§17. Development of Two-Dimensional Millimeter-Wave Imaging Array

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Millimeter-wave imaging diagnostic technique has been developed for measurements of density and temperature profiles and their fluctuation components in magnetically confined plasma. This technique uses a single set of optics and multichannel detector array instead of a multichannel optical path with a single detector for each chord.

We have developed a millimeter-wave imaging system for the application to the electron cyclotron emission (ECE) measurement on LHD.[1] Figure 1 shows the schematic of the experimental setup. The optics are designed by using a ray-tracing method to focus radiation signals onto a detector array. An ellipsoidal mirror and a plane mirror located inside the vacuum vessel converge the ECE signals to pass a fused-quartz vacuum window with 192 mm in diameter. An object plane located at the plasma center is 2.7 m in front of the ellipsoidal mirror. The Airy pattern of a point source is measured in order to confirm the performance of the optical system along the x and y-axes. The results are in good agreement with the theoretical values. The magnification of the optical system is also investigated experimentally, which agrees well with the designed value of 0.68.

The frequency of the second-harmonic ECE on LHD ranges from 120 GHz to 180 GHz. In order to cover this frequency range, detectors using MMIC (microwave monolithic integrated circuit) technology are designed and fabricated as shown in Fig. 2. The MMIC detector consists of the integration of a bow-tie antenna, down-converting mixer using a Schottky barrier diode, and hetero-junction bipolar transistor (HBT) amplifiers on a GaAs substrate. Figure 2 (a) is the first mask pattern, and (b) is the recent one. The GaAs chip sizes are 4.0 mm × 2.0 mm and 2.0 mm × 2.0 mm, respectively. In Fig. 2 (b), a coplanar waveguide (CPW) is directly connected to the bow-tie antenna, and the Schottky barrier diode is inserted between the signal and the ground line of the CPW. The lower cutoff frequency increases up to 44 GHz due to the small size of antenna, however, the improvement of IF bandwidth is expected.

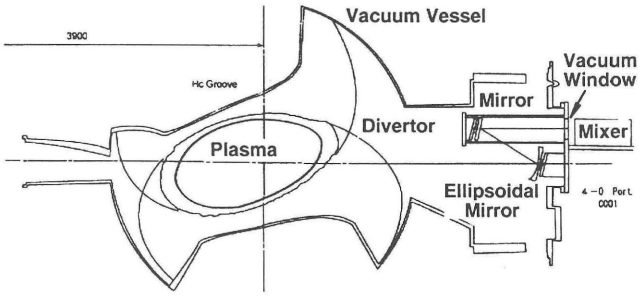
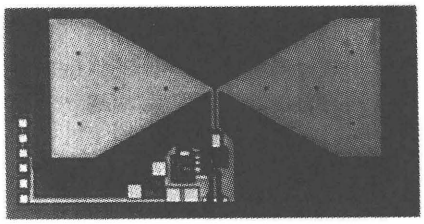


Fig. 1. Schematic of the LHD Imaging System.

The heterodyne characteristics of the MMIC detector are measured in a test stand using two oscillators in the frequency range of 70-140 GHz. The IF response of 10 GHz is ~20 % better than that of the first design.

(a)



(b)

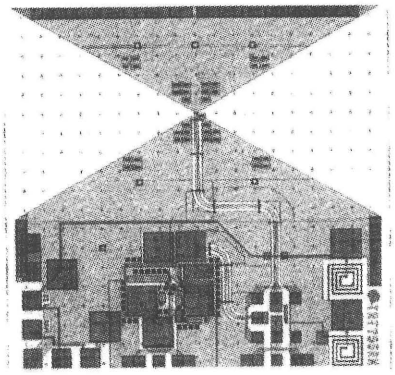


Fig. 2. Mask pattern of the monolithic detector.

The first experiment on the ECE imaging was performed from the end of January till the beginning of February 2001. The ECE signal is obtained at each IF channel and detector.

Reference

1) Mase, A. et al., Rev. Sci. Instrum. **72**(2001)375.