

REPORTS OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

ISSN 2224-5227

Volume 5, Number 309 (2016), 14 – 19

Zh.Sh. Zhantayev¹, K.S. Kuratov^{1,2,3}, A.M. Seytimbetov², A.T. Mailybayev^{1,2},
N.Sh. Alimgazina^{1,2}, A.B. Manapbayeva², A.K. Kuratova^{1,2}, N.T. Iztleuov²

¹National Center of Space Researches and Technologies, Almaty, Kazakhstan;

²Al-Farabi Kazakh National University, Almaty, Kazakhstan;

³Fesenkov Astrophysical Institute, Almaty, Kazakhstan

e-mail: kenes_kuratov@mail.ru, Nazgul.Alimgazina@kaznu.kz

TWO-MATRIX PHOTOMETER CONTROL SYSTEM

Abstract: In this paper astronomical two-matrix photometer is described. It differs from common one CCD camera photometers with application of the second CCD camera. It enables to carry out the light inputs measurements of studied star and standard star simultaneously. The second camera application enables to significantly increase measurements accuracy and to decrease of one star observation time at least twice. The increase of measurements accuracy is reached by carrying out simultaneous observations, and errors caused by the Earth atmosphere fluctuation are the same for both studied star and standard star. Time decrease is reached by carrying out both stars' observation simultaneously.

In this paper photometer's optical mechanics scheme is given. The motion mechanism of receiving and recording block with micrometer screw rotated by stepping motor is described. It is demonstrated that exact coordinates of matrix position attached to clutch on micrometer screw are shoot by absolute magnetic encoder.

The applied electronic equipment of two-matrix photometer control system is described. The algorithm of photometer operation control installed on 1-meter Tien-Shan Astronomical Observatory telescope is presented.

Keywords: star, telescope, photometer, CCD-matrix, optical mechanics scheme, control system.

Introduction. During the astronomical photometry observations it is important to measure the studied stars and standard stars at the same time. But standard star is at far distance from the studied star, even by using CCD-camera with maximum dimensions (50x50 mm), it does not come in view of the radiation detector (matrix). All known photometers (e.g. [1]) use a matrix. Therefore we have to observe stars separately. Separate measurement, firstly, leads to deterioration the measurement accuracy due to all possible time fluctuations in the Earth's atmosphere, and secondly, increases the costs for photometry observation time for each of the studied object. These disadvantages can be eliminated only by simultaneous measurement of the studied stars and standard stars, and then the effects of atmospheric fluctuations will be the same on both stars.

In addition, astrophysics has urgent tasks that are impossible or difficult to solve with existing photometers. For example, during astrological and seismological observations of faint objects, searching for extrasolar planets and other problems, where changes (fluctuations) in stellar brightness are low and fluctuations in the Earth's atmosphere do not allow the measurement or heavily distort them. In order to detect such changes in stellar brightness, series of observations using a complex mathematical analysis (e.g. Fourier analysis) are carried out. However, many of these problems cannot be solved by using one-matrix photometers and simply cannot be solved. In the one-matrix photometers these fluctuations in brightness "sink" in the noise of atmospheric fluctuations.

Thus, the development of two-matrix photometer and its introduction into astronomical observation will enable to:

1. significantly increase the accuracy of photometric measurements by simultaneous observations of the studied stars and standard star;
2. halve the time of observation, and thus improve the effectiveness of observing time on telescope more than twice;
3. solve a number of tasks that impossible to produce using a photometer-matrix and expand the range of the studied objects.

1. The equipment structure and control algorithms

In order to create two-matrix astronomical photometer, it was necessary to develop, manufacture and debugging of its optical and mechanical assembly, electronics control and software.

Two 1-meter telescopes of Tien-Shan Astronomical Observatory (TSHAO) have Ritchey-Chrétien system, which allows creating a large undistorted field in the focus of the telescope, and provides additional benefits for the two-matrix photometer application.

