§52. Rotatable Imaging Mirror in Vacuum for Optimization of Illumination Angle of MIR

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Microwave Imaging Reflectometry (MIR) is under development[1)] for 2-D/3-D measurement of the electron density fluctuations in LHD. Illumination sources with frequency of 69, 66 and 53 GHz are utilized to probe beams. The beam is launched from port 4-O to the plasma center in X-mode or O-mode. The reflected beam is focused by an imaging optical system, and it is detected by heterodyne receivers. The LHD plasma has a twisted elliptical or triangular cross-section, so the elliptical cross-section is tilted downward near the equatorial plane at the port 4-O. The optimum illumination angle is different between O-mode and X-mode. For example, as the density is higher, the right-hand cutoff layer is more tilted. As the magnetic axis shifts to outboard, the illumination beam should be more tilted upward. The illumination angle should be adjusted according to the inclination of the reflection surface.

In the new setup the angle of the ellipsoidal mirror in vacuumn can be adjusted by using remote-controlled actuators with ultrasonic motors, which is driven by piezoelectric ceramic elements. Since the ultrasonic motor is non-magnetic, it doesn't disturb the magnetic fields of plasma. Figure 1 shows the schematic of the rotating mechanism with three pushrods and one weight. The ellipsoidal mirror is connected to a rectangular back plate with a horizontal rotation axis. The back plate is connected to the base plate with a vertical rotation axis. Both the horizontal axis and the vertical axis pass the center of the concave surface of the ellipsoidal mirror. The left hand side of the back plane is pushed by the rod of actuator #1. The right left hand side of the back plane is pushed by a free rod, which is connected an ICF70 flange. This flange is guided by two bars and is connected to the LHD vacuum vessel with a bellows. The free rod can move freely in one direction and the atmosphere pressure pushes the ellipsoidal mirror with the free rod. So the ellipsoidal mirror can be rotated around the vertical axis by controlling the actuator #1. The lower part of the ellipsoidal mirror is pushed by a rod of actuator #2. A weight is attached at the bottom of the mirror. Since the gravitational force due to the weight pushes the mirror to the rod of actuator #2, the ellipsoidal mirror can be rotated round the horizontal axis by controlling the actuator #2. The slide bearings are coated with the titanium nitride so that the friction is fairly reduced in vacuum. Non-magnetic stainless-steel (SUS304) ball bearings are used as well. These mechanisms allow the smooth mirror rotation by one degree per second with the allowance of the mirror angle less than 0.1 degree.

The mirror angle is optimized in the LHD plasma experiment. The time-averaged amplitude of fluctuations in the MIR signal is measured by scanning of the vertical mirror angle as shown in Fig. 2. The optimum illumination angle is about 3 degree upward in O-mode, as shown in Fig.2 (a) and that it is about 1.5 degree upward in X-mode, as shown in Fig.2 (b). Since the profile is very narrow with half width of about 1 degree, the optimization of the illumination angles is very necessary to detect the reflected beam power from the twisted reflection surface. Typical MIR signals before and after the optimization is shown in Fig. 3. By optimizing the beam direction, the MIR signal becomes high enough to measure the density fluctuation.

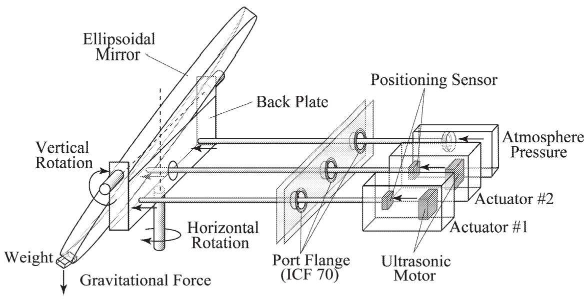

Fig. 1 Schematic of the rotatable ellipsoidal mirror with the three pushrods in vacuum.

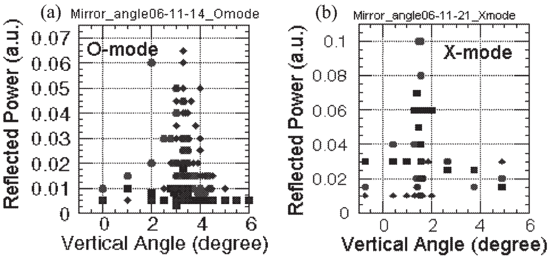

Fig. 2 Optimized illumination angle in the case of O-mode (a) and X-mode (b) measured in the plasma experiment.

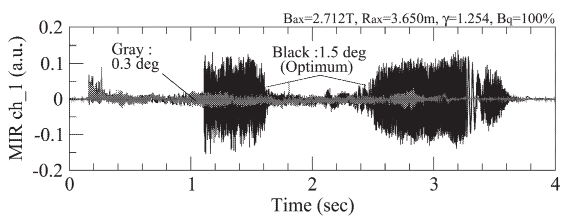

Fig. 3 MIR signals before and after the optimization of the mirror angle.

Reference

1) Yamaguchi, S., et al., Rev. Sci. Instrum. **77**, (2006) 10E930