# Photo-induced absorption in photorefractive crystals as result of long-living energy levels

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We present investigations of the photoinduced absorption in photorefractive BTO crystals. We explain this effect by the model of several long- and short-living levels. A dynamic model of these levels is also presented. Cw radiation of 514nm, 532nm, 633nm and pulse radiation of 532 nm are used for inducing and controlling of the effect.

## 1 Introduction

Photo-induced absorption is the change of the absorption of light as the result of irradiation. Any influence of the light on the internal structure of the photorefractive crystals, which is connected with the energy redistribution of charge carriers, can change the absorption. The temporal and amplitude behaviour of this effect depends strongly on the energy levels and the relaxation characteristics of the materials. Most of the characteristic effects are often disregarded in the quasi-stationary regimes because of their relatively short lifetime ~ 1-100 ps or weak exposure intensities [1]. But sometimes there are effects with the long lifetimes. This paper presents an experimental investigation of the long-lived photochromic effect (light-induced absorption) in photorefractive $Bi_{12}TiO_{20}$ (BTO) crystals.

## 2 Induced absorption

Under normal conditions of room temperature and without pre-exposure the absorption is coursed only by the excitation of charges from deep levels (deep traps DT) and the valence band (VB) to the conducting band (CB) (fig. 2). The DT can be attributed to the spreading of the VB due to impurities and defects. The population of the DT is coursed e. g. by a stochastic excitation of charges from the VB and is much weaker than the population of the VB. The forbidden band of BTO crystals is approximately 3.1 eV (ca. 400nm) [2]. In our case for an irradiation at 532 nm the excitation of electrons basically takes place from the DT to the CB. If the charges are excited into the CB they can recombine back to the VB and DT as well as to the long-lived intermediate traps (IT). The lifetime of charges in the CB is about 10-100ps [1]. The charges of the long-lived levels can be excited again into the CB by photons with lower energy. A growth of the photo-induced absorption is observed at wavelengths below 900 nm (fig. 1). The photo-induced absorption is connected with the excitation of charges from the intermediate traps (IT) to the CB. There are two long-lived energy levels as the IT in the forbidden band on a depth of 1.6 and 2.6 eV below CB with widths of 0.2 eV and 0.6 eV respectively [3]. A schematic illustration of the long-lived levels is shown in fig.2.

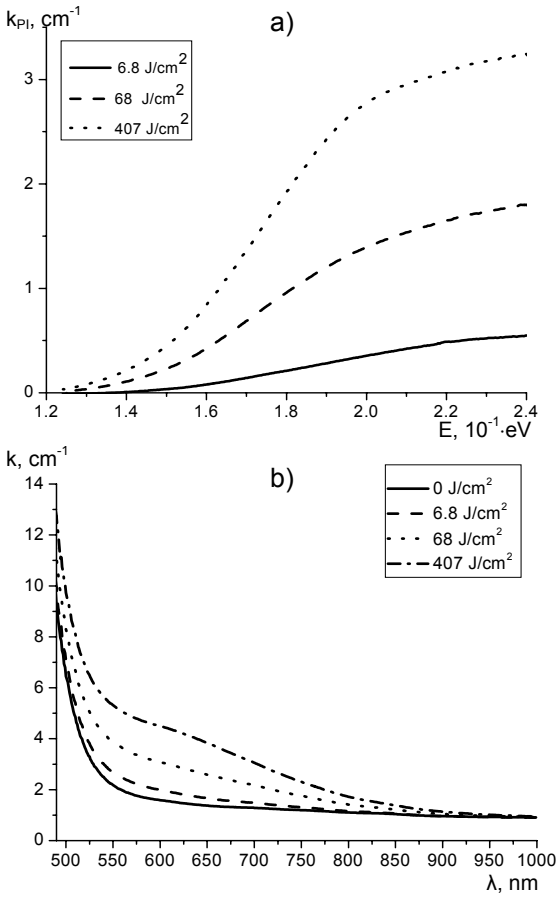


***Fig. 1*** *Dependence of the photo-induced absorption $k_{PI}$ (difference between integral absorption k and initial absorption without exposition $k_0$) on the energy of the photon. b) Dependence of the absorption spectrum of BTO on the total exposed energy. k is the absorption coefficient. The pulse laser was used with an average intensity of 110 mW/cm$^2$ at 532 nm.*