One of the CCDs (main) is set on the main optical axis of the telescope. It helps to measure the studied star. Light input from the standard star with the help of the diagonal mirror is "displayed" on the side surface of the photometer with rotation of 90 degrees. The assembly of single optical unit consists of diagonal mirror, filters and CCD-matrix is assembled is movable in the focal plane of the telescope in one of the coordinates. Moving on the second coordinate is carried out by rotating the photometer on telescope wheel. This is because the standard stars may be located at different distances and angles from the studied star. By moving the second CCD-matrix in two directions, we can almost always bring coordinates on standard star.

Optical scheme of the main channel of the photometer (for observations of studied star) with CCD-camera Apogee U10 is given in Figure 1.

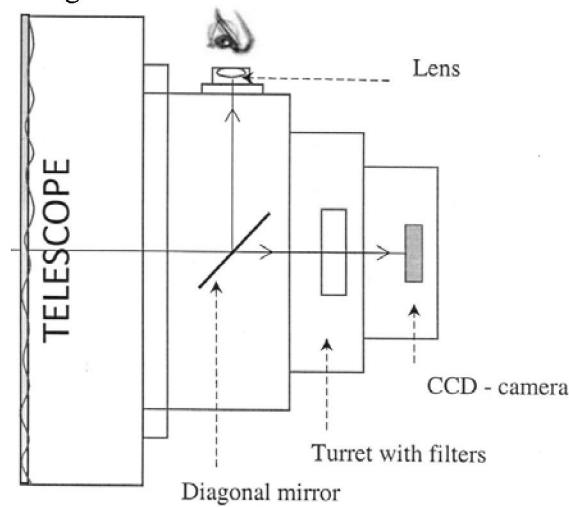


Figure 1 – Optical scheme of main channel of photometer

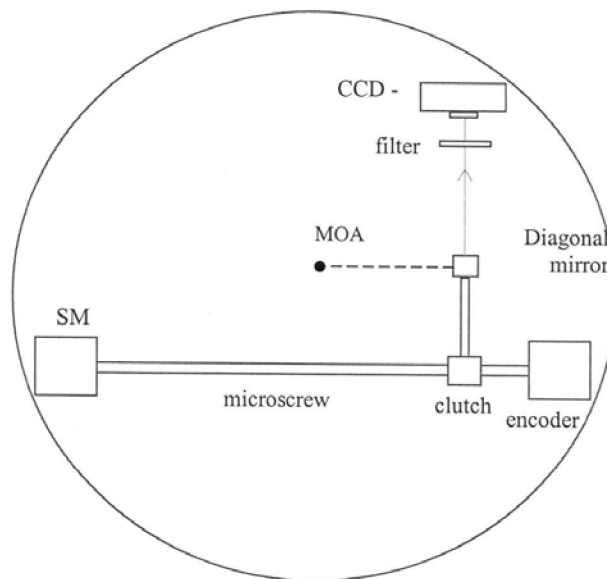


Figure 2 – Optical and mechanical scheme of the second channel of photometer

In the second channel we can use a simple matrix without refrigeration. As brightness of standard

star is always higher, it is possible to use less sensitive, small and lightweight CCD receivers. Small size and weight are significant, because the optical unit with matrix has to move within photometer. The principle of operation of transfer mechanism of the second channel matrix is as follows: with the help of the microscrews which have a worm gear and rotate by the stepping motor (SM), we move the optical unit with diagonal mirror, filters and CCD-matrix in one direction till 14 cm with the possibility of intersection with the main optical axis (MOA) of the telescope. During crossing of telescope MOA, it is possible to test both matrixes and identify instrumental corrections. The exact coordinates of the position of the optical unit are determined by absolute magnetic encoder, which is connected to the microscrew.

2. Electronic equipment of control system of two-matrix photometer

Figure 3 shows structural scheme of control system of two-matrix photometer.

