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Qualitative similarities between edge localised modes (ELMs) in fusion plasmas and complex space charge configurations (CSCCs) in low-temperature plasmas

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1. Introduction

In tokamaks it was observed that, by increasing the heating power, first a degradation of the energy and particle confinement in fusion plasma occurs (L-mode). However, above a certain value of the power, a regime of improved energy and particle confinement is attained. This is the well-known H-mode [1,2]. The H-mode operation of a tokamak plasma is characterized by the formation of an edge transport barrier (ETB) [3], i.e. a thin layer with suppressed anomalous transport near the magnetic separatrix, resulting in a steep edge density gradient (the so-called pedestal) and improved confinement. The H-mode is often perturbed by the onset of a quasi-periodic series of relaxation oscillations involving bursts of MHD activity, known as edge localized modes (ELMs). These result in rapid losses of particles and energy from the region near the plasma boundary, reducing the average global energy confinement by 10-20% [4]. The energy impact on the plasma-facing components may lead to an unacceptable heat load on the divertor. However, ELMs provide an efficient mechanism by which helium ash and impurities can be removed from the plasma, and if they can be controlled a stationary H-mode operation is possible.

There are several types of ELMs [5]. At heating powers just above the threshold of the L-H transition, the so-called type III ELMs occur. Their frequency decreases as the heating power increases until finally they are stabilized. With a further rise in the heating power, so-called type I (or "giant") ELMs appear. The type II (or "grassy") ELMs occur in strongly-shaped plasma, when the plasma edge lies in the connection region between first and second stable ballooning regimes. A cycle of L-H-L transitions prior to the transition to H-mode can also occur [6], known as dithering H-mode or dithering ELMs.

In low-temperature plasma, under certain experimental conditions, up to a threshold value of the power injected into the plasma, a complex space charge configuration (CSCC) can appear in form of an ion-enriched plasma region, confined by an electrical double layer (DL) [7]. Qualitative similarities were emphasized between a CSCC and a toroidal fusion plasma in H-mode [8]. When the power injected into the plasma increases up to a certain threshold value, the CSCC transits into a dynamic state, during which the structure periodically aggregates and disrupts [8], energy and particles being released into the surrounding plasma. The frequency of this dynamic state increases with an increase of the input power [9]. There are many modes of this dynamic behaviour, characterized by different parameters such as amplitude or frequency [10].

2. Experimental results and discussion

The experiments were performed in the diffusion plasma of a double plasma (DP) machine (extensively described in [9]) as well as into the magnetized plasma column of a Q machine (extensively described in [10]).

In the case of the DP-machine we used only the target chamber, under the following experimental conditions: argon pressure $p = 5\times10^{-3}$ mbar, plasma density $n_{pl} \cong 10^9$ cm^{-3}. The diffusion plasma was pulled away from equilibrium by biasing positively a tantalum disk electrode of 2 cm diameter with respect to the plasma potential. At a critical value of the potential on this electrode, a CSCC appears in front of it, in form of a quasi-spherical intense luminous plasma body. If the noise level is high inside the plasma system, and the potential on the electrode is close to the critical value, fluctuations of the current through the plasma conductor were recorded (see Fig. 1). These uncorrelated oscillations correspond to the random appearances and disruptions of CSCC, driven by noise, similar as in the case of dithering ELMs.

When the potential on the electrode reaches a second critical value, the CSCC passes into a dynamic state, during which the DL at its border periodically disrupts and re-aggregates [7]. Simultaneously with the disruption of the structure, energy and particles stored in the DL are injected periodically into the surrounding plasma. Fig. 2 shows the electron satu-

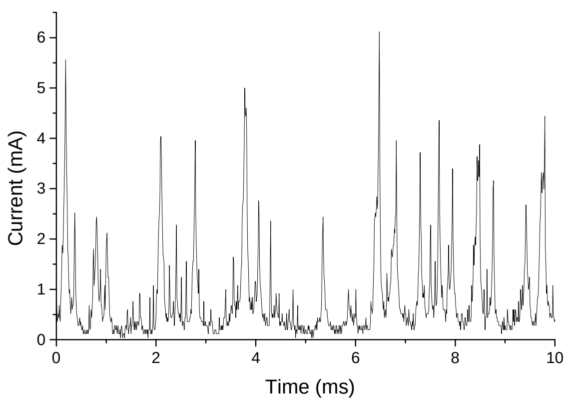

Fig. 1: Fluctuations of the current through the plasma conductor near the onset of CSCC.

