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HOLOGRAPHIC MATERIALS, NONLINEAR OPTICAL MEDIA AND INFORMATION RECORDING SYSTEMS

Change in Absorption Induced in a $Bi_{12}TiO_{20}$: Ca Crystal by 870-nm Infrared Radiation

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Owing to their sensitivity in the visible and near-infrared spectral regions, photorefractive bismuth titanate $Bi_{12}TiO_{20}$ (BTO) crystals hold attention as a promising material for the fabrication of dynamic holographic devices [1]. The irradiation of BTO crystals with visible light leads to a reversible change in optical absorption (photochromic effect) [2, 3], which is supposed to be due to charge exchange by defect centers with different photoionization cross sections [4].

For implementation of dynamic holographic devices, it is important to know the parameters of centers populated by electrons during irradiation of BTO crystals with visible light.

In this paper, we present the results of experimental study and numerical simulation of the spectral dependence of optical absorption in a calcium-doped bismuth titanate ($Bi_{12}TiO_{20}$: Ca) crystal after successive irradiation with green and near-infrared light.

The calcium-doped bismuth titanate crystal used in the experiments was cut along the [100] crystallographic direction and had a thickness of 5.9 mm; the radiation sources were semiconductor light-emitting

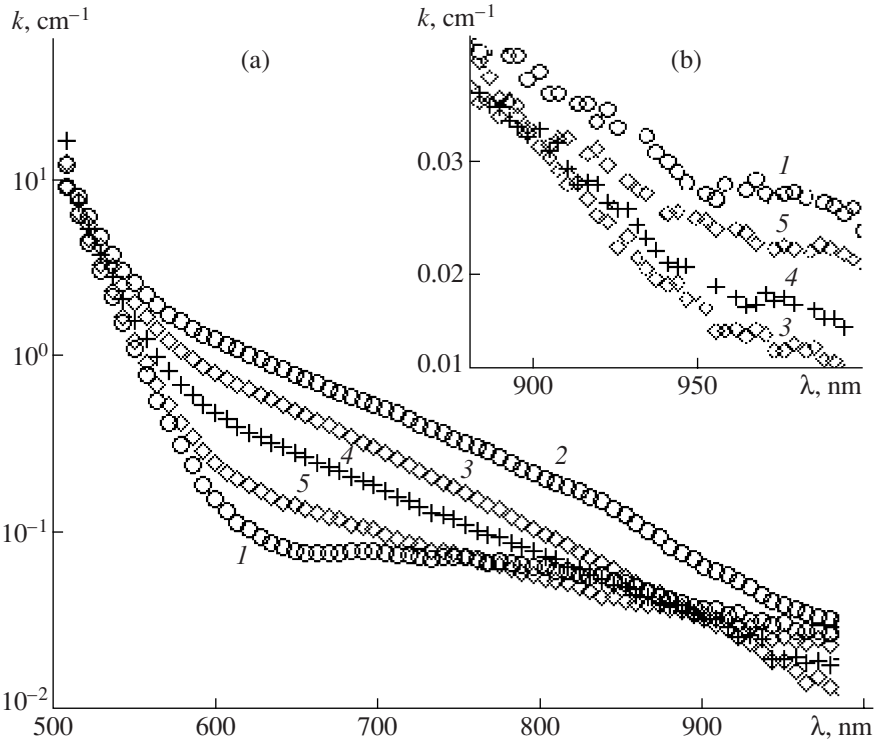

Fig. 1. Spectral dependences of the absorption coefficient of the $Bi_{12}TiO_{20}$: Ca crystal (*1*) before irradiation, (*2*) after irradiation with green light (λ = 505 nm), (*3*) after successive irradiation with green (λ = 505 nm) and IR (λ = 870 nm) light, (*4*) 3 h after irradiation, and (*5*) 24 h after irradiation.

