UDC 681.785.3 (043.2)

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PHOTOPOLARIMETRIC METHOD OF POLARIZATION RADIATION PARAMETERS DETERMINATION

This work is devoted to the development and description of optical radiation Stokes vector components determination method. The method relies on the measurement of ellipticity angle and ellipse azimuth of optical radiation polarization by the photopolarimetric method

Usage of polarization methods for research of different sort of solutions, matters, objects surfaces gives the wide picture of their properties and structure. These methods found application in medicine [1, 2], research of materials surface [3], and also aerospace remote sensing [4 – 6]. There are studies about polarimetric researches of comets [4], asteroids [5], planets moons [5, 6]. During polarimetric researches conclusions about analyzable object properties are done on the basis of the polarization state of its radiation or radiation which interacted with it.

There are a lot of different stokes-polarimeters, which measure all four Stokes vector components I, M, C, S [7 – 10]. Some authors think that there are two basic types of diagrams [7, 10]: including polarization transformers with mechanically controlled parameters (polarizers, phase plates and others) and electrically controlled parameters (magnetooptical, electrooptical, acoustooptical cells and others). Work of such stokes-polarimeters is based in forming of equations set which is relative to four Stokes vector components. Radiation intensity, passing through a stokes-polarimeter, at the different azimuths of its component elements is measured for this purpose.

Some authors [8, 9] also sort out the third type of stokes-polarimeters, in which for measuring of Stokes parameters the phase plate rotating with certain frequency is used. During registration of radiation intensity, passed through the rotating phase plate and analyzer motionlessly set before a photodetector, a photoelectric signal is modulated with frequencies, which are multiple of phase plate rotation frequency. This signal carries in itself information about radiation polarization descriptions.

The disadvantages of the first two types of stokes-polarimeters are a necessity of four measurement execution, while changing the azimuths of polarimeter component elements, the optimum values of which calculated for errors minimization. It increases the time of research execution and limits application potentiality of these types of stokes-polarimeters. The disadvantages of multichannel stokes-polarimeters are a presence of large number of component elements, each of which is needed to be orientated with maximal exactness on a certain azimuth, previously calculated for errors minimization.

In the third type of stokes-polarimeters one of the basic errors source is inaccuracy in setting of its component elements on the previously calculated optimum azimuths. In addition, regardless the reducing of measurement duration by these stokes-polarimeters, the received results require considerable time on processing for the calculation of Stokes vector components. Also there are rotating phase plate in the stokes-polarimeter that can decrease reliability of these diagrams during the execution of the prolonged experiments.

But above all, in all types of stokes-polarimeters for Stokes vector components finding intensity is measured, determination exactness of which does not usually exceed 1%.

The photopolarimetric method of Stokes vector components measuring which will allow to raise considerably determination exactness of their relative values is offered in this work.

For polarization radiation parameters determination a photopolarimetric method is offered, basis of which is determination of Stokes vector components relative values through measuring of ellipticity angle ω and ellipse azimuth of optical radiation polarization λ. The offered method of Stokes vector components measuring can be realized, for example, with using of two modulators (see fig. 1) on which by turns control signals are given. As a modulator it is suggested to use the magnetooptical Faraday cell with an yttrium ferrite-garnet crystal. These crystals at the magnetic fields to 80 A/m allow to get the modulation amplitude of polarization plane up to 100^o, that enables to work with the low quality optical channels [11].

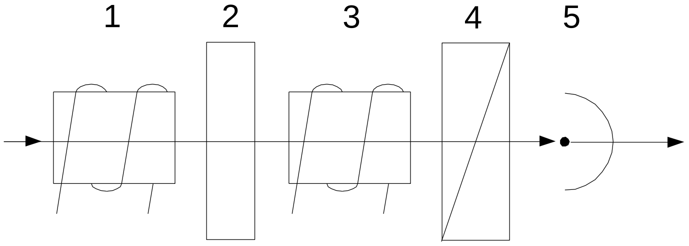

Fig. 1. Block diagram of stokes-polarimeter:
1 – Modulator; 2 – quarter-wave phase plate; 3 – modulator; 4 – analyzer; 5 – photodetector

For λ and ω parameters determination it is necessary to make two measuring. In first case, we orient the most speed plane azimuth of phase plate α in relation to the most transmission plane azimuth of analyzer β on the 90^o angle. Control signals will give only on a modulator *1*, a modulator *3* is not connected (see fig. 1). The intensity on analyzer output will be:

$$I_{OUT} = \frac{I}{2}\left[1 - \frac{I'}{I} p' \cos 2\omega \cos 2(\alpha - \lambda + \theta + \theta_{=})\right],$$

where $I = I' + I''$ is the total intensity of incident ray; I', I'' are fully polarized and fully depolarized intensity components of the incident ray respectively; p' is the degree of polarization of modulator; $\theta_{=}$ is the additional polarization plane rotation angle of light, associated to the geometrical defects, retentivity of ferrit; θ is the oscillation angular amplitude of polarization plane vibrations, changing according to the periodic law: $\theta = \theta_0 \Phi(t)$, where $\Phi(t)$ is the arbitrary periodic function, which is vary with time with Ω frequency.

