertor Plasma. *Contributions to Plasma Physics* **50**, 292-298 (2010).
- Krämer-Flecken, A., J. Krom, B. Landgraf and H. T. Lambertz:* Remote Participation tools at Textor. *Fusion Engineering and Design* **85**, 625-627 (2010).
- Kraus, W., U. Fantz and P. Franzen:* Long pulse H<sup>-</sup> beam extraction with an rf driven ion source on a high power level. *Review of Scientific Instruments* **81**, 02B110 (2010).
- Kuznetsov, A. S., R. W. E. van de Kruijs, M. A. Gleeson, K. Schmid and F. Bijkerk:* Hydrogen Interaction with EUVL-Relevant Optical Materials. *Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques* **4**, 563-566 (2010).
- Landgraf, B., A. Krämer-Flecken and J. G. Krom:* Integration of PCI Modules in JDAQ. *Fusion Engineering and Design* **85**, 332-334 (2010).
- Lapillonne, X., B. F. McMillan, T. Görler, S. Brunner, T. Dannert, F. Jenko, F. Merz and L. Villard:* Nonlinear quasisteady state benchmark of global gyrokinetic codes. *Physics of Plasmas* **17**, 112321 (2010).

- Laqua, H., D. Aßmus, T. Bluhm, P. Heimann, S. Heinrich, C. Hennig, U. Herbst, E. Köster, H. Kroiss, G. Kühner, J. Maier, I. Müller, M. Lewerentz, M. Otte, S. Pingel, H. Riemann, J. Sachtleben, J. Schacht, A. Spring, A. Wölk, A. Werner and M. Zilker: Test of the steady state W7-X control and data acquisition system at the WEGA stellarator. *Fusion Engineering and Design* **85**, 520-524 (2010).
- Leauthaud, A., A. Finoguenov, J.-P. Kneib, J. E. Taylor, R. Massey, J. Rhodes, O. Ilbert, K. Bundy, J. Tinker, M. R. George, P. Capak, A. M. Koekemoer, D. E. Johnston, Y.-Y. Zhang, N. Cappelluti, R. S. Ellis, M. Elvis, S. Giodini, C. Heymans, O. Le Fèvre, S. Lilly, H. J. McCracken, Y. Mellier, A. Réfrégier, M. Salvato, N. Scoville, G. Smoot, M. Tanaka, L. Van Waerbeke and M. Wolk: A weak lensing study of x-ray groups in the COSMOS survey: form and evolution of the mass-luminosity relation. *The Astrophysical Journal* **709**, 97-114 (2010).
- Lee, N., E. Le Floch, D. B. Sanders, T. Frayer, S. Arnouts, S. Ilbert, H. Aussel, M. Salvato, N. Z. Scoville and J. S. Kartaltepe: A far-infrared characterization of 24  $\mu\text{m}$  selected galaxies at  $0 < z < 2.5$  using stacking at 70  $\mu\text{m}$  and 160  $\mu\text{m}$  in the COSMOS field. *The Astrophysical Journal* **717**, 175-182 (2010).
- Liang, Y., H.-R. Koslowski, S. Jachmich, A. Alfier, C. G. Gimblett, E. Nardon, P. K. Browning, P. Devoy, T. Eich, C. Giroud, G. Maddison, P. T. Lang, M. P. Gryaznevich, D. Harting, M. Heyn, S. Saarelma, Y. Sun, R. Wenninger, C. Wiegmann, T. Zhang and JET EFDA Contributors: Overview of ELM Control by Low n Magnetic Perturbations on JET. *Plasma and Fusion Research* **5**, S2018 (2010).
- Liang, Y., H. R. Koslowski, P. R. Thomas, E. Nardon, S. Jachmich, A. Alfier, G. Arnoux, Y. Baranov, M. Bécoulet, M. Beurskens, R. Coelho, Th. Eich, E. De La Luna, W. Fundamenski, S. Gerasimov, C. Giroud, M. P. Gryaznevich, D. Harting, A. Huber, A. Kreter, L. Moreira, V. Parail, S. D. Pinches, S. Saarelma, O. Schmitz and JET EFDA Contributors: Active Control of Type-I Edge Localized Modes with n=1 and n=2 fields on JET. *Nuclear Fusion* **50**, 020513 (2010).
- Lischtschenko, O., K. Bystrov, G. De Temmerman, J. Howard, R. J. E. Jaspers and R. König: Density measurements using coherence imaging spectroscopy based on Stark broadening. *Review of Scientific Instruments* **81**, 10E521 (2010).
- Lunt, T., J. C. Fuchs, K. Mank, Y. Feng, F. Brochard, A. Herrmann, V. Rohde, N. Endstrasser and ASDEX Upgrade Team: A new 3D viewer as an interface between the ASDEX Upgrade CAD models and data from plasma modelling and experiment. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **623**, 812-814 (2010).
- Lusso, E., A. Comastri, C. Vignali, G. Zamorani, M. Brusa, R. Gilli, K. Iwasawa, M. Salvato, F. Civano, M. Elvis, A. Merloni, A. Bongiorno, J. R. Trump, A. M. Koekemoer, E. Schinnerer, E. Le Floch, N. Cappelluti, K. Jahnke, M. Sargent, J. Silverman, V. Mainieri, F. Fiore, M. Bolzonella, O. Le Fèvre, B. Garilli, A. Iovino, J. P. Kneib, F. Lamareille, S. Lilly, M. Mignoli, M. Scodeggio and D. Vergani: The X-ray to optical-UV luminosity ratio of X-ray selected type 1 AGN in XMM-COSMOS. *Astronomy & Astrophysics* **512**, A34 (2010).
- Lutz, D., V. Mainieri, D. Rafferty, L. Shao, G. Hasinger, A. Weiß, F. Walter, I. Smail, D. M. Alexander, W. N. Brandt, S. Chapman, K. Coppin, N. M. Förster Schreiber, E. Gawiser, R. Genzel, T. R. Greve, R. J. Ivison, A. M. Koekemoer, P. Kurczynski, K. M. Mentens, R. Nordon, P. Popesso, E. Schinnerer, J. D. Silverman, J. Wardlow and Y. Q. Xue: The LABOCA survey of the extended Chandra deep field south: two modes of star formation in active galactic nucleus hosts? *The Astrophysical Journal* **712**, 1287-1301 (2010).
- Maaßberg, H. and C. Beidler: Benchmarking of collision operators with momentum source corrections. *Physics of Plasmas* **17**, 052507 (2010).
- Maggi, C.: Progress in understanding the physics of the H-mode pedestal and ELM dynamics. *Nuclear Fusion* **50**, 066001 (2010).
- Maggi, C. F., R. J. Groebner, C. Angioni, T. Hein, L. D. Horton, C. Konz, A. W. Leonard, C. C. Petty, A. C. C. Sips, P. B. Snyder, J. Candy, R. E. Waltz, ASDEX Upgrade and DIII-D Teams: Pedestal and core confinement of hybrid scenario in ASDEX Upgrade and DIII-D. *Nuclear Fusion* **50**, 025023 (2010).
- Mainieri, V., C. Vignali, A. Merloni, F. Civano, S. Puccetti, M. Brusa, R. Gilli, M. Bolzonella, A. Comastri, G. Zamorani, M. Aller, M. Carollo, C. Scarlata, M. Elvis, T. L. Aldcroft, N. Cappelluti, G. Fabbiano, A. Finoguenov, F. Fiore, A. Fruscione, A. M. Koekemoer, T. Contini, J.-P. Kneib, O. Le Fèvre, S. Lilly, A. Renzini, M. Scodeggio, S. Bardelli, A. Bongiorno, K. Caputi, G. Coppa, O. Cucciati, S. de la Torre, L. de Ravel, P. Franzetti, B. Garilli, A. Iovino, P. Kampczyk, C. Knobel, K. Kovac, F. Lamareille, J.-F. Le Borgne, V. Le Brun, C. Maier, M. Mignoli, R. Pello, Y. Peng, E. Perez Montero, E. Ricciardelli, J. D. Silverman, M. Tanaka, L. Tasca, L. Tresse, D. Vergani, E. Zucca, P. Capak, O. Ilbert, C. Impey, M. Salvato, N. Scoville, Y. Taniguchi and J. Trump: Ultraluminous X-ray sources out to  $z \sim 0.3$  in the COSMOS field. *Astronomy & Astrophysics* **514**, A85 (2010).
- Maj, O., A. A. Balakin and E. Poli: Effects of aberration on paraxial wave beams: beam tracing versus quasi-optical solutions. *Plasma Physics and Controlled Fusion* **52**, 085006 (2010).

- Mancini, C., E. Daddi, A. Renzini, F. Salmi, H. J. McCracken, A. Cimatti, M. Onodera, M. Salvato, A. M. Koekemoer, H. Aussel, E. Le Floch, C. Willot and P. Capak: High-redshift elliptical galaxies: are they (all) really compact? *Monthly Notices of the Royal Astronomical Society* **401**, 933-940 (2010).
- Mantica, P., T. Tala, J. S. Ferreira, A. G. Peeters, A. Salmi, D. Strintzi, J. Weiland, M. Brix, C. Giroud, G. Corrigan, V. Naulin, G. Tardini and K.-D. Zastrow: Perturbative studies of toroidal momentum transport using neutral beam injection modulation in the Joint European Torus: Experimental results, analysis methodology, and first principles modeling. *Physics of Plasmas* **17**, 092505 (2010).
- Marr, K. D., B. Lipschultz, P. J. Catto, R. M. McDermott, M. L. Reinke and A. N. Simakov: Comparison of neoclassical predictions with measured flows and evaluation of a poloidal impurity density asymmetry. *Plasma Physics and Controlled Fusion* **52**, 055010 (2010).
- Matyash, K., R. Schneider, R. Ikkurthi, L. Lewerentz and A. Melzer: P<sup>3</sup>M simulations of dusty plasmas (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124016 (2010).
- Matyash, K., R. Schneider, A. Mutzke, O. Kalentev, F. Taccogna, N. Koch and M. Schirra: Kinetic Simulations of SPT and HEMP Thrusters Including the Near-Field Plume Region. *IEEE Transactions on Plasma Science* **38**, 2274-2280 (2010).
- Mayer, M., K. Arstila and U. von Toussaint: Skewness of energy-loss straggling and multiple-scattering energy distributions. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **268**, 1744-1748 (2010).
- Mazon, D., A. Murari, C. Boulbe, B. Faugeras, J. Blum, J. Svensson, T. Quilichini, M. Gelfusa and JET-EFDA Contributors: Validation of Magnetic Reconstruction Codes for Real-Time Applications. *Fusion Science and Technology* **58**, 742-754 (2010).
- McCracken, H. J., P. Capak, M. Salvato, H. Aussel, D. Thompson, E. Daddi, D. B. Sanders, J.-P. Kneib, C. J. Willott, C. Mancini, A. Renzini, R. Cook, O. Le Fèvre, O. Ilbert, J. Kartaltepe, A. M. Koekemoer, Y. Mellier, T. Murayama, N. Z. Scoville, Y. Shioya and Y. Taniguchi: The COSMOS-WIRCam Near-infrared Imaging Survey. I. BzK-Selected Passive and Star-Forming Galaxy Candidates at  $z_{\text{gsim}} 1.4^*$ . *The Astrophysical Journal* **708**, 202-217 (2010).
- McMillan, B. F., S. Jolliet, A. Bottino, P. Angelino, T. M. Tran and L. Villard: Rapid Fourier space solution of linear partial integro-differential equations in toroidal magnetic confinement geometries. *Computer Physics Communications* **181**, 715-719 (2010).
- McMillan, B. F., X. Lapillonne, S. Brunner, L. Villard, S. Jolliet, A. Bottino, T. Görler and F. Jenko: System Size Effects on Gyrokinetic Turbulence. *Physical Review Letters* **105**, 155001 (2010).
- McNeely, P. and L. Schiesko: Investigation of fringe plasma parameters on a high power rf driven ion source. *Review of Scientific Instruments* **81**, 02B111 (2010).
- Meister, H., T. Eich, N. Endstrasser, L. Giannone, M. Kanna-müller, A. Kling, J. Koll, T. Trautmann, P. Detemple and S. Schmitt: Optimization of a bolometer detector for ITER based on Pt absorber on SiN membrane. *Review of Scientific Instruments* **81**, 10E132 (2010).
- Melnikov, A., L. Eliseev, R. Jiménez-Gómez, E. Ascasibar, C. Hidalgo, A. Chmyga, T. Ido, S. Khrebtov, A. Könies, A. Komarov, A. Kozachek, I. Krasilnikov, L. Krupnik, M. Liniers, S. Lysenko, V. Mavrin, K. Nagaoka, M. Ochando, J. de Pablos, M. Pedrosa, S. Perfilov, A. Smolyakov, Y. Tashev, M. Ufimtsev, S. Yamamoto and A. Zhezhera: Study of Alfvén Eigenmodes in the TJ-II Stellarator. *Plasma and Fusion Research* **5**, S2019 (2010).
- Meo, F., M. Stejner, M. Salewski, H. Bindslev, T. Eich, V. Furtula, S. B. Korsholm, F. Leuterer, F. Leipold, P. K. Michelsen, D. Moseev, S. K. Nielsen, B. Reiter, J. Stober, D. Wagner, P. Woskov and ASDEX Upgrade Team: First results and analysis of collective Thomson scattering (CTS) fast ion distribution measurements on ASDEX Upgrade. *Journal of Physics: Conference Series* **227**, 012010 (2010).
- Merloni, A., A. Bongiorno, M. Bolzonella, M. Brusa, F. Civano, A. Comastri, M. Elvis, F. Fiore, R. Gilli, H. Hao, K. Jahnke, A. M. Koekemoer, E. Lusso, V. Mainieri, M. Mignoli, T. Miyaji, A. Renzini, M. Salvato, J. Silverman, J. Trump, C. Vignali, G. Zamorani, P. Capak, S. J. Lilly, D. Sanders, Y. Taniguchi, S. Bardelli, C. M. Carollo, K. Caputi, T. Contini, G. Coppa, O. Cucciati, S. de la Torre, L. de Ravel, P. Franzetti, B. Garilli, G. Hasinger, C. Impey, A. Iovino, K. Iwasawa, P. Kampczyk, J.-P. Kneib, C. Knobel, K. Kovac, F. Lamareille, J.-F. Le Borgne, V. Le Brun, O. Le Fèvre, C. Maier, R. Pello, Y. Peng, E. Perez Montero, E. Ricciardelli, M. Scodeggio, M. Tanaka, L. A. M. Tasca, L. Tresse, D. Vergani and E. Zucca: On the cosmic evolution of the scaling relations between black holes and their host galaxies: Broad-line AGN in the zCOSMOS survey. *The Astrophysical Journal* **708**, 137-157 (2010).
- Merz, F. and F. Jenko: Nonlinear interplay of TEM and ITG turbulence and its effect on transport. *Nuclear Fusion* **50**, 054005 (2010).

- Michel, G.: Numerical Modeling of Millimeter-Wave Transmission Lines. *IEEE Transactions on Plasma Science* **38**, 1375-1384 (2010).
- Milch, I.: Die frühen Jahre – Pinche und Co. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 6-11 (2010).
- Mlynek, A., G. Schramm, H. Eixenberger, G. Sips, K. McCormick, M. Zilker, K. Behler, J. Eheberger and ASDEX Upgrade Team: Design of a digital multiradian phase detector and its application in fusion plasma interferometry. *Review of Scientific Instruments* **81**, 033507 (2010).
- Moshkunov, K. A., K. Schmid, M. Mayer, V. A. Kurnaev and Y. Gasparyan: Air exposure and sample storage time influence on hydrogen release from tungsten. *Journal of Nuclear Materials* **404**, 174-177 (2010).
- Mucke, M., M. Braune, S. Barth, M. Förstel, T. Lischke, V. Ulrich, T. Arion, A. M. Bradshaw, U. Becker and U. Hergenbahn: A hitherto unrecognized source of low energy electrons in water. *Nature Physics* **6**, 143-146 (2010).
- Müller, H. W., J. Adamek, J. Horacek, C. Ionita, F. Mehlmann, V. Rohde and ASDEX Upgrade Team: Towards Fast Measurement of the Electron Temperature in the SOL of ASDEX Upgrade Using Swept Langmuir Probes. *Contributions to Plasma Physics* **50**, 847-853 (2010).
- Müller, W.-C. and R. Grappin: Nonlinear cascades and spatial structure of magnetohydrodynamic turbulence. *Relaxation Dynamics in Laboratory and Astrophysical Plasmas*. (Eds.) P. H. Diamond, X. Garbet, P. Ghendrih, Y. Sarazin. *Biennial Reviews of the Theory of Magnetized Plasmas* **1**. World Scientific, Singapore, 187-212 (2010).
- Murari, A., J. Vega, D. Mazon, G. A. Ratta, J. Svensson, S. Palazzo, G. Vagliasindi, P. Arena, C. Boulbe, B. Faugeras, L. Fortuna, D. Moreau and JET-EFDA Contributors: Innovative signal processing and data analysis methods on JET for control in the perspective of next-step devices. *Nuclear Fusion* **50**, 055005 (2010).
- Murari, A., J. Vega, D. Mazon, G. A. Ratta, J. Svensson, G. Vagliasindi, J. Blum, C. Boulbe, B. Faugeras and JET-EFDA Contributors: New information processing methods for control on JET. *Fusion Engineering and Design* **85**, 428-432 (2010).
- Mynick, H., N. Pomphrey and P. Xanthopoulos: Optimizing Stellarators for Turbulent Transport. *Physical Review Letters* **105**, 095004 (2010).
- Nabais, F., D. Borba, M. Garcia-Munoz, T. Johnson, V. G. Kiptily, M. Reich, M. F. F. Nave, S. D. Pinches, S. E. Sharapov and JET-EFDA Contributors: Impact of strongly driven fishbones and Alfvén Eigenmodes on fast ion losses. *Nuclear Fusion* **50**, 115006 (2010).
- Naujoks, D.: General Criteria and Operation Limits of a Steady-State Fusion Reactor with Respect to Plasma-Material Interaction. *Plasma Interaction in Controlled Fusion Devices: 3<sup>rd</sup> ITER International Summer School*. (Ed.) S. Benkadda. *AIP Conference Proceedings* **1237**. American Institute of Physics, Melville, NY, 3-17 (2010).
- Neumaier, P., A. Bergmaier, W. Eckstein, R. Fischer, H. Hofsäss, H. U. Jäger, H. Kröger, C. Ronning and G. Dollinger: Bimodal range distributions of low-energy carbon ions in tetrahedral amorphous carbon. *Europhysics Letters* **90**, 46002 (2010).
- Neu, R.: Experience with High-Z Plasma Facing Materials and Extrapolation to Future Devices. *IEEE Transactions on Plasma Science* **38**, 453-460 (2010).
- Neu, R.: Benefits and Challenges of the Use of High-Z Plasma Facing Materials in Fusion Devices. *Plasma Interaction in Controlled Fusion Devices: 3<sup>rd</sup> ITER International Summer School*. (Ed.) S. Benkadda. *AIP Conference Proceedings* **1237**. American Institute of Physics, Melville, NY, 62-77 (2010).
- Nishijima, D., R. P. Doerner, D. G. Whyte, M. J. Baldwin and T. Schwarz-Selinger: Measurements of Mo I S/XB values. *Journal of Physics B: Atomic, Molecular and Optical Physics* **43**, 225701 (2010).
- Nold, B., G. D. Conway, T. Happel, H. W. Müller, M. Ramisch, V. Rohde, U. Stroth and ASDEX Upgrade Team: Generation of blobs and holes in the edge of the ASDEX Upgrade tokamak. *Plasma Physics and Controlled Fusion* **52**, 065005 (2010).
- Nührenberg, C., M. I. Mikhailov, J. Nührenberg and V. D. Shafranov: Quasi-helical symmetry at finite aspect ratio. *Plasma Physics Reports* **36**, 558-562 (2010).
- Nührenberg, J.: Development of quasi-isodynamic stellarators (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124003 (2010).
- Nührenberg, J.: Der optimierte Stellarator. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 18-21 (2010).



*Oberkofler, M. and Ch. Linsmeier:* Properties of nitrogen-implanted beryllium and its interaction with energetic deuterium. *Nuclear Fusion* **50**, 125001 (2010).

*Oehrlein, G. S., T. Schwarz-Selinger, K. Schmid, M. Schlüter and W. Jacob:* Stages in the Interaction of Deuterium Atoms with Amorphous Hydrogenated Carbon Films: Isotope Exchange, Soft-Layer Formation and Steady-State Erosion. *Journal of Applied Physics* **108**, 043307 (2010).

*Oesch, P. A., C. M. Carollo, R. Feldmann, O. Hahn, S. J. Lilly, M. T. Sargent, C. Scarlata, M. C. Aller, H. Aussel, M. Bolzonella, T. Bschorr, K. Bundy, P. Capak, O. Ilbert, J.-P. Kneib, A. M. Koekemoer, K. Kovac, A. Leauthaud, E. Le Floch, R. Massey, H. J. McCracken, L. Pozzetti, A. Renzini, J. Rhodes, M. Salvato, D. B. Sanders, N. Scoville, K. Sheth, Y. Taniguchi and D. Thompson:* The Buildup of the Hubble Sequence in the Cosmos Field. *The Astrophysical Journal Letters* **714**, L47-L51 (2010).

*Otte, M., H. P. Laqua, E. Chlechowicz, P. Drewelow, M. Glaubitz, S. Marsen, E. Müller, Y. Podoba, J. Schacht, T. Stange, F. Steffen, F. Wagner, R. Wolf and D. Zhang:* Overview of Experimental Results from the WEGA Stellarator. *Contributions to Plasma Physics* **50**, 780-784 (2010).

*Otte, M., H. P. Laqua, E. Chlechowicz, M. Glaubitz, S. Marsen, Y. Podoba, T. Stange, F. Wagner, R. C. Wolf and D. Zhang:* Electron Bernstein Waves at the WEGA Stellarator – Heating and Emission. *Plasma and Fusion Research* **5**, S2011 (2010).

*Otte, M., H. P. Laqua, S. Marsen, Y. Podoba, T. Stange, D. Zhang and F. Wagner:* Overdense Plasma Operation in WEGA Stellarator. *Contributions to Plasma Physics* **50**, 785-789 (2010).

*Pace, D. C., R. K. Fisher, M. Garcia-Munoz, D. S. Darrow, W. W. Heidbrink, C. M. Muscatello, R. Nazikian, M. A. Van Zeeland and Y. B. Zhu:* Modeling the response of a fast ion loss detector using orbit tracing techniques in a neutral beam prompt-loss study on the DIII-D tokamak. *Review of Scientific Instruments* **81**, 10D305 (2010).

*Pankratov, I. M., A. A. Beletskii, V. L. Berezhnyj, P. Y. Burchenko, V. V. Chechkin, L. L. Grigor'eva, D. Hartmann, R. Koch, V. G. Kononov, A. Y. Kulaga, G. G. Lesnyakov, A. V. Lozin, A. I. Lyssoivan, S. M. Maznichenko, Y. K. Mironov, V. Y. Moissenko, V. K. Pashnev, A. A. Petruchenya, A. V. Prokopenko, V. S. Romanov, A. N. Shapoval, A. F. Shtan, D. A. Sitnikov, A. L. Skibenko, A. S. Slavyj, S. L. Solodovchenko, E. I. Sorokovoy, Y. I. Sorokovoy, O. M. Shvets, Y. S. Stadnik, I. K. Tarasov, V. I. Tereshin, S. A. Tsybenko, N. V. Zamanov and Y. D. Volkov:* Behavior of RF Discharge Plasmas in the Uragan-3M and Uragan-2M Torsatrons. *Contributions to Plasma Physics* **50**, 520-528 (2010).

*Peng, Y., S. J. Lilly, K. Kovac, M. Bolzonella, L. Pozzetti, A. Renzini, G. Zamorani, O. Ilbert, C. Nobel, A. Iovino, C. Maier, O. Cucciati, L. Tasca, C. M. Carollo, J. Silverman, P. Kampeczyk, L. de Ravel, D. Sanders, N. Scoville, T. Contini, V. Mainieri, M. Scodeggio, J. P. Kneib, O. Le Fèvre, S. Bardelli, A. Bongiorno, K. Caputi, G. Coppia, S. de la Torre, P. Franzetti, B. Garilli, F. Lamareille, J. F. Le Borgne, V. Le Brun, M. Mignoli, E. Perez Montero, R. Pello, E. Ricciardelli, M. Tanaka, L. Tresse, D. Vergani, N. Welikala, E. Zucca, P. Oesch, U. Abbas, L. Barnes, R. Bordoloi, D. Bottini, A. Cappi, P. Cassata, A. Cimatti, M. Fumana, G. Hasinger, A. Koekemoer, A. Leauthaud, D. Maccagni, C. Marinoni, H. McCracken, P. Memeo, B. Meneux, P. Nair, C. Porciani, V. Presotto and R. Scaramella:* Mass and Environment as Drivers of Galaxy Evolution in SDSS and zCOSMOS and the Origin of the Schechter Function. *The Astrophysical Journal* **721**, 193-221 (2010).

*Perez von Thun, C., A. Perona, T. Johnson, S. E. Sharapov, M. Reich, V. G. Kiptily, M. Cecconello, A. Salmi, V. Ya Goloborod'ko, S. D. Pinches, M. Garcia-Munoz, D. Darrow, M. Brix, I. Voitsekhovitch and JET EFDA Contributors:* MeV-range fast ion losses induced by fishbones on JET. *Nuclear Fusion* **50**, 084009 (2010).

*Philipps, V., P. Mertens, G. F. Matthews, H. Maier and JET-EFDA Contributors:* Overview of the JET ITER-like wall project. *Fusion Engineering and Design* **85**, 1581-1586 (2010).

*Piconcelli, E., G. Lanzuisi, F. Fiore, C. Feruglio, C. Vignali, M. Salvato and C. Gruppioni:* Type 2 Quasars at the heart of dust-obscured galaxies (DOGs) at high z. *Proceedings of the International Conference on X-ray Astronomy 2009. Present Status, Multi-Wavelength Approach and Future Perspectives.* (Eds.) A. Comastri, L. Angelini, M. Cappi. *AIP Conference Proceedings* **1248**. American Institute of Physics, Melville, NY, 493-494 (2010).

*Pinkau, K.:* History of gamma-ray telescopes and astronomy. *400 Years of Astronomical Telescopes. A Review of History, Science and Technology.* (Eds.) B. R. Brandl, R. Stuik, J. K. Katgert-Merkelijn. Springer, New York, NY, 155-169 (2010).

*Pintsuk, G., J. Blumm, W. Hohenauer, R. C. Hula, T. Koppitz, S. Lindig, D. Pitzer, M. Rohde, P. Schoderböck, T. Schubert, F. Tietz and O. Wouters:* Interlaboratory Test on Thermophysical Properties of the ITER Grade Heat Sink Material Copper-Chromium-Zirconium. *International Journal of Thermophysics* **31**, 2147-2158 (2010).

*Podoba, Y., M. Otte, F. Wagner, L. Krupnik and A. Zhezhera:* Heavy ion beam probe coordinate mapping and calibration at WEGA stellarator. *Review of Scientific Instruments* **81**, 013505 (2010).

- Poli, E., A. Bottino, W. A. Hornsby, A. G. Peeters, T. Ribeiro, B. D. Scott and M. Siccino: Gyrokinetic and gyrofluid investigation of magnetic islands in tokamaks (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124021 (2010).
- Poli, F. M., P. T. Lang, S. E. Sharapov, B. Alper, H. R. Koslowski and JET-EFDA Contributors: Spectra of magnetic perturbations triggered by pellets in JET plasmas. *Nuclear Fusion* **50**, 025004 (2010).
- Predebon, I., C. Angioni and S. C. Guo: Gyrokinetic simulations of ion temperature gradient modes in the reversed field pinch. *Physics of Plasmas* **17**, 012304 (2010).
- Predehl, P., R. Andritschke, H. Böhringer, W. Bornemann, H. Bräuninger, H. Brunner, M. Brusa, W. Burkert, V. Burwitz, N. Cappelluti, E. Churazov, K. Dennerl, J. Eder, J. Elbs, M. Freyberg, P. Friedrich, M. Fürmetz, R. Gaida, O. Hälker, G. Hartner, G. Hasinger, S. Hermann, H. Huber, E. Kendziorra, A. von Kienlin, W. Kink, I. Kreykenbohm, G. Lamer, I. Lapchov, K. Lehmann, N. Meidinger, B. Mican, J. Mohr, M. Mühlegger, S. Müller, K. Nandra, M. Pavlinsky, E. Pfeffermann, T. Reiprich, J. Robrade, C. Rohé, A. Santangelo, G. Schächner, T. Schanz, C. Schmid, J. Schmitt, R. Schreib, F. Schrey, A. Schwoppe, M. Steinmetz, L. Strüder, R. Sunyaev, C. Tenzer, L. Tiedemann, M. Vongehr and J. Wilms: eROSITA on SRG. *Proceedings of the SPIE* **7732**, 77320U (2010).
- Predehl, P., H. Böhringer, H. Brunner, V. Burwitz, N. Cappelluti, E. Churazov, K. Dennerl, M. Freyberg, P. Friedrich, G. Hasinger, E. Kendziorra, I. Kreykenbohm, C. Schmid, J. Wilms, G. Lamer, N. Meidinger, M. Mühlegger, M. Pavlinsky, J. Robrade, A. Santangelo, J. Schmitt, A. Schwoppe, M. Steinmetz, L. Strüder, R. Sunyaev and C. Tenzer: eROSITA on SRG. *Proceedings of the International Conference on X-ray Astronomy 2009. Present Status, Multi-Wavelength Approach and Future Perspectives.* (Eds.) A. Comastri, L. Angelini, M. Cappi. *AIP Conference Proceedings* **1248**. American Institute of Physics, Melville, NY, 543-548 (2010).
- Pueschel, M. J., T. Dannert and F. Jenko: On the role of numerical dissipation in gyrokinetic Vlasov simulations of plasma microturbulence. *Computer Physics Communications* **181**, 1428-1437 (2010).
- Pueschel, M. J. and F. Jenko: Transport properties of finite- $\beta$  microturbulence. *Physics of Plasmas* **17**, 062307 (2010).
- Pütterich, T., R. Neu, R. Dux, A. D. Whiteford, M. G. O. Mullane, H. P. Summers and ASDEX Upgrade Team: Calculation and Experimental Test of the Cooling Factor of Tungsten. *Nuclear Fusion* **50**, 025012 (2010).
- Raffray, A. R., R. Nygren, D. G. Whyte, S. Abdel-Khalik, R. Doerner, F. Escourbiac, T. Evans, R. J. Goldston, D. T. Hoelzer, S. Konishi, P. Lorenzetto, M. Merola, R. Neu, P. Norajitra, R. A. Pitts, M. Rieth, M. Roedig, T. Rognlien, S. Suzuki, M. S. Tillack and C. Wong: High heat flux components – Readiness to proceed from near term fusion systems to power plants. *Fusion Engineering and Design* **85**, 93-108 (2010).
- Rahbarnia, K., S. Ullrich, K. Sauer, O. Grulke and T. Klinger: Alfvén wave dispersion behavior in single- and multicomponent plasmas. *Physics of Plasmas* **17**, 032102 (2010).
- Rai, A., A. Mutzke and R. Schneider: Modeling of chemical erosion of graphite due to hydrogen by inclusion of chemical reactions in SDTrimSP. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **268**, 2639-2648 (2010).
- Rathgeber, S. K., R. Fischer, S. Fietz, J. Hobirk, A. Kallenbach, H. Meister, T. Pütterich, F. Rytter, G. Tardini, E. Wolfrum and ASDEX Upgrade Team: Estimation of profiles of the effective ion charge at ASDEX Upgrade with Integrated Data Analysis. *Plasma Physics and Controlled Fusion* **52**, 095008 (2010).
- Rau, A., G. H. A. Roelofs, P. J. Groot, T. R. Marsh, G. Nelemans, D. Steeghs, M. Salvato and M. M. Kasliwal: A Census of AM SVn Stars: Three New Candidates and One Confirmed 48.3-Minute Binary. *The Astrophysical Journal* **708**, 456-461 (2010).
- Raupp, G., K. Behler, H. Eixenberger, M. Fitzek, H. Kollotzek, A. Lohs, K. Lüddecke, P. Müller, R. Merkel, G. Neu, J. Schacht, G. Schramm, W. Treutterer, D. Zasche, T. Zehetbauer and ASDEX Upgrade Team: Time accuracy requirements for fusion experiments: A case study at ASDEX Upgrade. *Fusion Engineering and Design* **85**, 356-359 (2010).
- Reich, M., K. Behler, R. Drube, L. Giannone, A. Kallenbach, A. Mlynek, J. Stober, W. Treutterer and ASDEX Upgrade Team: Real-Time Diagnostics and their Applications at ASDEX Upgrade. *Fusion Science and Technology* **58**, 727-732 (2010).
- Reimer, R., A. Dinklage, J. Geiger, J. Hobirk, M. Reich, R. Wolf, ASDEX Upgrade Team and Wendelstein 7-X Team: Motional Stark Effect Spectra Simulations of Wendelstein 7-X. *Contributions to Plasma Physics* **50**, 731-735 (2010).
- Ribeiro, T. T. and B. D. Scott: Conformal Tokamak Geometry for Turbulence Computations. *IEEE Transactions on Plasma Science* **38**, 2159-2168 (2010).
- Riemann, H., T. Bluhm, P. Heimann, C. Hennig, G. Kühner, H. Kroiss, H. Laqua, M. Lewerentz, J. Maier, J. Schacht,

- A. Spring, A. Werner and M. Zilker:* Experiment planning using the high level parameter concept. *Fusion Engineering and Design* **85**, 478-781 (2010).
- Riße, K., T. Rummel, G. Ehrke and M. Köppen:* Design, Tests, and Repair Procedures for the Electrical Insulation of the Superconducting W7-X Magnets. *IEEE Transactions on Applied Superconductivity* **20**, 447-450 (2010).
- Rodríguez-Pascual, M., B. D. Scott, T. T. Ribeiro, F. C. Magaña and R. M. García:* gGEM: A Gyrofluid model to be used on distributed platforms. *IEEE Transactions on Plasma Science* **38**, 2111-2118 (2010).
- Roman, J. E., M. Kammerer, F. Merz and F. Jenko:* Fast eigenvalue calculations in a massively parallel plasma turbulence code. *Parallel Computing* **36**, 339-358 (2010).
- Roth, J.:* Wandprobleme. Max-Planck-Institut für Plasma-physik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 40-43 (2010).
- Rovilos, E., V. Burwitz, N. Bouché, S. Berta, D. Lutz, R. Genzel, G. Szokoly, G. Hasinger, M. Salvato and E. Egami:* The Lockman Hole Multi-Wavelength Survey. *Proceedings of the 9<sup>th</sup> International Conference of the Hellenic Astronomical Society*. (Eds.) K. Tsinganos, D. Hatzidimitriou, T. Matsakos. *ASP Conference Series* **424**. Astronomical Society of the Pacific, Orem, UT, 271-276 (2010).
- Rovilos, E., I. Georgantopoulos, A. Akylas and S. Fotopoulou:* Optically faint X-ray sources in the Chandra deep field North: Spitzer constraints. *Astronomy & Astrophysics* **522**, A11 (2010).
- Rozhansky, V., E. Kaveeva, P. Molchanov, I. Veselova, S. Vosboynikov, D. Coster, A. Kirk, S. Lisgo and E. Nardon:* Modification of the edge transport barrier by resonant magnetic perturbations. *Nuclear Fusion* **50**, 034005 (2010).
- Rozhansky, V., I. Veselova, E. Kaveeva, S. Voskoboynikov and D. Coster:* Towards Modeling of ITER H-mode. *Contributions to Plasma Physics* **50**, 338-342 (2010).
- Ryter, F., R. Dux, P. Mantica and T. Tala:* Perturbative studies of transport phenomena in fusion devices (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124043 (2010).
- Salewski, M., F. Meo, M. Stejner, O. Asunta, H. Bindslev, V. Furtula, S. B. Korsholm, T. Kurki-Suonio, F. Leipold, F. Leuterer, P. K. Michelsen, D. Moseev, S. K. Nielsen, J. Stober, G. Tardini, D. Wagner, P. Woskov and ASDEX Upgrade Team:* Comparison of fast ion collective Thomson scattering measurements at ASDEX Upgrade with numerical simulations. *Nuclear Fusion* **50**, 035012 (2010).
- Sanchez, E., R. Kleiber, R. Hatzky, A. Soba, X. Saez, F. Castejon and J. Cela:* Linear and Nonlinear Simulations Using the EUTERPE Gyrokinetic Code. *IEEE Transactions on Plasma Science* **38**, 2119-2128 (2010).
- Santos, J., L. Guimaraes, M. Manso and ASDEX Upgrade Team:* Real-time reflectometry measurement validation in H-mode regimes for plasma position control. *Review of Scientific Instruments* **81**, 10D926 (2010).
- Sargent, M. T., E. Schinnerer, E. Murphy, H. Aussel, E. Le Floch, D. T. Frayer, A. Martinez-Sansigre, P. Oesch, M. Salvato, V. Smolic, G. Zamorani, M. Brusa, N. Cappelluti, C. L. Carilli, C. M. Carollo, O. Ilbert, J. Kartaltepe, A. M. Koekemoer, S. J. Lilly, D. B. Sanders and N. Z. Scoville:* The VLA-COSMOS perspective on the infrared-radio relation I. New constraints on selection biases and the non-evolution of the infrared/radio properties of star-forming and active galactic nucleus galaxies at intermediate and high redshift. *The Astrophysical Journal. Supplement Series* **186**, 341-377 (2010).
- Sargent, M. T., E. Schinnerer, E. Murphy, C. L. Carilli, G. Helou, H. Aussel, E. Le Floch, D. T. Frayer, O. Ilbert, P. Oesch, M. Salvato, V. Smolic, J. Kartaltepe and D. B. Sanders:* No evolution in the IR-Radio relation for IR-luminous galaxies at  $z < 2$  in the COSMOS field. *The Astrophysical Journal Letters* **714**, L190-L195 (2010).
- Sassenberg, K., M. Maraschek, P. J. McCarthy, W. Bobkov, M. Garcia-Munoz, N. Hicks, V. Igochine, P. Lauber, S. Günter and ASDEX Upgrade Team:* ICRH beatwave excited toroidicity induced Alfvén eigenmodes in ASDEX Upgrade. *Nuclear Fusion* **50**, 052003 (2010).
- Sauter, O., M. A. Henderson, G. Ramponi, H. Zohm and C. Zucca:* On the requirements to control neoclassical tearing modes in burning plasmas. *Plasma Physics and Controlled Fusion* **52**, 025002 (2010).
- Scarabosio, A., P. Sauter and G. Haas:* Modelling and optimisation of ionisation gauges for magnetic nuclear devices. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **623**, 667-671 (2010).
- Schacht, J., H. Laqua, M. Lewerentz and A. Spring:* A New Concept for Experiment Program Planning for the Fusion Experiment Wendelstein 7-X. *IEEE Transactions on Nuclear Science* **57**, 673-678 (2010).



