PHOTOMETER "DIFOS" FOR THE STUDY OF SOLAR BRIGHTNESS VARIATIONS

E.A. GURTOVENKO, I.G. KESELMAN, R.I. KOSTYK AND S.N. OSIPOV
Main Astronomical Observatory, Ukrainian Academy of Sciences, 252127, Kiev, Ukraine.

N.I. LEBEDEV, I.M. KOPAYEV, V.N. ORAEVSKY, AND YUD. ZHUGZHDA
IZMIRAN, Russian Academy of Sciences, 142092, Troitsk, Russia

ABSTRACT. A photometer has been designed for measuring solar irradiance within three wide spectral bands with a relative error 0.00001 and time resolution of 16 sec. It is elaborated according to the international space project KORONAS and is planned to be launched at the beginning of 1994. A description of its layout and operation is given briefly.

1. LAYOUT OF THE PHOTOMETER

The device consists of three identical channels whose optical axes are parallel and placed at equal (25 mm) distances from each other. Spectral transmittances of the channels are given in the following table:

<table>
<thead>
<tr>
<th>Channel number</th>
<th>Filters</th>
<th>Wavelengths of maximum of transmittance</th>
<th>Range of transmittance, nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>neutral</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>green</td>
<td>526</td>
<td>494-600</td>
</tr>
<tr>
<td>3</td>
<td>red</td>
<td>710</td>
<td>690-790</td>
</tr>
</tbody>
</table>

A section of the photometer through a plane containing any pair of channel axes is displayed in Figure 1. When designing the photometer, besides the limitation of its weight and dimensions, we also had to take into account the following factors.

1. During the experiment the receivers’ photo-sensitive surface (a, diameter is 2.5 mm, Figure 1) must be illuminated by radiation from the whole solar disk. At the same time the angle of vision, α, from each point of the photosensitive surface (a) in the direction of the photometer optical axis should be minimum, in order to prevent the unpredictable parasitic illumination from the Earth surface, upper atmospheric layers and apparatus mounted on the satellite platform, and also to diminish heating of the photodiode frame.

2. Estimation of the angle, α, should be made while accounting for the accuracy of centering of the entrance photometer apertures (b) and photodiode apertures (a) on the optical axis (the inaccuracy in both cases is 0.2 mm) as well as the error of photometer mounting (several minutes of arc) on the satellite platform.

3. The photosensitive photodiode area should not be illuminated by light passing through entrance apertures of both neighboring channels.

4. Transmittance of filters may be different at different parts of their area. Under limited accuracy (10 min. of arc) of satellite axis pointing to the Sun this may cause false effects in the output signal.

Accounting for the photometer dimensions (Figure 1) and the factors noted above in points 1 and 2, the angle of vision

\[ \alpha = 2 \arctan \left(\frac{b - a}{2} \right) \]

is put equal to 200° and the size of the entrance aperture is $b = 8$ mm. Diaphragms $D$ meet the demands noted in point 3. They also act as traps for scattered light. In order to avoid the effects noted in point 4, the filters are put onto the photodiode frame. Diaphragms $D'$ behind filters are designed in such a way that their apertures are always illuminated by radiation from the whole solar disk, even if the maximum rocking of the satellite axis takes place.

2. OPTIMUM CONDITIONS FOR OPERATION OF RECEIVERS

Silicon photodiodes FD-293 with the band of spectral sensitivity 440-950 nm are used in all three channels. The spectral transmittance of photometer channels is displayed in Figure 2.

The optimum operating regime of the photodiodes is with photocurrent between 80-160 $\mu$A. To meet this demand it was necessary, first - to equalize the fluxes in all channels
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Fig. 3. Structural scheme of the photometer:
1 - photodetectors; 2 - analogue-digital converter (ADC) (analogue part); 3 - controller of ADC; 4 - adapter of interface of onboard data system gathering; 5 - thermoregulator; 6 - source of ADC power supply.

(using an appropriate neutral filter) and secondly - to equalize them in such a manner that the required photocurrent (80-160 μA) would be obtained under working conditions in space. Thus, the photometer was installed before the main mirror of solar telescope ATsU-5 in the parallel solar light beam, and was oriented along the telescope optical axis. The photometer’s recorded photocurrent is decreased (in comparison with the conditions during the space experiment) due to the reflectivity of the coelostat mirrors and to atmospheric extinction. Extinction by the coelostat mirrors is small, and can be estimated easily. In order to account for the atmospheric extinction we have measured the photocurrent over a whole day, and then by using "cosecant method" we extrapolated it to its value in space. Thereupon the neutral filters were sorted out in all channels so as to make the extrapolated photocurrent approximately (within 10 percent) equal to the optimum value.

Adjustment of the photometer and its testing were performed with the help of a specially designed stable light source, whose spectral radiance corresponds to the solar one. A halogen battery filament lamp KGM-24-150 (24V, 150W) was used as a light source.

3. OPERATION OF THE APPARATUS

Detectors are mounted on the autonomous platform which provides a high equality of their temperatures as well as perfect thermoisolation from the photometer body.

To eliminate the influence of temperature variations upon receiver sensitivity a system of active thermoregulation was designed. Because the surrounding temperature \( T_s \) can not be predicted reliably, we have utilized the principle of adaptive setting of thermoregulation temperature \( T_h \); preliminary measured temperature of the surroundings, \( T_s \), establish the temperature of thermoregulation, \( T_h \). A diode serves as the temperature sensor and is mounted on the receiver’s platform with perfect thermal contact with it.

The thermoregulator represents a system of proportional regulation. It consists of the following elements: transducer which transforms the temperature of the crystal diode into voltage, digital-analogue converter which converts the input current (corresponding to the temperature of
thermoregulation) into voltage, amplifiers of the signal mismatching and of the power gain, a heater which is fastened to the platform of receivers, and a controller.

Conversion of photocurrent into its equivalent digital code is performed with the help of a three-channel parallel analogue-digital converter (ADC) of integrating type. Choice of this ADC is conditioned by the demands of high resolving power (about 16 bits) and of high noise stability.

As the photometer is destined for measuring the relative solar variations the ADC is designed as a differential converter. Thus, an additional standard compensation current is inserted into the system. It corresponds to the mean value of the photocurrent, and during observations the deviation of signal from its average value is recorded. Two ranges of recording are foreseen - fine and rough. On the rough range the photocurrent is diminished by two times.

Utilization of all techniques mentioned above enables us to attain a relative resolving power equal to 0.00001 under 16 sec storage time and with the unit signal-to-noise ratio (theoretical resolving power is 0.000002). The analogue part of the ADC is placed into the electromagnetic shield which is made of an alloy having a high magnetic permeability. Electric power for the ADC is supplied by the autonomous stabilized voltage converter which performs also the galvanic isolation of the ADC from the internal network of the photometer power supply. Control bus is optoisolated from the analogue part of the ADC.

Photometer is fed from the board net of electric power supply via autonomous voltage converter which performs the galvanic isolation of the photometer electrical circuits from the board network and also forms the required stabilized voltages.

Structural scheme of the apparatus is shown in Figure 3.

Solar irradiance variations will be measured on the background of the solar flux trend caused by the change of the Sun-Earth distance. The trend may also serve as a control for the stability of the photometer sensitivity.

Orbit of the satellite allows to perform continuous observations of the Sun during 20 days, periodically.

Spacecraft KORONAS is planned to be launched at the beginning of 1994.