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CHARACTERIZATION OF ELM PHENOMENA BY MEANS OF VISIBLE IMAGING IN THE WENDELSTEIN 7-AS STELLARATOR

H. Thomsen, R. König, M. Endler, T. Klinger and the W7-AS Team

Max-Planck-Institut für Plasmaphysik, EURATOM Association, Greifswald, Germany

1. Introduction

Edge Localized Modes (ELMs) are burst-events which transport energy and particles from the confinement region into the plasma edge. They are commonly observed in the plasma edge of tokamaks [1]. Depending on rotational transform and density threshold, ELMy H-modes are found in the Wendelstein 7-AS stellarator (W7-AS) [2,3]. The recent installation of an island divertor in W7-AS [4] led to the discovery of another high-confinement regime with very high densities and low impurity confinement (High Density H-mode, HDH-regime [5]). The access phase to the HDH-regime is accompanied by ELM phenomena, whereas the HDH-regime is ELM-free. In this paper we show first results from measurements with a fast framing CCD-camera (Specifications: 8 bit resolution, 13.5 kHz at 128x128 pixels and 40.5 kHz at 64x64 pixels), which observes the poloidal-toroidal strike pattern at a divertor target in the light of H_α. The main interest is the spatio-temporal dynamics of ELMs at their characteristic time-scale.

2. Setup on Wendelstein 7-AS

Fig. 1 shows the view of the camera. The H_α light emission is limited to a thin zone of colder plasma directly above the divertor target. This zone is only a few mm thick. Therefore, the observation of the target through the bulk plasma delivers the local H_α light intensity in the proximity of the target. In this paper we concentrate on discharge #55595, which exhibits ELM-behavior in the initial phase before the HDH-mode is established at ≈ 0.28 s (cf. Fig. 2). A thorough analysis of this discharge with a detailed discussion of the HDH-mode is given in Ref. [6]. The fast camera was operated at a frame rate of 13.5 kHz during this discharge.

3. Results

In Fig. 3 the maximum intensity of each frame is plotted versus time. Qualitatively, this time series compares well to the H_α signal from a photo diode shown in Fig. 2. The small differences result from the different lines of sight. Fig. 4 shows the time evolution of the strike pattern for the ELM in the range f. The pattern itself remains unchanged during an ELM, only the intensity varies. This is found for all analyzed ELM events so far. As a next step the poloidal profiles for one divertor tile (tile # 11, cf. Fig. 1) are extracted from the frames. The widths of the poloidal profiles (FWHM) do not show a significant change during an ELM (change below 10 %). A general feature during an ELM seems to be a poloidal movement of the maximum light intensity in the inward direction (cf. Fig.

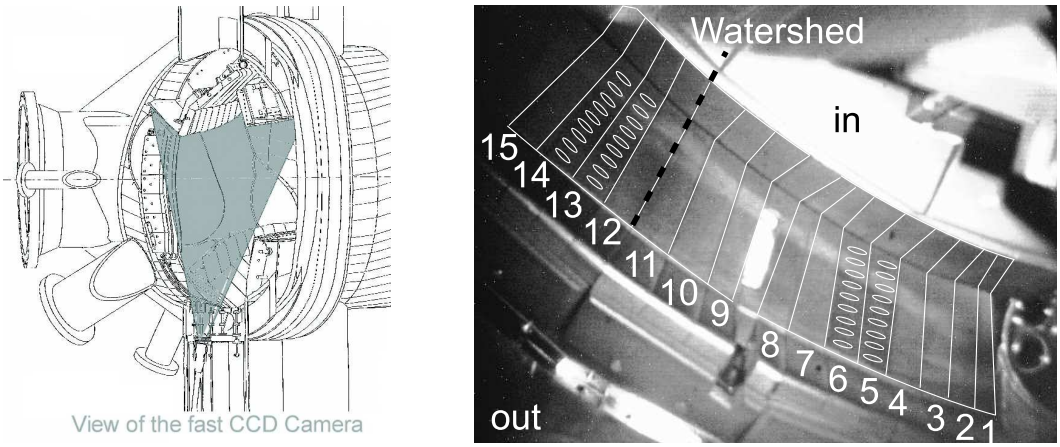

Figure 1: Left: View into module 2 of W7-AS along the torus axis. The fast framing camera (bottom) is observing the top divertor. Right: The actual observation area. The divertor tiles are numbered. The white circles indicate the positions of the Langmuir probe tips.

