§73. High Harmonic Electron Cyclotron Heating by 77GHz High Power Injection

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High-harmonic electron cyclotron heating is an effective method to heat high density and high β plasmas. In place of the fundamental ordinary (O1) mode and the second harmonic extraordinary (X2) mode heating, sufficient heating efficiency will be expected using the second ordinary (O2) mode and the third extraordinary (X3) mode heating scenario, when the temperature and density of a target plasma is sufficiently high[1)]. For example, a cut-off density of the X3 and O2 mode wave propagation is 4/3 times and double of X2 mode cut-off density, respectively. The objective of this research is to confirm the effectiveness of X3 and O2 mode heating experimentally.

In the O2 heating experiment, the toroidal injection angle dependence of the O2 mode heating efficiency was investigated using 77GHz power injection with 2-O antenna that was installed in the horizontally elongated cross section. A target plasma was sustained by NBI, and its density was ramped-up from 1 to $5\times10^{19}\mathrm{m}^{-3}$ above the X2 cut-off density ($3.7 \times 10^{19}\mathrm{m}^{-3}$) during the discharge time of 1.5 s. The magnetic field strength at the magnetic axis of 3.6 m was 1.43 T. Four ECH pulses with 200 ms pulse width and 1 MW power were injected every 300 ms. The absorption rate gradually decreased from 50 % to 30 % when the line-averaged density increased from 1 to $4 \times 10^{19}\mathrm{m}^{-3}$. The injection angle dependence, however, could not be noticed clearly.

For X3 mode heating, the dependence of the heating efficiency on the focal position of U-antenna injection (9.5-U and 5.5-U) was investigated. A target plasma was sustained by NBI, and its electron density, temperature and β-value were $0.7 \times 10^{19}\mathrm{m}^{-3}$, about 1.2 keV and 0.6 %, respectively. The absorption rate was evaluated at on- and off-timing of the ECH pulses. Figures 1 (a) shows the absorption rate as a function of radial focal position on the equatorial plane R_f of 9.5-U antenna. The 3rd harmonic electron cyclotron resonance exists at $R = 2.743$ m. The absorption rate has a maximum around $R_f \sim 3.66$ m for the on-timing estimation and $R_f \sim 3.7$ m for off-timing estimation, respectively. Time variations of sniffer probe signals that were detected at the 9.5-L port just opposite side of the 9.5-U antenna are plotted in Fig.1 (b) for $R_f \sim 3.72$ m case and in Fig.1 (c) for $R_f \sim 3.6$ m case, respectively. Because a bigger signal of the sniffer probe suggests poorer absorption, the signal levels at ECH on- and off-timings shown in Fig.1 (b) and (c) can partly explain the dependence of the absorption rate in Fig.1 (a). This suggests that changes in temperature and density at the focal point strongly affect the wave trajectory and absorption. The experimental results give the information of the optimum antenna setting for the best absorption. A change of the hitting position on the graphite target plate installed at the opposite side of 9.5-U antenna with and without a plasma suggests a deflection of the wave ray by the plasma and necessity of feedback control of antenna focal point according to the change of plasma parameters.

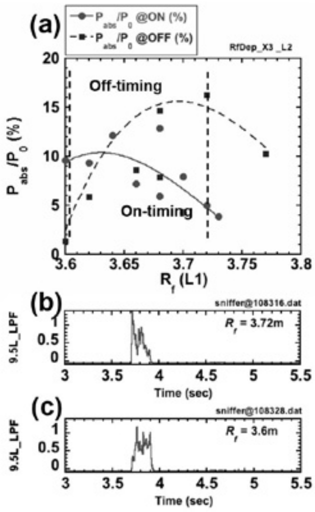

Fig. 1: The absorption rate for 9.5-U antenna is plotted as a function of radial focal position R_f (m) on (a). The values were evaluated at the on- (closed circles) and off-timing (closed squares) of ECH pulse. (b) Time variation of the sniffer probe signal detected at 9.5-L port for the $R_f = 3.72$ m case. (c) Time variation of the sniffer probe signal for the $R_f = 3.6$ m case.

Figure 2 shows the electron temperature and density profiles before and during stair-like ECH power injection. Using three 77GHz gyrotron, totally 3 MW power was injected during the highest power injection period. The central electron temperature increased significantly by about 0.5 keV with almost constant density.

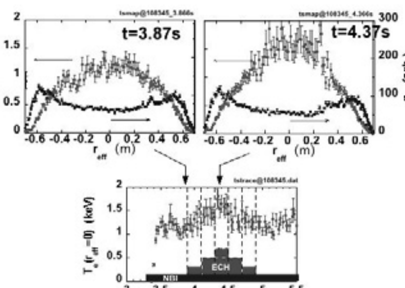

Fig. 2: The electron temperature and density profiles before and during stair-like ECH pulse.Time evolution of a central temperature and ECH pulse timing are also plotted.

1) T Shimozuma, *et al.*, PFR, (2008) Vol.3, S1080.