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

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
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
Figure 3: Resulting spot diagrams for images

<table>
<thead>
<tr>
<th>Surf</th>
<th>Comment</th>
<th>Radius</th>
<th>Thickness</th>
<th>d Surf</th>
<th>Glass</th>
<th>Conic (e²2)</th>
<th>Semi-Diamet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary mirror</td>
<td>3230.17</td>
<td>1442.34</td>
<td>0</td>
<td>MIRROR</td>
<td>1.576</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Lens 1</td>
<td>170.76</td>
<td>7.1</td>
<td>1442.34</td>
<td>F1</td>
<td>57.529</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>126.5</td>
<td>8.8</td>
<td>1449.44</td>
<td>0</td>
<td>55.21</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Lens 2</td>
<td>397.6</td>
<td>9</td>
<td>1458.24</td>
<td>K8</td>
<td>55.213</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-600.12</td>
<td>124.488</td>
<td>1467.24</td>
<td>0</td>
<td></td>
<td>54.912</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Protective glass</td>
<td>Infinity</td>
<td>3.2</td>
<td>1591.728</td>
<td>QUARTZ</td>
<td>26.207</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Infinity</td>
<td>5.334</td>
<td>1594.928</td>
<td></td>
<td>25.725</td>
<td></td>
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<tr>
<td>IMA</td>
<td>Chip</td>
<td>Infinity</td>
<td></td>
<td>-1600.262</td>
<td></td>
<td>24.542</td>
<td></td>
</tr>
</tbody>
</table>

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

Figure 4: Optical system data

<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>F1</th>
<th>K5</th>
<th>Glass Catalog</th>
<th>GOST SCHOTT MISK</th>
</tr>
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<tbody>
<tr>
<td>0.46613</td>
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<td>1.5219510778</td>
<td>1.465312648246</td>
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<td>0.58756</td>
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<td>1.5103678780</td>
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<tr>
<td>0.85627</td>
<td>1.6080598941</td>
<td>1.5138911579</td>
<td>1.4563668190</td>
<td></td>
</tr>
</tbody>
</table>

Fpr. mirror = 1615.09  
1/Apr. mirror = 2.89

Fequiv. = 1365.79  
1/Aequiv. = 2.28

Field (mm)/(1 deg.) = 49.041  
DFocal= 1600.262

mm²/T = 0.409  
corr. power= 0.92506938

Ary disk = 0.0027
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 $\mu$m, 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 $\mu$m, 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.

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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References


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