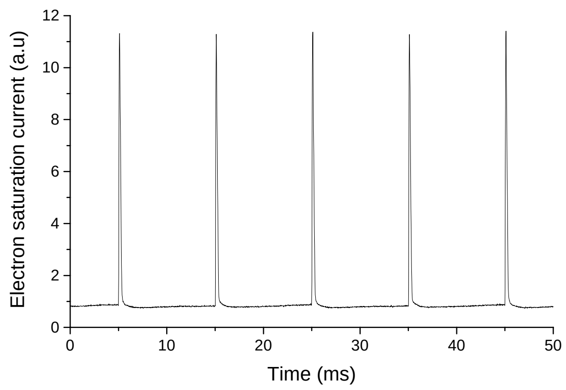

Fig. 2: Bursts of electrons during the dynamic regime of CSCC.

ration current of a small plane Langmuir probe inserted into the plasma, showing periodic bursts of electrons during the dynamic state of CSCC. The frequency of these bursts is proportional to the current through the plasma conductor [9].

In a Q-machine we worked under the following experimental conditions: background pressure $p < 10^{-5}$ mbar, potassium plasma density $n_{pl} \cong 10^9$ cm^{-3}, confining axial magnetic field $B = 0.2$ T. A tantalum electrode of 1 cm diameter was inserted into the plasma column, perpendicular to the magnetic field. By biasing this collector positively, an electron current was drawn through a channel of roughly the same diameter as the collector. Up to a critical value of the potential on the electrode with respect to the plasma potential, the well-known potential relaxation instability (PRI) was excited [11]. Under slightly different conditions also the electrostatic ion-cyclotron instability (EICI) can appear [12]. Both instabilities consist of strong oscillations of the plasma parameters (potential, electron and ion density, current through the plasma column) [13]. Previous experiments proved that also in this case in front of the electrode a CSCC (similar to that described above in a DP-machine) appears in an elongated form. This is due to the action of the magnetic field [14], and the PRI and the EICI are due to the nonlinear dynamics of the DL at the border of the CSCC. In such a case, the dynamical current-voltage characteristic of the collector has typically the form shown in Fig. 3. This was obtained by recording the current collected by the collector simultaneously with the fast increase of the potential on it. We can observe the development of two modes of the CSCC dynamics (cf. Fig. 3): (A) one characterized by low-amplitude oscillations of the current through the plasma, at lower potentials on the collector, and (B) one characterized by high-amplitude oscillations of the plasma current, at higher potentials on the electrode. This characteristic has a certain similarity with that obtained for increasing input

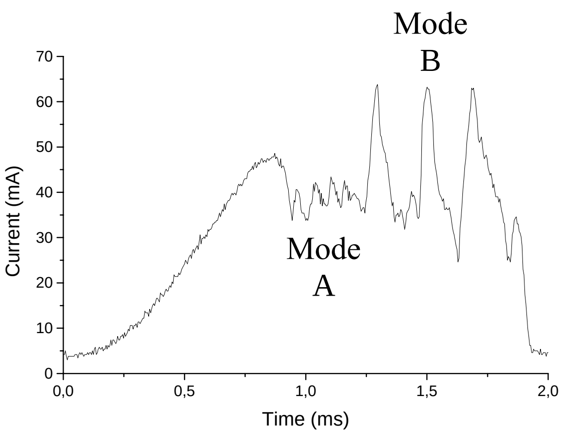

Fig. 3: Dynamic current-voltage characteristic of the electrode recorded in magnetized plasma, showing two modes of CSCC dynamics

