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Measurement of Electron Density Fluctuations using Microwave Reflectometer in Heliotron J
ヘリオトロンJにおけるマイクロ波反射計を用いた電子密度揺動計測

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A microwave reflectometer for measurement of electron density fluctuations is developed in Heliotron J. The injection frequency of microwave ranges from 24.75 to 42 GHz corresponding to the O-mode cut-off density from 0.8 to 2.2×10^{19} m^{-3}. A characteristic test with a vibrating reflector shows that the output signal from the emitting horn has intensity from -10 to -5 dBm over the frequency range and that the reflectometer can measure fluctuations corresponding to frequency given to the vibrating reflector.

1. Introduction

It is necessary to understand the mechanism of anomalous transport to improve plasma confinement. It is considered that anomalous transport comes from fluctuations of magnetic field, electric field, plasma density, and temperature out of various instability of plasma. Therefore, it is important to measure these parameters.

Measurement of density fluctuations with Langmuir probes and a beam emission spectroscopy has been developed and performed in Heliotron J. However, they can apply only to edge plasma or NBI plasma. Microwave reflectometer has a capability of measuring fluctuations over the confinement region for ECH and/or NBI plasmas by choosing injection frequency. In this research, we have been developing a microwave reflectometer system to measure electron density fluctuations. The goal of this research is to study the characteristics of plasma confinement by means of investigating MHD instabilities of energetic particles and long-range correlation of fluctuations by combining the reflectometer with other measurement methods.

2. Principle of Reflectometer

Microwaves produced by an oscillator are injected to plasma and reflected at an electron density corresponding to the cutoff frequency [1, 2]. When electron density fluctuations arise, the position of cutoff layer also changes with the fluctuations. The received waves with the fluctuations are mixed with the reference waves, and then the fluctuations are extracted by a phase detector. We measure electron density fluctuations at various cutoff layers by changing frequency of microwaves. For the measurement system reported here, we use the O-mode of which the cutoff frequency depends only on electron density.

3. System Configuration

We have designed and assembled a microwave reflectometer as shown in Figure 1 and performed a

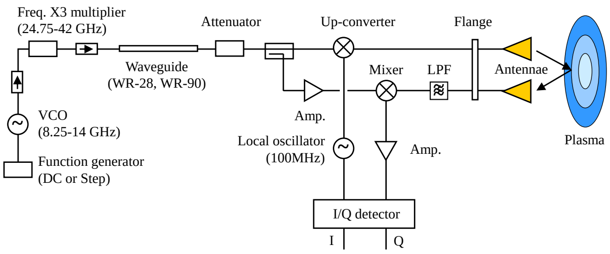

Figure 1 Schematic of reflectometer

characteristic test. The injection frequency of microwaves to plasma ranges from 24.75 to 42 GHz (Ka-band), corresponding to the O-mode cut-off density from 0.8 to 2.2×10^{19} m^{-3}.

A function generator supplies DC or step function to a voltage controlled oscillator (VCO). The frequency band of 24.75-42 GHz is generated by the VCO and a x3 frequency multiplier. The oversized waveguides of WR-90 are used for transmission of 5.8 m long in order to suppress transmission loss. The microwaves are then divided into the waves injected to plasma and the reference waves by using a directional coupler. After the injection waves are up-converted with a signal of 100 MHz generated by a local oscillator, they are injected into the Heliotron J plasma through a pyramidal horn. Two antennae are used as one for injecting waves and the other for receiving waves, located inside the vacuum vessel to remove parasitic reflection. At the receiver section, a low-pass filter is assembled to remove noise coming from a high-power 70 GHz gyrotron. The received microwaves are mixed with the other waves divided by the directional coupler to down-convert to the frequency of 100 MHz with fluctuations, delivering to an I/Q detector. We can estimate the complex phase difference between the received waves and the reference waves through the I and Q signals. The sampling frequency of a data acquisition system is 1 MHz.

4. Characteristic Test

We have examined the performance of the reflectometer in a test stand by using a vibrating reflector to simulate plasma fluctuations. Figure 2 shows the intensity of microwaves in the test stand.

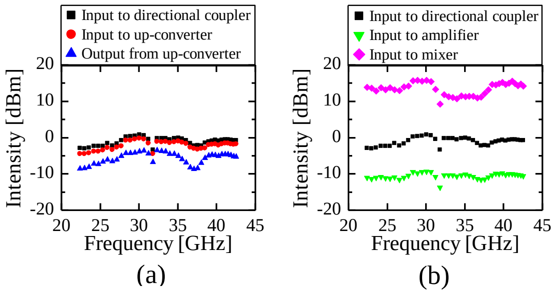

Figure 2 Intensity of microwave in test stand

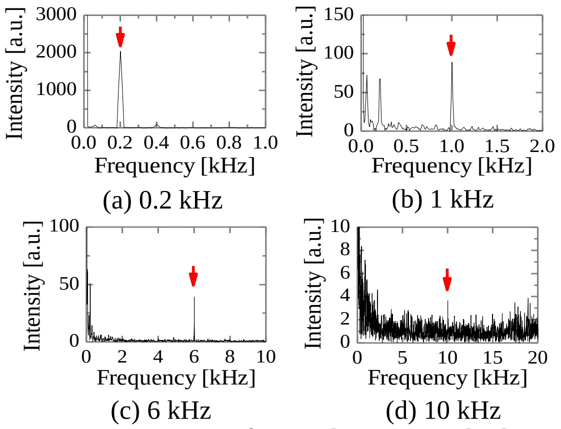

Figure 3 Spectrum of I signal in test stand. The frequency of incident microwaves is 29.5 GHz.

The intensity of microwaves at each point is adjusted by an attenuator located before the directional coupler so that the input signal to the mixer is less than 15 dBm to avoid the damage. The average signal intensity and the flatness after the up-converter are -5.6 dBm and 5.2 dB, respectively.

Figure 3 shows the FFT result of the I signal of I/Q detector. It is found that a peak appears at the frequency of the vibrating reflector, indicating that the simulating fluctuations are measured as designed. The maximum measurable frequency of the fluctuations is 10 kHz in the test stand. The amplitude of fluctuations at the frequency higher than 10 kHz from the vibrating reflector may be too low to be measured. It is expected that this system can measure fluctuations of higher frequency because the I/Q detector can measure up to 1 MHz signals as the specifications. In fact, we confirmed in last experimental campaign that fluctuations of 200 kHz could be measured in Heliotron J plasma with a Q-band reflectometer with the same I/Q detector. We will start the density fluctuation measurement using the new Ka-band reflectometer in ongoing experimental campaign.

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