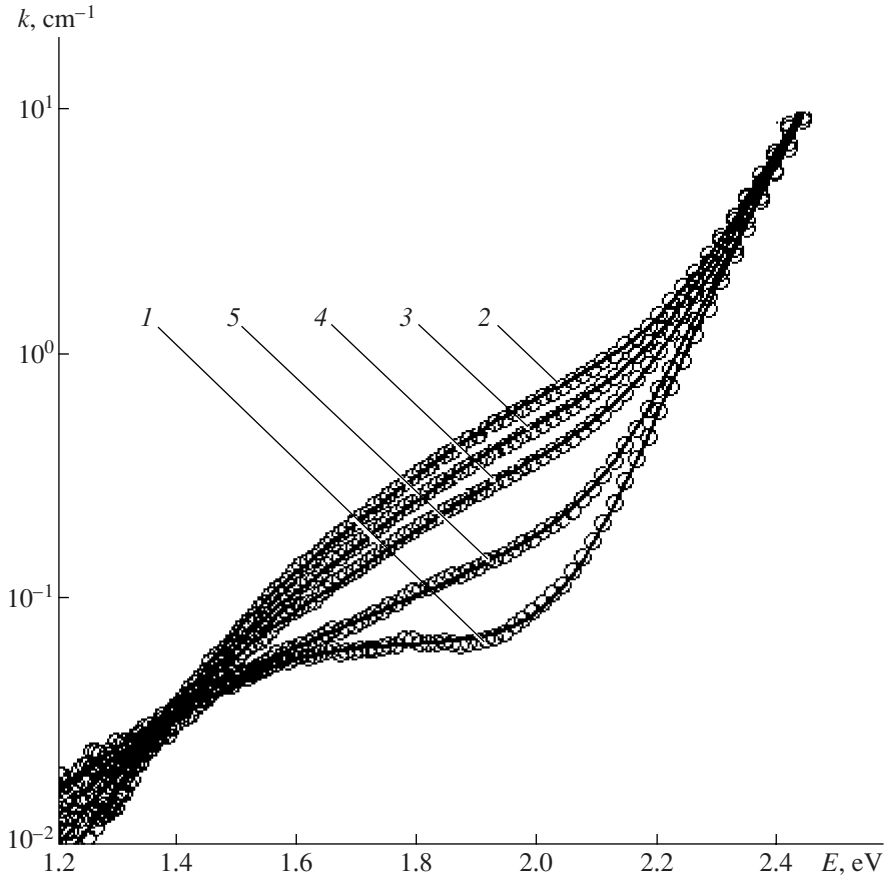

Fig. 2. Experimental and calculated spectral dependences of the absorption coefficient in the $Bi_{12}TiO_{20}$: Ca crystal (*1*) before irradiation; (*2*) after successive irradiation with green (λ = 505 nm) and IR (λ = 870 nm) light; and at the step of relaxation for (*3*) 1, (*4*) 3, and (*5*) 24 h. The symbols and the solid curves refer to the experimental and calculated data, respectively.

diodes with intensities of 15 and 54 mW/cm^2 in the green (λ ≈ 505 nm) and IR (λ ≈ 870 nm) spectral regions, respectively.

The transmission spectra $T(\lambda)$ of the crystal in the range 508–1000 nm were recorded on an SF-56 spectrophotometer. The $T(\lambda)$ spectra were measured immediately before irradiation of the crystal, immediately after the successive irradiation with green and IR light for 1 h, and at the step of relaxation of induced perturbations in the dark. All experiments were run at room temperature.

Figure 1 presents the spectral dependences of the absorption coefficient $k(\lambda)$ of the $Bi_{12}TiO_{20}$: Ca crystal as measured before irradiation, after irradiation with quasi-monochromatic green radiation from a light-emitting diode, after the successive exposure to radiation from green and IR light-emitting diodes, and at the relaxation step.

As is seen from Fig. 1a, the absorption coefficient of the BTO : Ca crystal increases over the entire range of examined wavelengths after its irradiation with green light. The successive irradiation of the crystal with green and IR light increases the optical absorption in the region of 508–880 nm and decreases it at 880–1000 nm (Fig. 1b). However, the induced changes in the absorption are smaller in magnitude than those in the case of irradiation of the crystal with the green light alone. During the dark relaxation, the photoinduced changes disappear over a period longer than 150 h.

To rationalize the results, we employed a model that suggests the presence in the bandgap of the crystal of donor-trapping centers with the normal energy distribution of concentrations [5] and makes it possible to satisfactorily approximate the spectral dependence of the absorption coefficient. The results of approximation of the experimental dependences $k(E)$ with allowance for five centers with mean ionization energies of $E_1 = 1.27$, $E_2 = 1.46$, $E_3 = 1.89$, $E_4 = 2.43$, and $E_5 = 2.89$ eV are shown by solid lines in Fig. 2.

The approximation revealed that the irradiation of the $Bi_{12}TiO_{20}$: Ca crystal with green and IR light leads to a decrease in the electron population of the center with an ionization energy of $E_1 = 1.27$ eV and an increase in the population of the centers with energies of $E_2 = 1.46$, $E_3 = 1.89$, and $E_4 = 2.43$ eV. This behavior can explain the observed increase in optical absorption in the quantum energy region of 1.4–2.5 eV and its decrease at $E = 1.2$–1.4 eV.

In summary, the successive irradiation of the $Bi_{12}TiO_{20}$: Ca crystal with green and IR light increases optical absorption at 500–880 nm and decreases it at 880–1000 nm, changes that are due to the redistribution of electrons between donor trapping centers with mean ionization energies of $E_1 = 1.27$, $E_2 = 1.46$, $E_3 = 1.89$, $E_4 = 2.43$, and $E_5 = 2.90$ eV.

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