Fast wave electron heating experiments focusing on competition between damping mechanisms on Large Helical Device

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The fast wave (FW) can be used for electron heating and current drive in high density, high beta plasmas. FW experiments have been investigated in tokamaks [1-3], and there are many challenging works in helical devices. For a helical demo reactor with very high plasma density (10^{22} m^{-3}), core plasma heating (e.g., by NBI) is key issue. FW is useful for heating the plasma to ignition, because there is no high density accessibility limit. Since ion cyclotron heating often creates high energy ions that can damage the antenna and the vacuum vessel, FW electron heating is desirable. In Large Helical Device [4], initial FW electron heating experiments were performed successfully [5]. At high harmonics of ion cyclotron frequency, electron Landau damping (ELD) and magnetic pumping (MP) can dominate over ion cyclotron harmonic damping [6]. In this experiment, magnetic fields B = 1.5 T and 1.86 T were used. In the 1.5 T case, the hydrogen second harmonic cyclotron resonance ($2\Omega_H$) layer exists around $\rho = 0.5$, and there is competition between CD (cyclotron damping) and ELD/MP. In the 1.86 T case, the $2\Omega_H$ layer exists around $\rho = 0.9$. Since the LHD antenna [7] is not arrayed, the $k_{||}$ (wavenumber parallel to the magnetic field) spectrum is broad and centered around zero. For effective Landau damping, $\omega/(k_{||}v_{the}) \cong O(1)$, high electron temperature is needed. Here ω is the FW angular frequency and v_{the} is the electron thermal velocity. In the 1.5 T case with electron cyclotron (EC) and neutral beam (NB) heating, the electron temperature increased from 0.9 keV to 1.1 keV by FW heating. Electron cyclotron emission using modulation techniques of FW injection indicated central electron heating. In the 1.86 T case, there was no evidence of direct electron heating. Energetic ions were observed during FW heating of the NB preheated plasma. In this case, the EC resonance was off-axis, and the electron temperature was not high enough to absorb the FW.

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