Optical Testing for TAOS Telescope

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Background

The optical quality of the TAOS telescopes (Taiwan-America Occultation Survey) has been an important issue for the performance of the project. The Shack-Hartmann wavefront sensing technology is used to analyze the performance of the system. The result is compared with the Zemax simulation data to get quantitative parameters. Further actions to correct the aberration is planned in the near future.

Fig 1. TAOS telescopes

Wavefront sensor

Model : Haso-3-128
Supplier : Imagine Optic
Aperture dimension : 15 x 15 mm²
Refractive microlens technology : standard square
Sub-apertures dedicated for analysis : 128 x 128
Spatial resolution : ~115 µm
Working wavelength range : 350 - 1100 nm

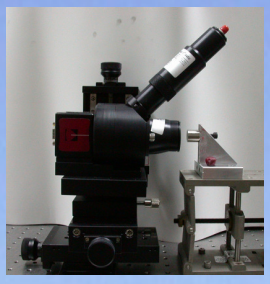

Fig 2. HASO wavefront sensor system

Fig 3. Microlenses and the CCD of HASO wavefront sensor

Zernike polynomials

The Zernike polynomials are the interface between HASO wavefront sensor and Zemax optical simulation software. We can obtain the aberration coefficients from HASO analysis data first and then use Zemax to simulate and get quantitative data by comparing Zernike coefficients.

Zernike Polynomials		
No.	**Polynomials**	**Aberration description**
1	$2\,\rho\cos(\theta)$	Tilt at 0°
2	$2\,\rho\sin(\theta)$	Tilt at 90°
3	$\sqrt{3}.(2\rho^2 - 1)$	Focus
4	$\sqrt{6}.(\rho^2\cos(2\theta))$	Astigmatism at 0°
5	$\sqrt{6}.(\rho^2\sin(2\theta))$	Astigmatism at 45°
6	$\sqrt{8}.((3\rho^2-2)\rho\cos(\theta))$	Coma at 0°
7	$\sqrt{8}.((3\rho^2-2)\rho\sin(\theta))$	Coma at 90°
8	$\sqrt{5}.(6\rho^4 - 6\rho^2 + 1)$	3rd order spherical aberration
9	$\sqrt{8}.(\rho^3\cos(3\theta))$	Trefoil at 0°
10	$\sqrt{8}.(\rho^3\sin(3\theta))$	Trefoil at 90°
⋮	⋮	⋮

Fig 4. The cross reference items of Zernike coefficients between HASO and Zemax.

Wavefront error result

Wavefront sensor output :

TAOSD telescope was tested in Jan. 2008 with a magnitude 3 star. By neglecting the tilt and focus items, the major aberration was found to be the " spherical " aberration from HASO wavefront sensor analysis result. (Fig. 5, 6)

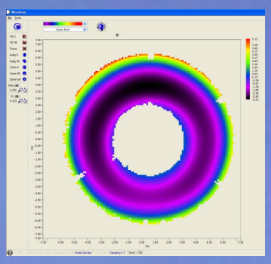

Fig 5. 2-D wavefront profile

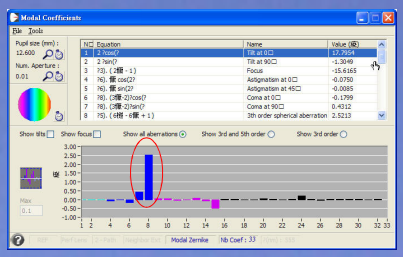

Fig 6. Zernike coefficients result of HASO wavefront sensor software

Zemax simulation output :

The Zemax simulation was performed to reproduce the measured wavefront error by changing the tilt, decenter and distance of the optics. We found the spherical aberration was dominated by the distance between secondary mirror and corrector cell. (Fig. 7)

Zemax parameter		**Zernike coefficients**									
Thickness (mm)*	**Shift distance (mm)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
-416.41157	0	0	0	0.2922	0	0	0	0	0.0242	0	0
-411.41157	5	0	0	-1.3748	0	0	0	0	1.8819	0	0
-410.41157	6	0	0	-1.7083	0	0	0	0	2.2546	0	0
-409.41157	7	0	0	-2.0418	0	0	0	0	2.627	0	0
* Thickness = The distance between secondary lens and colimated lens											

Fig 7. Zernike coefficient of Zemax simulation data

Future actions

TAOS telescope consists of 3 elements (primary mirror, secondary mirror and corrector cell). The primary mirror and corrector cell are fixed. The secondary mirror is moveable for focusing. (Fig. 8, 9)

From the comparison above, the distance between the secondary mirror and corrector cell needs to be optimized. Shimmers will be used to adjust the position of the corrector cell. (Fig. 10, 11)

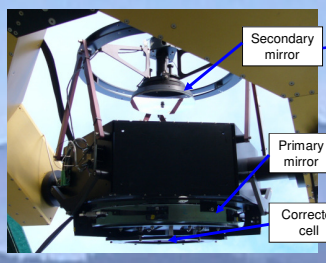

Fig 8. TAOS telescope structure

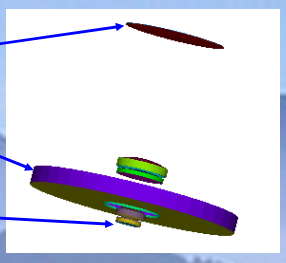

Fig 9. TAOS telescope (side view)

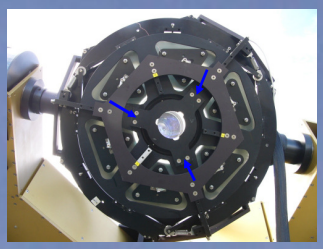

Fig 10. TAOS telescope (bottom view) and the location for the spacer to change the position of corrector cell.

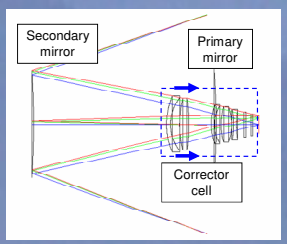

Fig 11. The schematics of the telescope.