SCRAPE-OFF LAYER INVESTIGATIONS BY LANGMUIR PROBES IN ASDEX

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Introduction: The scrape-off layer (SOL) of ASDEX in the hardened divertor configuration (DV-II) was investigated by two fast moving Langmuir probes. Multiple tip heads have been used in several arrangements: standard triple probe for n_e, T_e, Φ_{fl} profiles and/or time evolution, a configuration to measure fluctuations and Mach number probe. The main chamber probe scans 10 cm in radial direction in the equatorial plane. For the divertor probe, a tilt mechanism permits scanning in both radial and poloidal directions. Thus the recycling region close to the divertor plate can be investigated in two dimensions. The two probes are nearly at the same toroidal position on top of each other and can be correlated along field lines by adjusting q(a), typically around $q \approx 3$. The experimental set-up is shown in fig.1.

Experimental results: The SOL plasma parameters have been proved to be strong functions not only of main plasma parameters, ($\overline{n}_e$, plasma current, toroidal field) but also of wall conditions, instantaneous and time integrated gas puff, pumping and confinement regime /1,2/. In an attempt to make detailed comparison between midplane and divertor probe data as well as between probe and other SOL diagnostics (Thomson scattering, lithium beam, microwave interferometry, infrared thermography), simultaneous measurements have been done. A set of typical radial profiles from Langmuir probes in midplane and divertor are shown in fig.2. The profiles display the same qualitative characteristics as in the old , uncooled divertor configuration (DV-I) /1,3,4/: clear profile maxima in the divertor just outside the separatrix, roughly exponential decay close to the separatrix, followed by a plateau type shoulder a few cm outside with high, radially increasing, low frequency fluctuations. The shoulders are narrower now everywhere, as are the divertor slits.

The radial range of midplane profiles was extended further inward than previously /5,6/, in a few cases beyond the nominal separatrix /6/.The electron temperature and density profiles obtained in midplane agree with those inferred from laser scattering and lithium beam measurements till a "turning point" located approx. 1-1.5 cm outside from the nominal separatrix. Its exact nature is not yet clear, but the electron temperature reaches about 40 eV there and the triple probe approaches its limit. Strong heating and even melting of the tips was sometimes also observed in this high power region, despite the short residence time there (10-20 ms).Extrapolating the exponential part to the nominal separatrix radius, we regain the values of T_{es} and n_{es} of the laser and lithium beam within ±25 percent. As discussed below, the true separatrix position is very likely about 1 cm outside the nominal one, requiring a downward adjustment of the separatrix plasma parameters.

Apart from the global similarity /1,3,4/ there are also clear differences from the old divertor: The relation of peak electron temperature and density in the divertor to the average line density $\bar{n}_e$ in the main chamber deviates from the previous relation for $\bar{n}_e > 3*10^{19}$ m^{-3}, with $T_{e,new} > T_{e,old}$ and $n_{e,new} < n_{e,old}$. Also the positively charged region around the separatrix is maintained to a higher n_e than previously /4/. These differences are marked during density plateau phases (low gas puff rate) and strongly diminished during density ramp up (high gas puff). They are correlated with changes in the mid plane separatrix density and are attributed to different confinement regimes (SOC, IOC /2/).

The new 3 mm microwave interferometer installed in the upper outer divertor permits an independent check on the probe density data.Good agreement was obtained over the entire range of divertor densities, when the geometric probe area was extended by the local ion Larmor radius (similar to /7/).

Due to the thermal charcteristics of the copper target plates /8/, comparison of probe data with thermography is possible in the new divertor only with auxilliary heating. In the few ICRH and NI heated discharges good agreement both in absolute value and width of the power deposition is found. The glancing incidence of the magnetic field lines on the target plates (now about 3 degrees), however, introduces an uncertainty.