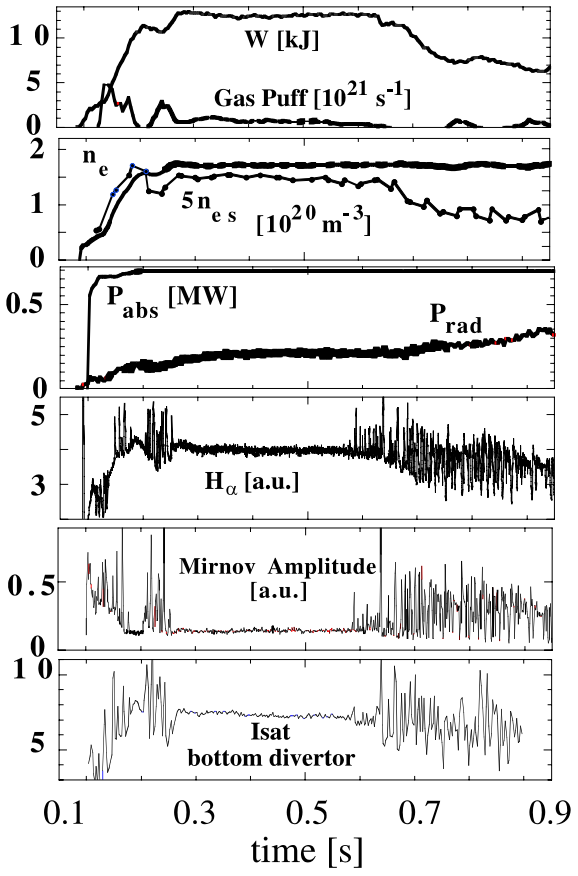

Figure 2: Plasma parameters for W7-AS discharge #55595. During the HDH-phase ($0.28 - 0.62\,\mathrm{s}$) no ELM activity is observable, but the entrance and the exit of the discharge shows ELMs on Mirnov, Langmuir probe (Isat) and H_α signals. Compare Ref. [6]

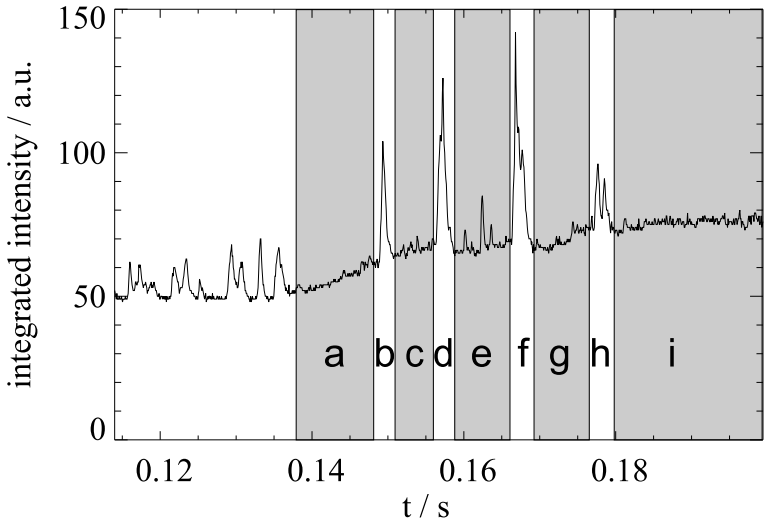

Figure 3: Maximum intensity of each frame versus time (frame rate 13.5 kHz). The large ELM events (ranges denoted by letters b, d, f and h) and the intermediate quiescent ranges (denoted by letters a, c, e, g and i) are easily distinguished. A fine structure during an ELM is observable in the time series.

