§8. Observation of ELM-free H-phase in ETB Plasmas of LHD

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Low to high confinement regime (L-H) transition and edge transport barrier (ETB) formation are observed in LHD having a unique helical divertor configuration. Characters of the transition are similar to those in tokamak H-mode plasmas: clear depression of Hα emission, rapid rise of edge electron density, rapid increase in the stored energy, and appearance of edge localized modes (ELMs). In LHD, ELMs are thought to be generated by nonlinear evolution of resistive interchange modes excited in magnetic hill region near the plasma edge. On the other hand, peeling and/or ballooning modes excite ELMs in a tokamak H-mode. ELMs may lead to serious damages to plasma facing components in a fusion device such as ITER, and suppression or mitigation of ELM impacts is one of important issues. Excitation of ELMs links closely to plasma transport and MHD stability in the plasma edge.

In LHD, ETB plasmas are mostly obtained in the so-called inward-shifted configurations of Rax ≤ 3.6m, and ELMs are excited just after the transition[1-3]. Magnetic fluctuations near the edge are enhanced, compared with those in the L-phase, which is a clear difference with a tokamak H-mode. Recently, ETB plasmas have been obtained in the configuration of Rax=3.75m. In these ETB plasmas, ELMs are also excited in the H-phase. However, an ETB plasma without any ELMs has been obtained, as shown in Fig.1. In this shot, the line averaged electron density increases by more than a factor of two. Low frequency magnetic fluctuations (<10kHz) related to edge MHD modes are enhanced moderately in the H-phase. However, the magnetic fluctuations do not have any bursting amplitude modulation, and this may lead to suppression of ELMs. This may be caused by enhanced plasma current in the counter direction.

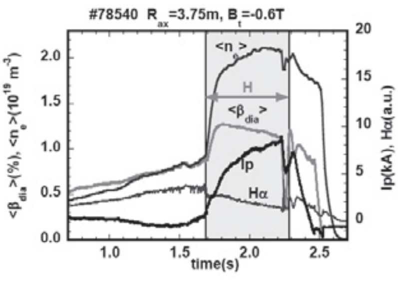
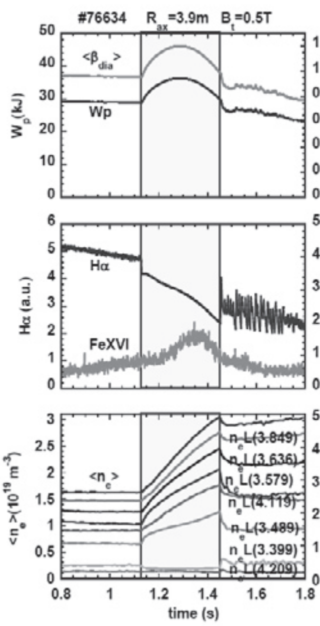


Fig.1 ELM-free ETB plasma obtained at Bt=-0.6T and Rax=3.75m.

A more interesting ETB plasma has been obtained in further outward-shifted configuration of Rax=3.9m. Figure 2(a) shows time evolutions of the stored energy, Hα emission and line-integrated electron densities. The role over of the stored energy is caused by appreciable increase in radiation power due to strong rise in electron density. Coherent soft X-ray fluctuations having a peak around ι/2π=1(ι/2π: the rotational transform) are clearly suppressed just after the transition. Moreover, magnetic fluctuations in the range less than 10 kHz are also clearly suppressed, as shown in Fig.2(b). This character is similar to that in a tokamak H-mode. Understanding of suppression of edge MHD modes that would be related to resistive interchange modes is very interesting and important to improve MHD stability in the plasma edge and enhance plasma performance of ETB plasma on LHD. Enhanced radial electric field by the L-H transition may play a role in suppression of resistive interchange modes.

(a)



(b)

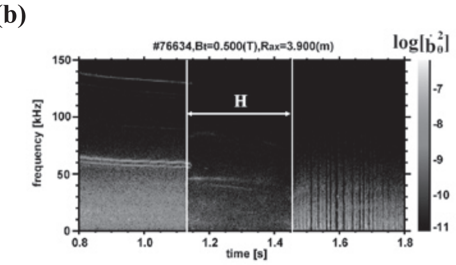


Fig.2 (a) ELM-free ETB plasma at Bt=0.5T and Rax=3.9m. (b) Spectrogram of magnetic fluctuations. A color code indicates the level of $\log_{10}[(db_\theta/dt)^2]$.

[1] K. Toi et al., Phys. Plasmas 12, 020701 (2005).
[2] K. Toi et al., Plasma Phys. Control. Fusion 48, A295 (2006).
[3] F. Watanabe, Plasma Phys. Control. Fusion 48, A201 (2006).