§ 12. Electron Heating Using ICRF Fast Wave

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An ICRF fast wave electron heating has been studied on the LHD. The electron heating via a mode conversion was succeeded and the direct electron heating via an electron Landau damping is planned.

It is predicted that the Landau damping depends on the electron temperature (T_e) and the plasma electron density (n_e). Therefore when those parameters are increased, it is physically interested in whether the direct electron heating is observed or not. In the ICRF heating experiment there are several proposals as follows: (i) the high power injection to achieve high T_e and n_e based on the third experimental campaign [1]. (ii) verification of the electron heating via the Landau damping in the absence of the ion cyclotron resonance layer, (iii) the electron heating in the higher harmonic ion cyclotron frequency using a innovative antenna, i.e., a combline antenna [2], which is under development.

In the 6th experimental campaign, the electron heating experiment via the Landau damping was carried out using two frequencies; 44.1MHz (shot #38627) and 44.1MHz and 38.47MHz (shot #38644). The experimental condition was B=2.14T, R_{ax}=3.6m, γ=1.254 and P_{ICH}=500kW. The electron density and the minority ratio were $<n_e>=1.2\times10^{19}m^{-3}$ and $n_H/(n_H+n_{He})=0.1$ in the plasma discharge with 44.1MHz, and $<n_e>=2.6\times10^{19}m^{-3}$ and $n_H/(n_H+n_{He})=0.05$ in the plasma discharge with 38.47MHz and 44.1MHz. The position of ion cyclotron layer was located near the plasma edge in both frequencies as shown in Fig.1.

The time evolutions of the electron temperature measured by the ECE (electron cyclotron emission) are shown in Fig.2; (a) in the plasma discharge with 44.1MHz and (b) with 44.1MHz and 38.47MHz. The turn-off time of the ICRF heating is 1.4s. The electron heating is observed in the plasma discharge with 44.1MHz and 38.47MHz because of the fast decay of the electron temperature. As the energy exchange time between ions and electrons is about 60ms and the electron decay time is an order of a few ms, the electron heating power source is not the power flow from the high-energy ions. The electron is heated directly in the plasma discharge with 44.1MHz and 38.47MHz. The heating power density to electrons is given by the following equation at the ICRF power turn-off time.

$$P_e = \frac{3}{2} e n_e \left[\left.\frac{dT_e}{dt}\right|_{t=t_0-0} - \left.\frac{dT_e}{dt}\right|_{t=t_0+0} \right]$$

The absorbed power over the normalized radius of ρ=0.265 to ρ=0.378, i.e., $P_e=3/2e\int n_e(dT_e/dt)dV$ is calculated to be 65kW in the plasma discharge with 44.1MHz and 38.47MHz. In the other series experiments of the electron density scanned from 2.3 $\times10^{19}m^3$ to $4.0\times10^{19}m^3$ in the plasma discharge with 44.1MHz and 38.47MHz, little difference of the electron heating efficiency was observed. As the ion cyclotron resonance layers are located near the plasma edge, the minority heating is thought to be weak and the effective electron heating from the direct fast via the Landau damping would have been expected. The observed electron heating is deduced to be the mode conversion heating in the fast wave with 38.47MHz. The position of mode conversion layer depends on the ratio of n_H/n_e. Though it was changed among the discharges of n_e scan, the calculated shift of the mode conversion layer is assessed to be 1 cm using the plasma parameters. It is a small normalized value of $\Delta\rho$=0.02, so the shift of the heating regime is not be noticeable in the present experiment.

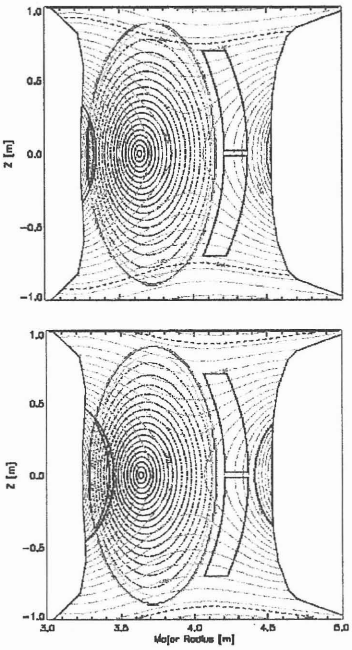

Fig.1 H cyclotron resonance layer (a) f=44.1MHz (b) f=38.47MHz and f=44.1MHz.

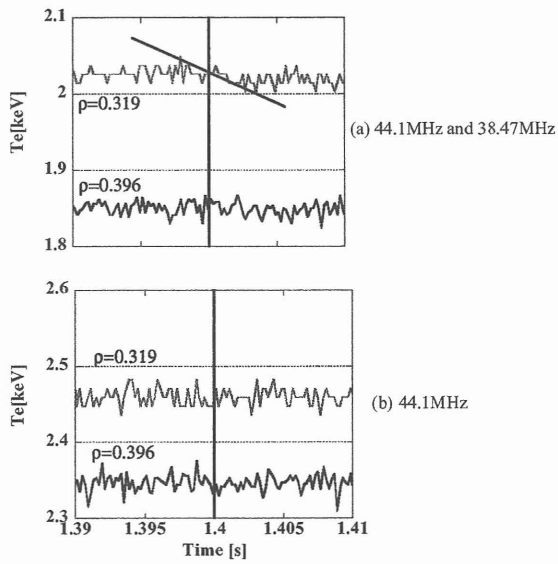

Fig.2 The time evolution of electron temperature

Reference

1) K. Saito, *et al.*, Nuclear Fusion, vol.41, (2001)
2) N. Takeuchi, *et al.*, J. Plasma Fusion Res. SERIES, vol.5, (2002)