Sh. D. Kakichashvili. *Polarization holography.* In its original form, the holographic method assumed the possibility of recording scalar intensity distributions.[1,2] Such recording is actually a polarization comparison of object and reference fields, and remains such also for reconstruction. As a result, an essential characteristic of the field scattered by the object—its polarization state—is not reporduced in the reconstruction process. Schematic solutions of this problem have been unsuccessful due to distortions that it is impossible in principle to remove.[3]

Attention was first drawn in Ref. 4 to the fact that when the object and reference waves interact, the field distribution in the plane of the hologram is of an essentially vector nature, but that this is not reflected in any way in the registration process. The conclusion to be drawn from this is that it is necessary to use media that map the polarization state of the resultant wave point by point. The conditions under which such recording could solve the problem required detailed investigation.

We know that when polarized light interacts with a medium, anisotropy is induced under certain conditions in addition to the usual isotropic change.[5] A similar anisotropy can be fixed in photochemical systems.[6] The aggregate scalar-vector change of the medium under the action of polarized light can be described by the system

$$\left.\begin{aligned} \hat{\varepsilon}_1-\hat{\varepsilon}_0 &= \hat{v}(E_1^2-E_2^2)+\hat{s}(E_1^2+E_2^2),\\ \hat{\varepsilon}_2-\hat{\varepsilon}_0 &= -\hat{v}(E_1^2-E_2^2)+\hat{s}(E_1^2+E_2^2),\\ \hat{\varepsilon}_3-\hat{\varepsilon}_0 &= -\hat{v}(E_1^2+E_2^2)+\hat{s}(E_1^2+E_2^2), \end{aligned}\right\} \tag{1}$$

where $\hat{\varepsilon}_0$ and $\hat{\varepsilon}_j$ are the initial and final complex dielectric permittivities of the medium, $\hat{v}$ and $\hat{s}$ are the complex coefficients of the vector and scalar reactions of the medium, respectively, and E_1^2 and E_2^2 are the intensities along the major and minor axes of the polarization ellipse of the incident field.

Use of system (1) as a measure of the anisotropy induced by the field makes possible theoretical analysis of anisotropic holograms.[7] This also requires modification of the Kirchhoff scalar diffraction integral for the vector case.[8,9]

Making use of the preservation of the polarization state of the beam in an elementary diffraction event and correcting the amplitude components in the equatorial and meridional diffraction planes, we obtain for the electric vector

$$\mathbf{E}=-\frac{i\varkappa}{2\pi}\int\limits_{S_0}\begin{pmatrix} l^2-(1+n) & lm \\ lm & m^2-(1+n) \\ l(1+n) & m(1+n)\end{pmatrix}\begin{pmatrix}\frac{n}{\sqrt{1-m^2}} & 0\\ 0 & \sqrt{1-m^2}\end{pmatrix} \times M_0\mathbf{E}_0\frac{e^{i(\omega t-\varkappa R)}}{R}ds_0, \tag{2}$$

where M_0 is a 2×2 Jones matrix, which describes a diffracting screen with anisotropy variable over S_0, $\mathbf{E}_0$ is the Jones vector of the field illuminating the screen, l, m, n are the direction cosines of the diffracted beam, and $R(x_0, y_0, x, y, z)$ is the distance from point x_0, y_0 on the screen to the observing point x, y, z.

Using the Jones vector-matrix method and relations (1), (2), we derive vector expressions for the reconstruction field. Assuming $\hat{s}=0$ for simplicity of analysis, we take as an example the reconstruction field of the virtual and real images:

$$\begin{gathered}\mathbf{E}_{-1}\sim\begin{pmatrix}\psi_x^2+\psi_y^2 & 2i\psi_x\psi_y\sin(\alpha_y-\alpha_x)\\ -2i\psi_x\psi_y\sin(\alpha_y-\alpha_x) & \psi_x^2+\varphi_y^2\end{pmatrix}\Xi,\\ \mathbf{E}_{+1}\sim-(\psi_x^2e^{i2\alpha_x}+\psi_y^2e^{i2\alpha_y})\,\Xi^*,\end{gathered} \tag{3}$$

where $\Psi=\begin{pmatrix}\psi_x e^{i\alpha_x}\\ \psi_y e^{ia_y}\end{pmatrix}$ is the Jones column vector of the reference wave and Ξ is the column vector that describes the object.

It follows from (3) that use of a linearly polarized reference wave solves the problem of reconstructing the polarization of the object. Here the virtual and real images are equivalent from the information standpoint. In the general case of reference-wave polarization, there is a distinct asymmetry in the polarization state of these images. In particular, use of a circularly polarized reference wave results in complete disappearance of the real image.[10]

Experimental production-engineering work has been done with the object of developing photoanisotropic media with adequate sensitivity. An incidental problem was that of eliminating the scalar response of the medium.[11,12]

The results obtained in theory were confirmed by experiments in polarization holographic recording on various photoanisotropic materials.[13]

In summary, we note that holographic reconstruction of the polarization state of the object field, together with reconstruction of the complex amplitude and wavelength, is of essential importance for *a posteriori* ellipsometric measurements in many scientific and technical areas and in systems that process optical information.

Polarization holography would appear to have a decisive role in the development of holographic interferometry and photoelasticity techniques, making possible comparative measurements of states of stress in any objects of interest.

There is a promising possibility of obtaining values of the vector parameters of various media for problems in molecular-optical research from polarization-holographic measurements.

The methods of polarization holography can be used to create artificial anisotropic optical systems of practically any predetermined structure with broad functional capabilities. Thus, for example, polarization-holographic gratings with variable-profile transmission planes can be used to separate an incoming field into mutually orthogonal components, directing them into diffraction orders −1 and +1, respectively.

Finally, we should note that development of the method has resulted in a rather general approach to problems of diffraction by anisotropic structures or arbitrary nature, solution of which had appeared to be hopelessly complex.

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