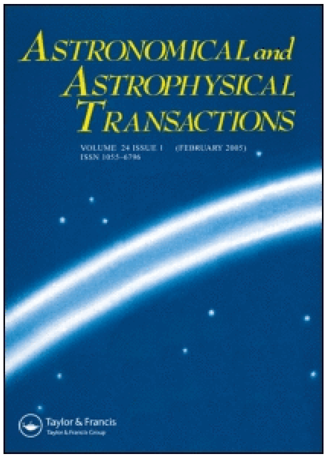

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

CCD micrometer of the Mykolayiv Axial Meridian Circle

A. N. Kovalchuk [a]; Yu. I. Protsyuk [a]; A. V. Shulga [a]
[a] Mykolayiv Astronomical Observatory, Mykolaiv, Ukraine

Online Publication Date: 01 July 1997
To cite this Article: Kovalchuk, A. N., Protsyuk, Yu. I. and Shulga, A. V. (1997) 'CCD micrometer of the Mykolayiv Axial Meridian Circle', Astronomical & Astrophysical Transactions, 13:1, 23 - 28
To link to this article: DOI: 10.1080/10556799708208111
URL: http://dx.doi.org/10.1080/10556799708208111

Astronomical and Astrophysical Transactions, 1997, Vol. 13, pp. 23–28
Reprints available directly from the publisher
Photocopying permitted by license only

CCD MICROMETER OF THE MYKOLAYIV AXIAL MERIDIAN CIRCLE

A. N. KOVALCHUK, Yu. I. PROTSYUK, and A. V. SHULGA

Mykolayiv Astronomical Observatory, Observatorna 1, 327030 Mykolaiv, Ukraine

(Received November 14, 1995)

The observations of faint stars are very effective with a CCD eyepiece micrometer. Such a micrometer was designed for the Axial Meridian Circle (AMC) of the Mykolayiv Astronomical Observatory. It includes the CCD matrix 256 × 288 with pixel size 32 × 24 μm. The matrix is mounted into a vacuum camera and cooled down to −40° C with thermoelectric Peltier elements. PC/AT-486 is used in the capacity of control computer. The trials investigation of the pilot CCD micrometer showed positional accuracy of 0.1 arcsec for objects up to 11 magnitude.

KEY WORDS Astrometry, meridian circle, CCD

1 INTRODUCTION

The Axial Meridian Circle (AMC) was put into operation in the Mykolayiv Astronomical Observatory (MAO) in 1995 and is intended for absolute and differential observations with an accuracy not worse than 0.02 arcsec. The AMC is an instrument of horizontal design which was described in the papers (Pinigin *et al.*, 1994, 1995). The CCD micrometer was designed and made in the years 1994–1995 by MAO. This one is intended for position measurements of stars, planets and artificial marks in the focal plane of the AMC.

2 PHOTOSENSITIVE DEVICE WITH COOLER

CCD-13M is used as an image sensor. This one was produced by the St. Petersburg plant ELECTRON in Russia. CCD-13M is a silicon matrix photosensitive device with volume n-channel and p-tape circuitry. CCD-13M has the following geometrical and photometrical parameters:

pixel count	288 x 256
pixel size, μm	24 x 32
integral sensitivity, mV/lx	170
threshold integral exposition, W s/pixel	10–16
quantum efficiency (6230 A), %	50

The cooler of the CCD has been performed on the base of a four-level scheme of Peltier elements. Thermoelements and the CCD are embedded inside a vacuum camera. The electric power used is 60W. The time delay before operational mode is 15 min. The cooler was produced by SATEL corporation (Ukraine) under the MAO order.

3 ELECTRONICS

The electronics of the micrometer can conditionally be divided into two parts.

3.1 Distant Block of Electronics

A distant block of electronics is situated near by the CCD and includes:

(1) a signal transformer,

(2) a shaper of continuous biases,

(3) a preliminary amplifier of the CCD signal.