- Schauer, E., H. Wobig, K. Egorov, V. Bykov and M. Köppen: Extrapolation of the W7-X Magnet System to Reactor Size. *Contributions to Plasma Physics* **50**, 750-755 (2010).
- Schlickeiser, R. and F. Jenko: Cosmic ray transport in non-uniform magnetic fields: consequences of gradient and curvature drifts. *Journal of Plasma Physics* **76**, 317-327 (2010).
- Schmid, K., A. Manhard, Ch. Linsmeier, A. Wiltner, T. Schwarz-Selinger, W. Jacob and S. Mändl: Interaction of nitrogen plasmas with tungsten. *Nuclear Fusion* **50**, 025006 (2010).
- Schmid, K., M. Mayer, C. Adelhelm, M. Balden, S. Lindig and ASDEX Upgrade Team: Impact of gyro-motion and sheath acceleration on the flux distribution on rough surfaces. *Nuclear Fusion* **50**, 105004 (2010).
- Schmid, K. and J. Roth: Erosion processes due to energetic particle-surface interaction. *Plasma Interaction in Controlled Fusion Devices: 3<sup>rd</sup> ITER International Summer School*. (Ed.) S. Benkadda. AIP Conference Proceedings **1237**. American Institute of Physics, Melville, NY, 18-31 (2010).
- Schrittwieser, R., M. Laux, K.-H. Spatschek, M. Bonitz, T. Klinger, U. Stroth, D. Naujoks and M. Dewitz (Eds.): 8<sup>th</sup> International Workshop on Electric Probes in Magnetized Plasmas (IWEP2009). *Contributions to Plasma Physics* **50**, 9. WILEY-VCH, Weinheim, 791-921 (2010).
- Schrittwieser, R. W., C. Ionita, N. Vianello, H. W. Müller, F. Mehlmann, M. Zuin, V. Naulin, J. J. Rasmussen, V. Rohde, R. Cavazzana, C. Lupu, M. Maraschek, C. Maszl and ASDEX Upgrade Team: A Probe Head for Simultaneous Measurements of Electrostatic and Magnetic Fluctuations in ASDEX Upgrade Edge Plasma. *Contributions to Plasma Physics* **50**, 860-865 (2010).
- Schulz, M., A. C. Laforge, K. N. Egodapitiya, J. S. Alexander, A. Hasan, M. F. Ciappina, A. C. Roy, R. Dey, A. Samolov and A. L. Godunov: Doubly differential spectra of scattered protons in ionization of atomic hydrogen. *Physical Review A* **81**, 052705 (2010).
- Scott, B.: Derivation via free energy conservation constraints of gyrofluid equations with finite-gyroradius electromagnetic nonlinearities. *Physics of Plasmas* **17**, 102306 (2010).
- Scott, B. D., A. Kendl and T. Ribeiro: Nonlinear Dynamics in the Tokamak Edge. *Contributions to Plasma Physics* **50**, 228-241 (2010).
- Scott, B. and J. Smirnov: Energetic consistency and momentum conservation in the gyrokinetic description of tokamak plasmas. *Physics of Plasmas* **17**, 112302 (2010).
- Shao, L., D. Lutz, R. Nordon, R. Maiolino, D. M. Alexander, B. Altieri, P. Andreani, H. Aussel, F. E. Bauer, S. Berta, A. Bongiovanni, W. N. Brandt, M. Brusa, A. Cava, J. Cepa, A. Cimatti, E. Daddi, H. Dominguez-Sanchez, D. Elbaz, N. M. Förster Schreiber, N. Geis, R. Genzel, A. Grazian, C. Gruppioni, G. Magdis, B. Magnelli, V. Mainieri, A. M. Pérez García, A. Poglitsch, P. Popesso, F. Pozzi, L. Riguccini, G. Rodighiero, E. Rovilos, A. Saintonge, M. Salvato, M. Sanchez Portal, P. Santini, E. Sturm, L. J. Tacconi, I. Valtchanov, M. Wetzstein and E. Wierprecht: Star formation in AGN hosts in GOODS-N. *Astronomy & Astrophysics* **518**, L26 (2010).
- Siccinio, M., E. Poli, W. A. Hornsby and A. G. Peeters: Gyrokinetic investigation of magnetic islands in tokamaks. *Journal of Physics: Conference Series* **260**, 1, 012019 (2010).
- Silverman, J. D., V. Mainieri, M. Salvato, G. Hasinger, J. Bergeron, P. Capak, G. Szokoly, A. Finoguenov, R. Gilli, P. Rosati, P. Tozzi, C. Vignali, D. M. Alexander, W. N. Brandt, B. D. Lehmer, B. Luo, D. Rafferty, Y. Q. Xue, I. Balestra, F. E. Bauer, M. Brusa, A. Comastri, J. Kartaltepe, A. M. Koekemoer, T. Miyaji, D. P. Schneider, E. Treister, L. Wisotski and M. Schramm: The Extended Chandra Deep Field-South Survey: Optical Spectroscopy of Faint X-ray Sources with the VLT and Keck. *The Astrophysical Journal. Supplement Series* **191**, 124-142 (2010).
- Simakov, A. N., L. Chacon and A. Zocco: Fundamental role of ion viscosity on fast magnetic reconnection in large-guide-fluid regimes. *Physics of Plasmas* **17**, 060701 (2010).
- Solano, E. R., P. J. Lomas, B. Alper, G. S. Xu, Y. Andrew, G. Arnoux, A. Boboc, L. Barrera, P. Belo, M. N. A. Beurskens, M. Brix, K. Crombe, E. de la Luna, S. Devaux, T. Eich, S. Gerasimov, C. Giroud, D. Harting, D. Howell, A. Huber, G. Kocsis, A. Korotkov, A. Lopez-Fraguas, M. F. F. Nave, E. Rachlew, F. Rimini, S. Saarelma, A. Sirinelli, S. D. Pinches, H. Thomsen, L. Zabeo and D. Zarzoso: Observation of Confined Current Ribbon in JET Plasmas. *Physical Review Letters* **104**, 185003 (2010).
- Speth, E., J.-M. Noterdaeme, V. Erckmann, H. Laqua and F. Leuterer: Neutralteilchen- und Hochfrequenz-Heizungen. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 34-39 (2010).
- Spong, D. A., B. N. Breizmann, D. L. Brower, E. D'Azevedao, C. B. Deng, A. Könies, Y. Todo and K. Toi: Energetic-Particle-Driven Instabilities in General Toroidal Configurations. *Contributions to Plasma Physics* **50**, 708-712 (2010).
- Spring, A., M. Lewerentz, T. Bluhm, P. Heimann, C. Hennig, G. Kühner, H. Kroiss, H. Laqua, J. Maier, H. Riemann, J. Schacht,



- A. Werner and M. Zilker*: A first W7-X experiment program editor. *Fusion Engineering and Design* **85**, 525-528 (2010).
- Stoschus, H., O. Schmitz, H. Frerichs, M. W. Jakubowski, B. Unterberg, S. S. Abdullaev, M. Clever, J. W. Coenen, U. Kruezi, D. Schega and U. Samm*: Rotation dependence of a phase delay between plasma edge electron density and temperature fields due to a fast rotating, resonant magnetic perturbation field. *Physics of Plasmas* **17**, 060702 (2010).
- Strand, P. I., R. Coelho, D. Coster, L.-G. Eriksson, F. Imbeaux, B. Guillerminet and the Euforia Project*: Simulation and high performance computing – Building a predictive capability for fusion. *Fusion Engineering and Design* **85**, 383-387 (2010).
- Strumberger, E., S. Günter, P. Merkel, E. Schwarz and C. Tichmann*: Self-consistent three-dimensional computations of non-axisymmetric ITER equilibria. *Nuclear Fusion* **50**, 025008 (2010).
- Sturm, R., F. Haberl, B. Aschenbach and G. Hasinger*: High resolution X-ray spectroscopy of SN 1987 A: monitoring with XMM-Newton. *Astronomy & Astrophysics* **515**, A5 (2010).
- Sugiyama, K., M. Mayer, V. Rohde, M. Balden, T. Dürbeck, A. Herrmann, S. Lindig, A. Wiltner, H. W. Müller, R. Neu and ASDEX Upgrade Team*: Deuterium inventory in the full-tungsten divertor of ASDEX Upgrade. *Nuclear Fusion* **50**, 035001 (2010).
- Sugiyama, K., Y. Sakawa, T. Tanabe, D. Watanabe, T. Shibahara and K. Masaki*: Removal of the deposition on JT-60 tile by nano-sec pulsed-laser irradiation. *Journal of Nuclear Materials* **405**, 70-73 (2010).
- Suzuki, Y., J. Geiger, C. Wiegmann, Y. Liang and N. Ohyaibu*: Three-Dimensional Effects on Stochasticity in Non-Axisymmetric Tori. *Contributions to Plasma Physics* **50**, 576-581 (2010).
- Tanaka, M., Y. Kawahata, S. Tokuzawa, S. Akiyama, N. Yokoyama, T. Shoji, M. Michael, H. Vyacheslavov, T. Murakami, N. Wakasa, M. Mishchenko, I. Muraoka, K. Okajima, A. Takanaga and LHD Experiment Group*: Particle Transport of LHD. *Fusion Science and Technology* **58**, 70-90 (2010).
- Terranova, D., D. Bonfiglio, A. H. Boozer, A. W. Cooper, M. Gobbin, S. P. Hirshman, R. Lorenzini, L. Marrelli, E. Martines, B. Momo, N. Pomphrey, I. Predebon, R. Sanchez, G. Spizzo, M. Agostini, A. Alfieri, L. Apolloni, F. Auremma, M. Baruzzo, T. Bolzonella, F. Bonomo, M. Brombin, A. Canton, S. Cappello, L. Carraro, R. Cavazzana, S. Dal Bello, R. Delogu, G. De Masi, M. Drevlak, A. Fassina, A. Ferro, P. Franz, E. Gaio, E. Gazza, L. Giudicotti, L. Grando, S. C. Guo, P. Innocente, D. López-Bruna, G. Manduchi, G. Marchiori, P. Martin, S. Martini, S. Menmuir, S. Munaretto, L. Novello, R. Paccagnella, R. Pasqualotto, G. V. Pereverzev, R. Piovan, P. Piovesan, L. Piron, M. E. Puiatti, M. Recchia, F. Sattin, P. Scarin, G. Serianni, A. Soppelsa, S. Spagnolo, M. Spolaore, C. Taliercio, M. Valisa, N. Vianello, Z. Wang, A. Zamengo, B. Zaniol, L. Zanutto, P. Zanca and M. Zuin*: A 3D approach to equilibrium, stability and transport studies in RFX-mod improved regimes (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124023 (2010).
- Throumoulopoulos, G. N. and H. Tasso*: Magnetohydrodynamic counter-rotating vortices and synergetic stabilizing effects of magnetic field and plasma flow. *Physics of Plasmas* **17**, 032508 (2010).
- Timko, H., F. Djurabekova, K. Nordlund, L. Costelle, K. Matyash, R. Schneider, A. Toerklep, G. Arnau-Izquierdo, A. Descoeudres, S. Calatroni, M. Taborrelli and W. Wuensch*: Mechanism of surface modification in the plasma-surface interaction in electrical arcs. *Physical Review B* **81**, 184109 (2010).
- Toi, K., M. Isotobe, M. Osakabe, F. Watanabe, K. Ogawa, S. Yamamoto, N. Nakajima, D. A. Spong, K. Ida, T. Ido, T. Ito, S. Morita, K. Nagaoka, K. Narihara, M. Nishiura, S. Ohdachi, S. Sakakibara, A. Shimizu, K. Tanaka, Y. Todo, T. Tokuzawa, A. Weller and LHD Experiment Group*: MHD Modes Destabilized by Energetic Ions on LHD. *Fusion Science and Technology* **58**, 186-193 (2010).
- Toi, K., F. Watanabe, S. Ohdachi, S. Morita, X. Gao, K. Narihara, S. Sakakibara, K. Tanaka, T. Tokuzawa, H. Urano, A. Weller, I. Yamada, L. Yan and LHD Experiment Group*: L-H Transition and Edge Transport Barrier Formation on LHD. *Fusion Science and Technology* **58**, 61-69 (2010).
- Told, D. and F. Jenko*: Applicability of different geometry approaches to simulations of turbulence in highly sheared magnetic fields. *Physics of Plasmas* **17**, 042302 (2010).
- Toma, M., X. Bonnin, K. Hoshino, A. Hatayama, R. Schneider and D. Coster*: First Steps Towards the Coupling of the IMPGYRO and SOLPS Codes to Analyze Tokamak Plasmas with Tungsten Impurities. *Contributions to Plasma Physics* **50**, 392-397 (2010).
- Treutterer, W., G. Neu, G. Raupp, T. Zehetbauer, D. Zasche, K. Lüddecke, R. Cole and ASDEX Upgrade Team*: Real-time signal communication between diagnostic and control in ASDEX Upgrade. *Fusion Engineering and Design* **85**, 466-469 (2010).
- Urso, L., R. Fischer, A. Isayama, ASDEX Upgrade Team and JT-60 Team*: Application of the Bayesian analysis to the modified Rutherford equation for NTM stabilization. *Plasma Physics and Controlled Fusion* **52**, 055012 (2010).

- Urso, L., H. Zohm, A. Isayama, M. Maraschek, E. Poli, ASDEX Upgrade Team and JT-60 Team: ASDEX Upgrade – JT-60U comparison and ECRH power requirements for NTM stabilization in ITER. *Nuclear Fusion* **50**, 025010 (2010).
- Varela, P., A. Silva, F. da Silva, S. da Graca, M. E. Manso, G. D. Conway and ASDEX Upgrade Team: Improved time-frequency analysis of ASDEX Upgrade reflectometry data using the reassigned spectrogram technique. *Review of Scientific Instruments* **81**, 10D925 (2010).
- Verdoolaege, G., R. Fischer and G. Van Oost: Integrated analysis and consistency measurement of bremsstrahlung and charge exchange spectroscopy data for the determination of the ion effective charge. *Review of Scientific Instruments* **81**, 10D733 (2010).
- Verdoolaege, G., R. Fischer and G. Van Oost: Potential of a Bayesian Integrated Determination of the Ion Effective Charge via Bremsstrahlung and Charge Exchange Spectroscopy in Tokamak Plasmas. *IEEE Transactions on Plasma Science* **38**, 3168-3196 (2010).
- Vernay, T., S. Brunner, L. Villard, B. F. McMillan, O. Sauter, S. Jolliet, T. M. Tran and A. Bottino: Global collisional gyrokinetic simulations of ITG microturbulence starting from a neoclassical equilibrium. *Journal of Physics: Conference Series* **260**, 1, 012021 (2010).
- Vernay, T., S. Brunner, L. Villard, B. McMillan, S. Jolliet, T. M. Tran, A. Bottino and J. P. Graves: Neoclassical equilibria as starting point for global gyrokinetic microturbulence simulations. *Physics of Plasmas* **17**, 122301 (2010).
- Versloot, T. W., P. C. de Vries, C. Giroud, M. D. Hua, M. N. A. Beurskens, M. Brix, T. Eich, E. de la Luna, T. Tala, V. Naulin, K. D. Zastrow and JET-EFDA Contributors: Effect of ELMs on rotation and momentum confinement in H-mode discharges in JET. *Plasma Physics and Controlled Fusion* **52**, 045014 (2010).
- Villard, L., A. Bottino, S. Brunner, A. Casati, J. Chowdhury, T. Dannert, R. Ganesh, X. Garbet, T. G'rler, V. Grandgirard, R. Hatzky, Y. Idomura, F. Jenko, S. Jolliet, S. Khosh Aghdam, X. Lapillonne, G. Latu, B. F. McMillan, F. Merz, Y. Sarazin, T. M. Tran and T. Vernay: Gyrokinetic simulations of turbulent transport: size scaling and chaotic behaviour (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124038 (2010).
- Voitsekhovitch, I., A. C. C. Sips, B. Alper, M. Beurskens, I. Coffey, J. Conboy, T. Gerbuad, C. Giroud, T. Johnson, F. Köchl, E. de la Luna, D. C. McDonald, I. Pavlenko, G. V. Pereverzev, S. Popovichev, A. N. Saveliev, G. Sergienko, S. Sharapov, M. Stamp and JET-EFDA Contributors: Modelling of the JET current ramp-up experiments and projection to ITER. *Plasma Physics and Controlled Fusion* **52**, 105011 (2010).
- Von Toussaint, U., T. Schwarz-Selinger, M. Mayer and S. Gori: Optimizing NRA depth profiling using Bayesian experimental design. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **268**, 2115-2118 (2010).
- Wagner, D., D. Schmid-Lorch, J. Stober, H. Höhnle, F. Leuterer, E. Poli, F. Monaco, M. Münich, H. Schütz and ASDEX Upgrade Team: Feed Forward Polarization Control during ECRH discharges at ASDEX Upgrade. *Fusion Science and Technology* **58**, 658-665 (2010).
- Wagner, F., A. Becoulet, R. V. Budny, V. Erckmann, D. Farina, G. Giruzzi, Y. Kamada, A. Kaye, F. Koechl, K. Lackner, N. Marushchenko, M. Murakami, T. Oikawa, V. Parail, J. M. Park, G. Ramponi, O. Sauter, D. Stork, P. R. Thomas, Q. M. Tran, D. Ward, H. Zohm and C. Zucca: On the heating mix of ITER (invited paper). *Plasma Physics and Controlled Fusion* **52**, 124044 (2010).
- Wagner, F. and H. Zohm: Pulsator, ASDEX und ASDEX Upgrade. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 22-27 (2010).
- Wakasa, A., S. Murakami, A. Fukuyama, C. D. Beidler, H. Maaßberg, M. Yokoyama and M. Sato: Development of the Neoclassical Transport Module for the Integrated Simulation Code in Helical Plasmas. *Contributions to Plasma Physics* **50**, 582-585 (2010).
- Weinzettl, V., D. I. Naydenkova, D. Sestak, J. Vlcek, J. Mlynar, R. Melich, D. Jares, J. Malot, D. Sarychev and V. Igochine: Design of multi-range tomographic system for transport studies in tokamak plasmas. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **623**, 806-808 (2010).
- Weller, A.: Diagnostics for magnetic confinement fusion research. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **623**, 801-805 (2010).
- Werner, A., J. Svensson, G. K'hner, T. Bluhm, P. Heimann, S. Jakob, C. Henning, H. Kroiss, H. Laqua, M. Lewerentz, H. Riemann, J. Schacht, A. Spring, M. Zilker and J. Maier: Scientific component framework for W7-X using service oriented GRID middleware. *Fusion Engineering and Design* **85**, 394-398 (2010).

- Wethekam, S., H. Zettergren, Ch. Linsmeier, H. Cederquist and H. Winter: Resonant electron capture by C60 ions at a metal surface with projected band gap. *Physical Review B* **81**, 121416(R) (2010).
- Wiese, R., V. Sushkov, H. Kersten, V. R. Ikkurthi, R. Schneider and R. Hippler: Behavior of a porous particle in a radiofrequency plasma under pulsed argon ion beam bombardment. *New Journal of Physics* **12**, 033036 (2010).  
<http://iopscience.iop.org/1367-2630/12/3/033036/>
- Windisch, T., K. Rahbarnia, O. Grulke and T. Klinger: Study of a scalable large-area radio-frequency helicon plasma source. *Plasma Sources Science and Technology* **19**, 055002 (2010).
- Wolf, A., H. B. Pedersen, L. Lammich, B. Jordon-Thaden, S. Altevogt, C. Domesle, U. Hergenbahn, M. Förstel and O. Heber: Soft-x-ray fragmentation studies of molecular ions. *Journal of Physics B: Atomic, Molecular and Optical Physics* **43**, 194007 (2010).
- Wolf, R. C., C. D. Beidler, R. Burhenn, J. Geiger, M. Hirsch, J. Kießlinger, H. Maaßberg, A. Weller, A. Werner and Wendelstein 7-X Team: From Wendelstein 7-X to a Stellarator Reactor. *Plasma and Fusion Research* **5**, S1011 (2010).
- Wright, G. M., M. Mayer, K. Ertl, G. de Saint-Aubin and J. Rapp: Hydrogenic retention in irradiated tungsten exposed to high-flux plasma. *Nuclear Fusion* **50**, 075006 (2010).
- Xuereb, A., M. Groth, K. Krieger, O. Asunta, T. Kurki-Suonio, J. Likonen, D. P. Coster and ASDEX Upgrade Team: DIVIMP-B2-EIRENE modelling of  $^{13}\text{C}$  migration and deposition in ASDEX-Upgrade L-mode plasmas. *Journal of Nuclear Materials* **396**, 228-233 (2010).
- Yakovenko, Y. V., Y. I. Kolesnichenko, V. V. Lutsenko, R. B. White and A. Werner: Mode coupling in Alfvén instabilities. *Nuclear Fusion* **50**, 084015 (2010).
- Yang, J., S. Zhu, Q. Yu and G. Zhuang: Study on the change of electron temperature inside magnetic island caused by localized radio frequency heating. *Physics of Plasmas* **17**, 052309 (2010).
- Ye, M., M. Laux, S. Lindig, R. Laube and H. Greuner: Developments of Divertor Target-Imbedded Langmuir Probes for W7-X. *Contributions to Plasma Physics* **50**, 830-835 (2010).
- Yu, Q.: Linear and nonlinear stability of drift-tearing mode. *Nuclear Fusion* **50**, 025014 (2010).
- Zagorski, R., G. Telesca, W. Fundamenski and K. McCormick: Modelling with COREDIV Code of JET ILW Configuration. *Contributions to Plasma Physics* **50**, 306-312 (2010).
- Zhang, D., R. Burhenn, R. König, L. Giannone, P. A. Grodzki, B. Klein, K. Grosser, J. Baldzuhn, K. Ewert, V. Erckmann, M. Hirsch, H. P. Laqua and J. W. Oosterbeek: Design criteria of the bolometer diagnostic for steady-state operation of the W7-X stellarator. *Review of Scientific Instruments* **81**, 10E134 (2010).
- Zhou, S., W. W. Heidbrink, H. Boehmer, R. McWilliams, T. Carter, S. Vincena, S. K. P. Tripathi, P. Popovich, B. Friedman and F. Jenko: Turbulent transport of fast ions in the Large Plasma Device. *Physics of Plasmas* **17**, 092103 (2010).
- Zilker, M., K. Behler, T. Bluhm, P. Heimann, C. Hennig, H. Kroiss, G. Kühner, H. Laqua, M. Lewerentz, J. Maier, G. Neu, G. Raupp, M. Reich, H. Riemann, J. Schacht, A. Spring, W. Treutterer, A. Werner and T. Zehetbauer: Development and implementation of real-time data acquisition systems for fusion devices with Open Source software. *Fusion Engineering and Design* **85**, 378-382 (2010).
- Zohm, H.: On the minimum size of DEMO. *Fusion Science and Technology* **58**, 613-624 (2010).
- Zohm, H.: ITER, DEMO und das erste Kraftwerk. Max-Planck-Institut für Plasmaphysik – 50 Jahre Forschung für die Energie der Zukunft. Max-Planck-Institut für Plasmaphysik (IPP), Garching und Greifswald, 44-47 (2010).
- Zoletnik, S., M. Agostin, E. Belonohy, G. Bonhomme, D. Dunai, P. Lang, P. Garcia-Martinez, A. D. Gurchenko, C. Hidalgo, A. Kendl, G. Kocsis, Ch. Maszl, K. McCormick, H. W. Müller, S. Spagnolo, E. R. Solano, S. Soldatov, M. Spolaore and Y. Xu: Summary of the Workshop on Electric Fields, Turbulence and Self-organization in Magnetized Plasmas (EFTSOMP) 2009: 6-7 July 2009, Sofia, Bulgaria. *Nuclear Fusion* **50**, 047001 (2010).
- Zonca, F., A. Biancalani, I. Chavdarovski, L. Chen, C. Di Troia and X. Wang: Kinetic structures of shear Alfvén and acoustic wave spectra in burning plasmas. *Journal of Physics: Conference Series* **260**, 012022 (2010).
- Zweben, S. J., R. J. Maqueda, R. Hager, K. Hallatschek, S. M. Kaye, T. Munsat, F. M. Poli, A. L. Roquemore, Y. Sechrest and D. P. Stotler: Quiet periods in edge turbulence preceding the L-H transition in the National Spherical Torus Experiment. *Physics of Plasmas* **17**, 102502 (2010).

## Conference Papers

*Äkäslompolo, S., E. Hirvijoki, T. Kurki-Suonio and ASDEX Upgrade Team:* Implementing beam-beam CX-reactions in the ASCOT-code and prediction of active NPA measurement. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P5.113 (2010).

*Alper, B., A. Boboc, D. Frigione, D. Garnier, L. Garzotti, G. Kocsis, P. T. Lang, A. Sirinelli, M. Stamp, M. Tsalas, R. Wenninger and EFDA-JET Contributors:* Insight from Fast Data on Pellet ELM Pacing at JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.173 (2010).

*Appel, L. C., M. J. Hole, J. Svensson, G. von Nessi and MAST Team:* Bayesian Inference applied to Magnetic Equilibrium on MAST. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.103 (2010).

*Bardin, S., F. Brochard, J.-L. Briançon, J. Boudrigal, N. Endstrasser, T. Lunt, V. Rohde, R. Neu and ASDEX Upgrade Team:* Automatic video tracking and first analysis of dust particles trajectories from all tungsten ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.120 (2010).

*Basiuk, V., P. Huynh, D. Coster, F. Imbeaux, D. Kalupin, G. Pereverzev, G. Huysmans, O. Sauter, C. Konz and Contributors to the ITM-TF Work Programme:* European Transport Solver: first results, validation and benchmark. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1009 (2010).

*Belonohy, E., K. Gál, O. Kardaun, P. Lang, B. Lovász and ASDEX Upgrade Team:* Magnetic Field Dependence of Pellet Penetration. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P5.143 (2010).

*Bergmann, A., M. Brüdgam, S. D. Pinches and E. Wolfrum:* Monte Carlo delta-f simulations of neoclassical flows and currents in the pedestal region of an H-mode tokamak plasma. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.118 (2010).

*Biancalani, A., L. Chen, F. Pegoraro and F. Zonca:* Continuous spectrum of shear Alfvén waves inside magnetic islands. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.109 (2010).

*Biancalani, A. and B. D. Scott:* Two-dimensional and three-dimensional collisionless reconnection. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.108 (2010).

*Bilato, R., M. Brambilla, Y. Feng and G. Tardini:* A neutral beam injection source for the TORIC/SSFPQL package. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P5.144 (2010).

*Boom, J. E., I. G. J. Classen, P. C. de Vries, W. Suttrop, T. Eich, N. K. Hicks, E. Wolfrum, R. Wenninger, B. J. Tobias, C. W. Domier, N. C. Luhmann Jr., H. K. Park and ASDEX Upgrade Team:* 2D ECE-Imaging measurements of Edge Localized Modes (ELMs) at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.119 (2010).

*Breu, T., C. Konz, B. Scott, T. Ribeiro and S. Günter:* Comparison of linear and nonlinear ballooning mode stability in a Tokamak equilibrium. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.112 (2010).

*Cannas, B., A. Fanni, G. Pautasso, G. Sias and ASDEX Upgrade Team:* Boundary Inspection in SOM Mapping of Plasma Disruption Scenarios at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.191 (2010).

*Classen, I. G. J., J. E. Boom, B. Tobias, C. W. Domier, N. C. Luhmann Jr., M. Garcia Munoz, M. A. Van Zeeland, H. K. Park and ASDEX Upgrade Team:* ECE-Imaging measurements of the 2D mode structure of Reversed Shear Alfvén Eigenmodes at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.182 (2010).

*Cooper, W. A., M. I. Mikhailov, C. Nührenberg, J. Nührenberg and V. D. Shafranov:* Properties of an N=4 optimized quasi-



isodynamic configuration. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.146 (2010).

Curran, D., P. Lauber, P. J. McCarthy, S. da Graca, V. Igochine and ASDEX Upgrade Team: Evolution of Alfvén Eigenmodes during the Sawtooth Cycle at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.117 (2010).

Czarnecka, A., V. Bobkov, I. H. Coffey, L. Colas, A. C. A. Figueiredo, P. Jacquet, K. D. Lawson, E. Lerche, M.-L. Mayoral, I. Monakhov, J. Ongena, D. Van Eester, K.-D. Zastrow and JET EFDA Contributors: Impurity production by the ICRF antennas in JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.147 (2010).

Da Graca, S., G. D. Conway, P. Lauber, D. Curran, I. Classen, F. Da Silva, R. McDermott, M. Garcia-Munoz, M. Maraschek, P. McCarthy, A. Silva, F. Serra, M. E. Manso, M. Van Zeeland and ASDEX Upgrade Team: Alfvén Cascade mode studies in ASDEX Upgrade using reflectometry. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.118 (2010).

Dobes, K., M. Hinterhofer, K. Tichmann, A. Golczewski, T. Schwarz-Selinger, W. Jacob and F. Aumayr: The evolution of a hydrogen-depleted surface layer on a-C:H during bombardment with  $N_2^+$  ions. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.125 (2010).

Elfimov, A. G., R. M. O. Galvao, M. Garcia-Munoz, V. Igochine, P. Lauber, M. Maraschek and ASDEX Upgrade Team: Identification of geodesic chirping Alfvén modes and q-factor estimation in hot core tokamak plasmas in ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1026 (2010).

Fehér, T., H. M. Smith, T. Fülöp and K. Gál: Simulation of runaway electron generation during plasma shutdown by impurity injection. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.177 (2010).

Fischer, R., S. K. Rathgeber, S. Fietz, J. Hobirk, A. Kallenbach, H. Meister, T. Pütterich, F. Rytter, G. Tardini, E. Wolftrum,

H. Zohm and ASDEX Upgrade Team: Effective ion charge  $Z_{\text{eff}}$  from integrated analysis of multiple diagnostics at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.107 (2010).

Fisher, R. K., D. C. Pace, M. García-Muñoz, R. L. Boivin, E. D. Frederickson, W. W. Heidbrink, C. M. Muscatello, R. Nazikian, C. C. Petty, M. A. Van Zeeland and Y. B. Zhu: Measurements of beam ion losses on DIII-D due to MHD instabilities. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.108 (2010).

Frassinetti, L., M. N. A. Beurskens, D. C. McDonald, J. Hobirk, D. Zarzoso, P. Buratti, F. Crisanti, C. Challis, E. Giovannozzi, E. Joffrin, P. Lomas, J. Lonnroth, C. Maggi, I. Nunes, S. Saarelma, G. Saibene and JET EFDA Contributors: Pedestal confinement in hybrid versus baseline plasmas in JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1031 (2010).

Garcia-Munoz, M., N. Hicks, R. van Voornveld, I. G. J. Classen, R. Bilato, V. Bobkov, M. Bruedgam, H.-U. Fahrbach, V. Igochine, S. Äkäslompolo, P. Lauber, M. Maraschek, K. Sassenberg, M. Schneller and ASDEX Upgrade Team: Convective and Diffusive Energetic Particles Losses Induced by Shear Alfvén Waves in the ASDEX Upgrade Tokamak. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, O4.113 (2010).

Garzotti, L., P. T. Lang, A. Alonso, B. Alper, E. Belonohy, A. Boboc, S. Devaux, T. Eich, D. Frigione, K. Gál, A. Géraud, G. Kocsis, F. Köchl, K. Lackner, A. Loarte, P. J. Lomas, M. Maraschek, H. W. Müller, G. Petravich, G. Saibene, J. Schweinzer, H. Thomsen, M. Tsalas, R. Wenninger and JET EFDA Contributors: Investigating pellet ELM triggering physics using the new small size pellet launcher at JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.131 (2010).

Giannone, L., R. Fischer, J. C. Fuchs, O. Gruber, K. Lackner, P. J. McCarthy, R. Preuss, W. Schneider, K. H. Schuhbeck, U. Seidel and ASDEX Upgrade Team: Self consistency of magnetic probe and flux loop response to poloidal field currents on ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.122 (2010).

Giannone, L., R. Fischer, K. Lackner, P. J. McCarthy, ASDEX Upgrade Team, Q. Ruan, A. Veeramani, M. Cerna, J. Nagle, M. Ravindran, D. Schmidt, A. Vrancic and L. Wenzel: Computational Strategies in Optimizing a Real-Time Grad-Shafranov PDE Solver Using High-Level Graphical Programming and COTS Technology. Proceedings of PCaPAC 2010 Canadian Light Source, Saskatoon, THPL024, 180-182 (2010).

Grulke, O., J. L. Terry, B. LaBombard, I. Cziegler and S. J. Zweben: Parallel correlation of turbulent fluctuations in the SOL of Alcator C-Mod. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1036 (2010).

Gude, A., M. Maraschek, C. Angioni, J. Stober and ASDEX Upgrade Team: Hollow central radiation profiles and inverse sawtooth-like crashes in ASDEX Upgrade plasmas with central wave heating. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.124 (2010).

Guertler, N. and K. Hallatschek: Numerical studies of zonal flow turbulence interaction. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1037 (2010).

Häberle, E., J. Kopecki, A. Mutzke, R. Schneider, A. Schulz, M. Walkerl and U. Stroth: Control of layer growth by substrate bias. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.324 (2010).

Hager, R. and K. Hallatschek: Magnetic geometry effects on geodesic acoustic modes. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1038 (2010).

Hallatschek, K. and R. Hager: Non-Boussinesq properties of Zonal Flows and GAMs. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, O4.114 (2010).

Happel, T., T. Estrada, G. D. Conway, E. Blanco, TJ-III Team and ASDEX Upgrade Team: Scale-resolved Turbulence Studies in L- and H-mode Plasmas of TJ-II and ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on

Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1039 (2010).

Herrmann, A., O. Gruber, U. Seidel, T. Lunt, G. Pautasso, V. Rohde and ASDEX Upgrade Team: Plasma induced arcs in remote areas of ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.134 (2010).

Hogewey, G. M. D., V. Basiuk, J. Citrin, J. Ferreira, J. Garcia, J. Hobirk, F. Imbeaux, F. Köch, X. Litaudon, P. Lomas, J. Lönnroth, I. Nunes, V. Parail, G. Pereverzev, Y. Peysson, M. Schneider, A. C. C. Sips, G. Tardini, I. Voitsekhovitch, JET-EFDA Contributors, Tore Supra Team, ASDEX Upgrade Team and Contributors of the EU-ITM ITER: Current ramp-up in tokamaks: from present experiments to ITER scenarios. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1041 (2010).

Igochine, V., I. Chapman, V. Bobkov, M. Maraschek, D. Moseev, M. Reich, J. Stober and ASDEX Upgrade Team: Destabilization of fast particle stabilized sawteeth in ASDEX Upgrade with ECCD. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.133 (2010).