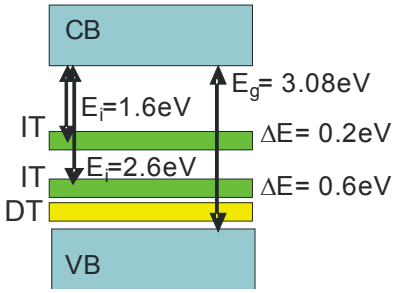


***Fig. 2*** *Scheme of BTO energy levels. VB – valence band, CB – conducting band, $E_g$ – width of the forbidden band, $E_i$ depth of the energy levels connected with the long-lived centres*

## 3 Control of the induced absorption

The relaxation of the photoinduced absorption can be slowed down using cw-radiation with low intensities (fig. 3). If the photo-induced absorption is generated with an intensity of 110 mW/cm$^2$ at 532nm, it is enough to use cw-radiation at the wavelengths 532 nm and 514 nm with low intensities (e. g. 12 mW/cm$^2$ and 15 mW/cm$^2$ correspondingly) to stop the relaxation process and save the spectrum of absorption constant (fig. 3). In such a way it is possible to stop the relaxation at any stage. If one switches off the low cw-radiation, the relaxation process resumes. If the BTO crystal with the recently photo-induced absorption is exposed by cw-radiation at 633 nm with low intensity (e. g. 17 mW/cm$^2$), the relaxation is accelerated and is $10^3$ s (fig. 4) instead of $10^5$ s. If one switches off the low cw-radiation of 633 nm, the relaxation process resumes with the evolution as without previous acceleration. We noted that the low intensity cw-radiation of the wavelengths 514 nm, 532 nm and 633 nm didn't produce enough photo-induced absorption to be experimentally detected. Thus, one can use low intensity expositions at different wavelengths in order to control the photo-induced absorption.

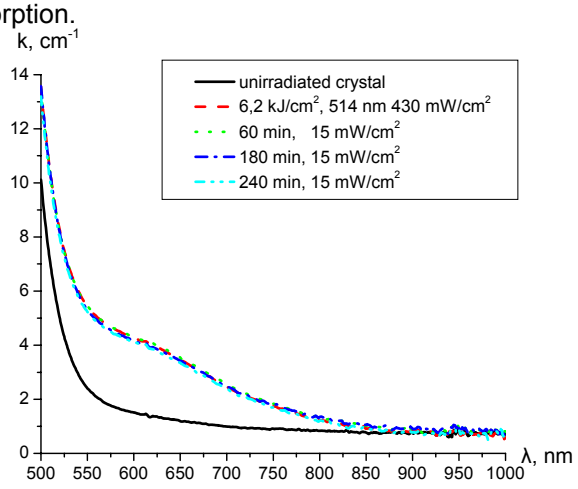


***Fig. 3*** *Influence of the cw-radiation with low intensity 15 mW/cm$^2$ and wavelength 514 nm on changing of the photo-induced absorption of BTO. The absorption is generated by a pulse laser with an average intensity of 110 mW/cm$^2$ at 532 nm*

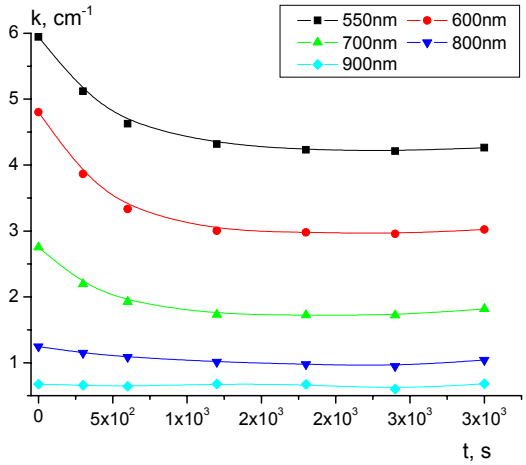


***Fig. 4*** *Example of the dependence of the coefficient of absorption on the time of exposition by a cw-radiation with low intensity 17 mW/cm$^2$ at 633 nm for the given-wavelengths in BTO.*

## References


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