Conference Paper

Dynamics of Changes in Optical Absorption Induced By Nanosecond Laser Pulses in the $Bi_{12}TiO_{20}$:Al Crystal

V.G. Dyu, D.V. Sokolov, T.D. Tokhmashev, and S.M. Shandarov

Tomsk State University of Control Systems and Radioelectronics (TUSUR University) 40 Lenin Avenue, Tomsk 634050, Russia

Abstract

The dynamics of the changes in optical absorption in $Bi_{12}TiO_{20}$:Al crystal at the wavelength of 655 nm, which were induced by a packet of laser pulses with the wavelength of 526.5 nm, pulse width of 10 ns, repetition frequency from 10 Hz to 1 kHz and pulse energy of 9-15 μJ had been experimentally investigated.

Keywords: light-induced absorption, bismuth titanium oxide crystal, impulse radiation

Corresponding Author:
V.G. Dyu
valeriya.dyu@gmail.com

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1. Introduction

Photorefractive bismuth titanium oxide crystals are used both in basic elements of dynamic holography devices and in studies of new self-action effects of light beams due to advantageous combination of its characteristics such as low specific optical rotation, relatively high speed, good handling properties and resistance to external temperature and mechanical durability [1-5].The significant photoinduced changes in optical absorption (the photochromic effect) are observed in these crystals [6-14]. It should be taken into account when developing real devices and when interpreting the various phenomena of photorefractive nonlinear optics. The physical reason of the photochromic effect is usually considered the charge exchanges of defect centers with the different photoionization cross section under the influence of light [8-13], features of which depend on the limited timespan of the acting optical radiation [10-14]. The dynamic of changes in optical absorption $\Delta\alpha$ (t) in bismuth titanium oxide crystals wich related with switch-on and shut-down of continuous radiation with different wavelengths from the visible range [10, 12] allowed to refine the energy diagram of the corresponding defective centers [12] and satisfactorily describe the experimental time dependences. Such refined model proposed for the doped crystals $Bi_{12}TiO_{20}$:Cu,

$Bi_{12}TiO_{20}$:Cu,Fe и $Bi_{12}TiO_{20}$:Cu,Co successfully used in [13] for the numerical simulation of the time dependence of the optical absorption of the undoped $Bi_{12}TiO_{20}$crystal at the wavelength of 633 nm induced by picosecond laser pulses with the wavelength of 532 nm. In this case, the absorption increases after exposure by a pulse with a duration of 70 ps and an average energy of about 50 mJ (it is accorging to the exposition of 60 mJ/cm^2) for 90 ns first, and then returns to the initial level in a time of ~ 0.2 s, coinciding with the repetition period of the inducing pulses. The experiments carried out in [14] showed that for a lower intensity equal to ~ 5 mJ/cm^2 the time of such return of the absorption to the initial level decreased to 70 ms. It will be observed the work [11], wherein was found that the exposure of the $Bi_{12}TiO_{20}$ crystal by the laser pulses with the wavelength of 532 nm, duration of 30-50 ns and single impulse energy of 0.5 mJ leads to increase in the optical absorption in the spectral range 492-840 nm. The changes in the crystal absorption are observed noticeable when the exposure of pulsed laser radiation equal to about 300 J/cm^2. The relaxation of such induced changes in the absorption continued for more than 60 hours.

In the present work, results of experiments on the dynamics of the changes in optical absorption at the wavelength λ_p= 655 nm in an aluminum-doped bismuth titanium oxide crystal, which were caused by a packet of several laser pulses having the wavelength λ_i= 526.5 nm and a duration of 10 ns are given. Frequency of pulses ranged from 10 Hz to 1 kHz and energy of a single pulse ranged from 9 to 15 μJ. The exposition of crysta for single pulse with cross cut of 0.06 cm^2 was less than 0.25 μJ/ cm^2

2. Materials and methods

For studying the dynamics of changes in the optical absorption we used the aluminum-doped bismuth titanium oxide crystal ($Bi_{12}TiO_{20}$:Al) grown by TSSG method and had polished faces and thickness *d*=6,6 mm along [100] crystallographic direction. The scheme of the experimental setup is shown in Fig. 1. Photoinduced changes in the absorption in the study sample 11 were induced by laser pulses with the wavelength of λ_i= 536.5 nm and the duration of 10 ns generated by a frequency doubling scheme involving a pulsed laser 2 (LCS-DTL-328QT model with a wavelength 1053 nm) in non-linear crystal 5. In order to keep condition of angle synchronism of «*oo – e*» type pumping emition was focused with a cylindric lens 4, therefore it is waist match the center of the crystal. The pumping and second harmonic beams were separated by a corner using a prism 6 from LiF and the diaphragm 7 transmitted radiation at the wavelength of 526.5 nm and blocked the pumping beam. The number of inducing

pulses was determined by the exposure established by the mechanical shutter 8 of the FED-3 camera and their repetition frequency from 10 Hz to 1 kHz. The induced beam had the cross cut of 0.06 cm^2 hold up to 13 pulses. Each pulse had energy of 9-15 μJ depending on pumping-to-induced beam transmitting efficiency.

