SOLAR SYSTEM

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A NEW WIDE-FIELD TELESCOPE WITH A MIRROR DIAMETER OF 600 MM FOR THE TELESCOPE NETWORK OF THE ODESSA OBSERVATORY

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ABSTRACT. Optical scheme of the new wide-field telescope of the telescope network of Odessa Observatory is described.The telescope optical layout is designed as a mirror-lens system with a Ross-type two-lens corrector and a hyperbolic primary mirror with diameter of 600 mm. The prime focus corrector is capable of imaging a field of 2 degrees, the root-mean-square radius of the diffraction spot is about 4.5 μm, which is 2.5 times larger than that of the diffraction-limited spot (Airy disk).

Keywords: Astronomical instrumentation, methods and techniques

АНОТАЦІЯ. Після появи професійних оптичних CCD-матриць з високою чутливістю з'явилася можливість застосування телескопів з малим дзеркалом для вирішення широкого кола важливих наукових завдань. Використання телескопів з малим дзеркалом дозволяє не обмежувати кількість часу на спостереження. Крім того, невеликі телескопи незамінні для реалізації дослідницьких програм ближнього космосу (навколоземного, Сонячної системи). Такі інструменти використовуються для вивчення метеорів, астероїдів, комет, планет разом зі своїми супутниками, а також штучних об'єктів в космосі.

У цій роботі розглядаються перші етапи проектування телескопа з діаметром первинного дзеркала 600-мм, який має унікальний оптичний дизайн та широке поле зору. Оптичну схему телескопа розробив науковий співробітник Астрономічної обсерваторії Одеського національного університету Микола Фащевський у кінці свеї дуже плідної наукової та практичної діяльності, цю схему він назвав "Гіперболічний Росс". Ця оптична система дуже схожа на дволінзовий коректор, який був розроблений Россом (1935) для параболічного первинного дзеркала 200-дюймового (5 м) телескопа Хейла обсерваторії Маунт Паломар.

У роботі наданий опис оптичної схеми нового телескопа з широким полем зору, який створюється для мережі телескопів Астрономічної обсерваторії Одеського національного університету. Оптична схема складається з дзеркально-лінзової комбінації з дволінзовим коректором Росса і гіперболічним дзеркалом, діаметр якого складає 600 мм. Коректор первинного фокусу дає змогу отримати поле зору до двох градусів. Середньоквадратичний радіус дифракційного кола розсіювання складає 4.5 мікрон, що у 2.5 рази більше, ніж дифракційна межа (диск Ері). Проектування та виробництво оптичної системи 600-мм телескопа вже завершено, і зараз закінчується побудова труби телескопа та модернізація астрономічного паралактичного штатива, який повинен нести вагу труби.

Ключові слова: Астрономічне приладобудування, методи і техніка

1. Introduction

Just a few decades ago astronomy with small telescopes seemed to be receding into the past. Such views stretched from a growing number of optical telescopes with mirrors of larger diameters, which had been built and put in operation in those days. However, it soon turned out that small telescopes managed to carve a niche for themselves in areas related to astronomy. It is mainly due to the fact that the operational time on large telescopes is quite costly, and it is allocated among numerous observation programmes with a wide range of objectives, which are usually focused on deep space exploration. Telescopes with small mirrors, by contrast, are often employed within the

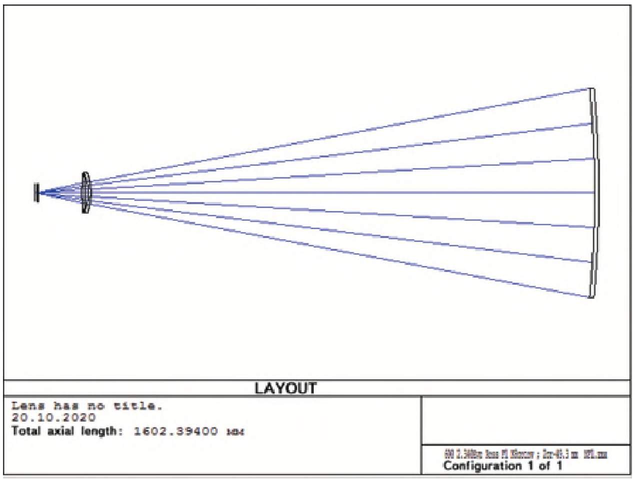


Figure 1: Original optical layout of the 600-mm telescope

scope of a particular programme, thus putting no limits on the amount of operating time for an individual observer. Besides, small telescopes are indispensable to the implementation of near-space (near-Earth, Solar System) research programmes. Such instruments are used to study meteors, asteroids, comets, planets along with their satellites, as well as man-made objects in space.One of the good examples related to the Odessa Observatory telescope network is OMT-800 (Andrievsky et al., 2013).