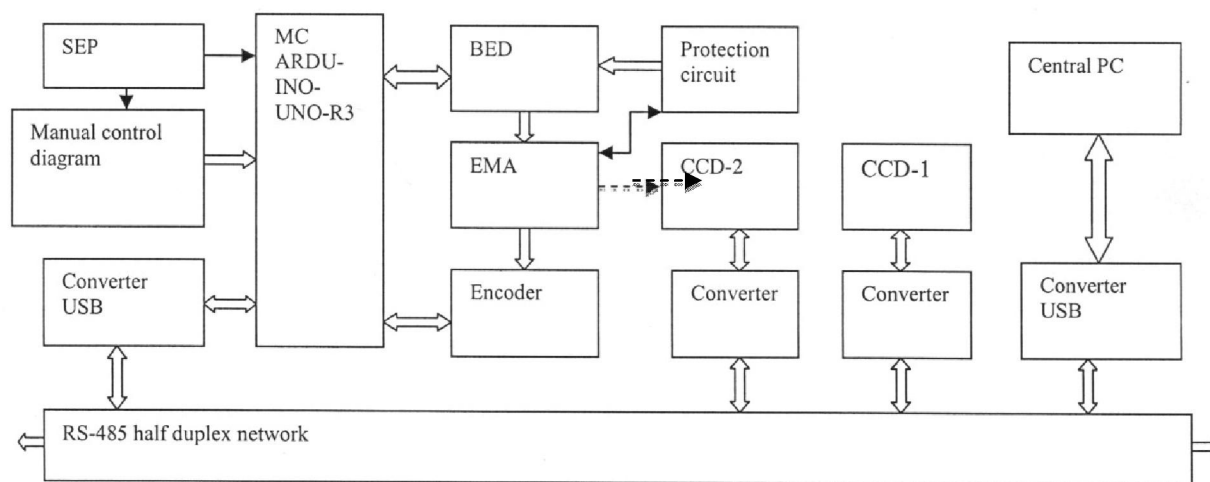


Figure 3 – Structure of control system of two-matrix photometer

The structure of the hardware of two-matrix photometer includes the following components:

1. The central control element is the type of microcontroller platform ARDUINO UNO [2], which is called microcontroller (MC). Module Arduino Uno is a device based on ATmega328 microcontroller. The microcontroller ATmega16U2 provides signals of transceiver with computer USB-port, and when connected to a PC allows Arduino to define as a virtual COM-port. Upgrade of 16U2 chip uses standard USB-COM driver that is why installation of external drivers are not required. On the Windows platform only the appropriate .inf-file is necessary.

2. Electromechanical assembly (EMA) consists of 25cm long microscrew, which moves the optical unit, which comprises the diagonal mirror, turrets with filters and two CCD-matrixes. Moving is carried out by stepper motor (SM), which rotates microscrew and moves the optical unit with the second matrix with accuracy of 0.05 μm . SM management [3] is carried out by the driver A3967 EasyDriver V4.4. Driver management is carried out by a controller Arduino, with the help of special programmes.

3. As all electronic assemblies of the telescope are connected by distributed network and are located at a considerable distance, all the assemblies are connected by converters RS-485 [4]. We chose RS-485, as it may lead to 32 receivers with data speed specification till 10 Mbaud/sec over a distance of 1200 m.

4. In control system of two-matrix photometer we applied angle sensor of microscrews (encoder) for the correct positioning of the system and control the movement of the optical unit with the second matrix. As the angle sensor we used absolute magnetic encoder Baumer Electric CH-8501, which unique feature is data storage of angle sensor in the fall or failure of voltage, or when the computer restarts. If the shaft encoder has been turned at a certain angle, then when a voltage occurs, the encoder immediately will issue new, the actual angular position of the shaft and the actual turnover number. Due to this process, we will not have to produce the movement of mechanical parts of the machine to the start position, which is a huge advantage of absolute encoders.

5. The protection circuit includes a mechanism of limit switches at both boundaries of optical unit

moving on microscrews which prevents mechanical breakdown and produces a signal MC on achieving moving boundaries.

