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Four-channel imaging Stokes polarimeter for small telescopes

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Abstract. The design of the imaging polarimeter based on the sectoral polarizer to measure the linear polarization of the extended and point celestial objects is presented. The spectral range of the instrument is 420-850 nm. It is limited by combination of the CCD quantum efficiency and polarizer transmittance. The field of view is $0.25° \times 0.25°$. The device is designed to work with up to 1m telescope and a relative aperture of f/10.

Key words: polarization – imaging Stokes polarimeter

1. Introduction

Previously, the authors proposed a concept of an astronomical spectropolarimeter, according to which the instrument was developed in the Main Astronomical Observatory NAS of Ukraine (Vidmachenko, 2006; Ivanov, 2006). To analyze the polarization we used a rotating superachromatic phase plate (Samolov, 2004).

However, in some cases, the observations must be determined simultaneously for all Stokes vectors and within a large field of view. This article describes the development of the Stokes polarimeter, which allows us to determine the three Stokes parameters simultaneously (i.e. I, Q and U, because it is a linear polarimeter).

2. Optical Layout

The optical system of the instrument consists of: the collimator, the sectoral polarizer, the system of compose wedges for beams breeding, replacement filters or a diffraction grating, and the camera lens. Fig. 1 shows a section of the instrument optical layout on two channels (upper and lower). The collimator performs several functions: partial correction of field aberrations of the telescope, builds the pupil of telescope and collimation of the light.

In the pupil plane the polarizer is placed. It allows us to perform simultaneously four measurements of intensity of radiation transmitted through it for the analysis of linear polarization. Thus there are formed four optical channels. A scheme of the polarizer is shown in Fig. 2.

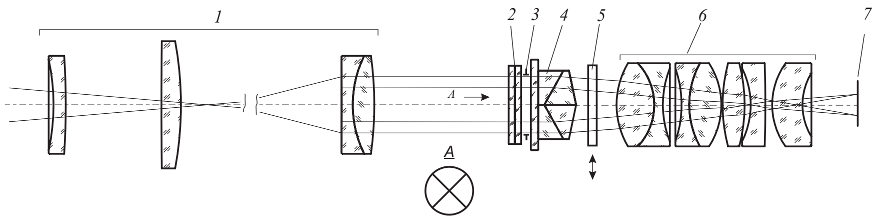

Figure 1. The optical layout of the Stokes-polarimeter: 1- the collimator, 2- the segment polarizer, 3- the pupil of a telescope, 4- the system of compose wedges for beams breeding, 5- replacement filters or a diffraction grating, 6- the camera lens, 7- the image plane, A- a view of the telescope pupil with a polarizer set.

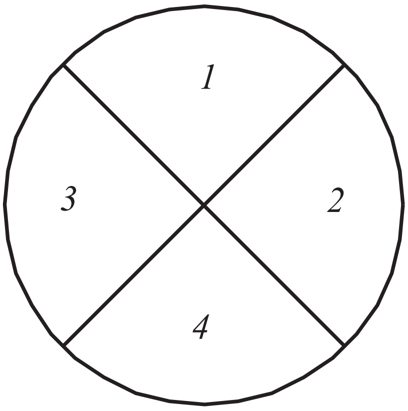

Figure 2. A sectoral polarizer of the Stokes polarimeter. Orientation of the polarization element: 1- 0 °,2- 90 °, 3- 45 °,4- 135 °.

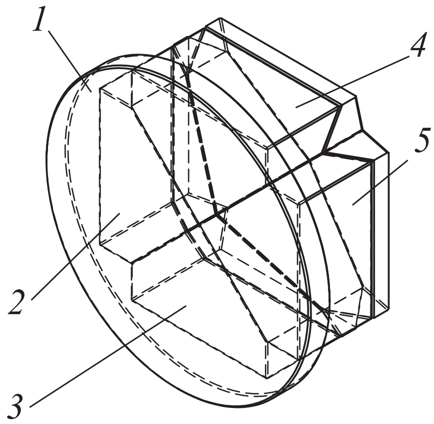

Figure 3. The system of breeding images : 1- a glass substrate, 2-5- an achromatic pair of wedges for each channel.

There are several options for constructing such polarizer. One of them is a pair of two-beam polarizing prisms whose optical axes are deployed at angle 45 °. Prisms fill sectors 1-2 and 3-4 respectively. In polarimeters also wedged double Wollaston prisms are used (Oliva, 1997). However, particular dispersion of the prism requires to add additional compensation wedges and still can not provide a high-quality image in a large field of view and wide spectral range. It should be noted that dispersion of prisms is different for the two orthogonal directions of beams propagation which leads to nonidentical images.

Another option is polarizing films. Compared with the prisms, the film has decreasing transmittance about 45-85 % in the range 420-800 nm (polarizer BVO 900, Bolder Vision Optik company). But in this analyzer with a wide field of view the vignetting of inclined field rays is practically absent due to a smaller thickness compared with prisms.

For the spatial separation of channels (to form four images on CCD) are used four pairs of achromatic prisms located just behind the analyzer. It is shown in Fig. 3.

For spectral selection the replaceable filters g', r', i' and z'(with the use of the IR polarizer), as well as transparent diffracting grating are used. The camera lens consists of seven components and builds four images of a sky in the different polarization on the detector SBIG STL 1301E with the size of the sensitive area equal to 20.4x16,5 mm.

3. Main Parameters

Structurally, the Stokes polarimeter consists of units: the collimator, the unit of removable diaphragm and slits are placed in composite tube having sufficient rigidity, the unit of replaceable filters, and the unit of the camera lens. For carrying out observations with a maximum field of view is necessary to set the aperture in the focal plane of the telescope in order to avoid the superposition of images of adjacent channels. And for spectropolarimetric observations of extended objects a narrow slit is used.

4. Conclusion

We are developing the imaging Stokes polarimeter based on the composite film polarizer. It allows us simultaneous acquisition of the three Stokes parameter I, Q, U without any moving parts. Presently the polarimeter is in the assembly and testing phase, and will be installed soon at the Celestron 91037-XTL telescope.

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