The optical layout of the telescope is designed as a mirror-lens system with a Ross-type two-lens corrector and a hyperbolic primary mirror (Figure 1).

The present paper discusses the first stages of the design and construction of a telescope with a 600-mm diameter primary mirror, unique optical design and a wide field of view.

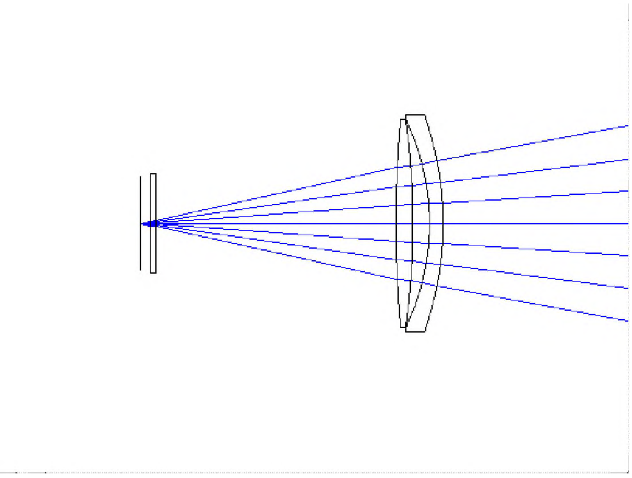


Figure 2: A Ross-type two-lens corrector of the telescope optical system

2. Optical layout of the 600-mm telescope

A research scientist of Astronomical Observatory of Odesa National University, Nikolay N. Fashchevsky, at the end of his fruitful scientific career and practical activities, performed complex computations of an original optical design for the telescope, which he named "Hyperbolic Ross" (Figure 2).

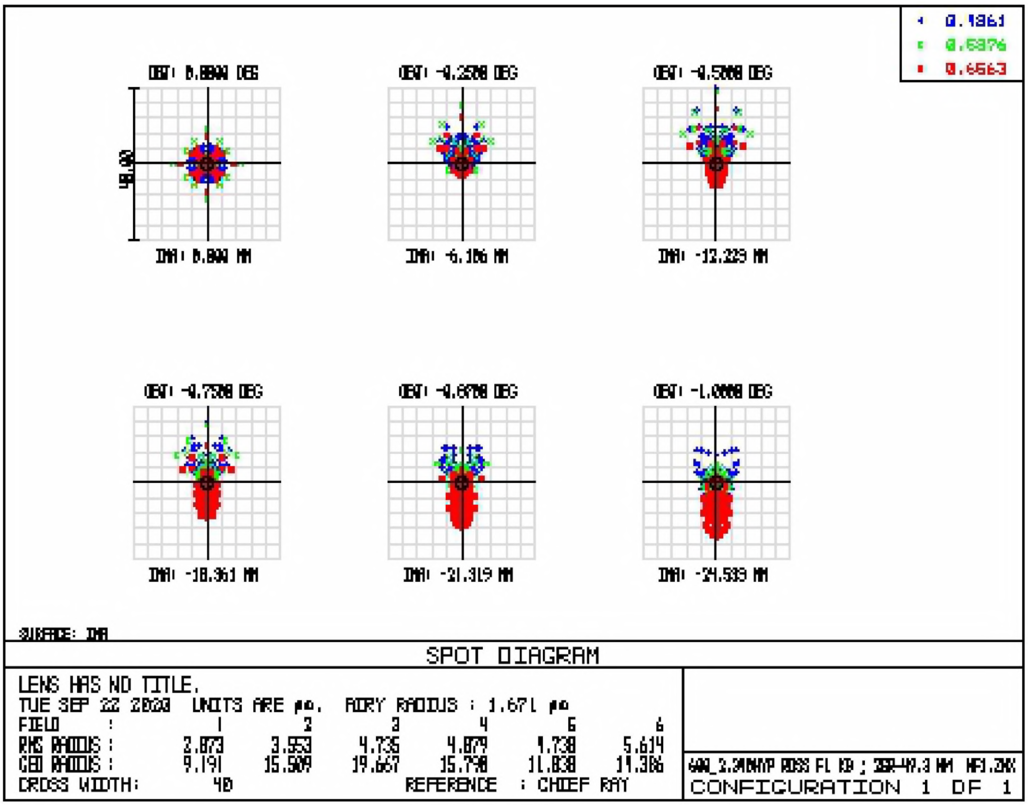
This optical system is very similar to the doublet lens corrector designed by Ross (1935) for the parabolic primary mirror on the 200-inch (5-m) Hale Telescope at the Mount Palomar observatory. However, the optical design developed by Fashchevsky has several distinguishing features. The original Ross corrector consists of two lenses made of optical glass of the same grade with zero optical power; it was designed specifically for correcting coma of mirrors exclusively (that is, as a coma-corrector). In our optical system, the corrector is comprised of different types of optical glass, namely F1 and K8, with low positive optical power of 0.8-dioptres. The primary mirror is a hyperboloid of high asphericity, which allows us to have a sufficient number of free parameters for practical correction of all five third-order aberrations. The result obtained is illustrated in the spot diagrams for images, presented in Figure 3.

