Compensation Detector of Birefringence

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ABSTRACT

The paper describes the device for measuring the normal-reflection birefringence with using of the compensation method. The suggested scheme may be used for research of optical anisotropy in optical recording disks, inner stress in transparent solid body, birefringence of crystals and for the measuring of temperature, pressure, electrical and magnetic field strength.

Keywords:
Polarization, birefringence, polarimetric sensor, optical disks

1.INTRODUCTION

Optical polarization devices for investigating birefringence properties of an object under test in a passing or slantingly reflected beam have as separate parts an optical scheme for formation polarization of a sounding beam and a scheme for analysing polarization of a light passed through or reflected from an object[1,2]. In the devices with an autocollimational beam path formation and analysis of beam polarization are made by the same optical elements. Owing to superposition of a sounding and inverse beams these devices have the following advantages:

a) due to the double passing of the beam through the object the threshold of sensitivity lowers;

b) if direct access is difficult or impossible distance controlling can be realised;

c) if the object under test is disposed in a hermetically isolated cell for entrance and exit of radiation the same window is used;

d)decrease in the number of optical elements simplifies the device, makes it cheaper and shows us prospects of its further diminishing;

e) the device can easily be adjusted for common use with polarimetric optical-fiber sensors made by a single-fiber scheme;

f) while investigating optical constant high-absorbing anisotropic mediums the conduct of experiment and analysis of results are simplified, the influence of a transition is minimised as well as sensitivity for errors of the incident beam angle.

Unlike devices which compensate the component whose polarization is collinear with that of probe beam[3], our device compensates the reflect beam component, which has a polarization perpendicular to that of the probe beam. In the first case[3] a semitransparent beamsplitter has to be included to separate the probe beam and the beam reflected from the specimen. As a result, the light power fed to the photodetector is attenuated by a factor of more than four. Hence at equal parameters of optical components our device has a sensitivity higher by a factor of about two and therefore a smaller measurement error. Besides, there is only one position in the configuration[3] for the $\lambda/4$ plate and polaroid in which the component with the initial polarization is fully compensated. This makes testing an object with an unknown orientation of the principle axes more difficult. If the phase shift introduced by the $\lambda/4$ plate is not exactly 90 °, there is no orientation of an object with a slight birefringence in which the reflected flux is fully compensated.

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2.DESCRIPTION OF THE DETECTOR

A scheme of the suggested detector[4] is shown in Fig.1. The optical configuration involves a laser I, a polarimetric block II, a modulator III, a control unit IV , and the specimen V. The modulator should not change the light polarization, and therefore a chopper 11 driven by a engine 12 is used. The best position for the chopper disk is between the polarimetric block and the specimen so that the probe radiation scattered in the polarimetric block is not modulated. A parallel transparent birefringent layer 13 on a reflecting surface 14 can be tested. Principal planes of the first $\lambda/4$ plate are placed an angle 45° to the first polaroid principal plane, which is parallel to the polarization beamsplitter principal plane.

The initial circularly polarized laser beam passes the polarimetric block and becomes linearly polarized. The beam's polarization plane can be rotated to a required angle by turning the first rotating body 1, which contains the first $\lambda/4$ plate 3, the first polaroid 4 and a polarization beamsplitter 5. The output beam intensity remains unchanged.

Then the linearly polarized beam illuminates the specimen which reflects the beam back. If the probe's polarization plane is parallel to one of the principal planes of the object, the reflected beam has the same polarization. When the polarization plane does not coincide with the principal axes of the object, the reflected beam has a different polarization. Hence a component with the polarization perpendicular to that of the probe beams is present in the reflected beam. This component is reflected onto a photodetector 7 by the polarization beamsplitter 5. Since this beamsplitter with an interference polarization coating is used, an additional polaroid 6 is used to eliminate the small collinear component in the beam reflected from the splitter. The intensity of the radiation incident on the photodetectors 7 is measured by the control unit.