Afterwards adjusting the photopolarimeter on a minimum of the signal on an output, measuring the phase plate azimuth, it is possible to define the λ parameter without knowing the value of ellipticity angle ω:

$$\lambda = \alpha_{\min} + \Delta + \theta_{=},$$

where $\alpha_{\min}$ is the most speed plane azimuth of phase plate, at which the output intensity is minimal; Δ is the measurement error.

The intensity on analyzer output will be:

$$I_{OUT\,\min} = \frac{I}{2}\left[1 - P\cos 2\theta + 2\Delta P \sin 2\theta\right],$$

where $P = pp'p_E = \frac{I'}{I} p' \cos 2\omega$; *p* is the degree of light polarization in an environment.

For ellipticity angle ω determination we set the most speed plane azimuth of phase plate in the line of major (or minor) axis of polarization ellipse of light. The previous condition is not preserved and control signals are given only on a modulator *3* (see fig. 1). In this case, an expression of the output light intensity will be transformed to the following:

$$I_{OUT} = \frac{I}{2}\left[1 + \frac{I'}{I} p' \cos 2(\omega - \beta + \lambda + \theta + \theta_{=})\right].$$

As well as during determination of the λ parameter, will measure ω, adjusting the photopolarimeter on a minimum of the signal on an output according to the condition:

$$\omega - \beta_{\min} + \lambda + \theta_{=} = \frac{\pi}{2},$$

where $\beta_{\min}$ is the most transmission plane azimuth of the analyzer, at which output intensity is minimal.

The intensity on analyzer output will be following:

$$I_{ВЫХ \min} = \frac{I}{2}\left[1 - pp'\cos 2\theta + 2\Delta pp'\sin 2\theta\right].$$

Thereby:

$$\omega = \frac{\pi}{2} + \beta_{\min} - \lambda + \Delta + \theta_{=}.$$

To find all Stokes vector components absolute values it is necessary to define the degree of polarization of the investigated stream p and its intensity I. For this purpose will set a phase plate on a zero azimuth (α=0), and its phase shift on δ=0 (or it is possible to remove the phase plate from the diagram). The intensity on analyzer output will be following in this case:

$$I_{OUT} = \frac{I}{2}\left[1 + \frac{I'}{I}\cos 2\omega \cos 2(\beta - \lambda)\right] = \frac{I}{2}\left[1 + p\cos 2\omega \cos 2(\beta - \lambda)\right].$$

Adjusting the photopolarimeter on a maximum and a minimum of light transmission, will find maximal $I_{OUT\max}$ and minimal $I_{OUT\min}$ intensity on the analyzer output respectively. Expressions for finding of Stokes vector components absolute values are following:

$$I = I_{OUT\max} + I_{OUT\min};$$

$$M = p\cos 2\omega \cos 2\lambda = \frac{I_{OUT\max} - I_{OUT\min}}{I}\cos 2\left(\alpha_{\min} + \Delta + \theta_{=}\right);$$

$$C = p\cos 2\omega \sin 2\lambda = \frac{I_{OUT\max} - I_{OUT\min}}{I}\sin 2\left(\alpha_{\min} + \Delta + \theta_{=}\right);$$

$$S = p\sin 2\omega = \frac{I_{OUT\max} - I_{OUT\min}}{I\cos 2\left(\frac{\pi}{2} + \beta_{\min} - \lambda + \Delta\right)}\sin 2\left(\frac{\pi}{2} + \beta_{\min} - \lambda + \Delta + \theta_{=}\right).$$

Conclusions

1. The offered method allows with photopolarimetric exactness, which is up to angular seconds, to determine the relative values of Stokes vector components *M*, *C* and *S* of incident radiation.
2. To find absolute values of all Stokes vector components it is necessary to define fully polarized I' and fully depolarized I'' intensity components of incident ray, that limits measurement exactness to 1%.
3. Usage of the modulator on an yttrium ferrite-garnet will allow to increase exactness of measuring of the ellipticity angle and the ellipse azimuth of polarization, and, consequently, of Stokes vector components *M*, *C* and *S* of incident radiation relative values due to the additional modulation of optical radiation polarization plane.
4. If polarization of incident light ray is circular or near to such, using the offered method is impossible, that is its limitation.

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