As is seen from the spot diagrams above, the prime focus corrector is capable of imaging a field of 2 degrees, the root-mean-square radius of the diffraction spot is about 4.5 μm, which is 2.5 times larger than that of the diffraction-limited spot (that is, the radius of the Airy disc). This is quite a good result for such a field of view.

Key characteristics of the computed optical design, along with some additional parameters, are listed in the table presented below in scheme (Figure 4).

Nikolay Fashchevsky made a report on the results obtained to the Scientific Council of the Astronomical Observatory of Odesa National University, and the Council made a decision approving optics manufacturing. The manufacturing process got underway. The primary mirror was polished and configured, getting it preliminary ready for operation. Regretfully, Nikolay Fashchevsky did not have time to proceed with all the works planned. The mirror was lying idle for several years. Under such circumstances, the Head of the Observatory, Sergey M. Andrievsky, came to a decision to resume the optical-system manufacturing activities.

To further the work, first of all, it was needed to design, construct and test a prototype of the optical system, in particular to manufacture a compensating spherical mirror of 400 mm in diameter and a set of alignment mirrors. We managed to accomplish all these works successfully. The test (reference) layout



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LENS HAS NO TITLE.
TUE SEP 22 2020   UNITS ARE µm.   AIRY RADIUS : 1.671 µm
FIELD       :        1        2        3        4        5        6
RMS RADIUS :     2.873    3.553    4.735    4.879    4.738    5.614
GEO RADIUS :     9.191   15.909   19.667   15.798   11.838   14.386
CROSS WIDTH:        40                 REFERENCE  : CHIEF RAY
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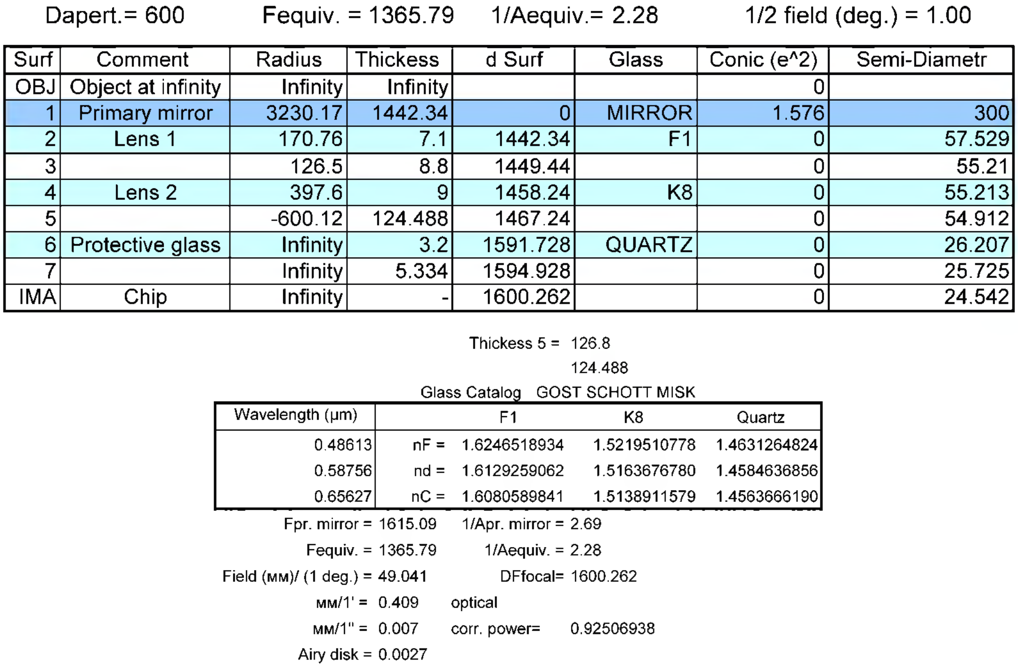
Figure 3: Resulting spot diagrams for images



