§5. Development of the O-mode Microwave Imaging Reflectometry (O-MIR) in LHD

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Microwave Imaging Reflectometry (MIR) has been intensively developed in Large Helical Device (LHD). The X-mode MIR system had been working so far[1]. Figure 1 shows typical example of n_e profile in the ion ITB plasma in LHD, and the cutoff densities of the 63 GHz X-mode wave and the 26 – 35 GHz O-mode wave. Usually the n_e profile is hollow, and the X-mode reflectometry is useful to observe the plasma center. However, observable plasma is very limited because the frequency of the X-mode depends on the magnetic field. The cut off density of X-MIR is too low to observe the ion ITB. In the case of ion ITB plasma, the n_e profile is peaked and the O-mode MIR (O-MIR) is useful to observe the ITB region, which is usually observed near R=4.2 m as shown in Fig. 1.

An O-MIR system has been newly developed in order to observe the ion ITB plasma. In O-MIR, four frequencies of 26 and 35 GHz are simultaneously illuminated the LHD plasma. So, the observable density is $0.84 – 1.5 \times 10^{19}$ m^{-3}. The frequency generator and the imaging detector named Horn-antenna Mixer Array (HMA) are newly developed. Schematic diagram of the four frequency generator is shown in Fig. 2. A wave synthesizer, which is controlled by a computer with a LabVIEW program, generates the base wave. Four voltage controlled oscillators generates different frequencies. They are mixed with the base wave and these frequencies are multiplied by four.

The plasma image of the scattered wave is detected by the Ka-band HMA, which is developed based on the new concept[2]. The block diagram of the new HMA is shown in Fig. 3. In HMA, each printed circuit board (PCB) is installed between aluminum frames, each of which have half cut horn antenna array. The signal wave entering into the horn antenna is transduced from the waveguide to the micro-strip line by the fine-line transducer, of which efficiency is as high as -1.5 dB[2]. The signal wave is amplified by 12 dB before mixing in order to compensate the conversion loss (12dB) of the double balanced mixer (DBM). The half frequency (ω_0) of LO (ω_{LO}) wave is delivered by coaxial cables. The half frequency is divided by Wilkinson power divider on PCB and is doubled by active doublers just before entering into DBM.

The new HMA includes many technologies which improve the sensitivity, such as fin-line transducer, RF amplifier, DBM and adjustment of LO power. The optical imaging system of O-MIR is much simpler than that of X-MIR. Observed noise of O-MIR is 4 mV, while the noise of X-MIR is 800 mV. The sensitivity of O-MIR is improved. The O-MIR shall be useful to investigate micro instabilities in confined plasmas.

1) Nagayama, Y. et al: Rev. Sci. Instrum. **83**, 10E305 (2012).
2) Kuwahara, D. et al: Rev. Sci. Instrum. **85**, 11D805 (2014).

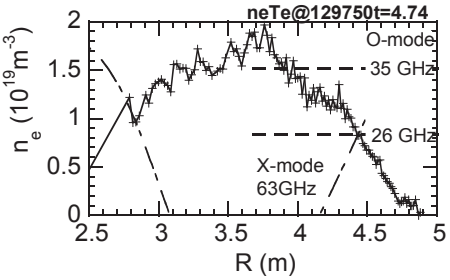

Fig. 1 Typical example of n_e profile in the ion ITB plasma and cutoff densities of O-mode wave.

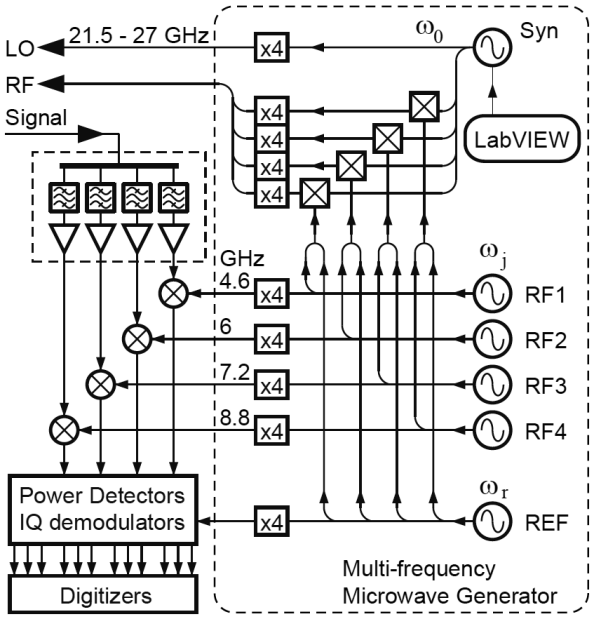

Fig. 2 Four frequency generator and separators.

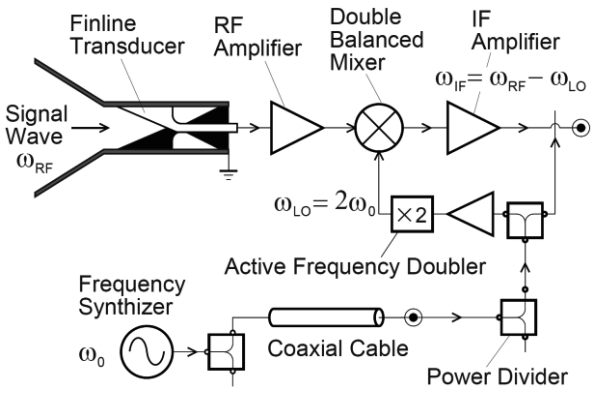

Fig.3 Block diagram of Ka-band HMA element.