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Excitation Experiments of Electron Bernstein Waves via O-X-B mode conversion in the Internal Coil Device Mini-RT

内部導体装置Mini-RTにおけるO-X-B変換による
電子バーンスタイン波励起実験

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Electron Bernstein Waves, which have no cut-off density, are excited at the Upper Hybrid Resonance layer by mode conversion from X-mode waves. The possibility of O-X-B mode conversion was investigated in the internal coil device Mini-RT. The magnetic and electric field profiles in the plasmas were measured directly with interferometry system by injection diagnostic microwaves different from that of ECH. As a result, wave characteristics corresponding to EBWs, i.e. short wavelength, longitudinally polarized, and backward wave mode, were observed only at some initial injection angles that were expected by numerical analysis.

1. Introduction

The Mini-RT is an internal coil device that was constructed to confine high beta plasma by a magnetic field similar to that of a planet. In this device, so-called overdense plasmas have been observed with levitation of an internal superconducting magnetic coil [1], and heating with Electron Bernstein Waves (EBWs) is expected.

Since the cutoff density exists, it is difficult to generate and heat the high-density plasma with electron cyclotron heating (ECH). Therefore, EBW heating is expected to be one of the most promising methods for generating and heating high-density plasmas. Inserting antennas enables the direct investigation of waves in the plasma. E. Yatsuka *et al.* developed directly measurement systems in Mini-RT [2], and revealed wave characteristics of the Electron Cyclotron Range of Frequencies (ECRF) corresponding to EBW in FX-SX-B mode conversion in Mini-RT [3].

We have an interest other excitation scenario of EBW. Here, to examine O-X-B mode conversion in Mini-RT experiments, we are attempting to investigate the propagation of waves in the ECRF in overdense plasmas, sifting the initial injection angle of diagnostic microwaves.

2. O-X-B Conversion Scheme

To excite EBWs in plasma, microwaves have to access to the Upper Hybrid Resonance (UHR) layer, and in the O-X-B conversion, there are two mode conversion processes i.e., the first transition from O-mode to slow X-mode and the second one from slow X-mode to EBW mode. The efficiency of the O-SX transition process in the two dimensions is given by Mjolhus [4],

$$T = exp\left(-\pi k_0 L \left(\frac{\Omega_e}{2\omega}\right)^{\frac{1}{2}} \left(2\left(1+\frac{\Omega_e}{\omega}\right)\left(N_{\parallel}^2 - N_{\parallel opt}^2\right)^2\right)\right) \quad (1)$$

where $\vec{N} = \vec{k}c/\omega$, $\vec{k}$ is the wave number vector, ω is the wave angular frequency, k_0 is the wave number of the incident wave in vacuum and L is the characteristics density scale length at the UHR respectively. The maximum conversion efficiency is obtained at $N_{//} = N_{//\,opt}$, which corresponds to the optimal angle $\theta_{opt} = cos^{-1}\sqrt{(\Omega_e/(\omega+\Omega_e)}$.

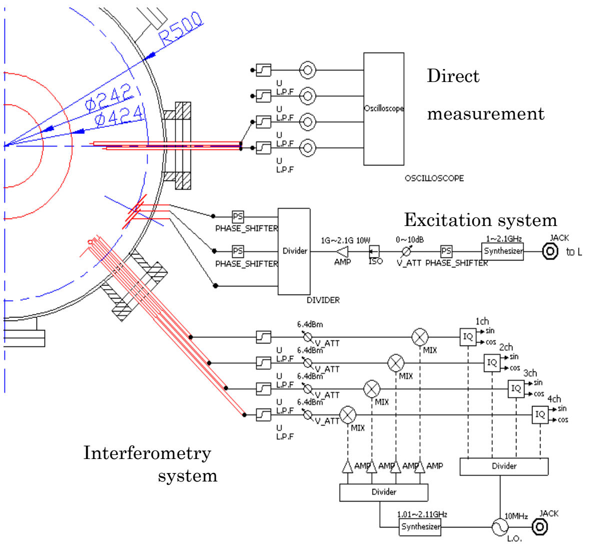

Fig. 1 Measurement system

3. Internal Coil Device Mini-RT

The Mini-RT device has an internal coil with a high-temperature superconductor (HTS) that produces a purely poloidal magnetic field in a vacuum vessel.

A plasma is produced in Mini-RT by ECH with continuous injection of microwaves at 2.45 GHz and 2.5 kW. The plasma confinement region and density profiles can be changed easily by applying a levitation coil current.

