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Management of rigorous optomechanical constraints using non planar symmetrical systems

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Abstract: An exploration of non planar symmetric geometries for a three mirror anastigmat telescope is performed and show that for some highly constrained systems, such assymetric designs could represent a viable solution. © 2021 The Author(s)

1. Introduction

Three mirror anastigmat (TMA) have been described as the best planar symmetric design for aberration design using freeform surfaces [1]. TMA have been widely studied and used in recent years. However some systems have very specific geometrical specifications, either for compactness or because the optical subsystem must be fitted in a volume that has an unconventional shape. In such cases, a non planar symmetric design could be the only solution. Here a solution for a non planar symmetric TMA is optimized using commercial optical software and the system shows that non planar symmetric catoptric systems are an alternative to classical planar symmetric designs.

2. Discussion

The system specifications are as described in Table 1:

Table 1. Specifications of the optical system and corresponding parameters of the generated systems

specification	value	symmetric system	assymetric system
focal length	270mm	270mm	270mm
maximal volume (X*Y*Z)	100x100x100mm^3	54,3x93,8x77,2 mm^3	54,1x87,1x81,1 mm^3
F#	5	5,03	5,04
field of view	3°(X) x 2.25°(Y)	3°(X) x 2.25°(Y)	3°(X) x 2.25°(Y)

A reference planar symmetric system has been defined using three freeform surfaces. Each surface is defined as a reference sphere and a departure from this base sphere. The departure is defined using polynomial subsets up to the fifth order in ρ, ρ being the radial coordinate of the point. To reach a diffraction limited system in the visible spectrum, a method inspired by literature [2] has been developed. An unobstructed TMA with spherical surfaces is optimized first with adequate constraints on the volume, focal length and aperture. All optimizations have been performed using Zemax OpticStudio software. The purpose of this first optimization is to create a starting point for the optimization that meets all geometrical constraints including volume restrictions and constraints to ensure an unobstructed design. The starting design has a poor image quality due to nodal aberrations appearing in such systems [3, 4]. The design is then optimized again. The optical quality is improved by using freeform surfaces using a subset of the XY polynomials up to the fifth order.

$$z(x,y) = \frac{c\rho}{1+\sqrt{1-c^2\rho^2}} + \sum_{i=0}^{5}\sum_{j=0}^{5-i} a_{i,j}x^i y^j \tag{1}$$

c is the curvature of the surface, $\rho = \sqrt{x^2+y^2}$ is the radial coordinate of the point, and $a_{i,j}$ are the coefficients of the monomials.

A non planar symmetric system is then optimized using the reference system as a starting point, modifying only the position of the mirrors to place the detector next to the secondary mirror along the X axis instead of the Y axis. Both layouts of the reference system and the non planar symmetric system are visible in Figure 1. A finer analysis shown that parabasal ray path has been conserved, and thus overall volume of both system are equivalent, the new system being more compact in the Y dimension but longer along the Z axis. X dimension is maintained as the X extent is defined by the primary mirror diameter. Volume of each system is given in Table 1. The volume repartition makes the non planar symmetric system more suitable to be fitted in a cubic volume.