The signal transformer (ST) is destined for transformation of the TTL sequence into multilevel signals to provide an exposition, a transfer and a read out of charge batches. The ST has the following parameters:

(1) a maximum pulse with repetition frequency, 1 MHz,

(2) an amplitude of control pulses, $-5 \div +15$ V.

The shaper of continuous biases produces continuous voltages to provide an operation of the CCD. The preliminary amplifier amplifies the CCD signal and transfers it through a connection line to CAMAC. The amplification rate of voltage is 25.

3.2 Control and Signal Processing Electronics

The control and signal processing electronics is situated inside a standard interface CAMAC at a distance of 15 metres from CCD. The control and signal processing electronics includes:

(1) a control module of the CCD micrometer,

(2) an analog module of signal processing,

(3) a A/D converter,

(4) a buffer memory.

The control module consists of an interface and functional parts. The interface provides an interaction between the control module and computer through a CAMAC bus. The functional part is destined for signal generation to provide CCD operation, namely: phase section pulses, phase pulses of output register and an exposition pulse. There are the adjustments of all modes by the software: for transfer frequency from 0.0001 Hz to 400 kHz with a discretization of 400 ns, for read out frequency up to 400 kHz. The output pulses of the control module correspond to standard TTL levels. The video signal from the preliminary amplifier is transferred to the analog module of signal processing for amplification to the necessary level and noise suppression with a scheme for double correlation sampling. An amplifier of the analog module is a programmable device and has 16 gradations of amplification rate. The A/D converter consists of an interface and a functional part. The interface is designed for connection between the ADC and the computer through a CAMAC bus. The functional part produces an analog-digital conversion of signal. 10-ary 1108 PV2 is used in the capacity of ADC with quantization noise of 3 mV. Digital signal is transferred to the buffer dynamic memory for temporary storage of output data. 10-ary storage for 128 Kb of 10-ary words is used in the capacity of the buffer memory. The electronics operates under the control of PC AT-486. The software is written on Pascal with assembler fragments.

4 MODES OF THE MICROMETER

The micrometer has the following operational modes.

4.1 Intransfer Exposition and Quick Read Out

In this mode, an exposition without charge transfer during a time fixed by software after that quick read out of output data to the buffer memory and furtheron to the computer memory through CAMAC bus are produced for the following data processing. This mode is used for near-pole observations and positional measurements of artificial marks. The range of exposition time is determined by software from 0.001 to 3 s for artificial marks.

4.2 Exposition with Transfer of Charge Batch

In this mode, an exposition and transfer of charge batch are produced simultaneously. The transfer velocity is equal to the image velocity of the observed object.

The exposition time is equal to the multiplication of the transfer velocity by the linear size of matrix. For the angular scale of the AMC, it totalled 51 s for the equatorial zone. It is possible to produce a strip of any length by the delay of a few seconds for writing output data to computer memory. The width of strip for the AMC is about eight arcminutes on the sky.

4.3 Short Exposition and Quick Transfer

In this mode, exposition is produced as in the previous mode 4.2 but the exposition time is limited to prevent signal saturation. Then the charge batch is quickly transferred on some number of lines and read out to the computer memory. This mode is used for observations of bright objects.

Therebye, one can produce observations of a wide-range of objects by using listed modes.

5 SOFTWARE

The choice of mode needed is performed by the executive program during the observing process. The executive program permits us to control the micrometer and change some parameters when necessary. The executive program also indicates current output information on the computer monitor in a real-time mode. Therefore, it is possible to obtain current information about the quality of observations.

5.1 Image Processing

The accuracy of the position of stars depends on the signal-to-noise ratio. The limited stellar magnitude is also limited by some amount of noise. Mathematical methods of image processing permit a great increase in the signal-to-noise ratio and, therefore, to improve the accuracy of position and limited magnitude. The output CCD signal contains stellar and noise parts. In its turn, the noise signal presents by itself a mixture from some sources. An application of hardware to suppress noise has not provided a desirable effect because of particularities of the output signal and hardware design. It is possible to increase the signal-to-noise ratio by using methods of digital filtering. We use some of the following methods for noise suppression.