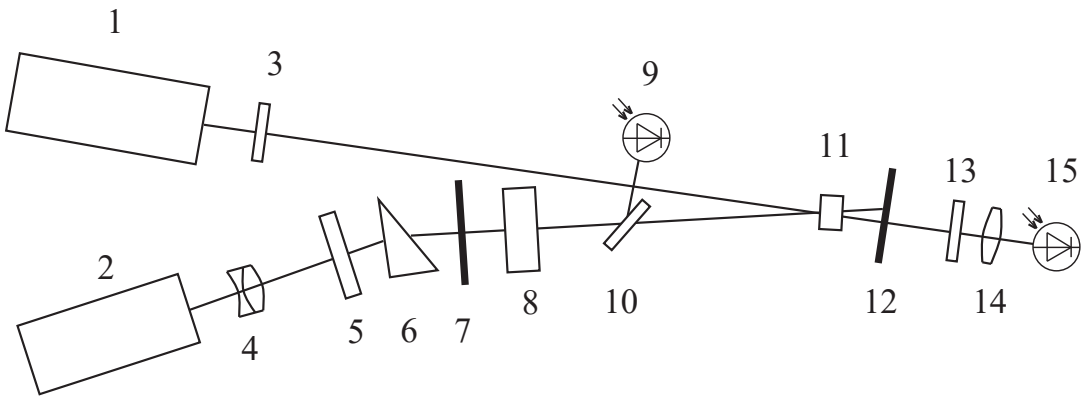

Figure 1: Experimental setup: 1 - semiconductor laser; 2 - nanosecond laser DTL-328QT; 3, 13 - light filters; 4 - converging cylindrical lens; 5 - frequency doubler on lithium niobate; 6 - prism; 10 - beam splitter; 7, 12 - diaphragm; 8 - mechanical shutter; 9, 15 – pin-photodiodes; 11 - Bi12TiO20: Al crystal; 14 - converging lens.

For the changes detection in the optical absorption we used the continuous laser radiation 1 with the wavelength of λ_p=655 nm and aperture of 1 mm. This probing beam went through illuminated center of the crystal. Dynamic of intensity of probing beam was registered by pin-photodiode BPW24R 15 with applied resistance of 107 kOm, backward-bias potential 30 V and digital oscilloscope TektronixTDS2012B. Synchronizing signal for oscilloscope was created by beam splitter 10 and detected by another pin photodiode 9. Diaphragm 12, filter 13 and focusing lens 14 were used to reduce parasitic illumination on pin-photodiode 15 caused by dispersion of pulse radiation with wavelength of 526,5 nm on the elements of the experimental setup. All experiments were carried out at room temperature without external irradiation. Between the experiments the crystal was kept in opaqueness box.

3. Experimental results

In all experiments the increase of the optical absorption at the wavelength of 655 nm caused by the packet of inducing pulses with the wavelength of 526,5 nm and monopulse exposition bellow 0,25 mJ/ $см^2$ had been recorded. The typical diagram for time evolution of changes of optical absorption $\Delta\alpha(t)$ induced by single laser pulse with energy of 15 μJ exceeded by shutter 8 with frequency 10 Hz is shown by light circles on the Fig. 2. The increase of optical absorption presented by two points only due to

the used oscilloscope time scale and photodiode parameters. It is occurs in the time approximately close to an induced pulse duration. However, the relaxation of induced changes of optical absorption that takes place in absence of induced short wavelength radiation with λ_i=526.5nm but with exposure of probing radiation with λ_p=655 nm and relatively weak intensity $I_p \approx$ 0.8 mW/cm^2 is slow. This process can be approximated sufficiently by exponent function with relaxation time τ = 22 ms as shown by solid curves on Fig. 2.

