§4. Establishment of Wavenumber Measurement Method of Electron Gyro-scale Density Fluctuation with the Use of Microwave Scattering at UHR Layer

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A diagnostic technique for detecting the wave numbers of electron density fluctuations at electron gyro-scales in an electron cyclotron frequency range is proposed. The technique is a modified version of the microwave scattering technique invented by Novik and Piliya[1]. The novel method adopts forward scattering of injected extraordinary waves (X-waves) at the upper hybrid resonance (UHR) layer instead of the backward-scattering adopted by the original method, enabling the measurement of the wave-numbers of the fine scale density fluctuations in the electron–cyclotron frequency band by means of phase measurement of the scattered waves. We call this technique UHR forward scattering (UFS). The technique is a suitable means to detect electron Bernstein waves (EBWs) excited via linear mode conversion from electromagnetic waves in torus plasma experiments. In this project, the development of a UFS system has been conducted for verifying the principle of the diagnostics. This year, we conducted a proof-of-principle experiment in University of Tokyo Spherical Toakamak (UTST) and identified scattered waves.

We applied the developed UFS system to the proof-of-principle experiment (Fig. 1). Slow X-mode probe waves, whose frequency was set to the UHR frequency at the position of the target density fluctuation, were amplitude-modulated and injected from the high field side of the torus plasma through the Yagi-Uda type launcher. The density fluctuation was externally excited by the EBW exciter in the vicinity of the UHR layer. The probe wave is to be scattered as a result of a nonlinear coupling between the probe wave and the density fluctuation. The scattered wave has the summed frequency, f_s, of the frequencies of the probe wave, f_{probe}, and the density fluctuation, $f_{exciter}$; that is, $f_s = f_{probe} + f_{exciter}$. The scattered waves belong to the fast X-mode branch and are forward-scattered waves that propagate toward the low field side (LFS), so as to be detected. Figure 2 shows time evolution of (a) the forward power of the amplitude-modulated–probe wave, (b) the receiver signal $I_{receiver}$ and (c) that in a no-modulation case as a reference. The frequency of the amplitude moduation of the probe wave was 50 kHz, that is, the signal power should have been modulated at 100 kHz. In Fig. 2 (b), the $I_{receiver}$ modulated at 100 kHz was clearly observed. The scattering efficiency was estimated to be approximately 10^{-8}, which is six order smaller than that evaluated in a one-dimensional particle-in-cell simulation. This low scattering efficiency was attributed to insufficient excitation of EBWs by the external drive because of the impedance mismatch between the exciter, which employs a bow-tie anntenna, and the target plasma.

The scattered wave contains information about phase of the target density fluctuation. Therefore, by extracting the phase information from the scattered waves, for example by a frequency scan of the probe wave, group delay measurement, and so on, the wave-number of the fluctuation can be obtained.

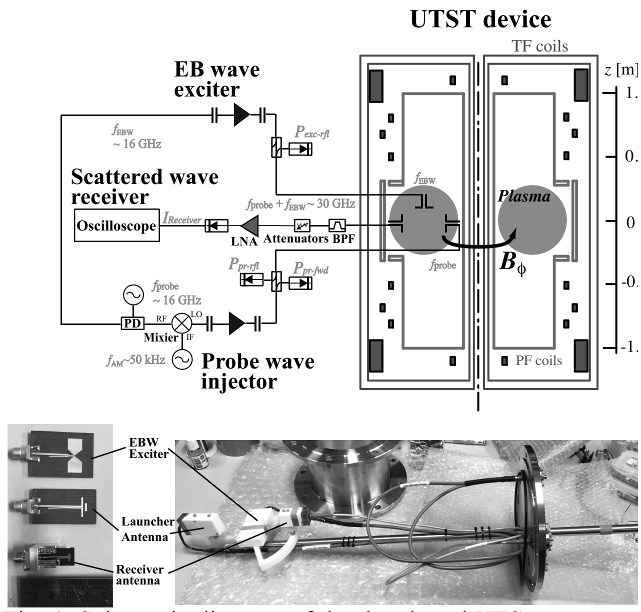

Fig. 1. Schematic diagram of the developed UFS system with the UTST device (top) and photos of the antenna array system (bottom right) and the antennas (bottom left).

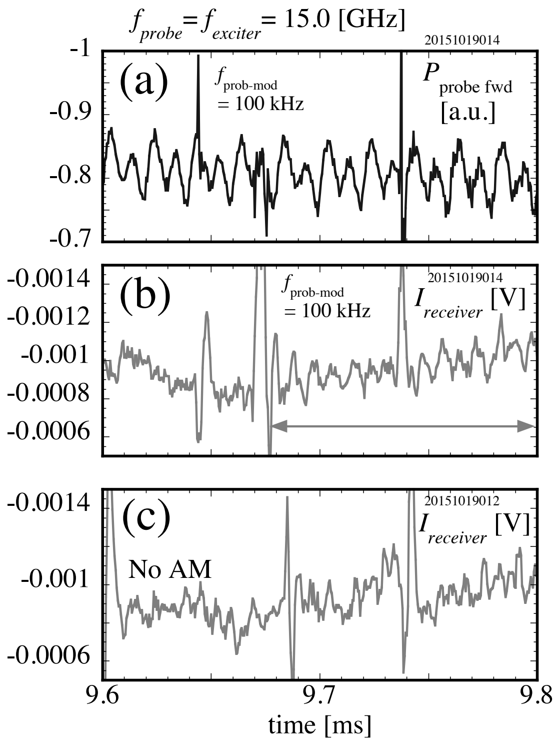

Fig. 2 Time evolution of (a) the forward power of the amplitude-modulated–probe wave (b) the receiver signal $I_{receiver}$ and (c) that in a no-modulation case as a reference.

1) K. M. Novik, A. D. Piliya, Plasma Phys. Controlled Fusion **35** (1994) 357-381.