§ 22. ECE Imaging on LHD

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In magnetically confined plasmas, the measurement of electron cyclotron emission (ECE) has become a main diagnostic to determine temporal and spatial behaviors of electron temperature. The radiation intensity of optically thick ECE harmonics reaches that of black body radiation. Therefore, the electron temperature and its fluctuations can be diagnosed by measuring the intensity of ECE. Time resolved 1D temperature profiles can be obtained by using a conventional radiometer. On the other hand, ECE imaging (ECEI) is a method whereby two-dimensional (2D) to three-dimensional (3D) images of temperature fluctuations as well as temperature profiles can be obtained.

The imaging system consists of quasi-optical focusing optics and planar type detectors. The detectors have been developed and fabricated in a collaboration between Kyushu University, Tratec 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. The GaAs chip size is 2.0 mm×2.0 mm. In the present 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 second-harmonic ECE signals in the extraordinary mode are mixed with an LO power on the detector array. The IF signals are amplified by a chain of amplifiers (0.5-8 GHz bandwidth and 73 dB gain) and subsequently separated into 4-8 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 signals are then passed through square-law detectors and fed to the LHD data processing system.

The key issue is to obtain two signals, which have uncorrelated thermal fluctuations, or radiation noise. This decorrelated intrinsic noise can then be averaged out in statistical analysis to reveal the usually smaller electron temperature fluctuations due to plasma instabilities, as the latter have different coherence properties from the thermal fluctuations. The cross-correlation spectra between two detectors at two IF channels are obtained. 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.

In the end of FY2002, a collaboration project using 10 Gbps ultrahigh-speed network (super SINET) has been started relating to the ECE imaging. The system is shown in Fig. 1. We can participate the LHD experiment via remote control system and transfer experimental data for the online data processing from NIFS to Kyushu. We have also started the study of microwave imaging reflectometry (MIR). In standard reflectometry the probing wave is launched and received on the equatorial plane using a pair of antennas. The measurement is essentially a point measurement, and does not provide direct information on the spatial structure of fluctuations. The 1D geometrical optics approximation, usually adopted, breaks down in the case of turbulent fluctuations, where there are large radial and poloidal variations. The need for MIR has been well documented through detailed reflectometry studies. A new type of antenna array such as dual-dipole antenna and a dichroic plate which separates the ECE and reflectometry signals has been designed for a convined system of ECEI and MIR. Figure 2 shows the transmission characteristics of the dichroic plate designed for the measurements of 70 GHz MIR and 140 GHz ECEI.

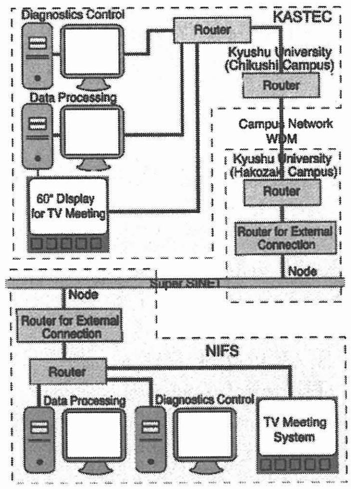

Fig. 1. Remote experiment system for LHD.

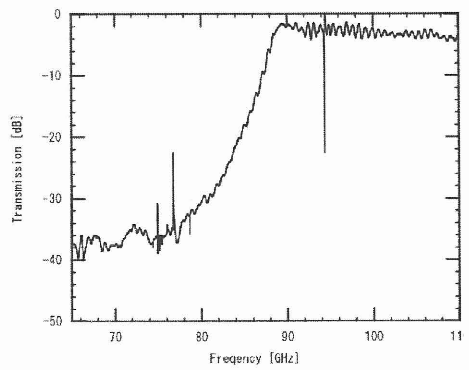

Fig. 2. Transmissivity of a dichroic plate

In summary, the time evolution and intensity of ECE signals obtained by an imaging system agree with those obtained by a conventional heterodyne receiver. The cross-correlation spectra of the signals obtained with different IF frequencies (radial correlation) and different detectors (poloidal correlation) are obtained. The convined system, ECE imaging and microwave imaging reflectometry, is being prepared for the next stage of LHD operation.

Reference
1) Mase, A. et al., Rev. Sci. Instrum. **74**(2003)1445.