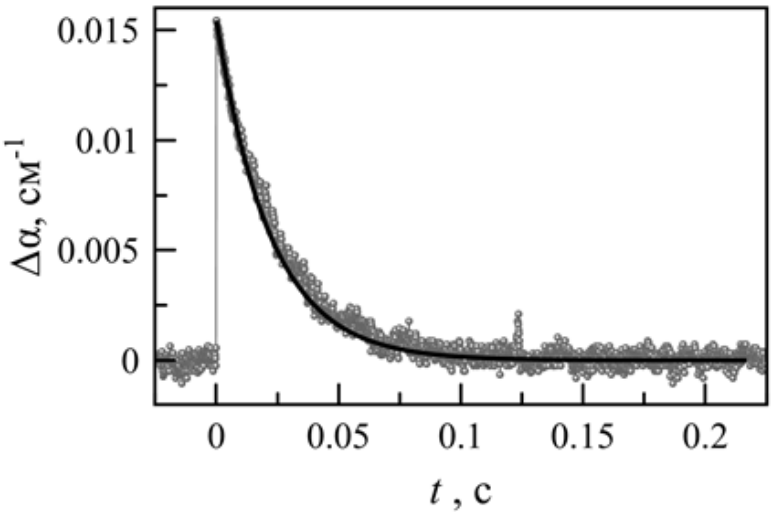

Figure 2: Time dependences of changes in the absorption index at 655 nm induced by a single nanosecond pulse with the wavelength of 526.5 nm in the $Bi_{12}TiO_{20}$:Al crystal.

The dynamics of changes in the absorption index of the $Bi_{12}TiO_{20}$:Al crystal at the wavelength λ_p = 655 nm induced by the packet of two pulses with an energy of 9 μJ each, separated by the shutter 8 from a repetition pulse train with the frequency of 30 Hz and λ_i = 526.5 nm is shown by the light circles in Fig. 3.

In this case, the probing beam was used with the same intensity as before with single-pulse inducing in optical absorption (see Fig. 2), so that its relaxation in the interval between the pulses and after exposure by the second one in the crystal was also well approximated by exponent functions (solid curves in Fig. 3) with the relaxation time τ = 23 ms. The second pulse in the packet leads to greater changes in Δα (t) than the first one. However, the experiments with different number of inducing pulses (8 or more) conducted for repetition frequencies up to 1 kHz showed that the maximum attainable values of the changes in the absorption index do not exceed 0.015 cm $^{-1}$.

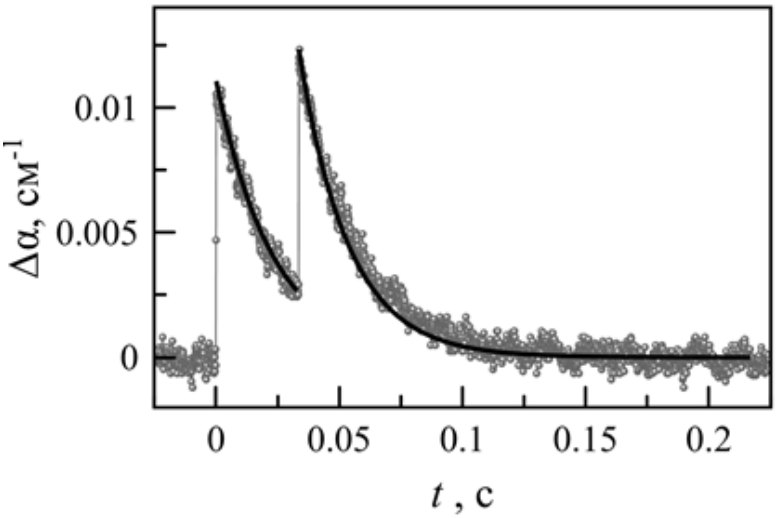

Figure 3: Time dependences of changes in the absorption index at 655 nm induced by two nanosecond pulses with the wavelength of 526.5 nm in the $Bi_{12}TiO_{20}$:Al crystal.

4. Conclusion

Thus, the experimental studies have demonstrated the possibility of studying the dynamics of photoinduced changes caused in the $Bi_{12}TiO_{20}$: Al crystal in the red region of the spectrum both by single nanosecond laser pulses with a wavelength of 526.5 nm and the packet of such pulses with the energy of each of them about 10 μJ. The maximum changes in the absorption index of the crystal at the wavelength of 655 nm are 0.015 cm^{-1} when the exposure of one pulse reaches 0.25 mJ/cm^2. In the experiments this magnitude of the induced changes was the limit, independent of the number of inducing laser pulses in the used packet. The relaxation of the induced changes in the interval between the pulses and after the last of them occurred exponentially with a time constant of about 20 ms at the intensity of the probing beam with a wavelength of 655 nm equal to 0.8 mW/cm^2.

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