6. Manual control diagram allows conducting the button reset to the initial position, sets the command to move and select of motion direction in the test mode.

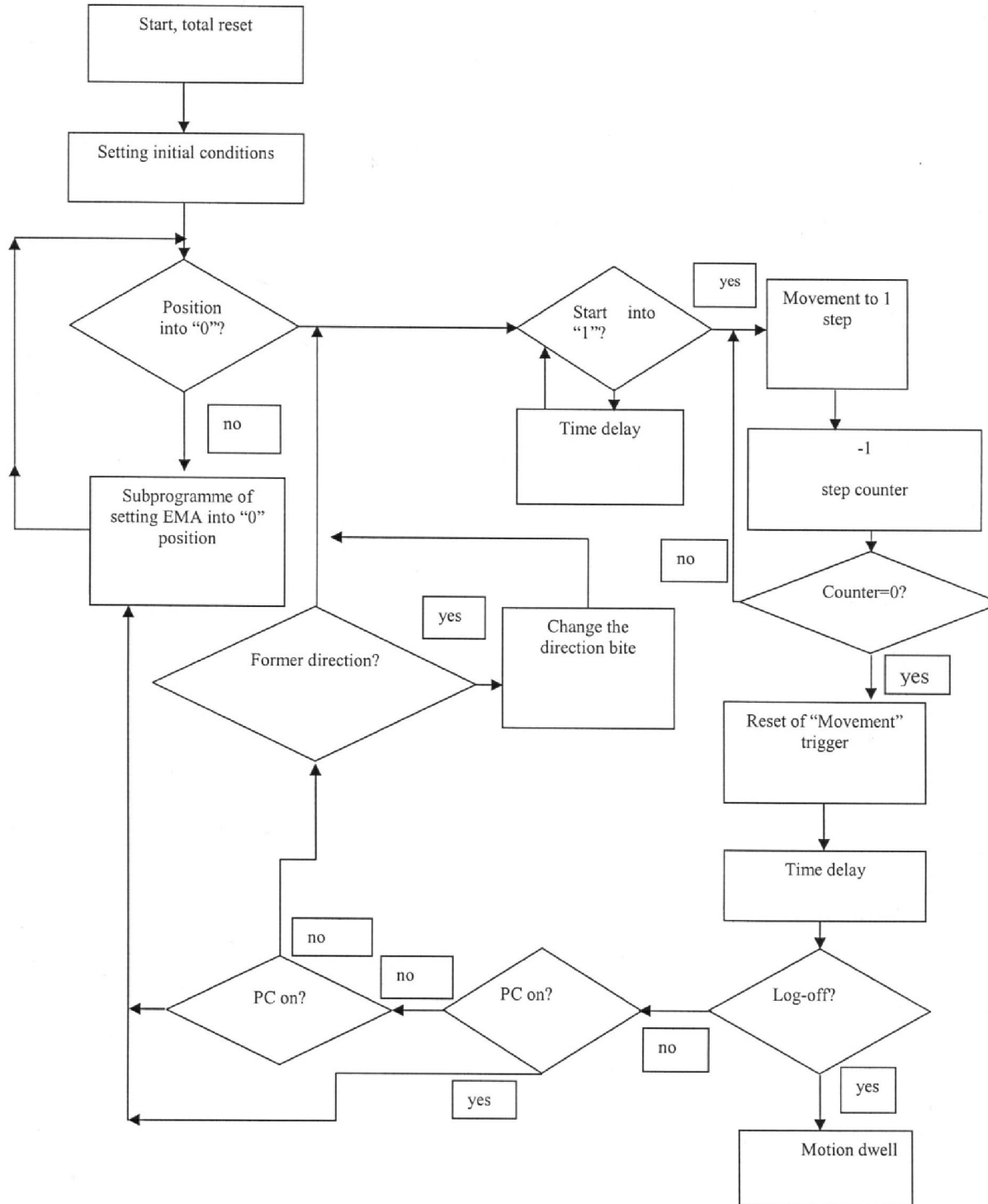


Figure 4 – The control algorithm of the movement of the diagonal from MC

3. The control algorithm of the movement of the diagonal mirror from MC

The development of software is based on the Arduino development environment [5], and contains the following main elements, such as a text editor for code writing, an area for displaying messages, text console, instrument panel with traditional buttons and the main menu. This software allows the computer to communicate with the Arduino for data transmission and for code firmware in the controller.

