# THE PHOTOELECTRIC MERIDIAN CIRCLE OF THE PULKOVO.

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ABSTRACT.
The paper reports on the new semiautomatical meridian circle of the Pulkovo observatory. It is equipped with a scanning photoelectric micrometer and a photoelectric circle reading system. The standard errors of a single registration of a star are $0\overset{s}{.}016$ and $0\overset{''}{.}35$ in RA and declination, respectively. The limiting magnitude is $10.5^{m}$. The instrument can be used for IRS differential observations.

## INTRODUCTION.

The modification of the Pulkovo observatory meridian circle has been completed. It achieved an improvement of the precision and observing efficiency. The tube of the old MC consisting of four sections was too long and thus not sufficiently rigid. Besides, the mounting of the old divided circle was not satisfactory. All these were responsible for large flexure effects and deformations of the circle.

As part of the modification the design of the telescope was improved. A photoelectric registration system and a photoelectric system for reading the silver circle were provided. The work began in 1972 and was carried out mainly by the Pulkovo observatory staff. The mechanical and optical units of the telescope and the photoelectric star measuring system (photoelectric micrometer) were designed and assembled in 1980. From 1980 to 1983, RA observations were made. These enabled us to compile a RA catalogue of circumpolar stars and estimate the precision of the instrument in RA observations. In 1983 the declinations observations were begun and a preliminary estimation of the precision in declination observations was derived.
Only the horizontal axis with the setting and divided circles of the old telescope was used for the modified



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instrument. All other telescope parts (objective, bearings, balancing mechanism, eyepiece micrometer, circle reading system) were replaced with new parts made at Pulkovo. New silver circle divisions were also engraved. A new pavillion was built to house the instrument.

## PERFORMANCE SPECIFICATIONS.

The performance specifications of the new meridian circle (named MK-200) are as follows: 2000 mm focal length, 1230 mm distance between the pivot working sections and pivots of 100 mm diameter. The divided circle has a diameter 720 mm and is graduated in intervals of 2'. The average precision of the instrument corresponds to standard errors of $0\overset{s}{.}016$ and $0\overset{''}{.}35$ in RA and declination respectively (unknown division corrections were not taken into account). The instrument allows one to observe stars of about $10\overset{m}{.}5$ (fainter stars cannot be seen). The registration time of one transit is $40\text{-}60^s$ and is independent of declination. The time interval required between two consecutive transit observations is about $20\text{-}30^s$ . The results of the observations are punched and processed on the EC-1033 computer. The instrument is supplied with a striding level and two meridian collimators. The sidereal time signals originate from the atomic clock located elsewhere.
The MK-200 can be used for differential observations of stars and planets at night.

## MICROMETER.

The photoelectric micrometer operates by scanning the star image with a system of two analyzing V-shaped slits attached to a movable carriage frame. In order to move the slits accurately in the focal plane of the telescope we use a spring frame in the form of a rhomboid (without any guiding units). There is a window at the upper plate of the rhomboid where the light enters. V-shaped slits are installed at the lower plate. The prism, located behind the slits, guides the light ray parallel to the motion of the slits. The prism also deflects this light onto the cathode of the photomultiplier. One could introduce another prism into a light beam and divert it to the eyepiece which has a reticle, with which one may visually accurately set the telescope tube before observation.

The carriage frame is moved by a micrometric screw of 0.5 mm pitch. This screw is coupled with an angular digital magnetic sensor. The coordinates of the carriage are measured by this sensor, which has an angular discrimination of 512 elements per circle, corresponding to about $0\overset{''}{.}1$ in the focal plane of the telescope (taking into account the pitch of the screw). The screw is rotated with a stepping motor through two spring links.

The luminous flux from the star, modulated by the slits, is transformed to current pulses by a photomultiplier ФЭУ-79, working in the analogous regime, which was chosen as the easiest instead of the preferred photon counting mode. There is an RC-filter at the amplifier input to decrease the photo-current fluctuations of high frequency, which originate in noises from the sky background, scintillation, atmospheric turbulence, photomultiplier noise and amplifier noise. The output signal of the amplifier is compared with the stabilized reference voltage (threshold level). When a signal equals the threshold level the logical unit controlling the micrometer movements and registrating the slits coordinate is activated. This coordinate and the corresponding sidereal time epoch are punched simultaneously.

