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

Mase, A. (Advanced Science and Technology Center for Cooperative Research, Kyushu Univ.), Negishi, H. (Plasma Research Center, Univ. Tsukuba),
Nagayama, Y., Kawahata, K., Matsuura, H., Uchida, K., Miura, A. (R&D Dept. 1, Teratec Co.)

Millimeter-wave imaging diagnostic technique has been developed for measurements of density and temperature profiles and their fluctuation components in magnetically confined plasmas [1, 2]. 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 two-dimensional imaging system for the application to the GAMMA 10 tandem mirror at the University of Tsukuba. It consists of a quasi-optical transmission and a heterodyne receiver with frequency of 70 GHz. The detector is 16 elements of beam-lead GaAs Schottky barrier diodes bonded to bow-tie antennas, which is called as a hybrid detector. The imaging system has been constructed in order to apply to the ECE measurement on LHD. The frequency of the second-harmonic ECE on LHD ranges from 120 GHz to 180 GHz. In order to cover this frequency range, monolithic-type (MMIC) detectors are designed and fabricated. The characteristics of the MMIC detector and the results of the experimental evaluation of the optics are reported in this paper.

The optics for LHD ECE-imaging system 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 converges 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 magnification of the optics is 0.68.

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. The HBT works as an IF amplifier with 10 dB voltage gain. The GaAs chip with 4.0 mm$\times$2.0 mm$\times$0.625 mm is mounted on the case made of gold-plated brass together with alumina substrate for dc bias of the SBD and HBT amplifiers. A coplanar waveguide on the other substrate is used for the connection of the IF output to an SMA connector.

The heterodyne characteristics of the MMIC detector are measured in a test stand using two oscillators in the frequency range of 70-140 GHz. One oscillator is used as an LO signal and the other as a radio frequency (RF) signal. Figure 2 shows the heterodyne signal intensity as a function of IF measured with a spectrum analyzer. It is noted that rather flat response from 0.2 to 9 GHz is obtained in contrast to a hybrid detector using a beam-lead SBD, which is probably due to the method of housing of the semiconductor chip as well as due to the small inductance of the signal line and the performance of the SBD.

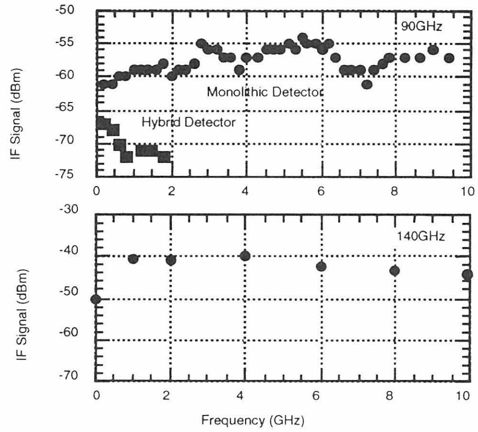

Fig. 1 The heterodyne characteristics of the two-types of detectors.

The Airy pattern of a point source is measured in order to confirm the performance of the optical system. A 140 GHz source is located at the position corresponding to the plasma center. The source is imaged onto the detector array. The magnification of the optical system is also investigated experimentally, which agrees well with the designed value.

The heterodyne detection test of the receiver system is performed using the present optical system. A 0.1 μW signal of frequency 140 GHz is detected with good signal to noise ratio (~10). We should obtain better response by increasing an LO power up to a few mW, which is necessary to measure the fluctuation component of electron temperature. The optical system will be installed in LHD next fiscal year.

References
[1] B. H. Deng *et al.*, Rev. Sci. Instrum. **70** (1999) 998.
[2] A. Mase *et al.*, Fusion Eng Design (to be published).