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ECE Imaging diagnostics on LHD
LHDにおけるECEイメージング計測

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Electron Cyclotron Emission Imaging (ECEI) has been developed to investigate 2-D/3-D structure of temperature fluctuations in the Large Helical Device (LHD). ECEI is an advanced ECE diagnostic method. Key devices are a detector array, optics, and a multi-frequency receiver array. The detector array consists of a 1-D horn antenna array and a printed circuit board (PCB) with mixer diodes and MMICs. The ECE images of the plasmas are obtained with a microwave optical system for the microwave imaging reflectometry (MIR). A multi-frequency receiver array consists of a band-pass filter array made on a PCB. At the presentation, the ECEI system and results will be reported.

1. Introduction

A combined system of MIR and the ECEI has been developed in LHD [1-3]. Microwave imaging diagnostics has potential to observe fluctuations of the electron density and the electron temperature profiles in magnetically confined high temperature plasmas. When the plasma density and temperature are sufficiently high, the intensity of Electron Cyclotron Emission (ECE) equals to a black body radiation in magnetically confined plasma. The electron temperature profile can be determined by measuring intensity of each frequency of the ECE, since the ECE frequency corresponds to the radial position. By using a 1-D receiving antenna array, the 2-D ECE profile (radial and poloidal directions) can be obtained. The electron temperature is considered to be equal on the same magnetic flux surface so that ECEI can be one of the most powerful diagnostics to investigate MHD instabilities.

2. ECE Frequency

MIR and ECEI are equipped with the same imaging optics and an imaging detector 1-D/2-D detector array. MIR is an active imaging system, whereas ECEI is a passive one. The frequencies of MIR and ECEI are different. Examples of the frequency profiles of MIR and ECEI are shown in Fig. 1, in the LHD plasma with $n_{e0}=3\times10^{19}$ m^{-3}, $B_{ax}=2.75$ T and $R_{ax}=3.6$ m. In this configuration, the second harmonic ECE of 96.5 – 104.5 GHz corresponds to the observation range of 4.44 – 4.55 m of the major radius. Because ECE of which frequency is higher than the X-mode cutoff is observable, the ECE frequency should be higher than the MIR frequency.

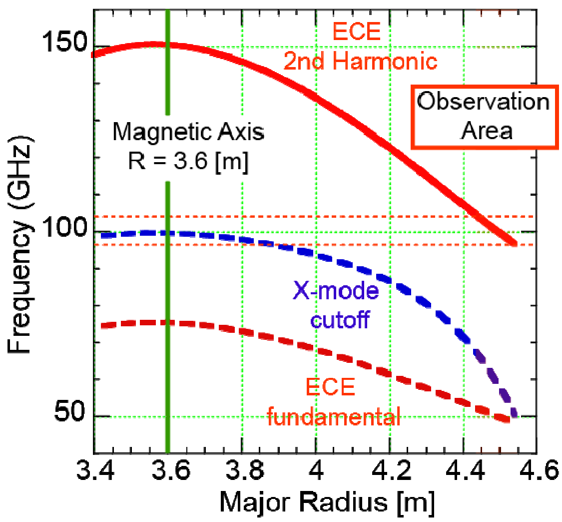

Fig.1 Profile of ECE and cutoff frequencies in the LHD plasma with $n_{e0}=3\times10^{19}$ m^{-3} and $B_{ax}=2.75$ T ($R_{ax}=3.6$ m).

3. ECE Imaging System

Figure 2 shows a schematic diagram of ECEI detection system. The ECE signals from plasma are focused on Horn-antenna Mixer Array (HMA) with the focusing optics. In HMA, each antenna element receives both ECE signals and the local oscillation (LO) wave, and mixer unit generates IF signal. The frequency spectrum of IF signal is detected by the band-pass filter (BPF) bank detection system. The frequencies of each BPF are separated by 1 GHz between 2 GHz and 9 GHz. The designed bandwidth of each BPF is 500 MHz. Fig.3 shows observation area of this system, in the case of B_{ax} = 2.1 T, R_{ax} = 3.6 m. Sights of poloidal directions are determined by the imaging optics. On the other hand, radial channels are determined by frequencies.

