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Fluctuations Observed by Microwave Imaging in LHD

LHDにおけるマイクロ波イメージングを用いた揺動観測

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The Microwave Imaging Reflectometry (MIR) and the Electron Cyclotron Emission Imaging (ECEI) has been developed in order to observe the electron density fluctuations and the electron temperature fluctuations, respectively. The edge harmonic oscillation (EHO) is observed by using 2-D MIR. The 2-D microwave image of EHO is has a narrow structure along the magnetic field line near the iota=1.5 surface.

While the magnetic plasma confinement is highly affected by the turbulence and micro-instabilities, diagnostics for turbulence have not been well established. In this work, the microwave imaging diagnostic systems (MIDS) such as the Microwave Imaging Reflectometry (MIR) and the Electron Cyclotron Emission Imaging (ECEI) has been developed in order to observe the electron density and the electron temperature fluctuations, respectively [1-4]. The

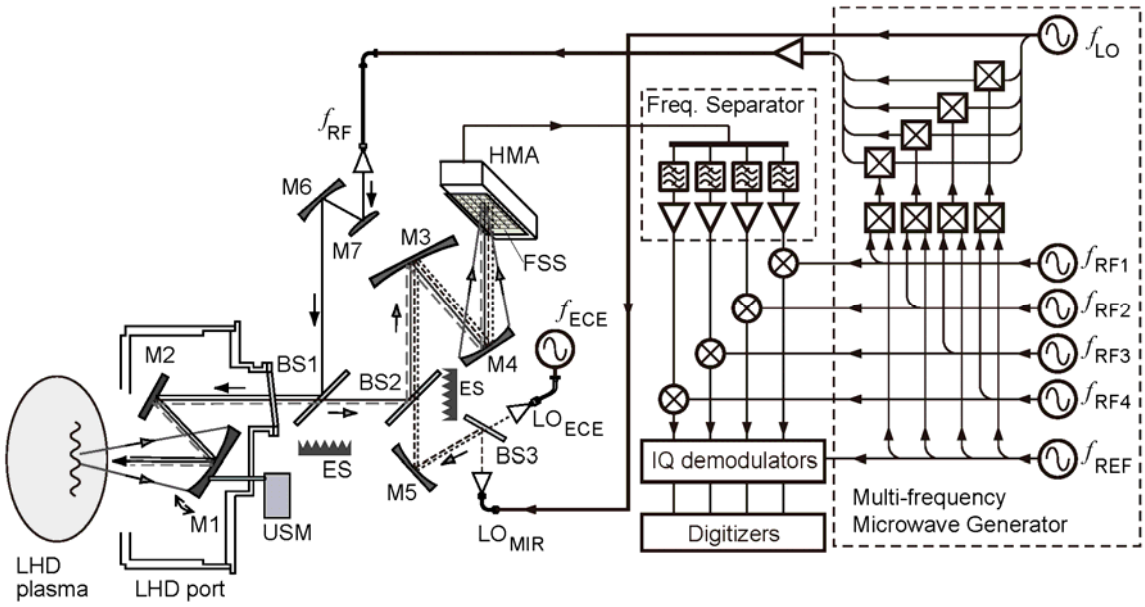

Fig.1 Microwave imaging diagnostic system (MIDS) in LHD.

plasma reflects the X-mode microwave of

$$\omega_{\mathrm{R}} = \frac{1}{2}\left\{\omega_{ce} + \left(\omega_{ce}^2 + 4\omega_{pe}^2\right)^{1/2}\right\} \quad (1)$$

where ω_{ce} and ω_{pe} are the electron cyclotron frequency and the plasma frequency, respectively. As frequencies of illumination wave are f_{RF}=60.4, 61.8, 63, 64.6 GHz, the plasma image on 4 different plasma layers can be detected by the 7×7 Horn-antenna Mixer Arrays (HMA) [1,2]. The frequency of ECEI is between 97 and 105 GHz. Fig. 1 shows a schematic view of MIDS in LHD. The optics is designed by using a FDTD simulation as the plane LO wave illuminates the HMA uniformly, and each channel of the antenna array is focused to a point of the object plasma [3]. MIR and ECEI use almost the same components. Differences are the frequency, the illumination wave and the phase detector. MIDS uses many channels of imaging detectors, frequency separators and IF amplifiers. In LHD, they are made of beam lead type electronics parts (resistor, capacitor, inductor, diode, MMIC, etc.) and thin Teflon printed circuit board (PCB) by using the micro-strip-line technology.

