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On automatic measurement of birefringent medium properties

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In this paper, a new and easy-to-automatize method of complex measurement of some properties of birefringent media is presented. These properties are: optical path, azimuth, and also ellipticity and transmission coefficients of the eigenwaves.

1. Introduction

A complex measurement of the properties of the birefringent media, *i.e.*, such as optical path difference, birefringence, azimuth, ellipticity, handedness and dichroism of the eigenwaves consists in measureing the changes in intensity and polarization state of the light transmitted through the examined medium. This method has been described by Ratajczyk and Urbańczyk [1] and next improved by Woźniak and Kurzynowski [2]. The improved method requires the examined medium to be illuminated in succession by three different linearly polarized light beams of different azimuth α_i of the polarization states amounting to 0, 90 and 45°, and having intensities I_1, I_2 and I_3, respectively (Fig. 1). Next, the light intensity

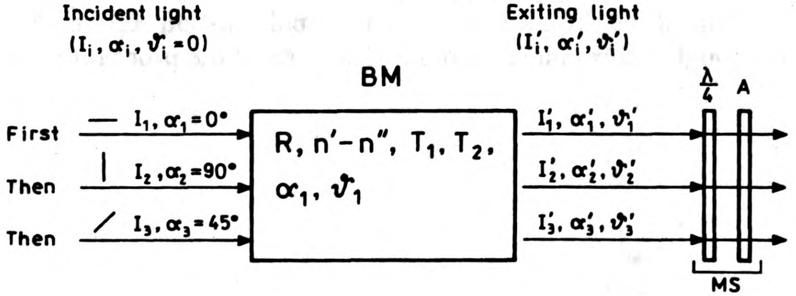

Fig. 1. Nonautomatized setup for measuring the birefringent properties of the media. I_i, I'_i – light intensities, α_i, α'_i – azimuths, ϑ_i, ϑ'_i – ellipticity angles, EM – examined birefringent medium, R – optical path difference, n', n'' – refractive indices of the eigenwaves, α_1 ϑ_1 – azimuth and ellipticity of the fast eigenwave, T_1, T_2 – amplitude transmission of the eigenwaves, $\lambda/4$ – quarterwave retarder, A – analyser, MS – measuring system for determining the polarization state

I'_i, azimuth α'_i and ellipticity ϑ'_i of the light of each of three beams must be measured after their passage through the examined medium. Consequently, the following 9 measurement results are obtained: I'_i/I_i, α'_i, ϑ'_i, where $i = 1, 2, 3$. Based on the above, the due algorithm [2] allows us to calculate the required parameters of the medium. The traditional measurement of the polarization state of the light emerging from the examined medium, using the up-to-date methods cannot be easily automatized. Such a possibility first arose after publication by Ratajczyk, Woźniak and Kurzynowski of the method of polarization state measurement based on general Malus law [3]. The particular feature of this method is that the measuring operations aiming to determine the light polarization state are reduced to the measurement of the quotient of the intensities I_{ij} of the light beams emerging from the measuring system MS and the intensities I'_i of the corresponding beams entering the measuring system without necessity of looking for extremum of the intensity, while rotating any element of the measuring system.

2. Description of the automatic method of measurement of the birefringent media

Similarly to the classical case, in the automatic method of the measurement of the birefringent medium properties, the examined medium is tested subsequently by three different linearly polarized light beams of azimuths 0, 90 and 45° (non-primed magnitudes of index i), Fig. 2. From the medium three elliptically polarized light beams (primed magnitudes of index i) go out. In order to examine their polarization states, each of them should be transmitted through the three analysers A_j, *i.e.*: linear one of azimuth 0°, linear one of azimuth 45° and a circular one of dextrorotation, and measuring each time the light intensity I_{ij} behind them. These intensities as well as the intensities of both testing beams I_i and those emerging from the examined object I'_i are recorded by the recorder and transmitted to a transducer R of the data. They suffice to calculate the properties of the examined medium.

An outline of the data processing procedure consists of two stages.

