§59. Demonstration of Electron Bernstein Wave Heating via the O-X-B Mode Conversion Process by High Power 77GHz Millimeter Wave Launching

Igami, H., Yoshimura, Y., Kubo, S., Shimozuma, T., Takahashi, H., Kumazawa, R.,
Idei, H. (Kyushu Univ.)

In extremely high dense plasmas where the electron density exceeds the cutoff density of the electron cyclotron wave, electron cyclotron wave heating (ECH) by electron Bernstein wave (EBW) has been expected a possible substitute for ECH by normal electromagnetic modes. Excitation of EBW via the Ordinary (O) – the extraordinary (X) – EBW (B) mode conversion process by launching the O-mode from the low field side has no density limit in application. Thus this method which is so called the O-X-B method has possibility for additional local heating in the super dense core (SDC) plasma.

In the 14th experimental campaign, change of the gradient of the stored energy during the launching of 77GHz millimeter wave from the low field side was observed when the electron density exceeded the cutoff density of 77GHz (7.35 x $10^{19}m^{-3}$) in the most region inside the last closed flux surface (LCFS). Figure 1 shows the discharge waveforms in the experiment. In this experiment helium was selected as the working gas for production of high dense plasma in relatively low magnetic field configuration where (R_{ax}, B_t, γ, Bq)=(3.75m, 2.2T, 1.2538, 100%). This configuration was adopted to locate the power absorption region inside the LCFS by reference to the previous numerical investigation. The gradient of the stored energy (Wp) increases after turning on the 1.08MW ECH power as the O-mode and it decreases after turning off the ECH power. We estimated the absorbed power by the change of the gradient of the Wp after turning on/off of the EC power. The averaged estimated absorbed power was about 16% of the launched power. The line-averaged density does not increase by launching of the ECH power. Therefore the gradient change of Wp may mainly cause from the increase of the electron temperature by ECH by the excited EBW.

Figure 2 shows the contours of the O-X-B mode conversion rate T_{OXB} plotted as a function of the aiming point at R=3.9m of the launched millimeter wave. T_{OXB} for the aiming point adopted in the experiment is 20% that is consistent with the estimated absorbed power if all of the excited EBW is absorbed. In this experimental configuration the maximum T_{OXB} is about 60% in the range of settable aiming point without being prohibited by the wall.

For each ray of the beam center and the points 60 degrees apart in a circle of 1/e power of the beam, characteristics of the propagation and the power absorption were numerically analyzed by ray-tracing calculation with the experimental condition. About 8-20% of the excited EBW is absorbed at ρ~0.3 where ρ is the normalized minor radius and the rest is absorbed at ρ~0.9. The trajectory of the ray can be affected by the density profile outside the LCFS. Near the divertor legs the density profile spreads apart from the LCFS while the region distant from the divertor legs the plasma boundary mat be near the LCFS. In the ray tracing calculation, a density profile whose boundary is located at the last closed flux surface was adopted. The contour map shown in figure 2 is also obtained with use of the same density profile. If the different density profile whose spreads outside the LCFS is adopted T_{OXB} at the experimental aiming point is almost zero. It may be important to know the poloidal asymmetry density profile outside the LCFS for ray tracing calculation with high accuracy. Information of the power absorption region is important to verify the result of the calculation considering the density profile with the experimental result. The soft X-ray emission measurement may help to observe the change of the electron temperature if the change of the electron density is negligible.

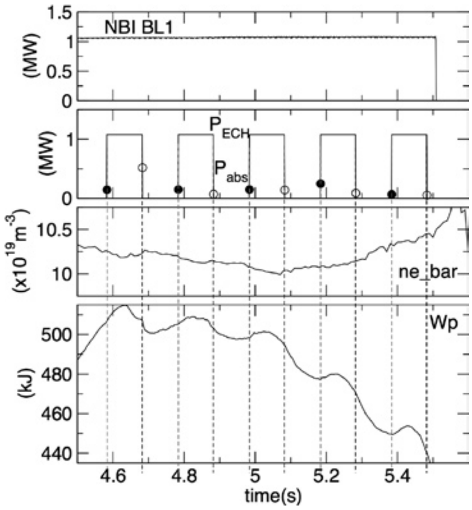

Figure 1 : (From the top) NBI #1 pulse, ECH pulses and absorbed power estimated from the change of the gradient of the stored energy, line integrated electron density, stored energy (Wp).

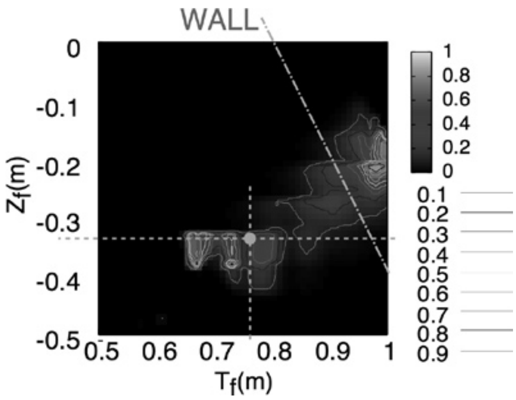

Figure 2: O-X-B mode conversion rate T_{OXB} plotted as a function of the aiming point at R=3.9m. The aiming point set on the discharge shown in figure 1 is shown by circle.