Janzer, M., R. Dux, T. Pütterich and ASDEX Upgrade Team: Investigating Tungsten Transport in the Plasma Edge at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1046 (2010).

Kammel, A. and K. Hallatschek: Properties of zonal flow transport bifurcations driven by drift wave turbulence. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1048 (2010).

Kauffmann, K., R. Kleiber and R. Hatzky: Collisional effects on global gyrokinetic particle-in-cell simulations of ITG and TEM instabilities in tokamaks. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1049 (2010).

Klingshirn, H.-J., D. Coster and X. Bonnin: An adaptive code for scrape-off layer plasma fluid simulations. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.140 (2010).

Kocsis, G., J. A. Alonso, B. Alper, G. Arnoux, J. Figueiredo, D. Frigione, L. Garzotti, M. Lampert, P. T. Lang, G. Petravich, R. Wenninger and JET EFDA Contributors: Comparison of the onset of pellet triggered and spontaneous ELMs. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.136 (2010).

Koechl, F., G. Corrigan, D. Frigione, L. Garzotti, G. Kamelander, P. Lang, H. Nehme, V. Parail, B. Pégourié, M. Valovié, S. Wiesen and JET EFDA Contributors: Integrated Modelling of Pellet Experiments at JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, O4.123 (2010).

Konz, C., G. T. A. Huysmans, W. Zwingmann, B. Guillerminet, F. Imbeaux, P. Huynh, V. Drozdov, P. Strand, JET EFDA Contributors and ITM-TF Contributors: Scientific Workflows for the Linear MHD Stability Analysis Chain. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.137 (2010).

Krieger, K. and R. Kleiber (Eds.): IPP Summer University for Plasma Physics, September 20-24, 2009, Garching. Max-Planck-Institut für Plasmaphysik, Garching, 290 p. (2010).

Lukash, V. E., R. R. Khayrutdinov, G. Pautasso and ASDEX Upgrade Team: Validation of halo current model with the DINA code against ASDEX Upgrade disruption shots. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P4.140 (2010).

Maj, O., R. Bilato, M. Brambilla and E. Marsch: A steady-state Fokker-Planck solver for wave-particle interaction in solar coronal holes. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.406 (2010).

Marsen, S., M. Otte and R. C. Wolf: Turbulence in Magnetic Islands: An Investigation of the Poloidal Dynamics in the WEGA Stellarator. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1058 (2010).

McCarthy, P. J. and ASDEX Upgrade Team: Recovery of edge moments of the current density profile in a tokamak from external magnetic measurements. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, O4.116 (2010).

McDermott, R. M., C. Angioni, R. Dux, A. Gude, T. Pütterich, F. Ryter, G. Tardini and ASDEX Upgrade Team: Core Toroidal Rotation Changes Observed with ECRH Power in NBI Heated H-modes on ADSEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1062 (2010).

McMillan, B. F., T. Vernay, A. Bottino, S. Jolliet and L. Villard: Effects of toroidal and poloidal shear flow in global gyrokinetic simulations. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1063 (2010).

Mehlmann, F., C. Ionita, V. Naulin, J. J. Rasmussen, H. W. Müller, N. Vianello, C. Maszl, V. Rohde, M. Zuin, R. Cavazzana, M. Maraschek, R. Schrittwieser and ASDEX Upgrade Team: Transport of Momentum in the Sol of ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P1.1064 (2010).

Meo, F., M. Salewski, H. Bindslev, J. Hobirk, S. B. Korsholm, F. Leuterer, F. Leipold, P. K. Michelsen, D. Moseev, M. Garcia-Munoz, S. K. Nielsen, M. Stejner, J. Stober, G. Tardini, D. Wagner and ASDEX Upgrade Team: Spatially resolved fast ion velocity distribution results from on-axis and off-axis NBI heated plasmas on ASDEX Upgrade using the Collective Thomson Scattering (CTS). 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P5.168 (2010).

Moiseenko, V. E., M. B. Dreval, P. Y. Burchenko, A. V. Losin, V. L. Bereznyj, V. N. Bondarenko, V. V. Chechkin, L. I. Grigor'eva, D. Hartmann, R. Koch, V. G. Konovavlov, V. D. Kotsubanov, Y. D. Kramskoi, A. E. Kulaga, A. I. Lyssioivan, V. K. Mironov, R. O. Pavlichenko, V. S. Romanov, A. N. Shapoval, A. I. Skibenko, A. S. Slavnyi, V. I. Tereshin and V. S. Voitsenya: RF heating below ion-cyclotron frequencies in uragan torsatrons. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P5.171 (2010).

Nakamura, Y., G. Pautasso, M. Sugihara, S. Miyamoto, S. Toshimitsu, R. Yoshino and ASDEX Upgrade Team: TSC Modelling Approach to Mimicking the Halo Current in ASDEX Upgrade Disruptive Discharges. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA 34A. European Physical Society, Geneva, P2.184 (2010).



Nold, B., S. Marsen, M. Ramisch, A. A. Beletskii, V. V. Chechkin, A. Dinklage, M. Endler, L. I. Grigor'eva, H. W. Müller, I. M. Pankratov, U. Stroth, P. Tamain and R. Wilcox: Dynamics of blobs: Statistical analysis based on the international edge turbulence data base. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1073 (2010).

Nordman, H., A. Skyman, P. Strand, C. Giroud, F. Jenko, F. Merz, M. Valisa, P. Belo, G. Corrigan, V. Naulin, V. Parail, T. Tala and JET EFDA Contributors: Modelling of impurity transport experiments at the Joint European Torus. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1074 (2010).

Nührenberg, C. and A. H. Boozer: Computational Study of Error-field Effects on W7-X Stellarator Equilibria. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.151 (2010).

Otte, M., J. Belapure, E. Chlechowicz, M. Glaubitz, G. Hasinger, B. Huber, M. Krychowiak, H. P. Laqua, S. Marsen, E. Müller, D. M. Schlosser, T. Stange, F. Wagner, A. Weller, R. Wolf and D. Zhang: Diagnostic Development for Wendelstein 7-X at the WEGA Stellarator. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.125 (2010).

Pamela, S. J. P., G. T. A. Huysmans, M. N. A. Beurskens, G. Arnoux, A. Kirk, T. Eich, S. Devaux, S. Benkadda, L. Frassinetti and JET EFDA Contributors: Simulation of ELMs in JET. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, O2.106 (2010).

Pautasso, G., L. Giannone, A. Herrmann, M. Bernert and ASDEX Upgrade Team: Evolution of the halo current in ASDEX Upgrade disruptions. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.152 (2010).

Pinsker, R. I., M.-L. Mayoral, V. Bobkov, M. Goniche, J. C. Hosea, S. J. Wukitch, S. Moriyama, F. W. Baity, L. Colas, F. Durodie, A. Ekedahl, G. R. Hanson, P. Jacquet, P. Lamalle, I. Monakhov, M. Murakami, A. Nagy, M. Nightingale, J.-M. Noterdaeme, J. Ongena, M. Porkolab, P. M. Ryan, M. Vrancken, J. R. Wilson and ASDEX Upgrade Team: Experiments on gas puffing to enhance ICRF antenna coupling. 37<sup>th</sup> European Physical

Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, O4.124 (2010).

Pokol, G. I., N. Lazanyil, G. Por, A. Magyarkuti, G. Papp, A. Gude, V. Igochine, M. Maraschek and ASDEX Upgrade Team: A wavelet based method for detecting transient plasma waves and determining their spatial structure. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.129 (2010).

Pueschel, M. J., H. Doerk, T. Görler and F. Jenko: Gyrokinetic turbulence simulations of high- $\beta$  plasmas. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1081 (2010).

Reich, M., K. Behler, L. Giannone, A. Mlynec, J. Stober, W. Treutterer and ASDEX Upgrade Team: ECCD-based NTM control using the ASDEX Upgrade real-time system. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.189 (2010).

Ribeiro, T. T., B. Scott and A. Kendl: Conformal coordinates for turbulence computations on shaped tokamak geometries. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1083 (2010).

Riesch, J., Ch. Linsmeier and S. F. Nielsen: In-situ tomographic observation of crack formation and propagation in tungsten materials in the framework of FEMaS-CA. Challenges in materials science and possibilities in 3D and 4D characterization techniques – Proceedings of the 31<sup>st</sup> Risø International Symposium on Materials Science; 6-10 September, 2010, (Ed.) N. Hansen. Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi, Roskilde, 405-412 (2010).

Rozhansky, V., P. Molchanov, S. Voskoboinikov, A. Kirk, H. Meyer and D. Coster: Modeling of He distribution in the edge plasma of MAST. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.190 (2010).

Saarelma, S., A. Bottino, J. Candy, G. Colyer, A. Field, W. Gutenfelder, P. Hill, A. Peeters, C. M. Roach and MAST Team: Global gyrokinetic ITG turbulence simulations of MAST plasmas. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1085 (2010).



*Sassenberg, K., M. Maraschek, P. J. Mc Carthy, V. Bobkov, M. Garcia-Munoz, N. Hicks, V. Igochine, P. Lauber, S. Günter and ASDEX Upgrade Team:* TAEs excited by ICRH beat-waves in the ASDEX Upgrade Tokamak. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, D1.507 (2010).

*Schneider, P. A., E. Wolfrum, S. Günter, B. Kurzan, H. Zohm and ASDEX Upgrade Team:* Alternative method for characterization of inter ELM edge profiles of type-I ELMy H-modes in ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.157 (2010).

*Schneider, W., M. R. Turnyanskiy, V. I. Afanasyev, F. V. Chernyshev and T. Richert:* Influence of the stray magnetic field on the neutral particle diagnostic performance. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.130 (2010).

*Schrittwieser, R., J. Gruenwald, F. Mehlmann, T. Windisch, R. Stärz, C. Ionita, K. Rahbarnia, O. Grulke and T. Klinger:* New results on a laser-heated emissive probe. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.304 (2010).

*Sertoli, M., C. Angioni, R. Dux, R. Neu, T. Pütterich and ASDEX Upgrade Team:* Local Effects of ECRH on Argon Transport in L-Mode Discharges at ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1109 (2010).

*Skyman, A., H. Nordman, P. Strand, F. Jenko and F. Merz:* Impurity transport in ITG and TE mode dominated turbulence. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1092 (2010).

*Snicker, A., E. Poli, T. Kurki-Suonio and ASDEX Upgrade Team:* ASCOT simulations of neoclassical tearing mode effects on fast ion losses. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.187 (2010).

*Svensson, J., O. Ford, A. Werner, G. von Nessi, M. Hole, D. C. McDonald, L. Appel, M. Beurskens, A. Boboc, M. Brix, J. Howard, B. D. Blackwell, J. Bertram, D. Pretty and JET*

*EFDA Contributors:* Connecting physics models and diagnostic data using Bayesian Graphical Models. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, O4.117 (2010).

*Tardini, G., R. M. McDermott, F. Jenko, T. Pütterich, S. K. Rathgeber, M. Schneller, J. Schweinzer, D. Told and ASDEX Upgrade Team:* Core transport and pedestal characteristics of nitrogen seeded H-mode discharges in ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1097 (2010).

*Wagner, D., E. Fable, A. Pitzschke, O. Sauter, H. Weisen and TCV Team:* Particle transport in TCV H-modes. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1101 (2010).

*Wenninger, R., S. Devaux, T. Eich, G. Huysmans, P. T. Lang and JET EFDA Contributors:* Filament footprints of pellet induced ELMs observed on divertor target. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.173 (2010).

*Wieland, B., E. Wolfrum, R. Fischer, P. A. Schneider and ASDEX Upgrade Team:* Radial electric fields from passive He II emission in the edge transport barrier of ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P5.139 (2010).

*Windisch, T., O. Grulke and T. Klinger:* Formation and radial proagation of turbulent structures in the linear helicon device VINETA. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P1.1104 (2010).

*Wolfrum, E., A. Burckhart, J. E. Boom, I. G. J. Classen, G. D. Conway, R. Fischer, A. Gude, M. Maraschek, T. Pütterich, J. Vincente, B. Wieland and ASDEX Upgrade Team:* Edge profile and MHD characterization of the type-II ELMy regime in ASDEX Upgrade. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.169 (2010).

*Zarzoso, D., M. N. A. Beurskens, L. Frassinetti, T. Eich, E. Joffrin, A. Loarte, G. Maddison, F. G. Rimini, G. Saibene, E. R. Solano, H. Thomsen and JET EFDA Contributors:* ELM size analysis

in JET advanced tokamak and hybrid scenarios. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.171 (2010).

Zhang, Y., G. Pautasso, O. Kardaun, G. Tardini, X. D. Zhang and ASDEX Upgrade Team: Prediction of ASDEX Upgrade disruptions using discriminant analysis. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P2.194 (2010).

Zwingmann, W., R. Coelho, V. Drozdov, L.-G. Eriksson, B. Guillerminet, P. Huynh, G. T. A. Huysmans, C. Konz, F. Imbeaux, D. C. McDonald, P. Navaro, W. Schippers, J. Signoret, P. Strand, ITM-TF Contributors and JET EFDA Contributors: Validation Procedure of the Tokamak Equilibrium Reconstruction Code EQUAL with a Scientific Workflow System. 37<sup>th</sup> European Physical Society Conference on Plasma Physics. Contributed Papers, (Ed.) C. McKenna. ECA **34A**. European Physical Society, Geneva, P4.180 (2010).

## Theses

Bernert, M.: Bolometry with Diodes at the Tokamak ASDEX Upgrade. Diplom, Technische Universität München (2010).

Detloff, A. and W. Junghans: Aufbau und Modellierung einer Quarzmikrowaage. Diplom, Universität der Bundeswehr, München (2010).

Fietz, S.: Experimentelle Untersuchung der Stromauf- und Stromabbauphase am Tokamak ASDEX Upgrade. Diplom, Ludwig-Maximilians-Universität München (2010).

Höhbauer, C.: Modellierung der Neutronenproduktion in Plasmaentladungen am Fusionsexperiment ASDEX Upgrade. Diplom, Ludwig-Maximilians-Universität München (2010).

Penzel, F.O.: Realisierung eines Kalibrierprototypen mit rechnergestützter Steuerung und Automatisierung. Diplom, Technische Universität München (2010).

Phan, T.: Compound formation at the beryllium surface during nitrogen ion implantation. Master, ENSCP – Chimie ParisTech, Paris (2010).

Pietzka, M.: Zeitaufgelöste massenspektrometrische Untersuchung von gepulsten Methanplasmen. Diplom, Ludwig-Maximilians-Universität München (2010).

Reimold, F.: Numerical simulations of tungsten impurity transport in ASDEX Upgrade. Diplom, Technische Universität München (2010).

Sieglin, B.: Temperature in the Scrape-off Layer of ASDEX Upgrade by Line Integrated Helium I Emission Lines. Diplom, Technische Universität München (2010).

Sommer, F.: Charakterisierung und Interpretation von MHD Aktivität zwischen ELMs am Tokamak ASDEX Upgrade. Diplom, Technische Universität München (2010).

Stegmeir, A.: Anwendung der Beam Tracing Methode zur Diagnostik von Fusionsplasmen. Diplom, Technische Universität München (2010).

Visser, M.: Upgrade of a Heliumdetectorsystem for ASDEX Upgrade. Bachelor, Fachhochschule München (2010).

Werkstetter, M.: Charakterisierung von Erbiumoxid-Schichten durch Wasserstoff-Permeationsmessungen. Bachelor, Fachhochschule München (2010).

*Zhukov, I.:* Development of a Grad-Shafranov equation solver for GPGPUs. Master, Technische Universität München (2010).

#### PhD-Theses

*Braun, S.:* Effect of Impurities on Kinetic Transport Processes in Fusion Plasmas. Ernst-Moritz-Arndt-Universität Greifswald (2010).

*Brüdgam, M.:* Nonlinear Effects of Energetic Particle Driven Modes in Tokamaks. Technische Universität München (2010).

*de Rooij, D.:* Molecular Dynamics Simulations of Interactions between Hydrogen and Fusion-relevant Materials. University Utrecht (2010).

*Hölzl, M.:* Diffusive Heat Transport across Magnetic Island and Stochastic Layers in Tokamaks. Technische Universität München (2010).

*Maya, P. N.:* Simulation Studies on Co-Deposited Hydrocarbon Films and Hydrogen Retention. Devi Ahilya Vishwavidyalaya, Indore (2010).

*Mlynek, A.:* Real-time control of the plasma density profile on ASDEX Upgrade. Ludwig-Maximilians-Universität München (2010).

*Paffenholz, V.:* Synthese und Charakterisierung von SiC<sub>f</sub>/Cu-Matrix-Verbundwerkstoffen und ihre Anwendung in einem Modell einer Divertor-Komponente. Technische Universität München (2010).

*Reiter, B.:* Radiative Response on massive noble gas injection for runaway suppression in disruptive plasmas. Ludwig-Maximilians-Universität München (2010).

*Sertoli, M.:* Local Effects of ECRH on Argon Transport at ASDEX Upgrade. Ludwig-Maximilians-Universität München (2010).

*Siccinio, M.:* Kinetic Investigation of Magnetic Islands in Tokamaks. Technische Universität München (2010).

*Tyburska, B.:* Deuterium Retention in Carbon and Self-Implanted Tungsten. Marie Curie-Sklodowska University, Department of Mathematics, Physics, and Computer Science, Lublin (2010).

#### Habilitations

*Angioni, C.:* Theoretical and experimental research on particle and impurity transport in the core of tokamak plasmas. Université de Provence, Aix-Marseille (2010).

*Linsmeier, C.:* Surface chemistry of fusion first wall materials. Technische Universität München (2010).

*You, J. H.:* Synchrotron X ray experiments for materials science. Universität Ulm (2010).

#### Patents

*Baldzuhn, J., C. Li, A. Cardella, A. Killinger and M. Floristan:* Microwave Absorber Coating. Erfindungsmeldung: 16.07.2010. Freigabe der Erfindung: 04.10.2010.

*Bau, H., U. Meyer and J. Glasow:* Verfahren und Vorrichtung zur Zuführung eines flüssigen Gases in ein Gefäß (Tube Extension for Helium Transfer). Nachanmeldung in den PCT Staaten: 13.04.2010. Erteilung des Deutschen Patents: 23.08.2010.

*Berger, N.:* Vorrichtung zur berührungslosen Füllstandsmessung druckloser Helium-Patterspeicher (Ballone). Erfindungsmeldung: 20.09.2010. Freigabe der Erfindung: 18.10.2010.

*Brockmann, R.:* Verfahren und Vorrichtung zur Leckprüfung. Teilübertragung der Rechte innerhalb der europäischen Patentanmeldung für Deutschland auf die MPG: 27.04.2010. Erteilung des Europäischen Patents: 21.07.2010.

*Erckmann, V., G. Dammertz, and M. Schmid:* Advanced collector sweeping with homogenous power desposition of electron beams in high-power rf vacuum tubes. Erteilung des Russischen Patents PCT/EP/2007/003958: 26.09.2010.

*Schauer, F.:* Stromzuführungseinrichtung für einen Tieftemperaturleiter und Verfahren zur Kühlung. Freigabe der Europäischen Anmeldung: 25.01.2010.

*Sihler, C.:* Verfahren und Dämpfungsvorrichtung zur Dämpfung einer Torsionsschwingung in einem rotierenden Antriebsstrang. Erteilung des Chinesischen Patents Nr. 200480016518.9: 28.04.2010. Stellung des Registrierungsantrags um das Chinesische Patent auf Hongkong auszuweiten: 13.07.2010.

*Wanner, M.:* Sicherheitseinrichtung für eine Austrittsöffnung eines Vakuumbehälters. Freigabe der Deutschen Patentanmeldung: 20.09.2010.

## Laboratory Reports

### Internal IPP Reports

#### IPP 1/338

*Igochine, V., A. Gude, M. Maraschek and ASDEX Upgrade Team:* Hotlink bases Soft X-ray Diagnostic on ASDEX Upgrade. Max-Planck-Institut für Plasmaphysik. 22 p. (2010).

#### IPP 1/339

*Höhbauer, C.:* Modellierung der Neutronenproduktion in Plasmaentladungen am Fusionsexperiment ASDEX Upgrade. 71 p. (2010).

#### IPP 5/121

*Malapaka, S. K.:* A Study of Magnetic Helicity in Decaying and Forced 3D-MHD Turbulence. 160 p. (2010).

#### IPP 5/122

*Kraus, M.:* Heiz- und Stromprofile bei Neutralteilcheninjektion in Tokamakplasmen. 152 p. (2010).

#### IPP 5/123

*Kang, K. S.:* Parallelization of the Multigrid Method on High Performance Computers. 33 p. (2010).

#### IPP 5/124

*Hammer, N. J. and R. Hatzky:* Combining Runge-Kutta discontinuous Galerkin methods with various limiting methods. 23 p. (2010).

#### IPP 5/125

*Siccinio, M.:* Kinetic Investigation of Magnetic Islands in Tokamaks. 135 p. (2010).

#### IPP 10/38

*Hölzl, M.:* Diffusive Heat Transport across Magnetic Island and Stochastic Layers in Tokamaks. 149 p. (2010).

#### IPP 10/39

*Sertoli, M.:* Local Effects of ECRH on Argon transport at ASDEX Upgrade. 143 p. (2010).

#### IPP 12/6

*Wobig, H.:* On Dissipative Plasma Equilibria in Stellarator Configurations. 12 p. (2010).

#### IPP 12/7

*Braun, S.:* Effect of Impurities on Kinetic Transport Processes in Fusion Plasmas. 151 p. (2010).

#### IPP 13/17

*Krüger, A.:* Entwicklung einer Lösung zur Verteilung und Überwachung von Alalysenmoulen am Wendelstein 7-X. 47 p. (2010).

#### IPP 13/18

*Engel, F.:* Verteilung von Experiment-Software für Wendelstein 7-X. 49 p. (2010).

#### IPP 13/19

*Chlechowicz, E.:* Plasma Current and Pressure Measurements at the WEGA Stellarator. 116 p. (2010).

#### IPP 16/21

*Böhme, P.:* Stadtstrukturbildung durch Selbstorganisation. 90 p. (2010).

#### IPP 17/18

*Schindler, T.:* Analyse und Interpretation des Risswachstums an thermisch hochbelasteten Bauteilen für die Fusionsforschung mittels IR Diagnostik und FE Modellierung. 111 p. (2010).

#### IPP 17/19

*Linsmeier, Ch.:* Surface chemistry of fusion first wall materials. 346 p. (2010).

#### IPP 17/20

*Eckstein, W.:* Penetration (Range). 67 p. (2010).

#### IPP 17/21

*de Rooij, D.:* Molecular Dynamics Simulations of Interactions between Hydrogen and Fusion-relevant Materials. 134 p. (2010).

#### IPP 17/22

*Paffenholz, V.:* Synthese und Charakterisierung von SiCf/Cu-Matrix-Verbundwerkstoffen und ihre Anwendung in einem Modell einer Divertor-Komponente. 146 p. (2010).

#### IPP 17/23

*Maya, P. N.:* Simulation Studies on Co-Deposited Hydrocarbon Films and Hydrogen Retention. 197 p. (2010).

#### IPP 17/24

*Tyburska, B.:* Deuterium Retention in Carbon and Self-Implanted Tungsten. 144 p. (2010).



# Lectures

*Abriola, D., A. F. Gurbich, N. P. Barradas, I. Bogdanovic-Radovic, M. Chiari, C. Jeynes, M. Kokkoris, M. Mayer, A. R. Ramos, L. Shi and I. Vickridge:* Development of a Reference Database for Ion Beam Analysis at the IAEA and Future Perspectives. (10<sup>th</sup> European Conference on Accelerators in Applied Research and Technology, 2010-09-13 to 2010-09-17, Athens).

*Adamek, J., C. Ionita, V. Rohde, H. W. Müller, R. Schrittwieser, F. Mehlmann, J. Stöckel, J. Horacek, V. Weinzettl and ASDEX Upgrade Team:* Ball-Pen Probe for direct measurements of the plasma potential. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Aho-Mantila, L., M. Wischmeier, K. Krieger, M. Groth, M. I. Airila, D. P. Coster, A. Kirschner and ASDEX Upgrade Team:* Effect of E×B Driven Transport on the Deposition of Carbon in the Outer Divertor of ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Albajar, F., M. Bornatici and F. Engelmann:* EC radiative transport in fusion plasmas with an anisotropic distribution of suprathermal electrons. (16<sup>th</sup> Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (EC-16), 2010-04-12 to 2010-04-15, Sanya).

*Alimov, V. K., B. Tyburska, O. Ogorodnikova, J. Roth, K. Isobe and T. Yamanishi:* Deuterium Retention in Porous Vacuum Plasma Sprayed Tungsten Coating Exposed to Low-Energy, High Flux Pure and Helium-Seeded D Plasmas. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Andersson, J. and P. Xanthopoulos:* Statistical properties of heat flux in toroidal ITG turbulence. (Workshop on Self-Organization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

*Angioni, C., R. M. McDermott, T. Pütterich, F. Ryter, G. Tardini and ASDEX Upgrade Team:* Combined gyrokinetic modeling of electron and boron density profiles of H-mode plasmas in ASDEX Upgrade. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Arnoux, G., B. Bazylev, S. Devaux, T. Eich, W. Fundamenski, T. Hender, S. Jachmich, A. Huber, M. Lehnen, A. Loarte, U. Kruezi, V. Riccardo, G. Sergienko, H. Thomsen and JET EFDA Contributors:* Heat Load Measurements on the JET First Wall during Disruptions. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Arter, W., M. A. Barnes, C. M. Roach, P. Knight, N. J. Hammer and R. Hatzky:* Optimisation of the GS2 gyro-kinetic code. (International Sherwood Fusion Theory Conference, 2010-04-19 to 2010-04-21, Seattle, WA).

*Bachmann, C., M. Sugihara, R. Roccella, G. Sannazzaro, Y. Gribov, V. Riccardo, T. C. Hender, S. N. Gerasimov, G. Pautasso, A. Belov, E. Lamzin and M. Roccella:* Specification of Asymmetric VDE Loads of the ITER Tokamak. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Balden, M.:* Characterization of nano-structured W, Ti, V, and Zr doped carbon films. (E-MRS 2010 Spring Meeting, Symposium L: Carbon- or Nitrogen-containing Nanostructured Composite Films, 2010-06-07 to 2010-06-11, Strasbourg).

*Balden, M.:* How does Nitrogen-seeding in deuterium plasmas affect the blistering of tungsten? (Seminary Talk, PISCES Lab, 2010-08-27, San Diego, CA).

*Balden, M., N. Endstrasser, V. Rohde, T. Lunt, F. Brochard, S. Bardin, J. L. Briancon, S. Lindig, R. Neu and ASDEX Upgrade Team:* Morphology Classification and Video Tracking of Dust Particles in ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Balden, M., N. Endstrasser, V. Rohde, R. Neu, S. Lindig and ASDEX Upgrade Team:* Statistical analysis of dust and dust production mechanism. (14<sup>th</sup> ITPA Meeting on SOL/Divertor Physics, 2010-10-18 to 2010-10-21, Seoul).

*Balden, M. and S. Lindig:* Mechanism of surface feature formation of deuterium bombarded tungsten clarified by EBSD on the subsurface region. (EBSD-Workshop der D-A-CH Länder: DGM-DVM AK-Treffen 2010 "Mikrountersuchungen im REM", 2010-04-27 to 2010-04-28, Hochschule Augsburg).

*Balden, M., S. Lindig and A. Manhard:* Classification and Mechanistic Analysis of Blister-like Structures on Hydrogen-Implanted Tungsten. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Balden, M., S. Lindig, A. Manhard, O. Ogorodnikova, J. Roth, V. Alimov and Y. Yamanishi:* SEM analysis of morphology changes in D irradiated W assisted by FIB. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Balden, M., S. Lindig, A. Manhard, O. Ogorodnikova, J. Roth, V. Alimov and T. Yamanishi:* Surface morphology changes at

high fluence. (14<sup>th</sup> ITPA meeting on SOL/Divertor Physics, 2010-10-18 to 2010-10-21, Seoul).

*Balden, M., V. Rohde, N. Endstrasser, R. Neu and ASDEX Upgrade Team:* Post-mortem analysis of dust particles from all tungsten ASDEX-Upgrade. (SEWG Meeting on Dust, 2010-06-08 to 2010-06-11, Garching).

*Balden, M., I. Segues Guridi, C. Adelhelm and P. A. Sauter:* Oxidative Behaviour of Metal-Doped Carbon Films. (E-MRS 2010 Spring Meeting, Symposium N: Nuclear Materials IV, 2010-06-07 to 2010-06-11, Strasbourg).

*Bandyopadhyay, I., S. Gerhardt, S. C. Jardin, R. Sayer, Y. Nakamura, S. Miyamoto, G. Pautasso, M. Sugihara, ASDEX Upgrade Team and NSTX Team:* TSC Modelling of Major Disruption and VDE Events in NSTX and ASDEX Upgrade and Predictions for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Barnes, M., I. G. Abel, G. Colyer, S. C. Cowley, P. Dellar, W. Dorland, T. Görler, G. W. Hammett, E. Highcock, N. F. Loureiro, S. Newton, F. I. Parra, M. Reshko, C. Roach and A. A. Schekochihin:* Shear Flow Suppression of Turbulent Transport and Self-Consistent Profile Evolution within a Multi-Scale Gyrokinetic Framework. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Barnes, M., I. G. Abel, G. Colyer, W. Dorland, T. Görler, G. W. Hammett, F. Jenko and F. I. Parra:* First-principles simulations of momentum transport and profile evolution within the multi-scale gyrokinetic framework. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Baumgaertel, J. A., W. Guttenfelder, G. W. Hammett, D. R. Mikkelsen, P. Xanthopoulos, H. Maaßberg, J. Geiger, Y. Turkin, W. Dorland and E. Belli:* Linear gyrokinetic studies in W7-AS and W7-X stellarators with the GS2 code. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Behler, K., R. Cole, L. Giannone, K. Lüddecke, ASDEX Upgrade Team, G. Neu, G. Raupp, M. Reich, W. Treutterer, D. Zasche and T. Zehetbauer:* Integrated operation of diagnostics and control. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Beidler, C.:* Benchmarking of the Three Neoclassical Mono-Energetic Transport Coefficients – Results from an International Cooperation. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Belmondo, V., R. Bilato, M. Brambilla and O. Maj:* Orbit-averaged quasilinear diffusion operator in the ion-cyclotron range of frequencies. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Bernert, M., T. Eich, C. Fuchs, B. Reiter, A. Kallenbach and ASDEX Upgrade Team:* Bolometrie mit Dioden am Tokamak ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Beurskens, M. N. A., T. H. Osborne, P. A. Schneider, E. Wolfrum, L. Frassinetti, R. Groebner, P. Lomas, I. Nunes, S. Saarelma, R. Scannell, P. B. Snyder, D. Zarzoso, I. Balboa, B. Bray, M. Brix, J. Flanagan, C. Giroud, E. Giovannozzi, M. Kempenaars, A. Loarte, E. de la Luna, G. Maddison, C. F. Maggi, D. McDonald, R. Pasqualotto, G. Saibene, R. Sartori, E. Solano, M. Walsh, L. Zabeo, DIII-D Team, The ASDEX Upgrade Team and JET-EFDA Contributors:* H-Mode pedestal scaling in DIII-D, AUG and JET. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Bieg, B., M. Hirsch and Y. A. Kravtsov:* Numerical modeling of IR polarization state in geometry of W7-X. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Birus, D., M. Schneider, T. Rummel and M. Fricke:* The Quench Detection System of W7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Blackwell, B. D., J. Howard, D. G. Pretty, J. W. Read, S. T. A. Kumar, R. L. Dewar, M. J. Hole, J. Bertram, C. A. Nührenberg, S. Haskey and M. McGann:* The Australian Plasma Fusion Research Facility: Recent Results and Upgrade Plans. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Bobkov, V., F. Braun, R. Dux, H. Faugel, L. Giannone, A. Herrmann, A. Kallenbach, R. Neu, J.-M. Noterdaeme, T. Pütterich and ASDEX Upgrade Team:* ICRF antenna-plasma interactions and its influence on W sputtering in ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Bohlin, H.:* Investigation of Table Top X-Pinches. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Bolt, H., J. Linke and Ch. Linsmeier:* Material challenges for plasma-facing materials in future fusion reactors. (12<sup>th</sup> International Conference on Modern Materials and Technologies (CIMTEC 2010), 2010-06-06 to 2010-06-18, Montecatini Terme, Tuscany).

*Bolt, H. and Ch. Linsmeier:* What do we need in European Energy Research: Cooperation, large facilities, more science? (Neutrons for Global Energy Solutions, 2010-09-26 to 2010-09-29, Bonn).

*Bonnin, X. and D. Coster:* Full-tungsten plasma edge simulations with SOLPS. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Boscary, J., R. Stadler, A. Peacock, F. Hurd, A. Vorkörper, B. Medevitch, A. Cardella, H. Pirsch, H. Tittes, J. Tretter, C. Li and M. Smirnow:* Design and Technological Solutions for the Plasma Facing Components of Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Bosch, H.-S.:* Basic Nuclear Fusion. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Bosch, H.-S.:* Physics of Nuclear Fusion. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Bosch, H.-S.:* Struktur der Materie für Umweltwissenschaften. (SS 2010. Vorlesung, Ernst-Moritz-Arndt-Universität Greifswald).

*Bosch, H.-S. and T. Klinger:* Fusionsphysik. (SS 2010. Vorlesung, Ernst-Moritz-Arndt-Universität Greifswald).

*Bosch, H.-S. (for the Wendelstein 7-X Team):* Wendelstein 7-X – Status of Construction and Prospects. (6<sup>th</sup> IAEA Technical Meeting on Steady State Operation of Magnetic Fusion Devices, 2010-12-06 to 2010-12-10, Vienna).

*Bosch, H.-S. and Wendelstein 7-X Team:* Overview of the Construction and Scientific Objectives of the Wendelstein 7-X Stellarator. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Bottino, A., M. Borchart, T. B. Feher, R. Hatzky, K. Kauffmann, R. Kleiber, A. Könies, A. Mishchenko, A. G. Peeters, E. Poli and B. Scott:* Global Nonlinear Gyrokinetic Simulations of Electromagnetic Turbulence in Tokamaks and Stellarators. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Bräuer, T., T. Andreeva and M. Endler:* Alignment of the first two magnet modules of Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Brakel, R.:* Experimental results from stellarators. (Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Braun, S.:* Impurity Redistribution in Stellarators. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Brezinsek, S., W. Fundamenski, T. Eich, J. P. Coad, K. McCormick, C. Giroud, A. Huber, S. Jachmich, E. Joffrin, K. Krieger, M. Lehnen, T. Loarer, E. de la Luna, G. Maddison, G. F. Matthews, P. Mertens, I. Nunes, V. Philipps, V. Riccardo, M. Rubel, M. F. Stamp, M. Tsalias and JET EFDA Contributors:* Overview of the Experimental Preparation for the ITER-like Wall at JET. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Brezinsek, S., T. Loarer, K. Krieger, S. Jachmich, M. Tsalias, I. Coey, T. Eich, C. Giroud, S. Grünhagen, A. Huber, U. Kruezi, S. Knipe, G. P. Maddison, K. McCormick, A. G. Meigs, P. Morgan, V. Philipps, G. Sergienko, R. Stagg, M. F. Stamp, W. Fundamenski and JET-EFDA Contributors:* Fuel Retention in Discharges with Impurity Seeding after Strong Be Evaporation in JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Briefi, S. and U. Fantz:* Vergleich der Plasmaparameter von induktiv und kapazitiv gekoppelten Niederdruckentladungen in Röhrengometrie. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Brix, M., D. Dodt, A. Korotkov, P. Morgan, D. Dunai, R. Fischer, A. Meigs, I. S. Nedzelskiy, J. Schweinzer, J. Vince, S. Zoletnik and JET-EFDA Contributors:* Upgrade of the lithium beam diagnostic at JET. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HPTD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Bruschi, A., E. Alessi, W. Bin, O. D’Arcangelo, V. Erckmann, W. Kasperek, A. Moro, V. Muzzini and M. I. Petelin:* Development of Alternative Concepts of Fast Switches and Combiners (FADIS-BC) for High-Power Millimeter-Wave Beams. (35<sup>th</sup> International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2010), 2010-09-05 to 2010-09-10, Rome).

