§20. The Bifurcation Behavior of Potential in LHD

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Radial electric field, E_r, is an important parameter to study the confinement physics of magnetically confined plasmas. For example, the reduction of ripple transport in $1/\nu$ regime in helical device, and the suppression of turbulence by shear flow are attractive issues related to E_r, so we have been studying the E_r formation physics in the Large Helical Device (LHD) by using a heavy ion beam probe (HIBP)[1)].

With a HIBP diagnostic system, we can measure directly the potential in the high temperature plasma with good spatial/temporal resolution. In recent experiment, the abrupt change of potential was observed with HIBP in LHD. One typical shot is a discharge produced and sustained by neutral beam injection heating (NBI). Other shot is a discharge heated by low power electron cyclotron heating (ECH). In. Fig.1, the time evolution of line averaged density, heating methods, and plasma potential at the center measured with HIBP are shown. The parameters of magnetic field configuration on this experiment are as follows: Toroidal magnetic field strength B_t is 1.5 T, pitch parameter γ is 1.254, the quadropole component of magnetic field B_q is 100 %. The power of ECH is about 300 kW. The frequency of electron cyclotron wave is 77 GHz and the heating position is not on the plasma center (namely, off-axis heating). Line averaged electron density is gradually increased, and the potential decreases with the density increase. In the potential decreasing phase, the abrupt change of potential is observed. The enlarged view of Fig.1 for the time period of 3.64 ~ 3.70 s is shown in Fig.2. In this figure, the fast drop of potential is seen at 3.655 s. After the fast drop, back transition is observed. The time constant of potential drop is estimated by using a fitting function, $\Phi = \Phi_0 + a \times \tanh((t-t_0)/\tau)$. The time constant of potential drop at 3.655 s is about 0.1 ms, that is shorter than the energy confinement time of this discharge (~ 30 ms). The time constant of recovery phase at 3.655s is about 0.93 ms, but at 3.677s it is 0.07 ms and very short. After several times of potential drop and back transition, the potential goes down and keeps the gradually decreasing state. The radial potential profiles before (3.64 ~ 3.65 s) and after the transition (3.73 ~ 3.74 s) are shown in Fig. 3. These two profiles are obtained from eight sequential shots, of which plasma parameters are similar. However the timing of potential transition is not exactly same; in the duration 3.65 ~ 3.73 s, potential of some shots is on the upper state, but of the other shots is on the lower state, therefore we do not show the potential profile in this duration. The potential in all radial positions is different between before and after the transition. As for the radial electric field (the differential of potential), in the region where r_{eff} > 0.2 the positive electric field before the transition is stronger than that of after transition. The physics of this phenomenon is considered to be similar to experimental results in CHS[2)], but the detail analysis based on the neoclassical theory is not yet completed. The time constant of potential change in LHD tends to be slower than in CHS; it is 100 μs ~ 1 ms in LHD, although 30 ~ 70 μs in CHS[2)]. The explanation of this difference is also a remained issue.

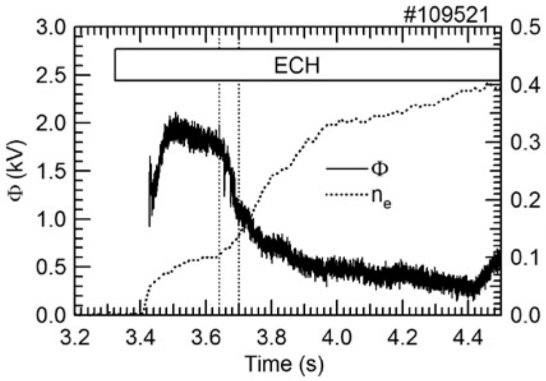

Fig. 1. Temporal evolution of potential, line averaged density and heating methods

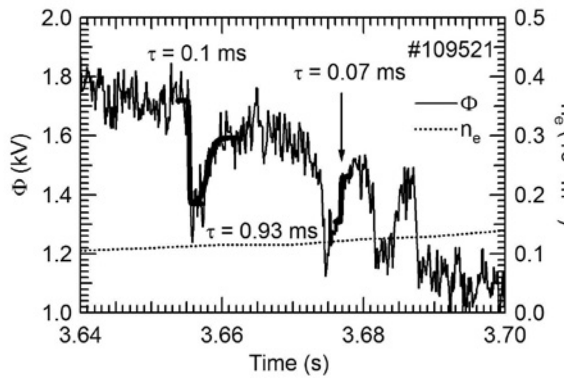

Fig. 2. Detail of potential change is shown. This figure is an enlarged view of Fig.1 for the time period of 3.64 ~ 3.70 s.

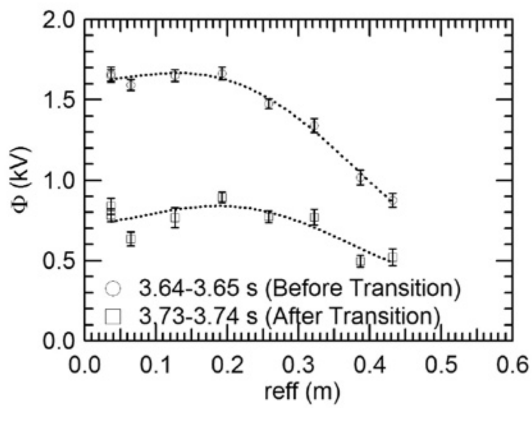

Fig. 3. Potential profiles before (3.64 ~ 3.65 s) and after the transition (3.73 ~ 3.74 s).

1) Shimizu, A., Ido, T., Nishiura, M. et al.: J. Plasma Fusion Res. **5** (2010) S1015.
2) Fujisawa, A., Iguchi, H., Minami, T. et al.: Phys. Rev. Lett. **79** (1997) 1054.