§23. Higher Harmonic Electron Cyclotron Emission Diagnostics

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Electron cyclotron emission (ECE) measurement has been a main diagnostic to measure the temporal behavior of electron temperature profiles in plasmas. The second harmonic ECE is widely used for the electron temperature diagnostics. The higher harmonic components are important to diagnose the non-thermal energetic-electron distributions in plasmas. In the LHD experiment, the second harmonic component is measured using heterodyne radiometers with high time and spatial resolutions, while the higher harmonic components are measured using a Michelson spectrometer. A double-side-band high frequency (~300GHz) radiometer system has been developed to measure the higher harmonic components. In order to measure the ECE signal with high time resolution, a local oscillator with a fast frequency-switching synthesizer was prepared. The frequency- switching time was 5 μs for the 288 MHz step in the high frequency range. The radiometer has much higher time and frequency resolutions than those of the Michelson spectrometer.

In the setup of the high frequency radiometer to the LHD, a quasi-optical system to couple the emission transmitted by the corrugated waveguide into a receiver horn antenna was designed. Figure 1 shows beam intensity profiles from the horn antenna along the beam. The x axis is in perpendicular to the propagating z axis. The operation frequency was 318GHz. The waist size and position were derived from the beam-size evolution along the propagation direction using Gaussian optics, and thus, a quasi-optical mirror was designed for the coupling between the waveguide and the antenna using the obtained Gaussian parameters. In the LHD, a vacuum quartz-window with a thickness of 12 mm was used at the viewing port. The transmission at the window was tested in the high frequency range of 291-320GHz. Figure 2 shows frequency dependencies of the measured and calculated transmission rates. The measured rate has a sinusoidal dependence with a period of about 6GHz as calculated, but is deformed with some aberrations. The detector was set across the window from the millimeter launcher. The measured transmission rate was affected by the reflection and scattering at the window as resulted in the interference. The transmission rate will be measured in the quasi-optical transmission to reduce the reflection and scattering effects in the measurement, again.

The sensitivity of the radiometer system, including the waveguide and quasi-optical transmissions, and the window, will be calibrated using a high temperature (~800K) calibration source. The frequency dependence of the sensitivity can be checked from the signals modulated by the frequency switching. This fast frequency-switching radiometer system will be applied to the higher harmonic ECE diagnostics for the LHD experiments.

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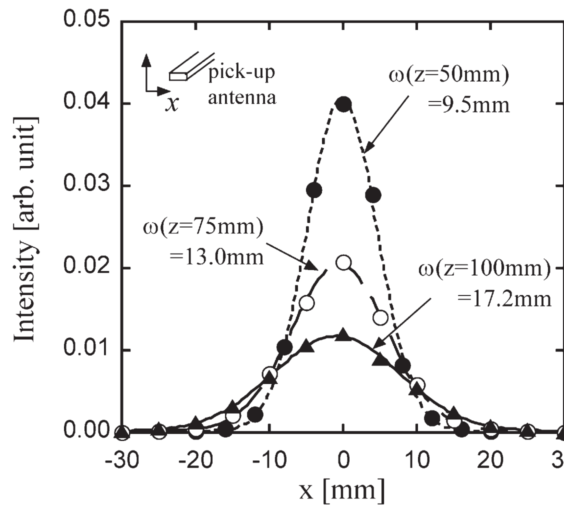

Fig. 1. Beam intensity profiles from the horn antenna along the propagation.

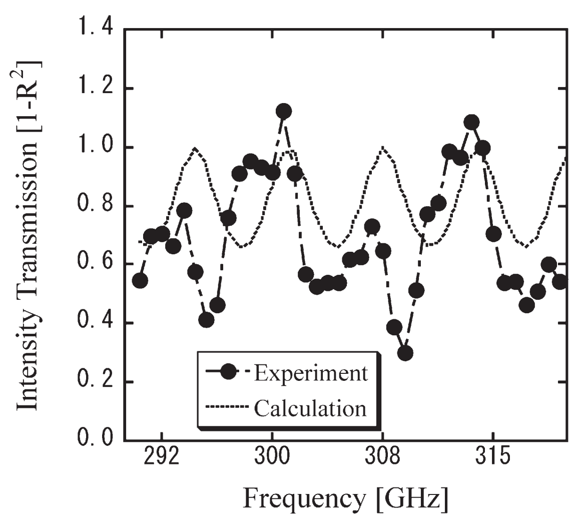

Fig.2. Frequency dependencies of measured and calculated transmission rates at a vacuum quartz-window with a thickness of 12 mm.