§ 17. Development of ECH Method for High Density Plasma Heating

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Recently, there arises considerable interest in ECH methods by using mode-converted electron Bernstein (B) waves for heating and current drive in high density plasmas. The O-X-B method, where obliquely injected O waves are mode-converted to X waves at plasma cutoff layer and then B waves at upper hybrid resonance layer, is a possible way to excite B waves in the plasma. Here we present technical progress of polarizer for application to LHD, theoretical result on polarization adjustment of incident transverse electromagnetic (TEM) wave for optimal mode conversion to B waves and the result on Low Aspect ratio Experiment device at Kyoto University.

In the O-X-B method we need to inject TEM waves in the form of O mode at the appropriate angle to the magnetic field toward the plasma surface. The oblique O wave at the plasma surface has the elliptical polarization with the longer axis along the magnetic field line and electric field rotating left-handedly to the magnetic field direction. The ellipticity depends on the ratio of the wave frequency to the cyclotron frequency at the injection point at the plasma surface. Therefore, we have developed a mode converter, which transforms the linearly polarized waves at the gyrotron output into the elliptical polarization waves for injection to the plasma, and a polarization monitor at a corner of the transmission line. The test results show that we can produce the appropriate elliptical polarizations for the O-X-B injection to LHD.

We have developed a method of polarization adjustment of incident TEM waves for optimal mode conversion to B waves by analyzing the general character of mode conversion process and using the symmetry of time reversal in physical systems. The results show that the optimized incident TEM mode is effective for the case of rather steep density gradient near the mode conversion layer around the upper hybrid resonance layer. The results also show that the emitted TEM waves generated via mode conversion from internally excited B waves have the same polarization as the optimized incident TEM waves. Thus we can find the optimal incident TEM mode by detecting the emitted TEM waves by using the injection antenna for O-X-B injection as a receiving antenna and the polarization monitor mentioned above.

In the LATE device [1], 2.45GHz microwave power at 5 kW from a magnetron was injected in the vacuum vessel filled with hydrogen at 1.0 x10^{-2} Pa. with pulse lengths 4 seconds. Under a steady external vertical magnetic field, the discharge quickly starts and the plasma current is generated, after a while quickly increases over 1 kA and is maintained. With subsequent slow ramp of the vertical fields the plasma current further increases and finally reaches 2.9 kA at the vertical field of 30 Gauss. Figure 1 shows that low aspect ratio plasma is generated in the final stage with the outermost magnetic surface of major and minor radii of 23 cm and 18 cm, respectively. The line averaged electron density is found to be over 2 times of the plasma cutoff density for 2.45 GHz, suggesting ECH by mode-converted B waves takes place.

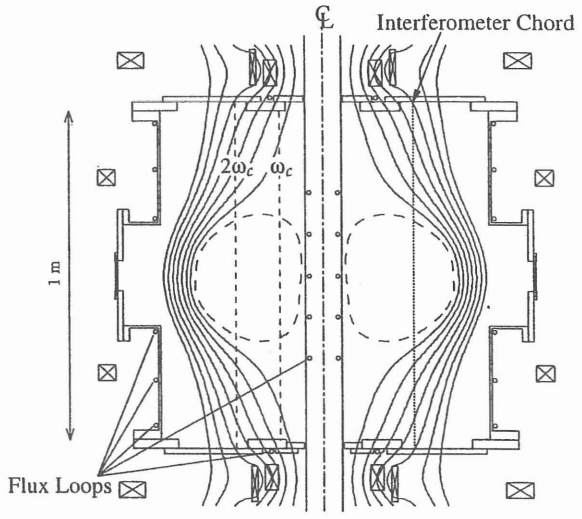

Fig. 1 The magnetic flux at the plasma current 2.6 kA by 2.45 GHz microwave at 5 kW.

References

[1] H. Tanaka, K. Higaki, T. Yoshinaga, H. Igami, M. Uchida and T. Maekawa, Proc. 29th EPS Conf. on Plasma Phys. and Contr. P-5, 050 (2002).