Optical Design and Acceptable Tolerance Range of MESSIER satellite telescope (LAF-TMS D400F3)

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A MESSIER satellite aims to measure the Extremely-Low Surface Brightness (LSB) objects. For observing the LSB with the high-quality images over a Wide Field of View, the telescope adopts Linear Astigmatism Free-Three Mirror System with freeform surfaces. It is important to investigate the feasibility through a tolerance analysis. The sensitivity analysis and Monte-Carlo simulation were performed as the tolerance analysis, and these studies offer a sensitivity of each mirror and acceptable alignment error budgets of the telescope structures.

I. Introduction

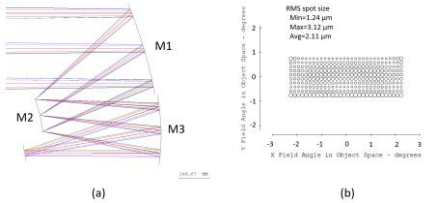
The MESSER surveyor is a space mission for surveying the Low Surface Brightness (LSB), with surface brightness level of 34 mag arcsec^{-2}, in UV-visible (200 nm - 1000 nm) wavelength range. For measuring the LSB over the wide-Field of View (FoV), the MESSIER adopts the optical design of the Linear Astigmatism Free-Three Mirror System (LAF-TMS).[1, 2]

The conventional off-axis reflecting telescope has no optical performance degradation by the secondary mirror, but it has serious linear astigmatism at the wide field angle.. The LAF-TMS is a confocal off-axis reflecting system in which the linear astigmatism is completely removed, so this telescope can achieve a high-quality image over the wide-FoV without any correcting lens.

It is important to investigate the opto-mechnaical feasibility through tolerance analysis. In this study, we introduce the LAF-TMS D400F3 and investigate the tolerance range of the MESSIER.

II. Optical Design

The MESSIER has an entrance pupil diameter of 400 mm and a focal ratio of 3 with FoV of 4.5˚ x 1.5˚ in a wavelength range of 200 - 1000 nm. Figure 1 shows the optical design and RMS spot size. The RMS spot size is smaller than 5 μm over the all image plane.



[Fig.1] Optical Design of LAF-TMS D400F3 (a) and RMS spot size over the image plane (b).

III. Tolerance Analysis Result

The sensitivity analysis and Monte-Carlo simulation were performed as a tolerance analysis. In the sensitivity analysis, we investigate the performance sensitivity of each alignment element due to the error. Through Monte-Carlo simulation, we can check the tolerance budget satisfying the required optical performance. The performance requirement is Nyquist sampling, which is 2 pixels per 80% encircled energy diameter.

The sensitivity analysis shows that the tilts of the M1 freeform mirror is the most critical to the optical performance. Table 1 shows tolerance budgets of the LAF-TMS D400F3 that are calculated from the Monte-Carlo simulation. The tolerance ranges are the tilt of ±10.8, ±36.0, ±18.0 arcsec for M1, M2. M3 respectively, decenter of ±0.06 mm, and despace of ±0.12 mm.

Tilt [arcsec]			Decenter [mm]	Despace [mm]	Focus [mm]	80%EED [μm]
M1	M2	M3				
±10.8	±36.0	±18.0	±0.06	±0.12	±1.00	10.1

[Table.1] Acceptable tolerance ranges of the LAF-TMS D400F3.

IV. Summary and Discussion

The LAF-TMS D400F3 satisfies the image quality requirments for the LSB observation. For more accurate performance evaluations and conceiving the optomechanical design, we will analysis the stray light effects and the complete simulation results using the Photon Simulation (PhoSim).

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References

[1] D. Valls-Gabaud, et, al., “The MESSIER surveyor: unveiling the ultra-low surface brightness universe,” Proc. Int. Astron. Union 321, 199–201 (2017).

[2] E. Muslimov, et, al., “Fast, wide-field and distortion-free telescope with curved detectors for surveys at ultralow surface brightness,” AO, 56, 31 (2017).