

Electron density and temperature structures during edge localized modes in the edge plasma of ASDEX Upgrade

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Introduction

Past investigations of electron density and temperature (n_e , T_e) structures of type I edge localized modes (ELMs) [1] were hampered by the low frequency of hitting an ELM with the lasers of the Thomson scattering diagnostic, because the duration of an ELM was only about 1 ms. The ELMs in the discharges presented here, have a duration of up to 7 ms, and are hit by the lasers much more frequently. A zoo of 2D electron density and temperature structures is observed now during the ELM. Additionally indications for high temperature, low density filaments are found when a limiter is introduced in the scrape-off layer (SOL).

Setup of edge TS system and 2D snapshots of electron density and temperature

The edge TS system [2] is equipped with 6 lasers with a repetition rate of 20 Hz each. The scattering volumes of length 25 mm in the vertical (z) direction and diameter 1.5 mm of the 6 lasers and 11 spatial channels form a 6×11 (R , z) matrix in the plasma. When the 6 lasers are fired within $2.5 \mu\text{s}$ in burst mode operation, 2D snapshots of the electron density and temperature are obtained. The position of the separatrix is determined by fitting a 1.5D heat transport model [3] to an ensemble of 6 electron temperature profiles mapped by a single magnetic equilibrium to the outer mid-plane. The obtained separatrix position is now more accurate (± 1 mm), than the value obtained from magnetic equilibrium reconstruction (± 5 mm). For obtaining relative electron density and temperature structures Δn_e , ΔT_e the fitted functions (1.5D heat transport model for T_e and a modified hyperbolic tangent function for n_e) are subtracted from the T_e , n_e values. The significance of the correlations in Δn_e , ΔT_e structures, is given by the covariance $\Delta n_e \Delta T_e / (\sigma n_e \sigma T_e)$, with σn_e , σT_e as the errors of measurement of n_e , T_e . In the 2D snapshots flux surfaces of the magnetic equilibrium are overlaid: the position of the separatrix, is indicated in blue, and the positions of the first wall contacts of the flux surfaces on the high and low field side are marked in green and red respectively.

Discharge parameters

The investigated discharges are hydrogen plasmas with hydrogen neutral beam injection and toroidal magnetic field $B_t = -2.5$ T: For the discharge #31721 the plasma parameters are $\bar{n}_e = 5 \times 10^{19} \text{m}^{-3}$, $I_p = 0.8$ MA, $P_{NBI} = 3.5$ MW, $P_{ECRH} = 2-3$ MW, and for the discharges #31726/7,

$\bar{n}_e=7\times 10^{19}\text{m}^{-3}$, $I_p=1.0\text{MA}$, $P_{NBI}=5.4\text{MW}$, $P_{ECRH}=2.1\text{MW}$.

Electron density and temperature structures during and in-between ELMs

During the ELM a non-zero halo current (signal $I_{polsola}$) flows between the inner and outer divertor. It is used to define the beginning and end of an ELM. The according time points are indicated by red and green vertical line in the signal traces of $I_{polsola}$ in fig. 1. The D_α -radiation in the divertor usually shows a peak before the rise of the poloidal halo current and is low during the ELM (see fig. 1). The electron density and temperature structures observed during the ELM, are: A hole in both the electron density, and temperature exists at the same position inside the separatrix (fig. 1a). Additionally to the first case also an electron temperature blob outside the separatrix is correlated with a hole in the electron density (fig. 1b). A density blob at the separatrix and a density hole in the SOL can be both anti-correlated with the electron temperature (fig. 1c). A hole in the electron temperature can exist inside the separatrix, which is not correlated with a corresponding structure in the electron density (fig. 1d). In inter-ELM phases, with peaking D_α radiation in the divertor, the observed structures are: At the separatrix small scale structures with higher quasi-mode number are found, where the blobs and holes in the electron density and temperature are in sync (fig. 1e). Some cases exist, where anti-correlated blobs and holes in electron density, and temperature exist over a radial distance of about 12 cm (fig. 1f).

Hot filaments in the far SOL at and behind the limiter

A limiter is introduced at a position in the SOL, where the open flux surfaces do not connect to the divertor plates, but to wall elements outside the divertor. Here the flux surfaces connect to the middle of the inner heat shield and the lower passive stabilizing loop. Local halo current measurements indicate that during the ELM plasma is transported into the limiter shadow. Usually a background plasma with electron density $n_e \approx 3\times 10^{18}\text{m}^{-3}$ and temperature $T_e \approx (30\pm 18)\text{eV}$ is observed here (fig. 2a). Sometimes hot filamentary structures with electron density $n_e \approx 3\times 10^{18}\text{m}^{-3}$ and temperature $T_e \approx (100\pm 60)\text{eV}$ are observed in the limiter shadow (fig. 2b). Note that the relative error of measurement of the electron temperature is $\sigma T_e/T_e = 60\%$ for both the background plasma and the hot filament. The relative error scales with the electron density, which is about the same for both cases.

