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Excitation and Propagation of Electron Bernstein Wave by OXB injection on LATE

LATE装置におけるOXB入射法による電子バーンスタイン波の励起と伝播

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A linearly polarized microwave(1.5GHz,10W) is obliquely injected into overdense ECR plasmas(typical peak density is 3×10^{16} m^{-3} , Te ~10eV), which are produced and maintained by 2.45GHz, 1kW microwave injection. Optimum injection angle is determined by using cold plasma model. Wave electric fields are detected with movable monopole probes and downconverted by mixer circuits. The wave amplitude and phase change of 1.5GHz microwave are obtained. A steep spike in electric field amplitude has been detected near the UHR layer. Comparison between the experimental results and the numerical analysis will be presented.

1. Introduction

Electron cyclotron resonance (ECR) heating is a useful and often indispensable method to heat a plasma. However, if the plasma frequency ω_{pe} exceeds the injected microwave frequency, the microwave is reflected and can no longer be absorbed at the plasma core. One possibility to overcome this problem is to use electron Bernstein waves (EBWs), which have no high-density cutoff and are very well absorbed at ECR and its harmonics. EBWs are electrostatic waves that need to be mode-converted from the injected electromagnetic waves, and the ordinary-extraordinary-Bernstein(OXB) and extraordinary-Bernstein(XB) mode conversion process are known for efficient mode-conversion. The both method have restrictions in the range of density gradient and injection angle.

This study aims to examine the whole process of excitation of EBW at the UHR layer, propagation toward the ECR layer, and strong resonance absorption near the ECR layer, and to look for the condition to obtain the optimum coupling efficiency from electromagnetic waves to EBW.

The experiments are carried out in the Low Aspect ratio Torus Experiment (LATE) device. The advantage of low aspect ratio tokamak plasmas to study EBW is that the ratio of electron cyclotron frequency to frequency of the injected microwave varies over a wide range in the plasma, therefore entire process of excitation, propagation and absorption of EBW can be separately studied.

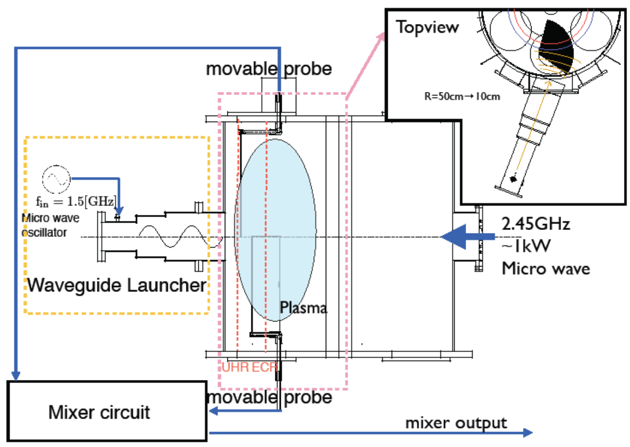

Figure1. Electric field measurement system

2. Numerical determination of optimal injection angle

To estimate the optimal injection angle, we conducted numerical calculations based on the cold plasma resonance absorption model. Calculation results show that the optimal injection angle for EBW excitation is $N_{//}$~0.6 oblique injection while the mode conversion efficiency is very low at $N_{//}$ =0 in the present plasma condition. Therefore we employed the OXB mode conversion method. In the OXB mode conversion process, first an externary launched O mode is coupled to a X mode in the region O mode cutoff. Then the X mode propagates back to the UHR layer and is converted into EBW. The EBW propagates into the overdense plasma and is absorbed near the ECR layer.

Raytracing calculations were performed in order to find the optimal trajectory of movable probes. Wavelength of EBW is estimated from the dispersion relation[1] as ~2mm at the vicinity of the UHR layer.

3. Experimental set-up

A wave field measurement system has been developed in order to excite and detect the mode-converted EBW. Figure.1 shows the overall view of the system.

An ECR plasma is produced and maintained by 2.45GHz, 1kW microwave injection. A 1.5GHz, 10W microwave is injected obliquely into the ECR-plasma using waveguide launcher to excite EBW with horizontal polarization(Quasi O-mode). The radial profiles of the wave electric fields for this microwave injection are detected using movable coaxially-fed monopole probes, which are ~4mm in length and 0.5mm in diameter. Received signals are downconverted to 200kHz and bandpass filtered by a mixer circuit. The phase and amplitude of wave fields are evaluated from the detected wave pattern. As the reference input, signals detected with another movable probe in the plasma and signals divided from oscilator for micro wave injection can be utilized.

. Electron density profile and electron temperature are measured by movable probes and calibrated using 70GHz RF interferometry system. Typical peak density is $3\times10^{16}\,m^{-3}$ and Te is ~10eV.

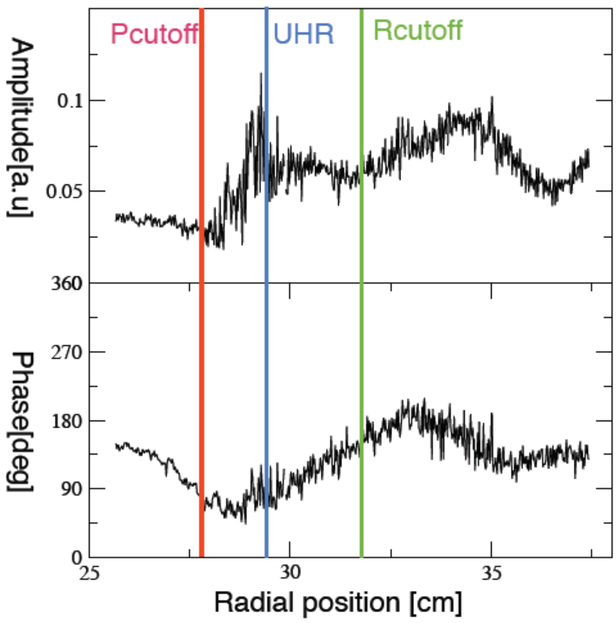

Figure 2. Amplitude and phase change of detected electric field

4. Experiment and results

Figure 2. shows the radial profile of the amplitude and the phase change of measured electric fields at horizontal polarization. The reference signal has been divided from the oscilator for microwave injection.

Although there is no short wavelength wave pattern in phase change, we can see a steep spike at major radius R~29cm ,near the UHR layer. This spike could not be seen at vertical polarization injection (Quasi X-mode). In the present condition, mode conversion rate of QO mode is higher than QX mode, therefore this steep spike might be associated with EBW excitation.

5. Summary

Wave patterns near the UHR layer have been measured by injecting a linearly polarized microwave (1.5GHz, 10W) into the plasma obliquely to magnetic field. The comparison between experimental results and calculation using a cold plasma slab model will be discussed.

References

[1] T. H. Stix, Waves in plasmas (American Institute of Physics, New York, 1992).