§52. Behavior of High Energy Electrons during High Power ECRH

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The generation and the behavior of high energy electrons are especially important in high power electron cyclotron resonance heated (ECRH) plasma helical plasma confinement magnetic configurations since they can play an essential role in controlling the electron flux that induces radial electric field in the collisionless regime. In order to clarify the generation mechanism of the supra-thermal electrons and their interaction with ECRH, second and higher harmonics ECE are calculated and compared with the experiment.

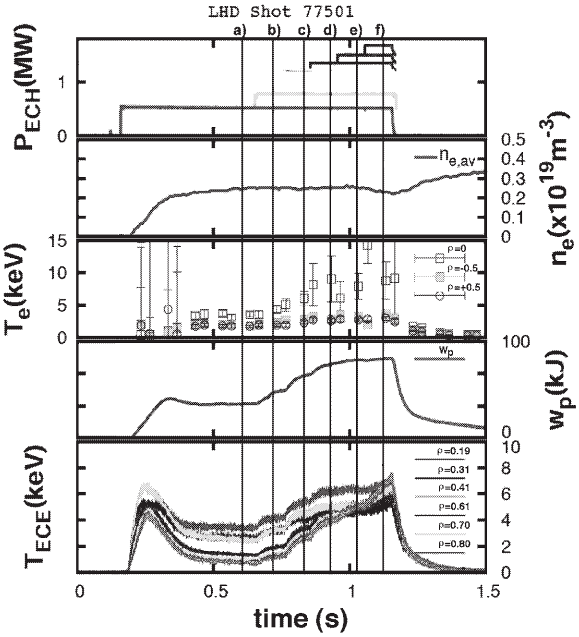

Fig. 1: Time evolutions of ECRH power P_{ECH}, averaged electron density n_e, Thomson temperature $T_e(\rho = 0, -0.5, +0.5)$, stored energy W_p and ECE radiation temperature $T_{\mathrm{ECE}}(\rho = 0.19, 0.31, 0.41, 0.61, 0.70, 0.80)$, during low density, high power ECRH experiment.

High power ECRH experiments have been performed on relatively low density ($n_e \leq 0.3 \times 10^{19}$ m^{-3}) with total input power of 1.8 MW. Typical discharge waveforms are shown in Fig.1. ECRH power from one 77 GHz, one 84 GHz, two 82.7 GHz and three 168 GHz is injected in to LHD stepwise successively to attain 1.8 MW in total. The density is adjusted to keep $n_e \leq 0.3 \times 10^{19}$ m^{-3} as shown in the second column. Time evolutions of the central and half radius electron temperature measured by Thomson scattering are plotted on the third column. The central electron temperature increases as the power increased up to 1 MW, but the increase saturates or begins to scatter after the power exceeds 1MW. Stored energy

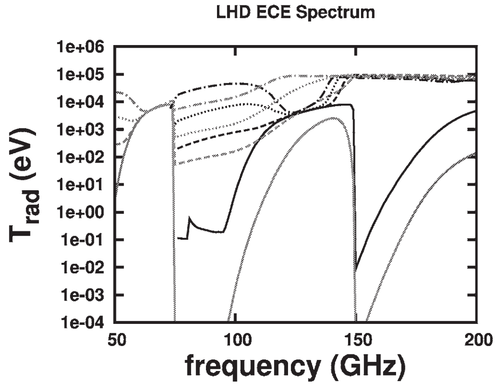

Fig. 2: Calculated spectra of ECE for a horizontal line of sight of LHD. All spectra are calculated for the bulk electron temperature T_{e0}=8 keV with peaked profile and n_{e0} 5 × 10^{18} m^{-3} with flattened profile. Black and gray lines show those for X mode and O mode, respectively. Solid lines are those without high energy electrons. Broken, dotted and dash-dotted lines correspond to those with high energy density ratio of 0.01 %, 0.1 %, 1 % of bulk electrons, respectively. Included high energy electrons are fixed at 100 keV Maxwellian.

increases almost in proportional to the injected ECRH power and finally reaches 80 kJ. In the bottom column of Fig.1 are shown the ECE radiation temperature evolutions at ρ = 0.2, 0.3, 0.5, 0.6, 0.7, 0.8. The peripheral ECE channels, corresponding to ρ=0.7 and 0.8 shown in the bottom column of Fig.1 clearly show non-thermal feature at the ECRH injection power of more than 1 MW. Hard X-ray (HX) pulse height analysis (PHA) along several vertical chords are performed simultaneously. The X-rays at energy range of 10 to 100 keV increase as the injection power (and the temperature as a result) Those at the energy range of more than 100 keV also begin to appear just in correspondence to the non-thermal feature of ECE discussed above. These results suggest that high energy electrons of more than 100 keV are generated at high power of more than 1 MW ECRH phase.

In order to investigate the ECE spectrum with the presence of high energy components, calculation method integrating the radiation transfer equation in LHD is newly developed. In Fig.2 are shown the calculated spectra for X and O mode without and with the high energy electrons of 100 keV of 0.01 %, 0.1% and 1% bulk density. The energy and the density profiles are assumed to be the same as the bulk electrons. The shape of the spectrum without high energy component reflects the bulk electron temperature profile. The emission of the frequency corresponding to the second harmonic at the core plasma region (120 to 130 GHz) is strongly absorbed due to the high optical thickness and becomes almost thermal level. These results indicated that the ECE spectra are sensitive to the presence of high energy electrons, but reabsorption mechanism suppress the non-thermal emission at optically thick region. Measured and calculated ECE spectra show in good correspondence assuming the high energy electron of 75 to 100 keV and 0.01-0.1 % of bulk electron density.