§63. Study on Electron Heating and Current Drive by Electron Bernstein Waves

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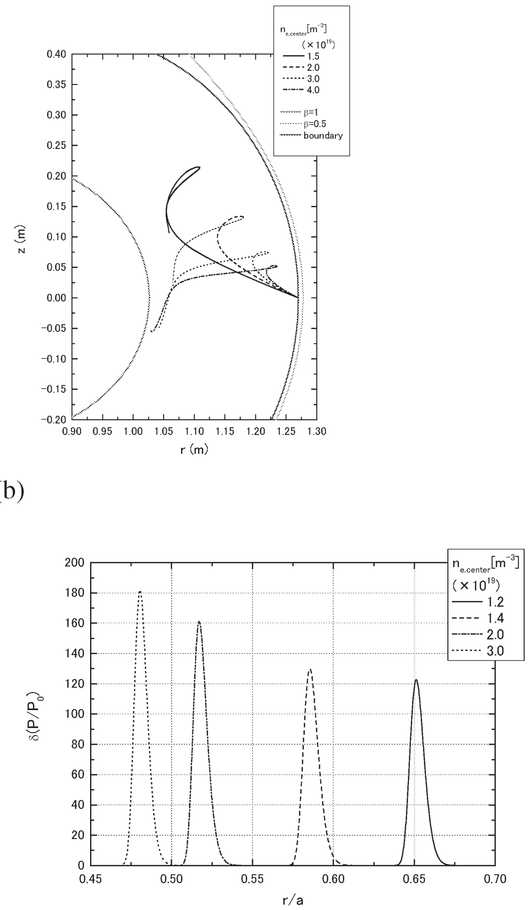
Electron cyclotron heating (ECH) and electron cyclotron current drive (ECCD) provides plasma production, control of electron temperature profile, suppression of MHD instabilities. Electromagnetic waves such as a fundamental O-mode and a second harmonic X-mode are conventionally used for ECH and ECCD because of the high single pass absorption. However, these electromagnetic modes inevitably have upper density limit, so called cut-off, which prevents the waves from accessing the core region at high density plasmas. To overcome this problem and access high density region, use of electrostatic waves is proposed. The electron Bernstein waves (EBW), one of electrostatic waves, can be excited though mode conversion from electromagnetic waves [1][2]. The EBW has advantage of no cut-off density and very high single pass absorption even at low electron temperature. There are three kind of mode conversion method to excite the EBW, that is, O-slow X-B, slow X-B and fast X-B. In this report, we concentrate on the O-slow X-B mode conversion method.

We have developed ray tracing codes for calculating the propagation and power deposition of the EBW in toroidal fusion devices. If we assume that inhomogeneity of plasma parameters is weak and geometrical optics approximation is valid, the ray trajectory of both electromagnetic and electrostatic waves can be obtained by solving the differential ray equations numerically. The dispersion relation of electromagnetic waves is given by using a cold plasma approximation. The numerical method is similar to a ray tracing code for H-1 Heliac [3]. The absorption coefficient of electromagnetic waves can be obtained by considering weakly relativistic effect in dielectric tensor. On the other hand, the dispersion relation for the EBW can be given by using a hot plasma approximation.

The EBW is considered to be an important heating and current drive scheme in spherical tori since the conventional electromagnetic waves is not suitable because of low magnetic field strength. Since the toroidal magnetic field is weak and comparable to the poloidal magnetic field compared to conventional tokamaks, the approximation of magnetic field structure using only the toroidal field is not valid as well as helical systems for calculating the power deposition of the EBW heating and current drive. Figure 1 shows the calculation results of the O-X-B mode conversion based on the NSTX model. The injected O-mode is coupled to the slow X-mode at the O-mode cut-off layer, $\omega=\omega_{ce}$, then the slow X-mode is converted into the EBW at the upper hybrid resonance layer, moving toward the core plasma region. The EBW is absorbed at the strongly Doppler-shifted cyclotron resonance. Figure 2 shows the dependence of absorption profile on the electron density. As the core electron density increases, the EBW is excited earlier, and travels towards to the resonance layer. Although the optimum orientation for O-X mode conversion moves in the outer direction of the plasma with an increase of the electron density, the optimum injection angle changes only slightly, that is, 9 deg and 8 deg in the poloidal and toroidal directions, respectively. The calculation results indicate that the O-X-B heating is realistic in spherical tori, and the absorption profile can be controlled by changing the magnetic field and electron density.

(a)



(b)

Fig 1 Ray tracing calculation results of O-X-B heating in spherical tori, (a) ray trajectories and (b) power deposition profiles

Reference

1) Nagasaki, K., et al., Plasma. Phys. Cont. Fusion 44 (2001) 409
2) Mizuuchi, T., et al., J. Plasma Fusion Res. 77 (2001) 484
3) Nagasaki, K., et al., J. Phys. Soc. Jpn. 70 (2001) 617-620