§13. Study on Accessibility of Electron Bernstein Wave to Core Region of Ultra High Beta Plasmas

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This research project conducts a feasibility study of electron Bernstein wave (EBW) heating of extreme high-beta plasmas. To this end we investigate accessibility of EBW in extreme high-beta plasmas by means of experimental and numerical approaches. Specifically, we study (a) mode conversion between EBW and an electromagnetic mode, (b) collisional damping, (c) propagation and (d) resonant absorption of EBW in high beta plasmas. For (a) and (b), we have developed a radiometer for measurement of EBW emission (EBE) in TS-3 compact torus (CT) plasma experiment at University of Tokyo. For (c) and (d), we plan to newly develop a wavenumber measurement system.

In this fiscal year, we have implemented the following: (1) measurement of EBE from merging spherical tokamaks (STs), (2) development of a new bandpass filter (BPF) circuit with high frequency resolution for the radiometer (which is still under development), (3) design of the wavenumber measurement system and (4) procurement of components for the system.

Figure 1 is a schematic illustration of the TS-3 device and the radiometer. The radiometer is absolutely calibrated for radiation-temperature measurement. The waveguide antenna (receiver) is 90-degree angle-steerable in toroidal plane. The radiometer system covers frequency range of 2.1–5.1 GHz with four channels using previous BPFs. Magnetic field strength and electron density of a typical TS-3 CT are 0.01–0.1 T and the order of 10^{20} m^{-3}, respectively. These parameters correspond to $\omega_{pe}/\omega_{ce} \geq 20$, where ω_{pe} and ω_{ce} are angular frequency of the plasma oscillation and the electron cycltron angular frequency.

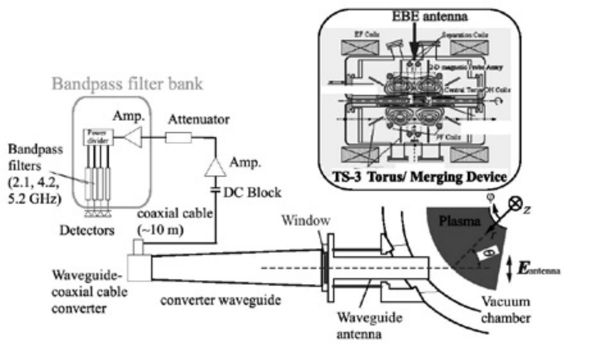

Fig. 1. Schematic of TS-3 device and the radiometer system.

Figure 2 gives the mode conversion efficiencies $\eta^{meas}_{EBW\text{-}EM}$ and $\eta^{calc}_{EBW\text{-}EM}$ as a function of receiver angle θ (the definition is given in Fig. 1). We

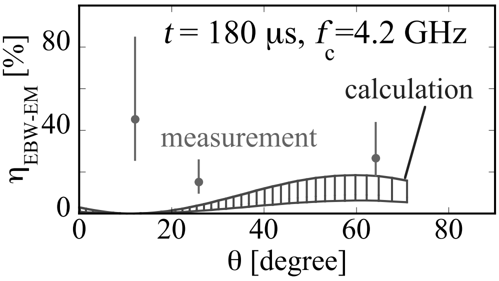

Fig. 2. The mode conversion efficiency (closed circle: measurement, hatched region: calculation) between EB and EM waves during merging of two STs as a function of receiver angle θ.

regard T_{rad}/T_e^{LP} as the conversion efficiency $\eta^{meas}_{EBW\text{-}EM}$ between EB and EM modes on the assumption of the blackbody EB radiation thermally-equilibrated with the electrons, where T_{rad} is radiation temperature of microwave emitted from the merging STs and T_e^{LP} is electron temperature measured with a triple-probe. $\eta^{calc}_{EBW\text{-}EM}$ is the efficiency numerically calculated for the TS-3 ST plasma by using the cold plasma resonance absorption model [1] in slab geometry. $\eta^{meas}_{EBW\text{-}EM}$ for θ= 12 degrees reached ~50 %. Although $\eta^{meas}_{EBW\text{-}EM}$ agrees in order of magnitude with $\eta^{calc}_{EBW\text{-}EM}$ except in the vicinity of θ~ 10 degrees, discrepancy between $\eta^{meas}_{EBW\text{-}EM}$ and $\eta^{calc}_{EBW\text{-}EM}$ is significant. We are investigating the cause by taking the possibility of electron cyclotron emission, upper hybrid radiation and so on into consideration.

We have started development of the wavenumber measurement system which is a interferometer with multichannel receiver antennas. Figure 3 shows perpendicular wavenumber of EBW as a function of radial position of the TS-3 merging STs. This is calculated from electrostatic dispersion relation using a Maxwellian velocity distribution function of electrons. Plasma parameters used for this calculation are those measured in the TS-3 experiment. The ordinate represents wavenumber perpendicular to the background magnetic field. The wavenumber is normalized by the electron Lamor radius. The perpendicular wavelength of EBW becomes comparable to the electron Lamor radius. Based on this calculation result, we are developing an antenna system of the wave number measurement system.

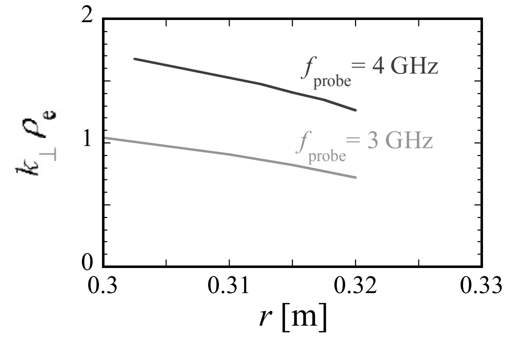

Fig. 3. Perpendicular wave number of EBW as a function of radial position of the TS-3 STs.

1) H. Igami, M Uchida, H. Tanaka and T. Maekawa, Plasma Phys. Control. Fusion **46** (2004) 261–275.