§45. Evidence of Stochastic Region near a Rational Surface in Core Plasmas of LHD

Ida, K., Inagaki, S. (Kyushu Univ.), Tsuchiya, H., Tamura, N., Suzuki, Y., Yoshinuma, M., Suzuki, C., Narushima, Y., Shimozuma, T., Kubo, S., Takahashi, H., LHD Experiment Group

A stochastization of the magnetic surfaces has been considered to be important, because the partial stochastization of the magnetic surfaces due to perturbation fields can contribute the mitigation of Edge-Localized-Modes (ELMs). Moreover a spontaneous transition from the stochastic state to helical equilibrium in a RFP[1] and a bifurcation phenomena of a magnetic island at a rational surface in LHD[2] suggest the stochastization of the magnetic surfaces is a self-organized transition phenomena. In spite of the importance of the experimental confirmation of the stochastization of the magnetic surface, it is difficult to measure the stochastization of the magnetic surface directly. One piece of evidence of stochastization of the magnetic surfaces is the flattening of T_e profile, however, the flattening can occur due to the lack of heat flux crossing the magnetic flux as seen in the magnetic island even if the magnetic flux surface is nested inside. In the cold pulse propagation experiment using Tracer Encapsulated Solid Pellet (TESPEL) in LHD, slow pulse propagation of a cold pulse has been observed because of the relatively good heat transport in the nested magnetic island[3]. In LHD, experimental confirmation of stochastization of the magnetic surface is carried out by the analysis of heat pulse propagation driven by modulated electron cyclotron heating (MECH) with a frequency of 39Hz .

Figure 1 shows the radial profiles of Te and the delay time of heat pulses driven by MECH at three time slices; just before the switching of NBI, a half second and one second after the NBI switch. There is no flattening region in the Te profile before the NBI switch, when the magnetic shear at $\iota = 0.5$ is high enough to heal the magnetic island as seen in Fig.1(a). However, after the magnetic shear drops below a critical value, partial flattening at one-third of plasma minor radius or a large core flattening of T_e up to half of plasma minor radius is observed as seen in Fig.1(c) and Fig.1(e), respectively. The power deposition of MECH is localized at the magnetic axis and a heat pulse propagates from the plasma center toward the plasma edge (outward) when there is no magnetic island as seen in Fig.1(b). When a partial flattening in the T_e profile appears at one-third of plasma minor radius, the slow propagation of the heat pulse observed in the partial flat region of T_e as seen in Fig.1(d). The propagation of the heat pulse inside the m/n=2/1 magnetic island is bidirectional (inward and outward radially, from the magnetic island boundary to the magnetic island center at O-point) and is even slower than that outside the magnetic island because of better heat transport. However, when there is flat region of T_e profile up to half of plasma minor radius observed, the heat pulse propagates rapidly in the T_e flat region (no time delay within the accuracy of the measurements) as seen in Fig.1(f), which is a clear evidence stochastization of magnetic surface. In conclusion, there are significant differences (slow and fast) in the heat pulse propagation at the T_e flat region in LHD. A slow heat pulse propagation is evidence of a nested magnetic island and fast heat pulse propagation is evidence of stochastization of the magnetic surfaces.

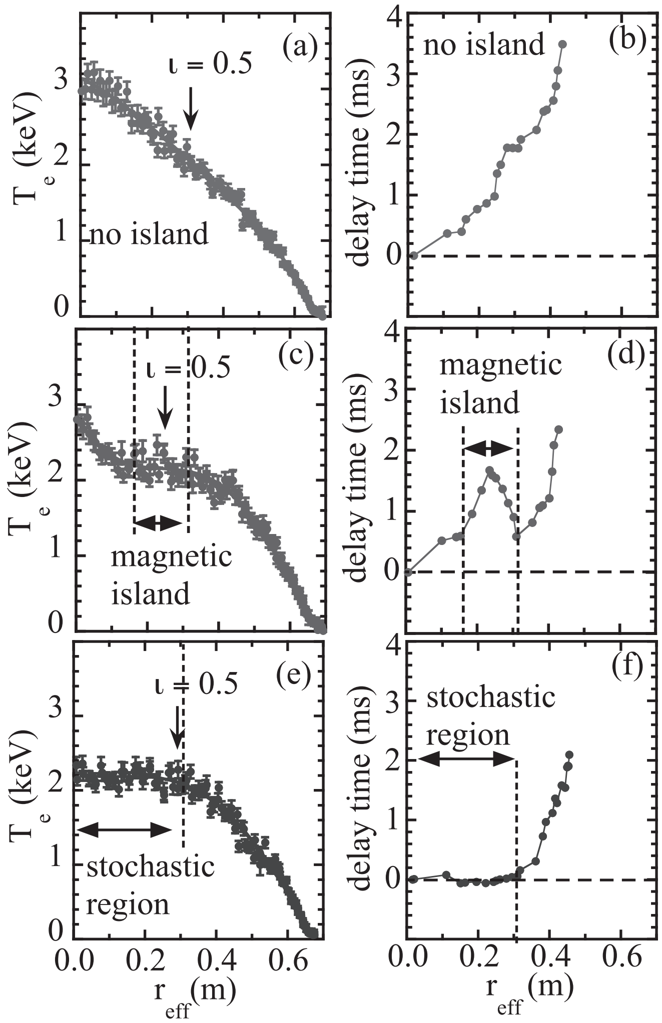

Fig. 1: Radial profile of electron temperature and time delay of the heat pulse due to the modulated ECH in the plasma with (a)(b) no magnetic island, (c)(d) m/n=2/1 magnetic island (near the O-point) and (e)(f) stochastic region. The locations of rational surface of $\iota = 0.5$ are indicated with arrows.

1) R. Lorenzini, et. al., Nature Physics 14 June (2009).

2) K.Ida, et. al., Phys. Rev. Lett. 100 (2008) 045003.

3) S.Inagaki, et. al., Phys. Rev. Lett. 92 (2004) 055002.