29: S425 ~ S426, 1996

NEW OPTICAL TECHNIQUES FOR THE "STRUVE" SPACE ASTROMETRIC PROJECT

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ABSTRACT

A few optical schemes for the future Russian astrometric satellite ("Struve") are discussed. New optical materials and techniques developed at the Vavilov State Optical Institute are planned to be used for the on-board telescopes. Optical characteristics of the reflecting Schmidt and a three - mirror scheme for the on-board telescopes are compared.

Key Words : space astrometry, space optics, stability of optics

I. INTRODUCTION

The Struve astrometric satellite which is being developed at Pulkovo Observatory in cooperation with Krasnoyarsk Institute of Applied Mechanics, S.I.Vavilov State Optical Institute and some other space instrumentation institutes will conduct second-epoch observations of the Hipparcos stars. The project is devoted to maintaining the Hipparcos coordinate system as well as extending it to a density of $\approx$ 100 stars per square degree. The satellite is being designed rotating very smoothly in order to improve the accuracy of observations. Wide arcs on the sky will be measured by combining separated fields of the sky in one telescope. The basic measuring angle will be formed by a special beam combiner placed in front of the telescope. Two different basic angles and two telescopes are planned to be used on board the Struve satellite. The telescope diffraction quality field of view is to be at least $1° \times 1°$, and the focal length is 2.5 m. Both telescopes are to be folded inside a limited volume of the satellite (a cylinder of 3 m diameter and 1.5 m height).

II. SCHMIDT OPTION

Initially, a Schmidt optical scheme of the on-board telescopes has been designed with 40-cm diameter entrance pupils and with quartz glass correction plates. It is similar to the Hipparcos telescope. The beam combiner is placed at the center of the instrument, and additional flat mirrors are used in order to fold the optics in the two–level cells of the inner space of the satellite. The objective is calculated for the spectral range 0.3 – 0.7 μm.

Calculations of the temperature – dependent aberrations for the temperature intervals $20° \pm 0.1°$ and $20° \pm 0.5°$ have demonstrated rather small variations of aberrations in comparison with variations of the focal length. The latter ones depend on the material of the spherical mirror. The variations of the focal length are 0.53 μm and 2.9 μm, respectively for the two taken temperature intervals, if SiC is chosen for the optical elements (expansion coefficient $2.6 \cdot 10^{-6}$). When using SiO_2 (expansion $2 \cdot 10^{-7}$), the focal length varies only within 0.05 μm and 0.23 μm, respectively. The objective mounts was assumed to be made of Invar or Titanium, and the mount is estimated to influence very little to the stability of the focal length, field aberrations and the back focal distance S'. The opto-mechanical design of the telescope is shown on Fig. 1.

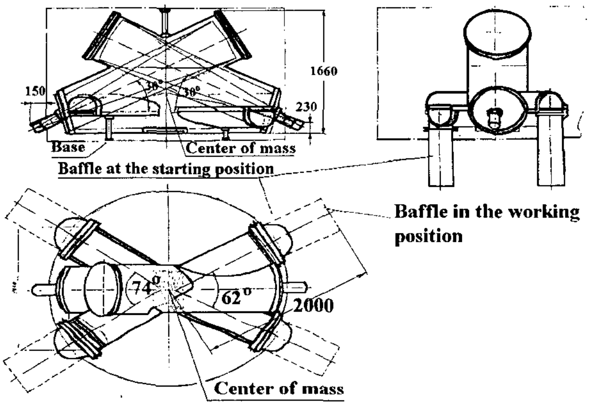

Fig. 1.— Opto-mechanical block (Schmidt option).

A disadvantage of the Schmidt telescope is that it is difficult to fold it inside a limited space of the satellite.

III. THREE – MIRROR SCHEME

A three-mirror option (similar to the Korsch scheme) was designed as an alternative solution for the on-board telescope. New materials (SiC or SiO_2) are also assumed to be used for this design. The entrance pupil is proved to be possible to increase up to 610 mm (keeping the 2.5 m focal distance and one square degree field of view). The scheme of the objective is shown on Fig.2).

