Profiles of electron density and temperature observed with the upgraded Thomson scattering system in ASDEX Upgrade

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Introduction

Since the early years of ASDEX Upgrade (AUG) a 16 channel "Vertical Thomson Scattering" (VTS) diagnostic [1] exists, which was used to measure electron density and temperature profiles alternatively in the core plasma with a spatial resolution of 25 mm, or in the edge plasma with a resolution of 2.7 mm. For obtaining complete profiles of electron density and temperature a discharge had to be run twice with the same parameters, but with the VTS system set to the core, or edge position. A second Thomson scattering (TS) system with 10 spatial channels has been installed on the AUG tokamak, to measure radial profiles of electron density and temperature only at the plasma edge. It is designed to have practically the same high spatial resolution as the VTS system, although in a slightly different geometry. Together with the VTS system, which is now used for measuring profiles only of the core plasma, profiles of the core and edge are now measured in a single discharge, thus saving experimental time.

As an application effects of the newly installed magnetic perturbation (MP) coils [3] on the edge temperature profiles are presented.

Setup of the Thomson scattering systems

The new edge TS system is placed closer to the torus than the VTS system, resulting in a modified scattering geometry. The light is imaged directly into the newly designed polychromators of the edge TS system. Thus mirrors in front of the poly-

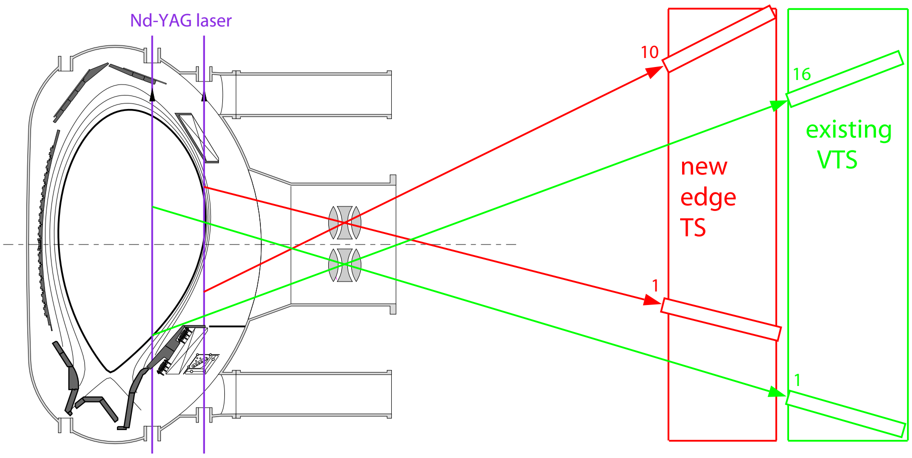

Figure 1: *Edge and core TS systems, poloidal cross sections.*

chromators, which are used for aligning the VTS system, are no longer needed.

The scattering volumes of both the new edge TS, and the VTS system have a length of 25 mm. They are imaged directly through air to the polychromators to maximize the amount of observed scattered light (fig. 1). For the VTS system the poloidal plane is also the plane of observation. The plane of observation for the new edge TS system is inclined by 4 degrees with respect to the poloidal plane (fig. 2). Thus the images of the scattering volumes of both TS systems are separated in the toroidal direction by about 24 cm, so that the entrance slits of the VTS polychromators are not shadowed by the polychromators of the edge system which are located at smaller major radii, than the VTS polychromators. [2] (fig. 2).

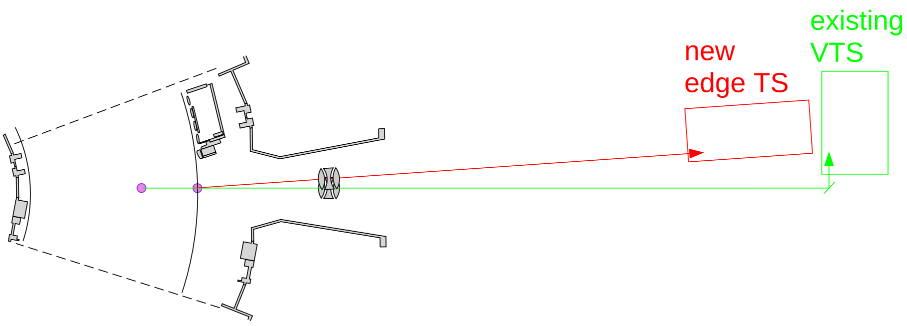

Figure 2: *Edge and core TS systems, toroidal cross sections.*

The scattering volume is imaged into the entrance slit of the polychromator (fig. 3). A relay lens (L5) in the entrance slit then images the main objective lens to the objective lenses (L1 to L4) in front of the detectors (D1 to D4), which give a demagnified image of the entrance slit on the detector.