*Budny, R. V., L. Berry, R. Bilato, P. Bonoli, M. Brambilla, R. Dumont, E. F. Jaeger, A. Fukuyama, E. Lerche, C. K. Phillips, V. Vdovin, J. Wright and Members of the ITPA-IOs:* Benchmarking ICRF Simulations for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Buratti, P., M. Baruzzo, R. J. Buttery, C. D. Challis, I. T. Chapman, F. Crisanti, M. Gryaznevich, T. C. Hender, D. F. Howell, E. Joffrin, J. Hobirk, F. Imbeaux, X. Litaudon, J. Mailloux and JET EFDA Contributors:* Kink Instabilities

in High-Beta JET Advanced Scenarios. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Burhenn, R., J. Baldzuhn, W. Biel, H. Dreier, M. Endler, H.-J. Hartfuß, D. Hildebrandt, M. Hirsch, R. König, P. Korniejew, M. Krychowiak, H. P. Laqua, M. Laux, J. W. Oosterbeek, E. Pasch, W. Schneider, H. Thomsen, A. Weller, A. Werner, R. C. Wolf and D. Zhang:* Diagnostics development towards steady state operation in fusion devices. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Bykov, V., F. Schauer, K. Egorov, P. van Eeten, J. Fellingner, M. Sochor, N. Jaksic, A. Tereshchenko, A. Dübner, A. Dudek, D. Zacharias, D. Hathiramani, P. Czarkowski and Q. Yang:* Structural Analysis of W7-X : From design to assembly and operation. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Cantarini, J., R. Barnsley and D. Thomas:* Modelling reflections on ITER CXRS diagnostic. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Capak, P. L., N. Z. Scoville, D. B. Sanders, B. Mobasher, D. Master and M. Salvato:* A Large Sample of  $z > 3.5$  Galaxies with Keck Deimos Spectroscopy. (Biannual Meeting of the American Astronomical Society, 2010-01-03 to 2010-01-07, Washington, DC).

*Cappello, S., D. Bonfiglio, D. F. Escande, S. C. Guo, I. Predebon, F. Sattin, M. Veranda, P. Zanca, C. Angioni, L. Chacon, J. C. Dong, X. Garbet and S. F. Liu:* Equilibrium and Transport for Quasi Helical Reversed Field Pinches. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Cardinali, A., M. Baruzzo, C. Di Troia, M. Marinucci, A. Bierwage, G. Breyiannis, S. Briguglio, G. Fogaccia, G. Vlad, X. Wang, F. Zonca, V. Basiuk, R. Bilato, M. Brambilla, F. Imbeaux, S. Podda and M. Schneider:* Energetic Particle Physics in FAST H-Mode Scenario with Combined NNBI and ICRH. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Chankin, A. V., W. Fundamenski, M. Groth, D. Moutlon and JET-EFDA Contributors:* Effect of Neutrals on the Power Decay Length at the Divertor Target. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Chapman, I. T., R. J. Akers, N. C. Barrat, A. R. Field, K. J. Gibson, M. P. Gryaznevich, R. J. Hastie, T. C. Hender, D. F. Howell, M. D. Hua, G. Huysmans, Y. Q. Liu, M. Maraschek, C. Michael,*

*G. Naylor, T. O’Gorman, S. D. Pinches, R. Scannell, S. A. Sabbagh, H. R. Wilson and MAST Team:* Macroscopic Stability of High Beta MAST Plasmas. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Chatziantonaki, I., C. Tsironis, E. Poli and L. Vlahos:* Electron-cyclotron wave propagation, absorption and current drive in the presence of Neoclassical Tearing Modes. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Chikada, T., A. Suzuki, C. Adelhelm, H. Maier, T. Terai and T. Muroga:* Deuterium Permeation Mechanism through Erbium Oxide Coating for Tritium Permeation Barrier. (9<sup>th</sup> International Conference on Tritium Science and Technology (TRITIUM 2010), 2010-10-24 to 2010-10-29, Nara).

*Chikada, T., A. Suzuki, C. Adelhelm, H. Maier, T. Terai and T. Muroga:* Surface Behavior in Deuterium Permeation through Erbium Oxide Coating. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Chlechowicz, E.:* Plasma Current and Pressure Measurements at the WEGA Stellarator. (General Atomics, 2010-07-20, San Diego, CA).

*Chlechowicz, E.:* Plasma Current and Pressure Measurements at the WEGA Stellarator. (Princeton Plasma Physics Laboratory, 2010-08-10, Princeton, NJ).

*Chlechowicz, E., H. P. Laqua, S. Marsen, T. Stange, A. Werner and M. Otte:* Bestimmung des diamagnetischen Effekts in WEGA-Plasmen. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Chlechowicz, E., H. P. Laqua, J. Urban, A. Werner and M. Otte:* Stromtriebexperimente am Stellarator WEGA. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Classen, I., J. E. Boom, W. Suttrop, E. Schmid, M. Garcia-Munoz, B. Tobias, C. W. Domier, N. C. Luhmann, H. K. Park and ASDEX Upgrade Team:* 2D Electron Cyclotron Emission Imaging at ASDEX Upgrade. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Conway, G. D., C. Angioni, T. Happel, E. Poli, F. Ryter, P. Sauter, B. Scott, J. Vicente and ASDEX Upgrade Team:* Behaviour of Mean and Oscillating  $E \times B$  Plasma Flows and Turbulence Interactions during Confinement Mode Transitions. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).



Conway, G. D., C. Angioni, F. Ryter, P. Sauter, J. Vincente and ASDEX Upgrade Team: Interaction of mean oscillating  $E \times B$  flows across the L-H transition. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

Conway, G. D. and ASDEX Upgrade Team: Turbulence and flow behaviour in improved confinement modes. (ASDEX Upgrade Edge Physics Forum, 2010-05-10, Garching).

Coster, D. P.: Detachment physics in SOLPS simulations. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Coster, D. P., A. Chankin, H.-J. Klingshirn, C. Konz, X. Bonnin, D. Reiter, V. Kotov, V. Rozhansky, S. Voskoboinikov, E. Kaveeva and Contributors to the EFDA TF ITM: SOLPS and PMI modeling. (ARIES Town Meeting on “Edge Plasma Physics and Plasma Material Interactions in the Fusion Power Plant Regime”, 2010-05-20 to 2010-05-21, San Diego, CA).

Craciunescu, T., P. Lang, A. Murari, T. Szepesi, S. Kalvin, G. Kocsis, A. Alonso, I. Tiseanu, V. Zoita and JET EFDA Contributors: Determination of the pellets parameters by image processing methods. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Cseh, G., S. Kalvin, G. Kocsis, P. Lang, T. Szepesi and ASDEX Upgrade Team: A database for pellet ablation investigations in ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

De La Luna, P. T., A. Thomsen, B. Saibene, E. Eich, A. Lomas, S. McDonald, T. Beurskens, D. Boboc, K. Giroud, L. Devaux, A. Garzotti, G. Lönnroth, F. Nardon, K. Nunes, A. Parail, P. J. Sartori, M. Solano, H. W. Voitsekhovitch, G. Zabeo and JET-EFDA Contributors: Effect of ELM Mitigation on Confinement and Divertor Heat Loads on JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

De Marné, P., A. Herrmann and ASDEX Upgrade Team: The problem of Jitter and its correction for diagnostics at ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

De Temmerman, G., M. Balden, K. Bystrov, L. Marot and G. Matern: Morphology changes and erosion of Mo and W under He plasma exposure in Pilot-PSI. (Joint FZJ/FOM Meeting, 2010-04-29, Jülich).

De Temmerman, G., M. Balden, K. Bystrov, L. Marot, G. Matern and J. Zielinski: Erosion and morphology changes

of high-Z metals under high ion fluxes. (14<sup>th</sup> ITPA Meeting on SOL/Divertor Physics, 2010-10-18 to 2010-10-21, Seoul).

Devaux, S., T. Eich, G. Arnoux, W. Fundamenski, H. Thomsen and JET EFDA Contributors: Type I ELM filamentary substructure on the JET divertor target. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Dhard, C., H. Bau, M. Nagel, A. Friedrich, U. Meyer and S. Raatz: Instrumentations for W7-X cryogenic system. (23<sup>th</sup> International Cryogenic Engineering Conference and International Cryogenic Materials Conference 2010 (ICEC 23 – ICMC 2010), 2010-07-19 to 2010-07-23, Wroclaw).

Dhard, C. and S. Raatz: Cooling Scheme for W7-X Divertor Cryo-Vacuum Pumps. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Dhard, C., S. Raatz, H. Bau, L. Decker and U. Nüsslein: Progress of Helium Refrigeration System for Wendelstein 7-X. (DKV-Tagung 2010, 2010-11-17 to 2010-11-19, Magdeburg).

D’Inca, R., F. Braun, B. Eckert and J.-M. Noterdaeme: Design of a Sub-Harmonic Arc Detector for ITER. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Dinklage, A., R. Fischer, A. Kus, M. Reich, R. Reimer, R. C. Wolf, C. Konz, D. Coster and R. Coelho: Simulation of MSE spectra from predictive fusion plasma simulations. (ITM General Meeting, 2010-09-13 to 2010-09-15, Lisbon).

Dinklage, A., R. Reimer, R. C. Wolf and M. Reich: Forward Modeling of Motional Stark Effect Spectra. (6<sup>th</sup> Workshop on Fusion Data Processing, Validation and Analysis, 2010-01-25 to 2010-01-27, Madrid).

Dittmar, T., E. Tsitrone, B. Pegourie, E. Gauthier, P. Languille, J. Likonen, A. Litnovsky, C. Martin, M. Mayer, J. Y. Pascal, C. Pardanaud, B. Pasquet, V. Philipps, J. Roth, P. Roubin and I. Roure: Deuterium Inventory in Tore Supra: fuel retention in the gaps. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Douai, D., A. Lyssoivan, V. Philipps, V. Rhode, T. Wauters, T. Blackman, V. Bobkov, S. Brémond, S. Brezinsek, E. de la Cal, E. Coyne, E. Gauthier, M. Graham, S. Jachmich, E. Joffrin, R. Koch, A. Kreter, P. U. Lamalle, E. Lerche, G. Lombard, M. Maslov, M.-L. Mayoral, A. Miller, I. Monakhov, J.-M. Noterdaeme, J. Ongena, M. K. Paul, B. Pégourié, R. Pitts, V. Plyusnin, F. C. Schüller, G. Sergienko, M. Shimada, W. Suttrop, C. Sozzi,

*M. Tsalias, T. Tsitrone, D. Van Eester, M. Vervier, TORE SUPPA Team, TEXTOR Team, ASDEX Upgrade Team and JET EFDA Contributors:* ICRF assisted wall conditioning on mid and large size Tokamaks. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Douai, D., A. Lysoivan, V. Philipps, V. Rohde, T. Wauters, T. Blackman, V. Bobkov, S. Bremond, S. Brezinsek, E. de la Cal, T. Coyne, E. Gauthier, M. Graham, S. Jachmich, E. Joffrin, A. Kreter, P. U. Lamalle, E. Lerche, G. Lombard, M. Maslov, M.-L. Mayoral, A. Miller, I. Monakhov, J.-M. Noterdaeme, J. Ongena, M. K. Paul, B. Pegourie, R. A. Pitts, V. Plyusnin, F. C. Schüller, G. Sergienko, M. Shimada, W. Suttrop, C. Sozzi, M. Tsalias, E. Tsitrone, D. Van Eester, M. Vervier, Tore Supra Team, TEXTOR Team, ASDEX Upgrade Team and JET EFDA Contributors:* Recent results on ICRF assisted wall conditioning in mid and large size tokamaks. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Douai, D., A. Lysoivan, V. Philipps, V. Rohde, T. Wauters, T. Blackman, V. Bobkov, S. Bremond, S. Brezinsek, E. De la Cal, T. Coyne, E. Gauthier, M. Graham, S. Jachmich, E. Joffrin, R. Koch, A. Kreter, P. U. Lamalle, E. Lerche, G. Lombard, M.-L. Mayoral, A. Miller, I. Monakhov, J.-M. Noterdaeme, J. Ongena, M. K. Paul, B. Pegourie, R. Pitts, V. Plyusnin, F. C. Schüller, G. Sergienko, M. Shimada, W. Suttrop, E. Tsitrone, D. Van Eester, TORE SUPRA Team, TEXTOR Team, ASDEX Upgrade Team and JET EFDA Contributors:* Recent Results on Ion Cyclotron Wall Conditioning in Mid and Large Size Tokamaks. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Dreier, H., P. Bagryansky, W. Biel, M. Hirsch, P. Kornejew, H. T. Lambert, A. Lizunov, B. Schweer and A. Solomakhin:* Four-channel dispersion interferometer at textor. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Drube, R., G. Neu, R. Cole and K. Lüddecke:* A Real Time Video Safety System to Avoid Damages during Plasma Discharges in ASDEX Upgrade. (4<sup>th</sup> International Conference on Image and Signal Processing (ICISP 2010), 2010-06-30 to 2010-07-02, Quebec).

*Dudek, A., A. Benndorf, V. Bykov, P. van Eeten, J. Fellingner, D. Hathiramani, D. Kuse, F. Meisel, S. Padelt, D. Pilopp, F. Schauer and L. Sonnerup:* Bolted coil support at the W7-X module interface. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Durodié, F., I. Monakhov, M. Nightingale, M. L. Mayoral, A. Argouarch, G. Berger-By, T. Blackman, V. Cocilovo,*

*A. Czarnecka, S. Dowson, D. Frigione, R. Goulding, M. Graham, J. Hobirk, S. Huygen, S. Jachmich, P. Jacquet, E. Lerche, T. Loarer, R. Maggiora, A. Messiaen, D. Milanese, M. F. F. Nave, J. Ongena, F. Rimini, H. Sheikh, C. Sozzi, M. Tsalias, D. Van Eester, M. Vrancken, A. Whitehurst, E. Woolridge, K.-D. Zastrow and JET-EFDA Contributors:* Latest Achievements of the JET ICRF Systems in View of ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Dux, R.:* Plasmaphysik und Fusionsforschung. (WS 2009/2010. Proseminar, Universität Augsburg).

*Dux, R., A. Janzer, T. Pütterich and ASDEX Upgrade Team:* Erosion and Confinement of Tungsten in ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Eich, T., H. Thomsen, S. Devaux, A. Herrmann, A. Kallenbach, G. Arnoux, W. Fundamenski, S. Jachmich, A. Scarabosio, V. Riccardo, M. N. A. Beurskens and JET-EFDA Contributors:* ELM resolved power load scaling and energy balance in JET. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Eliseev, L. G., A. V. Melnikov, R. Jiménez-Gómez, E. Ascasibar, C. Hidalgo, A. A. Chmyga, A. D. Komarov, A. S. Kozachok, I. A. Krasilnikov, L. I. Krupnik, S. M. Khrebtov, A. Könies, Y. K. Kuznetsov, M. Liniers, S. E. Lysenko, V. A. Mavrin, J. L. de Pablos, M. A. Pedros, S. V. Perlov, A. I. Smolyakov, D. Spong, M. V. Umtsev, T. Ido, K. Nagaoka, S. Yamamoto and A. I. Zhezhera:* Alfvén Eigenmodes Properties and Dynamics in the TJ-II Stellarator. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Elvis, M., F. Civano, G. Lanzuisi, F. Fiore, M. Salvato, C. Feruglio, S. Puccetti, C. Vignali, A. Comastri, M. Brusa, N. Cappellutti and COSMOS Team:* Obscured AGNs in the Chandra COSMOS Survey. (215<sup>th</sup> AAS Meeting, 2010-01-03 to 2010-01-07, Washington, DC).

*Endstrasser, N., M. Balden, V. Rohde, G. Matern, S. Lindig, J. P. Sharpe, R. Neu and ASDEX Upgrade Team:* Video Tracking and Post-mortem Analysis of Dust Particles from All Tungsten ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Endstrasser, N., M. Balden, V. Rohde, R. Neu and ASDEX Upgrade Team:* Post-mortem analysis of dust particles from all tungsten ASDEX-Upgrade. (Abtragsmechanismen und Spotbewegung auf reaktorrelevanten Materialien, 2010-09-16, Wildau).

*Ertle, D., P. Starke and U. Fantz:* Teilchendichten und -flüsse in HF-angeregten Wasserstoffplasmen. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Esposito, B., G. Granucci, M. Maraschek, A. Gude, V. Igochine, S. Nowak, J. Stober, H. Zohm and ASDEX Upgrade Team:* Avoidance of disruptions at high  $\beta_N$  in ASDEX Upgrade with off-axis ECRH. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Esteban, L., M. Sánchez, P. Kornejew, M. Hirsch, P. Pedreira and P. Acedo:* Comparative study between the FPGA based phase meter of TJ-II and the analog phase meter used in W7-X IR interferometer prototype. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Esteban, L., M. Sánchez, J. Sánchez, P. Kornejew, M. Hirsch, H.-J. Hartfuß, J. A. López, O. Nieto-Taladriz and A. Fernández:* Real time phase measurement in the W7-X IR-interferometer by means of an FPGA and high speed ADCs. (6<sup>th</sup> Workshop on Fusion Data Processing, Validation and Analysis, 2010-01-25 to 2010-01-27, Madrid).

*Fable, E., C. Angioni, S. Fietz, J. Hobirk, G. Pereverzev and ASDEX Upgrade Team:* Transport Physics of ASDEX Upgrade Current Ramps: Experiment and Theory. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Fable, E., C. Angioni, J. Hobirk, G. Pereverzev, F. Rytter, S. Fietz and ASDEX Upgrade Team:* Characteristics of electron transport during current ramps in the ASDEX Upgrade Tokamak. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Fantz, U.:* Atom-, Molekül- und Kernphysik. (WS 2009/2010. Vorlesung, Universität Augsburg).

*Fantz, U.:* Diagnostics of Negative Hydrogen Ion Sources for ITER. A Comparative Study. (CERN Ion Source Seminar, 2010-02-02, Genf).

*Fantz, U.:* Leuchtende Plasmabälle: Plasmaoide oder Kugelblitze. (Lange Nacht der Wissenschaft, 2010-05-15, Garching).

*Fantz, U.:* Powerful Plasma Sources for Negative Hydrogen Ions: A Challenge to Sustain the Fire in ITER. (Physikalisches Kolloquium, 2010-05-03, Bochum).

*Fantz, U.:* Physikalisches Praktikum für Fortgeschrittene, Teil B. (WS 2009/2010. Praktikum, Universität Augsburg).

*Fantz, U.:* Physikalisches Praktikum für Fortgeschrittene, Teil B. (SS 2010. Praktikum, Universität Augsburg).

*Fantz, U., S. Briefi and R. Friedl:* Modelling the radiation of diatomic molecules in low pressure discharges. (12<sup>th</sup> International Symposium on the Science and Technology of Light Sources (LS12) and International Conference on White LEDs and Solid State Lighting (White LED3), 2010-07-11 to 2010-07-16, Eindhoven).

*Fantz, U. and R. Dux:* Plasmaphysik und Fusionsforschung I. (WS 2009/2010. Vorlesung, Universität Augsburg).

*Fantz, U. and R. Dux:* Plasmaphysik und Fusionsforschung II. (SS 2010. Vorlesung, Universität Augsburg).

*Fantz, U., R. Gutser and P. Franzen:* Plasma heating: neutral beam injection. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Fantz, U. and T. Hamacher:* Physikalische Grundlagen der Energiewandlung und Verteilung. (WS 2009/2010. Vorlesung/Seminar, Universität Augsburg).

*Fantz, U., L. Schiesko, A. Herttrich and NNBI Team:* Langmuir Probe Measurements in Powerful RF-Sources for Negative Hydrogen Ions. (20<sup>th</sup> European Conference on the Atomic and Molecular Physics of Ionized Gases (ESCAMPIG), 2010-07-13 to 2010-07-17, Novi Sad).

*Fantz, U. and M. Schreck:* Niedertemperaturplasmen als industrielle Schlüsseltechnologie. (WS 2009/2010. Seminar/Vorlesung, Universität Augsburg).

*Fantz, U. and M. Schreck:* Niedertemperaturplasmen als industrielle Schlüsseltechnologie. (SS 2010. Seminar/Vorlesung, Universität Augsburg).

*Fantz, U. and C. Wimmer:* Quantification of cesium in negative hydrogen ion sources by laser absorption spectroscopy. (2<sup>nd</sup> International Symposium on Negative Ions, Beams and Sources (NIBS2010), 2010-11-16 to 2010-11-19, Takayama).

*Fantz, U. and D. Wunderlich:* Atomic and molecular collisional radiative modelling for spectroscopy of both low temperature and magnetic fusion plasmas. (7<sup>th</sup> International Conference on Atomic and Molecular Data and their Applications (ICAMDATA), 2010-09-21 to 2010-09-24, Vilnius).

*Fantz, U. and D. Wunderlich:* The relevance of dissociative recombination for fusion plasmas. (8<sup>th</sup> International Conference on Dissociative Recombination: Theory, Experiments & Applications (DR2010), 2010-08-16 to 2010-08-20, Granlibakken, CA).

*Faugel, H., F. Braun, V. Bobkov, Th. Franke, M. Kircher, J.-M. Noterdaeme and G. Siegl:* An improved method to measure the antenna resistance and radiated power of ICRF-Antennas using current probes. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Fehér, T., A. Könies, R. Kleiber and R. Hatzky:* Linear benchmarks with the CKA/Euterpe hybrid code. (4<sup>th</sup> Meeting of the ITPA TG on Energetic Particle Physics, 2010-04-26 to 2010-04-28, Garching).

*Feist, J. H. and Wendelstein 7-X Team:* Wendelstein 7-X aus der Sicht des Qualitätsmanagements oder Wofür braucht man ein TÜV-Zertifikat? (Tag der offenen Tür, 2010-09-25, Greifswald).

*Fellinger, J. H., T. Bergmann, S. Freundt, D. Hathiramani, V. Bykov and F. Schauer:* Dynamic response analysis of superconducting coils in Wendelstein 7-X, and mechanical quench test. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Feng, Y., M. Kobayashi, T. Lunt and D. Reiter:* Comparison between Stellarator and Tokamak Divertor Transport. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Fenstermacher, M. E., M. Becoulet, P. Cahyna, J. Canik, C. S. Chang, T. E. Evans, A. Kirk, A. Loarte, Y. Liang, R. Maingi, O. Schmitz, W. Suttrop and H. Wilson:* ELM Control by Resonant Magnetic Perturbations: Overview of Research by the ITPA Pedestal and Edge Physics Group. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Fischer, R., A. Burckhart, C. J. Fuchs, N. Hicks, A. Kallenbach, B. Kurzan, B. Langer, C. F. Maggi, H. Meister, T. Pütterich, S. Rathgeber, E. Wolfrum and ASDEX Upgrade Team:* Recent Applications of Integrated Data Analysis at ASDEX Upgrade. (6<sup>th</sup> Workshop on Fusion Data Processing, Validation and Analysis, 2010-01-25 to 2010-01-27, Madrid).

*Floristan, M., P. Müller, A. Gebhardt, A. Killinger, A. Cardella, C. Li, R. Stadler, G. Zangl, M. Hirsch, H. Laqua and X. Kaspereke:* Development and testing of a 140 GHz absorber coating for the water baffle of W7-X cryopumps. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Förstel, M., M. Mucke, T. Arion, T. Lischke, A. Bradshaw and U. Hergenrohn:* The observation of electronic energy bands in argon clusters. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Fortuna-Zalesna, E., M. Rubel, R. Neu, M. Rasinski, V. Rohde, W. Zielinski, M. Andrzejczuk, K. J. Kurzydowski, TEXTOR*

*Team and ASDEX Upgrade Team:* Examination of dust particles from present-day controlled fusion devices. (World Materials Research Institute Forum (WMRIF). 2<sup>nd</sup> International Workshop for Young Materials Scientists, 2010-08-31 to 2010-09-03, Berlin).

*Franzen, P., U. Fantz and NNBI Team:* Beam Homogeneity Dependence on the Magnetic Filter Field at the IPP Test Facility MANITU. (2<sup>nd</sup> International Symposium on Negative Ions, Beams and Sources (NIBS2010), 2010-11-16 to 2010-11-19, Takayama).

*Friedl, R., U. Fantz and P. Starke:* Spektrale Intensität der N<sub>2</sub>-Strahlung in einer Argon-Niederdruck-Bogenentladung für den Einsatz als Lichtquelle. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Friedl, R., U. Fantz and F. Vogel:* Spectral intensity of the N<sub>2</sub> emission in rare gas low-pressure arc discharges. (12<sup>th</sup> International Symposium on the Science and Technology of Light Sources (LS12) and International Conference on White LEDs and Solid State Lighting (White LED3), 2010-07-11 to 2010-07-16, Eindhoven).

*Frigione, D., L. Garzotti, E. Giovannozzi, F. Köchl, B. Alper, E. Belonohy, A. Boboc, K. G-l, G. Kocsis, T. Lang, Y. Liang and JET EFDA Contributors:* Particle Deposition, Transport and Fuelling in Pellet Injection Experiments at JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Fuchs, J. C., M. Bernert, T. Eich, A. Herrmann, P. de Marné, B. Reiter and ASDEX Upgrade Team:* Radiation Losses of Type-I ELMs during Impurity Seeding Experiments in the Full Tungsten ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Fülöp, T., S. Braun and I. Pusztai:* Impurity Transport driven by Electrostatic Turbulence in Tokamak Plasmas. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Fundamenski, W., T. Eich, S. Devaux, S. Brezinsek, G. Maddison, K. McCormick, G. Arnoux, M. Jakubowski, H. Thomsen, A. Huber, S. Jachmich and JET-EFDA Contributors:* Effect of Ion Mass and Charge on Divertor Heat Load Profiles on JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Gaio, E., A. Zamengo, V. Toigo, L. Zanutto, M. Rott, W. Suttrop and ASDEX Upgrade Team:* Conceptual design of the power supply system for the in-vessel saddle coils for MHD control in ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).



*Gantenbein, G., V. Erckmann, S. Illy, S. Kern, W. Kasperek, C. Lechte, W. Leonhardt, C. Liévin, A. Samartsev, A. Schlaich, M. Schmid and M. Thumm:* 140 GHz, 1 MW CW Gyrotron Development for the ECH System of the Stellarator W7-X. (35<sup>th</sup> International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2010), 2010-09-05 to 2010-09-10, Rome).

*Garcia-Munoz, M., I. G. J. Classen, M. A. Van Zeeland, B. Geiger, R. Bilato, V. Bobkov, M. Brüdgam, S. da Graca, W. W. Heidbrink, N. Hicks, V. Igochine, S. Jämsä, P. Lauber, M. Maraschek, F. Meo, K. Sassenberg, R. van Voornveld and ASDEX Upgrade Team:* Fast-Ion Transport Induced by Alfvén Eigenmodes in ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Gasior, P., M. Bieda, M. Kubkowska, R. Neu, J. Wolowski and ASDEX Upgrade Team:* Laser induced breakdown spectroscopy as diagnostics for fuel retention and removal and wall composition in fusion reactors with mixed-material components. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Gasparian, Y., V. Burlaka, S. Krat, A. Pisarev and K. Sugiyama:* Recycling of Deuterium and the Cathode Material in Magnetron. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials. Satellite Workshop of the 19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Gasparian, Y., S. Yarko, M. Mayer, V. Kurnaev and A. Pisarev:* Modeling of deuterium permeation through tungsten coated with a carbon film. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Gates, D., J. Baumgaertel, M. Bitter, A. Boozer, T. Brown, D. Darrow, T. Dodson, W. Guttentfelder, G. Hammett, P. Heitzenroeder, K. Hill, L. Ku, D. Mikkelsen, H. Neilson, N. Pomphrey, A. Reiman, C. Skinner, B. Stratton, M. Zarnstorff, M. Cole, J. Harris, P. Fogarty, R. Sanchez, M. Goto, K. Ida, M. Isobe, S. Morita, S. Sakakibara, Y. Suzuki, K. Tanaka, H. Yamada, M. Yosinuma, C. Baylard, H. S. Bosch, T. Bräuer, R. Haange, T. Klinger, R. König, L. Wegener, A. Werner, R. Wolf and P. Xanthopoulos:* Overview of the US Collaborative Program in Stellarator Experiments. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Geiger, J.:* Status Equilibrium Database. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Geiger, J.:* Status & Plans for 3D-Equilibria for W7-AS. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Geiger, J.:* Thoughts on Tokamak – Stellarator/Heliotron Comparison. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Geiger, J., C. Beidler, M. Drevlak, Y. Feng, P. Helander, N. Marushchenko, H. Maaßberg, C. Nührenberg, Y. Turkin and P. Xanthopoulos:* Physics Modeling for Steady-State Experiments at Wendelstein 7-X. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Geiger, J. and J. Hanson:* VMEC Profile Specification. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Gentzsch, W., A. Kennedy, H. Lederer, G. Pringle, J. Reetz, M. Riedel, B. Schuller, A. Streit and J. Wolfrat:* DEISA: e-Science in a Collaborative, Secure, Interoperable and User-Friendly Environment. (eChanges Conference, 2010-10-27 to 2010-10-29, Warsaw).

*Giannone, L., T. Eich, J. C. Fuchs, M. Ravindran, Q. Ruan, L. Wenzel, M. Cerna and S. Concezzi:* Data acquisition and real-time bolometer tomography using LabVIEW RT. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Giannone, L., R. Fischer, K. Lackner, P. J. McCarthy and ASDEX Upgrade Team:* Computational Strategies in Optimizing a Real-Time Grad-Shafranov PDE Solver Using High-Level Graphical Programming and COTS Technology. (8<sup>th</sup> International Workshop on Personal Computers and Particle Accelerators (PCaPAC 2010), 2010-10-05 to 2010-10-08, Saskatoon).

*Giroud, C., G. Maddison, K. McCormick, A. Alonso, B. Alper, Y. Andrew, G. Arnoux, P. Belo, M. Beurskens, A. Boboc, A. Brett, S. Brezinsek, M. Brix, I. Coffey, E. de la Luna, S. Devaux, P. De Vries, T. Eich, R. Felton, W. Fundamenski, E. Giovannozzi, J. Harling, D. Harting, J. Hobirk, A. Huber, S. Jachmich, I. Jenkins, E. Joffrin, A. Kallenbach, M. Kempenaars, M. Lehnen, T. Loarer, P. Lomas, D. McDonald, J. Mailloux, A. Meigs, P. Morgan, D. Moulton, I. Nunes, V. Riccardo, F. Rimini, A. Sirinelli, M. Stamp, G. Telesca, H. Thomsen, I. Voitsekhovitch, S. Weisen and JET EFDA Contributors:* Integration of a Radiative Divertor for Heat Load Control into JET Operational Scenarios. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Giruzzi, G., M. Lennholm, A. Parkin, F. Bouquey, H. Braune, A. Bruschi, E. De La Luna, G. Denisov, T. Edlington, D. Farina, J. Farthing, L. Figini, S. Garavaglia, J. Garcia, T. Gerbaud, G. Granucci, M. Henderson, M. Jennison, P. Khilar, N. Kirneva, D. Kislov, A. Kuyanov, X. Litaudon, A. G. Litvak, A. Moro,*

*S. Nowak, V. Parail, G. Saibene, C. Sozzi, E. Trukhina and V. Vdovin:* Objectives, Physics Requirements and Conceptual Design of an ECRH System for JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Glaubitz, M., D. Zhang and M. Otte:* Untersuchung schneller Plasmaprozesse am WEGA Stellarator mit Hilfe eines Halbleiterbolometers. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Görler, T.:* Flux-driven global gyrokinetic simulation of tokamak turbulence. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Görler, T., X. Lapillonne, S. Brunner, J. Chowdhury, T. Dannert, F. Jenko, P. Marcus, B. F. McMillan, F. Merz, D. Told and L. Villard:* Nonlocal Effects in Gyrokinetic Turbulence Simulations using GENE. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Görler, T., X. Lapillonne, S. Brunner, T. Dannert, F. Jenko, F. Merz and D. Told:* Nonlinear gyrokinetic simulations covering multiple spatio-temporal scales. (Workshop on Self-Organization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

*Golubeva, A. V., A. V. Spitsyn, M. Mayer, F. Koch, T. Schwarz-Selinger and A. A. Skovoroda:* Gas-driven hydrogen isotopes permeation through coated graphite. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Greuner, H., Ch. Linsmeier and H. Maier:* High Heat Flux Facility GLADIS at IPP Garching. (International Workshop on Requirements for Next Generation Plasma-Material Interaction Test Stands in Fusion Research, 2010-08-31 to 2010-09-02, Oak Ridge, TN).

*Greuner, H., H. Maier, Ch. Linsmeier and M. Balden:* Thermal fatigue: comparative test under H and He beam loading of different armour W-alloys. (EFDA Topical Group Materials Science, 2010-02-03, Garching).

*Greuner, H., H. Maier, Ch. Linsmeier and M. Balden:* W & W-alloys under First Wall & Divertor condition, subjected to H and He neutral-beams. (EFDA Topical Group Materials Science, 2010-06-28 to 2010-06-29, San Sebastian).

*Greuner, H., U. von Toussaint, B. Böswirth, J. Boscary and H. Traxler:* Statistical assessment of the quality of CFC tile bonding on divertor components for W7-X. (26<sup>th</sup> Sym-

posium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Groth, M., S. Wiesen, M. Wischmeier, G. D. Porter, M. E. Rensink, T. D. Rognlien, S. Jachmich, H. W. Müller, J. G. Watkins, M. N. A. Beurskens, S. Brezinsek, N. H. Brooks, R. Dux, T. Eich, M. E. Fenstermacher, C. Fuchs, A. Huber, A. Kallenbach, C. J. Lasnier, A. W. Leonard, A. Meigs, D. L. Rudakov, M. F. Stamp, DIII-D Team, ASDEX Upgrade Team and JET Team:* Validation of divertor particle and heat loads in detached Ohmic and L-mode plasmas in DIII-D, AUG, and JET using UEDGE. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-29, San Diego, CA).

*Grukke, O., J. L. Terry and B. LaBombard:* Experimental investigations of the parallel dynamics of turbulent fluctuations in the scrape-off layer of Alcator C-Mod. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Günter, S.:* Energie erzeugen wie die Sonne – die Kernfusion im Energiemix der Zukunft. (10. Münchner Wissenschaftstage. Energie: Grundlage des Lebens – Motor für die Zukunft, 2010-10-23 to 2010-10-26, München).

*Günter, S.:* Turbulent Transport of Energetic Ions. (International Tokamak Physics Activity MHD Topical Group Meeting, 2010-10-18 to 2010-10-21, Seoul).

*Günter, S., D. Borba, A. Fasoli, A. Fukuyama, N. N. Gorelenkov, A. Könies, P. Lauber, N. Mellet, T. Panis, S. D. Pinches, S. Sharapov, D. Spong, D. Testa, ITPA Group on Energetic Particles and JET EFDA Contributors:* The Influence of Plasma Shaping Effects on the Damping of Toroidal Alfvén Eigenmodes. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Guertler, N. and K. Hallatschek:* Derivation of a Reynolds stress response functional for zonal flows from numerical studies. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Gulejová, B., R. Pitts, D. Tskhakaya and D. Coster:* Benchmark of fluid and kinetic simulations of type III elming H-mode on TCX. (International Youth Conference on Fusion Energy in Conjunction with the 23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Gunn, J. P., M. Kubic, N. Fedorczak and M. Kocan:* ITER start-up experiments in Tore Supra. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Gurbich, A., D. Abriola, N. P. Barradas, I. Bogdanovic-Radovic, M. Chiari, C. Jeynes, M. Kokkoris, A. R. Ramos, M. Mayer, L. Shi and I. Vickridge:* Measurements and Evaluation of Differential Cross Sections for Ion Beam Analysis. (International Conference on Nuclear Data for Science and Technology, 2010-04-26 to 2010-04-30, Jeju Island).

*Gusarov, A., S. Huysmans, L. Giannone and H. Meister:* Radiation stability of resistive bolometers intended for operation in the ITER environment. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Häberle, E., J. Kopecki, A. Schulz, M. Walker, U. Stroth, A. Mutzke and R. Schneider:* Optimierung von Barrierschichten mittels Substratbias. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Härtil, T.:* Measurement of gas retention in ASDEX Upgrade – A technical review. (Meeting of the EU TF PWI Special Expert Working Group on “Gas Balance and Fuel Retention”, 2010-07-19 to 2010-07-20, Garching).

*Hager, R. and K. Hallatschek:* Magnetic geometry effects on geodesic acoustic modes. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Hakola, A., J. Likonen, L. Aho-Mantila, M. Groth, S. Koivuranta, K. Krieger, M. Mayer, R. Neu, V. Rohde and ASDEX Upgrade Team:* Investigating Global Transport of Light Elements in the Full-W ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Hallatschek, K.:* Control of Turbulent Transport by GAMs. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Hallatschek, K.:* Radial transfer effects for poloidal rotation. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Hallatschek, K., N. Gürtler and R. Hager:* Radial transfer mechanisms of GAMs and zonal flows. (International Sherwood Fusion Theory Conference, 2010-04-19 to 2010-04-21, Seattle, WA).

*Hangan, D., V. Bobkov, F. Braun, R. D’Inca, H. Faugel and J.-M. Noterdaeme:* Analysis of dynamic matching networks for the ICRF System at ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Harris, P. R., F. W. Meyer, W. Jacob, T. Schwarz-Selinger and U. von Toussaint:* Molecular size effect in the chemical

sputtering of a-C:H thin films by low energy  $H^+$ ,  $H_2^+$ , and  $H_3^+$  ions. (18<sup>th</sup> International Workshop on Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).

