Photoelectromotive Force under Transverse-Moving Pulsed Illumination in the $Bi_{12}SiO_{20}$ and $Bi_{12}TiO_{20}$ Single Crystals

T.A. Kornienko[1 *], S.M. Shandarov[2], M.G. Kisteneva[2], and A.L. Tolstik[1]
[1]Physics Department, Belarusian State University
4 Nezavisimosti Avenue, Minsk, Belarus, 220030
[2]Department of Electronic Devices, Tomsk State University of Control Systems and Radioelectronics
40 Lenin Avenue, Tomsk 634050, Russia
*Tatiana Kornienko: tatianakornienko3@gmail.com

Photorefractive crystals of bismuth silicon and bismuth titanium oxides, $Bi_{12}TiO_{20}$ (BTO) and $Bi_{12}SiO_{20}$ (BSO), belong to wide-gap semiconductors with complicated level structure in band gap. In parallel with the photoconductive and electrooptic properties, they exhibit piezoelectric, photochromic, and gyrotropic ones. Furthermore, the significant photogalvanic response on pulse laser irradiation was detected and investigated in recent years[1]. There is notable interest in applications for sensors using the non-steady-state photoelectromotive force phenomena that are conventionally observed in BTO and BSO crystals when those crystals are exposed to continuous laser radiation[2]. Here we present the results of experimental revealing and a theoretical consideration of the non-steady-state photoelectromotive force phenomenon that has been observed in the motion of a focused pulsed laser beam in the transverse direction in the BTO and BSO samples.

We have experimentally registered the electrical signals from two copper electrodes glued on polished surfaces that were orthogonal to the input face of a BTO (or BSO) sample in the case of a transfer of a focused pulsed laser beam with the wavelength of 532 nm between these electrodes only. In bismuth silicon and bismuth titanium oxide crystals the photoelectromotive force manifests as an unsteady photoelectric effect due to the charge carrier transfer under laser illumination. One of the features of our experimental conditions is the illumination of crystals by nanosecond laser pulses, which have sharp inhomogeneities in the intensity distribution along the front surface of samples. When this illuminated area moves, an alternating electric current is generated in the direction orthogonal to the beam. The maximum values of the electrical current are about microamperes with linear dependencies on laser intensity making up about 100 kW/cm^2.

The origin of the observed current is associated with the processes of the photoconductivity and the space charge field formation. They are determined by the concentration of the deep and shallow traps in crystals as well as by the character of electron recombination in these traps. To get detailed information about the character of electron recombination by exploring the effects of photoconductivity, we have investigated the dynamics of a photorefractive sample by registering the electrical responses from the load resistance, which is connected in series with the sample. The constant 15 V voltage bias is applied to the electrical scheme; the load resistance value is chosen equal to 50 Om to get the response time less than a few nanoseconds.

To investigate the dynamics of light absorption, which was photoinduced by pulse radiation with the wavelengths of 532 nm, continuous lasers with wavelengths of 632.8 nm and of 532 nm were used. In the case of photoconductivity and photoinduced absorption, as the result of the pulse excitation we have obtained the relaxation dynamics, which are described by complicated multi-exponential functions. In BTO and BSO crystals, such processes of charge carrier excitation from valence band to conduction band and its further recombination are characterized mathematically by partial differential equation systems. According to our theoretical consideration, the obtained experimental results may be explained by association energy level structure of real crystals with the phenomenological model, including five energy levels in bandgap: shallow trap center near the bottom of the conduction band, two pairs of donor and acceptor deep trap centers. The relaxation times of photoconductivity dynamics in BSO and BTO crystals are in the nano- and microsecond ranges, while the relaxation times of photoinduced changes in absorption are in micro- and millisecond ranges.

[1] R.V. Romashko, A.I. Grachev, Yu.N. Kulchin, A.A. Kamshilin. Optics Express, 2010, vol. 18, no. 26, pp. 27142 - 27154.
[2] M. Bryushinin, V. Kulikov, I. Sokolov, P. Delaye, G. Pauliat. Optical Society of America, 2014, vol. 31, no. 4, pp. 723 – 729.