Silicon avalanche photo-diodes with integrated hybrid amplifier with a rectangular light sensitive area of 1 mm $\times$ 7 mm are used as detectors. Each avalanche photo-diode is temperature stabilized by heating the detector to 29 degrees Celsius to ensure constant absolute and spectral sensitivity: Due to the slight heating of the detector only a very small amount of additional heat is produced in the polychromator. Thus no active cooling of the polychromator is needed.

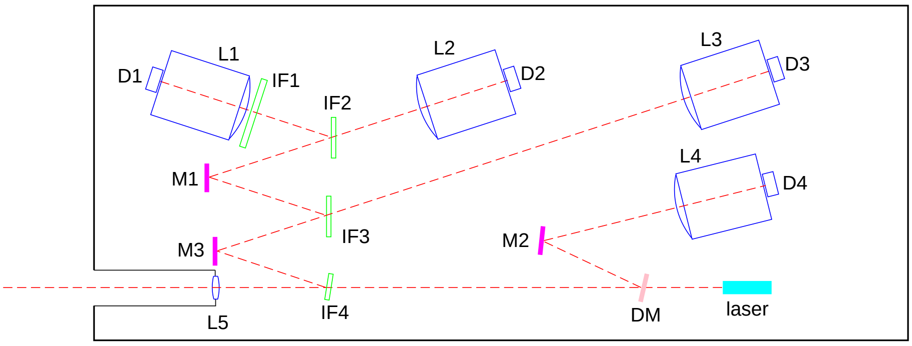

Figure 3: *Schematic of the polychromator of the new edge TS system.*

Four spectral channels are used in the polychromator. The spectral ranges are determined by interference filters (IF1 to IF4 in fig. 3). Metallic mirrors (M1 to M3) are used to fold the optical paths, which makes the polychromator more compact. For alignment purposes a diode laser is coupled onto the optical axis of the polychromator by a dielectric mirror (DM), which transmits the visible light of the alignment laser and reflects the near infrared spectral range passing to the detector.

Examples of measured T_e and n_e profiles

Electron density (n_e) and temperature (T_e) data are determined by a least square fit to the scattering signals. A typical example for electron density and temperature profiles, which are measured by the core and edge TS systems, is shown in fig. 4. For this plot the radial and vertical coordinates of the scattering volumes in real space are mapped to poloidal magnetic flux coordinates, ρ_p.

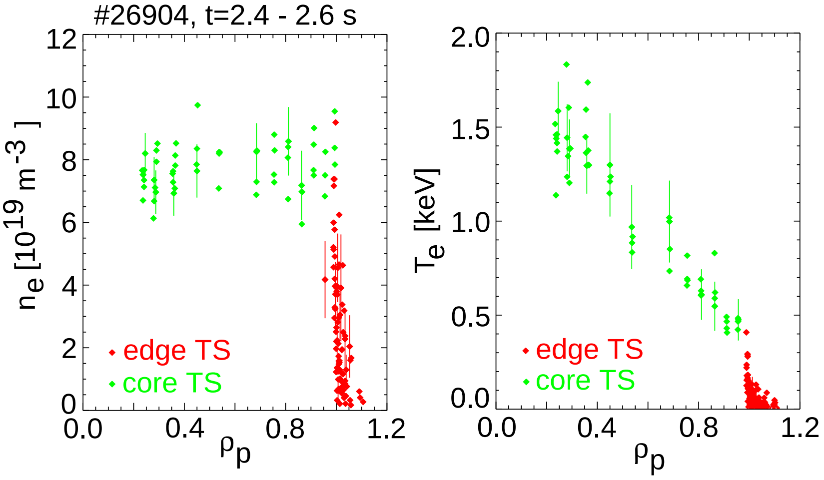

Figure 4: *Typical electron density (n_e) and temperature (T_e) profiles versus the poloidal magnetic flux coordinate ρ_P, measured by the core and the new edge TS systems.*

