Two-dimensional full wave analysis of O-X-B mode conversion of electron cyclotron waves in tokamak plasmas

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Electron cyclotron (EC) waves have been extensively employed for heating and current drive in tokamak plasmas because of good coupling with antenna, accessibility to high-density plasma, localized and controllable power deposition profile, and recent availability of high power sources. When the EC wave is launched from the low-field-side of a tokamak, both the ordinary (O) mode and the extra-ordinary (X) mode may encounter the cutoff layer at a certain density and cannot penetrate into high-density region. It has been shown by Hansen et al. [1], however, that the O mode with optimum injection angle is mode-converted to the X mode which penetrates into the higher-density region after converted to the electron Bernstein (B) wave.

In order to describe the O-X-B mode conversion in tokamak configuration, the one-dimensional kinetic full wave code (TASK/W1) was developed [2]. The code solves the integro-differential equation for the wave electric field with frequency ω with the integral form of the dielectric tensor where the electron gyro motion is fully take into account. This model describes the tunneling of the wave with non-optimum injection angle over the evanescent layer and the excitation of the short-wavelength Bernstein waves.

In a realistic plasma configuration, two-dimensional behavior of the wave in horizontal plane and poloidal plane has to be considered. First the wave structure in horizontal plane of the tokamak configuration is considered. Figure 1 shows the wave structure for typical spherical tokamak configuration (R_0=1.76m, a=1.28m, B_0=0.08T, n_{e0}=1.2x10^{17}m^{-3}, f=2.45GHz).
The O mode excited by the waveguide is converted to the X mode, reflected, further converted to the Bernstein wave, and absorbed near the electron cyclotron resonance. It has been shown that, with a small amount of collisions, $\nu/\omega \sim 10^{-5}$, the collisional absorption exceeds the cyclotron absorption.

The second analysis on the poloidal plane requires the two dimensional code (TASK/WF2D) with the finite-element-method and the integral form of the dielectric tensor including the effect of inhomogeneous cyclotron resonance. The results will be presented in the conference.

References

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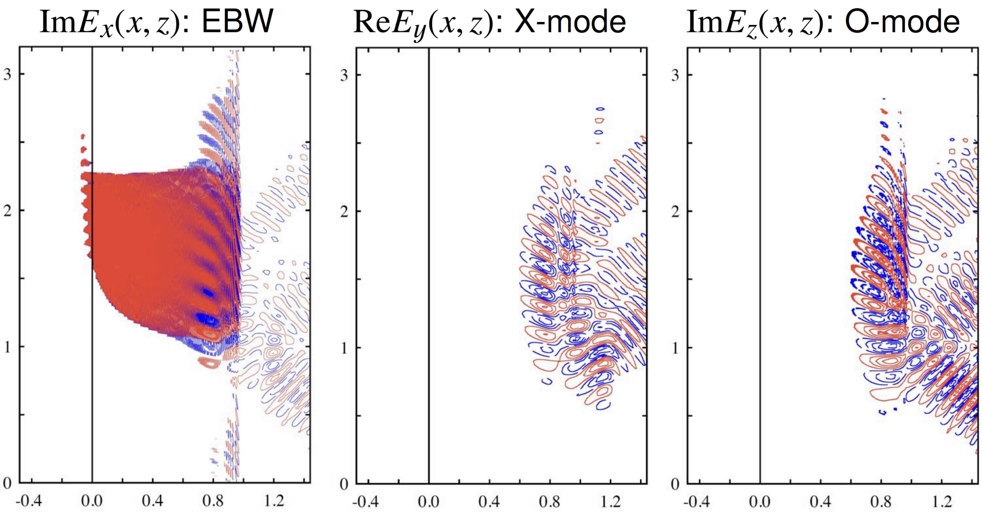

Figure 1. Wave electric field on the mid plane of the tokamak configuration. The horizontal axis is in the direction of major radius, and the vertical axis the toroidal direction. The figures show the imaginary part of E_x (the electron Bernstein wave,) real part of E_y (the X mode component), and the imaginary part of E_z (the O mode,) respectively from the left. The O mode is excited by the waveguide located near the lower right corner, mode-converted to the X mode near the cutoff ($x \sim 1.0$m), reflected near $x \sim 0.7$m, mode-converted to the Bernstein wave near the UHR ($x \sim 0.9$m) and absorbed near the electron cyclotron resonance ($x \sim 0.0$m).