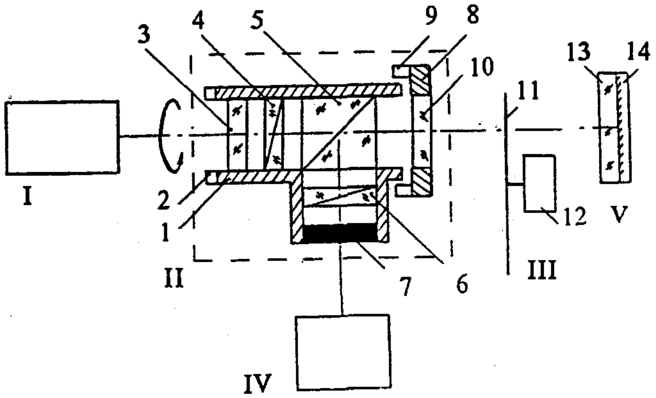

Fig.1. Configuration of the compensation detector measuring birefringence: Laser I, polarimetric block II, modulator III, control unit IV, specimen V. 1 and 8 - first and second rotating bodies, 2 and 9 - first and second angle- measuring limbs, 3 and 10- first and second $\lambda/4$ plates, 4 and 6- first and second polaroids, 5- polarization beamsplitter, 7- photodetector, 11- chopper; 12- engine, 13- transparent layer, 14- reflecting surface

3.MEASUREMENT OF BIREFRINGENCE

The scheme will be described in the Cartesian system of co-ordinates the X axis of which is parallel to the principal plane of the polarization beamsplitter, which specifies the polarization plane of the probe beam. In the general case the orthogonal component's intensity in the reflected beam Φ' is given by:

$$\Phi' = \{\sin(\Delta/2)\cos 2(\varphi-\theta)\sin 2(\varphi-\psi) - \cos(\Delta/2)\sin 2(\varphi-\theta)\}^2 R^2 \Phi, \qquad (1)$$

where Φ is the probe beam intensity, R is the amplitude reflectivity of the mirror surface of the specimen, Δ is the phase difference introduced into the beam by the specimen upon double passage of the radiation, φ, ψ and θ are the angular positions of the fast axes of the second $\lambda/4$ plate and the specimen, as well as of the principal plane of the polarization beamsplitter which specifies the polarization plane of the probe beam with respect to the zero direction of the device.

When the principal planes of the polarization beamsplitter and the second $\lambda/4$ plate coincide (i.e.,$\varphi=\theta$) Eq.(1) can be put in the following form:

$$\Phi' = \sin^2(\Delta/2)\ \sin^2 2(\psi-\theta)\, R^2 \Phi, \qquad (2)$$

In this case compensation of the intensity Φ' is achieved by simultaneous rotation of the polarization beamsplitter and the second $\lambda/4$ plate. In the position found, the orientation of the principal planes of the specimen corresponds to the orientation of the principal planes of the polarization beamsplitter.

Furthermore, we install the second $\lambda/4$ plate in such a way that its fast axis makes an angle of 45° with the fast axis of the specimen, i.e. $\varphi-\psi = 45°$. In this case

$$\Phi' = \sin^2\left[\frac{\Delta}{2} - 2(\varphi-\theta)\right] R^2 \Phi, \qquad (3)$$

By rotation the polarization beamsplitter with the second $\lambda/4$ plate fixed, one can attain compensation of the flux Φ' of the orthogonal component. The difference in the azimuths of the beamsplitter an the second $\lambda/4$ plate, latter being in the position found, makes it possible to determine the value of the phase shift of the specimen:

$$\Delta = 4(\varphi-\theta) + 360°\, m, \qquad (4)$$

where m is an integer.

As can be seen from (2) and (3), in our configuration the component wih the polarization orthogonal to the initial one is compensated in two position of the second $\lambda/4$ plate, thus first orientation of principal planes is found, then the phase difference is measured. The error in the phase differernce introduced by the accuracy of the principal planes orientations and yields a small error when determing a small phase difference introduced by a specimen.

4.CONCLUSION

This device enables rather simply to find the fast axis azimuth and phase difference of the reflecting specimen. Besides, due to the compensative method of measuring, a high level of sensitivity is secured. For instance, in our device the threshold of phase difference sensitivity amounts to 0.03°.

5.REFERENCES

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