Profiles taken for similar shots but different toroidal magnetic field direction and plasma current (thus indicative for the up/down asymmetry) reveal some pecularities (fig.3): With reversed polarity the "negative dip" /4/ is very strong and shifted inside away from the plasma profile maxima. Also the peaks of ion saturation current and temperature profiles are less closely in this case. As was pointed out in /4/, we believe the negative dip (produced by hot electrons leaving the plasma immediately at the boundary between open and closed field lines) represents the accurate, local separatrix position, which may differ by several millimeters or more from the magnetically determined one. The difference between the two profiles in fig.3 therefore seems to be relevant. Such a deviation is theoretically expected e.g. from the E X B drift (E being the poloidal presheath field), yielding typically a poloidal ion gyroradius, which is in fact several millimeters for ASDEX edge parameters.

Identification of the potential dip with the separatrix implies that the power deposition profile on the target plates is always situated in the expected part of the SOL, i.e. where field lines are connected to the main chamber.

Comparison with numerical simulations: The Langmuir probe results of fig.2 were compared with numerical simulations using a simplified version of the 2D multifluid edge code of B.Braams /9/, together with a quite realistic numerical neutral gas model. Starting with experimental values for ion and electron power and particle input into the scrape-off layer, the radial transport coefficients, the divertor recycling and the impurity radiation were varied. A reasonable fit is obtained with $D \approx 1 m^2/s$ and $\chi \approx 1.5 m^2/s$ in the steep part near the separatrix, corresponding roughly to Bohm diffusion (see fig.4 and points in fig.2). The plateau region 2 cm outside, however, could be fitted only by multiplying the coefficients by at least a factor of three, yielding numbers definitely above the local Bohm value. This tendency correlates with the fact that the fluctuation spectrum changes qualitatively in this region /10/. The reason for the high absolute transport coefficients is not clear, but might be connected with the plasma parameters at the target plate and the electric sheath there.

The connection of the two sets of profiles of fig.2 along field lines assuming approx. electron pressure constancy according to the numerical simulation (see pressure profiles of fig.2) leads to the location of the separatrix in the midplane at 1-1.5 cm outside of the nominal position. The same deviation was inferred from the study of soft x-rays produced by suprathermal electrons hitting the Langmuir probe shield /11/.

As in earlier simulations with a 1D code coupled to the DEGAS neutral Monte Carlo code /12/, classical heat conduction along field lines with only a moderate flux limitation must be assumed, if the corrected separatrix position is taken.

Conclusions: Detailed Langmuir probe measurements in main chamber and divertor give a quite consistent picture of the SOL structure in ASDEX. The results agree reasonably with other edge measurements. Numerical simulations yield Bohm diffusion near the separatrix and even higher values farther out. In addition, The parallel heat flux is best described by classical heat conduction with only a moderate flux limit. Simultaneous fit of midplane and divertor profiles require that the actual separatrix position in midplane is 1-1.5 cm outside the nominal one.

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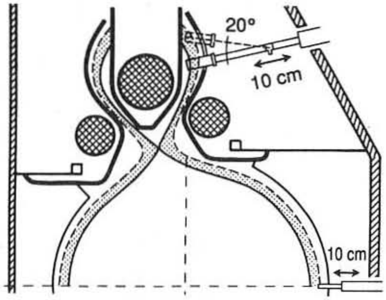


Fig.1. Langmuir probe location in the SOL of ASDEX

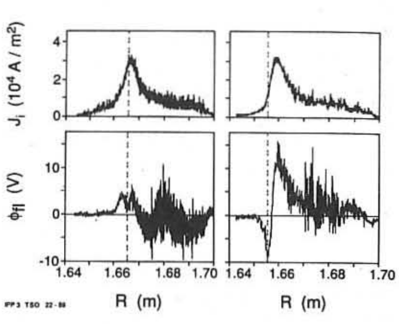
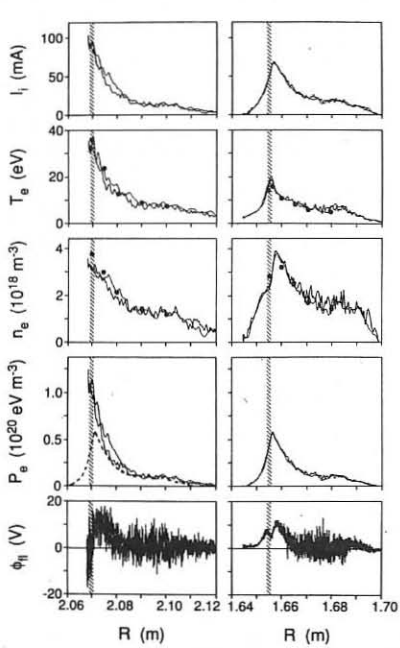


