PERIODIC THOMSON SCATTERING DIAGNOSTIC WITH 16 SPATIAL CHANNELS ON ASDEX

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The Nd-YAG Periodic Scattering System (PSS) was developped in teamwork with IPF of Stuttgart-University. At first a PSS with only one spatial channel was successfully tested in the ASDEX-Tokamak in 1982 /1/. Subsequently an upgraded system with 16 spatial channels was constructed. This new system is capable of measuring Te, Ne-profiles at 17 ms intervals during the entire ASDEX-Tokamak-discharge.
The PSS has been working successfully for the last one and a half years as a standard diagnostic method in the ASDEX-Tokamak. This means, that the measurement is being automatically performed during all plasma-discharges. The Te- and Ne-values are stored in the ASDEX-computer and every user has the possibility to get the Te(r,t), Ne(r,t)-data for his own needs.

The main purpose of the PSS at present time in the ASDEX is the determination of density- and temperature-profiles especailly in additional heating (Fig.3, 4,5) or pellet injection-experiments (Fig.6). With respect to the Single-Pulse-Ruby-Laser-Systems, the PSS has several advantages, the most important ones for Tokamak-physics are given below:

1. No series of reproducable discharges are necessary to evaluate the behavior of Te(r,t) and Ne(r,t).
2. The combination of Nd-YAG-Laser with detectors of high quantum-efficiency together with an optics of high luminosity, leads to a scattering device, where the photon-noise of the signals is sufficiently small at normal Tokamak-densities. The additional plasma-light-noise is also smaller than in Ruby-scattering devices, because plasma light is decreasing from the visible to the IR-region.
3. The large number of scattering and background signals can be used to make a calculation of the error-bars of the measurements. The PSS can reach an accuracy of about 5 % in Te- and 3 % in Ne-measurements in the normal Tokamak-regime.
4. The detectors (Si-Avalanche-Diodes) give an extremely linear response. Thus the PSS can work in a wide range without saturation effects, e.g. at high densities or high levels of plasma light. Magnetic fields do not influence the sensitivity of the diodes.

In some special discharges, the QSS is the only diagnostic method available for the reliable evaluation of Te, Ne-profiles, e.g. in the slide-away-region (Fig. 5) or during rapid density variations.

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MAIN FEATURES OF THE PERIODIC THOMSON SCATTERING SYSTEM (PSS) ON ASDEX

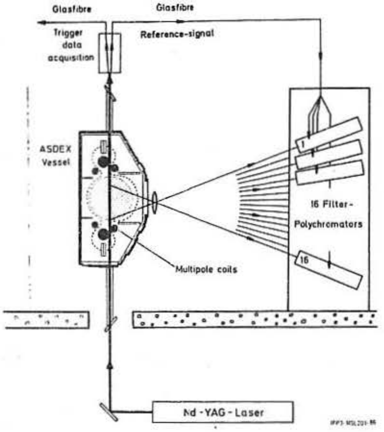

Fig. 1: Schematic of the optical set-up of the QSS.

The PSS simultaneously measures Te,Ne at 16 spatial points distributed over 3/4 of the diameter of the plasma-column (from z = -40 cm at the lower plasma-edge to z = 20 cm). The scattered light of every spatial point is spectrally divided into three parts by a separate polychromator (see Fig. 2). A small fraction of the transmitted laser-light is divided into 48 reference signals in order to calibrate the sensitivity of the detectors during the discharges. The main technical features of the PSS are:

Laser:
Nd-YAG at $\lambda = 1.06\ \mu m$; 400 pulses with 0.8 Joule energy and 40 ns duration each. Repetition frequency 60 Hz.

Detectors:
Si-Avalanche-diodes; quantum efficiency up to 0.9; size 1.7 mm^2; NEP $1.6 \times 10^{-13}\ W/\sqrt{Hz}$.

Range of Te- and Ne-measurements of the ASDEX-PSS:
The PSS is capable of measuring kTe in the range of 150 eV (at the plasma-edge) up to 5 keV (in the plasma-centre) using two matched types of filter polychromators. The lower density-limit is a few x $10^{12}\ cm^{-3}$. This limit can be further improved by averaging signals with respect to time.

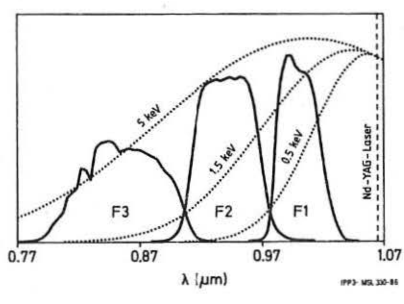

Fig. 2: Spectral sensitivity of the filter-polychromator for the central plasma region. The ratio of the signals F2/F1 is the basis for the calculation of kTe up to 1.5 keV; at higher Te, the ratio F3/(F1 + F2) is used. The system is density-calibrated by Anti-Stokes Raman-scattering in hydrogen /2/.

