§30. 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 start-up method of extreme high-beta spherical tokamak (ST) using electron Bernstein wave (EBW) heating and merging. To this end we have investigated accessibility of EBW in extreme high-beta plasmas by means of experimental and numerical approaches. We have applied the developed radiometer to EBW emission (EBE) measurement in TS-3 ST merging experiment at University of Tokyo. Also the mode conversion efficiency between EBW and electromagnetic (EM) wave has been calculated numerically.

The past experimental results have shown significant discrepancy in toroidal angle dependence of the mode conversion efficiencies between the measurement and the numerical calculation using cold plasma absorption model. To understand reasons of the discrepancy, radiation pattern of the receiver antenna of the radiometer was numerically calculated by using finite difference time domain method. Figure 1 shows spatial distributions of relative permittivity of the medium in the computational domain for the simulation (top row) and the wave field power for three cases of the antenna configuration of the TS-3 radiometer (bottom row). The EM waves whose frequency was 6 GHz

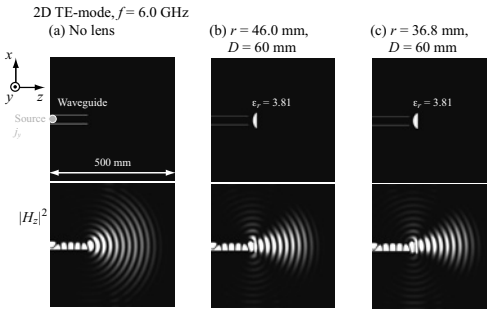

Fig. 1. Spatial profiles of the wave field power for three cases of the antenna configuration of the TS-3 radiometer.

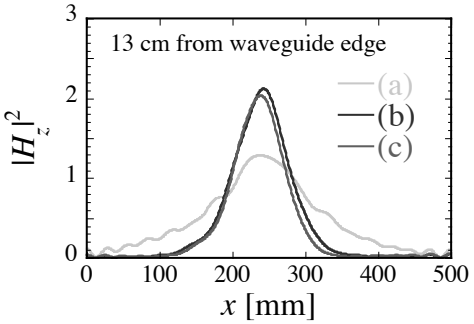

Fig. 2. Profiles of the wave field power for the three cases of Fig.1.

generated by the current source propagated in the wave guide and were launched into the vacuum region. Case (a) corresponds to the configuration of the antenna in the past TS-3 experiments. In cases (b) and (c), quartz lenses were used to focus the microwave beams. Obviously, directivity of the microwave radiation in case (a) is considerably poorer than that in the other two cases and considered as a cause of the discrepancy of the mode conversion efficiencies between the measurement and calculation. Figure 2 shows profiles of the wave field power measured at position where the plasma surface is supposed to be located for the three cases of Fig. 1. It is found that the spread of the radiation field can be halved if the optical lense is applied. A new receiver antenna was designed on the basis of these results and an upgrade of the band pass filter bank was implemented to cover wider and higher frequency band.

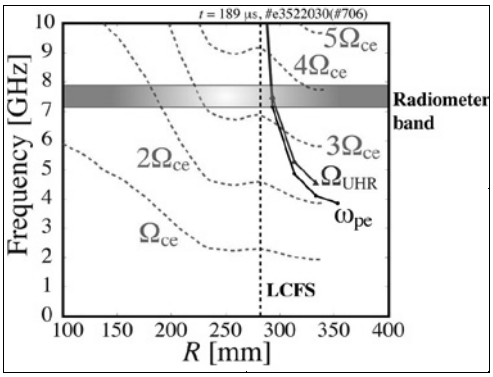

Fig. 3. Radial profiles of the characteristic frequencies of the merging STs.

Another possible cause of the discrepancy between the mode conversion efficiencies is existence of high density plasma at the edge region where the mode conversion layer existed in the experiments. The existence of the high density plasma makes the interpretation of results of the radiation measurement complicated because of, for example, difficulties in distinguishing EBE from electron cyclotron emission (ECE). To suppress the edge density, we applied metal limiters to TS-3 STs. Figure 3 shows radial profiles of the characteristic frequencies (the electron cyclotron frequency and its high harmonics, the upper hybrid resonance and plasma frequencies) of the merging STs obtained in the most recent EBE measurement in which the new radiometer and the metal limiters were applied. The density profiles were measured by a Langmuir triple probe array. It is found that the density (i.e. ω_{pe}) sharply dropped around the last closed flux surface (LCFS, r = 280mm) by the application of the limiters. In this experiment, the new radiometer detected 7.5 GHz-microwave emission from the merging STs. The significant reduction of the edge density and avoidance of the ECE frequency bands enabled the radiometer to access EBE inside LCFS through the mode conversion layer (the UHR layer) successfully. Detailed data analysis is ongoing.

Also we plan to add the effect of collisional damping into the mode conversion calculation because in the TS-3 plasmas the effect is considered significant.