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Causality of potential and temperature responses on a local electron heating in H and D plasmas of the LHD

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Electric fields in plasmas are widely recognized for their importance in plasma confinement mechanisms. In fusion plasmas, the electric field provokes diverse phenomena; L-H transition, internal transport barrier and improved confinement by flow and its shear are observed widely in toroidal plasmas. In Large Helical Device (LHD) and other stellarators, electron cyclotron heating (ECH) produces an improved confinement state so-called core electron root confinement [1]. The LHD is equipped with a heavy ion beam probe (HIBP) which injects a positive gold beam accelerated up to 6 MeV to measure an electric potential and its fluctuation at a plasma core region. It is reported by using the HIBP diagnostic that the potential profile between the HIBP diagnostic and the simulation based on neoclassical theory agrees well at a core plasma region [2, 3]. For understanding hydrogen isotope effect on the confinement performance, the formation of an electron internal transport barrier (e-ITB) was examined. A deuterium plasma formed an e-ITB with less input power of electron cyclotron heating (ECH) P_{ECH} than a hydrogen plasma, while an electrostatic potential transition existed [4]. Their survey covered $P_{ECH}/n_e < 1.5$, while the hydrogenic isotope effect on the transient electric potential and radial electric field at $P_{ECH}/n_e = 2.5$ in a plasma was explored by the HIBP in this report.

In a hydrogen and deuterium plasma, the ECH was modulated at 25 Hz (see Fig. 1). The on and off timings of the ECH power form and disappear an e-ITB, respectively. Then, the HIBP measures the time evolution of electric potential and its spatial profile under a fixed discharge condition shot-by-shot basis. Figure 2 exhibits the linear relation between ϕ_H and ϕ_D at $\rho = 0.0$, 0.2, and 0.8 when the ECH power was modulated at $P_{ECH}/n_e = 2.5$. The e-ITB was formed at the plasma core in ECH power turning on. The variations of ϕ_H and ϕ_D at $\rho = 0.0$ and 0.2 were more significant than those at $\rho = 0.8$. The linear relation between ϕ_H and ϕ_D at $0 < \rho < 0.8$ suggests the unclear isotope effect, even if ϕ_H and ϕ_D evolve. The former experiment [4] surveyed in the $0.35 < P_{ECH}/n_e < 1.5$ range. The apparent isotope effect appeared in the $0.5 < P_{ECH}/n_e < 1.2$ range, while the experimental region at $P_{ECH}/n_e = 2.5$ provided a new feature, which suggests that a window of P_{ECH}/n_e toward the hydrogenic isotope effect exists to form an e-ITB structure.

The time evolution of E_r with modulated ECH was evaluated at $\rho = 0$, 0.28, 0.42, and 0.55. The electron temperature T_e forms an e-ITB when the ECH is on, and the difference in ECH on and off is observed at $\rho < 0.5$, with the considerable change in E_r at $\rho = 0.55$ and almost no change in E_r at $\rho = 0$. The HIBP cannot approach at $\rho > 0.55$. The variation in potential is large around $\rho = 0$ and decreases towards the outside.

The width of the e-ITB differs between balanced and counter injections of NBI. Each foot of the e-ITB is located at $\rho = 0.5$ for the balanced injection and at $\rho = 0.25$ for the counter injection. The width of e-ITB in balanced injection case becomes broader than in the counter injection case. The flat portion of T_e between $\rho = 0.25$ and 0.5 seems to be associated with a magnetic island structure due to the counter plasma current.

We summarize that the threshold ECH power to form the e-ITB plasma at $P_{ECH}/n_e = 2.5$, which is higher than the previous report in [4], remains unchanged in H and D plasmas. In this condition, the response of ϕ_H and ϕ_D showed a linear relation.

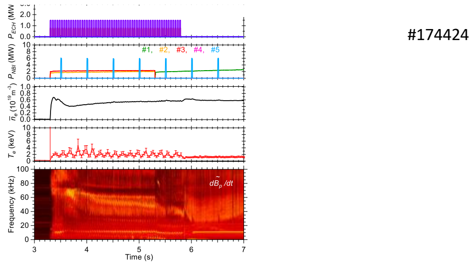

Fig. 1 Plasma discharge with modulated ECH and NBI. NBI#5 is blipped for ion temperature measurement. Line averaged density and electron temperature at the plasma center are plotted.

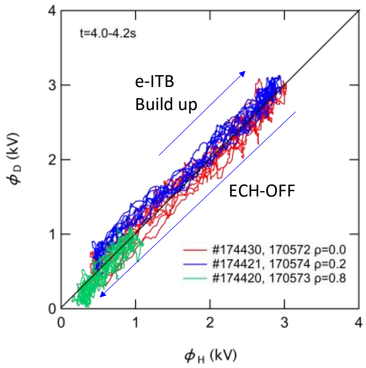

Fig. 2 Time evolution of a potential in H and D plasmas at the same powers of NBI and modulated ECH.

References

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