*Hartfuß, H.-J.:* Fusion Plasma Diagnostics with Microwaves. (20<sup>th</sup> International Conference on Applied Electromagnetics and Communications, 2010-09-20 to 2010-09-22, Dubrovnik).

*Hartfuß, H.-J.:* Introduction to plasma diagnostics. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Harting, D., S. Wiesen, H. Frerichs, P. Boerner, D. Reiter, Y. Feng and JET EFDA Contributors:* Application of the 3D Edge Code EMC3-EIRENE to Jet Single Null Configurations by Validating against 2D Simulations with EDGE2D-EIRENE. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Hartmann, D.:* Plasma heating. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Hasenbeck, F., H. Frerichs, D. Reiter and Y. Feng:* Simulation and analytical analysis of 3D plasma edge region regarding toroidal symmetry breaking block limiters. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Hasinger, G.:* Advanced Nuclear Energy Concepts. (Future Dialogue 2010: Business, Science and Politics in a Changing World, 2010-09-09, Beijing).

*Hasinger, G.:* Auf dem Weg zum Fusionskraftwerk. (Debattenabend der Stiftung Energie & Klimaschutz, 2010-04-13, Stuttgart).

*Hasinger, G.:* Energie erzeugen wie die Sonne: Auf dem Weg zu einem Fusionskraftwerk. (Emmy-Noether-Gymnasium, 2010-11-12, Erlangen).

*Hasinger, G.:* Energie erzeugen wie die Sonne: Auf dem Weg zu einem Fusionskraftwerk. (Felsengartenkellerei, 2010-10-29, Besigheim).

*Hasinger, G.:* Energie erzeugen wie die Sonne – die Kernfusion im Energiemix der Zukunft. (Besuch der Ludmilla-Realschule Bogen, 2010-10-14, IPP Garching).

*Hasinger, G.:* Energie erzeugen wie die Sonne – die Kernfusion im Energiemix der Zukunft. (Gigawatt – Highlights der Physik 2010, 2010-10-09 to 2010-09-14, Augsburg).

*Hasinger, G.*: Der Energiemix im 21. Jahrhundert. (10. Münchner Wissenschaftstage, 2010-10-23 to 2010-10-26, Ludwig-Maximilians-Universität München).

*Hasinger, G.*: Die Energie der Zukunft. (Forschungsbörse, 2010-03-20, Neues Rex Kino, München).

*Hasinger, G.*: Die Energie der Zukunft, Perspektiven einer nachhaltigen Entwicklung: Wie sieht die Welt von morgen aus? (Europäische Akademie, 2010-03-20, Otzenhausen).

*Hasinger, G.*: Energieversorgung der Zukunft – Die Kernfusion? (7. Wissenschaftstage am Helmholtz-Gymnasium, Forschungsbörse, 2010-02-24, Potsdam).

*Hasinger, G.*: Forschung für eine Vision – FUSION – Baustein für den Energiemix der Zukunft? (Deutsches ITER Industrie-forum, 2010-05-03, Berlin).

*Hasinger, G.*: Glückwunsch zur Einweihung des Neubaus II. (Feierliche Einweihung des Neubaus für Technologie-entwicklung und -transfer am Astrophysikalischen Institut Potsdam (AIP), 2010-04-22, Potsdam).

*Hasinger, G.*: How does our energy system look like in the year 2100? (Science & Art in Europe, 2010-05-12 to 2010-05-14, Warsaw).

*Hasinger, G.*: Irdisches Sonnenfeuer – löst die Fusion das Energieproblem? (Forschungsbörse, Max-Planck-Gymnasium, 2010-10-18, München-Pasing).

*Hasinger, G.*: Irdisches Sonnenfeuer – löst die Fusion das Energieproblem? (Lange Nacht der Wissenschaft zum 2. Öku-menischen Kirchentag, 2010-05-15, TUM Garching).

*Hasinger, G.*: Kernfusion – das Sonnenfeuer auf der Erde. (In Schwung gebracht – Gespräche über Energie, 2010-05-06, Max-Planck-Gesellschaft, München).

*Hasinger, G.*: Kernfusion als Beitrag zum Energiemix des 21. Jahrhunderts. (HGF-Forschungsfrühstück, 2010-05-21, Berlin).

*Hasinger, G.*: Kommt das erste Fusionskraftwerk zu spät? (Helmholtz-Salon, 2010-11-15, Berlin).

*Hasinger, G.*: Möglicher Beitrag der Fusion zum Energiemix der Zukunft. (Besuch der Forschungsabteilung des Bayerischen Staatsministeriums für Wissenschaft, Forschung und Kunst, 2010-11-11, IPP Garching).

*Hasinger, G.*: Möglicher Beitrag der Fusion zum Energiemix der Zukunft. (ERES Stiftung, 2010-11-04, München).

*Hasinger, G.*: Möglicher Beitrag der Fusion zum Energie-mix der Zukunft. (Senatssitzung der MPG, 2010-11-19, Siemens AG München).

*Hasinger, G.*: Mystars. Ökumenischer Campusgottesdienst, Evangelische Kirchengemeinde der TUM, 2010-07-13, Garching).

*Hasinger, G.*: Das Schicksal des Universums. (38<sup>th</sup> COSPAR Scientific Assembly, 2010-07-18 to 2010-07-25, Bremen).

*Hasinger, G.*: Sphärenmusik – Harmonie des Himmels. (Abschlusskonzert des OktoberMusikFestes, 2010-11-10, Cuvillies-Theater München).

*Hasinger, G.*: Stand der Fusionstechnik. (42. Kraftwerks-technisches Kolloquium, 2010-10-12 to 2010-10-13, Tech-nische Universität Dresden).

*Hasinger, G.*: Sustainable Energy for the Future. (IMPRS Interdisciplinary Symposium 2010 “New Frontiers in Science”, 2010-11-11 to 2010-11-12, Ludwig-Maximilians-Universität München).

*Hasinger, G.*: Vom Sternenfeuer zum Fusionskraftwerk. (Tag der Unternehmerschaft 2010, 2010-06-10, Hotel NIKKO, Düsseldorf).

*Hasinger, G.*: Vom Sternenfeuer zum Fusionskraftwerk. (TUM Schulcluster, 2010-03-16, Benediktbeuern).

*Hasinger, G.*: Von der Sonne auf die Erde: Die Energie der Zukunft. (1<sup>st</sup> European Symposium on the History of Physics: ‘echophysics’, 2010-05-28 to 2010-05-29, Pöllau).

*Hasinger, G.*: The Way to a Fusion Power Station. (MPIPKS Seminar & TURB10 Colloquium, Workshop on Self-Or-ganization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

*Hasinger, G.*: Der Weg zum Fusionskraftwerk. (FZD Kollo-quium, 2010-10-12, Dresden Rossendorf).

*Hasinger, G.*: Der Weg zu einem Fusionskraftwerk. (Bochumer Physikalisches Kolloquium, 2010-06-07, Ruhr-Universität Bochum).

*Hasinger, G.*: Der Weg zu einem Fusionskraftwerk. (Indus-trieclub Sachsen, 2010-02-02, Dresden).

*Hasinger, G.*: Der Weg zu einem Fusionskraftwerk. (Mathe-matisch-Physikalisches Kolloquium, 2010-05-04, Leibniz Universität Hannover).



*Hasinger, G.*: Der Weg zu einem Fusionskraftwerk – oder: Wie könnte die Energieversorgung der Zukunft aussehen? (Energimix 2050 – Die Rolle der Geowissenschaften für die zukünftige Energieversorgung, 2010-04-19 to 2010-04-20, Berlin-Brandenburgische Akademie der Wissenschaften, Berlin).

*Hasinger, G.*: Wie funktioniert die Kernfusion? (Lange Nacht der Wissenschaft zum 2. Ökumenischen Kirchentag, 2010-05-15, IPP Garching).

*Hasinger, G.*: Wie sieht die Energiewelt von morgen aus? (Deutsches ITER IndustrieForum, 2010-05-03, Berlin).

*Hasinger, G.*: Zeit – Schlüsselvariable der Evolution. (Akademievorlesung, 2010-02-04, Berlin-Brandenburgische Akademie der Wissenschaften, Berlin).

*Hasinger, G.*: Die Zukunft der Energie: Der Weg zu einem Fusionskraftwerk. (Volkshochschule und Agenda 21, 2010-09-28, Theater im Römerhof, Garching).

*Hasinger, G.*: Die Zukunft der Energie – Der Weg zu einem Fusionskraftwerk. (Urania, 2010-02-18, Berlin).

*Hathiramani, D., M. Schülke, T. Schneider, A. Dudek, K. Höchel and F. Schauer*: Increased Friction for W7-X Connections by using Micro-Formblock. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Hatzky, R.*: High performance computing Simulations of Microturbulence in Fusion Plasmas. (International Supercomputing Conference 2010, 2010-05-30 to 2010-06-03, Hamburg).

*Hatzky, R. and A. Bottino*: Particle-in-cell methods in plasma physics. (European-US Summer School on HPC Challenges in Computational Sciences, 2010-10-04 to 2010-10-07, Catania).

*Hatzky, R. and S. Günter*: The EFDA HPC Project. (EFDA ITM-TF Meeting, 2010-09-13 to 2010-09-15, Lisbon).

*Hayashi, N., V. Parail, F. Koechl, N. Aiba, T. Takizuka, S. Wiesen, P. T. Lang, N. Oyama and T. Ozeki*: Integrated Simulation of ELM Triggered by Pellet through Energy Absorption and Transport Enhancement. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Heidbrink, W. W., C. M. Muscatello, D. C. Pace, Y. B. Zhu, M. A. Van Zeeland, R. K. Fisher, W. M. Solomon and M. Garcia-Munoz*: New Measurements of Fast-ion Transport. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Hein, B., A. Cardella, D. Hermann, A. Hansen, F. Leher, A. Binni and J. Segl*: Manufacturing and Assembly of the Plasma- and Outer Vessel of the Cryostat for Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Heinemann, B., H.-D. Falter, U. Fantz, P. Franzen, M. Fröschle, W. Kraus, C. Martens, R. Nocentini, R. Riedl, E. Speth and A. Stäbler*: The Negative Ion Source Test Facility ELISE. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Hein, T., C. Angioni, E. Fable and J. Candy*: Theoretical study of the impact of beta on electron and impurity particle transport. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Helander, P.*: Magnetohydrodynamic. (WS 2009/2010. Vorlesung, Universität Greifswald).

*Helander, P.*: The role of the electric field in stellarators. (Workshop on Gyrokinetics in Laboratory and Astrophysical Plasmas, 2010-07-27 to 2010-08-13, Isaac Newton Institute Cambridge).

*Helander, P.*: Rotation and zonal flows in stellarators. (Workshop Gyrokinetics in Laboratory and Astrophysical Plasmas, 2010-07-19 to 2010-08-13, Isaac Newton Institute Cambridge).

*Helander, P.*: Transport Theory for high-temperature plasmas. (SS 2010. Vorlesung, Universität Greifswald).

*Helander, P., R. Kleiber, A. Mishchenko and P. Xanthopoulos*: On rotation and zonal flows in stellarators. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Helander, P. and A. Simakov*: Fast plasma rotation in a quasisymmetric stellarator. (International Sherwood Fusion Theory Conference, 2010-04-19 to 2010-04-21, Seattle, WA).

*Henderson, M. A., F. Albajar, S. Alberti, U. Baruah, T. Bigelow, B. Becket, R. Bertizzolo, T. Bonicelli, A. Bruschi, J. Caughman, R. Chavan, S. Cirant, A. Collazos, C. Cox, C. Darbos, M. de Baar, G. Denisov, D. Farina, F. Gandini, T. Gassman, T. P. Goodman, R. Heidinger, J. P. Hogge, S. Illy, O. Jean, J. Jin, K. Kajiwara, W. Kasperek, A. Kasugai, S. Kern, N. Kobayashi, H. Kumric, J. D. Landis, A. Moro, C. Nazare, Y. Oda, T. Omori, I. Paganakis, B. Piosczyk, P. Platania, B. Plaum, E. Poli, L. Porte, D. Purohit, G. Ramponi, T. Rzesnicki, S. L. Rao, D. Rasmussen, D. Ronden, G. Saibene, K. Sakamoto, F. Sanchez, T. Scherer, M. Shapiro,*

*C. Sozzi, P. Spaeh, D. Strauss, O. Sauter, K. Takahashi, A. Tanga, R. Temkin, M. Thumm, M. Q. Tran, V. S. Udintsev, H. Zohm and C. Zucca*: An Overview of the ITER EC H&CD System and Functional Capabilities. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Hergenbahn, U.*: Coherence and the loss of it in molecular photoionization. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Hergenbahn, U.*: Electron-electron coincidence experiments on free molecules and clusters. (Symposium on Trends in Experimental Physics: Multi-Particle Coincidence Spectroscopy of Atoms and Molecules, 2010-05-28, Uppsala).

*Hergenbahn, U.*: Photoionization and autoionization of weakly bonded clusters. (37<sup>th</sup> International Conference on Vacuum Ultraviolet and X-Ray Physics (VUVX2010), 2010-07-11 to 2010-07-16, Vancouver).

*Hergenbahn, U.*: Photoionization and autoionization of weakly bonded clusters explored with synchrotron radiation. ('Collisions with Molecules and Clusters', Meeting of the Molecular Physics Group and the Atomic and Molecular Interactions Group of the Institute of Physics, 2010-04-15 to 2010-04-16, Milton Keynes).

*Herrmann, A., R. Drube, P. de Marné and ASDEX Upgrade Team*: Real-time protection of in-vessel components in ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Herrmann, A., M. Laux, V. Rohde, O. Gruber, T. Lunt, U. Seidel and ASDEX Upgrade Team*: Arcs in ASDEX Upgrade. (International Workshop on the Role of Arcing and Hot Spots in Magnetic Fusion Devices, 2010-06-25 to 2010-06-26, Dublin).

*Hertrich, A., L. Schiesko, U. Fantz and NNBI Team*: Langmuirsondenmessungen zum Einfluss von externen Magnetfeldern auf Plasmaparameter einer HF-Wasserstoffionenquelle für ITER NBI. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Hirsch, M., T. Akiyama, T. Estrada, T. Mizuuchi, K. Toi and C. Hidalgo*: H-mode in Helical Devices. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Hirsch, M., J. W. Oosterbeek, D. Zhang, K. Ewert, M. Endler, M. Laux, H. P. Laqua and W7-X Team*: Qualifying plasma diagnostics for a high power microwave background of ECRH heated discharges. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Höhnle, H., W. Kasperek, J. Stober, A. Herrmann, R. Neu, J. Schweinzer, U. Stroth and ASDEX Upgrade Team*: Elektron-Zyklotron-Heizung in O2- und X3-Mode an ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Höhnle, H., W. Kasperek, U. Stroth, J. Stober, A. Herrmann, R. Neu and J. Schweinzer*: O2- and X3-heating Experiments on ASDEX Upgrade. (16<sup>th</sup> Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (EC-16), 2010-04-12 to 2010-04-15, Sanya).

*Höhnle, H., J. Stober, A. Herrmann, W. Kasperek, F. Leuterer, F. Monaco, R. Neu, D. Schmid-Lorch, H. Schütz, J. Schweinzer, U. Stroth, D. Wagner, S. Vorbrugg, E. Wolfrum and ASDEX Upgrade Team*: Extension of the ECRH Operational Space with O2- and X3-Heating Schemes to Control Tungsten Accumulation in ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Hole, M. J., G. von Nessi, J. Betram, D. Pretty, B. D. Blackwell, J. Howard, R. L. Dewar, J. Svensson and L. C. Appel*: Model/Data Fusion: Developing Bayesian Inversion to Constrain Equilibrium and Mode Structure. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Holtum, D., M. Fröschle, B. Heinemann, T. Liebe, R. Nocentini, R. Riedl, P. Rong, W. Schubert and A. Stäbler*: Calorimeter Design-Aspects for Neutral Beam Injection on W7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Hopf, C.*: Operational experience with NBI at ASDEX Upgrade. (CCNB Meeting, 2010-06-02 to 2010-06-04, Sofia).

*Horacek, J., J. Adamek, H. W. Müller, J. Seidl, A. H. Nielsen, V. Rohde, F. Mehlmann, C. Ionita, E. Havlickova and ASDEX Upgrade Team*: Fast measurement of plasma potential, temperature and density in SOL of ASDEX Upgrade. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Huber, A., G. Arnoux, M. N. A. Beurskens, S. A. Bozhnikov, S. Brezinsek, T. Eich, C. Fuchs, W. Fundamenski, S. Jachmich, U. Kruezi, M. Lehnen, A. Loarte, G. F. Matthews, P. Mertens, P. D. Morgan, V. Philipps, R. A. Pitts, V. Riccardo, U. Samm, B. Schweer, G. Sergienko, M. Stamp and JET EFDA Contributors*: Radiation loads on plasma-facing components of JET during transient events – experimental results and implications. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Igochine, V.*: Beta limit, resistive wall modes and plasma rotation. (18<sup>th</sup> European Fusion Physics Workshop (EFPW 2010), 2010-12-06 to 2010-12-08, Mayrhofen).

*Imbeaux, F., V. Basiuk, R. Budny, T. Casper, J. Citrin, J. Ferreira, J. Garcia, A. Fukuyama, N. Hayashi, J. Hobirk, D. Hogeweij, M. Honda, I. H. Hutchinson, G. Jackson, C. E. Kessel, F. Köchl, X. Litaudon, P. J. Lomas, J. Lönnroth, T. Luce, D. Mikkelsen, S. Miyamoto, Y. Nakamura, I. Nunes, V. Parail, G. Pereverzev, Y. Peysson, A. Polevoi, P. Politzer, M. Schneider, G. Sips, G. Tardini, I. Voitsekhovitch, S. M. Wolfe, ASDEX Upgrade Team, C-Mod Team, DIII-D Team, JET-EFDA Contributors, JT-60U Team, Tore Supra Team, Contributors to the EU-ITM ITER Scenario Modelling Group, ITPA "Integration Operation Scenarios" Group Members and Experts and ITPA "Transport and Confinement" Group Members and Experts*: Current Ramps in Tokamaks: from Present Experiments to ITER Scenarios. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Isaev, M., W. Cooper, N. Gorelenkov, A. Könies, S. Medvedev, D. Spong and Y. Todo*: First VENUS+δf applications for the linear TAE benchmarking. (4<sup>th</sup> Meeting of the ITPA TG on Energetic Particle Physics, 2010-04-26 to 2010-04-28, Garching).

*Jachmich, S., G. Arnoux, S. Brezinsek, S. Devaux, T. Eich, W. Fundamenski, C. Giroud, H. R. Koslowski, Y. Liang, P. Lomas, E. de la Luna, G. Maddison, F. Sartori and H. Thomsen*: Power and Particle Fluxes to Plasma Facing Components in ELM-mitigated H-mode discharges on JET. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Jacob, W. and T. Schwarz-Selinger*: Erosion and Deposition Chemistry in N<sub>2</sub> Containing Discharges and Fuel Removal in Tile Gaps and Castellations by O<sub>2</sub> Plasmas. (Joint Meeting of the EU Taskforce PWI SEWGs "Fuel Removal" and "Dust in a Tokamak", 2010-06-08 to 2010-06-09, Garching).

*Jacob, W., U. von Toussaint and K. Tichmann*: Sticking and Re-erosion of C<sub>x</sub>H<sub>y</sub> Molecules. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Jacquet, P., L. Colas, M. L. Mayoral, G. Arnoux, V. Bobkov, M. Brix, A. Czarnecka, D. Dodt, F. Durodié, A. Ekedahl, M. Fursdon, E. Gauthier, M. Goniche, E. Jorin, E. Lerche, J. Mailloux, I. Monakhov, J. Ongena, V. Petržilka, A. Korotkov, F. Rimini, A. Sirinelli, D. Frigione, C. Portafaix, V. Riccardo, Z. Vizvary, K. D. Zastrow and JET-EFDA Contributors*:

Heat-Loads on JET Plasma Facing Components from ICRF and LH Wave Absorption in the Scrape-off-Layer. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Jämsä, S., E. Hirvijoki, T. Kurki-Suonio, T. Pütterich and ASDEX Upgrade Team*: Implementing beam-beam CX-reactions in the ASCOT-code and prediction of active NPA measurement. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Jaksic, N., B. Mendelevitch and J. Tretter*: Advanced conceptual design of a magnet support structure for plasma fusion devices of stellarator type. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Jakubowski, M. W., T. E. Evans, C. J. Lasnier, O. Schmitz, M. E. Fenstermacher, R. Laengner, R. C. Wolf, L. B. Baylor, J. A. Boedo, K. H. Burrell, J. S. deGrassie, P. Gohil, R. A. Moyer, A. W. Leonard, C. C. Petty, R. I. Pinsker, T. L. Rhodes, M. J. Schaffer, P. B. Snyder, H. Stoschus, T. Osborne, D. Orlov, E. Unterberg and J. G. Watkins*: Toroidally resolved measurements of ELMs in RMP and non-RMP H-mode discharges on DIII-D. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Janzer, A., R. Dux, T. Pütterich and ASDEX Upgrade Team*: Investigating Tungsten Transport in the Plasma Edge of ASDEX Upgrade. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Jehl, J., G. Kocsis, P. Lang, M. Prechtel, S. Sotier, T. Szepesi and ASDEX Upgrade Team*: Pellet launcher optimization for ELM pacing in ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Jenko, F.*: Computational plasma physics. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Jenko, F.*: On our present theoretical understanding of electron heat transport. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Jenko, F., S. Brunner, T. Dannert, H. Doerk, T. Görler, S. Günter, T. Hauff, X. Lapillone, P. Marcus, F. Merz, M. J. Pueschel, M. Schneller, D. Told and P. Xanthopoulos*: Towards Multiscale Gyrokinetic Simulations of ITER-like Plasmas. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Joffrin, E., J. Hobirk, M. Beurskens, M. Brix, P. Buratti, C. Challis, F. Crisanti, C. Giroud, F. Imbeaux, D. C. McDonald, P. Maget, P. Mantica, F. Rimini, A. C. C. Sips, T. Tala, I. Voitsekovitch and JET EFDA Contributors:* High Confinement Hybrid Scenario in JET and its Significance for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Käsemann, C.-P., M. Huart, L. v. Lieshout, D. Habel, F. Stobbe and ASDEX Upgrade Team:* Extension of the Pulsed Power Supply Network of ASDEX Upgrade by a Set of Compact Modular Generators. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Kallenbach, A. and ASDEX Upgrade Team:* Overview of ASDEX Upgrade Results. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Kallenbach, A., M. Balden, R. Dux, T. Eich, C. Giroud, A. Huber, G. P. Maddison, M. Mayer, K. McCormick, R. Neu, T. Petrie, T. Pütterich, J. Rapp, M. Reinke, K. Schmid, J. Schweinzer, S. Wolfe, ALCATOR Team, ASDEX Upgrade Team, DIII-D Team and JET EFDA Contributors:* Plasma surface interactions in impurity seeded plasmas. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Kallenbach, A. and M. Wischmeier:* Einführung in die Plasmaspektroskopie. (WS 2009/2010. Vorlesung, Universität Augsburg).

*Kallmeyer, J. P., C. Caldwell-Nichols, P. Chen, M. Nitz, F. Scherwenke and F. Schauer:* Mechanical instrumentation of the Wendelstein 7-X cryogenic structure. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Kammel, A. and K. Hallatschek:* Transport bifurcations for zonal flows in 3D sheared slab drift wave systems. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Kang, K. S.:* On finite volume multigrid method. (European Multi-Grid Conference (EMG 2010), 2010-09-19 to 2010-09-23, Isola d'Ischia).

*Kasperek, W., V. Erckmann, F. Hollmann, G. Michel, F. Noke, F. Purps, B. Plaum, P. Brand, E. Filipovic, C. Lechte, M. Saliba, N. Doelman, R. van den Braber, W. Bongers, B. Krijger, M. Petelin, L. Lubyako, A. Bruschi, J. Stober and D. Wagner:* Compact resonant diplexers for advanced ECRH: Design, low- and high-power tests, and plans. (Workshop on RF Heating Technology of Fusion Plasmas, 2010-09-13 to 2010-09-15, Como).

*Kauffmann, K., R. Kleiber, R. Hatzky and M. Borchardt:* Global linear gyrokinetic simulations for LHD including collisions. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Kiptily, V. G., S. D. Pinches, S. E. Sharapov, D. Howell, F. E. Cecil, D. Darrow, V. Goloborod'ko, C. Perez von Thun, V. Plyusnin, A. I. Smolyakov, V. Yavorskij, M. Gatu Johnson, T. Craciunescu, C. Hellesen, T. Johnson, Y. Liang, H. R. Koslowski, J. Mailloux, F. Nabais, M. Reich, P. De Vries, V. L. Zpita and JET-EFDA Contributors:* Studies of MHD Effects on Fast Ions: towards Burning Plasma with ITER-like Wall on JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Kleiber, R.:* Introduction to stellarator theory. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Kleiber, R., K. Kauffmann and R. Hatzky:* Global linear gyrokinetic simulations for stellarators including collisions and kinetic electrons. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Klinger, T. and H.-S. Bosch:* Hochtemperatur-Plasmaphysik. (WS 2009/2010. Vorlesung, Ernst-Moritz-Arndt-Universität Greifswald).

*Kobayashi, M., S. Morita, C. Dong, S. Masuzaki, M. Goto, T. Morisaki, H. Zhou, H. Yamada, LHD Experimental Group, Y. Feng, Z. Y. Cui, Y. D. Pan, Y. D. Gao, P. Sun, Q. W. Yang and X. R. Duan:* Edge Impurity Transport Study in Stochastic Layer of LHD and Scrape-off Layer of HL-2A. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Kocan, M., J. P. Gunn, C. Fenzi, A. Herrmann, A. Kirk, M. Komm, H. W. Müller, J.-Y. Pascal, V. Rohde, J.-L. Segui, P. Tamain and ASDEX Upgrade Team:* Measurements of ion energies in the tokamak plasma boundary. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Könies, A., M. Bessenrodt-Weberpals, H. de Blank and R. Schneider:* Basic plasma physics. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Könies, A. and R. Kleiber:* A computational approach to continuum damping of Alfvén waves in two- and three-dimensional geometry. (4<sup>th</sup> Meeting of the ITPA TG on Energetic Particle Physics, 2010-04-26 to 2010-04-28, Garching).



König, R., J. Baldzuhn, W. Biel, C. Biedermann, R. Burhenn, J. Cantarini, H. Dreier, M. Endler, H.-J. Hartfuß, D. Hildebrandt, M. Hirsch, P. Kornejew, M. Krychowiak, H. Laqua, M. Laux, J. W. Oosterbeek, E. Pasch, T. Richert, W. Schneider, B. Schweer, H. Thomsen, A. Weller, A. Werner, R. C. Wolf and D. Zhang: Diagnostics design for steady-state operation of the W7-X stellarator. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

König, R., R. Burhenn, J. Baldzuhn, M. Endler, K. Ewert, R. Jiment-Gomez, H.-J. Hartfuß, M. Hirsch, H. P. Laqua, M. Laux, F. Noke, J. W. Oosterbeek, F. Purps and D. Zhang: ECRH Stray Radiation Experiments for W7-X. (18<sup>th</sup> Meeting of the Diagnostics Topical Group of the ITPA, 2010-05-11 to 2010-05-14, Oak Ridge, TN).

Köppen, M.: Investigation of Fusion Relevant Materials by Depth-Resolved Photoelectron Spectroscopy. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

Köppen, M., J. Du, H. Löchel, M. Oberkofler, V. Paffenholz, M. Richly, J. Riesch, A. Vollmer and Ch. Linsmeier: Untersuchung der Reaktionsmechanismen in quartären Oberflächen mit energieaufgelöster Photoelektronenspektroskopie. (Deutsche Tagung für Forschung mit Synchrotronstrahlung, Neutronen und Ionenstrahlen an Großgeräten, 2010-02-24 to 2010-02-26, Berlin).

Köppen, M., M. Hirsch, J. Ernst, V. Bykov, F. Schauer and W. A. Vliegenhart: Thermo-Mechanical analysis of retro-reflectors for interferometry and polarimetry in W7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Köppen, M. and Ch. Linsmeier: Chemical Phase Formation in Material Mixing. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

Köppen, M., H. Löchel, T. V. Phan, J. Riesch, A. Vollmer and Ch. Linsmeier: Chemistry at the first wall of future fusion devices: Interaction of energetic oxygen ions with Beryllium tungsten alloy. (2<sup>nd</sup> Joint HZB Users' Meeting, 2010-12-09 to 2010-12-10, Berlin).

Köppen, M., M. Oberkofler, T. V. Phan and Ch. Linsmeier: Depth-resolved XPS-investigation of O-implanted Be-W alloy and interaction of beryllium with energetic nitrogen ions. (Joint SEWG Meeting Material Migration and Material Mixing, 2010-06-30 to 2010-07-02, Jülich).

Koppe, T., A. Cardella, J. Reich, B. Missal, B. Hein, R. Krause, H. Jenzsch, F. Leher, A. Binni, J. Segl, R. Camin, L. Giordano,

S. Langone, J. Ridzewski and G. Coniani: Overview of Main-Mechanical-Components and Critical Manufacturing Aspects of the Wendelstein 7-X Cryostat. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Kraus, W., U. Fantz, P. Franzen and NNBI Team: Dependence of the Long Pulse Performance of the RF Driven Negative Ions Source on the Magnetic Filter Field. (2<sup>nd</sup> International Symposium on Negative Ions, Beams and Sources (NIBS2010), 2010-11-16 to 2010-11-19, Takayama).

Krieger, K.: Characteristics of induced tungsten melting events in the divertor of ASDEX Upgrade and their influence on plasma performance. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Krieger, K.: Experimental Studies and Modeling of Mixed-Material Surface Processes at the First Wall. (IAEA CRP Meeting on Data for Surface Composition Dynamics Relevant to Erosion Processes, 2010-09-13 to 2010-09-15, Vienna).

Krieger, K.: Plasma-material interactions and their implications for fusion reactor wall components. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

Krieger, K. and T. Lunt: Controlled tungsten melt studies in the divertor of ASDEX Upgrade. (Aalto University, Seminar of Department of Applied Physics, 2010-01-17, Espoo/Helsinki).

Krieger, K., T. Lunt, R. Dux, A. Janzer, A. Leitenstern, T. Pütterich, A. Kallenbach, R. Neu and ASDEX Upgrade Team: Controlled tungsten melting and droplet ejection studies in ASDEX Upgrade. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

Krieger, K., M. Reinelt, K. Schmid, S. Brezinsek, H. G. Esser, A. Kreter, S. Jachmich, M. Stamp and JET-EFDA Contributors: Be Migration Studies at JET and their Interpretation by an Integrated Model for Plasma Impurity Transport and Wall Composition Dynamics. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Krychowiak, M., M. Brix, D. Dodt, R. König, O. Schmitz, J. Svensson and R. Wolf: Bayesian modelling of a diagnostic helium beam. (ADAS Workshop 2010, 2010-10-03 to 2010-10-06, Armagh).

Krychowiak, M., M. Brix, D. Dodt, Y. Feng, R. König, O. Schmitz, J. Svensson and R. C. Wolf: Bayesian modelling of a thermal helium beam for measurement of electron density and temperature in the W7-X divertor plasma. (International Con-

ference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Kubkowska, M., A. Czarnecka, S. Jablonski, J. Kaczmarczyk, L. Ryc, J. Wolowski, R. König and A. Weller:* Prospects of soft x-ray diagnostics in the stellarator Wendelstein 7-X. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Kurki-Suonio, T., O. Asunta, T. Koskela, A. Snicker, T. Hauff, F. Jenko, E. Poli and S. Sipilä:* Fast Ion Power Loads on ITER First Wall Structures in the Presence of NTMs and Microturbulence. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Kurzan, B., E. Wolfrum, A. Burckhart, R. Fischer, T. Pütterich, P. Schneider, W. Suttrop, B. Wieland, H. Zohm and ASDEX Upgrade Team:* Transport in-between Edge Localized Modes in the Pedestal of ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Labit, B., A. Pochelon, M. Rancic, F. Piras, A. Bencze, A. Bottino, S. Brunner, Y. Camenen, P. K. Chattopdhyay, S. Coda, E. Fable, T. P. Goodman, S. Jolliet, A. Marioni, L. Porte, B. F. McMillan, S. Y. Medvedev, O. Sauter, V. S. Udintsev, L. Villard and TCV Team:* Transport and Turbulence with Innovative Plasma Shapes in the TCV Tokamak. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Lackner, K.:* Magnetohydrodynamik. (WS 2009/2010. Vorlesung, Universität Innsbruck).

*Lambertz, H. T., W. Biel, B. Schweer, J. Thomas, G. Esser, H. Dreier, P. Bagryansky, A. D. Khilchenko, Y. V. Kovalenko, A. Lizunov and A. Solomakhin:* Integration of an dispersion interferometer at TEXTOR: Analysis with respect to operational and safety relevant issues. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Lang, P. T.:* ELM control for ITER: reviewing pellet pace making. (18<sup>th</sup> ITPA Pedestal and Edge Physics Topical Group Meeting, 2010-04-21 to 2010-04-23, Naka).

*Lang, P. T.:* Overview: task and achievements of the pellet ELM pacing approach. (JET Science Meeting, 2010-02-01, Abingdon).

*Lang, P. T.:* Report on the status of pellet ELM pacing. (1<sup>st</sup> Meeting of the TAP Group for Assessment of the ITER ELM Coils, F4E, 2010-06-29, Barcelona).

*Lang, P. T., A. Alonso, B. Alper, E. Belonohy, A. Boboc, S. Devaux, T. Eich, D. Frigione, K. Gál, L. Garzotti, A. Geraud, G. Kocsis, F. Köchl, K. Lackner, A. Loarte, P. J. Lomas, M. Maraschek,*

*H. W. Müller, G. Petravich, G. Saibene, J. Schweinzer, H. Thomsen, M. Tsalas, R. Wenninger and JET-EFDA Contributors:* ELM Pacing Investigations at JET with the New Pellet Launcher. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Laqua, H. P., E. Chlechowicz, M. Glaubitz, S. Marsen, T. Stange, M. Otte, D. Zhang, J. Preinhaelter and J. Urban:* 28 GHz EBW heating, current drive and emission experiments at the WEGA Stellarator. (16<sup>th</sup> Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (EC-16), 2010-04-12 to 2010-04-15, Sanja).

*Laube, R., M. Laux, M. Ye, H. Greuner and S. Lindig:* Designs of Langmuir Probes for W7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Lauber, P., M. Brüdgam, D. Curran, V. Igochine, S. da Graca, M. Garcia-Munoz, S. Günter, M. Maraschek, P. McCarthy and ASDEX Upgrade Team:* Damping, Drive and Non-linear Effects of Kinetic Low-frequency Modes in Tokamaks. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-15, Daejeon).

*Lederer, H.:* The DEISA approach to advance computational sciences in Europe. (European US Summer School on HPC Challenges in Computational Sciences, 2010-10-04 to 2010-10-07, Acireale, Catania).

*Lederer, H.:* DEISA Extreme Computing. (DEISA PRACE Symposium 2010, 2010-05-10 to 2010-05-12, Barcelona).

*Lee, H. T., Y. Ueda, Y. Gasparyan, E. Markina and M. Mayer:* Deuterium Permeation Behavior Dependence on Tungsten Microstructure. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials, 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Le Guern, F., W. Gulden, S. Ciattaglia, G. Counsell, A. Bengaouer, J. Brinster, F. Dabbene, A. Denkevitz, T. Jordan, M. Kuznetsov, M. Porfiri, R. Redlinger, J. Roth, J. Segre, K. Sugiyama, I. Tkatschenko and Z. Xu:* F4E R&D Programme and Results on In-vessel Dust and Tritium. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Lehnen, M., A. Alonso, G. Arnoux, N. Baumgarten, S. A. Bozhnikov, S. Brezinsek, M. Brix, T. Eich, A. Huber, S. Jachmich, U. Kruezi, P. D. Morgan, V. V. Plyusnin, C. Reux, V. Riccardo, G. Sergienko, M. F. Stamp, A. Thornton, M. Koltunov, M. Tokar, B. Bazylev, I. Landman, S. Pestchanyi and JET-EFDA Contributors:* Disruption Mitigation by Massive Gas Injection in JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Leuterer, F.*: Application of high power microwaves in fusion experiments. (20<sup>th</sup> International Conference on Applied Electromagnetics and Communications (ICECom 2010), 2010-09-20 to 2010-09-23, Dubrovnik).

*Lindig, S. and M. Balden*: Small angle grain boundaries in “single” crystals: Limits of automated software. (EBSD-Workshop der D-A-CH Länder: DGM-DVM AK-Treffen 2010 “Mikrountersuchungen im REM”, 2010-04-27 to 2010-04-28, Hochschule Augsburg).