(1) The flat-field correction is used for the suppression of low-frequency field distortions because of the inequality of the dark signal and the inhomogeneous temperature of a CCD chip.

(2) Non-recursive digital filters are used for the suppression of high-frequency noise. Transfer functions are made up by Fourier transform and polynomial processing.

(3) There is an effective method for the allocation of useful signals under background noise by the convolution of the initial signal with the two-dimensional Gaussian distribution with a properly selected parameter. The result of the convolution is an auto-correlation function which has splashes of intensity at the location of signals from stars. It is possible to allocate useful signal under a signal-to-noise ratio of about one.

(4) Direct and inverse fast Fourier transform are used for filtering of periodic distortions (Hemming, 1980). A combination of methods increases the signal-to-noise ratio by a factor of about 10 without changing the stellar signal. Data compression is the next important item. An Elaborate stellar search algorithm permits us to determine star positions with pixel accuracy, to describe some standard vicinity around a star and thereby, to reduce the necessary computer memory drastically.

5.2 Preliminary Results

The automatic version determines single stars surely under a signal-to-noise ratio of not less than 1.5. There is also a manual version which permits us to select necessary stars with a mouse. As a result of this, a collection of standard records (Kazanasmas, 1981) is used for further processing, i.e. to obtain stellar coordinates and create a database of observed objects. The minimal requirements for an image processing program are a computer on the base i80286 with random-access memory 2 Mb, SVGA 512 Kb. The required volume of hard disk depends on the quantity of CCD frames. One initial frame of $8' \times 40'$ took about 300 Kb of disk space. After initial processing this volume is reduced by a factor of 10 under a mean stellar density of 8–12 per frame. The time of full processing with filtering and stellar allocation is equal to 1.5–2 minutes per frame for an i486DX computer. The trial observations were performed under the mentioned mode 4.2. The evaluation of the positional accuracy is shown in Table 1.

The volume of sample for calculations of positional accuracy is equal to 50. Elements of orientation and parameters of the instrument are measured with an accuracy not worse than 0.02 arcsec.

Table 1.

Magnitude	*rms Dec, arcsec*	*rms RA, arcsec*
9.0	0.02	0.02
9.5	0.02	0.03
10.0	0.03	0.04
10.5	0.05	0.07
11.0	0.08	0.09
11.5	0.13	0.17
12.0	0.19	0.27
12.5	0.29	0.39

6 CONCLUSIONS

The CCD micrometer permits us to perform a wide range of observational tasks as regards positional accuracy, limited magnitude and modes of operation. The obtained positional accuracy permits us to investigate elements of orientation, parameters of the instrument and to observe stars up to 9.5 magnitude with the accuracy mentioned of not worse than 0.02 arcsec. The researches are continuing at present. We are expecting to achieve a temperature of a CCD chip about −90° C and to obtain an accuracy of 0.1 arcsec for stars up to 14 magnitude.

Acknowledgements

The research described was made possible in part by Grant No. 95–02–06013a of the Russian Science Foundation and by Grant No. USW 000 of the International Science Foundation.

References

Hemming, R. V. (1980) *Digital filters*, Moscow, Soviet Radio.

Kazanasmas, M. S. (1981) *Atlas and Catalog of Stellar Magnitude of Standard*, Kiev, Naukova Dumka.

Pinigin, G. I., Shulga, A. V., Fedorov, P. N., Petrov, A. G., and Mazhaev, A. E. (1994) *Kinematics and Physics of Celestial Bodies*, No. 10, 54.

Pinigin, G. I., Shulga, A. V., Protsyuk, Yu. I., Kovalchuk, A. N., and Mazhaev, A. E. (1995) *Astron. Astrophys. Trans.* 8, No. 2, 161.