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

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ECH and ECCD are utilized for many purposes such as production of current-free plasmas, control of electron temperature profile, suppression of MHD instabilities. The electromagnetic modes are injected into plasmas, exciting the propagating modes, the O- and X-modes, which have upper density limits so called cut-off. Near the cut-off density, the waves suffer from strong refraction, and they can not reach the resonance layer. In order to overcome these problems and to access higher density regime, a mode conversion from electromagnetic waves to electrostatic waves is proposed. One of electrostatic waves, electron Bernstein wave (EBW) has advantages of no cut-off density limit and very high damping rate at the electron cyclotron resonance condition even at low electron temperature. The purpose of this study is to investigate a new heating and current drive scheme using EBW experimentally and theoretically. The EBW excitation and heating were performed in Heliotron J (IAE, Kyoto Univ.) and LATE (Grad. Sch. Energy Sci., Kyoto Univ.) experiments. However, the physical mechanism is not well understood. Good control ability of injection angle and polarization in LHD and CHS devices would enables us to perform systematic experimental study for proving the EBW heating and current drive.

In this fiscal year, we have analyzed electron cyclotron current drive using the second harmonic X-mode from experimental and theoretical aspects before carrying out the EBW experiment. The results are

1. The 200kW second harmonic X-mode has been injected obliquely in the toroidal direction from the top of the torus in the CHS device. The ECCD of maximum 6 kA are observed in the low density, $n_e=0.5\times10^{19}m^{-3}$.

2. The amplitude and direction of driven current depends on the injection angle as shown in Fig. 1. It changes its sign when the injection angle is reversed. The direction of driven current is agrees with a linear theory.

3. The driven current is comparable to the bootstrap current. We have demonstrated that the total current can be zero by controlling the injection angle.

A ray tracing code, TRECE is also applied to the Heliotron J plasma[2] to study the power absorption profile. The TRECE code, which was developed for the TJ-II device (Spain)[1], can deal with the complicated three dimensional

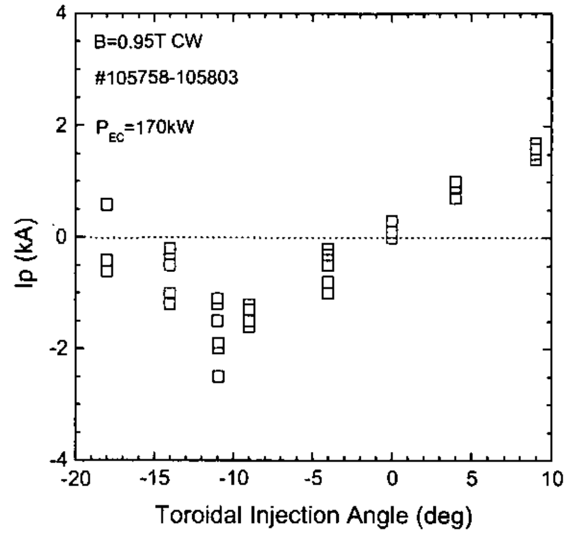

Fig. 1. Dependence of driven current on injection angle in CHS. The power up to 200 kW is injected obliquely in the toroidal direction from the top of the torus.

field structures, resulting that the power absorption profile and driven current profile can be calculated accurately. The fast computation is also possible by introducing a neural network training. The preliminary analysis shows that the calculated current direction agrees with the experimental result.

A theoretical calculation indicated that in the LHD configuration, both slow X-B and O-fast X-B mode conversion could be realized[3]. For the slow-X mode conversion heating, the 82.7 GHz or 84 GHz waves will be injected obliquely in the toroidal direction. When the waves enter from the high field side (coil side), the vacuum electromagnetic waves will be coupled to the slow-X mode. The slow X-mode is converted into the B-mode at the upper hybrid resonance, then absorbed at the strongly Doppler shifted cyclotron resonance condition. The advantage of the slow X-B mode conversion heating is that the high-density target plasma is not necessary. On the other hand, the O-mode injected from the low field side can be coupled to the fast-X mode at the O-mode cut-off if $N_{||}$ satisfies a specific condition. The fast-X mode is again converted into the B-mode at the upper hybrid resonance, then fully absorbed at the Doppler shifted cyclotron resonance. These two mode conversion schemes may be possible in the present 82.7 and 84 GHz injection system.

References

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