§2. Asphericalization of Light Collection Mirror on the LHD Thomson Scattering Diagnostic

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The LHD Thomson scattering (TS) system [1] adopts a spherical mirror for collecting scattered light. The mirror is composed of 11×12=132 hexagonal mirrors with assembled area 1.5 m ×1.8 m and radius of curvature ρ= 4.5m (Fig.2). This mirror forms an image of the laser beam of diameter less than 4 mm running along the major radius 2.25m $\leqq$R$\leqq$ 5m onto the ends of the arrayed optical fiber of 2 mm in diameter. By setting the center of the curvature nearly at the center of the view window, coma and astigmatism aberrations are almost removed for all scattering points. Figure 1 shows the spot diagram for 12 scattering points at R=250*m +2250 mm (m=0, 11).

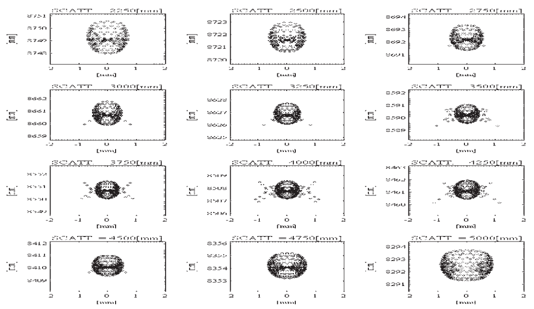

Fig. 1. Spot diagrams formed by the spherical multi-segment mirror for the 12 scattering points.

The larger spot sizes at both ends are owing to defocusing. The spherical aberration makes the spot size larger than 1mm in diameter. Although the optical fibers of 2mm in diameter collect most of thus blurred light, the collection efficiency becomes very sensitive to the misalignment between the image of the laser beam and the array of the optical fibers, thus introducing a systematic error on electron density measurement. In order to alleviate this problem, we numerically studied the possibility of reducing the spot size for all scattering points in the region 2.25m $\leqq$R$\leqq$ 5m by adjusting the inclination of each hexagonal mirror, which is equivalent to asphericalization. For this purpose, we first calculate the m^{th} image points $\{\mathbf{R}_{image}(\delta x,\delta y,i,j,k,m)\}$ formed by k^{th} point on the i^{th} raw j^{th} column hexagonal mirror whose center of curvature is shifted by ($\delta x,\delta y$) transversely, i.e., inclined by ($\delta x,\delta y$)/ ρ. Here k runs 0-5 on 6 points on each hexagonal mirror. With these we calculate the estimate function given by

$$H(\delta x,\delta y,i,j)=\sum_{m=0}^{11}\sum_{k=0}^{5}(R_{image}(\delta x,\delta y,i,j,k,m)-R_{ref}(m))^2$$

Here $R_{ref}(m)$ is a reference point for the m^{th} image. The minimum point of H in the ($\delta x,\delta y$) space is the inclination which gives the overall best imaging performance for all the scattering points. Distribution of the inclination vectors thus obtained is shown in Fig.2. The thus-adjusted mirror gives the spot diagrams for the 12 scattering points as shown in Fig. 3. Figure 4 compares the distribution functions for spot diagrams given in Fig. 1 and Fig. 3. We can notice that the asphericalization improves the imaging performance more than twice.

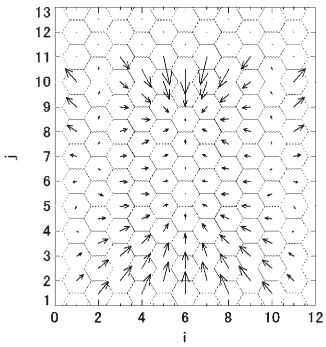

Fig. 2. Distribution of the inclination vectors that gives the overall best imaging performance.

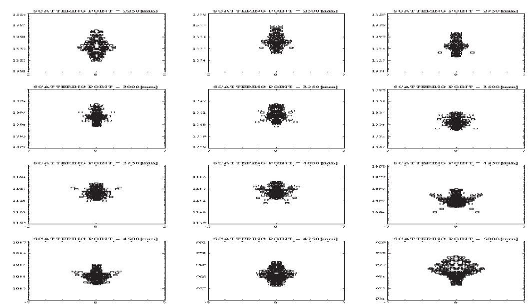

Fig. 3. Spot diagrams obtained by the inclination-adjusted mirror for the 12 scattering points.

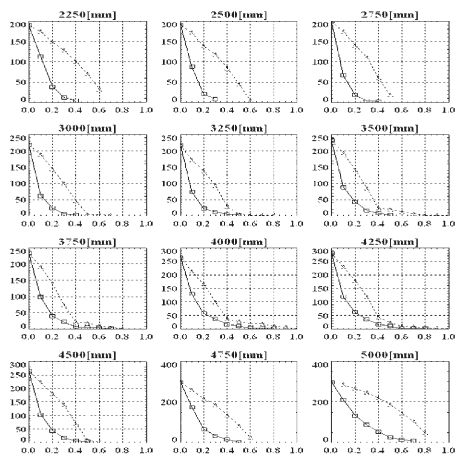

Fig.4. Distribution functions for the spot-diagrams shown in Fig. 3 (solid lines) and in Fig. 1 (dotted lines).

[1] K. Narihara, et al., Rev. Sci. Instrum., **72**, (2001) 1122.