Preliminary Design Performance Assessment of a Focal Reducer 0.8 m Ritchey–Chrétien telescope for NARIT's public regional observatory

Sirimougkont wutikanarug [a], Chanisa Kanjanasakul [b], Sasikan Suriyot [b], Sukrit Sucharitakul [a]
[a] Chiang Mai University 239, Huay Kaew Road, Muang District,Chiang Mai Thailand, 50200 ;
[b] National Astronomical Research Institute of Thailand (Public Organization), 260 Moo 4, T. Donkaew, A. Maerim, Chiangmai, Thailand 50180 ;

Abstract: This independent study focuses on increasing the Field of View for a 0.8 m Ritchey-Chrétien telescope in both Nasmyth and Cassegrain focus systems. The goal is to achieve a 0.25 degree FOV using a focal reducer. The design process was conducted using Ansys Zemax Optic Studio, starting with a study of commercial focal reducers (designed for 60–155 mm telescopes), the focal reducer used for the 2.4 m Thai National Telescope, and achromatic lens design principles. Calculations show that the telescope's focal length must be reduced to 4570 mm to capture a 0.25 degree Field of View on a full-frame sensor. The results indicate that: Cassegrain Focus: A 4 ens design achieved high performance. The RMS spot size at 0 and 0.25 degrees was 1.078 µm and 2.210 µm respectively, which is within the diffraction limit. Nasmyth Focus: With the same number of lenses, the system could not reach the diffraction-limited quality. Finally, a Tolerance Analysis was performed on the Cassegrain system to evaluate fabrication and alignment errors, as well as system stability. The study also analyzed stray light (ghosting image).

Method

1. Optical design

In the design process for the focal reducer, the initial parameters were set based on commercially available lenses and a literature review. Then, an optimization tool was used to find the best distances, as shown in the table below :

Table 1 : Optical design specifications

Parameter	Specifications
Aperture (mm)	800
Telescope F-number	5.7
Back focus (mm)	560
Full field of view (degrees)	0.5
Telescope focal length (mm)	4570
Dectector size diameter (mm)	40
Total length (mm)	2060

Table 2 : Len specifications

Len	Parameter	Specifications
L1	Fornt Daimeter (mm)	107
	Front radius ofcurvature (mm)	92.837
	Rare Daimeter (mm)	102
	Rare radius ofcurvature (mm)	-396.193
	Materials	N-FK58
L2	Fornt Daimeter (mm)	96
	Front radius ofcurvature (mm)	-225.975
	Rare Daimeter (mm)	87
	Rare radius ofcurvature (mm)	109.682
	Materials	N-KF9
L3	Fornt Daimeter (mm)	83
	Front radius ofcurvature (mm)	105.837
	Rare Daimeter (mm)	81
	Rare radius ofcurvature (mm)	-197.115
	Materials	P-BK7
L4	Fornt Daimeter (mm)	53
	Front radius ofcurvature (mm)	-90.56
	Rare Daimeter (mm)	50
	Rare radius ofcurvature (mm)	319.56
	Materials	N-KZFS4

>>> In this design, Zemax Optical Design Software was used. We assumed that if **the RMS spot radius is smaller than the Airy disk radius, the image quality is at its best—limited only by the physics of light (diffraction-limited)."**

2. Tolerance analysis

Tolerance analysis evaluates **how the RMS spot radius deviates from the ideal design** due to manufacturing, assembly, and stability errors, **to defining the acceptable tolerance limits for each stage.**

2.1 Individual Stage Tolerance Analysis

2.2 System Tolerance Analysis

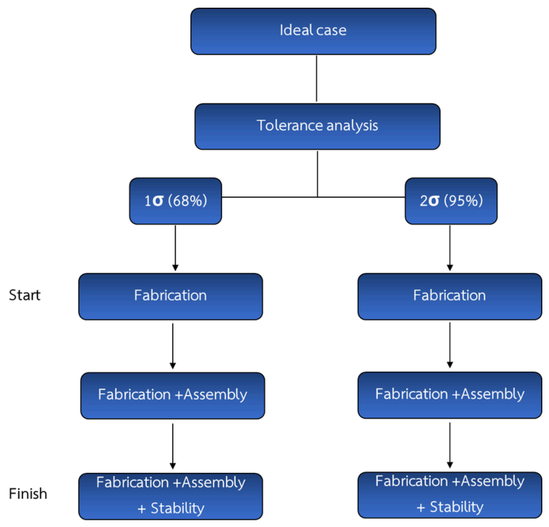


Figure 1: System Tolerance Analysis flow chart.

