§9. Heat Pulse Propagation near the Last Closed Magnetic Flux Surface in LHD

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Heat pulse propagation experiment has been recognized to be a useful tool to study the topology of the magnetic surfaces. When the magnetic flux surface becomes stochastic, the speed of the heat pulse becomes much faster than the speed expected from the radial transport across the magnetic flux surface. On the other hand, when the magnetic flux surface becomes open field, the amplitude of heat pulse drops more than that expected by radial diffusion. Therefore how much the magnetic flux surface becomes stochastic and whether the magnetic filed is closed or open can be investigated by measuring an amplitude and a delay time of the heat pulse in the plasma. Based on the success of identification of the stochastization of the magnetic surface in the core region using heat pulse propagation technique[1], the heat pulse propagation experiment was applied near the last closed magnetic flux surface (LCFS) in LHD.

Figure 1 shows the time evolution of electron cyclotron emission (ECE) signal in the discharge with modulated electron cyclotron heating (MECH) with a frequency of 39 Hz in the magnetic configuration with R_{axis} = 3.53 m, γ = 1.254, B_Q = 100%. The MECH is focused to the peripheral region of $\rho \sim 0.9$ (0.1m inside the LCFS) in order to measure the heat pulse propagation across the LCFS. In this experiment, the location of LCFS indicated with dashed lines ($R \sim 4.6$ m) is determined from the radial profile of radial electric field E_r as the location where the positive E_r starts to increases sharply, because the non-ambipolar electron loss is expected outside LCFS. The ECE signal shows significant modulation due to the MECH in the range of R = 4.35 $\sim$ 4.55 m across the LCFS. As seen in the radial profiles of relative amplitude of heat pulse and delay time, there is a clear discontinuity of the slope both in amplitude and delay time at the LCFS. The relative amplitude of the heat pulse starts to decreases outside the LCFS, while it increases gradually inside the LCFS, which indicates the magnetic field becomes open field. Although the speed of the heat pulse becomes faster outside the LCFS, it is still much slower than that expected in the case of stochastization of magnetic field. Therefore, the stochastization of the magnetic flux outside the LCFS in this configuration would be relatively weak if any.

In conclusion, the LCFS location evaluated from a clear discontinuity of the slope both in amplitude and delay time of the heat pulse is consistent with the LCFS location evaluated from the radial electric field profiles. The heat pulse propagation experiment near the lCFS suggested that this technique is also useful to determined the location of LCFS and also to investigate the magnitude of the stochastization near the LCFS. This experiments demonstrate the possible approach in determining the LCFS location and magnitude of the stochastization in the high beta plasma, where the change of magnetic topology from that in vacuum due to the healing current in the plasma is expected.

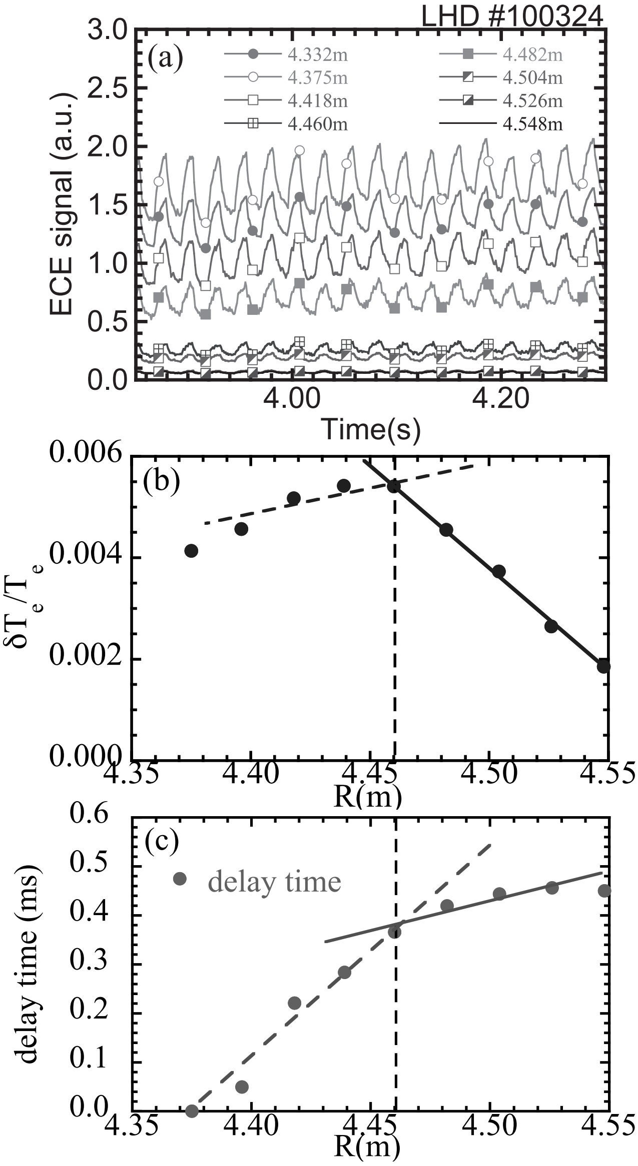

Fig. 1: (a)Time evolution of electron cyclotron emission (ECE) signal in the discharge with modulated electron cyclotron heating (MECH) and radial profiles of (b) relative amplitude of modulation and (c) delay time of the heat pulse. The dashed lines indicate the position of last closed magnetic flux surface (LCFS) evaluated from the radial profile of radial electric field.

1) Ida, K., et. al., IAEA FEC EXS-5-2, Daejeon 2010.