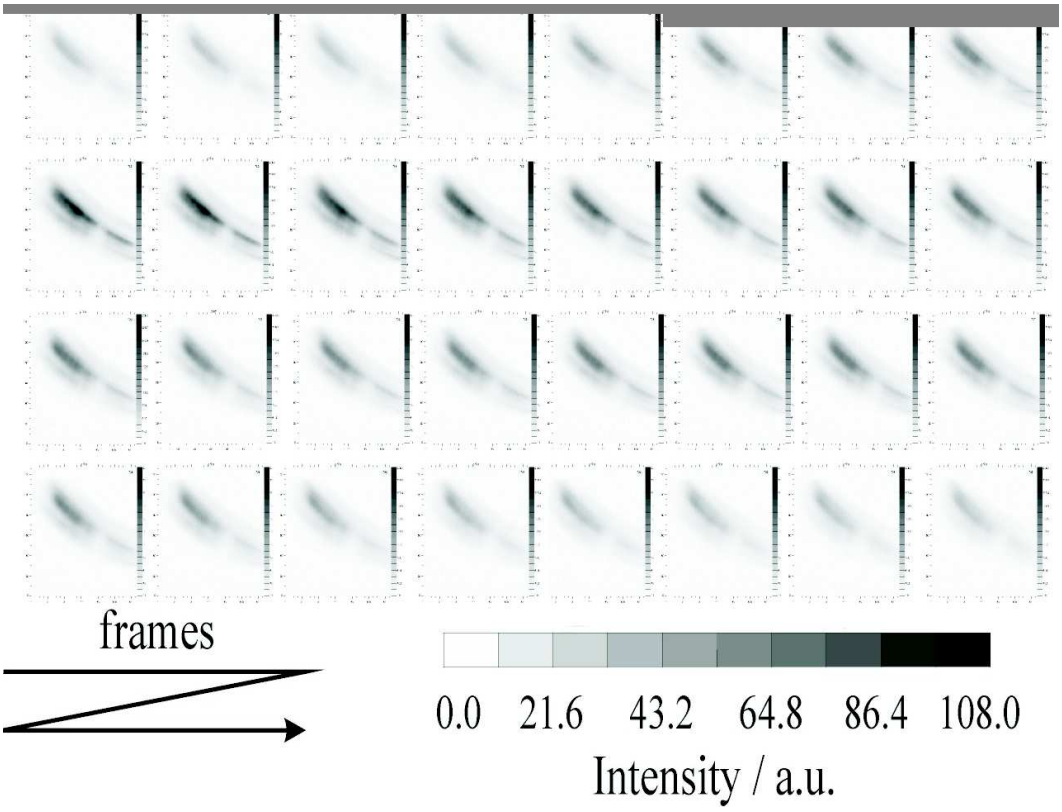

Figure 4: Time sequence of the strike pattern at the divertor for time range f. The time between two subsequent frames is 0.74 ms.

5). Taking the geometry of the divertor target plates into account, this observation is in agreement with a vertical shift of the plasma (or the X-point) toward the target during an ELM.

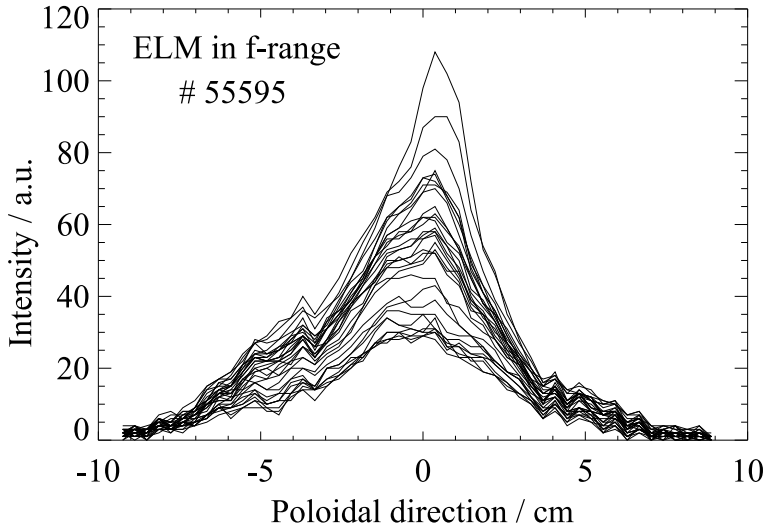

Figure 5: The time evolution of the poloidal profile during an ELM. A poloidal shift of the maximum of about 1 cm is observable.

4. Outlook

The fast framing camera is a very useful tool for investigations with high spatial and temporal resolution in the plasma boundary. Together with Langmuir probe data, the transport related to ELM events in the rather complicated three-dimensional island divertor on W7-AS can be estimated. Another focus issue is the analysis of the plasma boundary turbulence. Experiments are planed where the fast camera is viewing in toroidal direction and hence integrating along the largely elongated turbulent structures.

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