*Lindig, S., M. Balden and G. Weizmann*: Development of an advanced holder system for a wide field of sample sizes in a dualbeam FIB/SEM (Helios/FEI) with EBSD/EDX. (5. FIB-Workshop der D-A-CH-Länder, 2010-06-28 to 2010-06-29, Technische Universität Wien).

*Linsmeier, Ch.*: The first wall of fusion devices – A challenge for material synthesis and characterization. (Habilitationvortrag, 2010-07-19, Physik-Department, Technische Universität München).

*Linsmeier, Ch.*: Ion-induced surface chemistry in materials for fusion first wall applications. (Workshop on Dynamical Processes in Irradiated Materials, 2010-07-26 to 2010-07-28, San Sebastian).

*Linsmeier, Ch.*: Self-passivating tungsten alloys for first wall applications. (Forschungszentrum Jülich, 2010-07-14, Jülich).

*Linsmeier, Ch.*: Synchrotron- und neutronenbasierte Charakterisierung von Fusionsmaterialien. (DGM Fachausschuss “Werkstoffuntersuchungen mit Strahllinien”, 2010-04-30, DESY Hamburg).

*Linsmeier, C., F. Koch, C. Lenser, S. Lindig, M. Rasinski, M. Balden and A. Brendel*: Self-passivating tungsten alloys for first wall applications. (ARIES Town Meeting on “Edge Plasma Physics and Plasma Material Interactions in the Fusion Power Plant Regime”, 2010-05-20 to 2010-05-21, San Diego, CA).

*Linsmeier, Ch., F. Koch, S. Lindig, M. Balden and A. Brendel*: Self-passivating tungsten alloys. (EFDA TG Materials Science, 2010-02-03, Garching).

*Linsmeier, Ch., M. Oberkofler, M. Köppen and T.-V. Phan*: Ion-induced beryllium nitride formation and its influence on deuterium retention. (18<sup>th</sup> International Workshop on Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).

*Linsmeier, Ch., M. Reinelt and K. Schmid*: Surface chemistry of fusion first wall materials – from fundamental data to

modeling. (23<sup>rd</sup> Symposium on Surface Science 2010 (3S’10), 2010-03-07 to 2010-03-13, St. Christoph/Arlberg).

*Linsmeier, Ch., M. Reinelt and K. Schmid*: Surface chemistry of fusion first wall materials – from fundamental parameters to modeling. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Linsmeier, Ch., K. Schmid, M. Oberkofler, T. Phan and M. Köppen*: Influence of seeded nitrogen on first wall material properties. (EFDA Modeling Meeting EU-PWI Task Force, 2010-09-08, JET Culham).

*Lischtschenko, O., K. Bytsov, G. De Temmermann, J. Howard, R. J. E. Jaspers and R. König*: Density measurements using coherence imaging spectroscopy based on stark broadening. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Lischtschenko, O., P. de Vries, R. Jaspers, R. König and J. Howard*: Coherence Imaging Techniques applied to Divertor-like Plasma Conditions. (22<sup>nd</sup> NNV Symposium Plasma Physics and Radiation Technology, 2010-03-09 to 2010-03-10, Lunteren).

*Litaudon, X., Y. Sakamoto, P. C. De Vries, A. Salmi, T. Tala, C. Angioni, M. N. A. Beurskens, M. Brix, K. Crombe, T. Fujita, S. Futatani, X. Garbet, C. Giroud, N. C. Hawkes, N. Hayashi, G. T. Hoang, G. Matsunaga, N. Oyama, V. Parail, K. Shinohara, T. Suzuki, M. Takechi, H. Takenaga, T. Takizuka, H. Urano, I. Voitsekhovitch, M. Yoshida, ITPA Transport Group, JT-60 Team and JET-EFDA Contributors*: Core Transport Properties in JT-60U and JET Identity Plasmas. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Loarte, A., D. Campbell, Y. Gribov, R. Pitts, N. Klimov, V. Podkovyrov, A. Zhitlukhin, I. Landman, S. Pestchanyi, B. Bazylev, J. Linke, O. Schmitz, Y. Liang, M. E. Fenstermacher, T. E. Evans, M. Schaer, M. Becoulet, J. Canik, R. Maingi, B. Riccardi, G. Saibene, R. Sartori, T. Eich, P. T. Lang, H. Thomsen, W. Suttrop, E. De La Luna, H. Wilson, A. Kirk and E. Nardon*: ITER ELM Control Requirements, ELM Control Schemes and Required R&D. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Lopez-Ruiz, P., N. Ordas, C. Garcia-Rosales, F. Koch and S. Lindig*: Development of oxidation resistant self passivating W-Si-Cr alloys for fusion energy applications – Desarrollo de Aleaciones de W-Cr-Si Autopasivante Frente a la Oxidación para Aplicaciones de Fusión Nuclear. (XI Congreso Nacional de Materiales, 2010-06-23 to 2010-06-25, Zaragoza).

*Lopez-Ruiz, P., N. Ordas, C. Garcia-Rosales, F. Koch and S. Lindig:* Manufacturing of Self-Passivating W-Cr-Si Alloys by Mechanical Alloying and Hip. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Luce, T. C., C. D. Challis, E. Joffrin, J. Hobirk, S. Ide, A. Isayama, A. C. C. Sips, J. Stober, G. Giruzzi, C. E. Kessel, M. Murakami, J. M. Park, A. R. Polevoi, R. V. Budny, J. Citrin, J. Garcia, N. Hayashi, B. F. Hudson, F. Imbeaux, D. C. McDonald, V. V. Parail, T. W. Petrie, C. C. Petty, P. A. Politzer, T. Suzuki, M. R. Wade and ITPA IOS Members and Experts:* Development of Advanced Inductive Scenarios for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Lunt, T., Y. Feng, K. Krieger, A. Janzer, D. Coster, M. Wischmeier, A. Kallenbach, R. Neu, R. Dux, W. Suttrop, T. Pütterich, H. W. Müller, V. Rohde, E. Wolfrum, R. Fischer, R. Drube and ASDEX Upgrade Team:* Modelling of impurity sources and transport in 3D geometry. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Lunt, T., Y. Feng, K. Krieger, A. Kallenbach, R. Neu, V. Rohde, A. Janzer, R. Dux and ASDEX Upgrade Team:* 3D modeling of the ASDEX-Upgrade edge plasma exposed to a localized tungsten source by means of EMC3-Eirene. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Luo, Y., W. Heidbrink, E. Ruskov, D. Liu, M. Garcia-Munoz, B. Geiger, R. Akers and C. Michael:* Improvements to a Fast-ion D. Simulation Code. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Lyssoivan, A., R. Koch, D. Douai, J.-M. Noterdaeme, V. Philipps, V. Rohde, F. C. Schüller, G. Sergienko, D. van Eester, T. Wauters, T. Blackman, V. Bobkov, S. Bremond, S. Brezinscek, E. de la Cal, R. Dumont, M. Garcia-Munoz, E. Gauthier, M. Graham, S. Jachmich, E. Joffrin, P. U. Lamalle, E. Lerche, G. Lombard, F. Louche, M. Maslov, M.-L. Mayoral, V. E. Moiseenko, I. Monakhov, J. Ongena, M. K. Paul, R. Pitts, V. Plyusnin, M. Shimada, W. Suttrop, M. Van Schoor, G. Van Wassenhove, M. Vervier, R. Weynants, TEXTOR Team, TORE Supra Team, ASDEX Upgrade Team and JET EFDA Contributors:* ICRF Physics aspects of wall conditioning with conventional antennas. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Maddison, G., C. Giroud, K. McCormick, A. Alonso, B. Alper, Y. Andrew, G. Arnoux, P. Belo, M. Beurskens, A. Boboc, A. Brett, S. Brezinsek, M. Brix, I. Coffey, E. de la Luna, S. Devaux,*

*P. de Vries, P. Devynck, T. Eich, R. Felton, W. Fundamenski, J. Harling, D. Harting, J. Hobirk, A. Huber, S. Jachmich, I. Jenkins, E. Joffrin, A. Kallenbach, M. Kempenaars, M. Lehnen, T. Loarer, P. Lomas, D. McDonald, A. Meigs, P. Monier-Garbet, P. Morgan, D. Moulton, V. Riccardo, F. Rimini, G. Sergienko, A. Sirinelli, M. Stamp, G. Telesca, H. Thomsen, I. Voitsekhovitch and JET EFDA Contributors:* Moderation of target loads using fuelling and impurity seeding on JET in preparation for the ITER-like wall. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Maier, H.:* Das EU-Forschungsprojekt ExtreMat: Materialien für extreme Einsatzbedingungen. (7. Nanotechnologieforum Hessen, 2010-12-01, Darmstadt).

*Maier, H., H. Greuner, B. Böswirth, R. Neu, Ch. Hopf, M. Rasinski, M. Balden, S. Lindig, A. Wiltner, C. Ruset, E. Grigore, G. Matthews, G. Piazza, T. Hirai, V. Philipps and A. Schmidt:* Development of Tungsten Coatings for the ITER-like Wall of JET. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Maier, H., M. Rasinski, E. Grigore, C. Ruset, H. Greuner, B. Böswirth, G. F. Matthews, M. Balden, S. Lindig and JET EFDA Contributors:* Performance of W Coatings on CFC with respect to Carbide Formation. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Maier, T. and U. Fantz:* Laserdetachment zur Messung von H<sup>-</sup>-Ionendichten. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Manhard, A.:* Effects of recrystallization on the microstructure and deuterium retention in tungsten. (Lehrstuhlseminar EP IV "Physik dünner Schichten", 2010-10-28, Universität Augsburg).

*Manhard, A. and K. Schmid:* Effects of recrystallization on the deuterium retention in tungsten. (DPG Frühjahrstagung der Sektion Kondensierte Materie (SKM), 2010-03-21 to 2010-03-26, Regensburg).

*Manhard, A., K. Schmid, M. Balden and W. Jacob:* Deuterium retention in rolled and recrystallized tungsten. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials, 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Manhard, A., K. Schmid, M. Balden and W. Jacob:* Influence of the Microstructure on the Deuterium Retention in Tungsten. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).



*Mantica, P., B. Baiocchi, C. Challis, T. Johnson, A. Salmi, D. Strintzi, T. Tala, M. Tsalas, T. Versloot, P. De Vries, M. Baruzzo, M. Beurskens, P. Beyer, J. Bizarro, P. Buratti, J. Citrin, F. Crisanti, X. Garbet, C. Giroud, N. Hawkes, J. Hobirk, G. Hogeweij, F. Imbeaux, E. Joffrin, E. Lerche, D. McDonald, V. Naulin, A. G. Peeters, Y. Sarazin, C. Sozzi, D. Van Eester, J. Weiland and JET-EFDA Contributors:* A Key to Improved Ion Core Confinement in JET Tokamak: Ion Stiffness Mitigation due to Combined Plasma Rotation and Low Magnetic Shear. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Maqueda, R. J., S. J. Zweben, D. A. D'Ippolito, R. Hager, K. Hallatschek, S. Kaye, T. Munsat, J. R. Myra, F. M. Poli, A. L. Roquemore, D. A. Russell, Y. Sechrest and D. P. Stotler:* Edge turbulence and SOL blobs in the National Spherical Torus Experiment (NSTX). (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Markina, E., M. Mayer and H. T. Lee:* Measurement of H and He depth profiles in tungsten using ERDA with medium heavy ion beams. (10<sup>th</sup> European Conference on Accelerators in Applied Research and Technology, 2010-09-13 to 2010-09-17, Athens).

*Martin, Y., E. Fable, C. Angioni, Y. Camenen, D. Wagner, A. Bortolon, B. P. Duval, L. Federspiel, A. Karpushov, V. Piff, O. Sauter, H. Weisen and TCV Team:* Impurity Transport in TCV: Neoclassical and Turbulent Contributions. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Marushchenko, N., C. Beidler, S. Kasilov, W. Kernbichler, H. Maaberg, Y. Turkin and R. Prater:* ECCD models with parallel momentum conservations, finite collisionality, and high  $T_e$ . (16<sup>th</sup> Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (EC-16), 2010-04-12 to 2010-04-15, Sanya).

*Matthews, G. F., A. Loving, H. Maier, P. Mertens, V. Philipps, V. Riccardo, M. Rubel, C. Ruset, E. Villedieu and JET-EFDA Contributors to the ITER-like Wall Project:* Overview of the JET ITER-like Wall Project. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Matyash, K., R. Schneider, O. Kalentev, Y. Raitses and N. J. Fisch:* Kinetic simulations of a cylindrical Hall thruster. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Maya, P. N., S. P. Deshpande, M. Warriar and U. von Toussaint:* Multi-Scale Modeling of Tritium Retention in Co-Deposits. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Mayer, M., M. Balden, S. Lindig, G. Matern, R. Neu and ASDEX Upgrade Team:* Long-term evolution of tungsten surfaces in the divertor of ASDEX Upgrade. (Joint SEWG Meeting Material Migration and Material Mixing, 2010-06-30 to 2010-07-02, Julich).

*Mayer, M., W. Eckstein, H. Langhuth, F. Schiettekatte and U. von Toussaint:* Computer Simulation of Ion Beam Analysis: Possibilities and Limitations. (10<sup>th</sup> European Conference on Accelerators in Applied Research and Technology, 2010-09-13 to 2010-09-17, Athens).

*Mayer, M., E. Fortuna, A. Hakola, K. Krieger, J. Likonen, S. Lindig, G. Matern, R. Neu, M. Rasinski, V. Rohde, C. Ruset, K. Schmid, K. Sugiyama and ASDEX-Upgrade Team:* Erosion/deposition measurements using marker techniques. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Mayer, M., O. Ogorodnikova, V. Rohde, J. Roth, PWI Team and ASDEX Upgrade Team:* Hydrogen retention in tungsten – from laboratory experiments to ITER. (DPG AMOP Fruhjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Mayer, M., O. Ogorodnikova, V. Rohde, J. Roth, PWI Team and ASDEX Upgrade Team:* Hydrogen retention in tungsten – from laboratory experiments to ITER. (FOM Institute for Plasma Physics, 2010-04-01, Rijnhuizen).

*Mayoral, M.-L., V. Bobkov, L. Colas, M. Goniche, J. Hosea, J. G. Kwak, R. Pinsker, S. Moriyama, S. Wukitch, F. W. Baitny, A. Czarnecka, A. Ekedahl, G. Hanson, P. Jacquet, P. Lamalle, I. Monakhov, M. Murakami, A. Nagy, M. Nightingale, J.-M. Noterdaeme, J. Ongena, P. M. Ryan, M. Vrancken, J. R. Wilson, JET-EFDA Contributors, ASDEX Upgrade Team and ITPA "Integrated Operation Scenarios" Members and Experts:* On Maximizing the ICRF Antenna Loading for ITER Plasmas. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*McCormick, K., G. Maddison, C. Giroud, M. Beurskens, A. Boboc, S. Brezinsek, T. Eich, W. Fundamenski, S. Jachmich, D. Moulton, M. Stamp, H. Thomsen and JET EFDA Contributors:* Coupling between JET Pedestal  $n_e$ - $T_e$  & Outer Target Plate Recycling. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*McDermott, R. M., C. Angioni, R. Dux, A. Gude, T. Putterich, F. Ryter, G. Tardini and ASDEX Upgrade Team:* Core toroidal rotation changes observed in NBI heated discharges with ECRH power in ASDEX Upgrade. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US

Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*McDonald, D. C., G. Calabrò, M. Beurskens, I. Day, E. De La Luna, T. Eich, N. Fedorczak, O. Ford, C. Giroud, P. Gohil, M. Lennholm, J. Lönnroth, P. Lomas, G. P. Maddison, C. F. Maggi, I. Nunes, G. Saibene, R. Sartori, W. Studholme, E. Surrey, I. Voitsekhovitch, K. D. Zastrow and JET EFDA Contributors:* JET  $^4\text{He}$  ELMy H-mode Studies. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Meister, H., P. Detemple, T. Eich, L. Giannone, M. Kannamüller, A. Kling, J. Koll, S. Schmitt and T. Trautmann:* Optimization of a Bolometer detector for ITER based on Pt absorber on SiN membrane. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Meister, H., F. Penzel, L. Giannone, M. Kannamüller, A. Kling, J. Koll and T. Trautmann:* Development of an automatized method for in-situ measurement of the geometrical properties of the ITER bolometer diagnostic. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Melnikov, A., L. Eliseev, R. Jiménez-Gómez, E. Ascasibar, C. Hidalgo, A. Chmyga, A. Komarov, A. Kozachok, I. Krasilnikov, L. Krupnik, S. Khrebtov, A. Könies, Y. Kuznetsov, M. Liniers, S. Lysenko, V. Mavrin, J. de Pablos, M. Pedrosa, S. Perfilov, A. Smolyakov, D. Spong, M. Ufimtsev, T. Ido, K. Nagaoka, S. Yamamoto and A. Zhezhera:* HIBP study of Alfvén Eigenmodes Properties and Dynamics in the TJ-II Stellarator. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Mendelevitch, B., A. Vorköper, J. Boscary, A. Cardella, F. Hurd, Ch. Li, A. Peacock, H. Pirsch, R. Stadler and H. Tittes:* Design Analysis and Manufacturing of the cooling lines of the vessel components of Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Meo, F., M. Salewski, G. Tardini, H. Bindslev, M. Garcia-Munoz, S. Günter, J. Hobirk, F. Jenko, S. B. Korsholm, P. Lauber, F. Leipold, V. Furtula, R. McDermott, P. K. Michelsen, D. Moseev, S. K. Nielsen, M. Stejner and J. Stober:* Comparison of Central Fast Ion Distributions between Plasmas with on-axis and off-axis NBI Current Drive on ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Merli, S., E. Holzhauer, A. Köhn, M. Ramisch, D. Zhang and U. Stroth:* Magnetische und bolometrische Diagnostik am TJ-K. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Meyer, F. W., P. R. Harris, W. Jacob, T. Schwarz-Selinger and U. von Toussaint:* Erosion of a-C:D thin films by low energy  $\text{D}^+$ ,  $\text{D}_2^+$ , and  $\text{D}_3^+$  ion beam irradiation. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Meyer, H., M. de Bock, S. Freethy, K. Gibson, A. Kirk, C. Michael, T. Morgan, R. Scannell, G. Naylor, S. Saarelma, V. Shevchenko, W. Suttrop, D. Temple, R. Vann, M. Walsh and MAST Team:* L/H Transition and Pedestal Studies on MAST. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Meyer-Spasche, R.:* Über die Anfänge und die Entwicklung der Particle-in-Cell Methoden. (Festveranstaltung der Universität zum 100. Geburtstag von Lothar Collatz, 2010-10-04 to 2010-10-08, Hamburg).

*Meyer-Spasche, R.:* Oscar Buneman (1913-1993) und die Anfänge der Computational Plasma Physics. (10. Österreichisches Symposium zur Geschichte der Mathematik, 2010-05-30 to 2010-06-05, Miesenbach).

*Mishchenko, A., A. Könies, R. Hatzky and R. Kleiber:* Gyrokinetic PIC simulations of the diamagnetic effects on the Alfvénic modes. (4<sup>th</sup> Meeting of the ITPA TG on Energetic Particle Physics, 2010-04-26 to 2010-04-28, Garching).

*Missirlian, M., H. Greuner, T. Höschen, Ch. Linsmeier, M. Richou, M. Lipa, B. Böswirth and J. Boscary:* Influence of CFC quality on the performance of TS limiter elements under cyclic heat loading. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Miyato, N., B. D. Scott, S. Tokuda and M. Yagi:* Effects of Strong  $\text{E} \times \text{B}$  Flow on Gyrokinetics. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Mucke, M.:* Experimental investigation of ICD in weakly bound clusters. (Atomic & Cluster Physics Seminar, 2010-05-31, Uppsala).

*Mucke, M.:* Experimental investigation of non-local auto-ionisation transition in water and rare gas clusters. (Global COE Summer School, 2010-08-19 to 2010-08-20, Tohoku University Sendai).

*Mucke, M., M. Braune, S. Barth, M. Förstel, T. Lischke, V. Ulrich, T. Arion, U. Becker, A. M. Bradshaw and U. Hergenhan:* A hitherto unrecognized source of low energy electrons in water. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Mühlich, P., T. Hamacher, D. Ward, W. Han, C. Eherer, C. A. S. Silva, F. Gracceva, U. Ciorba, M. Biberacher, P. E. Grohnheit, Y. Lechon, A. Pina, H. Cabal Cuesta, T. Hartmann and G. C. Tosato: The Potential Role for Fusion Power in Future Energy Markets. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Müller, H. W., J. Adamek, R. Cavazzana, G. D. Conway, J. P. Gunn, A. Herrmann, J. Horacek, C. Ionita, M. Kocan, M. Maraschek, C. Maszl, F. Mehlmann, B. Nold, M. Peterka, V. Rohde, R. Schrittwieser, N. Vianello, M. Zuin and ASDEX Upgrade Team: Fluctuations, ELM Filaments and Turbulent Transport in the SOL at the Outer Midplane of ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Müller, H. W., P. Ghendrih, A. Kirk, O. Schmitz, W. Suttrop, P. Tamain, Y. Xu and ASDEX Upgrade Team: Effect of RMPs on the edge turbulence in ohmic and L-mode plasmas. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

Müller-Nutzinger, E.: Computational Physics. (WS 2009/2010. Vorlesung, Universität Bayreuth).

Müller, S. H., V. Naulin, C. Holland, G. R. Tynan, M. Xu, J. H. Yu, C. Brandt, O. Grulke, S. Ullrich and T. Windisch: Validation of the 3D global fluid turbulence code CYTO against fast-camera measurements on the linear devices CSDX and VINETA. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

Müller, W.-C.: Lagrangian frequency spectra of MHD turbulence. (Workshop on Self-Organization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

Murakami, M., G. Giruzzi, P. Bonoli, R. V. Budny, A. Fukuyama, J. Garcia, N. Hayashi, M. Honda, A. E. Hubbard, S. Ide, F. Imbeaux, C. E. Kessel, T. C. Luce, Y. S. Na, T. Oikawa, T. H. Osborne, V. Parail, J. M. Park, A. Polevoi, R. Prater, A. C. C. Sips, J. A. Snipes, P. B. Snyder, H. E. St. John and ITPA/Integrated Operation Scenario Group: Integrated Modeling of Steady-State Scenarios and Heating and Current Drive Mixes for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Nagasaki, K., S. Yamamoto, H. Yoshino, K. Sakamoto, N. Marushchenko, Y. Turkin, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Konoshima, M. Takeuchi, Y. Nakamura, S. Ohshima, K. Mukai, H. Lee, K. Mizuno, Y. Yoshimura, G. Motojima, A. Cappa, B. Blackwell and F. Sano: Experimental Study of Second

Harmonic ECCD in Heliotron J. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Nagel, M., A. Braatz, A. Gömöry, S. Hughes, C. Heenemann, S. Mohr, M. Pietsch, K. Riß, D. Theuerkauf, A. Binni, M. Prebeck and H. Posselt: Design and assembly progress of the thermal insulation of Wendelstein 7-X cryostat. (23<sup>th</sup> International Cryogenic Engineering Conference and International Cryogenic Materials Conference 2010 (ICEC 23 – ICMC 2010), 2010-07-19 to 2010-07-23, Wrocław).

Nagel, M., S. Freundt and H. Posselt: Thermal and Mechanical Analysis of Wendelstein 7-X Thermal Shield. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Naulin, V., N. Vianello, R. Schrittwieser, H. W. Müller, P. Migliucci, M. Zuin, C. Ionita, C. Maszl, F. Mehlmann, J. J. Rasmussen, V. Rohde, R. Cavazzana, M. Maraschek, ASDEX Upgrade Team and EFDA JET Contributors: Magnetic diagnostic of SOL-filaments generated by type I ELMs on JET and ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Nawka, S., T. Schubert, A. Brendel, A. Zivelonghi, J. H. You and B. Kieback: Synthesis, characterization and FEM-simulation of W/CuCrZr-Composites for extreme thermal applicants. (Powder Metallurgy World Congress & Exhibition (PM2010), 2010-10-10 to 2010-10-14, Florence).

Na, Y.-S., K. Kim, H. Kim, M. Maraschek, Y. S. Park, J. Stober, L. Terzolo and H. Zohm: Real-time Control of Neoclassical Tearing Mode in Time-dependent Simulations on KSTAR. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Neu, G., A. Buhler, C. Fuchs, O. Gruber, V. Mertens, G. Raupp, J. Schweinzer, W. Treutterer, D. Zasche, T. Zehetbauer and ASDEX Upgrade Team: Experiment planning and execution workflow at ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Neu, R.: The JET ILW under the TFs E1/E2. (9<sup>th</sup> Annual Meeting of the EU-PWI Task Force, 2010-11-03 to 2010-11-05, Vienna).

Neu, R.: First Wall Materials in Fusion. (PhD Network University, 2010-10-04, Padova/Lisbon/Munich).

Neu, R.: Fusionsforschung. (SS 2010. Vorlesung, Universität Tübingen).

*Neu, R.*: Einführung in die Plasmaphysik. (WS 2009/2010. Vorlesung, Universität Tübingen).

*Neu, R., S. Brezinsek, P. Coad, K. Schmid, K. Krieger, M. Lehnen, G. Maddaluno, M. Rubel, E. Tsitrone and R. Zagorski*: Strategy and goals of the EU TF on PWI. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall Interactions, 2010-12-06 to 2010-12-08, Garching).

*Neu, R., R. Dux, A. Janzer, A. Kallenbach, R. McDermott, H. W. Müller, S. Potzel, T. Pütterich, M. Sertoli and ASDEX Upgrade Team*: Tungsten behaviour in radiatively cooled plasma discharges in ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Neu, R., R. Dux, A. Janzer, A. Kallenbach, R. McDermott, H. W. Müller, S. Potzel, T. Pütterich, M. Sertoli, G. Van Rooij and ASDEX Upgrade Team*: W behaviour in N2 seeded discharges in ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Neu, R., J. C. Fuchs, A. Kallenbach, J. Rapp, R. Dux, T. Eich, O. Gruber, A. Herrmann, H. W. Müller, T. Pütterich, V. Rohde, K. Schmid, J. Schweinzer, M. Sertoli, G. van Rooij and ASDEX Upgrade Team*: Power and Particle Exhaust Control in All W ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Nocentini, R., R. Gutser, B. Heinemann, M. Froeschle and R. Riedl*: Optimization of the cooling circuit and thermomechanical analysis of the extraction grid of ELISE. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Nold, B., H. W. Müller, G. D. Conway, M. Ramisch, V. Rohde, U. Stroth and ASDEX Upgrade Team*: Blobdynamik am Rand des Tokamak ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Nold, B., H. W. Müller, M. Ramisch, V. Rohde, U. Stroth and ASDEX Upgrade Team*: Edge turbulence in L- and H-mode discharges. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Noterdaeme, J.-M.*: BNEN, the Interuniversity Programme leading to your Master in Nuclear Engineering. (Belgian Nuclear Society, 2010-03-02, Brussels).

*Noterdaeme, J.-M.*: EnTicE (Euratom network for Training ion cyclotron Engineers) part of the EFTS (Euratom Fusion Training Scheme). (Euratom Fusion Training, 2010-09-27, Porto).

*Noterdaeme, J.-M.*: ICRF at IPP. (Firma Spinner, 2010-06-01, IPP Garching).

*Noterdaeme, J.-M.*: Physics of RF Heating. (Advanced Course for the European Fusion Doctorate, 2010-09-28 to 2010-10-09, IPP Garching).

*Noterdaeme, J.-M.*: High power ICRF at IPP Garching: Past experience, status and future directions. (Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), 2010-10-20, Hefei).

*Noterdaeme, J.-M.*: Kernreactortheorie. (WS 2009/2010. Vorlesung, Universiteit Gent).

*Noterdaeme, J.-M.*: Is Nuclear Energy an Option? (Panel, Doctoral Symposium, 2010-12-01, Gent).

*Noterdaeme, J.-M.*: Nuclear Reactor Theory and Experiments. (SS 2010. Vorlesung – Interuniversity Program Master in Nuclear Engineering in SCK/CEN (Studiencentrum voor Kernenergie/Centre pour Energie Nucleaire), Mol).

*Noterdaeme, J.-M.*: Set up or improve your fusion laboratory. (Fusenet Meeting, 2010-11-04, Budapest).

*Noterdaeme, J.-M., V. Bobkov, R. D'Inca, F. Braun, P. Dumortier, R. Dux, H. Faugel, H. Fünfgelder, L. Giannone, D. Hancock, D. Hangan, A. Herrmann, T. Huijser, S. Huygen, A. Kallenbach, M. El Khaldi, M. Kocan, L. Liu, H. W. Müller, R. Neu, A. Onyshenko, Y. Podoba, K. Polozhiy, F. Pompon, T. Pütterich, V. Rohde, E. Würsching, I. Zammuto, ICRF Group and ASDEX Upgrade Team*: Advances in ICRF Physics and Technology on ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Oberkofler, M.*: D retention in pure beryllium, beryllium oxide and beryllium nitride. (Joint SEWG Meeting Material Migration and Material Mixing, 2010-06-30 to 2010-07-02, Jülich).

*Oberkofler, M., M. Köppen and Ch. Linsmeier*: Interaction of beryllium as a first wall material with energetic nitrogen ions. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Oberkofler, M., M. Reinelt and Ch. Linsmeier*: Retention and release mechanisms of deuterium implanted into beryllium as a fusion first wall material. (18<sup>th</sup> International Workshop on Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).



*Oberkofler, M., M. Reinelt and Ch. Linsmeier:* Deuterium release from implanted beryllium and beryllium oxide. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Ogorodnikova, O., M. Mayer, M. Balden, A. Manhard, L. Ciupinski, T. Plocinski and M. Rasinski:* Influence of microstructure on plasma-driven deuterium retention in tungsten. (Special Expert Working Group Meeting on High-Z Materials, 2010-07-21 to 2010-07-23, Garching).

*Ogorodnikova, O., B. Tyburska, V. Alimov and K. Ertl:* Modelling of the influence of radiation on deuterium retention in tungsten. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Ogorodnikova, O. V., B. Tyburska, G. Pintsuk, J. Linke, G. Matern and A. Manhard:* Deuterium retention in tungsten damaged by high heat load. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials, 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Osborne, T. H., M. N. A. Beurskens, L. Frassinetti, R. J. Groebner, L. D. Horton, A. W. Leonard, P. Lomas, I. Nunes, S. Saarela, P. B. Snyder, I. Balboa, B. D. Bray, J. Flanagan, C. Giroud, M. Kemenaars, A. Loarte, G. Maddison, D. McDonald, G. R. McKee, G. Saibene, E. Wolfrum, M. Walsh, Z. Yan and JET-EFDA Contributors:* Scaling of H-Mode Pedestal and ELM Characteristics in the JET and DIII-D Tokamaks. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Pace, D. C., R. K. Fisher, M. Garcia-Munoz, W. W. Heidbrink, Z. Lin, G. R. McKee, M. Murakami, C. Muscatello, R. Nazikian, J. M. Park, C. C. Petty, T. L. Rhodes, M. A. Van Zeeland, R. E. Waltz, R. B. White, J. H. Yu, W. Zhang and Y. B. Zhu:* Transport of Energetic Ions due to Microturbulence, Sawteeth, and Alfvén Eigenmodes. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Papp, G., M. Drevlak, T. Fülöp, P. Helander and G. Pokol:* Runaway Electron Drift Orbits in Magnetostatic Perturbed Fields. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Pardanaud, C., C. Martin, R. Ruffe, T. Angot, E. Aréou, C. Brosset, B. Pégourié, E. Tsitrone, T. Dittmar, C. Hopf, W. Jacob, T. Schwarz-Selinger and P. Roubin:* Deuterium Inventory in Tore Supra: Raman Study of CFC Tiles Extracted from the Toroidal Pump Limiter. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Pautasso, G. and ASDEX Upgrade Team:* ASDEX Upgrade contribution to disruption studies for ITER. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Pautasso, G., L. Giannone, A. Herrmann, O. Kardaun, R. R. Khayrutdinov, V. E. Lukash, Y. Nakamura, B. Reiter, G. Sias, M. Sugihara, G. Tardini, Y. Zhang and ASDEX Upgrade Team:* Contribution of ASDEX Upgrade to Disruption Studies for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Peacock, A., A. Grlinger, A. Vorkörper, J. Boscar, H. Greuner, F. Hurd, B. Mendelevitch, H. Pirsch, R. Stadler and G. Zangl:* The procurement and testing of the stainless steel in vessel panels of the W7-X stellartor. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Peeters, A. G., C. Angioni, A. Bortolon, Y. Camenen, F. J. Casson, B. Duval, L. Fiederspiel, W. A. Hornsby, N. Khuy, P. Mantica, A. P. Snodin, G. Szepesi, D. Srintzi, T. Tala, G. Tardini, P. de Vries and J. Weiland:* Toroidal Momentum Transport. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Pelicon, P., P. Vavpetic, N. Grlj, I. Cadez, S. Markelj, S. Brezinsek, A. Kreter, T. Dittmar, E. Tsitrone, B. Pegourie, P. Languille, M. Rubel and T. Schwarz-Selinger:* Deuterium mapping with micro-NRA using high energy focused 3He beam for fuel retention studies in the walls of fusion reactors. (12<sup>th</sup> International Conference on Nuclear Microprobe Technology (ICNMTA12), 2010-07-27 to 2010-07-30, Leipzig).

*Pereverzev, G. V., O. Maj and E. Poli:* Improved Description of Wave Absorption in Beam Tracing Technique. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Philipps, V., G. Matthews, H. Maier, P. H. Mertens and R. Neu:* Introduction to ILW and material properties. (1<sup>st</sup> General Planning Meeting ITER-like Wall, 2010-03-01, Culham).

*Pintsuk, G., J. Linke and H. Greuner:* Armour Material Optimisation – Testing of different tungsten grades under quasi-stationary thermal loads using H/He-beam and e-beam. (EFDA Topical Group Materials Science, 2010-06-28 to 2010-06-29, San Sebastian).

*Pisarev, A., Y. Gasparyan, A. Rusinov, N. Trifonov, V. Kurnaev, A. Spitsyn, B. Khripunov, T. Schwarz-Selinger, M. Rasinski and K. Sugiyama:* Deuterium thermal desorption from carbon based materials: a comparison of plasma exposure, ion implantation, gas loading, and C-D codeposition. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Plöckl, B., P. T. Lang, J. Jehl, M. Prechtel, S. Sotier, *ASDEX Upgrade Team and JET EFDA Contributors*: Comparison of Different Pellet Injection Systems for ELM Pacing. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Poli, E.: Kinetic theory. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

Poli, E.: Plasmaphysik I. (WS 2009/2010. Vorlesung, Universität Ulm).

Politzer, P. A., C. D. Challis, E. Joffrin, T. C. Luce, M. Beurskens, P. Buratti, F. Crisanti, J. C. DeBoo, J. R. Ferron, C. Giroud, J. Hobirk, C. T. Holcomb, A. W. Hyatt, F. Imbeaux, R. J. Jayakumar, J. E. Kinsey, R. J. La Haye, D. C. McDonald, C. C. Petty, F. Turco and M. R. Wadem: Understanding Confinement in Advanced Inductive Scenario Plasmas – Dependence on Gyroradius and Rotation. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Potzel, S., R. Dux, A. Scarabosio, M. Wischmeier and *ASDEX Upgrade Team*: Bestimmung der Elektronendichte im Divertor von ASDEX Upgrade mit Hilfe der Stark-Verbreiterung der Balmer-Linien. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Primetzhofer, D., M. Spitz, S. N. Markin, P. Bauer and E. Taglauer: He<sup>+</sup> Ion scattering from noble metal and alloy surfaces: Influence of Surface Structure and Composition on Neutralization. (23<sup>rd</sup> Symposium on Surface Science 2010 (3S'10), 2010-03-07 to 2010-03-13, St. Christoph/Arlberg).

Pütterich, T., A. Bueckhart, E. Wolfrum, R. Dux, M. A. Janzer, R. M. McDermott, T. Eich, N. Hicks, R. Fischer and *ASDEX Upgrade Team*: Pedestal Dynamics and Impurity Transport during the Inter-ELM Phase in ASDEX Upgrade. (Workshop of the US Transport Taskforce (TTF 2010), 2010-04-13 to 2010-04-16, Annapolis, MD).

Pütterich, T., R. Dux, M. A. Janzer and *ASDEX Upgrade Team*: ELM flushing and Impurity Transport in the H-mode Edge Barrier in ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Pütterich, T., H. Zohm and J. Stober: Plasmaphysik II: Kernfusionsforschung. Übersicht. (WS 2009/2010. Vorlesung/Übung, Ludwig-Maximilians-Universität München).

