§56. Electron Bernstein Wave Heating in Super Dense Core Plasmas on LHD

Tanaka, H., Maekawa, T., Uchida, M., Nishi, S. (Grad. School of Energy Science, Kyoto Univ.),
Kubo, S., Shimozuma, T., Yoshimura, Y., Igami, H.

On LHD, the central electron density in the super dense core (SDC) plasma exceeds 10^{21} m^{-3}, which is more than ten times higher than the cut off density of microwaves used for usual electron cyclotron heating (ECH). ECH by microwaves in such over-dense plasma is expected when the injected microwave is mode-converted at the upper hybrid resonance (UHR) layer to electron Bernstein wave (EBW). It can propagate into the high density plasma core without density limit and can be absorbed by electron cyclotron (EC) damping. The efficiency for the mode-conversion strongly depends on wave injection angle and position, polarization and density gradient. The purpose of this study is to search the optimal condition for EBW heating using existing ECH system.

Comparing the available microwave power with the neutral beam injection power necessary for sustaining the SDC plasmas, it is not expected to observe the distinct temperature increment by EBW heating. It is known that parametric decay instability is commonly excited during the extraordinary (X)- EBW (B) mode conversion process at the UHR layer. Therefore, the optimal condition for the mode-conversion to EBW is found by observing the excited amplitude of the parametric decay instability.

In the 11th experimental campaign, observation of the parametric decay spectrum in the lower hybrid (LH) wave range of frequency has been tried with the use of the ICRF antenna installed in 4.5-L bottom port for four microwave injection conditions, O- or X-mode in the perpendicular injection and O- or X-mode oblique injection. In the X-mode oblique injection, 84GHz microwaves are launched obliquely from the bottom port, so that the slow X-mode wave can access the UHR layer directly from the high magnetic field side and excites EBW. Figure 1 shows the frequency of the lower hybrid wave excited by the 84GHz pump wave at the UHR layer. Because the wave reaches the UHR layer located in the peripheral region where the electron density is low, the LH frequency is expected to be low as several hundreds MHz. The magnetic field configuration was (R_{ax}, B_{ax}, γ, Bq) = (3.6m, 2.75T, 1.2538, 100%) and the central electron density was 0.4 x 10^{19} m^{-3}, that was less than the cutoff density. Figure 2 shows the observed frequency spectra. In the case of perpendicular launching, a broad spectrum was obtained with the X-mode launching, however only very weak spectrum was obtained with the O-mode launching as shown in Fig. 2 (a). In the perpendicular propagation, the O-mode is well absorbed at the fundamental electron cyclotron resonance (ECR) layer. On the contrary, the X-mode cannot be absorbed well and suffers multiple reflections. Some of the multi-reflected waves might approach the UHR layer from the high field side as the X-mode and may induce the parametric instability. In the case of oblique launching, X-mode encounters the fundamental ECR layer before it reaches the UHR layer and has a possibility to be absorbed there as the X-mode. A stronger spectrum was obtained with the X–mode launching than the O-mode launching as shown in Fig. 2 (b). It suggests at least a part of the launched X-mode reaches the UHR layer without being completely damped out at the ECR layer and has possibility to excite EBW. Actually, power absorption is observed by ECE in the inner region of the plasma apart from the ECR layer though the wave approaches the ECR layer from the outer side.

Relative sensitivity calibration of the ICRF antenna to a loop antenna was done after the experimental campaign. Average sensitivity above 500MHz is about 20dB lower than that below 100MHz. Moreover, above 100MHz, the power sensitivity of the ICRF antenna drastically changes almost periodically within 100MHz. The difference between the peak and the bottom is about 30dB. These characteristics might explain the absence of the harmonics structure in these spectra.

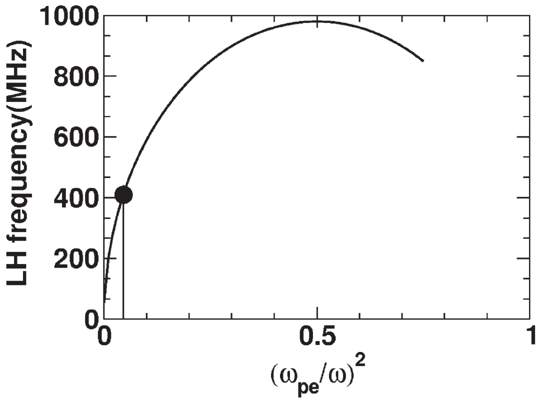

Fig. 1 : LH wave frequency in the pure hydrogen plasma plotted as a function of $(\omega_{pe}/\omega)^2$ that is proportional to the electron density at the UHR layer. Here, ω_{pe} is the plasma angular frequency and ω is the wave angular frequency.

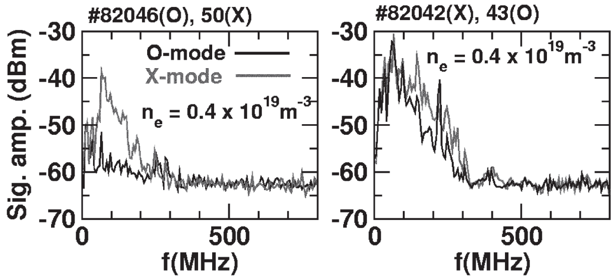

Fig 2. : Frequency spectra in LH wave range of frequency in the case of (a) perpendicular launching for usual ECH, and (b) oblique launching for X-B heating. Sensitivity calibration for each frequency is not done.