§5. Measurement of Electron Bernstein Wave Emission from Ultra High Beta Plasmas

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This experimental proposal aims to investigate feasibility of electron heating in extreme high-beta plasma by electron Bernstein wave (EBW). EBW is a method to overcome a density limit by which accessibility of conventional electron cyclotron resonance heating is limited. To this end, we employ electron Bernstein wave emission (EBE) measurement for compact torus experiments, which is an inverse process of mode conversion of EBW heating. We also carry out numerical survey of mode conversion efficiency from EBW to an electrostatic mode in various conditions. High-beta plasma here is defined as a plasma whose volume average beta is higher than 80%.

Figure 1 is a schematic illustration of the EBE measurement system we have developed for TS-3 field reversed configuration (FRC) plasma experiment at University of Tokyo. Typical FRC in TS-3 has magnetic field of 0.05 T and electron density in the order of 10^{20} m^{-3}, indicating $\omega_{pe}/\omega_{ce} \geq 20$). Electromagnetic (EM) wave emitted from TS-3 plasmas is received by a waveguide antenna and transmitted to a detector module through a waveguide-coaxial cable converter, coaxial cable, attenuators and amplifiers. The waveguide antenna has a 30-degree range of receiving angle in toroidal direction. According to numerical calculation of the mode conversion from EBW to EM mode using wave equation based on cold plasma dispersion relation, conversion rate of 20-70 % is expected under the condition of TS-3 FRC plasma. The detector module surrounded in a blue line frame in Fig. 1 was fabricated using microwave integrated circuit (MIC) technology by Kyushu University group [1]. Employment of the MIC technique had downsizing of the system and cost reduction of development enabled. The system covers frequency range of 2-5.1 GHz with four channels. Each channel has bandwidth of roughly 500 MHz.

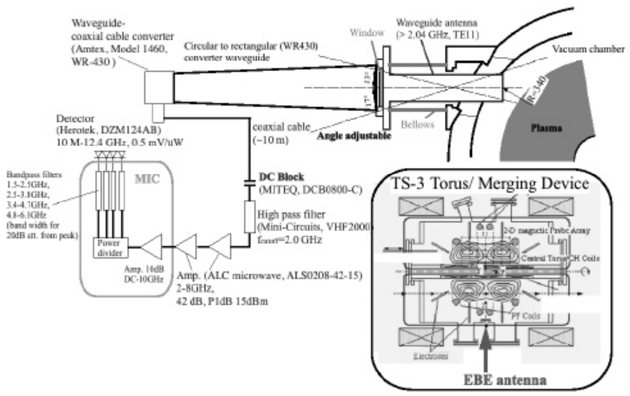

Fig. 1. Schematic of the EBE measurement system. Microwave integrated circuit (MIC) technology was utilized for the detector module.

The EBE system was applied to TS-3 FRC plasma experiment after installation of the system. Figure 2 shows time evolution of radiation signal measured by the EBE system. Frequency band of the measurement in this shot was 2-2.5 GHz. Output signal in case of a vacuum shot is also shown by grey curve for comparison. An FRC plasma was formed through a counterhelicity merging of two spheromaks at t= 180 μs. Although identification of the signal by the FRC plasma has not yet been completed, significant signal appeared in case of the discharge. It is necessary to figure out whether the emission was radiated inside separatrix of the plasma or at peripheral region.

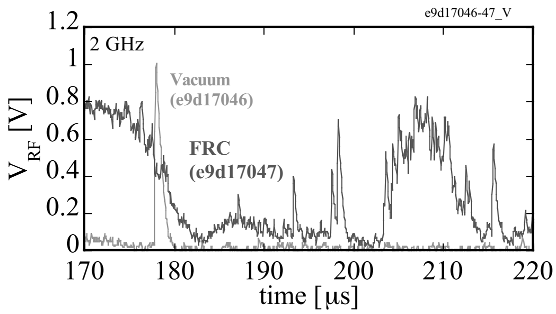

Fig. 2. Time traces of radiation signal measured by the EBE system.

Figure 3 shows (a) an MHD equilibrium of the FRC and (b) characteristic frequency curves of the FRC plasma as a function of radius. EBW mode originating at region of $f_{ce} \sim 2f_{ce}$ (r= 0.32-0.375 m) is possible to reach the EBE system through mode conversion. However, if the UHR layer was outside the separatrix, radiation of EBW in the core region can not access to the EBE antenna. In the case the measured signal may stem from thermal motion of edge electrons. We plan calibration of the EBE system to obtain radiation temperature.

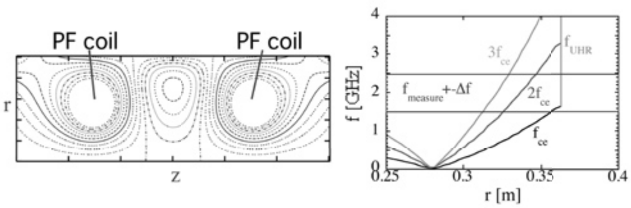

Fig. 3. MHD equilibrium of the FRC and (b) characteristic frequency curves of the FRC plasma. Uniform temperature of $T=T_i+T_e$=20+20eV is assumed.

[1] Y. Kogi, et al., "Development of IF system for ECE radiometer on KSTAR tokamak", in Proceedings of the 13th International Symposium on LASER-AIDED PLASMA DIAGNOSTICS, 18-21 September, 2007 Hida Hotel Plaza, Takayama, Japan (NIFS-Proc-68)