4. Experimental Setup

In the Mini-RT device, waves at frequencies lower than 2.45 GHz are injected to diagnose wave propagation in overdense plasmas; the plasma produced by 2.45 GHz microwaves acts as an overdense plasma with respect to lower frequency diagnostic microwaves. In this study, diagnostic O-waves at 1GHz and 10W are injected from low field side, and the angle between wave number vector *k* and the external magnetic field can be altered by changing position and angle of element of excitation antenna. To examine the mode conversion of waves in the internal coil device, electromagnetic and electrostatic components are measured with interferometry system by probing antennas inserted directly into plasmas. Interferometry enables us to obtain a snapshot of the electric or magnetic field. Probing antennas detect the injected diagnostic microwaves and send them to the mixer. They are modulated by IQ demodulators and output as sine and cosine components that contain information on the amplitude and phase of electromagnetic field. Fig.1 shows a schematic diagram of the diagnostics.

5. Initial Results

Figure 2 shows the density profile measured by the triple probe. Cutoff density for 1 GHz microwaves is 1.24×10^{16} m^{-3}, so the region inside the major radius R<285mm is the overdense region for diagnostic microwaves, and this density profile and magnetic field configuration give transmission coefficient profile depending on injection angel (Fig. 5) and the optimum injection angle θ_{opt} = 64.7°. In the radial electric field measurement, shown in Fig. 3, a short wavelength mode (λ = 20 mm) is observed at only the initial injection angel θ = 66.5°, while in other injection angle (ex. in Fig. 3 θ = 71.0°) this short wavelength mode waves are not observed. Figure 4 shows radial profiles of the phase in θ = 66.5° and 71.0°. The phase is function of the spatial position and length of the transmission lines; the gradient of the phase gives the wave number vector. The figure confirms a reversal of the phase gradient around the UHR in θ = 66.5°. This indicates a change in the direction of the phase velocity.

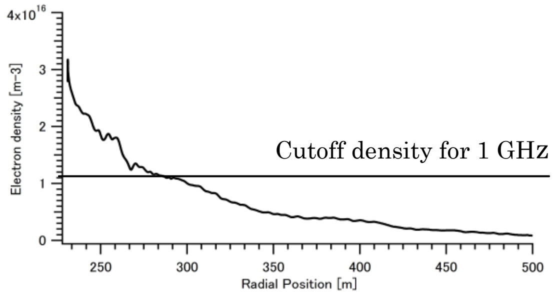

Fig.2 Electron density profile

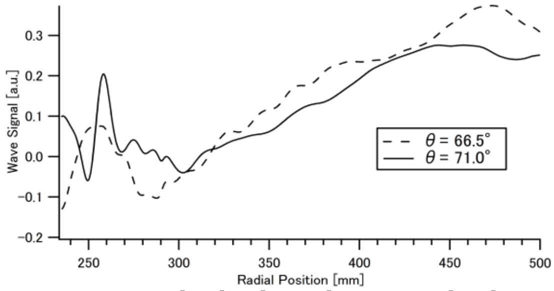

Fig.3 Longitudinal polarized wave amplitudes

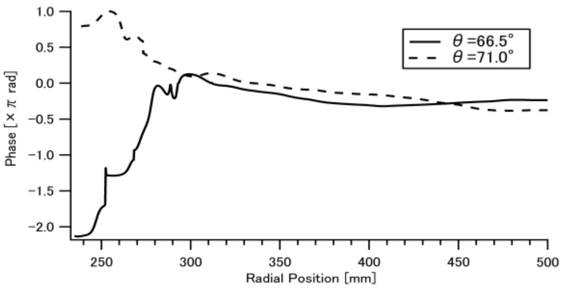

Fig.4 Phase profile

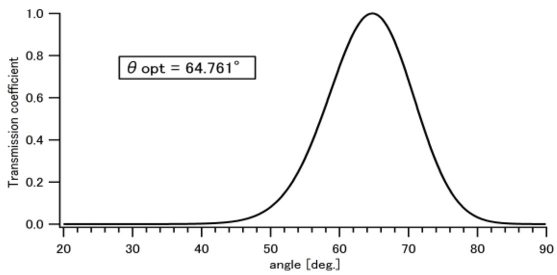

Fig.5 Injection angel dependence of Transmission

These results suggest that EBWs were mode converted from electromagnetic waves at the UHR.

References

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