EVALUATION OF TE(r,t) AND NE(r,t) BY PSS DURING ADDITIONAL HEATING IN ASDEX

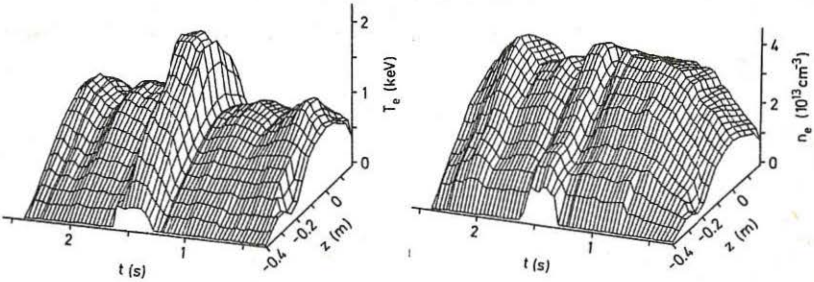

Fig. 3: Three-dimensional plots of Te and Ne of an ASDEX-discharge with Neutral Injection (P_{NI} = 3 MW). The behavior of Ne during Neutral-Injection indicates, that the discharge has changed from L- to H-regime.

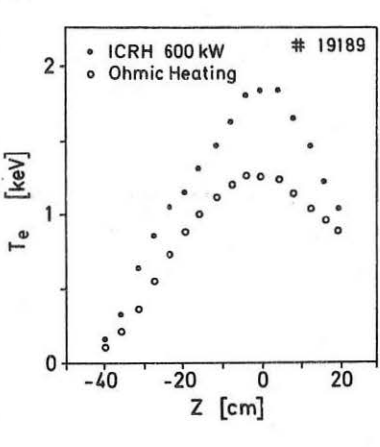

Fig. 4: Comparison of Te-profiles in an ASDEX-discharge during ohmic heating and during ICRH-minority heating (deuterium in hydrogen) with 600 kW RF-power.

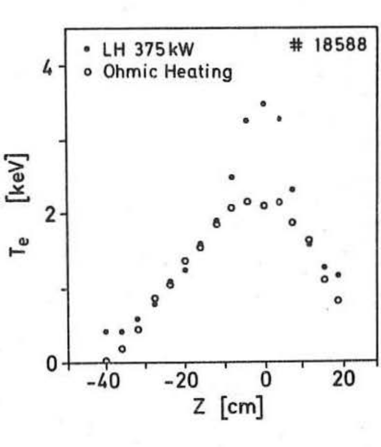

Fig. 5: Te-profile during LH-heating in ASDEX (open circles: ohmic profile before RF is switched on).

EVALUATION OF PLASMA-PARAMETERS DURING PELLET-INJECTION

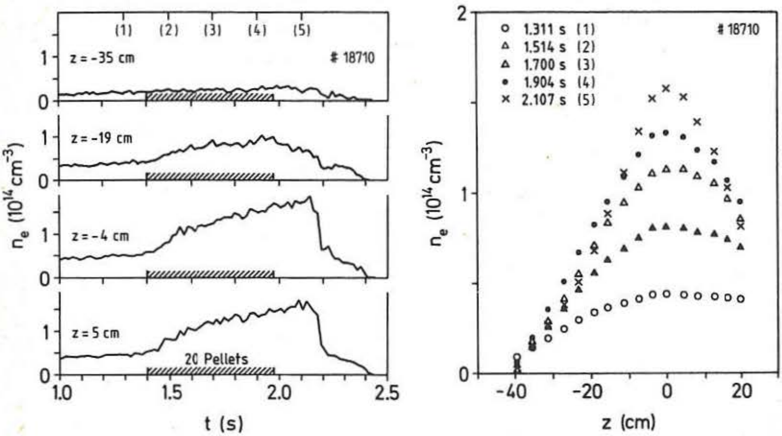

Fig. 6: Density increase of up to 1.5 x 10^{14} cm^{-3} by an injection of a series of pellets using a centrifuge. Time-evolution of Ne at different radii (Fig. 6a) as well as the corresponding Ne-profiles show, that the density raise occurs mainly in the plasma-centre, even when the pellet-injection has been discontinued.

The PSS-results are the basis for further calculations of plasma-parameters, e.g. heat-conductivity of electrons, diffusion-coefficients and so on. Profile measurements, which we have shown in a few examples, are necessary for any plasma-simulation by computer-codes or determination of the energy-balance of a Tokamak plasma. The PSS can deliver at present technical state the wanted parameters in a wide range of discharge-conditions.

References:

/1/ H. Röhr, K.-H. Steuer, G. Schramm, K. Hirsch, H. Salzmann, Nucl. Fus., Vol. 22, No. 8 (1982) 1099-1102.
/2/ H. Röhr, Phys. Letts., Vol. 81 A, No. 8 (1981) 451-53.