Linear diffraction of light waves on periodically poled domain structures in lithium niobate crystals: collinear, isotropic, and anisotropic geometries

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Abstract. The possible variants of experimental observation of light diffraction on periodically poled domain structures (PPDS) in the lithium niobate crystal with 180-degree domain Y-walls are considered. We experimentally investigated isotropic and anisotropic diffraction of coherent light (λ = 655nm) on the PPDS with spatial period Λ = 8.79 μm produced by poling method in a $LiNbO_3$: 5% MgO crystal. The central wavelength of irradiation experiencing a collinear diffraction on these PPDS is estimated as λ_c = 455 nm.

1. Introduction

Linear light diffraction on periodically polarized domain structures (PPDS) in ferroelectric crystals is an effective method of nondestructive testing of their characteristics and quality [1, 2]. In the absence of external applied electric field, such diffraction is caused by perturbations of the optical properties by crystal domain walls [1, 3, 4]. Within the framework of the known model of polarization distribution over the domain wall [5], expressions for the perturbations of the dielectric impenetrability components created by it in crystals with 3*m* symmetry have been obtained in [3]. From them it follows the possibility of realization of collinear and anisotropic diffraction on the PPDS in addition to isotropic diffraction. Experimentally, collinear diffraction was observed in a $LiNbO_3$:5 % MgO crystal on the PPDS with the spatial period Λ = 6.89 μm [3]. Authors [4] have been studied theoretically and experimentally the isotropic process with many diffraction maxima realized when the incident laser beam propagated along the Z axis of the $LiNbO_3$:5 % MgO crystal with the PPDS having the spatial period Λ = 9.43 μm.

In the present work, the special features of the isotropic and anisotropic Bragg diffractions of the coherent light beam propagating in the XY plane of the lithium niobate crystal in which PPDS with Y-walls having the spatial period Λ = 8.79 μm were produced by the polarization reversal method, are considered.

2. Materials

The examined PPDS were manufactured by Labfer LTD in the $LiNbO_3$: 5% MgO crystal having sizes 40 × 2 × 1 mm^3 along the X, Y, and Z axes, respectively, by the polarization reversal method in an external spatially-periodic electric field [6]. The periodic structure with $\Lambda = 8.79$ μm occupied completely the space between the sample faces perpendicular to the Z (h = 1 mm), Y (d = 2 mm) and X (L = 40 mm) axes.

3. Experimental results

Results of experiments on measuring the efficiency of the Bragg diffraction of ordinary (the subscript "*o*") or extraordinary (the subscript "*e*") light beam with the wavelength $\lambda = 655$ nm on the components of the Fourier spectrum of perturbations of optical properties with spatial frequencies $2\pi p/\Lambda$ (p = 1, 2, 3, …) into the diffracted beam with corresponding polarization are presented in Table 1.

Table1. Efficiency of the Bragg diffraction of light beams propagating in the XY plane

p	1	2	3	4	5	6	7	8
$\eta_{oo}\times100$	0.219	0.526	0.113	0.028	0.045	0.010	0.003	0.002
$\eta_{ee}\times100$	0.743	7.170	1.273	0.447	0.513	0.064	0.063	0.022
$\eta_{oe}\times100$	–	–	–	0.102	0.023	0.025	0.006	0.002
$\eta_{eo}\times100$	–	–	–	0.130	0.022	0.030	0.017	0.004

As follows from Table 1, the intensity of the odd maxima of the isotropic Bragg diffraction is nonzero, and its peak efficiency is observed for the second orders ($p = \pm2$). These specific features can be caused by the fact that two periodic systems of walls produced during synthesis of the PPDS with polarization changing along the x coordinate from $-\boldsymbol{P_S}$ to $\boldsymbol{P_S}$ and from $\boldsymbol{P_S}$ to $-\boldsymbol{P_S}$ can have the spatial shift that differs from the half-period $\Lambda/2$ by a certain value Δx [4].

A comparison of the theoretical dependence of the anisotropic diffraction efficiency on its order p with the experimental data presented in Table 1 demonstrated that the main contribution comes from perturbations of the components $\Delta\varepsilon_{23} = \Delta\varepsilon_{32}$ of the dielectric permittivity tensor in the PPDS caused by the electrostriction and photoelasticity effects [3]. This makes it possible to realize the collinear diffraction on the given PPDS of the light beam with the wavelength $\lambda_c = 455$ nm propagating along the X axis of the crystal.

4. Conclusions

The isotropic and anisotropic diffractions of coherent light beams on the PPDS with the spatial period $\Lambda = 8.79$ μm produced in the $LiNbO_3$: 5% MgO crystal have been studied experimentally. We have also demonstrated the possibility of collinear diffraction of light with a wavelength of 455 nm on these PPDS.

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