Fig.3. Divertor ion saturation current and floating potential for normal (left) and reversed (right) magnetic field polarity.



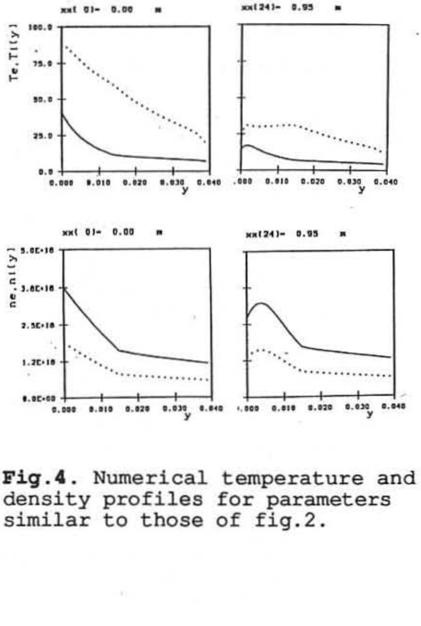


Fig.4. Numerical temperature and density profiles for parameters similar to those of fig.2.

Fig.2. Profiles of plasma parameters in the midplane (left) and divertor (right). $\overline{n}_e = 2.7*10^{19}\ m^{-3}$, $P_{OH} \approx 350$ kW.

THERMAL FLUX ASYMMETRIES IN THE FT EDGE PLASMA

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INTRODUCTION

A magnetized plasma loses energy through two main channels: by radiation diffusing uniformly to the vacuum chamber enclosing the plasma and by means of particles flowing along flux tubes to localized zones of the chamber. A knowledge of the relative amount of the two channels as a function of the plasma parameters is important for formulating models of the scrape-off layer (SOL) and for developing credible designs of the structures necessary to control the plasma (limiters/divertor plates) and improve the plasma performances (launcher structures for auxiliary heating).

The best method for investigating the thermal loads is surface thermography by infrared techniques, which can provide spatially- and temporally-resolved information during a discharge. When, as in FT, the machine compactness rules out this possibility, a set of thermocouples distributed in different zones in the vacuum chamber can be conveniently used to measure the total energy deposited per discharge in the different zones.

In FT we have used this philosophy inserting thermocouples in the vacuum chamber, the limiter and in other structures. Some experimental results have already been presented [1,2], and in this paper we report data obtained from two thermocouples embedded in the protective plates of the RF launcher structure.

EXPERIMENT

In FT the heating of the plasma with lower hybrid radiofrequency has been performed with different launcher structures. The current one, at 8 GHz, is an antenna of 16 waveguides with overall dimensions near the plasma of about 15 cm in the poloidal direction and 2.6 cm in the toroidal direction. The launcher structure is located on the outer equatorial plane at 90° toroidally from the main limiter. On both the electron and ion sides, a stainless steel protective plate has been mounted bearing a thermocouple embedded at 1.6 mm under the surface facing the plasma flow (normal to the toroidal field) and at about 3 mm from the waveguide tip. The radial position of the launcher structure has always been in the shadow of the limiter, which has a radius of 20 cm, and between 20.5 and 21.5 cm from its poloidal center of curvature.

RESULTS

Among the discharges which the guide temperature was monitored for, we only selected the ones not showing abnormal event such as disruptions, runaways, strong MHD activities, MARFEs. Because of the lack of time resolution during a discharge, the average values of the plasma position, density, energy and current were used in looking for any dependence of the thermocouple data on plasma parameters. In this way a total