§23. ECE Imaging on LHD

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Significant advances in microwave and millimeter wave technology have enabled the development of a new generation of imaging diagnostics as a visualization tool in this frequency region. Millimeter wave imaging diagnostic system is expected to be one of the most promising diagnostic methods that measure profiles and fluctuations in magnetically confined plasmas. We have developed an imaging system with frequency of 140 GHz for the application to the large helical device (LHD) at National Institute for Fusion Science.

The imaging system consists of quasi-optical focusing optics and planar type detectors. We have developed both hybrid and monolithic detectors. The monolithic detector differs from hybrid one in that the diodes are monolithically integrated directly onto the antennas for improved response of sensitivity and intermediate frequency (IF) in heterodyne detection, reproducibility, and reduced hand labor. It has been developed and fabricated for the measurement of high frequency electron cyclotron emission (ECE) of LHD plasmas in a collaboration between Kyushu University, Teratec Co, and Kyushu Hitachi Maxell, Ltd. It consists of the integration of a bow-tie antenna, down-converting mixer using a Schottky barrier diode, and hetero-junction bipolar transistors (HBTs) on a GaAs substrate. The HBTs work as an IF amplifier with ~10 dB voltage gain. The GaAs chip size is 2.0 mm×2.0 mm. In the recent mask pattern, a coplanar wave guide (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. The heterodyne characteristics of the monolithic 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 mask pattern.

The optics for ECE-imaging on LHD are shown in elsewhere.[1] An ellipsoidal mirror and a plane mirror located inside the vacuum vessel converge the ECE signals to pass a fused-quartz vacuum window with a diameter of 192 mm. The diameters of the mirrors are determined to obtain desired resolution calculated using diffraction theory. An object plane located at the plasma center is 2.7 m in front of the ellipsoidal mirror. The detector is installed inside an aluminum box for electrical shielding, and a pyramidal horn antenna array in TE_{10} mode is attached to the both sides of the detector. The second-harmonic ECE signals in the extraordinary mode are mixed with a LO power on the detector array. The LO beam is focused onto the detectors by using cylindrical lens. The IF signals amplified by a chain of amplifiers (1-8 GHz, 80 dB) are separated into four channels. Each signal is then band pass filtered. A range of filters is available with center frequency from 1 to 8 GHz at 1 GHz intervals; each has a 3 dB bandwidth of 300 MHz. The signal is then passed through a square-law detector.

The ECE measurement on LHD using present imaging system has started from 2001. Figure 1 shows the time evolution of the ECE signals obtained from each detector and IF channel (4-7 GHz) for a long time discharge. The system is calibrated using a millimeter-wave source. The peak electron temperature is thus evaluated as 3-4 keV, which is in good agreement with that obtained from a conventional radiometer installed in LHD. In Fig. 2 is shown a cross-correlation spectrum between two detectors. It is noted that the low frequency spectrum of 10-50 kHz which is in the range of MHD mode is enhanced, and drift-wave like mode with 100-500 kHz is not observed although it was observed in the experiments in a tokamak.

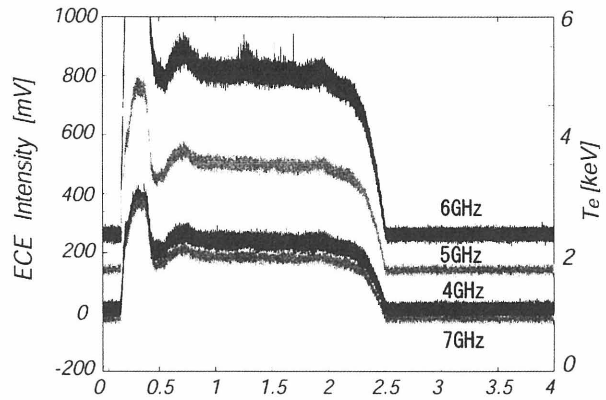

Fig. 1. Time evolution of the ECE signals for various IF channels: from top to bottom, IF=4, 5, 6, and 7 GHz.

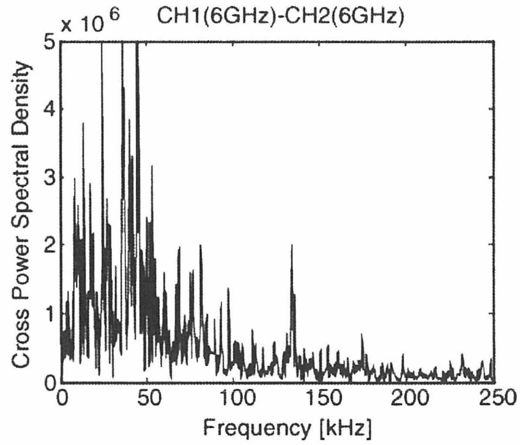

Fig. 2. Cross spectrum between two azimuthal detectors. The IF channel corresponds to 6 GHz.

Reference

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