Rai, A., A. Mutzke and R. Schneider: Modeling of chemical erosion of graphite due to hydrogen by inclusion of chemical

reactions in SDTrimSP. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Rampp, M.: Remote Visualization of Large HPC Simulations. (HP-CAST-14, 2010-05-28 to 2010-05-29, Hamburg).

Rampp, M.: Visualization of large HPC simulations: Providing Visualization Services for the Max-Planck Society. (Karlsruhe Institute of Technology, Engineering Mathematics and Computing Lab (KIT/EMCL), 2010-07-15, Karlsruhe).

Rapp, J., G. M. Wright, E. Alves, L. C. Alves, N. P. Barradas, G. De Temmerman, K. Ertl, J. Linke, M. Mayer, G. J. van Rooij, J. Westerhout, P. A. Zeijlmans van Emmichoven and A. W. Kley: Plasma-facing Materials Research for Fusion Reactors at FOM Rijnhuizen. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Rapson, C., O. Grulke and T. Klinger: Experiments with electron and ion beams in a linear plasma device. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Rasinski, M., E. Balden, Fortuna-Zalesna, R. Neu, M. Lewandowska, K. J. Kurzydowski and *ASDEX Upgrade Team*: High resolution scanning transmission electron microscopy (HR STEM) analysis of redeposited layer on ASDEX Upgrade tile. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Rasinski, M., H. Maier, C. Ruset, M. Lewadnowska and K. J. Kurzydowski: Carbide formation in tungsten coatings on CFC substrates. (E-MRS 2010 Spring Meeting, 2010-06-07 to 2010-06-11, Strasbourg).

Rasinski, M., T. Plocinski, C. Adelhelm, M. Balden, L. Ciupinski and K. J. Kurzydowski: High resolution scanning transmission electron microscopy (HR STEM) analysis of tungsten-doped amorphous carbon films. (European Energy Conference, 2010-04-20 to 2010-04-23, Barcelona).

Rasinski, M., T. Plocinski, C. Adelhelm, M. Balden, L. Ciupinski and K. J. Kurzydowski: HR TEM analyses of tungsten carbides in fusion reactor first wall materials. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

Rasinski, M., T. Plocinski, M. Balden, C. Adelhelm, M. Lewandowska and K. J. Kurzydowski: High resolution analysis of tungsten doped amorphous carbon thin films. (World Materials Research Institute Forum (WMRIF). 2<sup>nd</sup> International Workshop for Young Materials Scientists, 2010-08-31 to 2010-09-03, Berlin).

*Rasmussen, J. J., V. Naulin, N. Vianello, R. Schrittwieser, H. W. Müller, M. Zuin, C. Ionita, F. Mehlmann, V. Rohde, R. Cavazzana, M. Maraschek, Ch. Maszl, C. Lupu and ASDEX Upgrade Team:* Intermittent transport of particles, momentum and current in the scrape-off-layer of magnetically confined toroidal plasmas. (Birkeland Workshop, 2010-05-27 to 2010-05-31, Tromsø).

*Reich, M., K. Behler, R. Drube, L. Giannone, A. Kallenbach, A. Mlynec, J. Stober, W. Treutterer and ASDEX Upgrade Team:* Real-time diagnostics and their applications at ASDEX Upgrade. (6<sup>th</sup> Workshop on Fusion Data Processing, Validation and Analysis, 2010-01-25 to 2010-01-27, Madrid).

*Reiman, A., J. Krommes, D. Monticello, M. Zarnstorff, A. Weller, J. Geiger and W7-AS Team:* Three-Dimensional Equilibria with Stochastic Regions Supporting Finite Pressure Gradients. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Reimer, R., A. Dinklage, J. Hobirk, M. Reich and R. Wolf:* Spektral aufgelöster 'Motional Stark Effekt' am ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Reinelt, M., K. Krieger, S. Lisgo, K. Schmid, S. Bresinsek and JET TF-E:* Interpretation of Be migration studies at JET and validation of an integrated numerical model for plasma impurity transport and wall composition dynamics. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Reinelt, M., K. Krieger, S. Lisgo, K. Schmid and S. Bresinsek:* Computer code modelling of material migration in JET. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Reuter, K.:* Hydrodynamic waves and turbulence in a spherical MHD dynamo model. (Workshop on Self-Organization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

*Rice, J. E., Z. Yan, M. Xu, G. R. Tynan, P. H. Diamond, Ö. D. Gürcan, T. S. Hahm, C. Holland, J. Hughes, Y. Kosuga, R. McDermott, C. J. McDevitt, S. H. Müller and Y. Podpaly:* Progress towards a Physics based Phenomenology of Intrinsic Rotation in H-Mode and I-Mode. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Riemann, J.:* Kernfusion als Energieoption für die Zukunft. (Schulvortrag, 2010-03-12 to 2010-03-12, Henfling-Gymnasium Meiningen).

*Riemann, J.:* Kernfusion als Energieoption für die Zukunft. (Schulvortrag, 2010-03-18, Pädagogium, Bad Schwartau).

*Riemann, J.:* Kernfusion als Energieoption für die Zukunft. (Schulvortrag, 2010-06-04, Osterlandgymnasium Gera).

*Riesch, J., F. Koch, J. H. You, T. Höschen and J. Du:* Development and Characterisation of W<sub>f</sub>/W-Composites. (EFDA Monitoring Meeting, 2010-06-28 to 2010-07-02, San Sebastian).

*Riesch, J., Ch. Linsmeier and S. F. Nielsen:* In-situ tomographic observation of crack formation and propagation in tungsten materials in the framework of FEMaS-CA. (31<sup>st</sup> Risø International Symposium on Materials Science: Challenges in materials science and possibilities in 3D and 4D characterization techniques, 2010-09-06 to 2010-09-10, Roskilde).

*Riesch, J., J. H. You and T. Höschen:* Fracture behaviour of heterogeneous tungsten materials for fusion reactors. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

*Rieth, M., J. Linke and Ch. Linsmeier:* High Heat Flux Materials: Status and Perspectives. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Riße, K., M. Nagel, M. Pietsch, A. Braatz, A. Binni and H. Posselt:* Design and assembly technology for the thermal insulation of the W7-X cryostat. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Rohde, V.:* Arc surface damage in fusion reactors. (Breakdown Physics Workshop, 2010-05-06 to 2010-05-07, Geneva).

*Rohde, V.:* Installation of AUG-type dust collector at JET. (TF-FT JET Meeting, 2010-12-09 to 2010-12-10, Culham).

*Rohde, V.:* Recent dust investigations in full tungsten ASDEX Upgrade: Dust production by arcs, refined dust collection and analysis. (IAEA CRP Meeting, 2010-06-21 to 2010-06-23, IAEA Vienna).

*Rohde, V.:* Wolfram Erosion durch Bögen im Tokamak ASDEX Upgrade. (Technische Hochschule, 2010-09-16, Wildau).

*Rohde, V., M. Balden, N. Endstrasser, A. Hakkola, R. Neu, T. Lunt and ASDEX Upgrade Team:* Tungsten erosion by arcs in ASDEX Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Rohde, V., N. Endstrasser, U. von Toussaint, M. Balden, T. Lunt, R. Neu, A. Hakola, J. Bucalossi and ASDEX Upgrade Team:* Tungsten erosion by arcs in ASDEX Upgrade. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Rohde, V., V. Mertens, R. Neu and ASDEX Upgrade Team:* Dynamic Wall Loads Measured by Gas Balance Technique in all Tungsten ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Roth, J.:* Hydrogen retention in materials: a critical safety aspect in fusion research. (Workshop on Ion Beam Physics, 2010-03-29 to 2010-03-31, Dresden-Rossendorf).

*Roth, J.:* Multi machine scaling of fuel retention for ITER. (Monitoring Meeting of the EU TF PWI Special Expert Working Group on “Gas Balance and Fuel Retention”, 2010-07-19 to 2010-07-20, Garching).

*Roth, J., K. Schmid and Ch. Linsmeier:* Effect of Plasma-facing Materials on the Tritium Inventory in Fusion Devices. (12<sup>th</sup> International Conference on Modern Materials and Technologies (CIMTEC 2010). 5<sup>th</sup> Forum on New Materials. Symposium: Materials Challenges for Future Nuclear Fission and Fusion Technologies, 2010-06-13 to 2010-06-18, Tuscany).

*Roth, J., K. Sugiyama, A. Anghel, C. Porosnicu, M. Baldwin, R. Doerner, K. Krieger and C. P. Lungu:* Consequences of Deuterium Retention and Release from Be-containing Mixed Materials for ITER Tritium Inventory Control. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Roth, J., K. Sugiyama, K. Krieger, A. Anghel, C. Porosnicu, C. P. Lungu, M. J. Baldwin and R. P. Doerner:* Review of D retention and release behaviour of Be-relating mixed materials and consequences for ITER. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Rozhansky, V., E. Kaveeva, S. Voskoboinikov, D. Coster, E. Wolfrum, B. Langer, T. Puetterich and ASDEX Upgrade Team:* Simulation of edge radial electric fields in H-regimes of ASDEX-Upgrade. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Rozhansky, V., P. Molchanov, E. Kaveeva, S. Voskoboinikov, A. Kirk, E. Nardon, D. Coster and M. Tendler:* Modeling of the Edge Plasma of MAST in the Presence of Resonant Magnetic Perturbations. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Ruan, Q., M. Cerna, L. Wenzel, L. Giannone, M. Ravindran and S. Concezzi:* Data acquisition and real time tomography diagnostic using LabVIEW real-time and multicore technology. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Ruf, B., D. Wunderlich, U. Fantz and NNBI Team:* Cäsiumverteilung in großflächigen HF-Quellen für negative Wasserstoffionen. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Rummel, T., F. Füllenbach, G. Böhm, W. Kaesler, R. Burek, S. Pingel, A. Spring, J. Schacht and A. Wölk:* The power supplies for the glow discharge electrodes in Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Ruset, C., E. Grigore, H. Maier, R. Neu, H. Greuner, M. Mayer and G. Matthews:* Development of W Coatings for Fusion Applications. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Ruset, C., E. Grigore, I. Munteanu, N. Budica, H. Maier, R. Neu and G. Matthews:* Nano-structured W coatings for fusion applications – from research to production. (National Seminar of Nano-Science and Nano-Technology, 2010-03-16, Bucharest).

*Ruset, C., H. Maier and G. Matthews:* The limits of the W coatings deposited on CFC for the ILW project at JET (JW11-FT-4.19). (JET-EFDA Progress and Kick-off Meeting on Fusion Technologies, CCFE, 2010-12-08, Culham).

*Rust, N., B. Heinemann, B. Mendelevitch, A. Peacock and M. Smirnov:* W7-X Neutral-Beam-Injection: Selection of the NBI source positions for experiment start-up. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Sáez, X., A. Soba, E. Sánchez, R. Kleiber, R. Hatzky, F. Castejón and J. Cela:* Improvements of the Particle-In-Cell Code EUTERPE for Petascaling Machines. (Conference on Computational Physics (CCP 2010), 2010-06-23 to 2010-06-26, Trondheim).

*Sarazin, Y., V. Grandigard, J. Abiteboul, S. Allfrey, X. Garbet, P. Ghendrih, G. Latu, A. Strugarek, G. Dif-Pradalier, P. H. Diamond, S. Ku, C. S. Chang, B. F. McMillan, S. Jolliet, T. M. Tran, L. Villard, A. Bottino and P. Angelino:* Predictions on Heat Transport and Plasma Rotation from Global Gyrokinetic Simulations. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).



*Sartori, R., P. C. De Vries, F. Rimini, T. W. Verlsoot, G. Saibene, I. Voitsekhovitch, M. L. Mayoral, I. Monakhov, F. Durodié, M. Beurskens, D. C. McDonald, R. Budny, P. Mantica, E. De La Luna, T. Johnson, V. Parail, K. D. Zastrow, C. Giroud, A. Boboc, T. Eich, K. Crombe, F. Nave, V. Kiptily and JET-EFDA Contributors:* Comparison between Dominant NBI and Dominant ICRH Heated ELMy H-mode Discharges in JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Sauter, P. A. and M. Balden:* Deuterium retention in tungsten-doped carbon films at elevated temperatures. (E-MRS 2010 Spring Meeting, Symposium N: Nuclear Materials IV, 2010-06-07 to 2010-06-11, Strasbourg).

*Sauter, P. A. and M. Balden:* Temperature Dependence of the Deuterium Retention in Tungsten-doped Carbon Films. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Sauter, M., P. A. Balden, S. Jong, C. Adelhelm, S. Lindig, M. Rasinski and T. Plocinski:* Carbide formation in amorphous tungsten-containing carbon films by annealing. (E-MRS 2010 Spring Meeting, Symposium L: Carbon- or nitrogene-containing nanostructured composite films, 2010-06-07 to 2010-06-11, Strasbourg).

*Sauter, P., F. Ryter, D. Coster, T. Pütterich and E. Wolfrum:* L- to H-mode transitions in the low density regime. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Scarabosio, A., A. Herrmann, N. Hicks, H. W. Müller, T. Pütterich, F. Ryter, E. Wolfrum and ASDEX Upgrade Team:* ELM characteristics and divertor loads in ASDEX Upgrade helium discharges. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Schacht, J., S. Pingel and A. Wölk:* Piezo-Ventil Controller für das Gaseinlass-System des Fusionsexperimentes Wendelstein 7-X. (13. Symposium Maritime Elektrotechnik, Elektronik und Informationstechnologie, 2010-09-29 to 2010-10-01, Rostock).

*Schiesko, L., U. Fantz and NNBI Team:* Langmuir probe characterisation in a cesiated high density negative ion source. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Schiesko, L. and C. Hopf:* Copper sources identification at MANITU: experiments and calculations. (CCNB Meeting, 2010-06-02 to 2010-06-04, Sofia).

*Schillinger, B., H. Greuner and Ch. Linsmeier:* Neutron Computed Tomography of Plasma Facing Components for Fusion Experiments. (9<sup>th</sup> World Conference on Neutron Radiography (WCNR-9), 2010-10-03 to 2010-10-08, Kwa-Maritane).

*Schillinger, B., H. Greuner and Ch. Linsmeier:* Neutron tomography of highly heat loaded Divertor components. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

*Schmid, K., K. Krieger and M. Reinelt:* An integrated model of impurity migration and wall composition dynamics for tokamaks. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Schmid, K., K. Krieger and M. Reinelt:* An integrated model of impurity migration and wall composition dynamics for tokamaks with two plasma facing materials. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Schmid, K., M. Reinelt, M. Mayer, K. Krieger, C. Adelhelm and M. Balden:* Global erosion/deposition modeling and the implications of surface roughness. (Joint SEWG Meeting Material Migration and Material Mixing, 2010-06-30 to 2010-07-02, Jülich).

*Schmitz, O., T. Evans, M. Austin, J. Boedo, S. Brezinsek, N. Brooks, M. Clever, Y. Feng, M. Fenstermacher, H. Frerichs, M. Jakubowski, R. Laengner, C. Lasnier, M. Lehnen, A. Leonard, R. Moyer, T. Osborne, T. Petrie, H. Reimerdes, D. Reiter, D. Rudakov, U. Samm, H. Stoschus, B. Unterberg, E. Unterberg, J. Watkins, A. Wingen, J. Yu, DIII-D Research Team and TEXTOR Research Team:* Implications of three-dimensional stochastic boundaries applied for control of edge localized modes on plasma edge transport and plasma wall interaction. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-29, San Diego, CA).

*Schmitz, O., T. E. Evans, H. Stoschus, E. A. Unterberg, J. W. Coenen, M. E. Fenstermacher, H. Frerichs, M. W. Jakubowski, R. Laengner, C. L. Lasnier, S. Mordijck, R. Moyer, T. H. Osborne, H. Reimerdes, D. Reiter, U. Samm, B. Unterberg, DIII-D Team and TEXTOR Team:* Key Results from the DIII-D/TEXTOR Collaboration on the Physics of Stochastic Boundaries Projected to ELM Control at ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Schneider, R.:* Computational Many-Body Physics. (WS 2009/2010. Vorlesung, Universität Greifswald).

*Schneider, R.:* Programmiertechnik. (WS 2009/2010. Vorlesung und Übung, Universität Greifswald).

*Schneider, R., A. Mutzke, I. Bizyukov, J. Davis, A. Haasz, H. Langhuth and K. Krieger:* Bombardment of a Si pitch grating by  $C^+$  ions at an incident angle parallel to the structure. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Schneider, R. and P. Xanthopoulos:* Introduction to Tensor Analysis and Applications. (SS 2010. Vorlesung, Universität Greifswald).

*Schöbel, M., H. P. Degischer, A. Brendel, B. Harrer and M. Di Michiel:* 3D Characterization of thermal fatigue damage in monofilament reinforced copper for heat sink applications in fusion reactor systems. (13. Internationale Metallographie-Tagung 2010, 2010-09-29 to 2010-10-01, Leoben).

*Schrittwieser, R., C. Ionita, N. Vianello, H. W. Müller, F. Mehlmann, M. Zuin, V. Naulin, J. J. Rasmussen, V. Rohde, R. Cavazzanani, C. Lupu, M. Maraschek, C. Maszl and ASDEX Upgrade Team:* Measurements of electric and magnetic fluctuations in ASDEX Upgrade by means of a combined probe. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Schrittwieser, R., F. Mehlmann, C. Ionita, V. Naulin, J. J. Rasmussen, H. W. Müller, N. Vianello, C. Maszl, V. Rohde, M. Zuin, R. Cavazzana, M. Maraschek and ASDEX Upgrade Team:* Transport phenomena in the SOL of ASDEX Upgrade. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Schrittwieser, R., F. Mehlmann, C. Ionita, V. Naulin, J. J. Rasmussen, H. W. Müller, N. Vianello, C. Maszl, V. Rohde, M. Zuin, R. Cavazzana, M. Maraschek and ASDEX Upgrade Team:* Transport phenomena in the SOL at the outer mid-plane of ASDEX Upgrade. (15<sup>th</sup> International Conference on Plasma Physics and Applications (CPPA 2010), 2010-07-01 to 2010-07-04, Iasi).

*Schröder, M.:* Quality assurance on the welding work during the assembly of Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Schröder, T., O. Grulke and T. Klinger:* Experimentelle Untersuchung zur Entstehung von Doppelschichten in divergierenden Magnetfeldern. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Schwarz-Selinger, T., C. Hopf, M. Schlüter and W. Jacob:* Studying synergistic effects in chemical sputtering using dual beam irradiation. (18<sup>th</sup> International Workshop on

Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).

*Schwarz-Selinger, T. and W. Jacob:* Carbon removal from remote areas with plasma-produced reactive species. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Schwarz-Selinger, T., H. Kang, R. Preuss and V. Dose:* Bayesian decomposition of quadrupole mass spectra: What can be extracted from the data? (Physics Division Seminar. Oak Ridge National Laboratory, 2010-09-23, Oak Ridge, TN).

*Schweinzer, J., A. C. C. Sips, A. Kallenbach, O. Gruber, R. Fischer, J. C. Fuchs, N. Hicks, J. Hobirk, F. Jenko, C. F. Maggi, M. Maraschek, R. McDermott, R. Neu, T. Pütterich, S. K. Rathgeber, M. Reich, F. Rytter, M. Schneller, J. Stober, G. Tardini and ASDEX Upgrade Team:* Confinement of 'Improved H-modes' in the All-Tungsten ASDEX Upgrade. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Scott, B. D.:* An introduction to MHD, or magnetic fluid dynamics. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Scott, B., F. Da Silva, A. Kendl, N. Miyato and T. Ribeiro:* Gyrokinetic Studies of Turbulence, Equilibrium, and Flows in the Tokamak Edge. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Seo, S. H., H. M. Wi and A. Werner:* Development of Digital Integrator for the KSTAR Device. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Shaer, M. J., J. A. Snipes, P. Gohil, P. De Vries, M. E. Fenstermacher, T. E. Evans, X. Gao, A. M. Garofalo, D. A. Gates, C. M. Greenfield, W. W. Heidbrink, G. J. Kramer, S. Liu, A. Loarte, M. F. F. Nave, N. Oyama, J. K. Park, N. Ramasubramanian, H. Reimerdes, G. Saibene, A. Salmi, K. Shinohara, D. A. Spong, W. M. Solomon, T. Tala, J. A. Boedo, V. Chuyanov, E. J. Doyle, M. Jakubowski, H. Jhang, R. M. Nazikian, V. D. Pustovitov, O. Schmitz, T. H. Osborne, R. Srinivasan, T. S. Taylor, M. R. Wade, K. I. You, L. Zeng and DIII-D Team:* ITER Test Blanket Module Error Field Simulation Experiments at DIII-D. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Shimizu, S., T. Shimizu, W. Jacob, H. M. Thomas, N. Sato and G. E. Morfill:* Diamond fine particle growth in an rf plasma chamber equipped with a hot filament. (11<sup>th</sup> Workshop on Fine Particle Plasmas, 2010-11-19 to 2010-11-20, Toki, Gifu).

*Shinohara, K., T. Kurki-Suonio, D. Spong, O. Asunta, K. Tani, E. Strumberger, S. Briguglio, S. Günter, T. Koskela, G. Kramer, S. Putvinski, K. Hamamatsu and ITPA Group on Energetic Particles:* 3D Effect of Ferromagnetic Materials on Alpha Particle Power Loads on First Wall Structures and Equilibrium on ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Sias, G., B. Cannas, A. Fanni, G. Pautasso and ASDEX Upgrade Team:* Disruption prediction with adaptive neural networks for ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Siccinio, M., E. Poli, W. A. Hornsby and A. G. Peeters:* Gyrokinetic investigation of magnetic islands in tokamaks. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Sieglin, B., R. Fischer, E. Wolfrum, B. Wieland and ASDEX Upgrade Team:* Elektronentemperaturbestimmung in der Abschälschicht von ASDEX Upgrade durch Helium-I Linien und Bayes'sche Statistik. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Sinclair, L., J. W. Davis, B. W. N. Fitzpatrick, A. A. Haasz, C. Adelhelm, P. A. Sauter and M. Balden:* Thermo-Oxidation of Carbon films with Tungsten Impurities. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials, 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Smirnow, M.:* Messtechnik/Qualitätssicherung. (WS 2009/2010. Vorlesung, Fernhochschule Hamburg).

*Smirnow, M.:* Werkstofftechnik. (WS 2009/2010. Vorlesung, Fernhochschule Hamburg).

*Smirnow, M., N. Drescher, T. Höschen, A. Peacock, J. Boscary and R. Tivey:* Development of a thermo-hydraulic bypass leakage test method for the Wendelstein 7-X target element cooling structure. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Snicker, A., E. Poli, T. Kurki-Suonio and ASDEX Upgrade Team:* Neoclassical tearing modes in ASCOT code. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Sode, M., T. Schwarz-Selinger, W. Jacob, D. Wunderlich and U. Fantz:* Massenaufgelöste Ionenflüsse aus Wasserstoff-Argon-Niedertemperaturentladungen: Vergleich Experiment – Modell. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Sode, M., T. Schwarz-Selinger, W. Jacob, D. Wunderlich and U. Fantz:* Quantitative Bestimmungen der massenaufgelösten Ionenflüsse aus Wasserstoff-Argon-Plasmen. (XVII. Erfahrungsaustausch Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen, 2010-03-02 to 2010-03-04, Mühlleithen).

*Solano, E. R., P. J. Lomas, B. Alper, G. Arnoux, A. Boboc, L. Barrera, P. Belo, M. N. A. Beurskens, M. Brix, K. Crombe, E. De La Luna, S. Devaux, T. Eich, S. Gerasimov, C. Giroud, D. Harting, D. Howell, A. Huber, G. Kocsis, Y. Liang, A. Lopez-Fraguas, M. F. F. Nave, E. Nardon, C. P. von Thun, S. D. Pinches, E. Rachlew, F. Rimini, S. Saarelma, A. Sirinelli, H. Thomsen, I. Voitsekhovitch, G. S. Xu, L. Zabeo and JET-EFDA Contributors:* Observation of Con fined Current Structures in JET High Temperature Pedestals and Transient ELM Suppression. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Solomakhin, A. L., P. A. Bagryansky, W. Biel, H. Dreier, S. V. Ivanenko, A. N. Kvashnin, Y. V. Kovalenko, H. T. Lambertz, A. A. Lizunov, V. Y. Savkin and A. D. Khilchenko:* Multi-Channel Dispersion Interferometer for Control Plasma Density and Position. (37<sup>th</sup> Zvenigorod International Conference on Plasma Physics and Controlled Fusion, 2010-02-08 to 2010-02-12, Zvenigorod).

*Sommer, F., S. Günter, A. Kallenbach, M. Maraschek, J. Boom, R. Fischer, A. Gude, N. Hicks, E. Wolfrum and ASDEX Upgrade Team:* Charakterisierung und Interpretation der Edge Snake zwischen ELMs an ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Sonato, P., T. Bonicelli, A. K. Chakraborty, R. Hemsworth, K. Watanabe, C. Day, P. Franzen, C. Waldon and NBI International Team:* The ITER Neutral Beam Test Facility in Padua – Italy: a Joint International Effort for the Development of the ITER Heating Neutral Beam Injector Prototype. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Spring, A., A. Cardella, B. Brucker, B. Mendelevitch, H. Niedermeyer, O. Sellmeier, S. Schweizer and B. Streibl:* Design, manufacture and testing of the glow discharge electrodes for Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Stange, T., H. P. Laqua, M. Otte and S. Marsen:* Überdichte Plasmen am Stellarator WEGA. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Stober, J., G. Jackson, E. Ascasibar, Y.-S. Bae, J. Bucalossi, A. Cappa, M.-H. Cho, G. Granucci, K. Hanada, S. Ide,*

*J.-H. Jeong, W. Namkung, S.-I. Park, A. C. C. Sips, J. Schweinzer and ITPA “Integrated Operations Scenarios” Group Members and Experts:* ECRH Assisted Plasma Start-up with Toroidally Inclined Launch: Multi-Machine Comparison and Perspectives for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Stober, J. and T. Pütterich:* Plasmaphysik 2 – Kernfusionsforschung. (WS 2009/2010. Vorlesung, Ludwig-Maximilians-Universität München).

*Stober, J., D. Wagner, L. Giannone, F. Leuterer, F. Monaco, M. Maraschek, A. Mlynek, M. Münich, E. Poli, M. Reich, D. Schmid-Lorch, H. Schütz, J. Schweinzer, W. Treutterer, H. Zohm, A. Meier, T. Scherer, J. Flamm, M. Thumm, H. Höhnle, W. Kasperek, U. Stroth, A. Litvak, G. G. Denisov, A. V. Chirov, E. M. Tai, L. G. Popov, V. O. Nichiporenko, V. E. Myasnikov, E. A. Solyanova and S. A. Malygin:* ECRH on ASDEX Upgrade – System extension, new modes of operation, plasma physics results. (16<sup>th</sup> Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating (EC-16), 2010-04-12 to 2010-04-15, Sanya).

*Stoltzfus-Dueck, T.:* Weakly-nonadiabatic modeling of Hasegawa-Wakatani turbulence. (Workshop on Self-Organization in Turbulent Plasmas and Fluids, 2010-05-10 to 2010-05-14, Dresden).

*Stoschus, H., O. Schmitz, B. Unterberg, H. Frerichs, M. W. Jakubowski, U. Kruezi, U. Samm, D. Schega and TEXTOR Team:* Entwicklung von magnetischen Strukturen am Plasmarand aufgrund von rotierenden resonanten magnetischen Störfeldern. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Sugiyama, K., K. Krieger, J. Roth, A. Anghel, C. Porosnicu, C. P. Lungu, M. J. Baldwin and R. P. Doerner:* D retention and release behaviour of Be/C/W mixed materials. (Monitoring Meeting of the EU TF PWI Special Expert Working Group on “Gas Balance and Fuel Retention”, 2010-07-19 to 2010-07-20, Garching).

*Sugiyama, K., K. Krieger, J. Roth, A. Anghel, C. Porosnicu, C. P. Lungu, M. J. Baldwin and R. Doerner:* Impact of material mixing on D retention and release. (Joint SEWG Meeting Material Migration and Material Mixing, 2010-06-30 to 2010-07-02, Jülich).

*Sugiyama, K., M. Mayer, V. Rohde, K. Krieger, R. Neu, A. Hakola, S. Koivuranta and J. Likonien:* Contribution of Boron on the D retention in the AUG full-W wall regime. (Monitoring Meeting of the EU TF PWI Special Expert

Working Group on “Gas Balance and Fuel Retention”, 2010-07-19 to 2010-07-20, Garching).

*Sugiyama, K., J. Roth, A. Anghel, C. Porosnicu, R. Doerner, K. Krieger and C. P. Lungu:* Deuterium Retention and Release Behavior of Be-related Mixed Material Systems. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Sugiyama, K., J. Roth, K. Krieger, A. Anghel, C. Porosnicu, C. Lungu, M. Baldwin and R. Doerner:* D retention in Be-related mixed material. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials, 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Suttrop, W.:* Experimental results from tokamaks. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Suzuki, T., R. J. Akers, D. A. Gates, S. Günter, W. W. Heidbrink, J. Hobirk, T. C. Luce, M. Murakami, J. M. Park, M. Turnyanskiy and ITPA “Integrated Operation Scenarios” Group Members and Experts:* Experimental Investigation and Validation of Neutral Beam Current Drive for ITER through ITPA Joint Experiments. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Svensson, J. and O. Ford:* Modelling of JET Diagnostics using Bayesian Graphical Models. (International Conference on Plasma Diagnostics, 2010-04-12 to 2010-04-16, Pont-à-Mousson).

*Svensson, J., O. Ford, D. McDonald, A. Meakins, A. Werner, M. Brix, A. Boboc and M. Beurskens:* Modelling of JET diagnostics using Bayesian graphical models. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).

*Tereshin, V. I., V. E. Moiseenko, M. B. Dreval, P. Y. Burchenko, A. V. Losin, V. V. Chechkin, L. I. Grigor’eva, D. A. Hartmann, R. Koch, V. G. Konovalov, V. D. Konovalov, A. E. Kulaga, A. I. Lysoivan, V. K. Mironov, I. K. Nikol’skii, R. O. Pavlichenko, V. S. Romanov, A. N. Shapoval, A. I. Skibenko, A. S. Slavnyi and V. S. Voitsenya:* RF Plasma Production and Heating below Ion-cyclotron Frequencies in Uragan Torsatrons. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Terry, P. W., D. R. Hatch, W. M. Nevins, F. Jenko, F. Merz, J. H. Kim and K. Makwana:* Saturation of Plasma Microturbulence by Damped Eigenmodes. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).



*Thomsen, H., T. Eich, S. Devaux, G. Arnoux, S. Brezinsek, E. De la Luna, W. Fundamenski, A. Herrmann, A. Huber, S. Jachmich, P. Lomas, A. Kallenbach, I. Nunes, J. Rapp, G. Saibene, A. Scarabosio, J. Schweinzer and JET-EFDA Contributors:* Power Load Characterization for Type-I ELMy H-Modes in JET. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Throumoulopoulos, G. N., H. Tasso and G. Poulipoulis:* Equilibrium nonlinearity and combined stabilizing effects of magnetic field and plasma flow. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Tichmann, K., U. von Toussaint, T. Schwarz-Selinger and W. Jacob:* Measurement and modeling of reflection and sticking probabilities of energetic hydrocarbon species. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Tiseanu, I., M. Mayer, T. Craciunescu, C. Dobrea and ASDEX Upgrade Team:* X-ray microbeam transmission/fluorescence method for non-destructive characterization of tungsten coated carbon materials. (12<sup>th</sup> International Conference on Plasma Surface Engineering (PSE 2010), 2010-09-13 to 2010-09-17, Garmisch-Partenkirchen).

*Told, D., M. Schneller, G. Tardini, J. Schweinzer, A. Burckhart, E. Wolfrum, F. Jenko and ASDEX Upgrade Team:* Gyrokinetic studies of nitrogen seeding and edge ETG turbulence with GENE. (3<sup>rd</sup> EFDA Transport Topical Group Meeting combined with 15<sup>th</sup> EU-US Transport Task Force Meeting, 2010-09-07 to 2010-09-10, Cordoba).

*Toma, M., X. Bonnin, A. Hatayama, R. Schneider and D. Coster:* Analysis of tokamak plasmas with tungsten impurities using the coupled IMPGYRO-SOLPS codes. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Treutterer, W., K. Behler, R. Cole, L. Giannone, K. Lüddecke, G. Neu, G. Raupp, M. Reich, D. Zasche, T. Zehetbauer and ASDEX Upgrade Team:* Integrated operation of diagnostics and control. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Tsitroni, E., C. Brosset, J. Bucalossi, T. Dittmar, E. Gautier, P. Languille, P. Linez, T. Loarer, B. Pogouriol, Y. Marandet, C. Martin, P. Roubin, A. Kallenbach, K. Krieger, M. Mayer, R. Neu, V. Rohde, J. Roth, M. Rubel, S. Brezinsek, A. Kirschner, A. Kreter, A. Litnovsky, V. Philipps, P. Wienhold, J. Likonen, P. Coad, B. Lipschultz and R. Doerner:* Multi machine scaling of fuel retention in carbon dominated tokamaks. (19<sup>th</sup> Con-

ference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Tskhakaya, D., A. Soba, R. Schneider, M. Borchardt, E. Yurtesen and J. Westerholm:* PIC/MC code BIT1 for plasma simulations on HPC. (18<sup>th</sup> Euromicro International Conference on Parallel, Distributed and Network-based Processing (PDP 2010), 2010-02-17 to 2010-02-19, Pisa).

*Tuccillo, A. A., A. G. Alekseyev, A. Biancalani, A. Bierwage, G. Breyannis, L. Chen, X. Wang, M. Romanelli, FTU-Team and ECRH-Team:* Overview of the FTU Results. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Turkin, Y., C. Beidler, V. Erckmann, H. Laqua, H. Maaßberg, N. Marushchenko and W7-X Team:* Modeling of ECRH for W7-X. (22<sup>nd</sup> Joint Russian-German Meeting on ECRH and Gyrotrons, 2010-06-29 to 2010-07-05, Nizhniy Novgorod).

*Turkin, Y., C. Beidler, H. Maaßberg, S. Murakami, V. Tribaldos and A. Wakasa:* Benchmarking of Predictive Transport Simulations for LHD and TJ-II. (7<sup>th</sup> Coordinated Working Group Meeting, 2010-06-30 to 2010-07-02, Greifswald).

*Tyburnska, B., V. K. Alimov, O. Ogorodnikova, K. Ertl, K. Schmid and J. Roth:* Trapping of permeating deuterium in defect induced at the rear side of tungsten foil. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

*Ueda, Y., T. Wada, K. Sugiyama, S. Brezinsek, A. Kreter, V. Philipps and B. Schweer:* Structure and Retention of Carbon Deposition Layer on Tungsten. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials. Satellite Workshop of the 19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Umstadter, K., M. Baldwin, R. Doerner, T. Schwarz-Selinger, G. Tynan and J. Yu:* Effect of Simultaneous Plasma and Transient Heating on Beryllium Plasma Facing Components. (10<sup>th</sup> International Workshop on Hydrogen Isotopes in Fusion Reactor Materials. Satellite Workshop of the 19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-31 to 2010-06-01, Pleasanton, CA).

*Velasco, J. L., J. M. Garcia-Regana, F. Castejon, K. Allmaier, A. Cappa, W. Kernbichler, N. B. Marushchenko and M. Tereshchenko:* Electron Bernstein Driven and Bootstrap Current Estimations in the TJ-II Stellarator. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Vianello, N., M. Spolaore, E. Martines, M. Agostini, R. Cavazzana, P. Scarin, M. Zuin, V. Naulin, J. J. Rasmussen, R. Schrittwieser, C. Ionita, H. W. Müller, V. Rohde, I. Furno and C. Telier:* Current filaments in magnetized plasmas. (52<sup>nd</sup> Annual Meeting of the APS Division of Plasma Physics, 2010-11-08 to 2010-11-12, Chicago, IL).

*Vierle, T., R. Dux, M. Rott and B. Streibl:* PEEK-insulated conductors of fast in-vessel saddle coils for ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Viezzar, E., T. Pütterich, R. Dux, B. Geiger, A. Kallenbach, R. McDermott, D. Wünderlich and ASDEX Upgrade Team:* Investigation of passive edge emission at ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Vilbrandt, R. and W7-X Team:* Quality Assurance during assembly of Wendelstein 7-X. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Vogel, F., R. Friedl, U. Fantz and P. Starke:* Vergleich der Strahlungscharakteristik von Niederdruck-Bogenentladungen mit Stickstoff-Edelgasmischungen. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Vollmer, A., M. Köppen, H. Löchel, T.-V. Phan, J. Riesch and Ch. Linsmeier:* Surface chemistry at first wall of future fusion reactor. (27<sup>th</sup> European Conference on Surface Science, 2010-08-29 to 2010-09-03, Groningen).

