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► To cite this version:

Eduard Muslimov, Emmanuel Hugot, Xin Wang, David Valls Gabaud, Pascal Vola, et al.. The MESSIER path finder: a high performance, wide field, fast and distortion free telescope using a curved detector. European Optical Society (EOS) Conference Proc. on Optical Technologies, Jun 2017, Munich, Germany. hal-02057523

HAL Id: hal-02057523

<https://hal.science/hal-02057523>

Submitted on 5 Mar 2019

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**The MESSIER path finder:
a high performance, wide field, fast and distortion free telescope
using a curved detector.**

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Summary

We present optical design of a high-quality, 36-cm diameter, fast (F/2.5) VIS telescope with a large field of view (1.6°x2.6°) developed for space science applications. The design is based on a bi-folded all-reflective Schmidt scheme using a curved detector. We demonstrate its advantages in terms of optical quality and manufacturability.

Introduction

In the present work we study optical design for a MESSIER mission pathfinder. The scientific goals pursued by the mission require a survey of extended objects with very low surface brightness [1]. Such a goal requires a fast telescope to get the highest SNR in surface brightness, with the highest optical quality and smoothness for homogeneity of the PSF over the field of view, as well as a distortion as low as possible for scan-drift purposes.

We propose to build a pathfinder telescope in order to demonstrate that the target performances are reached and also to test the technology readiness for a full-scale mission. Thus, on the one hand it is necessary to use novel design concepts and technologies to fulfill the challenging requirements, and on the other hand, the design can actually be manufactured within the next few years.

We use the bi-folded reflective Schmidt scheme proposed in [2] as the baseline design with an entrance pupil diameter of 360 mm. The rest of the specifications are as follows: focal length 879 mm, field of view 1.6°x2.6°, working wavelengths 200-1000 nm, spatial resolution 12 µm in RMS, and distortion <0.5% in the scanning direction [2].

Optical design

The optical scheme represents a reflective Schmidt system with an additional folding mirror. Some mitigation in size and F-number are made for the pathfinder to get in-plane configuration with a relatively small angle of inclination of the primary mirror. Even then, for the chosen angle value of 11° it is impossible to use an axisymmetric profile of the aspherical mirror, and hence an anamorphic asphere should be used. The baseline design then implies the use of a curved detector [3], though a field flattener option is considered as well. It should also be noted that the optical scheme has a central obscuration, though it is only about 9% of the area and affects minimally the performance of the telescope. Fig. 1a represents the general view of the optical system, which was preliminary investigated in [4].

Spot diagrams RMS radii change from 1.5 to 2.8 µm across the field of view. The spatial resolution calculated from the MTF (see Fig. 1b) is 105-193 lines/mm, i.e. 1.2-2.2" in angular units. The maximum distortion is approximately 0.04 % and in both X and Y directions.

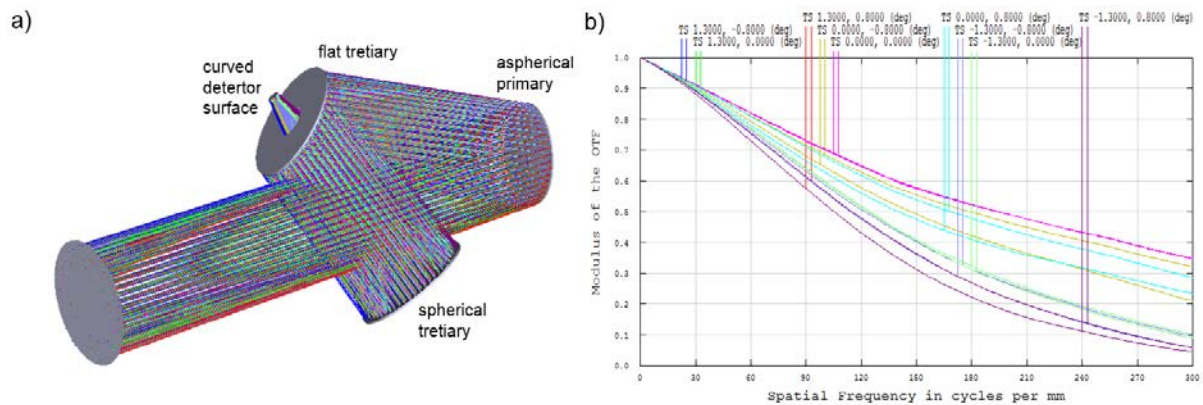


Fig. 1. Bi-folded Schmidt optical design: a – general view, b – module transfer function.

Tolerances and manufacturability estimations

The proposed design consists in relatively simple elements. The secondary and tertiary mirrors have simple shapes (flat and spherical) and do not raise any concerns. The detector parameters are within technologically realizable boundaries: the linear field of view is 40.3 x 24.8 mm with a radius of curvature of 886 mm. The aspherical primary has a maximum sag of 34.7 μm and is described by 4th order polynomials, so it can be manufactured by means of stress polishing [5].

The tolerancing was performed with the image quality criterion specified above. Assuming that the detector has an accurate 4-coordinate alignment, we obtained the following tolerance boundaries: the elements relative positions 0.1-0.2 mm, decenters 0.1-0.2 mm, tilts 1.8-12', surface irregularity 0.05-0.1 μm i.e. $\lambda/5$ - $\lambda/10$. If a lens field flattener is used these values remain almost unchanged, but the compensation parameters change increases several times.

Conclusions

An optical scheme of a wide-angle fast telescope prototype is developed to meet all the requirements for the optical quality, while the optical elements are as simple as possible. Thanks to the high nominal image quality and the use of a curved detector it becomes possible to guarantee a high performance with high tolerance and limited alignments, so that in principle this optical design can be manufactured without problems. The details of the primary mirror fabrication by stress polishing and optical testing issues will be considered elsewhere.

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