§49. Prospect of EBW Heating in the Over Dense Plasma with Use of an Existing Horizontal Antenna for ECH

Igami, H., Kubo, S., Ikeda, R., Shimozuma, T., Yoshimura, Y., Takahashi, H.,
Nagasaki, K. (IAE, Kyoto Univ.), Tanaka, H., Maekawa, T. (Grad. School of Energy Science, Kyoto Univ.)

Since the 12th experimental campaign, a 77GHz high power (1MW/5s, 0.3MW/CW) gyrotron has been installed in an existing transmission line that connects to one of the horizontal antennas. Because the horizontal antenna has flexibility of the launching direction, it is expected to excite the electron Bernstein wave (EBW) via the O-X-B mode conversion process and to perform electron cyclotron heating (ECH) in extremely high density plasmas like a super dense core (SDC) plasma. An investigation of the experimental configuration to excite the EBW in over dense plasmas has been performed with use of the ray-tracing code that has been improved to treat the mode conversion process to the EBW and propagation and deposition as the EBW. At first the mode conversion rate T_{OXB} was surveyed for various launching direction. The launching direction is defined as the aiming point of the focused Gaussian beam (R_f, T_f, Z_f), where the R-direction is the horizontal radial direction at the horizontally elongated cross section, The Z-direction is the vertical direction and the T-direction is the direction that is perpendicular to the R- and the Z- directions. For launching from the horizontal antenna, R_f is usually set to be 3.9 m, the aiming point it is written as (T_f, Z_f). For each case of (T_f, Z_f), the reflection point of the launched O-mode was found with the ray-tracing and T_{OXB} was calculated there with use the following equation [1].

$$T_{OXB}=\exp\{-\pi(\omega/c)L_n(\beta/2)^{1/2}[2(1+\beta)(N_{//}-N_{//opt})^2+N_v^2]\} \quad (1)$$

Where L_n is the scale length of the density gradient, $N_{//}$ is the parallel component of the refractive index, N_v is the component of the refractive index that is perpendicular to the direction of the density gradient and the direction of the external magnetic field, $N_{//opt}=\{\beta/(1+\beta)\}^{1/2}$ and $\beta=\Omega_{ce}/\omega$. In the ray-tracing, the calculation is started outside the last closed flux surface (LCFS). The ray approaches the cut off and is reflected there if $N_{//}\neq N_{//opt}$ and/or $N_v\neq 0$ because the evanescent layer for the O-mode appears between the plasma cutoff and the left handed cyclotron cutoff. Fig. 1 shows contour plots of T_{OXB}. The electron density and temperature profiles $n_{e0}(1-(\rho/1.1)^6)^2$, $n_{e0}=2\times10^{19}\ m^{-3}$ and $T_e(\rho)=T_{e0}(1-(\rho/1.1)^4)^2$, $T_{e0}=0.5$ keV

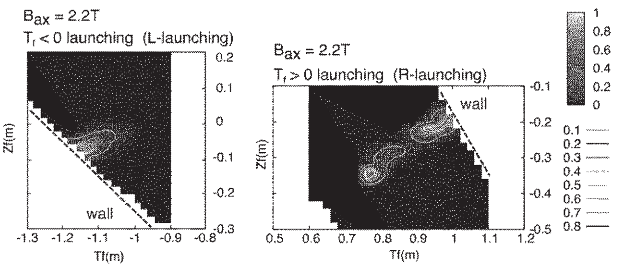

Fig.1: T_{OXB} obtained with each setting of (T_f, Z_f). [2]

are used for the calculation. We assume the slab geometry along the direction of the density gradient near the evanescent region and that the component of the wave vector that is perpendicular to the direction of the density gradient at the reflection point is conserved. The calculation is re-started at the higher density side of the evanescent region with using the conserved vector as the initial value. After re-starting, the propagating mode connects from the O-mode to the X-mode and then the ray turns back toward the upper hybrid resonance (UHR) layer, where propagating mode connects to the EBW. Fig.2 shows the results of the calculation considering various magnetic field strength B_{ax} on the magnetic axis R_{ax}=3.75m performed in both of the cases $T_f > 0$ and $T_f < 0$, where (T_f, Z_f) is selected so that the highest T_{OXB} is obtained. If B_{ax} is large, the EBW is absorbed in the Doppler shifted ECR layer near the UHR layer in the peripheral region. As B_{ax} decreases the resonance condition is realized in more central region. In some cases (B_{ax}=2.2, $T_f < 0$ and B_{ax}=2.4T, 2.2, $T_f > 0$), the ray deviates the resonance condition near the UHR layer before being damped out and penetrates in the central region. However the resonance condition is not realized there and the ray reaches the peripheral region in the inner side of the torus where $R<R_{ax}$. Since the magnetic field becomes strong there because of the inner helical coil, the resonance condition is realized again and the EBW is damped out. For the case of low B_{ax} the top of the contour map moves beyond the wall line as shown in Fig.1, thus (T_f, Z_f) can not be set so that high T_{OXB} is obtained because the launched beam hits the wall of the horizontal port. This may be why the power deposition of the EBW in the central region cannot be expected by reducing B_{ax}. Although the density profile used here is different from that of the SDC plasma in the core region, it is similar as far as in the region where $\rho > 0$. Therefore it can be said that replacement of the final mirror of the horizontal antenna is required to reduce the restriction to set (T_f, Z_f) caused by the existence of the wall of the horizontal port.

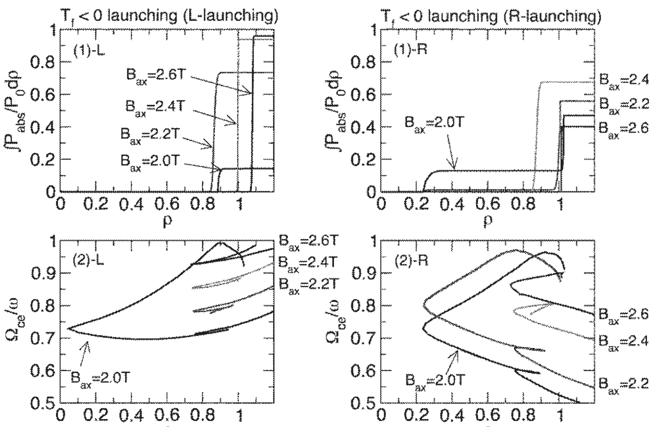

Fig.2 Normalized absorbed power integrated along ρ (upper column) and normalized electron cyclotron angular frequency, Ω_{ce}/ω (lower column) for the case of launching (1)(3) : $T_f < 0.0$ and (2)(4): $T_f > 0.0$. [3]

1) E. MJØLHUS, *J. Plasma Physics*, **31**, p. 7 (1984)
2) H. IGAMI et al., submitted to *Fusion Science and Technology*
3) H. IGAMI et al., submistted to *Plasma Science and Technology*