Stage 1. The calculation of the Stokes vector V'_i of the polarization state of the light after its passage through the examined medium. The basis of the procedure are the equations [3]:

$$M'_i p'_i = A_{i1},$$
$$C'_i p'_i = A_{i2},$$
$$S'_i p'_i = A_{i3}$$

where:

$$A_{ij} = \frac{(I_{ij}/I'_i) - T^+_{aj}}{T^-_{aj}},$$

p'_i – polarization degree of the light emerging from the examined medium,

$T^+_{aj} = (T^2_{agj} + T^2_{asj})/2$,

$T^-_{aj} = (T^2_{agj} - T^2_{asj})/2$,

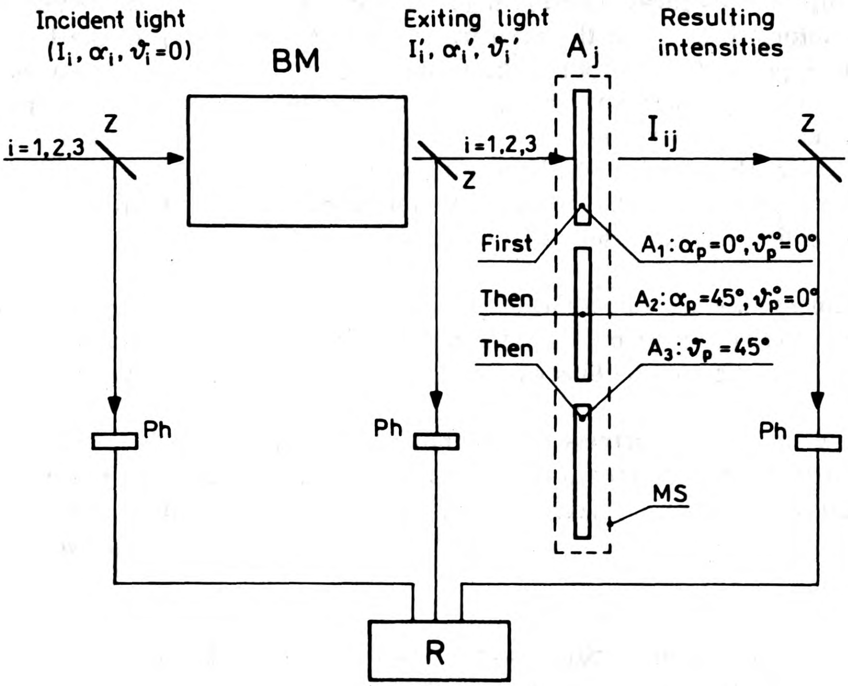

Fig. 2. Automatic system measuring the birefringent properties of the medium. I_i, I_i', I_{ij} – light intensities, α_i, α_i' – azimuths, ϑ_i, ϑ_i' – ellipticity angles, EM – examined birefringent medium, A_j – analysers, MS – measuring system for polarization state determination, Ph – photodetectors, Z – mirrors, R – recording and data processing unit

T_{agj}, T_{asj} – great (g) and small (s) amplitude transmission coefficients T_a of the analyser A_j,
$M_i' = \cos(2\vartheta_i')\cos(2\alpha_i')$,
$C_i' = \cos(2\vartheta_i')\sin(2\alpha_i')$,
$S_i' = \sin(2\vartheta_i')$.
The polarization degree is calculated from the formula

$$p_i = \sqrt{\sum_j A_{ij}^2}\ .$$

When knowing p_i, the quantities M_i', C_i' and S_i' and next α_i' and ϑ_i' can be calculated.

Stage 2. The light intensities I_i' and I_{ij}' are known from the direct measurements. The obtained set of measurements jointly with the input nonprimed data allows us to calculate the required parameters of the medium with the help of the procedure described in [2].

As we see, the determination of the birefringent medium properties may be carried out completely by measuring the light intensity, while such measurements may be easily automatized. Since the measurement and the recording of the light intensities at the input and the output of the examined object as well as those at the output of the measuring system may be carried out simultaneously, high measurement accuracy may be expected under the condition of a good consistence of the three photorecorders (Ph) used in the measuring system. They are not required to give good indications in terms of the absolute values but they must provide the quotients of the indications consistent with the quotients of the real intensities of the light beams.

This requirement may be easily fulfilled by directing sequentially (in short periods of time) the three measuring beams to one photorecorder only under the condition that the latter is characterized by linear relation between the photovoltage and the light intensity.

In order to check the correctness of the above idea, a model of the discussed device for automatized measurement of the anisotropic medium properties has been built in the Institute of Physics, Technical University of Wrocław (unfortunately without automatic recording and data processing) and the results obtained proved to be correct.

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