§11. 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)[1]. The X-mode MIR system has been working since 2010. Figure 1 shows typical example of n_e profile, and the cutoff densities of the 63 GHz X-mode wave and the 30 GHz O-mode wave. Since the n_e profile is hollow, 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.

We are developing the O-mode MIR in order to observe wide variety of plasma. The frequency of O-mode is much lower than the X-mode as shown in Fig. 1. In 2013, we modified the X-mode oscillator to the O-mode oscillator as shown in Fig. 2. The mixer Hittite HMC521LC4 works as down-convertor by connecting -90° signal of the quadrature divider to IF2, and 0° signal to IF1. As the × 6 frequency multipliers and the microwave power amplifiers are installed near the antennas, the microwave power is increased by 3. The cutoff frequency of V-band HMA for the X-mode MIR is 50 GHz, we have developed U-band HMA. The circuit of the U-band HMA is the same as the V-band HMA, as shown in Fig. 3. The U-band HMA has the waveguide with the inner width of 2.5 mm, the height of 5 mm and the length of 13.5 mm. The diode mixer (Skyworks DMK2790) is installed in the waveguide and the distance from the waveguide edge is 2.5 mm. The mouse size of horn is 20 ×20 mm and the horn angles are 40 degree in the E-plane and 34 degrees in the H-plane.

Since the E-component of the microwave follows the field line as propagating towards the plasma core[2], the E-component should be along the field line, which is about 30 degree at the plasma edge. Beam splitters (BS) are aluminum plates with narrow and long holes, as shown in Fig. 4. This structure is similar to the BS with wire grids. Wire grids fluctuate easily in the MIR optics. The idea of long holes is to connect wires. BS with narrow holes of constant length has a frequency response with peaks and dips, as shown in Fig. 5(a). The frequency response is improved by using narrow holes with random length, as shown in Fig. 5(b). The angle of long holes is 45 degree from the E-component. By using new BS, the reflection power increases by 3.

The O–MIR system worked at the first moment when it was installed to LHD. Signal level is significantly improved comparing the old sysem[1]. However, HMA got a trouble of spurious oscillation, and the experiment was failed.

1) Nagayama, Y. et al: Rev. Sci. Instrum. **83**, 10E305 (2012).
2) de Vries, P.C. et al: Phys. Plasmas 7, 3707 (2000).

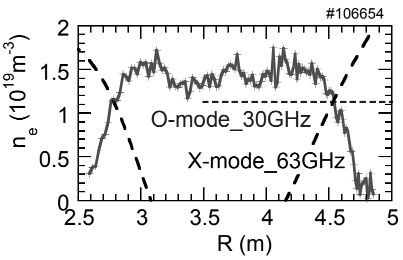

Fig. 1 Typical example of ne profile, and the cutoff densities of the 63 GHz X-mode wave and the 30 GHz O-mode wave.

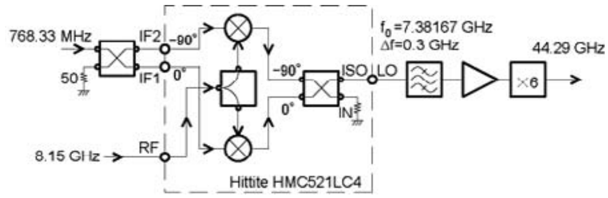

Fig. 2 Down convertor for the O-mode MIR system.

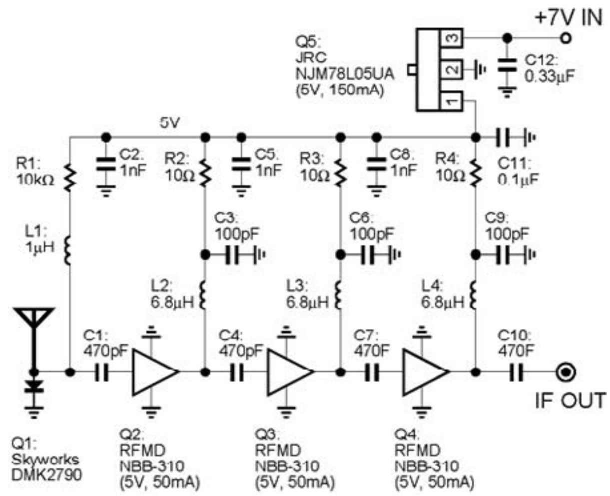

Fig. 3 Electrical circuit of the U-band HMA.

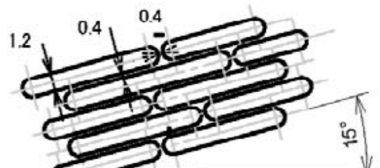

Fig. 4 Detail of the beam splitter for the O-MIR.

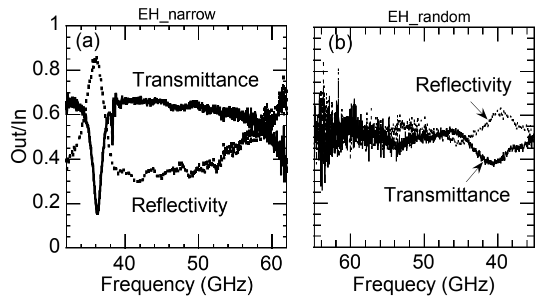

Fig. 5 Transmittance and reflection of beam splitter with the hole length of (a) 9 mm, (b) random.