§6. Extention of High T_e Regime in the Large Helical Device

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Enhancement of the output power per gyrotron has been planned in the Large Helical Device (LHD) and the replacement of the existing gyrotrons with higher-power tubes is in progress. An electron cycrotron resonance heating (ECRH) system with eight gyrotrons has been operated for preionization and plasma heating. Of these, high power 77-GHz gyrotrons with an output power of more than 1 MW each have been operated since the experimental campaign in 2007. At present, three 77-GHz gyrotrons are operational for plasma experiments. In addition, a high power gyrotron with the frequency of 154 GHz (1 MW/5 s, 0.5 MW/CW) was newly installed in 2012. Figure 1 shows the history of the ECRH power coupled to the transmission line P_{MOU} and the port-through power of ECRH into the LHD P_{ECRH_pt}. The heating capability of ECRH on the LHD has been upgraded year by year. The LHD now has 4.6 MW of a simultaneous-injection-ECRH power available for experiments. In the research, we tried the expansion of the high electron temperature regime of the LHD plasmas using the high power ECRH system.

In order to focus the high-power 77 GHz EC wave on the plasma center, the experiments were carried out under the magnetic configurations of R_{ax} = 3.53 m/ B_t = 2.705 T and R_{ax} = 3.60 m/ B_t = 2.705 T. Figure 2 shows the radial profiles of the electron temperature T_e and the electron density n_e in a typical high T_e plasma with the moderate high line-averaged electron density n_{e_fir} of $1\text{x}10^{19}$ m^{-3} produced using ECRH alone. Highly accurate T_e profiles were obtained by the accumulation of data of Thomson scattered light during 6 fixed-condition discharges with the three YAG laser beams all injected together. A central electron temperature of 13.5 keV was successfully achieved using a center-focused ECRH of 4.4 MW. The values of T_{e0} significantly exceeded 8.7 keV, obtained in previous experiments at n_{e_fir} of $1\text{x}10^{19}$ m^{-3}.

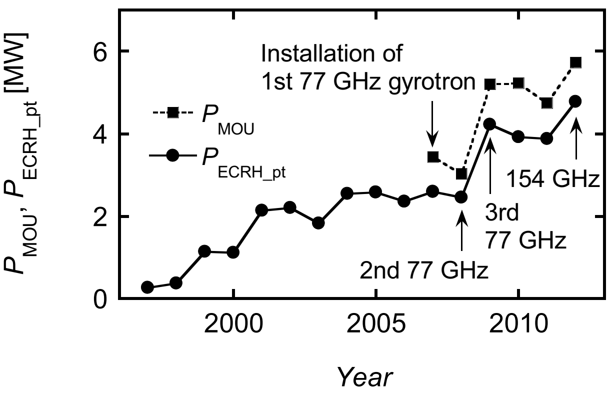

Figure 1. The history of P_{MOU} and P_{ECRH_pt}.

Higher-density operations with n_{e_fir} of more than $3\text{x}10^{19}$ m^{-3} were also carried out using ECRH alone. The plasma stored energy of 530 kJ with the energy confinement time of 120 ms was realized in the discharge without a radiation collapse. The value is new record of W_p in ECRH plasma and is 1.66 times larger than the previous achievement. Figure 3 shows the map of simultaneously attained T_{e0} and n_{e_fir} for ECRH discharges. The plasma parameter regime with regard to the electron temperature was successfully extended in high density conditions.

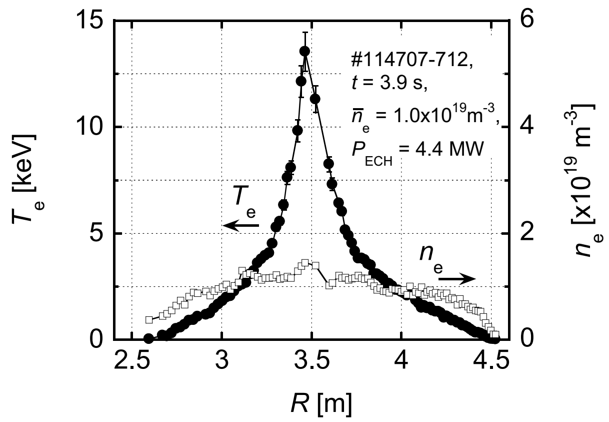

Figure 2. The radial profiles of T_e and n_e in a typical high T_e plasma with n_{e_fir} of $1\text{x}10^{19}$ m^{-3} produced using ECRH alone.

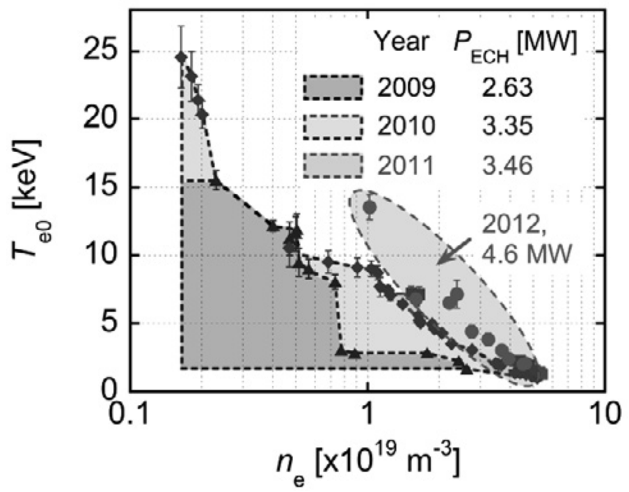

Figure 3. The map of simultaneously attained T_{e0} and n_{e_fir} for ECRH discharges.