When the whole SOL connects to the divertor (discharge #31721), hot filaments can also be observed. They are further away from the separatrix near the flux surfaces, which connect to the lower PSL and the lower part of the inner heat shield.

Summary and Discussion

The 2D structures of electron density and temperature observed during an ELM suggest,

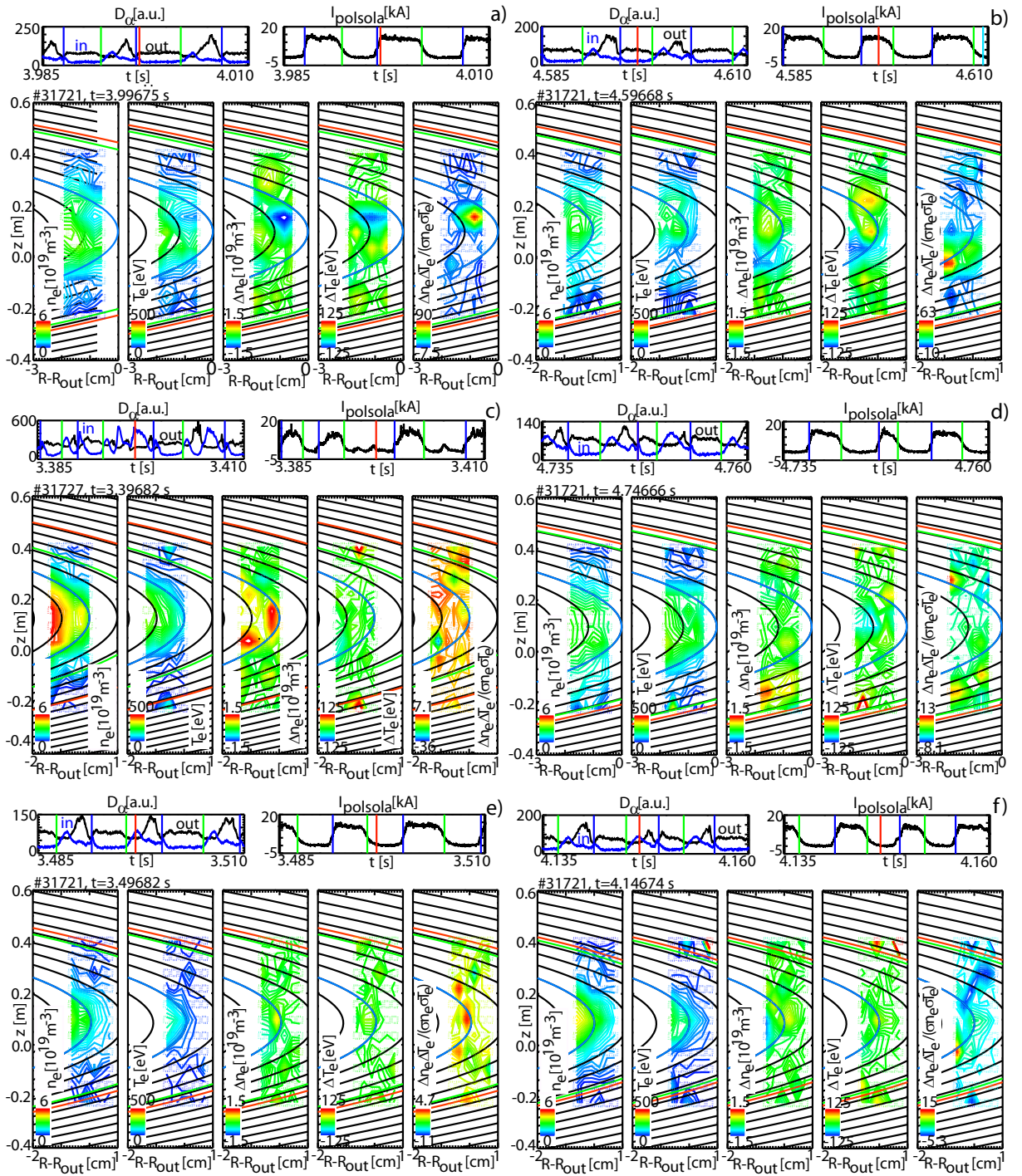


Figure 1: Electron density and temperature structures during ELMs, with non-zero $I_{polsola}$, a) - d), and in-between ELMs, with peaking D_α , e) - f). For details see the main text.