The design with a lens corrector at the focal plane has small chromaticism, and sphero-chromatic aberra-

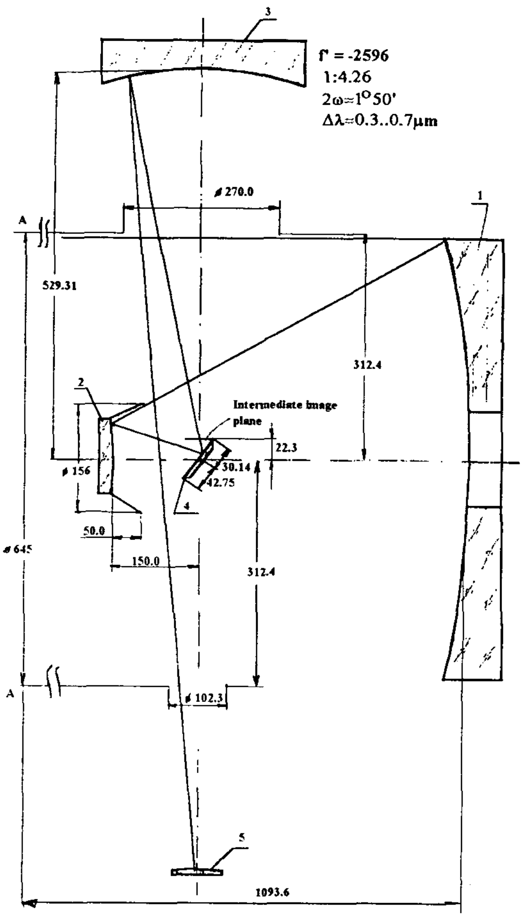

Fig. 2.— Scheme of the three-mirror objective.

tions not exceed 0.16λ for $\lambda = 0.45 - 0.6\ \mu$; chromaticism is $8.7 \cdot 10^{-4}$ for $2\omega = 77'$ and 0.001 for $2\omega = 110'$. All wave aberrations do not exceed 0.25λ for $\lambda = 0.45 - 0.6\ \mu$ and $2\omega = 110'$.

The energy concentration in a 6.7 μm circle is 84% for $\omega = 0°$, 84.3% for $\omega = 39'$, 83.5% for $\omega = 47'$, and 80.9% for $\omega = 55'$ (taking into account diffraction). For $2\omega = 110'$ and the spectral range $\lambda = 0.3 - 0.7\ \mu m$ the geometrical circle of scattering not exceeds 10 μm. Distortion for $\lambda = 0.4\ \mu m$ does not exceed $7 \cdot 10^{-5}$ mm, and if one takes $\lambda = 0.86\ \mu m$, the distortion increases up to $2.4 \cdot 10^{-4}$ mm. Changes of temperature cause changes in the distortion less than $5 \cdot 10^{-4}\ \mu m$ per $1°C$ and in the focal length less than 6 μm.

The three-mirror optical scheme is very compact ($\approx 0.6 \times 1 \times 1$ meters), and it provides an additional space inside the satellite for other scientific equipment.

IV. CALIBRATIONS

Many of the parameters of the telescopes will be included in equations for the great circle solution. Therefore, they will be determined during the flight. But some of the optical parameters are planned to be calibrated both on the ground and on board the spacecraft. Changes of the focal length will be measured with a special hologram placed on the surface of the primary mirror. This hologram will focus the light emitted by illuminated marks at the focal plane of the telescope forming their images close to the original marks that gives a possibility to control the focal length. The same marks one may use for checking distortion and chromaticism.

V. CONCLUSIONS

Two discussed optical schemes of the Struve onboard telescopes provide close to diffraction limited quality of images within more than 1.5° field of view. But the second scheme, having approximately the same mass as the first one (due to the usage of SiC or SiO_2), is much more compact and, in addition, gives a possibility to increase the accuracy due to its more than twice larger light collecting area.