§9. Electron Bernstein Wave Heating with the Direct Oblique Launching of the X-mode Toward the Peripheral Region

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Electron Bernstein wave (EBW) is an electrostatic mode and is required to be excited in the upper hybrid resonance (UHR) layer via the mode conversion process from the slow extraordinary (X)- mode. In LHD, direct launching of the slow X-mode toward the UHR layer is available with the use of two existing antennas installed in 1.5-L bottom port for the usual electron cyclotron heating (ECH) without installing any additional mirror. In addition to the experimental results obtained with the use of #4 antenna, characteristics of the power absorption profile in the slow X-B experiment has been investigated with the use of #5 antenna.

Fig. 1 shows an oblique cross section of LHD along the electromagnetic wave beam launched from #5 antenna. The beam path changes from the vicinity of the vacuum vessel wall toward the central region of the plasma shot by shot as (A), (B) and (C) drawn on the same cross section. Fig. 2 shows a set of discharge waveforms when the X-mode was launched toward the direction (B) with 100%, 39Hz power modulation. The stored energy and the electron temperature were modulated coincident with the ECH pulse. Fig. 3 (A)-(C) shows profiles of the 39Hz perturbation amplitude and the phase difference from the ECH pulse for each case of the launching direction (A)-(C) drawn in Fig. 1 respectively. In the case of (a), where the beam passes very close to the vacuum vessel wall, the increase of the electron temperature was the highest with the X-mode launching. Two sets of the peak of the perturbation amplitude and the bottom of the phase appeared. One of them is located near the fundamental ECR layer. While, the other was located in the inner region apart from the ECR layer.

In the oblique propagation, the fundamental X-mode has a possibility to be absorbed well in the ECR layer. The power absorption as an electromagnetic X-mode and the power absorption as the mode converted EBW might occur simultaneously in this case. The launched X-mode encounters the ECR layer at first and a part of the wave power was absorbed as the X-mode, then the residual wave reaches the UHR layer and excites EBW. As the X-mode beam bore off from the wall, the peak of the amplitude became lower and to be almost the same as the case of the O-mode launching. The absorption as the O-mode is very weak in this experimental configuration, therefore many part of the wave power might be absorbed after the multiple reflections in these cases of O-mode launching. The edge of the electron density profile widely expanded outside of the last closed flux surface in this experiment. Therefore the X-mode might encounter the right-handed cutoff and be reflected. Then the wave power might be absorbed across the wide region during multiple reflections.

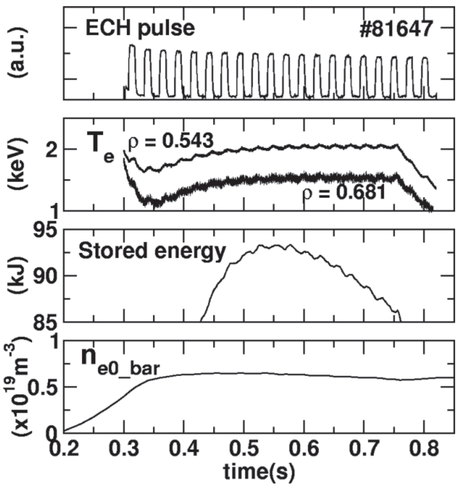

Fig.2: Discharge waveforms in another slow X-B experiment. The electron temperature and the stored energy increase with the modulated ECH pulse.

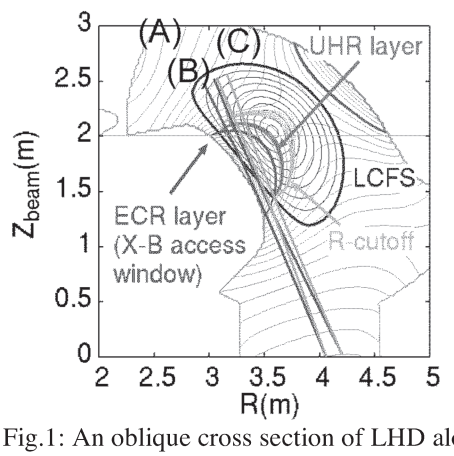

Fig.1: An oblique cross section of LHD along the EC-wave beam launched from #5 antenna. The wave can access the UHR layer through the ECR layer, that is X-B access window.

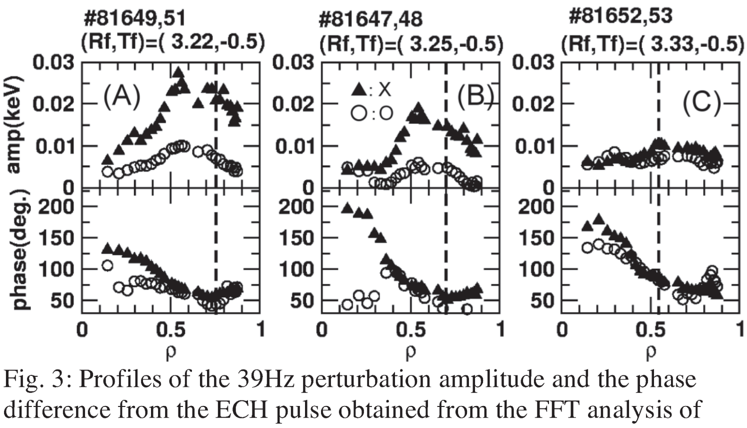

Fig. 3: Profiles of the 39Hz perturbation amplitude and the phase difference from the ECH pulse obtained from the FFT analysis of the ECE signals. Triangles means X-mode launching and circles means O-mode launching. (A), (B) and (C) correspond to each launching direction (A), (B) and (C) drawn in Fig. 1.