§3. Study of Electron Heating by Using Electron Bernstein Wave in Ultra High Beta Plasmas

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Development of current-drive technique is the most urgent issue in low-q compact torus plasmas. A method of plasma current drive in a low-q plasma using the Nernst effect is proposed by Hassam.[1] If a plasma has a steep temperature gradient in radial profile, the cross-field thermoelectric force is in the opposite direction to the usual resistive friction, thus maintaining the plasma current. In low-q plasmas such as a Field Reversed Configuration (FRC), however, maintaining the electron temperature profile is difficult because of its high beta property. Electron Cyclotron resonance heating (ECRH) is a very powerful method to heat magnetically confined plasmas. However, the accessible plasma density is limited by a critical density. Electron Bernstein wave is considered as a possibility for overcoming the density limit. Therefore, we investigated experimentally and numerically the possibility of heating such an extremely high-beta plasma by EBW. A 2.45 GHz magnetron with microwave power of 20kW for up to 200 μs is installed to TS-4 at the University of Tokyo. A launched X-mode (or O-mode) electromagnetic (EM) radiation is expected to efficiently couple power to EBWs through a mode conversion process at the upper hybrid resonance UHR. EM wave (X-mode wave) was injected into FRC plasmas produced by counterhelicity merging of two spheromaks. Figure 1 shows waveforms of trapped flux Ψ of FRCs without and with RF injection (top), net input microwave power into the TS-4 vacuum chamber (P_{net}) in the case of a shot with RF injection. Here, P_{net} is calculated as the difference between the input and the reflected powers measured in the circuit of the transmission line. The FRC formation was completed at *t*= 410 μs. No clear heating effect was observed as shown in Fig. 1. In this experiment, reflected power to the waveguide was 80 percent of that of incident wave. It is considered that a large fraction of the launched microwave power was reflected at cut-off layer without converting to EBW under the present experimental condition. An optimization of condition of RF injection is needed to achieve high conversion efficiency from EM wave to EBW.

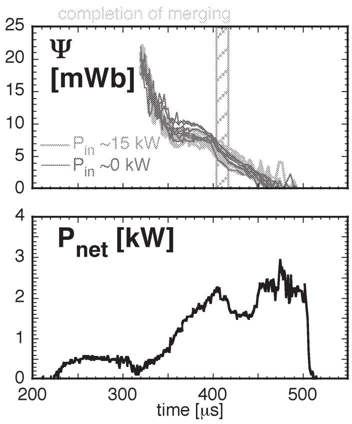

Fig. 1. Waveform of poloidal flux Ψ of FRCs without and with RF injection (top) and typical time evolution of net input power into the TS-4 in the case of RF injection (bottom).

Optimal RF injection condition (injection angle and polarization) for exciting EBW is investigated with a numerical calculation based on the cold plasma resonance absorption model. Figure 2 shows poloidal flux contour (top), radial profiles of magnetic field strength (middle) and electron density (bottom) which are used for the calculation. Contours of conversion efficiency from incident electromagnetic wave of the optimal polarization to EBW in Ny-Nz space are shown in Fig. 3, where Ny and Nz are the refractive indices for the toroidal and poloidal directions, respectively. The condition of the discharges in Fig. 1 corresponds to the condition of Ny=Nz=0 in the left contour of Fig. 3 and agrees with the result of conversion efficiency less than 10 %. The scan of background poloidal magnetic field and frequency of injected EM wave elucidates that conversion efficiency reaches higher than 90 % in the case of poloidal field 0.15 tesla and frequency 5 GHz (right contour of Fig. 3).

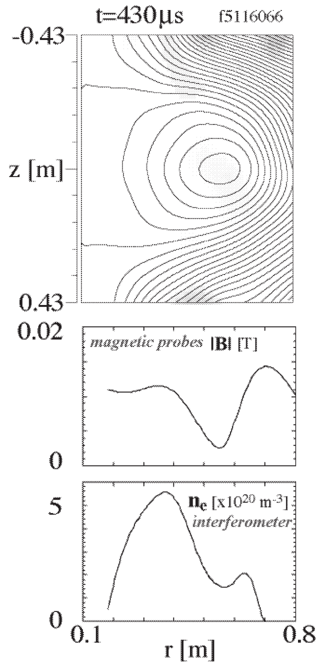

Fig. 2. Poloidal flux contour (top), radial profiles of magnetic field strength (middle) and electron density (bottom).

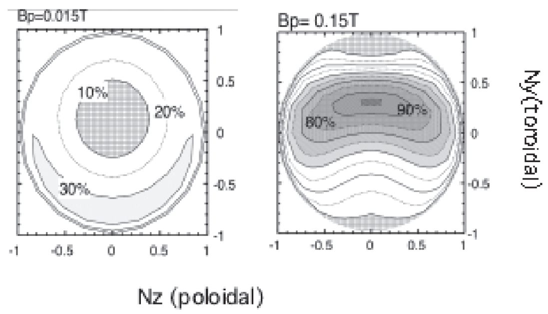

Fig. 3 Contours of conversion efficiency from incident EMW of the optimal polarization to EBW in Ny-Nz space.

Reference
[1]. Hassam, et.al., Phys. Rev. Lett, **83**, (1999) 2969.