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

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The aim of this research project is to investigate feasibility of electron heating of extreme high-beta plasma by electron Bernstein wave (EBW). EBW provides a method to overcome the density limit problem by which accessibility of conventional electron cyclotron resonance heating is limited. To this end, we have carried out electron Bernstein wave emission (EBE) measurement in compact torus experiments because EBE measurement can investigate an inverse process of mode conversion process of the EBW heating. Also we have implemented numerical calculation of efficiency of mode conversion between EBW and an electrostatic mode in high beta plasma under various conditions.

In this fiscal year, we have attempted measurement of EBE from spherical tokamak (ST) whose $<\beta>$ was about 0.1. Figure 1 is a schematic illustration of the EBE measurement system we have developed for TS-3 compact torus (CT) plasma experiment at University of Tokyo. 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. 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 cables, attenuators and amplifiers. The waveguide antenna has a 90-degree range of movement in receiving angle in the toroidal direction. The detection module of the EBE measurement system has four channels with different center frequencies. Band width of each channel of the EBE measurement system is 0.5 GHz. The system covers frequency range of 2.1-5.1 GHz with the four channels.

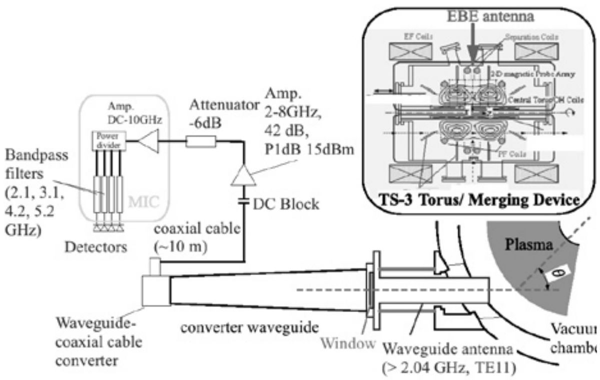

Fig. 1. Schematic of the EBE measurement system. The waveguide antenna has a 90-degree range of receiving angle in toroidal direction.

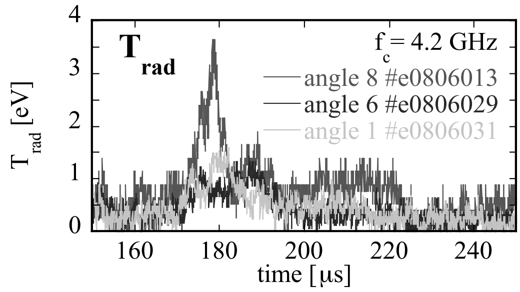

Fig. 2. Time evolution of radiation signal measured by the EBE system. Each curve with a different color shows T_{rad} for a different receiver angle θ.

The EBE system was applied to the TS-3 ST plasma experiment after calibration test of absolute temperature measurement by using liquid nitrogen. Figure 2 shows time evolution of radiation temperature T_{rad} of the ST plasmas measured by the EBE system. T_{rad} in the case of a different receiver angle θ (definition of θ is written in Fig. 1) is depicted by a different color. Center frequency of the measurement in these cases was 4.2 GHz. The ST plasma was produced through a co-helicity merging of two STs at t= 180-190 μs. Plasma current and $<\beta>$ of the ST plasma at t= 220 μs were 8 kA and 0.11, respectively. T_{rad} was in the range of 0.5-3.5 eV and depended on the receiver angle. This detected radiation was considered to originate from thermal electrons at the edge region of the ST. The frequency corresponds to 5-6f_{ce} at the edge region, where f_{ce} is the electron cyclotron frequency.

Figure 3 shows the relation between radiation temperature T_{rad} and receiver angle θ measured at t= 220 μs. T_{rad} was increased drastically as θ became smaller than 30 degree. The efficiency η of the mode conversion between EB and EM modes in the TS-3 ST plasma was numerically calculated by solving the wave equation of cold plasma with cold plasma resonance absorption model. The calculated η was almost constant in wide range of θ and the constant value 0.04 was consistent with the ratio between T_{rad} and the electron temperature measured by a Langmuir probe. In order to understand the dependence of T_{rad} on θ (Fig. 3), we plan to do the mode conversion calculation which takes into account Doppler effect and radiation pattern of the waveguide antenna of the EBE measurement system.

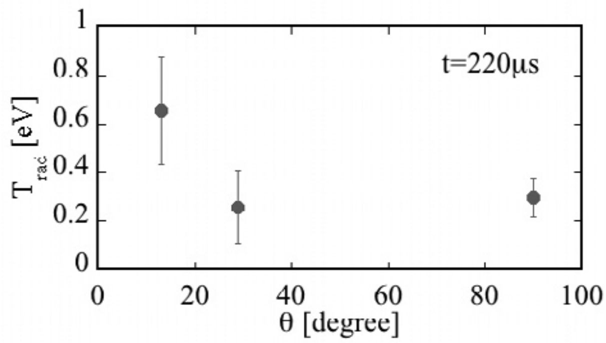

Fig. 3. Radiation temperature T_{rad} as a function of receiver angle θ.