MHD CHARACTERISTICS OF ELMs AND THEIR PRECURSORS

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Abstract

With a newly installed enhanced Mirnov diagnostic at ASDEX Upgrade a detailed analysis of ELMs and their precursors has been done. A new type of high frequent precursors could be observed. Detailed measurements of edge profiles were used for an equilibrium calculation with realistic pressure profiles with finite edge pressure gradient, in order to analyze the stability at the plasma edge.

1. Introduction

Experimentally it has been found that the pressure gradient at the plasma edge rises rapidly after an ELM and remains constant at a value presumably associated with the ideal ballooning stability threshold for type I ELMs [1, 2, 3]. It is therefore interesting to investigate the MHD activity before and during the enhanced transport phase of an ELM. This MHD activity may play a key role for understanding the saturation of the edge pressure gradient.

Therefore, a new enhanced magnetic diagnostic for measuring magnetic perturbations with high mode numbers and high Nyquist frequencies up to 250 kHz (500 kHz sampling rate) has been installed at ASDEX Upgrade. The new high frequency coils measure the fluctuations of the radial field at 6 toroidally non equidistant and 8 poloidally equidistant positions at the low field side of the torus. Additionally, with carefully measured edge profiles, equilibria for a stability analysis with finite edge pressure gradient have been investigated [4].

2. Precursor and MHD structure of type I ELMs

Prior to an ELM characteristic precursors have been described from various experiments [1]. One has to distinguish between two different types of ELMs, namely type I ($df_{ELM,I}/dP_{sep} > 0$) and type III ELMs ($df_{ELM,III}/dP_{sep} < 0$) [5]. The typical precursors at ASDEX Upgrade, in the case of co-injection of the neutral beam with respect to the plasma current, show frequencies of $f_{prec,III}$ = 50 - 70 kHz for type III ELMs. Usually 2-3 similar frequencies show a characteristic beating for type III ELMs. For type I ELMs precursors are difficult to detect and have very low frequencies of $f_{prec,I} \approx$ 5 kHz [2]. For counter-injection the frequencies are shifted upward to $f_{prec,III}$ = 80 - 120 kHz for type III ELMs and type I precursors can be clearly observed with $f_{prec,I}$ = 15 - 25 kHz. We are focused on type I ELMs in the co-injection case in this paper.

With the help of the enhanced Mirnov diagnostic a new type of precursors for type I ELMs could be detected. Typically several ms before the H_α rise in the divertor, marking the enhanced transport phase of an ELM, a set of high frequency modes with medium toroidal mode numbers can be observed. Fig. 1 a),b) show up to three different modes with n = 3,4,5 and frequencies in the range f_I = 75,110,145 kHz, respectively. The considered discharge #10050 had the following parameters: I_p = 1.2 MA, B_t = 3 T, q_{95} = 4, $\bar{n}_e$ = 7 $\cdot$ 10^{19} m^{-3}, P_{NI} = 10 MW. In other cases groups with n = 4,5,6 and slightly higher frequencies have been observed. These high frequency modes can last for half the time between two subsequent ELMs. They may be responsible for the saturation in the edge pressure gradient. These structures show, like the above described well known precursors, a characteristic frequency drop directly before the ELM. They have to be distinguished from the low frequency precursors of type I ELMs and the precursors of type III ELMs.

