§4. Achievement of High T_e Plasmas by Upgraded ECRH System in LHD

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Since 2006, the installation of 77 GHz gyrotrons with each output power of over 1 MW has progressed in the LHD.[1)] These high power gyrotrons enabled us to achieve a higher T_e than that previously obtained[2)] and also to survey properties of high T_e plasmas in wide configuration range due to the oscillation frequency selected as 77 GHz, which is different from those of the gyrotrons already installed in the LHD.

Figure 1 shows (a) the radial profiles of T_e for three configuration cases; (R_{ax}, B_0) = (3.53 m, 2.705 T), (3.60 m, 2.705 T) and (3.75 m, 2.75 T) with approximately same electron density of $n_e \sim 0.4\times10^{19}$ m^{-3}. The plasmas were produced and sustained only by centre-focused ECRH with $P_{ECRH} \sim 2.7$ MW. Highly accurate T_e profiles were successfully obtained by the accumulation of the intensity of Thomson scattered light through several fixed discharges with the three YAG lasers all injected together.[3)] As can be seen from Fig. 1, the steepest profile and the highest T_{e0} were obtained for R_{ax} = 3.53 m. Thus R_{ax} = 3.53 m is thought to be better configuration for an achievement of higher T_e plasmas. This result is consistent with a theoretical prediction of neoclassical transport,[4)] although the experimentally obtained thermal conductivity was more than ten times larger than the neoclassical one. PHA, SXCCD and ECE measurements showed that non-thermal electrons considerably existed in these high T_e, low collisional plasmas.[5)] However, we have already confirmed that there was only small amount of influence of the non-thermal electrons on the accuracy of the bulk T_e measurement by Thomson scattering diagnostics.[3)] Non-thermal electrons tended to be produced when an ECRH was obliquely injected. The increase of the population of the non-thermal electrons may increase the absorption power to non-thermal electrons and lead to less contribution of ECRH for bulk plasma heating.

Figure 2 shows (a) the radial profiles of T_e for four n_e cases; 0.23, 0.50, 0.73, 0.77×10^{19} m^{-3} and (b) the dependence of T_{e0} on density-normalized ECRH power (P_{ECRH}/n_e) for R_{ax} = 3.53 m, B_0 = 2.705 T. The rotational transform ($\iota/2\pi$) profile for a vacuum condition is attached in Fig. 2 (a). Clear threshold of n_e and/or that of P_{ECRH}/n_e for the formation of the e-ITB were found in Fig. 2. The T_e profile drastically changed from a flat one to a peaked one in the narrow range of $0.73 \le n_e \le 0.77\times10^{19}$ m^{-3}. Both the shoulder point of the flat T_e profile and the foot point of the e-ITB coincidentally located at the rational surface of $\iota/2\pi$ = 0.5. Once the e-ITB formed, T_{e0} increased with the proportional dependence of $\sim(P_{ECRH}/n_e)^{0.5}$. Finally more than 15 keV of T_{e0} was successfully achieved for low n_e plasmas (n_e = 0.2-0.3×10^{19} m^{-3}).

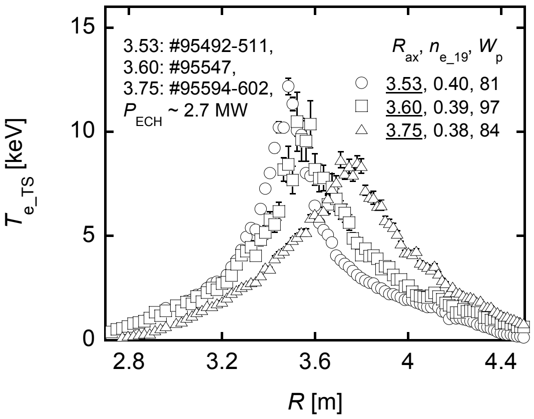

Fig. 1. Radial profiles of T_e for three configuration cases with $n_e \sim 0.4\times10^{19}$ m^{-3}. The plasmas were produced and sustained only by centre-focused ECRH.

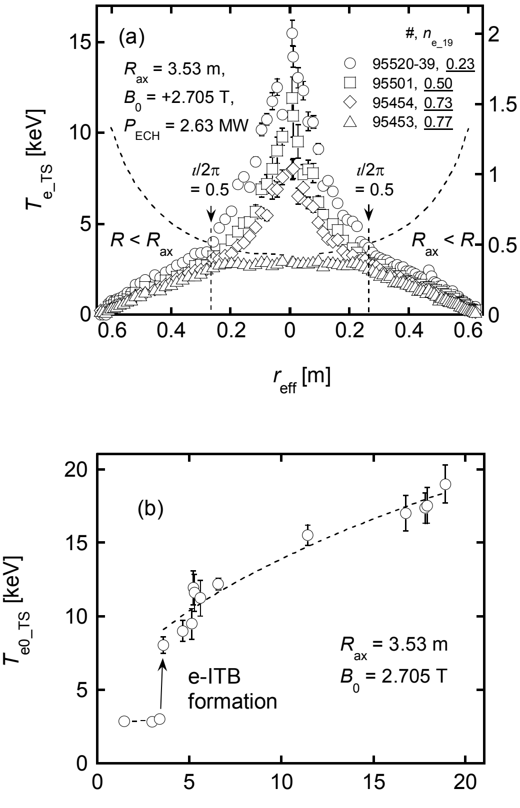

Fig. 2. (a) the radial profiles of T_e for four n_e cases and (b) the dependence of T_{e0} on density-normalized ECRH power for R_{ax} = 3.53 m, B_0 = 2.705 T.

1) H. Takahashi *et al.*, Fusion Sci. Technol. **57**, 19 (2010).
2) S. Kubo *et al.*, Plasma Phys. Control. Fusion **47**, A81 (2005).
3) I. Yamada *et al.*, submitted to Rev. Sci. Instrum.
4) S. Murakami *et al.*, Nucl. Fusion **42**, L19 (2002).
5) S. Kubo *et al.*, proceedings of the 16th Joint Workshop on ECE and ECRH, April 12-15, 2010, Sanya, China.