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DIFFRACTION EFFICIENCY OF MIXED HOLOGRAMS IN BTO CRYSTAL

V.V. Shepelevich[1], *A.V. Makarevich*[1], *S.M. Shandarov*[2]
[1] State Pedagogical University, Mozyr 247760, Belarus,
Corresponding author e-mail: aleksandr_makarevich@inbox.ru
[2] State University of Control System and Radioelectronics, Tomsk 634050, Russia

The photorefractive crystal $Bi_{12}TiO_{20}$ (BTO) is perspective photosensitive medium used in the holographic interferometry [1]. Therefore, the practical interest to optimization of the reading process of holographic gratings recorded in this crystal takes place.

It is well known from [2] that the diffraction efficiency of pure phase holograms recorded in a photorefractive crystal $Bi_{12}SiO_{20}$, can be increased by selecting the optimal values of the orientation angle of the crystal and the azimuth of polarization of the reading beam, which can be determined theoretically taking into account the electro-optic and inverse piezoelectric effects and the photoelasticity.

We spent the experimental studies of the hologram diffraction efficiency dependence in the $(\bar{1}\,\bar{1}0)$-cut BTO crystal on the orientation angle θ for two values of the linear polarization azimuth of the readout beam, $\Psi_0 = 0$ and $\Psi_0 = 90°$. As a result, it was found that for matching the experimental data with theoretical ones we should suggest the possibility of forming in the crystal the absorption holographic grating together with the phase one. The totality phase and absorption components of the holographic grating are called a mixed hologram [3].

Theoretical interpretation of the experimental data was based on solving set of linear differential equations of coupled waves:

$$\begin{cases} \dfrac{dR_\perp}{dz} = -\alpha R_\perp + \rho R_{||} + \left(ie^{-i\delta}\chi_1 - \dfrac{\varepsilon_i}{\cos\varphi}\right)S_\perp + ie^{-i\delta}\chi_2 S_{||}, \\ \dfrac{dR_{||}}{dz} = -\rho R_\perp - \alpha R_{||} + e^{-i\delta}\chi_3 S_\perp + \left(ie^{-i\delta}\chi_4 - \dfrac{\varepsilon_i \cos 2\varphi}{\cos\varphi}\right)S_{||}, \\ \dfrac{dS_\perp}{dz} = \left(ie^{i\delta}\chi_1 - \dfrac{\varepsilon_i}{\cos\varphi}\right)R_\perp + ie^{i\delta}\chi_3 R_{||} - \alpha S_\perp + \rho S_{||}, \\ \dfrac{dS_{||}}{dz} = ie^{i\delta}\chi_2 R_\perp + \left(ie^{i\delta}\chi_4 - \dfrac{\varepsilon_i \cos 2\varphi}{\cos\varphi}\right)R_{||} - \rho S_\perp - \alpha S_{||}. \end{cases}$$

Here $R_\perp$ and $R_{||}$, $S_\perp$ and $S_{||}$ are projections of vector amplitudes of R and S waves on the directions perpendicular to the plane of incidence (⊥) and lying in the plane of incidence (||); $\alpha = \alpha_\lambda/\cos\varphi$, where α_λ is the absorption coefficient of the crystal for a given wavelength of electromagnetic radiation; φ is the Bragg angle of the light waves inside the crystal; $\rho = \rho_0/\cos\varphi$, where ρ_0 is the specific rotation of the light wave polarization plane; ε_i is parameter for characterizing of the amplitude grating; $\delta = \pi/2$ – phase shift of the phase component of the hologram relative to the absorption component; χ_j is the coupling constants [2], where j = 1, 2, 3, 4.

For the calculation the parameters of BTO crystal from [4] were used. Furthermore, the specific rotation of plane of polarization $\rho_0 = 112$ rad/m and the absorption coefficient $\alpha_\lambda = 38.2$ m^{-1} were measured for the sample BTO crystal; electric field of space-charge for polarization azimuth of the readout beam $\Psi_0 = 0$ was assumed to be $8.25\cdot10^4$ V/m, and for azimuth of polarization $\Psi_0 = 90°$ one was took equal $9.75 \cdot 10^4$ V/m. In case of pure phase grating value ε_i was assumed to be 0, and in the case of mixed hologram one was equal 2.1 m^{-1}. The results are shown in Figure 1.

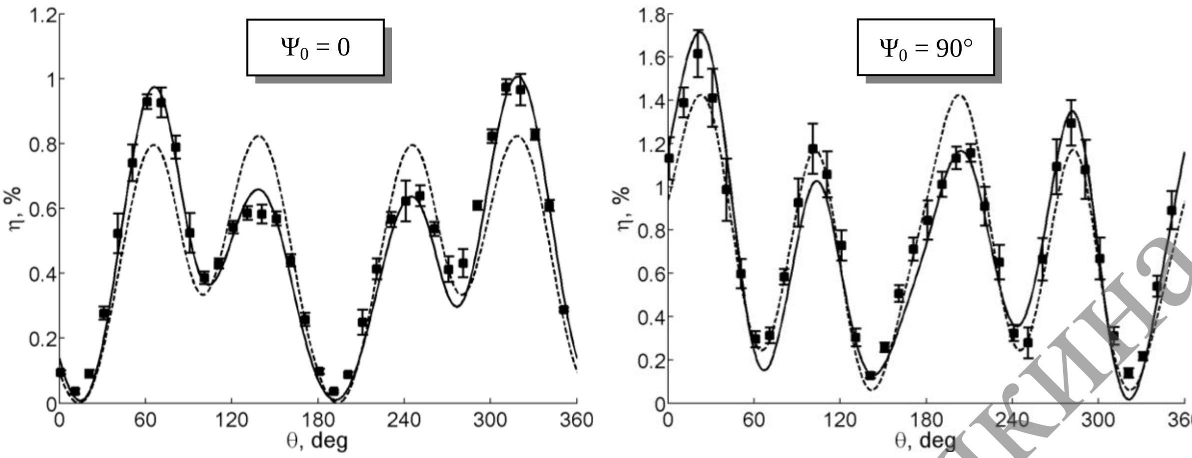

Figure 1. – Orientation dependences of holograms diffraction efficiency in BTO crystal: solid line – theoretical curves for mixed holograms; dashed line – theoretical curves for phase holograms; ■ – experimental results

As can be seen from Figure 1, accounting of the absorption component of the holographic grating leads to a better matching of the theoretical results and experimental data. Consequently, the contribution of the absorption component of the holographic grating should also be taking into account for the theoretical optimization of the hologram readout process in the BTO crystal.

In conclusion, it should be noted that the possibility of the existence of mixed holographic gratings was studied before in photorefractive crystal GaAs:Cr (symmetry class $\bar{4}3m$) [5]. Theoretical modeling of the possible increase in the diffraction efficiency of holograms in BSO crystal by incorporating photochromic gratings was presented in [6]. At the studying of the contribution of the flexoelectric effect to the interaction of light waves counter propagating in BTO crystal the possible existence of amplitude gratings is also indicated [7]. To our knowledge, the detailed theoretical and experimental research of contribution of amplitude component of holographic gratings in the diffraction efficiency of transmission holograms in the crystal BTO is considered in this paper for the first time.

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