

§64. Observation of Parametric Decay Waves Excited by O-mode Launching in a Super Dense Core Plasma

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In extremely high dens plasmas where the electron density exceeds the cutoff density of electron cyclotron (EC) waves, EC waves cannot propagate as the normal propagation modes of the electromagnetic wave. If the electron cyclotron layer is located in such an over-dens region usual ways of electron cyclotron resonance heating (ECRH) with normal electromagnetic modes cannot be applied. The electron Bernstein wave (EBW) is an electrostatic mode and can propagate in the plasma without the density limit. Since EBW is cyclotron damped, ECRH by EBW has been expected as a promising substitute for usual ECRH by electromagnetic modes. One way to excite EBW in over dens plasmas is to launch the ordinary (O-) mode from the low field the plasma so that it couples with the extraordinary (X-) mode at the point where the plasma cutoff of the O-mode and left handed cutoff of the X-mode coincide with each other. After the coupling, the X-mode proceeds toward the upper hybrid resonance (UHR) layer, where the mode conversion to the EBW occurs (O-X-B method).

In LHD when the super dense core (SDC) plasma is generated, the electron density around the ECR layer exceeds the cutoff density for 77GHz-84GHz millimeter waves used for ECRH. ECRH by EBW has been studied to expand applicable parameter ranges for ECRH in LHD. In the last 13th experimental campaign, 77GHz millimeter wave was launched to excite EBW in super dens core plasma. The magnetic configuration was (R_{ax} , B_t , γ , B_q)=(3.75m, 2.64T, 1.254, 100%). The maximum central electron density reached $1.0 \times 10^{21} \text{m}^{-3}$ that is more than ten times higher than the cutoff density of the 77GHz electromagnetic wave. Previous numerical studies for EBW excitation in LHD has suggested that the excited EBW is absorbed in the peripheral region sometimes outside the last closed flux surface¹⁾. Since the upper hybrid resonance layer of 77GHz EC wave is in the peripheral region near the helical coil and as soon as EBW is excited the Doppler-shifted resonance condition is fulfilled. It is better to adopt the second harmonic EC frequency range to put the UHR layer more inner side of the plasma to heat the central region. However, whether EBW itself could be excited in the UHR layer is verified by the measurement of the parametric decay wave that is excited by non-linear coupling process during the mode conversion in the UHR layer. Two kinds of frequency range of the parametric decay wave can be excited as follows.

$$\begin{aligned} f_1 &= f_{\text{ECH}} \pm n * f_{\text{LH}} \\ f_2 &= n * f_{\text{LH}} \end{aligned} \quad (n=1, 2, 3, \dots)$$

Where f_{LH} is the lower hybrid wave frequency and f_{ECH} is the frequency used for ECRH. For hydrogen plasmas

generated in LHD, f_{LH} is less than 1 GHz. Frequency spectrums in the frequency range around f_{ECH} was measured by the radiometer system originally constructed for the collective Thomson scattering measurement (CTS). In this experiment the probe beam and the receive beam were not crossed as normal way of CTS measurement. Fig. 1 shows a frequency spectrum during the left-handed circularly polarized wave (nearly the O-mode) injection to a SDC plasma. From -2GHz to +2GHz a spectrum structure was obtained. Fig. 2 also shows a spectrum structure when the right-handed circularly polarized (nearly the X-mode) however the intensity was about tenth of that of the case of the nearly O-mode injection. When the ECRH power was not injected, no spectrum structure was observed. In this experimental condition there were no background ECE signals in frequency ranges of CTS. Observation of the frequency spectrum structures which have a dependence of the polarization suggests that the condition of EBW excitation could be realized although no evidence of heating by injection of ECRH power was observed.

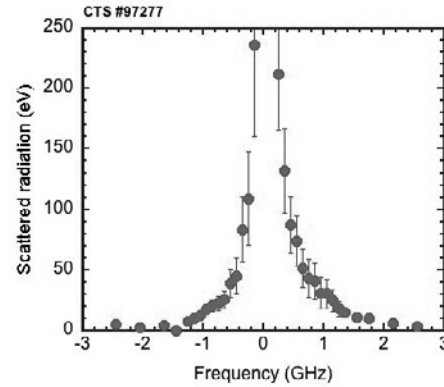


Fig. 1: Frequency spectrum measured by CTS radiometer during the nearly O-mode injection. The set aiming point was (R_f, T_f, Z_f) = (3.9m, 0.9m, -0.22m).

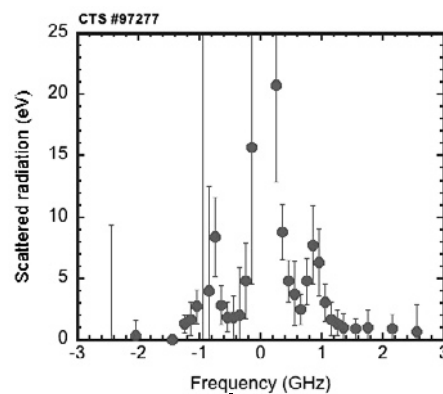


Fig. 2: Frequency spectrum measured by CTS radiometer during the nearly X-mode injection. The set aiming point was (R_f, T_f, Z_f) = (3.9m, 0.9m, -0.22m).