3. Straylight analysis

Stray light refers to unwanted light that enters the optical system or results from internal reflections, ultimately reaching the image sensor and degrading image quality.

>>> Stray light reduction techniques

- Anti-Reflection (AR) Coating: **Reduce internal reflections within the lens elements.**
- Buffle or Vane desig : **Block off-axis light from striking the inner tube walls.**

3.1 Ghost image analysis

Ghost images are unwanted reflections bouncing between lens surfaces, appearing as double images or bright artifacts on the sensor

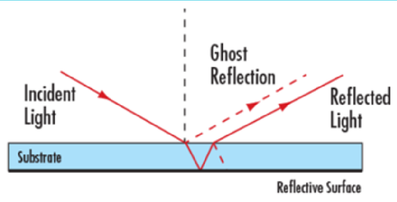


Figure 2: Figure of ghost image caused by multiple reflections within the lens elements.[1]

Result

1. Optical design and performance

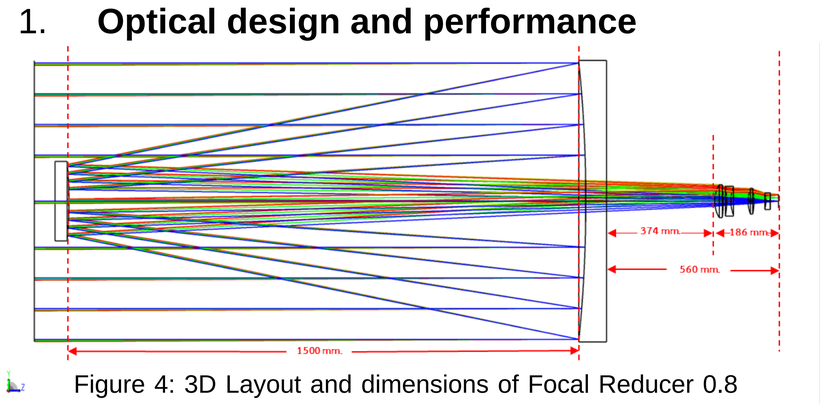


Figure 4: 3D Layout and dimensions of Focal Reducer 0.8 m Ritchey–Chrétien telescope

Optical performance : RMS spot radius

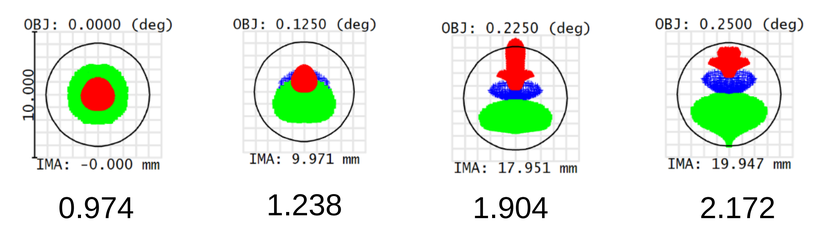


Figure 5: The spot diagram of the Focal Reducer 0.8 m Ritchey – Chrétien telescope where a black circle represents an Airydisk.The RMS spot radius at FOV 0,0.125,0.225 and 0.250 degrees are presented.

2. Tolerance analysis results

2.1.Individual Stage Tolerance results

Tolerance condition

• **Manufacturing** > OPTIMAX precision manufacturing level for L1,L2 and commercial level for L3,L4 [2]

• **Assembly** > Decenter x, y, z = ± 50µm.

> Tip/Tilt = ± 0.573degree

> Compensator back focus = ± 25mm.

• **Stability** > Decenter x, y, z = ±50µm.

> Tip/Tilt = ± 0.573degree

The 1000 systems were generated by using Monte Carlo.