Dapert.= 600 Fequiv. = 1365.79 1/Aequiv.= 2.28 1/2 field (deg.) = 1.00

Surf	Comment	Radius	Thickess	d Surf	Glass	Conic (e^2)	Semi-Diametr
OBJ	Object at infinity	Infinity	Infinity			0	
1	Primary mirror	3230.17	1442.34	0	MIRROR	1.576	300
2	Lens 1	170.76	7.1	1442.34	F1	0	57.529
3		126.5	8.8	1449.44		0	55.21
4	Lens 2	397.6	9	1458.24	K8	0	55.213
5		-600.12	124.488	1467.24		0	54.912
6	Protective glass	Infinity	3.2	1591.728	QUARTZ	0	26.207
7		Infinity	5.334	1594.928		0	25.725
IMA	Chip	Infinity	-	1600.262		0	24.542

Thickess 5 = 126.8
124.488

Glass Catalog GOST SCHOTT MISK

Wavelength (µm)		F1	K8	Quartz
0.48613	nF =	1.6246518934	1.5219510778	1.4631264824
0.58756	nd =	1.6129259062	1.5163676780	1.4584636856
0.65627	nC =	1.6080589841	1.5138911579	1.4563666190

Fpr. mirror = 1615.09 1/Apr. mirror = 2.69
Fequiv. = 1365.79 1/Aequiv. = 2.28
Field (мм)/ (1 deg.) = 49.041 DFfocal= 1600.262
мм/1' = 0.409 optical
мм/1'' = 0.007 corr. power= 0.92506938
Airy disk = 0.0027

Figure 4: Optical system data

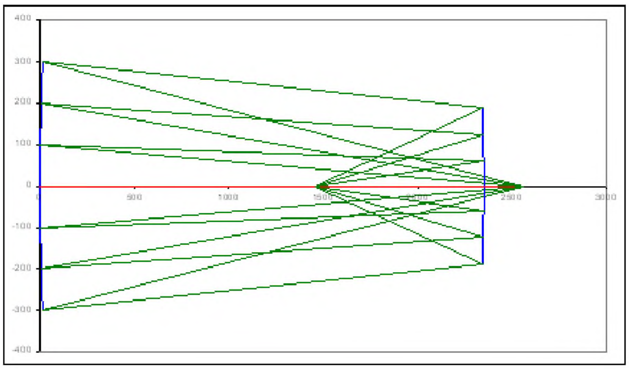


Figure 5: Test (reference) optical layout.

Figure 6: General view of the optical system prototype during test procedures.

of the primary mirror is depicted in Figure 5. It is a well-known Maksutov (1948) optical layout upgraded as suggested by Fashchevsky (2010). At the reference output point of the optical layout, an image is formed with a diffraction-spot radius of 8 μm, which is close to the diffraction limit.

The optical system prototype was assembled and aligned in the immediate vicinity of the polishing machine in the optical workshop of the Astronomical Observatory of Odesa National University; it enabled us to test the surface quality not removing the mirror from the polishing machine frame (Figure 6).

Then, the mirror had to be polished to form the desired shape. In so doing, the main challenge was associated with too high asphericity of the primary mirror, which was almost beyond our abilities; in particular, the eccentricity square was to be 1.58, the deviation from the best-fitting sphere – 11.8 μm, and the longitudinal spherical aberration – 25 mm. It was not feasible to attain the computed targets using classical methods and techniques. This is why, in order to solve such an issue, we selected a special polishing resin and manufactured specific polishing pads. As a result, the primary mirror was polished to a shape that was very close to the computed one within the errors.

Figure 7: Two corrector lenses.

Meanwhile, the Ross-type corrector lenses were manufactured. The first corrector concave-convex lens, made of F1 optical glass, and the second double convex lens, made of K8 glass, were polished and centred to the desired radii and thicknesses. After polishing, the lenses were treated with diluted acetic acid as an anti-reflection coating. The finished corrector lenses are shown in Figure 7.

3. Conclusion

All activities related to the design and manufacturing of the optical system of the 600-mm telescope have been accomplished, and we are currently finishing constructing the telescope tube and modernising the astronomical parallactic tripod, which is to bear the tube's weight.

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