*Von Stechow, A., O. Grulke and T. Klinger:* Experimentelle Untersuchungen zur Plasmadynamik am magnetischen Nullpunkt. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-13, Hannover).

*Von Toussaint, U.:* Plasma-Wall Interactions: Implications for ITER and beyond. (Institutsseminar, 2010-05-20, Technische Universität Graz).

*Von Toussaint, U.:* Status of MD modelling approaches of plasma-wall interaction. (2<sup>nd</sup> Sino-German Workshop on Plasma-Wall-Interactions in Fusion Devices, 2010-12-06 to 2010-12-10, Garching).

*Von Toussaint, U. and S. Gori:* Digital Particle Image Velocimetry Using Splines in Tension. (30<sup>th</sup> International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering (MaxEnt 2010), 2010-07-04 to 2010-07-09, Chamonix).

*Von Toussaint, U., T. Schwarz-Selinger, M. Mayer and S. Gori:* Experimental Design: Optimizing IBA depth profiling.

(Workshop on Ion Beam Physics, 2010-03-29 to 2010-03-31, Dresden-Rossendorf).

*Wagner, D., J. Stober, F. Letuerer, F. Monaco, M. München, M. Reich, D. Schmid-Lorch, H. Schütz, H. Zohm, M. Thumm, T. Scherer, A. Meier, G. Gantenbein, J. Flamm, W. Kasperek, H. Höhnle, C. Lechte, A. G. Litvak, G. G. Denisov, A. Chirkov, L. G. Popov, V. O. Nichiporenko, V. E. Myasnikov, E. M. Tai, E. A. Solyanova and S. A. Malygin:* Status of the Multi-frequency ECRH system at ASDEX Upgrade. (Workshop on RF Heating Technology of Fusion Plasmas, 2010-09-13 to 2010-09-15, Como).

*Wagner, D., J. Stober, F. Leuterer, F. Monaco, M. München, D. Schmid-Lorch, H. Schütz, H. Zohm, M. Thumm, R. Heidinger, A. Meier, G. Gantenbein, J. Flamm, W. Kasperek, H. Höhnle, C. Lechte, A. G. Litvak, G. G. Denisov, A. Chirkov, L. G. Popov, V. O. Nichiporenko, V. E. Myasnikov, E. M. Tai, E. A. Solyanova and S. A. Malygin:* Multi-Frequency ECRH System at ASDEX Upgrade. (35<sup>th</sup> International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2010), 2010-09-05 to 2010-09-10, Rome).

*Wagner, F.:* Beiträge zur Energiedebatte – Einführung in die Fusion. (50. Assistententagung “Öffentliches Recht”, 2010-02-24, Greifswald).

*Wagner, F.:* H-mode physics and relevance. (Colloquium of the University of Wisconsin, 2010-03-05, Madison, WI).

*Wagner, F.:* Large-Scale Research Infrastructure – Summary of the “Meeting on the Large Facilities Technology Network of the European Physical Society”. (26<sup>th</sup> Symposium on Fusion Technology (SOFT), 2010-09-27 to 2010-10-01, Porto).

*Wagner, F.:* Magnetic Confinement by Stellarators. (Lecture, 2010-11-17, University of Paris).

*Wagner, F.:* Physics and Art – is there any connection? (American Centre of Physics, 2010-05-07, College Park, MD).

*Wagner, F.:* The Wendelstein Stellarator Line. (Seminar at the University of Wisconsin, 2010-05-07, Madison, WI).

*Wagner, F., A. Becoulet, R. V. Budny, V. Erckmann, D. Farina, G. Giruzzi, Y. Kamada, A. Kaye, F. Kochl, K. Lackner, N. Marushchenko, M. Murakami, T. Oikawa, V. Parail, J. M. Park, G. Ramponi, O. Sauter, D. Stork, M. Q. Tran, D. Ward, H. Zohm and C. Zucca:* On the heating mix of ITER. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

Wagner, F., ITER Organization, ITER Doestic Agencies and ITER Collaborators and M. Henderson: Optimizing the ITER Heating and Current Drive Mix. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Wegener, L.: Status of Wendelstein 7-X Construction. (13. Symposium Maritime Elektrotechnik, Elektronik und Indromationstechnik, 2010-09-29 to 2010-09-01, Rostock).

Weinzettl, V., R. Panek, M. Hron, J. Stockel, F. Zacek, J. Havlicek, P. Bilkova, D. I. Naydenkova, J. Zajac, R. Dejarnac, J. Horacek, J. Adamek, J. Mlynar, F. Janky, M. Aftanas, P. Bohm, J. Brotankova, D. Sestak, I. Duran, R. Melich, D. Jares, J. Ghosh, G. Anda, G. Veres, A. Szappanos, S. Zoletnik, M. Berta, V. F. Shevchenko, R. Scannell, M. Walsh, H. W. Müller, V. Igochine, A. Silva, M. Manso, R. Gomes, T. Popov, D. Sarychev, V. Kiselov and S. Nanobashvili: Overview of the COMPASS diagnostics. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

Wesley, J. C., P. C. De Vries, N. W. Eidietis, S. M. Flanagan, S. P. Gerhardt, R. S. Granetz, Y. Gribov, T. C. Hender, E. M. Hollmann, A. W. Hyatt, M. F. Johnson, Y. Kawano, M. Lehnen, J. Lister, R. Martin, Y. R. Martin, J. Menard, G. Pautasso, C. Reux, V. Riccardo, S. A. Sabbagh, D. P. Schissel, F. Saint-Laurent, E. J. Strait and M. Sugihara: Disruption, Halo Current and Rapid Shutdown Database Activities for ITER. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

Wethekam, S., H. Zettergren, H. Cederquist, M. Busch, U. Specht, J. Merck, Ch. Linsmeier and H. Winter: Interactions of fullerenes during grazing scattering from surfaces. (18<sup>th</sup> International Workshop on Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).

Wieggers, R. C., D. Coster, H. J. De Blank and W. J. Goedheer: Characterization of Magnum-PSI and Pilot-PSI with the B2.5 Code. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Wiesen, S., M. Wischmeier, M. Groth, W. Fundamenski, S. Brezinsek, V. Naulin and JET EFDA Contributors: Relevance of transport model assumptions for divertor detachment multi-fluid modelling on JET. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Willensdorfer, M., E. Wolfrum, J. Schweinzer, F. Aumayr and ASDEX Upgrade Team: Improved chopping of a lithium beam for plasma edge diagnostic at ASDEX Upgrade. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Wimmer, C., S. Briefi and U. Fantz: Laserabsorptions-spektroskopie zur Quantifizierung von Caesium. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Windisch, T., O. Grulke and T. Klinger: Intermittent plasma transport. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Windisch, T., O. Grulke, T. Klinger and V. Naulin: Spatio-temporal dynamics of coherent turbulent structures in sheared E×B-flows. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

Wischmeier, M., M. Groth, S. Wiesen, A. V. Chankin, D. P. Coster, H. W. Müller, A. Scarabosio and ASDEX Upgrade Team: Assessment of edge modeling in support of ITER. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Wisotzky, M., O. Grulke and T. Klinger: Transiente Driftwellen in VINETA. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Wolf, R. C.: Kernfusion – Die Entwicklung einer neuen Primärenergiequelle. (Ringvorlesungen der Technischen Universität Bergakademie Freiberg, 2010-11-03, Freiberg).

Wolf, R. C.: Wendelstein 7-X: A magnetic confinement concept for the realization of a steady-state fusion plasma. (Graduiertenkolleg “Physik mit neuartigen kohärenten Strahlungsquellen”, 2010-05-18, Institut für Laser-Physik, Universität Hamburg).

Wolfrum, E., B. Wieland, P. Schneider, A. Bueckhart, B. Kurzan, R. Fischer, T. Pütterich and ASDEX Upgrade Team: The latest experimental results for the edge transport barrier in tokamaks. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

Wright, G. M., M. Mayer, K. Ertl, G. de Saint-Aubin and J. Rapp: Deuterium Retention in Pre-irradiated Tungsten Exposed to High-flux Plasma. (19<sup>th</sup> Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 19), 2010-05-24 to 2010-05-28, San Diego, CA).

Wright, G. M., D. G. Whyte, M. Mayer, R. Vila, H. S. Barnard, Z. S. Hartwig, P. W. Stahle, R. M. Sullivan and K. B. Woller: Damage and Analysis: the role of ion accelerators in plasma-surface interaction research. (21<sup>st</sup> International Conference on Application of Accelerators in Research and Industry (CAARI 2010), 2010-08-08 to 2010-08-13, Fort Worth, TX).

*Wunderlich, D., R. Gutser, U. Fantz and NNBI Team:* Transport of charged particles in the magnetic filter field of RF sources for the production of negative hydrogen ions. (20<sup>th</sup> European Conference on the Atomic and Molecular Physics of Ionized Gases (ESCAMPIG), 2010-07-13 to 2010-07-17, Novi Sad).

*Wunderlich, D., R. Gutser, U. Fantz and NNBI Team:* Transport geladener Plasmateilchen in der Randschicht von HF-Quellen zur Produktion negativer Wasserstoffionen. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Wurster, S. and J. H. You:* First results on in-situ micro-3-point-bending tests on W/W components. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

*Xanthopoulos, P., P. Helander, A. Mishchenko, H. E. Mynick, N. Pomphrey, H. Sugama and T.-H. Watanabe:* Gyrokinetic Simulations of Micro-Turbulence in Stellarators: The Effect of 3D Shaping on Transport. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

*Yang, Q. W., X. Q. Ji, Q. Yu, B. B. Feng and HL-2A Team:* First Observation of Persistent Small Magnetic Islands on HL-2A. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Ye, M. Y., V. Bykov, F. Schauer and A. Peacock:* Thermo-mechanical Analysis of the W7-X Divertor. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Yoshimura, Y., S. Kubo, T. Shimoizuma, H. Igami, H. Takahashi, K. Ida, M. Yoshinuma, C. Suzuki, Y. Takeiri, K. Ikeda, S. Sakakibara, K. Tanaka, K. Narihara, K. Nagasaki, T. Mutoh, H. Yamada, N. Marushchenko and Y. Turkin:* Dependence of EC-driven current on the direction of EC-wave beam in LHD. (20<sup>th</sup> International Toki Conference (ITC20) on the Next Twenty Years in Plasma and Fusion Science, 2010-12-07 to 2010-12-10, Ceratopia Toki, Toki-City, Gifu).

*You, J. H.:* Composites and coatings for plasma-facing components of fusion reactors: modelling & metallurgy. (Seminarvortrag Institutskolloquium, 2010-07-27, Karlsruher Institut für Technologie KIT).

*You, J. H.:* Dual scale modeling of composites for fusion reactor applications. (12<sup>th</sup> International Ceramics Congress (CIMTEC), 2010-06-07 to 2010-06-11, Montecatini Terme).

*You, J. H.:* Festkörperphysik. (WS 2009/2010. Praktikum, Universität Ulm).

*You, J. H.:* Mechanics of Materials. (SS 2010. Vorlesung, Universität Ulm).

*You, J. H.:* Nonlinear micromechanics of composites for high-heat-flux components. (Seminarvortrag am Lehrstuhl für Numerische Mechanik, 2010-10-10, Technische Universität München).

*You, J. H.:* Structural mechanics study of plasma-facing components with composite heat sinks & tungsten amorcs. (Seminarvortrag, 2010-05-10, Seoul National University, Nuclear Engineering Department).

*You, J. H.:* Synchrotron X ray experiments for materials science. (Habilitationvortrag, 2010-11-24, Fakultät für Naturwissenschaften, Universität Ulm).

*You, J. H., J. Du, W. Yao and T. Höschen:* Mechanical Testing Campaign for Tungsten, Tungsten Composite & Steel. (2<sup>nd</sup> FEMaS Workshop, 2010-01-13 to 2010-01-15, Athens).

*You, J. H., T. Höschen and G. Pintsuk:* High heat flux fatigue damage behavior of Eurofer97 steel. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Yu, Q. and S. Günter:* Plasma Response to Externally Applied Resonant Magnetic Perturbations. (23<sup>rd</sup> IAEA Fusion Energy Conference, 2010-10-11 to 2010-10-16, Daejeon).

*Zammuto, I., M. Rott, B. Streibl, W. Suttrop, T. Vierle and ASDEX Upgrade Team:* Conceptual design of in vessel mid-plane saddle coils for fast AC operation in ASDEX Upgrade. (26<sup>th</sup> Symposium on Fusion Technology (SOFT 2010), 2010-09-27 to 2010-10-01, Porto).

*Zeijlmans van Emmichoven, P. A., M. H. J. t' Hoen, G. M. Wright, M. Mayer, K. Ertl, A. W. Kleyn and J. Rapp:* Hydrogenic retention in tungsten exposed to high-flux plasmas. (18<sup>th</sup> International Workshop on Inelastic Ion-Surface Collisions (IISC-18), 2010-09-26 to 2010-10-01, Gatlinburg, TN).

*Zgardzinska, B., B. Tyburska and Z. Surowiec:* Studies of radiation defects in tungsten induced by W self-implanted. (39<sup>th</sup> Polish Seminar on Positron Annihilation, 2010-06-20 to 2010-06-25, Kazimierz).

*Zhang, D., R. Burhenn, R. König, L. Giannone, P. A. Grodzki, B. Klein, K. Grosser, M. Hirsch, H.-P. Laqua, J. W. Oosterbeek, K. Ewert and W7-X Team:* Design Criteria of the Bolometer System for Steady-State Operation of the W7-X Stellarator. (18<sup>th</sup> Topical Conference on High-Temperature Plasma Diagnostics (HTPD10), 2010-05-16 to 2010-05-20, Wildwood, NJ).



*Zhang, Y., G. Pautasso, O. Kardaun, G. Tardini, X. D. Zhang and ASDEX Upgrade Team:* Classifying predictor of disruptions in ASDEX Upgrade. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Zivelonghi, A. and J. H. You:* 2D and 3D Stress Fields Analysis Based on Direct Mapping of the Dual-scale Porous Network of Plasma-sprayed Tungsten. (5<sup>th</sup> International Conference on Multiscale Materials Modeling, 2010-10-04 to 2010-10-08, Freiburg).

*Zohm, H.:* Considerations on the size of DEMO. (22<sup>nd</sup> Joint Russian-German Meeting on ECRH and Gyrotrons, 2010-06-29 to 2010-07-05, Nizhny Novgorod).

*Zohm, H.:* Hydrodynamik. (WS 2009/2010. Vorlesung, Ludwig-Maximilians-Universität München).

*Zohm, H.:* ITER und DEMO: Der Weg zur Fusionsenergie. (Greifswalder Kollegforum: ENERGIE. Energietechnologien an der Ostsee: Rückschau und Ausblick, 2010-11-11 to 2010-11-12, Alfried Krupp Wissenschaftskolleg Greifswald).

*Zohm, H.:* The Physics Base for ITER and DEMO. (74. Jahrestagung der DPG und DPG Frühjahrstagung der Fachverbände, 2010-03-15 to 2010-03-19, Bonn).

*Zohm, H.:* Plasma Physics on the Road to ITER. (Physikalisches Kolloquium, 2010-01-22, Bonn).

*Zohm, H.:* Plasma physics – the scientific base for ITER. (DPG AMOP Frühjahrstagung, 2010-03-08 to 2010-03-12, Hannover).

*Zohm, H.:* Tokamaks: equilibrium, stability and transport. (IPP Summer University for Plasma Physics, 2010-09-20 to 2010-09-24, Garching).

*Zohm, H.:* What determines the size of DEMO? (CMFT Seminar, 2010-10-18, Hefei).

*Zohm, H. and ASDEX Upgrade Team:* News from the ASDEX Upgrade Tokamak Programme. (2010-02-03, Princeton, NJ).

*Zohm, H. and ASDEX Upgrade Team:* News from the ASDEX Upgrade Tokamak Programme. (General Atomics, 2010-04-26, San Diego, CA).

*Zohm, H., A. Burckhart, E. Wolfrum and ASDEX Upgrade Team:* A closer look at the ELM cycle. (37<sup>th</sup> EPS Conference on Plasma Physics, 2010-06-21 to 2010-06-25, Dublin).

*Zohm, H. and J. Stober:* Plasmaphysik I. (SS 2010. Vorlesung, Technische Universität München).

*Zonca, F., A. Biancalani, I. Chavdarovski, L. Chen, C. Di Troia and X. Wang:* Kinetic structures of shear Alfvén and acoustic wave spectra in burning plasma. (Joint Varenna-Lausanne International Workshop on Theory of Fusion Plasmas, 2010-08-30 to 2010-09-03, Varenna).

# Teams

## ASDEX Upgrade Team

J. Adamek\*, L. Aho-Mantila\*, S. Äkaslompola\*, C. Angioni, C. V. Atanasiu\*, M. Balden, R. Bauer, K. Behler, E. Belonohy, A. Bergmann, M. Bernert, R. Bilato, V. Bobkov, J. Boom, A. Bottino, F. Braun, M. Brüdgam, A. Buhler, A. Burckhart, A. Chankin, I. Classen, G. Conway, D. P. Coster, P. de Marné, R. D’Inca, R. Drube, R. Dux, T. Eich, N. Endstrasser, K. Engelhardt, B. Esposito\*, E. Fable, S. Fietz, R. Fischer, H. Fünfgelder, J. C. Fuchs, K. Gál\*, M. García Muñoz, B. Geiger, L. Gianonne, C. Giroud, T. Görler, S. da Graca\*, G. Granucci\*, H. Greuner, O. Gruber, A. Gude, S. Günter, G. Haas, A. H. Hakola\*, D. Hangan, T. Hauß, B. Heinemann, A. Herrmann, J. Hobirk, H. Höhnle\*, M. Hölzl, C. Hopf, M. Huart, V. Igochine, C. Ionita\*, S. Jämsä\*, M. Janzer, F. Jenko, A. Kallenbach, S. Kálvin\*, O. Kardaun, C. Käsemann-Wilke, M. Kaufmann, A. Kirk\*, H.-J. Klingshirn, M. Kocan, G. Kocsis\*, C. Konz, R. Koslowski, M. Kraus, K. Krieger, T. Kurki-Suonio\*, B. Kurzan, K. Lackner, P. T. Lang, P. Lauber, M. Laux, F. Leipold\*, F. Leuterer, A. Lohs, N. C. Luhmann, T. Lunt, A. Lyssoivan\*, C. Maggi, H. Maier, K. Mank, M.-E. Manso\*, M. Maraschek, P. Martin\*, M. Mayer, P. J. McCarthy\*, R. McDermott, H. Meister, L. Menchero, F. Meo\*, P. Merkel, R. Merkel, V. Mertens, F. Merz, A. Mlynek, F. Monaco, H. W. Müller, S. Müller, M. Münich, H. Murmann, G. Neu, R. Neu, B. Nold\*, J.-M. Noterdaeme, H. K. Park\*, G. Pautasso, G. Pereverzev, B. Plöckl, Y. Podoba, F. Pompon, E. Poli, K. Polochiy, S. Potzel, M. J. Püschel, T. Pütterich, S. K. Rathgeber, G. Raupp, M. Reich, B. Reiter, T. Ribeiro\*, R. Riedl, V. Rohde, J. Roth, M. Rott, F. Ryter, W. Sandmann, J. Santos\*, P. Sauter, A. Scarabosio, G. Schall, K. Schmid, P. A. Schneider, W. Schneider, R. Schrittwieser\*, J. Schweinzer, B. Scott, M. Sempf, F. Serra\*, M. Sertoli, M. Siccino, A. Sigalov, A. Silva\*, A. C. C. Sips, F. Sommer, E. Speth, A. Stäbler, J. Stober, F. Stobbe, B. Streibl, U. Stroth, E. Strumberger, K. Sugiyama, W. Suttrop, T. Szepesi\*, G. Tardini, C. Tichmann, D. Told, W. Treutterer, Sz. Tulipan, P. Varela\*, N. Vianello\*, J. Vincente\*, T. Vierle, E. Viezzer, C. Vorpahl, D. Wagner, V. Weinzettl\*, A. Weller, R. Wenninger, B. Wieland, C. Wigger, M. Willensdorfer\*, M. Wischmeier, E. Wolfrum, E. Würsching, Q. Yu, I. Zammuto, D. Zasche, T. Zehetbauer, Y. Zhang, M. Zilker, H. Zohm.

## ECRH Team

K. Baumann\*, B. Berndt, P. Brand\*, H. Braune, G. Dammertz\*, V. Erckmann, J. Flamm\*, G. Gantenbein\*, H. Höhnle\*, F. Hollmann, M. Huber\*, H. Hunger\*, S. Illy\*, J. Jin\*, L. Jonitz, W. Kasparek\*, S. Kern\*, H. Kumric\*, M. Kupper\*, R. Lang\*, H. P. Laqua, C. Lechte\*, W. Leonhardt\*, M. Losert\*, D. Mellein\*, G. Michel, S. Miksch\*, F. Müller\*, R. Munk\*, F. Noke, A. Papenfuß\*, B. Piosczyk\*, B. Plum\*,

S. Prets\*, F. Purps, T. Rzesnicki\*, P. Salzmann\*, A. Samartsev\*, K.-H. Schlüter\*, M. Schmid\*, T. Schulz, W. Spiess\*, D. Strauss\*, U. Stroth\*, J. Szczesny\*, M. Thumm\*, P. Uhren, J. Weggen\*, M. Weissgerber, A. Zeitler\*.

## ICRF Team

V. Bobkov, F. Braun, R. D’Inca, H. Faugel, H. Fünfgelder, D. Hancock<sup>++</sup>, D. Hangan<sup>++</sup>, A. Krivska<sup>++</sup>, L. Liu, J.-M. Noterdaeme, A. Onyshchenko\*, Y. Podoba, K. Polozhiy, F. Pompon<sup>+</sup>, I. Stepanov, K. Winkler, E. Würsching, I. Zammuto<sup>++</sup>.

## NBI Team

H. Falter, U. Fantz, P. Franzen, R. Friedl, M. Fröschle, R. Gutser, B. Heinemann, A. Hertrich, D. Holtum, C. Hopf, R. Kairys, M. Kick, W. Kraus, C. Martens, P. McNeely, R. Nocentini, S. Obermayer, R. Riedl, A. Röder, P. Rong, B. Ruf, N. Rust, J. Schäffler, R. Schroeder, L. Schiesko, J. Sielanko\*, E. Speth, A. Stäbler, P. Turba, D. Wunderlich.

## NNBI Team

H. Falter, U. Fantz, P. Franzen, R. Friedl, M. Fröschle, R. Gutser, B. Heinemann, A. Hertrich, D. Holtum, C. Hopf, W. Kraus, C. Martens, P. McNeely, R. Nocentini, S. Obermayer, R. Riedl, A. Röder, B. Ruf, L. Schiesko, E. Speth, A. Stäbler, P. Turba, D. Wunderlich.

## W7-X Team

J. Ahmels, Y. Altenburg, T. Andreeva, F. Ascher, D. Aßmus, M. Balden, K. Bald-Soliman, J. Baldzuhn, M. Banduch, H. Bau, Ch. Baylard\*, D. Beiersdorf, A. Benndorf, N. Berger, A. Bergmann, C. Biedermann, P. Biedunkiewicz, R. Binder, D. Birus, T. Bluhm, R. Blumenthal, J. Boscary, H.-S. Bosch, J. Boscary, B. Böswirth, S. Bozhenkov, A. Braatz, R. Brakel, H.-J. Bramow, T. Bräuer, M. Braun, H. Braune, T. Broszat, B. Brucker, R. Brüderl, R. Burhenn, V. Bykov, C. Caldwell-Nichols\*, J. Cantarini\*, A. Cardella, E. Castanos, D. Chauvin\*, E. Cherginov, M. Czerwinski, J. Dedic, N. Dekorsky, C. Dhard, A. Dinklage, A. Domscheidt, H. Dreier, P. Drewelow, A. Dübner, A. Dudek, H. Dutz, P. v. Eeten, K. Egorov, G. Ehrke, H. Eixenberger, A. Eller, M. Endler, V. Erckmann, H. Faugel, W. Fay, J.-H. Feist, J. Fellingner, F. Fischer, T. Franke, D. Freier, St. Freundt, A. Friedrich, N. Fuchs, F. Füllenbach, H. Fünfgelder, K. Gallowski, S. Geißler, G. Gliege, S. Gojdka, M. Gottschewsky, H. Greuner, H. Greve, H. Grote, D. Grünberg, H. Grunwald, T. Gyulai, M. Haas, D. Hagemeister, M. Hagen, E. Hahnke, N. Hajnal, A. Hansen, H.-J. Hartfuß\*, D. Hartmann, D. Hathiramani, D. Haus, P. Heimann, B. Hein, B. Heinemann, St. Heinrich,

K. Henkelmann, C. Hennig, U. Herbst, F. Herold, R. Herrmann, K. Hertel, D. Hildebrandt, M. Hirsch, A. Hölting, D. Holtum, A. Holtz, R. Holzthüm, A. Hübschmann, F. Hurd, M. Ihrke, N. Jaksic, M. Jakubowski, D. Jassmann, H. Jensen, H. Jenzsch, A. John, L. Jonitz, S. Jung, A. Junge, P. Junghanns, J. Kallmeyer, U. Kamionka, J. Kißlinger, T. Kluck, C. Klug, J. Knauer, F. Koch, R. König, T. Koppe, M. Köppen, P. Kornejev, R. Krampitz, R. Krause, H. Kroiss, J. Krom, U. Krybus, M. Krychowiak, G. Kühner, F. Kunkel, B. Kursinski, B. Kurzan, A. Kus, H. Laqua, H. P. Laqua, M. Laux, H. Lentz, M. Lewerentz, C. Li, S. Lindig, K. Loeckel, A. Lorenz, J. Maier, M. Marquardt, S. Marsen, C. Martens, C. Matern, M. Mayer, P. McNeely, B. Mendelevitch, G. Michel, B. Missal, H. Modrow, St. Mohr, T. Mönnich, A. Müller, E. Müller, I. Müller, J. Müller, K. Müller, M. Müller, S. Müller, H. Murmann, M. Nagel, D. Naujoks, U. Neumann, U. Neuner, M. Nitz, F. Noke, J.-M. Noterdaeme, S. Obermayer, A. Okkenga-Wolf, M. Otte, E. Pasch, A. Peacock, B. Petzold, M. Pietsch, D. Pilopp, S. Pingel, H. Pirsch, F. Pompon, B. Prieß, F. Purps, D. Rademann, T. Rajna, R. Reimer, L. Reinke, S. Renard\*, T. Richert, R. Riedl, H. Riemann, K. Riße, J. Roth, M. Rott, K. Rummel, Th. Rummel, N. Rust, N. Rüter, J. Sachtleben, J. Schacht, F. Schauer, F. Scherwenke, D. Schinkel, R.-C. Schmidt, M. Schneider, T. Schneider, W. Schneider, P. Scholz, M. Schröder, R. Schroeder, U. Schultz, E. Schwarzkopf, V. Schwuchow, Ch. von Sehren, K.-U. Seidler, O. Sellmeier, G. Siegl, B. Sitkowski, M. Smirnov, E. Speth, A. Spring, J. Springer, A. Stäbler, R. Stadler, T. Stange, F. Starke, M. Steffen, M. Stöcker, B. Streibl, J. Svensson, A. Tereshchenko, D. Theuerkauf, S. Thiel, H. Thomsen, H. Tittes, U. v. Toussaint, J. Tretter, P. Turba, P. Uhren, S. Valet, H. Viebke, T. Vierle, R. Vilbrandt, O. Volzke, S. Vorbrugg, A. Vorköper, D. Wagner, L. Wegener, M. Weissgerber, J. Wendorf, U. Wenzel, A. Werner, K.-D. Wiegand, M. Winkler, R. Wolf, Q. Yang, M. Ye, J. Zabojnik, D. Zacharias, G. Zangl, D. Zhang, M. Zilker, K. Zimmermann.

#### W7-X NBI Team

B. Heinemann, D. Holtum, R. Kairys, M. Kick, C. Martens, P. McNeely, S. Obermayer, R. Riedl, P. Rong, N. Rust, R. Schroeder, E. Speth, A. Stäbler, P. Turba.

\* external authors

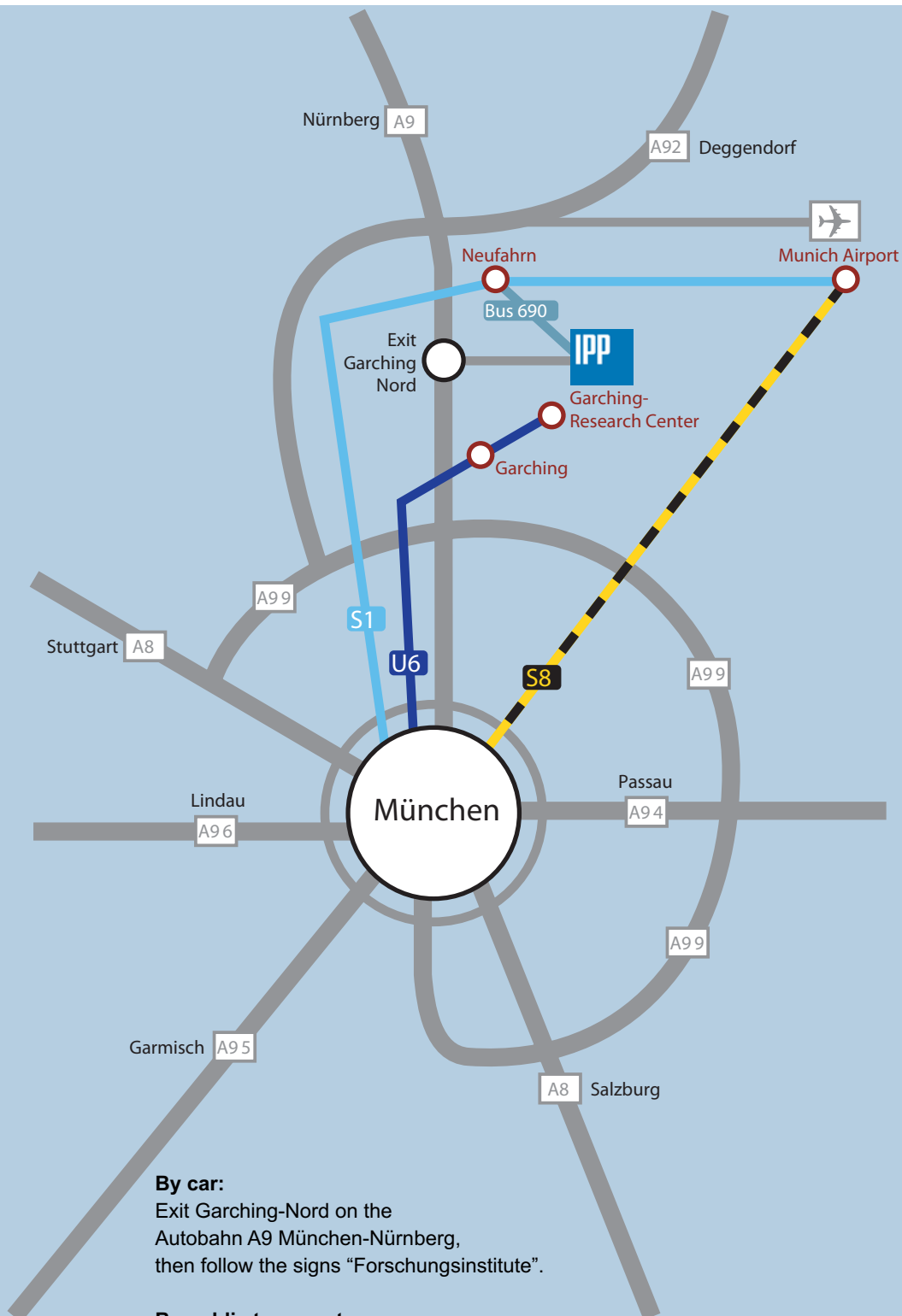
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## Appendix



## How to reach IPP in Garching



## How to reach Greifswald Branch Institute of IPP



### By air and train:

Via Berlin: from Berlin Tegel Airport by bus "JetExpressBus" to Hauptbahnhof (central station), by train to Greifswald.

Via Hamburg: from the airport to main Railway Station, by train to Greifswald main station.

### By bus:

From Greifswald-Railway Station by bus No. 1 to the "Südbahnhof", then change to bus No. 5 to the "Elisenpark" stop.

### By car:

Via Berlin, Neubrandenburg to Greifswald **or** via Hamburg, Lübeck, Stralsund to Greifswald, in Greifswald follow the signs "Max-Planck-Institut".

# IPP in Figures

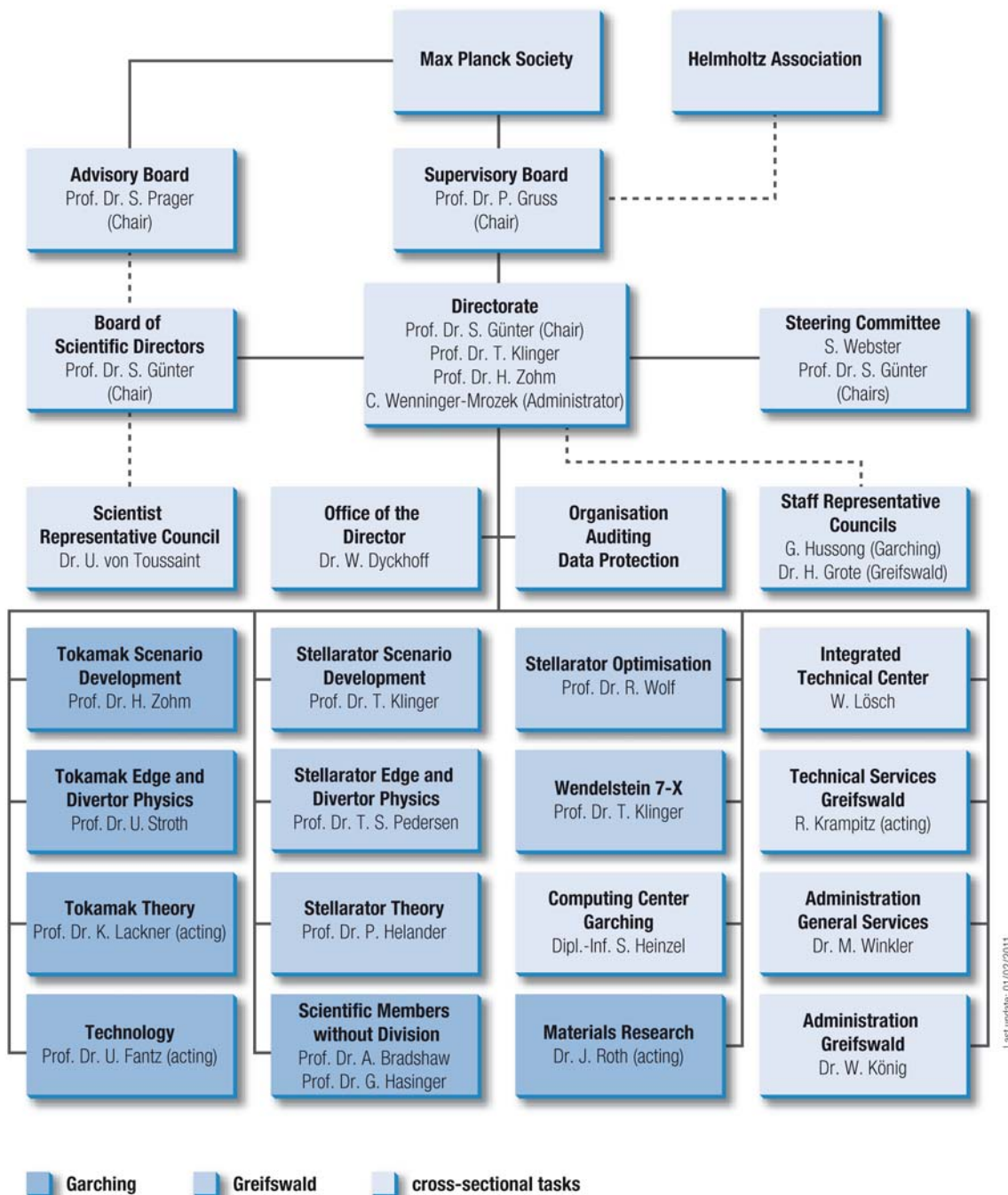
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## Scientific Staff

At the end of the year IPP had a total of 1171 members of staff, 446 of them worked at IPP's Greifswald site. The workforce comprised 296 researchers and scientists, 54 post-graduates and 38 postdocs. In addition, 12 guest researchers used the research infrastructure.

## Organisational Structure





## Imprint

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Max-Planck-Institut für Plasmaphysik (IPP)  
Boltzmannstraße 2, D-85748 Garching bei München  
phone +49 89 3299-01, [info@ipp.mpg.de](mailto:info@ipp.mpg.de)  
[www.ipp.mpg.de](http://www.ipp.mpg.de)

### **Editorial Team**

Julia Sieber  
Andrea Henze

### **Further Information**

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