During a single scan of a stellar image we obtain two readings of slit coordinates which correspond to the instants of the signal's emergence and of the signal's cessation. The epoch of a star image's transit through the center of a slit is calculated as an average value of the instants at which the "fronts" were recorded. The carriage coordinates at this instant are assumed as to be the arithmetic mean of the coordinates of the carriage at the same moments of time. The number of V-transits used in the 40-$60^s$ observation is 16, taking into account the to and fro scans.

Since the photomultiplier is operating in an analogous regime, using an RC-filter on the amplifier input, a systematic error due to signal delay is found to appear in the electronic unit. To decrease the error the scan regime is adopted so that the rate of relative movements of slit and star image remains constant, independent of the direction of the carriage movement and the declination of the star. The scanning velocity relative to the star is $15''$ per second of time and, hence, the velocity of the carriage frame varies from $15''$ to $30''$ per second, depending on the declination and on the direction of the carriage movement. Under these conditions the average of the registrations of the scans in opposite directions considered as a single measurement, which now no longer is affected by a delay error.

Information on the declination of a star is contained in the difference between the registration of the first and the second slit. The slits are $20''$ and measure $5''$ in the direction of scanning. The analizing slits make an angle of 45° with the direction of scanning which is that of the stars' diurnal motion.

## THE CIRCLE READING.

A photoelectric reading of the lines in the silver circle is difficult. Because gradual darkening of silver with time, the darkening is normally not homogeneous. All this makes the contrast weak also, and increases the reading errors. Our silver circle was coated with a special lacquer which is insensitive to unfavorable climatic conditions in order to protect it from blackening. Before coating, the silver circle was repolished and redivided.

Four microscopes with telecentric $10^x$ optics read the circles. The fields of view are illuminated with a photometric lamp. Its light passes through light-conductors to 45°-inclined semi-transparent mirrors located behind the microscopes objectives. The light then passes through objectives to the silver inlays which it strikes at right angle so that the brightness of the divisions to be measured is most homogeneous.

The images of two divisions in the focal plane of each microscope are scanned with the photoelectric screw micrometers, which are similiar to those of the telescope. These micrometers have a single rectangular slit ($4.0 \times 0.1$ mm$^2$) whose dimentions correspond to those of the images of the divisions in the focal planes of the microscopes.

One photomultiplier is used with all the micrometer microscopes. The modulated light from the micrometers passes to the photomultiplier through four light-conductors. Depending on which the number of the microscope is selected, the corresponding light-conductor is automatically positioned to the photocathode. The four microscopes are read consecutively, one reading requires about $10^s$ . The precision of one such reading corresponds to a standard error of about $0\overset{''}{.}08$. All circle reading operations are controlled by microprocessor, which also perform some preliminary reductions of the observations.

## CONCLUSIONS.

The first program to be observed starting in 1985 are about 40,000 "International Reference Stars" (IRS).

We now have some new capability to increase the accuracy. After the modifications, the precision of observations with the MK-200 will be significantly improved. We therefore propose, before the beginning of the observations, first to implement a photons counting mode for the star micrometer and to control this micrometer with a microprocessor, secondly, to replace the photoelectric micrometers of circle readings by linear charge coupled devices (CCD) and, finally, to replace the conventional bearings of the MK-200 by new aerostatic ones. In 1974-1975 we have investigated bearings of new type (hydrostatic) in conjunction with star observations and had encouraging results.

Aerostatic bearings are more convenient then conventional ones, and - as do hydrostatic bearing - make it unnecessary to consider the complex effects of the balancing mechanism. The likewise relax the requirements for pivot accuracy. We are expecting that the modernization of the bearings will improve the telescope accuracy immensely, because the observations from 1979-1982 have shown that accuracy generally depends heavily on the stability of the horizontal telescope axis.