§15. Development of Digital-based Millimeter-wave Interferometer and its Application to High Spatial Resolution Measurement of Electron Density Distribution

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Measurement of electron density distribution is important to control and investigate the plasma confinement. There are various promising ways to measure electron density distribution. Interferometer, reflectometer, Thomson scattering are frequently used in various plasma experimental devices. These measurement systems measure electron density of fixed position, and cannot move the measurable area without changing the system configuration. We propose a digital-based millimeter wave interferometer based on the interferometer. This system has the advantages basically in movable measurement area, simpler measurement system.

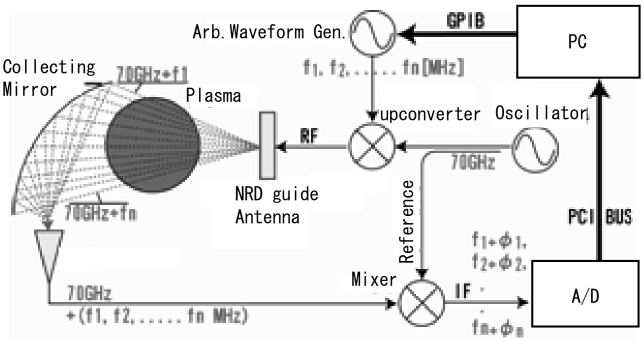

FIG. 1 Experimental apparatus of the digital-based millimeter-wave interferometer

Fig. 1 shows a concept of digital-based interferometer. A Gunn oscillator feeds a local oscillator (LO) signal to an upconverter and frequency mixer. Frequency of the oscillator is 70GHz. An arbitrary function generator signal is utilized to upconvert the LO signal. The resultant frequency for a transmitter is slightly upshifted by the upconverter, and is controlled by changing output frequency of the arbitrary function generator from the controller PC. The output from the upconverter is fed to a transmitter antenna. Here, we utilize a leaky wave antenna. The direction of the transmitted wave from the leaky wave antenna can vary by changing the input frequency into the antenna. The transmitted wave is passing through the plasma and is collected into a receiver horn antenna by an optical mirror. The received signal is then mixed with the LO signal, and is downconverted by the mixer. An intermediate frequency (IF) signal is sampled by an analog to digital (A/D) converter. Finally, the raw signal is analyzed by the software.

In order to realize the interferometer, we start to develop the leaky wave antenna. Fig. 2 shows the schematic view of the leaky wave antenna based on non-radiative dielectric (NRD) guide antenna. The transmission line of the NRD guide is fabricated simply as follows. A dielectric rod is sandwiched by two conductor plates. Electrical length of the propagating wave inside the dielectric rod is shorter than that in the air, since the dielectric constant of the rod is larger than that of the air. The thickness of the air gap between the plates, which is equal to height of the dielectric rod, is set in order that propagation condition in the air gap and the dielectric rod becomes cutoff and transmission, respectively. Propagating wave is confined inside the dielectric rod. This propagation method is called surface wave. We utilizes Teflon composite (dielectric constant is 5.8) as material of the dielectric rod. As shown in the cross-sectional view of the NRD guide in fig. 1, the length from the dielectric rod to the aperture of the one side is very short compared to the wave length, some part of the confined wave leaks from the aperture and radiates to the outside. We can utilize this NRD guide as the antenna. The radiation direction of the NRD guide antenna is a function of the frequency, since the propagation constant (wave number) along to the dielectric rod is a function of the frequency. In order to inject the millimeter wave to the NRD guide, we employ the waveguide-NRD guide transition as shown in fig. 1. The transition is composed from taper waveguide from WR-12 and a dielectric rod.

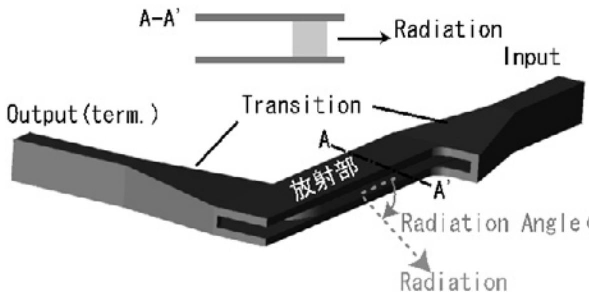

FIG. 2 Schematic view of the NRD guide antenna

We have performed the electromagnetic simulation of the NRD guide antenna by the finite element method (EMPRO by Agilent technology). Fig. 3 shows radiation pattern simulated by the EMPRO. Input frequency to the antenna varies from 71GHz to 75GHz by 1GHz step. It is confirmed that radiation direction is controllable by changing the input frequency. The angle change of the transmitting direction is 30 degree. Maximum of the field strength of the 71GHz pattern is less than the radiation pattern of other frequencies. This phenomenon is occurred due to the transmission in the NRD guide around cutoff region. We set the cutoff frequency of the NRD guide to be 70GHz.

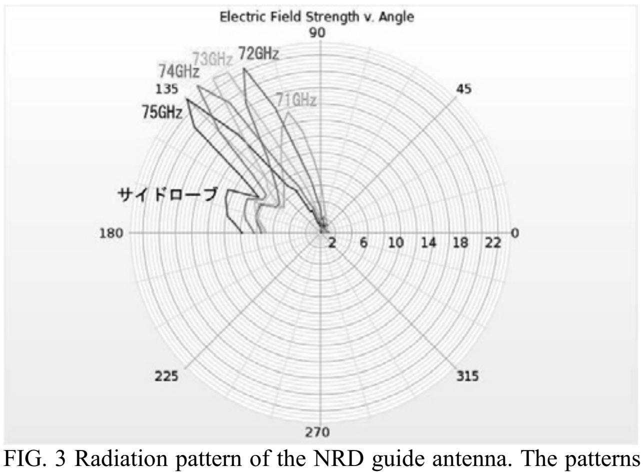

FIG. 3 Radiation pattern of the NRD guide antenna. The patterns of the input frequency from 71 to 75GHz are plotted.

Bandwidth over 4GHz needs to sweep the probe beam over 30 degree. We think this bandwidth is too wide to realize the ideal diagnostics system as shown in fig. 1. In the present condtion, the sampling frequency is limited to 2GHz. We must consider various improvements for achievement of our diagnostic system, including modification of electronics, utilizing higher dielectric constant material for the antenna.