§21. 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 production of over-dense plasmas by electron Bernstein wave (EBW) converted from long wavelength electromagnetic waves at very low toroidal magnetic field (B_t), and study of turbulent transport in thus produced plasmas. Over-dense plasma production using 2.45 GHz microwaves at very low $B_t \leq 0.1$T was initiated on the Compact Helical System (CHS), and were successfully carried out [1]. The power deposition profiles measured by power modulation technique were consistently explained by X-B and O-X-B mode conversion scenarios [1]. Moreover, ray tracing and absorption calculation of mode-converted EBW also confirmed that both conversion schemes are possible, because of low directivity and low selectivity of polarization at 2.45 GHz frequency range [2].

In the experimental campaign of FY2011, 2.45 GHz power was injected into a magnetic-shear less configuration having the external rotational transform of $\iota/2\pi\sim0.7$. O-mode wave was injected at ~45 degrees for the last closed flux surface (LCFS) as shown in Fig.1, where the angle between the wave injection direction and the magnetic field line is ~70 degrees. Two mode conversion scenarios to EBWs, i.e., O-X-B and X-B are possible, as similar to the experiments in CHS. Moreover, direct conversion of launched X-mode to EBW is also possible. The fundamental and 2nd harmonic cyclotron layers locate just inside or outside the LCFS.

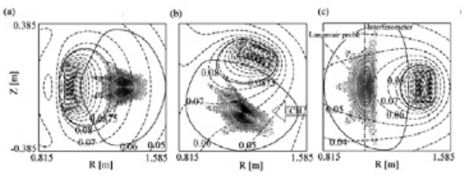

Fig.1 *Cross-section of magnetic surfaces and the contour of the magnetic field strength at three toroidal locations of Heliotron J, where B_t=650 G at the magnetic axis. The arrow in Fig.(b) indicates the microwave injection direction. The vertical and oblique lines in Fig.(c) respectively indicate the chord line of the interferometer and the measurement path of a triple Langmuir probe.*

When microwave power up to 18 kW was injected into neon gas, the line averaged electron density of $\langle n_e\rangle=7.5\times10^{17}$ m^{-3} was sustained quasi-stationary, which corresponds to ~10 times larger than the O-mode cutoff (Fig.2) [3]. The radial profiles of electron temperature (T_e) and density (n_e) were measured by the Langmuir probe. The n_e profile is considerably peaked and $n_e(0)=1.5\times10^{18}$ m^{-3} reaches at the center. The T_e profile is nearly flat and $T_e(0)$=8 eV. The power deposition profile measured by power modulation of 7 kHz is also strongly peaked, where the modulation rate is ~13 % (=2 kW/15 kW). The electron-ion collision frequency to the electron cyclotron frequency is ~10^{-4}, and collisional damping will play a role in addition to cyclotron damping of EBW.

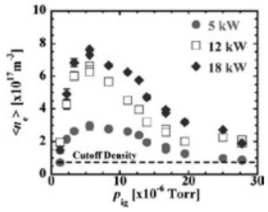

Fig.2 *Achieved $\langle n_e\rangle$ as a function of filling pressure of neon for three levels of injection power.*

On the other hand, $\langle n_e\rangle$ evolved in time considerably in deuterium over-dense plasmas, as shown in Fig.3. The electron density $\langle n_e\rangle$ rapidly increases from t~300 ms and suddenly decreases from t~350 ms, as shown in Figs.3 (a) and (b). The n_e profile became peaked considerably from t~300 ms (Fig.3 (d)). The T_e profile becomes peaky during the rapid decay phase of $\langle n_e\rangle$ (Fig.3(c)). Figure 3(e) shows the radial profile of absorbed power density at 2 kW power modulation. On-axis electron cyclotron wave heating usually leads to hollow density profile in helical plasmas. However, observed density profile is peaked under the condition of centrally peaked power deposition. This new and interesting fact may depend on collisionality regime, that is, the plasma shown in Fig.3 is still in plateau regime.

Direct detection of mode-converted EBW and transport study of EBW heated plasmas in low collisionality regime are left for future interesting and important research topics.

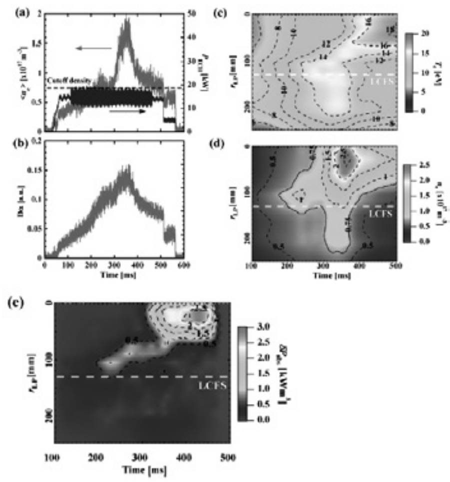

Fig.3 *Time evolutions of $\langle n_e\rangle$ (a), Hα emission(b), radial profiles of T_e(c)and n_e(d), and absorbed power density at 2 kW modulation (e). The wave form of the microwave power is also shown in Fig.(a), where the power modulation is applied from t=110ms to 460ms.*

[1] R. Ikeda et al., Phys. Plasmas **15**, 072505(2008).
[2] R. Ikeda et al., Contrib. Plasma Phys. **50**, 567 (2010).
[3] R. Ikeda et al., submitted to Plasma Sci. Technol. (2011).