Shift of the edge T_e profile with MP field

In the ASDEX Upgrade torus eight saddle coils are now installed on the low field side. Four coils each are mounted above and below the mid-plane and are equally distributed in the toroidal direction (see fig. 5). The non-axisymmetric magnetic fields generated by these magnetic perturbation (MP) coils were successfully used to mitigate edge localized modes (ELMs) [3]. Usually an axisymmetric magnetic equilibrium is used to map the data of a profile diagnostic from real space coordinates to magnetic flux coordinates. With the MP coils switched on, three dimensional magnetic equilibria must be used: For shot #26910, where the MP coils generated a MP field with n=2 mode number, odd

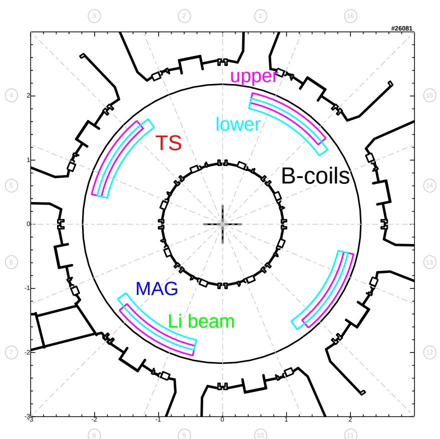

Figure 5: *MP coils in the toroidal cross section.*

parity and toroidal phase 90 deg, the magnetic structure of the combination of the two dimensional magnetic equilibrium and the magnetic perturbation were calculated by a field line tracing code [4]. It is found that the radial position of the separatrix on the low field side varies sinusoidally between the MP coils, with an amplitude of around 5 mm. The effect of the radial shift on the electron density profile at the plasma edge is shown in [4, 5]. Here the radial shift of the electron temperature profile is demonstrated in figure 6:

The two profiles where taken when the MP coils were switched off, and then shortly after they were switched on. Time points around ELMs were cut out. With MP coils switched on the T_e profile is shifted further inwards by about $\Delta\rho_p = 0.02$, when using the standard axisymmetric equilibrium. This corresponds to a radial shift of 1 cm in real space, which is twice as large as expected from the field line excursions due to the MP coils. On the other hand no shift of the Lithium beam profiles in real space is observed [5]. A possible explanation for this is that the position control of the plasma uses magnetic pick-up coils, which are in a sector near to the Lithium beam diagnostic, thus compensating the shift of the plasma in this sector. In the sector where the TS diagnostic is located twice the radial shift would then be found.

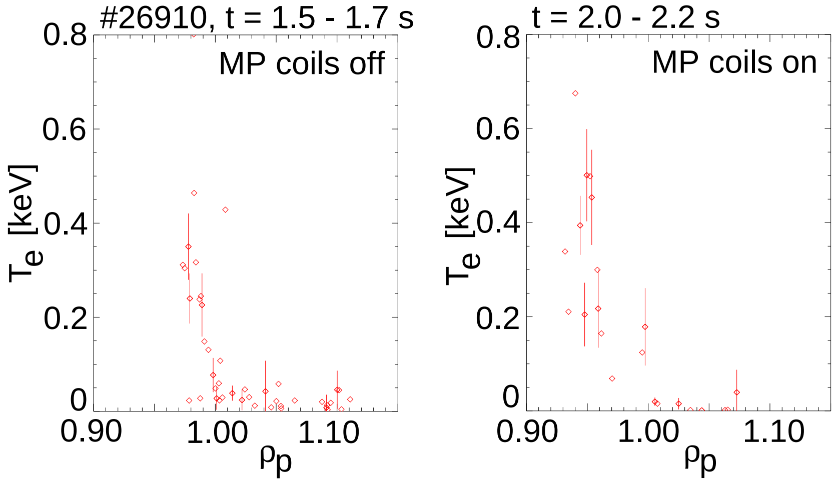

Figure 6: *Radial shift of the edge T_e profile when switching the MP coils on.*

References

[1] H. Murmann *et al.* Rev. Sci. Instrum. **63**, 4941 (1992)

[2] B. Kurzan *et al.* to be submitted to Rev. Sci. Instrum.

[3] W. Suttrop *et al.*, Phys. Rev. Lett. **106**, 225004 (2011) and contribution I2.109 at this conference

[4] Ch. Fuchs *et al.*, contribution P1.090 at this conference

[5] R. Fischer *et al.*, contribution P1.072 at this conference