§15. Electron Cyclotron Beam Measurement System in the LHD

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To determine the absorption and transmission power of the Cyclotron (EC) beam by calculation, it is important to compare with the experimental results because the calculation is also difficult in the complex helical plasma magnetic field structure. In order to evaluate the Electron Cyclotron Heating (ECH) power inside the Large Helical Device (LHD) vacuum vessel and to investigate the physics of the interaction between the EC beam and the plasma, the direct measurement system of the EC beam was employed in 2010. The credible heating efficiency of the ECH power absorption was obtained by the direct measurement, and the EC beam refraction due to the presence of the plasma was verified experimentally for the first time. However, the system could be operated under the condition of a relatively low magnetic field (less than 2 T at the plasma axis) due to the unfavorable effect of the stray magnetic field on the IR camera or low plasma density (less than 0.4×10^{19} m^{-3}) due to the shift of the center position of the EC beam implantation to the target plate because of the EC beam's refraction by passing through the plasma.

Figure 1 shows the schematic view of the developed EC beam measurement system for measure in high magnetic field, high density plasma. The system consists of an EC beam target plate, which was made of isotropic graphite and faced against the ECH through the plasma, and an IR camera for measuring the target plate temperature increase by the EC beam. Between the IR camera and target plate, an Al mirror and a BaF_2 window were installed connected by the SUS cylinder. In order to measure the EC beam under the high magnetic stray field, the IR camera was moved to a distant position. By changing the IR camera position, the peripheral magnetic field was reduced to 0.04 T from 0.18 T. The IR camera with the shield box made of 14 mm PB permalloy, which is the alloyed metal of Ni and Fe, worked fine. Another problem of the EC beam being removed from the target plate by the refraction was solved by installing a new target plate with a larger (ϕ280 mm to ϕ364 mm) diameter set closer to the plasma. Then the EC beam measurement system has become applicable to the higher magnetic field (up to 2.75 T) and twice higher density than the previous condition. The thinner plate was installed for increasing the sensitivity, and the EC beam was successfully measured in the typical LHD experimental conditions.

Figure 2 (a)-(e) shows the experimental results of the temperature increase by the EC beam through the plasma. Compared with the EC beam with (a) the no plasma case, (b)-(e) through the plasma case were reduced the temperature rising and the EC beam center position is shifted from the center to the outside of the target plate. By employing the 5 mm plate, the temperature increase could be clearly observed. This system successfully evaluated the beam absorption and refraction of the transmitted EC beam. The comparison with the calculation is a future work.

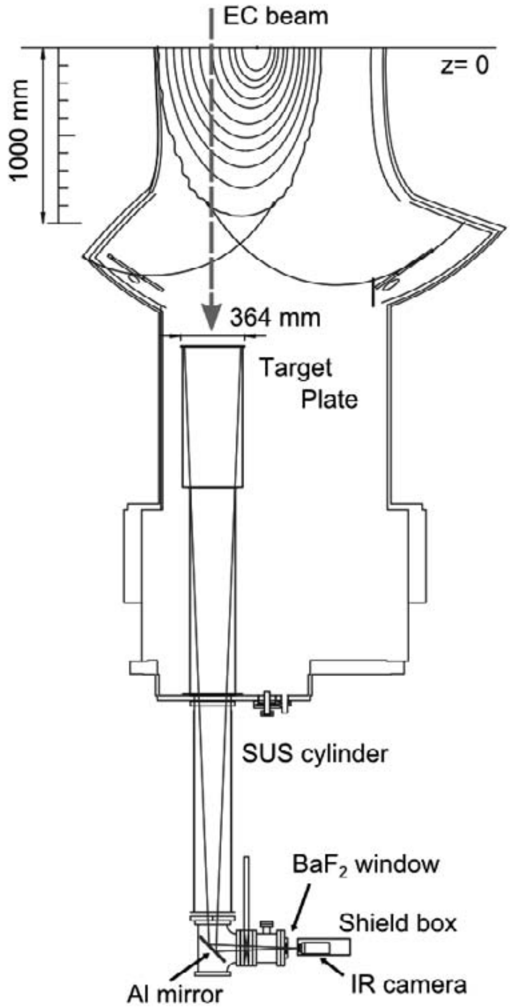

Fig. 1. LHD poloidal cross section with typical plasma and the EC beam measurement system. The EC beam is injected from the upper side antenna to the plasma.

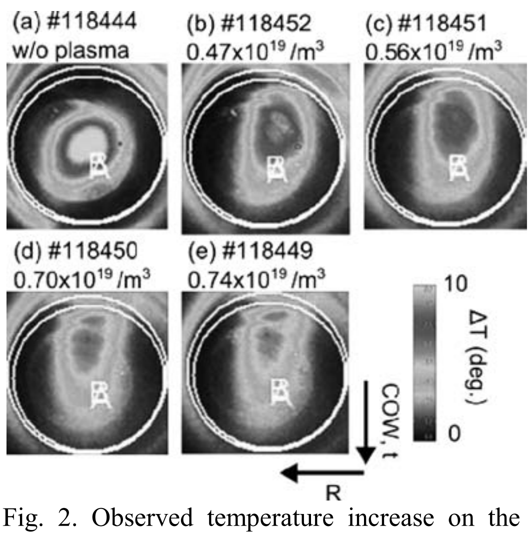

Fig. 2. Observed temperature increase on the target plate, (a) without plasma and (b)-(e) experimental results with various densities.