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Desensitized telescope optical design: NSOS-α case study

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Abstract. NSOS-α is a 1.5-m aperture, F/1.55, wide field prime focus telescope for the Korea Astronomy & Space Science Institute (KASI) to discover and catalogue near-Earth asteroids, especially Potentially Hazardous Asteroids. Among the different optical designs, the current baseline is based onto a design with reduced sensitivities to both manufacturing and alignment tolerances, to optimize as-built performances instead of reducing nominal aberrations only. Different optimization techniques have been used and compared. As result, a fast and effective optimization procedure has been identified and implemented, and it will be used also during the manufacturing process to improve overall performance.

1 Introduction

Korea Astronomy & Space Science Institute (hereafter KASI) will set up a wide field of view telescope at the southern hemisphere to discover and catalogue near-Earth asteroids, especially Potentially Hazardous Asteroids.
To achieve this goal, an optical telescope observation system with a primary mirror of 1.5 meter class and the field of view of 5 square degrees will be installed and operated at Cerro Tololo Inter-American Observatory in Chile (CTIO). The whole observation system is called Near Space Optical Survey- alpha (NSOS-α).
IDOM (Spain) has been recently awarded a contract to design and build the NSOS-α telescope, with Tomelleri S.r.l. (Italy) as main partner for the design and realization of the prime focus corrector. Main telescope characteristics are summarized in the Table 1.

Table 1. NSOS-α telescope main parameters.

Telescope	Prime Focus
Aperture	1.52 m
Focal ratio	F/1.55
Field of view	3.2°
Wavelengths	400-850 nm
Image quality (FWHM)	Telescope: <0.66 arcsec Tel. + seeing: <1 arcsec
Distortion	<0.2%
Optical transmission (incl. central obstruction)	>75%
Relative illumination drop	<10%

2 Optical design

2.1 Initial optical designs

The NSOS-α telescope initial design [1] was carried out by KASI as part of a preliminary study. It was based on a primary mirror and a field corrector with 7 bulky lenses, including a large, oil-coupled, doublet made of calcium fluoride and a high-transmission i-line glass from Ohara (Japan). While nominal image quality and overall optical performance were very good, a preliminary tolerance analysis identified critical areas, including some tight tolerances, like decenter and glass homogeneity.
Other alternative designs have been investigated during the early study phases, based on classical lens design approaches, aimed at reducing the number of optical elements, adding some aspherical surfaces to one or more lenses, and changing to other glass materials. While nominal performance were achieved, all these designs had one or more critical sensitivities.

2.2 Desensitized optical design

To overcome the previous issues, a new study was carried out, aimed at reducing optical tolerances as much as possible, so that manufacturability of optical components was improved, together with reduced sensitivities during integration, optical alignment, and during operations. Moreover, further design drivers were based on availability of lens materials, their cost, reducing the aspherical departure from the best fit sphere, and improving optical transmission.
Different techniques have been used in the past, like reducing the maximum angle of incidence on lens

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surfaces. Zemax © OpticStudio raytracing software has recently implemented a similar algorithm (high-yield optimization, [2]), by introducing a penalty factor to the optimization merit function that discourages high angles of incidence or exitance at each optical surface. These additional operands in the merit functions have been designed to provide a high computational speed. Older operands (e.g., TOLR) were very computational intensive, so that their use was not very effective or widespread.

Both techniques have been implemented and different solutions have been identified and compared with respect the initial designs. All of these new, less sensitive, designs have been found quite robust to both Monte Carlo tolerance analysis and RSS methods. Figure 1 shows one of these optical design, based on six lenses in four groups.

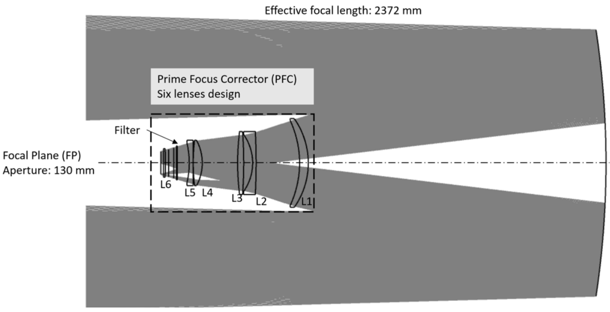

Fig. 1. Telescope baseline optical layout.

When compared to the other previous designs, they showed a large reduction (>10X) on critical tolerances. Just as an example, Figure 2 shows the sensitivities to changes in relative lens radius (manufacturing tolerance), while Figure 3 shows the sensitivities to lens lateral decenter and tilt (integration tolerance).

Similar histograms can be built for all degrees of freedom, showing similar behaviours.

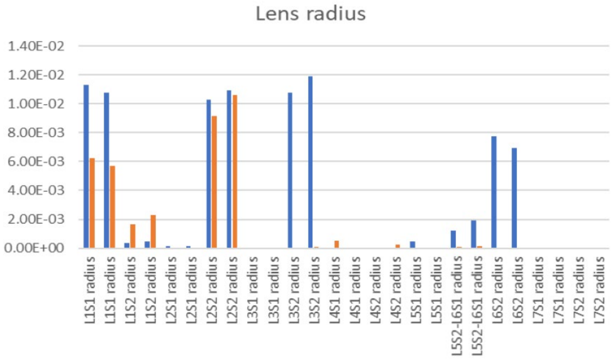

Fig. 2. Sensitivities to relative radius change for two different designs, the initial one (blue) and the current baseline (orange).

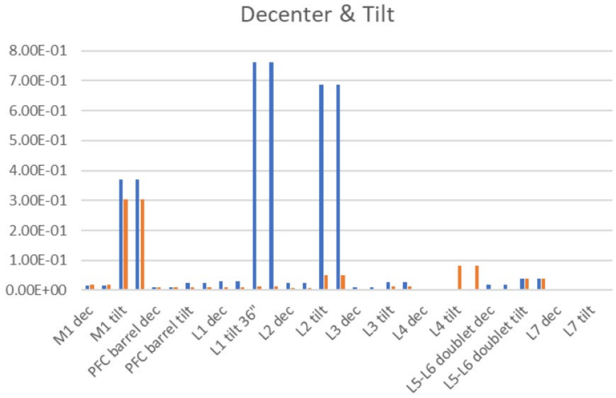

Fig. 3. Sensitivities to alignment degrees of freedom for two different designs, the initial one (blue) and the current baseline (orange)

3 CONCLUSIONS

The application of algorithms that penalize large angle of incidence or exitance at lens surfaces have shown to be effective to desensitize optical design to manufacturing and alignment tolerances, thus improving as-built performance.

This has been successfully applied to the design of a fast prime focus, wide field, telescope.

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