§50. Study of Heating Mechanism on Oblique Launching of the X-mode from the High Field Side

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

Oblique launching of the millimeter waves with use of the antennas installed in 1.5-L port on LHD. The wave launched obliquely toward the inner side wall of the vacuum vessel, approaches at first the exterior ECR layer that is located outside the last closed flux surface (LCFS) from the low field side (LFS). If the power absorption there is negligible, the wave can reach the high field side (HFS) and penetrate the inside of the LCFS. In such a case, electron cyclotron heating (ECH) by the fundamental X-mode around the interior ECR layer inside the LCFS is possible. Generally if $N_{//}$ becomes almost zero, power absorption of the X-mode weakens. In LHD since $N_{//}$ varies as the wave propagates because of the inhomogeneity of the external magnetic field, $N_{//}$ is able to become zero when the X-mode crosses the ECR layer by optimization of the launching direction. Therefore it is also expected that the X-mode can reach the upper hybrid resonance (UHR) layer without being damped out and excite the electron Bernstein wave (EBW). Here the launching direction is defined by the aiming point of the wave as (R_f, T_f), where the R-direction is the radial direction on the vertically elongated cross-section and the T-direction is the direction that is perpendicular to the R- and the vertical Z-direction. As Z_f is usually set to be zero it is not written. The existing ray-tracing code for LHD has been improved to analyze the propagation and heating mechanisms including the EBW. With use of the code, the propagating mode at the point where the wave is damped out has been surveyed for various (R_f, T_f). The results are shown in Fig.1 as color-coded maps. $T_e(\rho)= T_{e0}x(1.0-(\rho/1.05)^2)^1$, T_{e0}= 2.2keV, $n_e(\rho)= n_{e0}\ x(1.0-(\rho/1.1)^8)^2$, n_{e0}= 0.7, 1.0, 2.0, 5.0 x $10^{19}m^{-3}$ are assumed respectively. On the straight line that connects the antenna position and the aiming point, we set the start point of the ray-tracing in the HFS of the exterior ECR layer. If the start point is inside the edge of the assumed density profile, we considered that the X-mode launched from the LFS is reflected at the evanescent region between the right-handed cutoff (RC) and the UHR layer which appear the LFS of the ECR layer. For the case of (R_f, T_f) with that the EBW can be excited, $N_{//}$ becomes close to zero when the launched X-mode passes the ECR layer. Generally the power absorption as the X-mode weaken as the density increases, more deviation from $N_{//}$=0 is possible and the area of (R_f, T_f) with that excitation of the EBW is possible broadens.

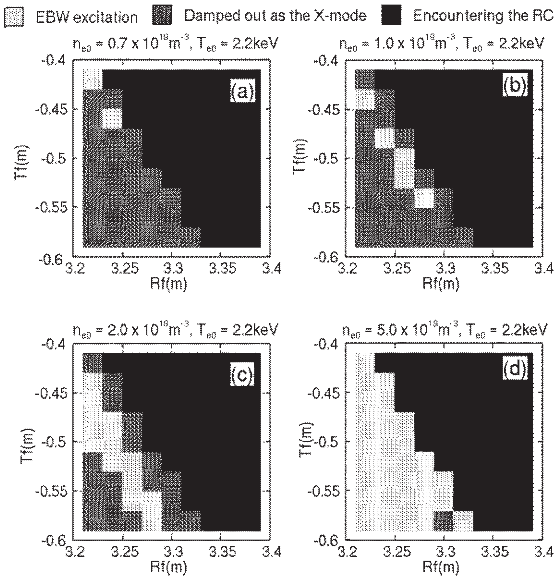

Fig.1: The propagating mode when the wave is damped out is shown by different colors for each setting of the launching direction

In the 12th experimental campaign, 84GHz wave was launched from 1.5-L port antenna as the X-mode with 39Hz, 100% power modulation toward the same aiming point (R_f, T_f) =(3.25m, -0.4m). The target plasma parameters are T_{e0}=2.3keV, n_{e0}=1×$10^{19}m^{-3}$ and T_{e0}=2.5keV, n_{e0}=2×$10^{19}m^{-3}$ respectively. Although the launched X-mode encounters the evanescent region with this (R_f, T_f) (see Fig. 1), increase of the electron temperature was observed as shown in Fig.2. Tunneling through the evanescent region supposedly occurs as the width of the evanescent region was narrow. Waves of low frequency (<500MHz) observed during the power injection suggest the launched X-mode excite the parametric decay waves in very low density region outside the LCFS. In the case of n_{e0}= 2.0 ×$10^{19}m^{-3}$ the observed frequency range is higher than the case of n_{e0}= 1 ×$10^{19}m^{-3}$. The increase of the density outside the LCFS may be reflected in the broadening of frequency spectrum to the high frequency range because the frequency of the decay wave increase as the density increases until 1000 MHz. The effect of the tunneling process should be taken into account for prospect of ECH by the oblique launching.

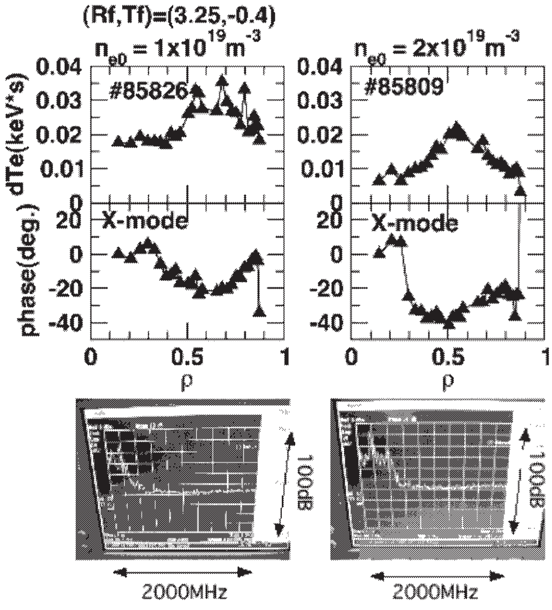

Fig.2: profiles of 39Hz perturbation amplitude and phase and spectrums measured by the loop antenna during power injection of 84GHz wave for ECH.