§11. Optical Design of ECE Imaging System on LHD

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ECE Imaging system will be install into LHD for the measurement of MHD instability structure and micro-size phenomena. The line of sight is on the mid plane of horizontally elongated magnetic field cross section (4-O port). Conventional ECE antenna was also installed on near opposite torus section of LHD [1]. The mili-wave of ECE without image can be transmitted though corrugated waveguides easily and can be detected by heterodyne detector with filter-bank system out of the torus hall. In case of ECE Imaging system, it is necessary to detect the ECE in the torus hall using imaging detectors. The detector have been developed originally as LO-Integrated Antenna array (LIA) [2].

The LIA includes local oscillators for heterodyne detection and amplifiers. Because the semiconductor devices must be protected from neutron radiation, the LIA should be separated from LHD. Figure 1 shows the layout of ECEI optical system, which is consisted of concaved mirrors (M1, M5, M6), plane mirrors (M2, M4) and window (P3). The optical path is not on the same plane to keep a clearance with neighboring devices. Because the mili-wave of ECE propagates as Gaussian beam in the free space, the mirrors are required to be large enough to cover the expanded beam. Figure 2 shows the side view conceptual diagram of the optical system. The mirror size and optical path length are restricted by the matching condition of Gaussian beam and effective radius of vacuum window. To match the Gaussian beam between M5 and M6, M5 and M6 are concaved mirrors, which is designed by the concept of constant phase mirror [3]. The surfaces is optimized for 50GHz, which is lowest target ECE frequency, because a long wavelength beam expands more widely than a short wavelength beam. The constant phase mirror is optimized for the propagation of Gaussian beam, and can control the shape and phase of the beam. Especially, it is important to keep the beam shape for the ECE imaging system. Figure 3 and 4 is the calculation result of the mirror surface and the development of designed beam radius. The restricted condition is the size of window (25mm in radius) and aperture of LIA (14mm in radius). The designed mirrors are made by a NC machine and installed to LHD after checking the beam shape.

1) Tsuchiya, H., et al.: Plasma Fusion Res. **6**, 2402114 (2011).
2) Kuwahara, D. et al.: Rev. Sci. Instrum. 85 (2014) 11D805.
3) Kubo, S., et al.: Fusion Eng. Des. **26**, 319 (1995).

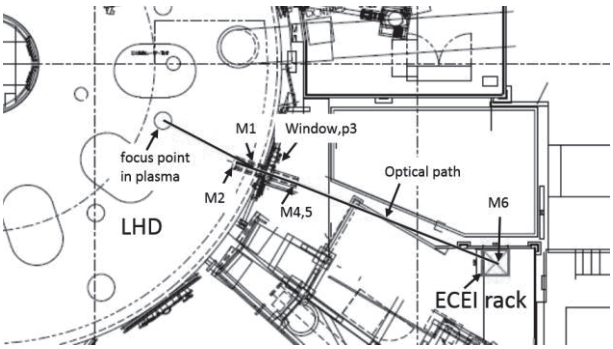

Fig. 1. Layout of ECEI optical system. This picture is a top view of LHD and measurement stage. Mirrors are indicated as M1,M2,M4,M5 and M6 on the optical path. P3 is the vacuum window.

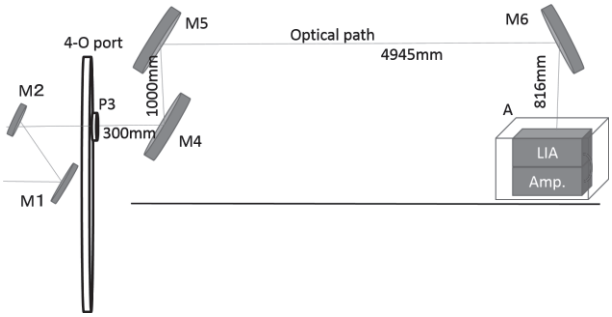

Fig. 2. Conceptual diagram of ECEI optical system (side view).

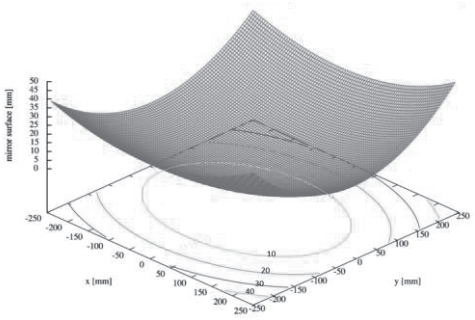

Fig.3. The M6 mirror surface designed by the concept of constant phase mirror.

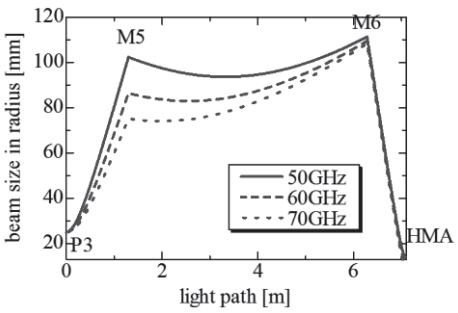

Fig.4 The development of designed beam radius from vacuum window (P3) to HMA.