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Development of Ka-band Microwave Reflectometer for Electron Density Fluctuation in Heliotron J
ヘリオトロンJにおける電子密度揺動計測用 Kaバンドマイクロ波反射計の開発

Ayako Suzuki[1], Hideki Kishikawa[1], Kazunobu Nagasaki[2], Kiyofumi Mukai[4], Takeshi Fukuda[3], Tohru Mizuuchi[2], Fumimichi Sano[2] et al.

鈴木 文子[1]，岸川 英樹[1]，長﨑 百伸[2]，向井 清史[4]，福田 武司[3]，水内 亨[2]，南 貴司[2]，小林 進二[2]，門 信一郎[2]，岡田 浩之[2]，山本 聡[2]，大島 慎介[2]，L. Zang[2]，釼持 尚輝[1]，大谷 芳明[1]，原田 伴誉[1]，桐本 充晃[1]，程 崧明[1]，安枝 樹生[1]，呂 湘潯[1]，Asavathavornvanit Nuttasart[1]，中山 裕介[1]，木谷 壮志[1]，西川 幸祐[1]，村上 弘一郎[1]，洪 重遠[1]，元嶋 誠[1]，中村 祐司[1]，木島 滋[2]，佐野 史道[2]

1 Graduate School of Energy Science, Kyoto University, Gokasho, Uji, Kyoto, Japan
京都大学大学院エネルギー科学研究科　〒611-0011　京都府宇治市五ヶ庄
2 Institute of Advanced Energy, Kyoto University, Gokasho, Uji, Kyoto, Japan
京都大学エネルギー理工学研究所　〒611-0011　京都府宇治市五ヶ庄
3 Center for Atomic and Molecular Technologies, Osaka University, 2-1, Yamadaoka, Suita, Osaka, Japan
大阪大学原子分子イオン制御理工学センター　〒565-0871　大阪府吹田市山田丘 2-1
4 National Institute for Fusion Science, Toki, 509-5292 Japan
核融合科学研究所　〒509-5292　岐阜県土岐市下石町 322-06

A microwave reflectometer for measurement of electron density fluctuations is developed in Heliotron J. The injection frequency of microwaves is swept from 26.3 to 41.1 GHz corresponding to the O-mode cut-off density from 0.86 to 2.10×10^{19} m^{-3}. Performance tests show that the phase of carrier frequency microwaves can be estimated by I and Q signals from an I/Q detector, suggesting that this system can measure the density fluctuations.

1. Introduction

It is necessary to understand physics of anomalous transport to improve plasma confinement. It is thought 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 electrostatic probes and a beam emission spectroscopy has been developed and used in Heliotron J. However, they can apply only to the edge plasma region. A microwave reflectometer has a capability of measuring electric density and its fluctuations over the confinement region for ECH and/or NBI plasmas by choosing the injection frequency [1][2]. In this research, we have been developing a microwave reflectometer system to measure electron density fluctuations. The goal of the research is to clarify the behavior of electron density fluctuations in the plasma where plasma confinement is improved or energetic-particle-driven MHD instabilities are excited.

2. System Configuration

Microwaves produced by an oscillator are injected to a Heliotron J plasma. The microwaves injected into the plasmas are reflected at a layer where the electron density is corresponding to the cutoff frequency. When electron density fluctuations arise, the position of the 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. The electron density fluctuations at various cutoff layers can be detected by changing frequency of microwaves. For the measurement system reported here, we use the O-mode waves where the cutoff frequency depends only on the electron density.

We have designed and assembled a microwave reflectometer and performed characteristic tests for each part. Figure 1 shows the schematic of the microwave reflectometer. The injection frequency of microwaves to plasma is swept from 26.3 to 41.1 GHz, corresponding that the O-mode cut-off electron density ranges from 0.86 to 2.10×10^{19} m^{-3}.

