Development of Microwave Imaging Diagnostics in LHD

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It is considered that the magnetic plasma confinement is highly affected by the turbulence and micro-instabilities. In the experimental work, both active device and diagnostics are required, but diagnostics for turbulence have not been well established. In this work, the Microwave Imaging Reflectometry (MIR) and the Electron Cyclotron Emission Imaging (ECEI) are being developed in order to observe the electron density fluctuations and the electron temperature fluctuations, respectively. MIR and ECEI use almost the same components. Differences are the frequency, the illumination wave and the phase detector. MIR uses the illumination wave and the phase detector in order to detect the motion of the cutoff surface. The frequency of ECEI is higher than that of MIR. A microwave imaging system 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 (PBC) by using the micro-strip-line technology. Therefore those components can have the reasonable size and cost. The development of imaging detector is challenging. In the first MIR system, which is installed in the TPE-RX RFP device, uses the 4×4 plenary Yagi-Uda antenna arrays for 20 GHz detection. The second MIR system, which is installed in the large helical device (LHD), uses the 8×5 horn antenna arrays for the V-band (50-75 GHz) detection. The horn antenna array has higher gain and wider frequency response than the Yagi-Uda antenna array. The horn antenna array has a sandwich structure of an upper metal frame, a PCB and a lower metal frame. Upper and lower metal frame have grooves which make waveguide and horn array. The mixer and amplifier are made on the PCB. The mixer generates IF signal from the RF signal and LO wave. The imaging optics has a half mirror that mixes RF and LO. In the second imaging system in LHD, the ECEI and MIR is separated by a dichroic plate, but the signal level is not high enough. In the third imaging system in LHD, MIR and ECEI use the same imaging optics. The optics is designed by using a FDTD simulation as the plane LO wave illuminates the horn antenna array uniformly, and each channel of the antenna array is focused to a point of the object plasma. The ECEI system also uses the horn antenna array, because it has good sensitivity at 95 GHz which is in the frequency range of the ECEI system. The MIR system has the illumination wave with 4 frequencies (60.410, 61.808, 63.008, 64.610 GHz) in order to observe 4 different plasma layers, since the radial structure of the plasma turbulence may affect the plasma confinement. Data analysis techniques (MEM, wavelet, Bicoherence, etc.) have been developed to study turbulence because waveforms of the signal of turbulence and noise are similar. In RFP, 2-D k-spectrum is observed in the turbulence. In LHD, the edge harmonic oscillation is observed by using the second imaging system. The third imaging system starts working from the 13-rd LHD experimental campaign.