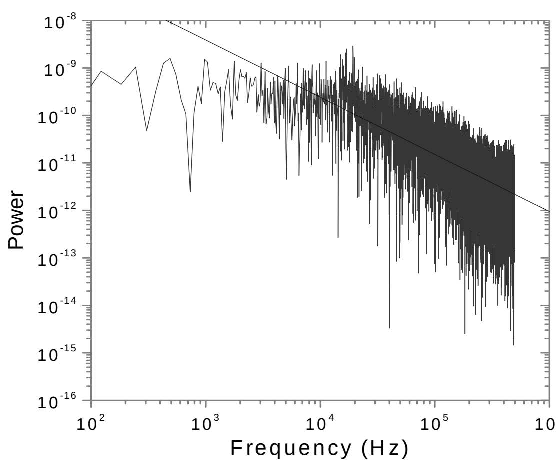

Fig. 4: Flicker noise associated with the nonlinear dynamics of CSCC, recorded at high potentials on the electrode

power in a tokamak plasma, when type III and type I ELMs, appear, respectively.

In both, DP and Q-machines, at high potentials on the electrode, the presence of flicker noise in the power spectrum of the current oscillations was recorded (see for example Fig. 4, for the case of the DP machine). The flicker noise was recently linked to the uncorrelated dynamics of multiple double layers [9], but it appears also frequently in connection with ELMs [15].

3. Conclusion

Experimental results on the dynamics of a CSCC in cold unmagnetized and magnetised plasmas show certain qualitative similarities with the L-H mode transition in hot toroidal fusion plasmas and with the appearance of ELMs. These observations could contribute to a better understanding of ELMs and the development of a new phenomenological model for a fusion plasma torus in H-mode. In this model, the plasma torus is seen as a complex space charge structure which, in addition to the magnetic confinement, is also electrically confined by an electrical double layer, while the geometry is imposed by the magnetic field configuration. The local disruptions of the confining DL determine a dynamic state, the result of which is the development of different types of edge localized modes.

Of course, there are also strong differences between the two plasmas and the two phenomena: not only are the plasma densities and electron and ion temperatures in a DP or Q-machine much lower, but also the geometry is different since in the case of a toroidal plasma the magnetic field is perpendicular to the direction of plasma transport, while also in our Q-machine experiment the transport is considered along the field lines. Nevertheless, we believe that the similarities described above are worth to be pointed out and that they could be signs of a deeper analogy between the two phenomena.

References

[1] F. Wagner et al., *Phys. Rev. Lett.* 49 (1982), 1408.
[2] J. W. Connor and H. R. Wilson, *Plasma Phys. Control. Fusion* 42 (2000), R1.
[3] T. N. Carlstrom et al., *Nucl. Fusion* 39 (1999), 1941.
[4] J. W. Connor, *Plasma Phys. Control. Fusion* 40 (1998), 191.
[5] H. Zohm, *Plasma Phys. Control. Fusion* 38 (1996), 105.
[6] H. Zohm, *Phys. Rev. Lett.* 72 (1994), 222.
[7] M. Sanduloviciu, E. Lozneanu, *Plasma Phys. Control. Fusion* 28 (1986), 585.
[8] D. G. Dimitriu, C. Ionita, R. Schrittwieser, *31st EPS Conf. Plasma Phys.* (London, Great Britain, 2004), *Europhy. Conf. Abstr.* 28G (2004), p. 4.222.
[9] C. Ionita, D. G. Dimitriu, R. Schrittwieser, *Int. J. Mass Spectrom.* 233 (2004), 343.
[10] D. G. Dimitriu, *Czech. J. Phys.* 54 (2004), C468.
[11] S. Iizuka et al., *Phys. Rev. Lett.* 48 (1982), 145.
[12] J.J. Rasmussen, R.W. Schrittwieser, *IEEE Trans. Plasma Sci.* 19 (1991), 457.
[13] R. Schrittwieser, *Phys. Fluids* 26 (1983), 2250.
[14] M. Sanduloviciu et al., *J. Plasma Fus. Res. SERIES* 4 (2001), 317.
[15] J. Greenhough et al., *Plasma Phys. Control. Fusion* 45 (2003), 747.