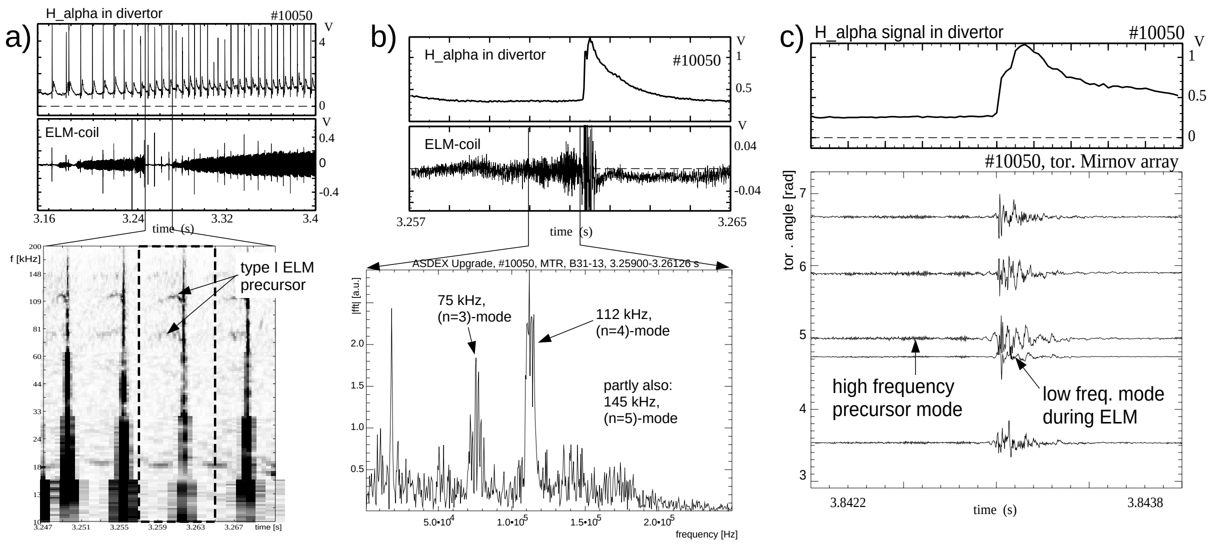

Figure 1. a) Type I ELM precursors as observed on the Mirnov diagnostic. The upper part of the figure shows the H_α emission in the divertor and a Mirnov time trace. In the lower part the time evolution of the frequencies as a wavelet plot is shown. b) Detailed structure for one single ELM with H_α emission, a Mirnov trace and a Fourier spectrum in the marked time window of the Mirnov data. c) Fluctuations during the enhanced transport phase of the ELM from the toroidal set of Mirnov coils together with an H_α signal.

During the enhanced transport phase of a type I ELM, marked by the rise in the H_α emission in the divertor chamber, large amplitude fluctuations with a broad frequency spectrum on the Mirnov diagnostic can be seen (Fig. 1 c). During this phase also clear frequencies around 20 kHz can be observed with typical mode numbers of n = 4 and $m \approx\geq$ 16 - 18. As these frequencies are much lower than the high frequency precursors, also an estimation of the poloidal mode number can be given. The mode numbers are consistent with an edge safety factor of q_{95} = 4 for the considered cases under the assumption of a macroscopic mode at a resonant surface at the edge.

3. Variation of the edge safety factor q_{95}

The observation of high frequency modes with n = 3 - 6 and $f \approx$ 75 - 140 kHz could explain the saturation of the edge pressure gradient before the ELM. As the low frequency modes during the ELMs are consistent with q_{95}, a small variation of the equilibrium, moving the resonant surface through the relevant region for the ELM transport, should influence the energy loss per ELM and could also modify the ELM frequency. Therefore, a small variation of the edge safety factor q_{95} has been performed by varying the main toroidal field B_t within one discharge in order to avoid changed discharge conditions in a B_t-scan in a set of discharges. By now, neither a clear variation in the ELM frequency nor in the energy loss per ELM could be found in these experiments. The only effect, which could be detected, is a variation of the high frequency precursor activity while the toroidal field is shifted during the discharge. During the change of the field the precursors periodically appear and disappear. This may be caused by the movement of higher rational surfaces in the edge, i.e. the region of these modes. Fig. 2 a) shows two subsequent time windows in which in the first time frame the precursors can be clearly seen, whereas in the second time frame no precursors are detectable.