In LHD, the edge harmonic oscillation (EHO) is often observed. MIR and ECEI observe the EHO simultaneously. EHO is a fluctuation in the edge plasma, and it was observed in the VH mode plasma in DIII-D when the ELM is absent. The feature of EHO is the frequency spectrum of equally separated higher harmonics. Fig.2 shows the FFT spectrum of the amplitude of MIR, and ECE of EHO in the case of standard LHD operation (R_{ax}=3.6 m, B_{ax}=2.75 T, n_{e0}=2.5×10^{19} m^{-3}). The rainbow color code indicates the fluctuation amplitude in the log scale. The fundamental frequency is 3 kHz and 10 harmonics is observed.

Figure 3 shows a typical example of 3-D MIR image of EHO. RF1, RF2, RF3 and RF4 correspond to R=4.56, 4.55, 4.54 and 4.525 m, respectively. The EHO is localized near the iota=1.5 surface, where R=4.525 m. Since the channel separation is 2 cm, the width of EHO may be 5 cm along the flux surface. Looking at the time, the EHO begins in the outer region and proceeds to the inner region. Thickness of EHO in the radial direction is 2 cm, because it appears between RF1 and RF2. So, the EHO has a single narrow structure along a field line. Moving narrow structure makes signal with many harmonics.

In conclusion, the 3-D microwave imaging diagnostic system has been developed in LHD. The 2-D microwave image of EHO that is obtained by MIR shows the EHO has a very narrow structure along the field line. This is the first 3-D MIR measurement in the world.

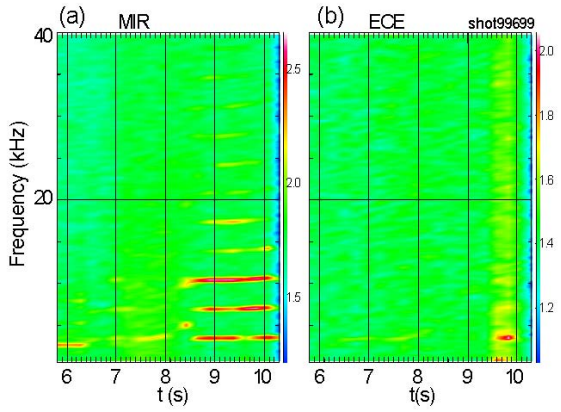

Fig.2 FFT spectrum of (a) the amplitude of MIR, and (b) ECE of the edge harmonic oscillations (EHO) in LHD.

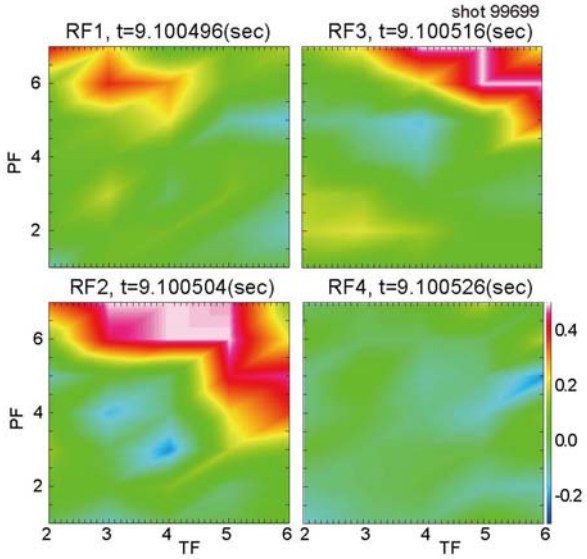

Fig.3 2 D MIR image of EHO shown in Fig.2.

Acknowledgments

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