§77. Influence of High Energy Electrons on ECRH in LHD

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Recent upgrade of the electron cyclotron resonance heating (ECRH) system in LHD enabled to study the plasma confinement properties at the far low collisional or collision-less regime in the helical system where specific confinement features are predicted from the neoclassical transport theory. In order to discuss the confinement properties in such collision-less regime, the accurate estimation of the behavior of the high energy electrons as well as that of the bulk electrons temperature is required, since the high energy electrons can absorb injected ECRH power at the relativistically down shifted frequency and can deposit their energy to the bulk electrons out of the region where they absorb the energy from injected EC wave. In order to achieve or to sustain higher bulk electron temperature in low the density region, ECRH heating scenario have to be explored taking such the relativistic effect into account. The electron cyclotron emission (ECE) is the inverse process of the ECRH absorption. Therefore, the ECE spectra are also sensitive to the presence of high energy electrons and include integrated information of the energy and distribution of the high energy electrons.

A series of experiment is conducted to investigate the acceleration and relaxation process of the high energy electrons. Three gyrotrons, each capable of delivering more than 1 MW power into LHD, are turned on to the low density (0.1×10^{19} m^{-3}) plasma. By changing the injection condition of each antenna and the antenna from which power is modulated, the response of the plasma is observed by diamagnetic stored energy, pulse height analysis of the hard X-ray, and ECE spectra. Figure 1 is the example of the response of the stored energy, w_p. Here are shown the time response of w_p to the 5 Hz power modulated ECRH injection for low (0.1 $\times$ 10^{19} m^{-3}). High density (0.9×10^{19} m^{-3}) case is also shown with dashed-dotted line. Maximum w_p in low density case reaches to the comparable level as that in the high density case. That is a clear indication of the presence of high energy electrons. The response time of the bulk electrons is the order of 20-50 ms at high density. While that of high energy components is 200 to 300 ms. The more high energy electrons are created and the response of w_p is enhanced as the heating position is shifted off-axis toward high field side. Those are qualitatively explained by the fact that the drift surface of the ripple trapped electrons and the effect of relativistically down shifted resonance.

ECE spectra gives detailed information about the energy and position of the high energy electrons. In Fig. 2 is shown the contour of the ECE spectra as time in horizontal axis and radial normalized position of the second harmonic cold resonance on the vertical axis. The peaks appear in the low frequency side (upper side corresponding to peripheral second harmonic cold resonance position) shows slower response than the high frequency side. Detailed comparison of the calculated ECE spectra including the high energy components and the results is underway.

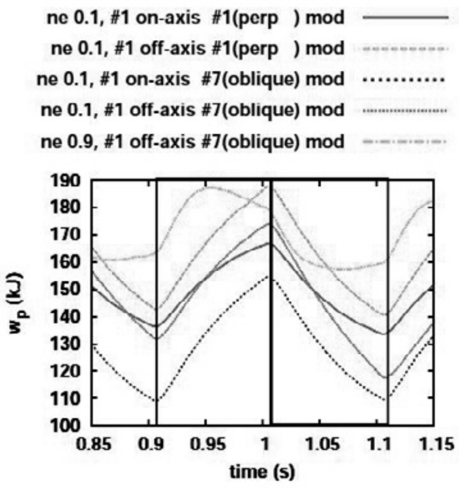

Fig. 1: Time response of the stored energy to 5 Hz modulated ECH for low density (0.1×10^{19} m^{-3}) cases. The cases for the perpendicular injection beam modulated with on-axis and off-axis are plotted with solid and broken lines, respectively. Dotted lines show the cases where oblique injection beam is modulated for on- and off- axis perpendicular heated plasma with rough and fine dots, respectively. High density case (0.9×10^{19}m^{-3}) with off-axis perpendicular are modulated oblique injection is shown with dashed-dotted line for reference.

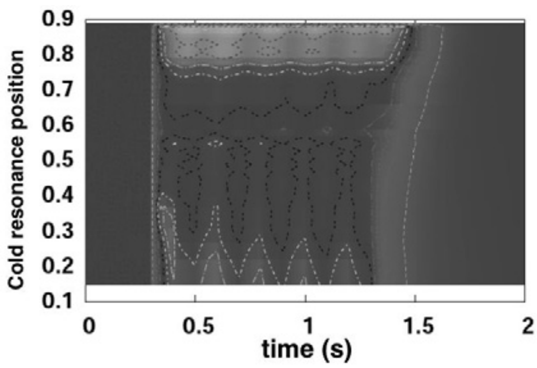

Fig. 2: ECE spectra contour showing the temporal change of the ECE spectrum a function of averaged minor radius corresponding to a second harmonic resonance position. Perpendicular off-axis injection beam is modulated with 5 Hz on the plasma sustained by obliquely injected ECRH.