§11. Improvement in Central Electron Temperature for High-T_i Plasmas in LHD

Takahashi, H., Yoshimura, Y., Osakabe, M., Nagaoka, K., Yamada, I., Murakami, S., Ida, K., Yoshinuma, M., Goto, M., Morita, S., Shimozuma, T., Kubo, S., Igami, H., Nishiura, M., Takeiri, Y., Mutoh, T., High-*T* Group

In order to realize an effective electron heating for high-T_i plasmas in LHD, the optimization of EC wave injection was carried out. In the present state, three 77 GHz gyrotrons with the output power of more then 1 MW were operated for the plasma experiments in LHD. In the research, two lines of these 77 GHz ECRH are used for the plasma startup and the remaining one was superposed on high-T_i phase.

Figure 1 shows the typical time evolution of (a) line-averaged electron density and (b) the central ion temperature T_{i0} and the central electron temperature T_{e0}. The waveform of the ECRH and the NBI are attached in fig. 1 (a). The experiments were performed under the magnetic configuration of R_{ax} = 3.6 m, B_t = -2.85 T. In the discharge, two lines of 77 GHz ECRH from 5.5U and 9.5U ports were used for the plasma startup and three tangential NBs and one perpendicular NB (1O) were injected during t = 3.3-4.5 s. A carbon pellet with ϕ = 1.2 mm was injected at t = 3.8 s and one perpendicular NB (5O) and 2O-77 GHz EC wave were superposed during t = 3.9-4.5 s. As can be seen from fig. 1 (b), the effective electron heating by 2O-77 GHz EC wave was realized for the high T_i plasma and T_{e0} increased up to 4.5 keV. In the case without superposition of the 77 GHz ECRH, T_{e0} in high T_i phase was 3.6 keV at most.

Figure 2 shows (a) the positional relation between the poloidal surface in the vacuum condition and the 2O-EC beam and (b) the time evolution of the magnetic axis position for the discharge of fig.1. In the vacuum condition, the resonance layer of 77 GHz ECRH (2.75 T) is ~15 cm away from the magnetic axis on the equatorial plane. As can be seen from fig. 2 (b), ~18 cm of Shafranov shift occurred after the carbon pellet injection, therefore the effective central heating was thought to be realized by perpendicular injected EC wave from the 2O antenna. In the experiments, the superposition of the 9.5U-77 GHz ECRH instead of the 2O line was carried out, however clear heating effect for the electron was not observed. In this case, centre-focused injection of the EC beam in high-T_i phase was difficult due to the shallow incident angle and the refraction of the EC wave.

Figure 3 shows the map of simultaneously attained T_{i0} and T_{e0}. The open and the solid symbols represent the data obtained previous and 2010 experimental campaign, respectively. The circles and the squares are the results of the discharges using a carbon pellet and the triangles and the diamonds correspond to those using He puff without a carbon pellet. In the 2010 campaign, the new record of T_i was successfully achieved due to the newly-installed perpendicular NB (1O). In addition, the T_e regime for the high T_i plasmas was significantly expanded by the effective electron heating using the 2O-77 GHz ECRH.

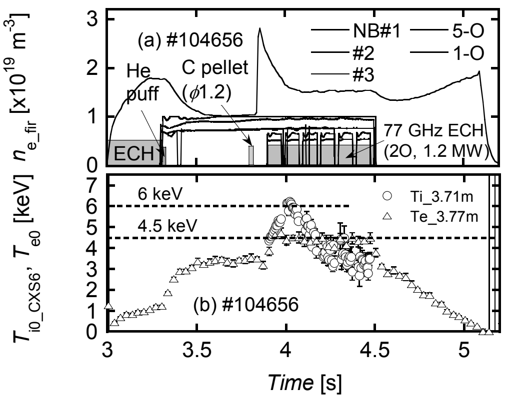

Fig. 1. The typical time evolution of (a) line-averaged electron density and (b) the central ion temperature T_{i0} and the central electron temperature T_{e0}

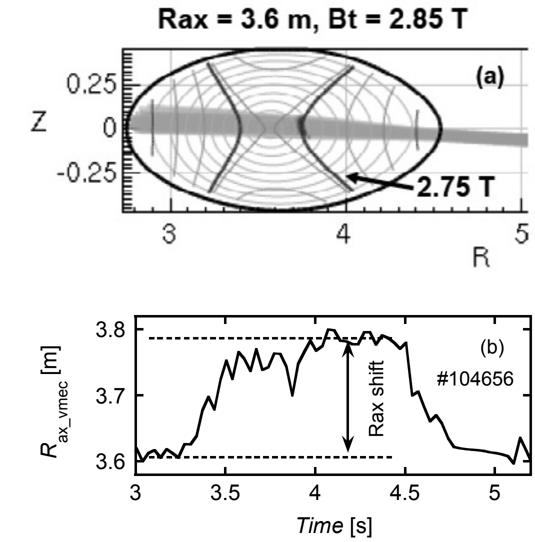

Fig. 2. (a) the positional relation between the poloidal surface in the vacuum condition and the 2O-EC beam and (b) the time evolution of the magnetic axis position

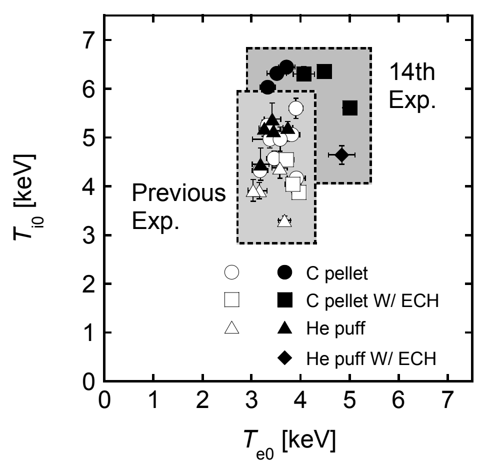

Fig. 3. The map of simultaneously attained T_{i0} and T_{e0}