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Development of numerically-processed millimeter-wave interferometer for electron density profile measurement, and evaluation experiment in a lab

電子密度分布計測のための数値処理型ミリ波干渉計の開発と実験室におけるトモグラフィー検証実験

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1. Introduction

Density profile measurement is important for plasma fusion experiment to evaluate confinement performance of experimental devices. For example, confinement improvement phenomenon like internal transport barrier (ITB) had been found and confirmed by some institute and experimental devices [1-3]. ITB is localized in internal thin-sheet area, and can be measured by precise density profile measurement. ITB is not well understood yet, however, it is considered that magnetic field sheer controlled by plasma current profile reduces transport due to turbulences. Plasma experiment operation is basically performed statically, i.e. time-schedule on an operation such as strength of an external magnetic field, injection time of neutral ion beam, and so on, is set before a plasma shot. In order to improve the plasma confinement, feedback control operation will be introduced in an experiment. Precise profile measurement together with feedback control helps improvement core plasma performance maintaining MHD stability. Profile measurement system for feedback control requires some feature. Firstly, high temporal resolution, i.e., real time measurement is necessary. Some control treatment has to be performed before instability affects the confinement. Secondary, wide measurable area and precise spatial resolution are required. For these features, we have been developing electron density profile measurement system based on an interferometry [4,5].

2. Interferometer system

Figure 1 shows a schematic illustration of the interferometer system. This interferometer is designed and being developed for central cell plasma on GAMMA10 [6] tandem mirror at university of Tsukuba. Maximum electron density of core plasma is around 2×10^{12} [cm^{-3}], so we utilize millimeter wave with frequency from 70 to 80 GHz as probing wave.

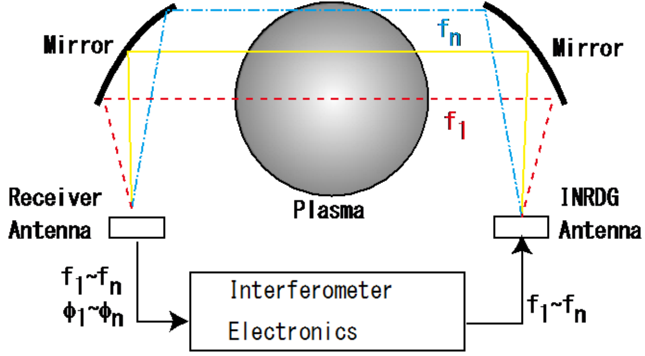

Fig. 1 numerical processed interferometer

An image non-radiative guide (INRDG) antenna can scan the probing wave direction by changing the input frequency of the INRDG antenna. Multiple measurement paths can be arranged by means of two parabolic reflectors, as shown in fig. 1. In the present experiment, we employ a vector network analyzer (VNA) utilizing frequency range between 2 to 12GHz. We utilize a frequency up and down-converter along with the VNA to generate millimeter wave range source . The VNA measures phase as a function of frequency between 70 and 80 GHz. The phase is proportional to the line integrated electron density. While, frequency is corresponding to vertical plasma position. Therefore, this interferometer system can measure a spatial electron (integrated) density image. Number of frequency measurement point, i.e. measurement position, is 601.

3. Validation experiment in a laboratory

We evaluated this interferometer system in a laboratory as shown in figure 2. Instead of plasma, a foamed styrol with a height of 30 mm, and thickness of 60 mm is placed in the middle of the reflectors.

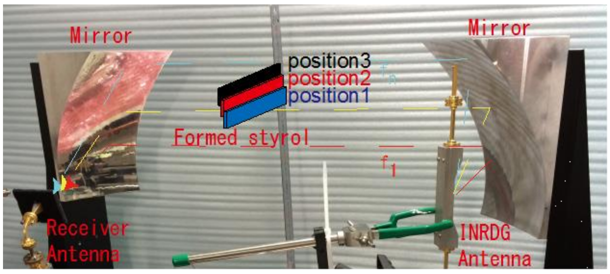

Fig. 2 validation experiment of the interferometer in the lab

Figure 3 shows the measurement results. Here, each curve is acquired by changing the vertical foamed styrol position (position 1-3) as shown in fig. 2. The most left (right) curve corresponds to position1 (3). Lower (higher) frequency in the bottom axis corresponds to lower (higher) vertical positon. It is found that peak frequency position is shifting to higher as spatial styrol positon is moving towards upper positon. It is considered that peak phase value of each curve corresponds to thickness and refractive index of the styrol; however, we cannot evaluate this value, because we do not have actual value of refractive index of the styrol. Shapes of the measurement results are smooth. Ideally, the shape of the curve must become rectangle, because the styrol is rectangular parallelepiped. This difference is due to finite spot size of the probing beam.

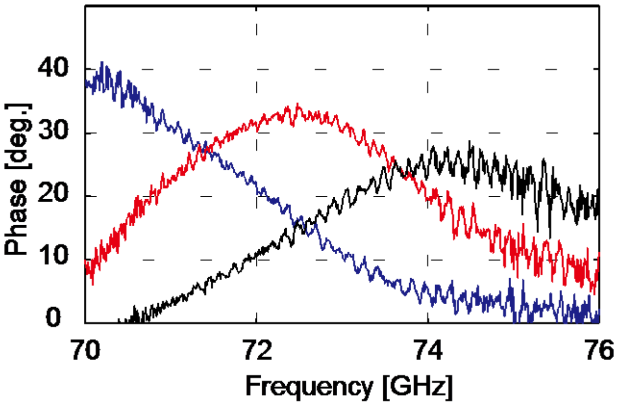

Fig. 3 Imaging results of the foamed styrol. The three curves from left to right correspond to the locations of the styrol from position 1 to 3, respectively.

In order to improve the image resolution considerably, we need to employ tomography technique to the analysis. By measuring beam power distribution at the foamed styrol positon, these bluer data is reconstructed to fine image. We plan to present a reconstructed image in the conference.

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