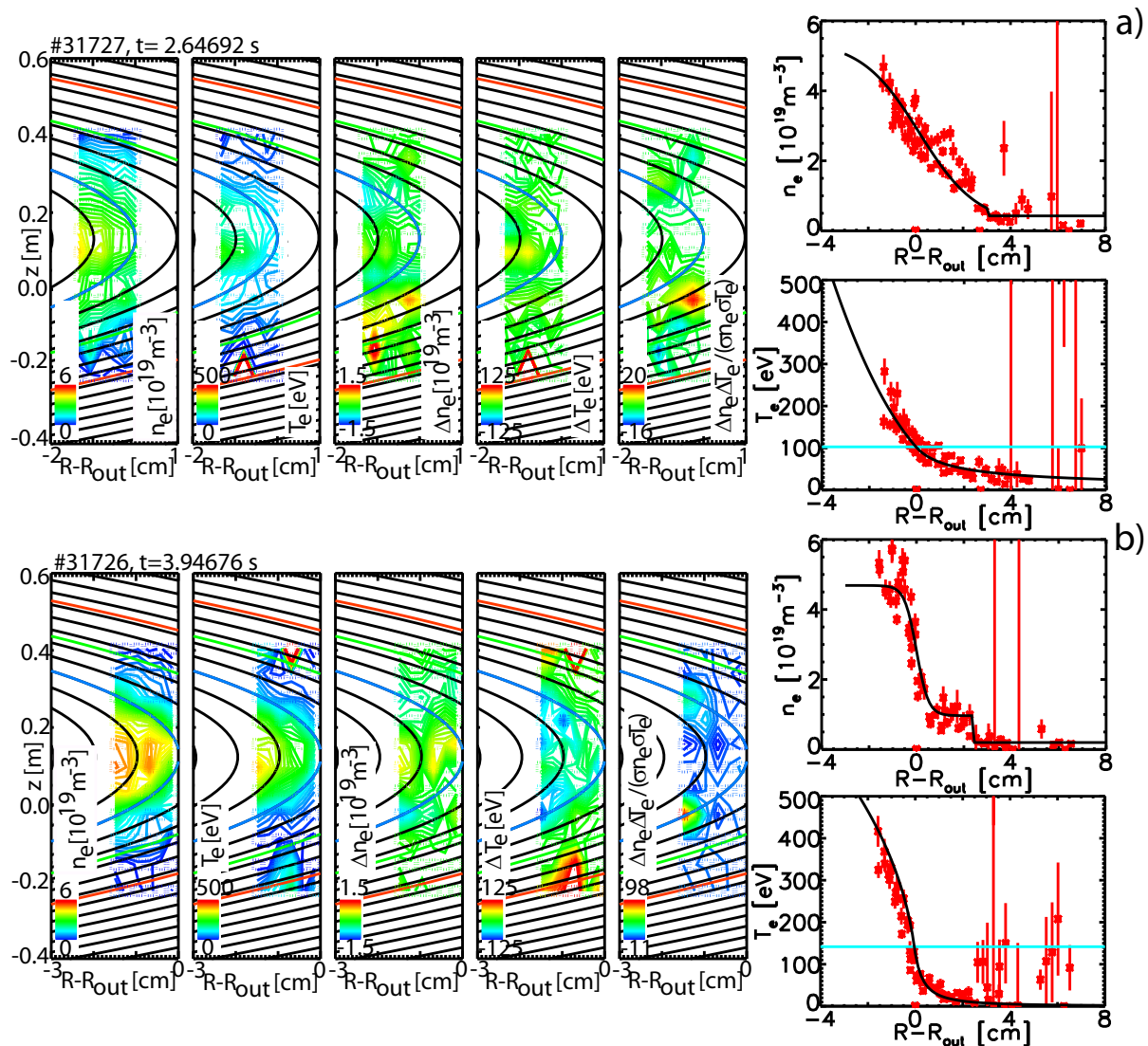


Figure 2: Observed profiles and structures in the far SOL: cold background profile (a), and hot filaments at and behind the limiter (b).

that the ELM is not only made up of electron density and temperature blobs in sync, which transport particles and heat. There exist also anti-correlated and uncorrelated electron density and temperature structures. The physics behind the high temperature and low density filaments close and behind the limiter in the SOL is not yet understood.

References

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- [3] V. Dose *et al.*, Nucl. Fus. **41**, 1671 (2001)