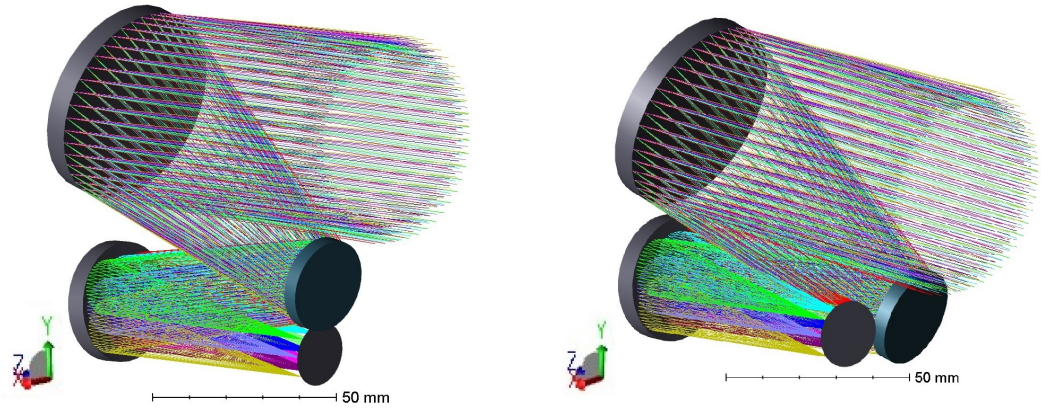


Fig. 1. Left: Layout of the reference system. Right: Layout of the non planar symmetric system

Optical quality of both systems are equivalent, as shown in Figure 2. This implies that non planar symmetric systems are a solution to consider for highly constrained systems.

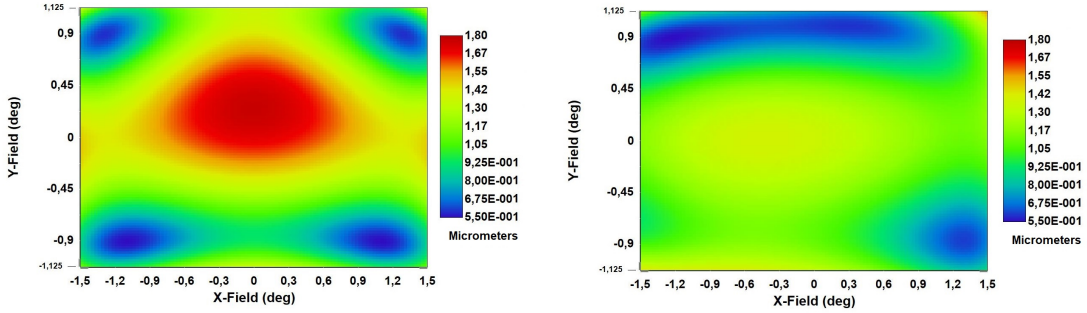


Fig. 2. Left: RMS spot radius of the reference system over field. (Max spot radius: 1,76μm) Right: RMS spot radius of the non planar symmetric system over field (Max spot radius: 1,52μm). Airy Radius: 6,15μm

Finally, we have assessed manufacturabily and alignment complexity by comparing several parameters such as freeform departure, local slopes of the surfaces and tolerancing of both systems. This implies that there is a whole unexplored domain of non planar symmetric catoptric systems that are already manufacturable, increasing the range of specifications that can be fulfilled with such designs.

References

1. Aaron M. Bauer, Eric M. Schiesser, and Jannick P. Rolland. "*Concurrent Engineering of a Next-Generation Freeform Telescope: Optical Design.*" In *Advanced Optics for Imaging Applications: UV through LWIR IV*, edited by Peter L. Marasco, Jasbinder S. Sanghera, and Jay N. Vizgaitis, 34. Baltimore, United States: SPIE, 2019.
2. Jun Zhu, Wei Hou, Xiaodong Zhang, and Guofan Jin. "*Design of a Low F-Number Freeform off-Axis Three-Mirror System with Rectangular Field-of-View.*" Journal of Optics 17, no. 1 (January 1, 2015): 015605.
3. Kevin P. Thompson, Tobias Schmid, and Jannick P. Rolland. "*The Misalignment Induced Aberrations of TMA Telescopes.*" Optics Express 16, no. 25 (December 8, 2008): 20345.
4. Kevin P. Thompson, Kyle Fuerschbach, Tobias Schmid, and Jannick P. Rolland. "*Using Nodal Aberration Theory to Understand the Aberrations of Multiple Unobscured Three Mirror Anastigmatic (TMA) Telescopes.*" edited by Richard N. Youngworth, 74330B. San Diego, CA, 2009.