§29. Effects of Electron Bernstein Wave Heating at Very Low Magnetic Filed on Plasma Confinement in Heliotron J

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The main objectives of this bi-directional cooperative research on Heliotron J are the studies of production of over-dense plasma by electron Bernstein waves (EBWs) converted from long wave length electromagnetic waves at very low toroidal magnetic field (B_t), and turbulent transport properties in thus produced plasmas. This research is motivated from the pioneering experiments using 2.45 GHz electron cyclotron wave (ECW) powers at very low B_t less than 1000G, on the Compact Helical System (CHS)[1,2]. In CHS, ECWs were injected perpendicularly and obliquely to the confinement magnetic field line. The former and latter launchings aim at X-B and O-X-B mode conversion scenarios, respectively [2]. Ray tracing and absorption of mode-converted EBW suggests that both conversion schemes are possible, because the injection antennas have only low directivity at 2.45 GHz frequency. The achieved electron density exceeded the O-mode cutoff density by a factor of two to four in hydrogen plasmas and a factor of ten in neon plasmas, with 8kw to 20 kW injection[2]. In those overdense plasmas, the mode conversion layer locates near the last closed flux surface (LCFS) or even outside LCFS.

In Heliotron-J, 2.45 GHz ECWs were injected to the magnetic surface having about 45 degrees, as shown in Fig.1. In this condition, ECWs are injected to the magnetic field line having ~70°. In this situation, both O-X-B and X-B scenarios are possible similar to CHS, because of low directivity of the injection antenna and the low selectivity of polarization. Direct conversion from injected X mode to EBW is also possible. The magnetic field strength on the magnetic axis was adjusted to be about 700 G. Although both fundamental and second harmonic resonance layers locate just outside the LCFS in the section shown in Fig.1, these resonances are inside LCFS in the other sections of Heliotron J. However, Helium plasmas were produced with low power 2.45 GHz ECW power (up to 4 kW). When the injected power was only 1 kW, electron density derived from a triple Langmuire probe (LP) was still below the O-mode cutoff density. Here, LP data was calibrated with the line integrated electron density measured with 2mm microwave interferometer. When the ECH power was increased up to 4 kW, line averaged electron density exceeded the cutoff density and reached ~2×10^{17} m^{-3}. Typical radial profiles of electron temperature and density in such overdense plasma are shown in Fig.2. The electron density exceeds the cutoff density in a whole plasma region, as seen from Fig.2. The central electron temperature and density are 8 eV and 3×10^{17} m^{-3}, respectively. The O-X mode conversion layer from injected ECW to EBW is expected to be well outside the LCFS of Heliotron J plasma. In previous experiments on CHS with more higher power (than 10 kW), electron temperature profile was always strongly hollow, suggesting off-axis power deposition. In contrast to the CHS results, electron temperature profile is centrally peaked. Note that the plasma volumes in CHS and Heliotron J are almost the same. The reason why electron temperature profile is obviously different in both experiments is not clarified yet. It is interesting and important to clarify what reasons control the difference in electron temperature profile, for instance, propagation and absorption of mode-converted EBW, magnetic configurations, nonlinear effects at high power and so on.

In the next experimental campaign, higher ECW power up to 20 kW will be injected into plasmas to study detailed physics process of oberdencse plasma production and particle/energy transport in the plasma for various magnetic configurations having different bumpy field components and the rotational transform.

[1] K. Toi, S. Kawada, G. Matsunaga et al., 29th EPS on Plasma Phys. Control. Fusion, Montereux, 2002, Paper No. P4-06.
[2] R. Ikeda, K. Toi, M. Takeuchi, C. Suzuki, T. Shoji et al., Phys. Plasmas 15, 072505(2008).

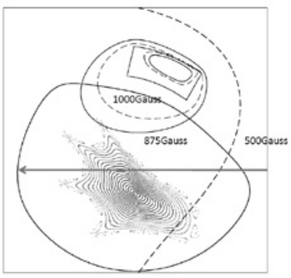

Fig.1 Launching geometry of 2.45GHz microwaves on the Heliotron J device. The ECH power is injected from the outboard side of the horizontal port as is indicated with an arrow.

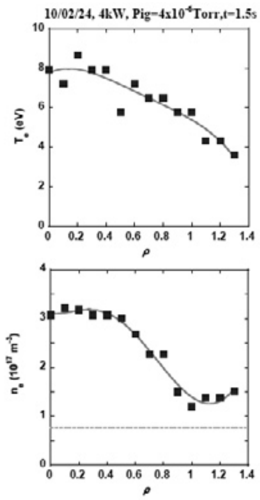

Fig.2 Radial profiles of electron temperature and density in an overdense plasma produced with 4 kW ECW power injection, where the magnetic field strength on the magnetic axis is ~700G. The horizontal line in the electron density profile indicates the cutoff density.