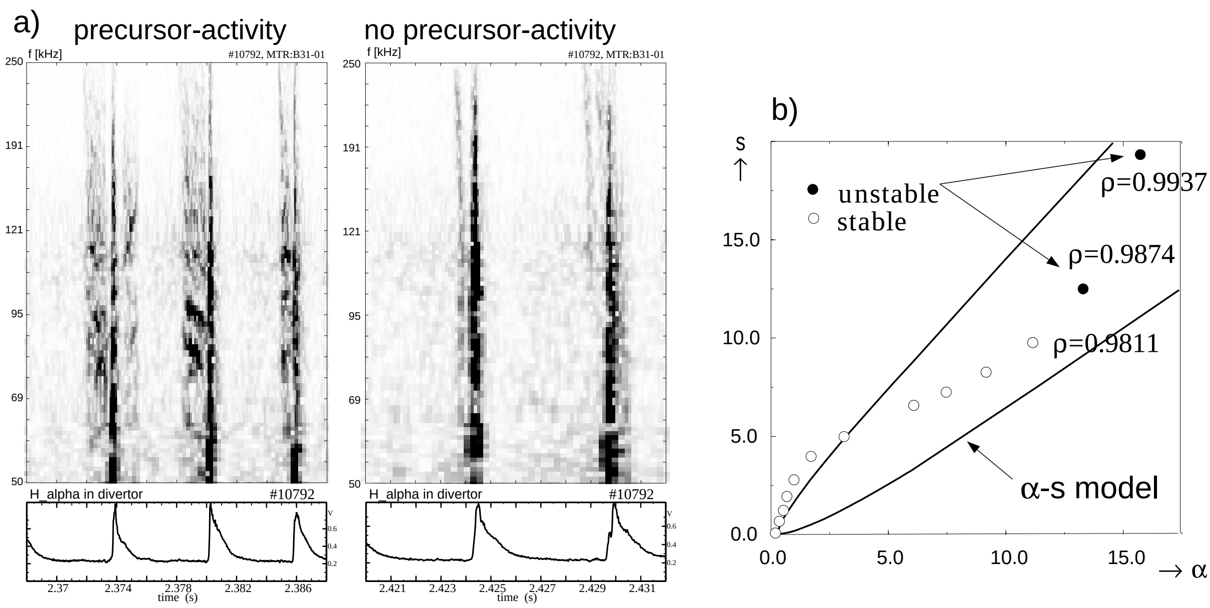

Figure 2. a) Wavelet plot of Mirnov data and H_α signal for two subsequent times in a discharge with varying magnetic field B_t. Clearly the presence in the first and the absence in the second time frame of ELM precursors can be seen. b) Stability diagram in $\alpha - s$-coordinates described in [4] together with the usual region of stability for the discharge #10050. For $\rho_p \geq$ 0.9874 the plasma edge is ballooning unstable for the considered pressure gradients at the edge.

4. Equilibrium calculation and stability

In order to get a realistic equilibrium reconstruction respecting the finite edge pressure and edge pressure gradients for an analysis against ballooning instability, the plasma profiles have been measured with special care for the edge. The electron temperature $T_e(\rho_p)$ is measured at the edge by a Thomson scattering system, and in the center by the ECE emission measurements. The density is measured by a DCN interferometer and a Lithium beam diagnostic at the plasma edge. The ion density has been assumed to be equal to the electron density $n_i(\rho_p) \approx n_e(\rho_p)$. The ion temperature has been measured by two different diagnostics from charge exchange for the center and edge separately. From these measurements the following pressure gradients have been determined for the discharge #10050: $\nabla p_e \approx$ 300 kPa/m, $\nabla p_i \approx$ 500 kPa/m and $\nabla p = \nabla p_e + \nabla p_i \approx$ 0.8 MPa/m on the low field side of the torus. These pressure gradients lead to a situation where the plasma edge is ballooning unstable for $\rho_p \geq$ 0.9874 or for $a - r \leq$ 0.74 cm [4]. The $\alpha - s$-diagram in Fig. 2 b) shows the stability for different ρ_p together with the usual region of stability.

5. Summary and conclusions

With the help of an enhanced Mirnov diagnostic type I ELMs have been analyzed. A new type of high frequency precursor mode could be detected, which could explain the saturation of the edge pressure gradient long before the ELM itself is destabilized. A variation of q_{95} by a slow variation of the toroidal field was performed to clarify the influence of resonant surfaces on the ELM behavior. With in detail measured edge pressure profiles an equilibrium and stability analysis with finite edge pressure gradient shows that the plasma edge is ballooning unstable in the considered cases.

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