Figure 4 shows a flowchart of the control algorithm of movement of the diagonal mirror from MC. The value of encoder code and limit switches is used for feedback, the movement of the optical unit of the second matrix is carried out in discrete steps, which are interspersed with long periods of removal of the photometric information about stellar objects. Motion control depends on the trigger values "Movement" and "Direction", and the discrete step is split into discrete microsteps, which number is defined by software down counter and determined by the necessary accuracy of movement.

Conclusion

Designed two-matrix photometer is an astronomical measuring instrument used for photometric observations. A distinctive feature of the device is that it can conduct simultaneous measurements of the light input of the studied star and standard star, with an increase in the measurement accuracy and decrease in time expenditure.

The use of two-matrix photometer is beneficial for astronomy, to study natural and artificial celestial objects.

REFERENCES

- [1] Liutyi V. M., Abdullaev B. I., Alekperov I. A., Giul'maliev N. I., Mikailov Kh. M., Rustamov B. N. *I. Reconciliation CCD photometer with Zeiss optics 600*, Azerbaijani astronomical journal, **2009**. Vol. 3-4, pp. 36-41. (in Russ.).
- [2] Petin V.A. *Projects using Arduino controller*, SPb: BKhV-Peterburg, **2015**, 464 p. (in Russ.).
- [3] Kenio T. *Stepper motors and microprocessor control systems*, Per.s angl. M.: Energoatomizdat, **1987**, 200 p. (in Russ.).
- [4] *RS-485 interface and description of connection*, www.radiomedtech.ucoz.ru/RS-485.pdf. (in Russ.).
- [5] Sommer U. *Programming microcontroller board Arduino/Freduino*, SPb. BKhV-Peterburg, **2015**, 256 p. (in Russ.).

ЛИТЕРАТУРА

- [1] Лютый В. М., Абдуллаев Б. И., Алекперов И. А., Гюльмалиев Н. И., Микайлов Х. М., Рустамов Б. Н. И. *Согласования ПЗС-фотометра с оптикой Цейсс-600 // Azerbaijani astronomical journal*. – 2009. – № 3-4. – С. 36-41.
- [2] Петин В.А. *Проекты с использованием контроллера Arduino*. – СПб: БХВ-Петербург, 2015. – 464 с.
- [3] Кенио Т. *Шаговые двигатели и их микропроцессорные системы управления*. Пер.с англ. М.: Энергоатомиздат, 1987. – 200 с.
- [4] *Интерфейс RS-485: описание, подключение*. – www.radiomedtech.ucoz.ru/RS-485.pdf
- [5] *Соммер У. Программирование микроконтроллерных плат Arduino/Freduino*. – СПб. БХВ-Петербург, 2015. – 256 с.

**Ж.Ш. Жантаев¹, К.С. Куратов^{1,2,3}, А.М. Сейтимбетов², А.Т. Майлыбаев^{1,2},
Н.Ш. Алимгазинова^{1,2}, А.Б. Манапбаева², А.К. Куратова^{1,2}, Н.Т. Изтлеуов²**