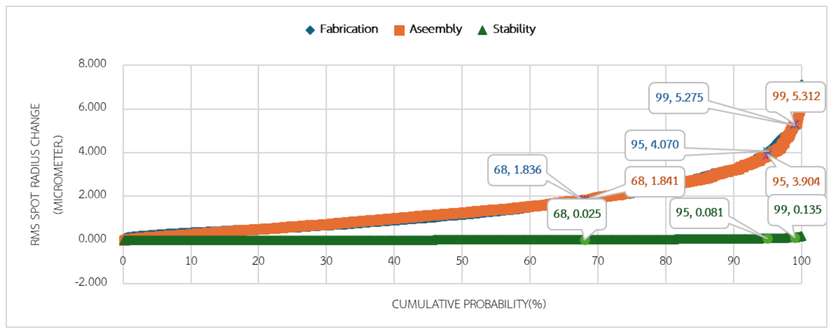


Figure 6 : A graph showing the relationship between the change in RMS spot radius and various cumulative probabilities for each process..

2.2 System Tolerance Analysis

Table 3 : Comparison of RMS Spot Radius: 1σ and 2σ

Tolerance process	Rms spot radius changed (µm)	
	1σ (68%)	2σ (95%)
Fabrication	3.103	5.337
Fabrication+Assembly	4.299	9.185
Fabrication+Assembly +stability	4.383	5.767
Airy radius	4.095	

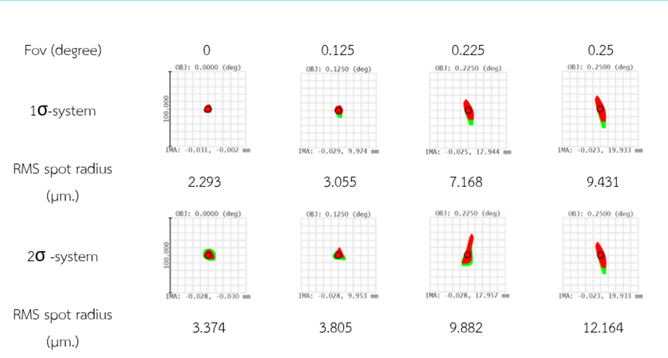


Figure 7 : Spot diagram of the System Tolerance for 1σ and 2σ systems. The RMS spot radius at different FOV is shown where a black circle represents an Airydisk

3. Straylight analysis results

3.1 Ghost image analysis

Ghosting occurs, causing noise in the region of interest with a noise power of approximately 10.

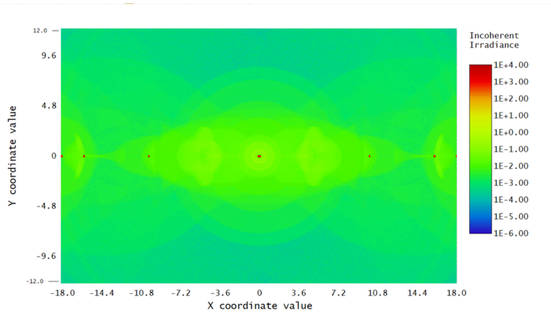


Figure 8 : Signal distribution on the imaging sensor: The red trace represents the Scientific ray from the target Field of View (FOV), while the green trace indicates ghosting noise caused by internal reflections within the focal reducer.



Figure 9 : Signal response comparison. The blue trace represents the system without coating, while the orange trace shows the performance after applying anti-reflection coating.

Conclusions

This study successfully designed a focal reducer for a 0.25° FOV, reducing the telescope's focal length to 4,570 mm with an RMS spot radius of 2.174 µm. Tolerance analysis specifies precision-grade manufacturing for Lenses L1, L22 and commercial-grade for Lenses L3, L4. Assembly tolerances are set at ±50 µm for decenter, ±100 µm for spacing. ±0.573° for tilt. Finally, 99% transmittance coatings effectively reduced ghosting artifacts by a factor of 1.5.

Reference

[1] EO Edmund Optics, Metallic Mirror Coatings

[2] Optimax Systems, Inc, level of manufacturing