4. Result

A typical example of ECEI signals is shown in Fig.4. Fig.4(a) indicates two ECE signals observed by different antenna channels, same frequency channels. Fig.4 (b) shows ECE spectrum of the "pol_2ch, 104 GHz" signal. During 7.2 to 7.7 seconds, 2 kHz fluctuation is observed.

5. Summary

A system that combines the V-band (60 – 65 GHz) MIR and the W-band (96.5 – 104.5 GHz) ECEI has been developed for the LHD. MIR and ECEI employs common imaging optics. They also adopt the HMA that has a wide frequency response 50 – 110 GHz. ECE with a frequency of more than 97 GHz is selected by using a 95 GHz local oscillator and a 93 GHz high-pass plate. A 1.5–9.5 GHz eight-channel multi-frequency detector has been developed for ECEI. The frequency of each channel is well separated. Initial results indicate that this ECEI system appears to work.

Acknowledgments

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References

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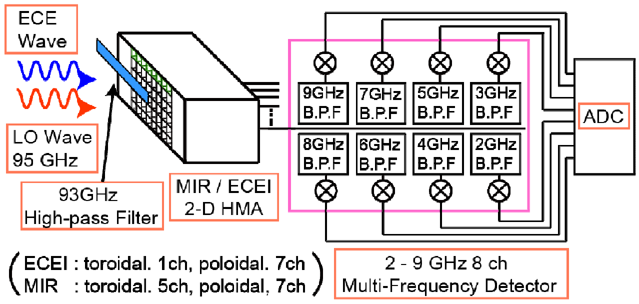

Fig.2 ECEI Detection System. ECE signals are down-converted in to 2 - 9 GHz IF signals by LO wave and each HMA element. Frequency detector measured spectrum of IF signals.

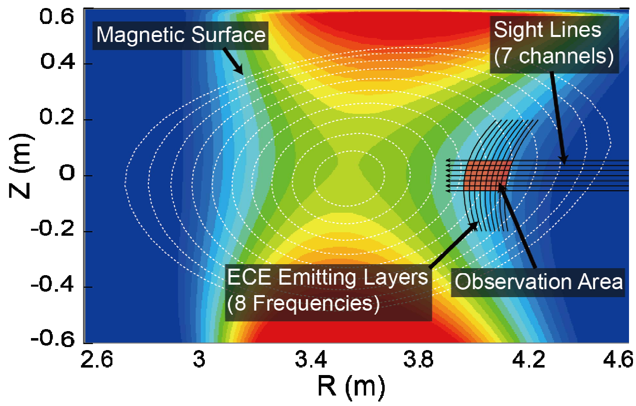

Fig.3 Observing Area of ECE Imaging. Color indicates field strength of B_{ax} = 2.1 T, R_{ax} = 3.6 m. Observing area is determined by sight lines of each antenna element and magnetic field.

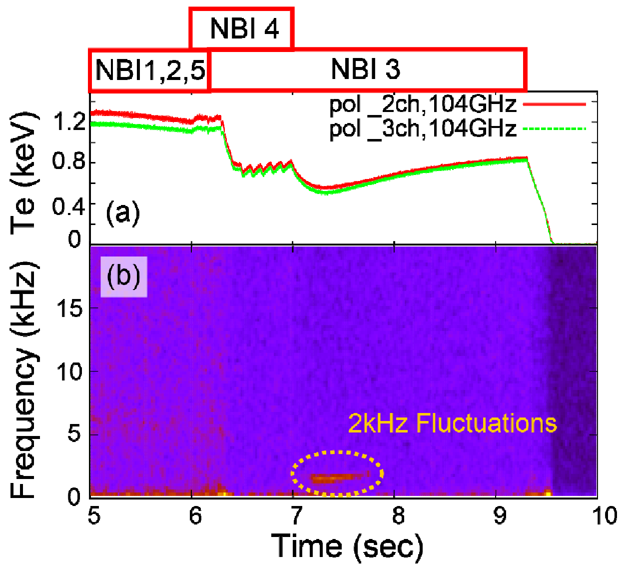

Fig.4 An example of ECE waveform and FFT analysis. (a) Waveforms of same frequency and different antenna channels (poloidal direction). (b) Spectrum of pol_2ch 104GHz.