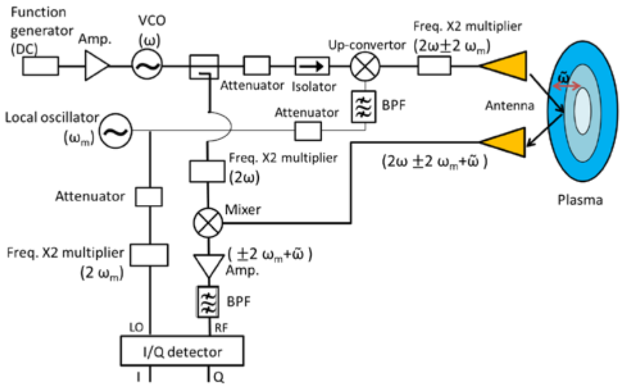

Fig. 1. Schematic of reflectometer

A function generator supplies DC or step function to a voltage controlled oscillator (VCO). The frequency band of VCO is 13.1-20.6 GHz.

The microwaves are then divided by using a directional coupler into the probe waves, which are injected to the plasma, and the reference waves. After the probe waves are up-converted with 100 MHz by a local oscillator, these frequency is doubled by a ×2 frequency multiplier and the waves whose frequency band is 26.3-41.1GHz (Ka-band) are injected into the Heliotron J plasma and received through pyramidal horns. The antennas are located inside the vacuum vessel.

The received microwaves are mixed with the reference waves to down-convert to the frequency of 200 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.

3. Performance Test

We have examined the performance of the reflectometer in a test stand. Figure 2 shows the intensity of incident microwaves. The maximum and minimum powers of incident microwaves are 11.9 dBm at 26.9 GHz and 6.33 dBm at 41.1 GHz, respectively, which may be high enough for density fluctuation measurement.

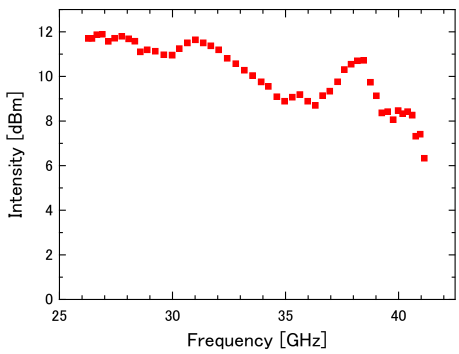

Fig.2. Frequency dependence of incident microwaves

Figure 3 shows the characteristic of the I/Q detector as the transmission distance of microwaves is changed. We moved the transmitter horn away from the receiver horn by 1mm interval and measured the intensity of the I and Q signals. The up-convertor generates both sideband frequency waves, making the I and Q signals with the constant phase. It is found that the wavelength estimated from the I or Q signal corresponds to that of carrier frequency, λ = 1.14cm. It suggests that the amplitude of the I and Q signals reflects the phase difference between the incident and reflected waves, meaning that we can measure the density fluctuations. In the future, the up-convertor will be changed into a single-sideband type, with which the measured I/Q phase is proportional to the density fluctuations.

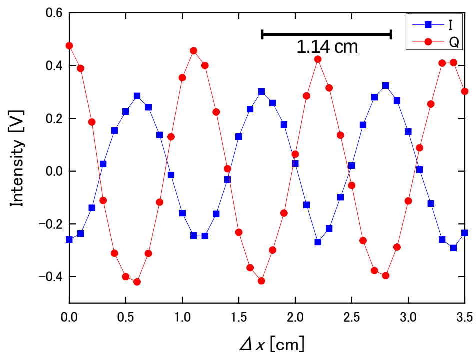

Fig. 3. Relationship between intensity of I and Q signals and the transmission distance change. The frequency of incident microwaves is 26.3 GHz.

4. Summary

We have constructed the reflectometer system for density fluctuation measurement in Heliotron J. The laboratory tests confirmed that the system can work for the phase measurement. We will start the density fluctuation measurement using this Ka-band reflectometer in Heliotron J experiments.

Acknowledgments

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