¹ Ұлттық ғарыштық зерттеулер мен технологиялар орталығы, Алматы, Қазақстан

² әл-Фараби атындағы Қазақ Ұлттық Университеті, Алматы, Қазақстан

³ В.Г. Фесенков атындағы астрофизика институты, Алматы, Қазақстан

ЕКІ МАТРИЦАЛЫ ФОТОМЕТРДІҢ БАСҚАРУ ЖҮЙЕСІ

Аннотация. Бұл мақалада астрономиялық екі матрицалы фотометр бейнеленген. Бір CCD камералы қарапайым фотометрден айырмашылығы, мұнда екінші CCD камера қолданылады. Осы кезде бір уақытта зерттелетін жұлдыздың және стандартты жұлдыздың жарық ағындарына өлшеулер жүргізеді. Екінші камераны қолдану айтарлықтай дәрежеде өлшеу дәлдігін жоғарылатуға мүмкіндік береді және бір жұлдызды бақылау кезінде екі есе уақыт шығынын азайтады. Бірінші жағдай бақылаулар бір уақытта жүргізілгендіктен, зерттелініп отырған жұлдызбен стандартты жұлдыз үшін Жер атмосферасындағы флукуация әсерінен болатын қателіктер бірдей болады. Екі жұлдызды бір уақытта бақылау кезінде ғана уақыт шығындарын азайту мүмкіндігіне жетуге болады.

Мақалада фотометрдің оптика-механикалық схемасы келтірілген. Қабылдау-тіркеуші блоктың орын ауыстыру механизмі келтірілген. Оның негізі ретінде қадамдық қозғалтқыштан айналатын микрометрлік

винт алынады. Микрометрлік винттегі муфтаға бекітілген матрица орналасуының нақты координаталары абсолютті магниттік энкодермен түсіріледі.

Екі матрицалы фотометрдің басқару жүйесінің қолданылатын электронды аппаратурасы бейнеленген. Тянь-Шань астрономиялық обсерваториясындағы 1-метрлік телескопқа орнатылған фотометрдің басқару жұмысының алгоритмі келтірілген.

Түйін сөздер: жұлдыз, телескоп, фотометр, CCD-матрица, оптика-механикалық схема, басқару жүйесі.

УДК 520.3

**Ж.Ш. Жантаев¹, К.С. Куратов^{1,2,3}, А.М. Сейтимбетов², А.Т.Майльбаев^{1,2},
Н.Ш. Алимгазина^{1,2}, А.Б. Манапбаева², А.К. Куратова^{1,2}, Н.Т.Изтлеуов²**

¹Национальный центр космических исследований и технологий, Алматы, Казахстан;

²Казахский национальный университет имени аль-Фараби, Алматы, Казахстан;

³Астрофизический институт имени В.Г. Фесенкова, Алматы, Казахстан

СИСТЕМА УПРАВЛЕНИЯ ДВУХМАТРИЧНЫМ ФОТОМЕТРОМ

Аннотация: В данной статье описывается астрономический двухматричный фотометр. От обычных фотометров с одной CCD камерой отличается тем, что применяется вторая CCD камера. Это позволяет одновременно проводить измерения световых потоков от исследуемой звезды и звезды-стандарта. Применение второй камеры позволяет существенно увеличить точность измерений и как минимум в два раза уменьшить затраты времени на наблюдение одной звезды. Первое достигается за счет того, что наблюдения проводятся одновременно и ошибки, обусловленные флуктуацией в Земной атмосфере одинаковы для исследуемой звезды и звезды-стандарта. Уменьшение затраты времени достигается за счет проведения одновременных наблюдений обеих звезд.

В статье приводится опико-механическая схема фотометра. Описан механизм перемещения приемно-регистрирующего блока, за основу которого взят микрометрический винт, вращающийся от шагового двигателя. Показано, что точные координаты положения матрицы, прикрепленной к муфте на микрометрическом винте снимаются абсолютным магнитным энкодером.

Описана используемая электронная аппаратура системы управления двухматричным фотометром. Представлен алгоритм управления работой фотометра, установленного на 1-метровом телескопе Тянь-Шаньской астрономической обсерватории.

Ключевые слова: звезда, телескоп, фотометр, CCD-матрица, опико-механическая схема, система управления