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The Induced Absorption of Photorefractive Crystals BSO

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KEYWORDS

- Photo induced absorption,
- BSO crystals,
- Photorefractive materials,
- Photochromic effect

ABSTRACT

This study aims to calculate the induced absorption coefficient in the photorefractive crystals ($Bi_{12}\,SiO_{20}$). A theoretical model was proposed and by using mathcad14 program the results were obtained .The average of induced absorption coefficient (α) was highest at (420 cm^{-1}). Through using the proposed program, the induced absorption coefficient was found theoretically then compared with the experimental results through different situations. The exciting wavelengths of laser were 530, 500mm. It is noticed that the practical results conforms with the theoretical ones. The induced absorption coefficient increases with the increasing the applied powers. Practically, different laser rays of various wavelength have been focused on the crystal BSO. The spectrometer was used to get the spectrum of each wavelength and then the spectrum of crystal was found without radiation . Using a laser generator (Parametric light generator LT-2215), different wavelengths were obtained (520, 530, 545, 580, 590, 600) nm. The induced absorption coefficient increases when the exciting wavelength decreases, where the influential wavelength was 520nm.

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الامتصاص المحتث في البلورات الكاسرة للضوء BSO

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الكلمات المفتاحية

- الامتصاص المحتث
- بلورة البزموث
- سيلكات اوكسايد
- المواد الكاسرة للضوء
- الظاهرة الفوتولونية

الـــخُـــلاصـــة

في هذا البحث تم حساب معامل الامتصاص المحتث في البلورات الكاسرة للضوء ($Bi_{12}SiO_{20}$) حيث تم اقتراح نموذج نظري ومن خلال استخدام برنامج الماثكاد١٤ تم الحصول على النتائج . ان معامل الامتصاص المحتث (α) الذي تم حسابه يكون اعظم قيمة له (420cm-1) و باستخدام النموذج النظري المقترح فان معامل الامتصاص المحتث تم حسابه نظريا ومقارنته مع النتائج العملية باستخدام قدرات مختلفة عندما كان الطولين الموجين للاشعاع الليزري المحرض 530,500nm حيث لوحظ ان النتائج العملية تتفق مع النتائج النظرية بشكل جيد وان معامل الامتصاص المحتث يزداد مع زيادة القدرات المستخدمة. عمليا تم تسليط اشعة ليزرية ذات اطوال موجية مختلفة على البلورة المستخدمة (BSO) وتم اخذ الطيف لكل طول موجي محرض و في البداية تم اخذ الطيف للبلورة بدون تشعيعها باستخدام جهاز السبيكتروميتر ثم بدأ تشعيعها و باستخدام جهاز مولد النبضات الليزرية (light generator LT-2215 Parametric تم الحصول على اطوال موجية مختلفة(520،530،545،580،590،600)nm . ان معامل الامتصاص المحتث يزداد كلما قل الطول الموجي المستخدم للتحريض حيث كان الطول الموجي الأكثر تاثيرا هو 520nm.

1. Introduction

photochromic effect of crystal of bismuth silicate oxides and crystal of bismuth germanium oxide [16,17]. The experiments that have been conducted on the photoinduced absorption in crystal of bismuth titanium oxide achieved by Kobozev in 1999 [18]. During 2003 Marinova was searched the properties of the induced absorption in the crystal of bismuth titanium oxide inlaid with the ruthenium and studied it in the crystal itself inlaid with the calcium element. Marinova showed that the effect of the impurities on the induced absorption that occurred in the crystal had a time span of numerous hours [19]. The same scientist studied the phenomenon of induced absorption in the plane waves depending on the thin films of the bismuth crystals, silicate oxides, and bismuth titanium oxide coated with copper[20]. In the energy gap of the crystals there are secondary levels which are usually located between the valence band and the conduction band. The installation of these levels depends on the impurities present in the crystals. Essentially induced absorption is influenced by impurity and also influenced by temperature, and this is illustrated by the research work of Martin and Briat [21-23]. There is a phenomenon called photochromic effect resulting from the induced absorption ,in this effect the electrons returns to the levels within the energy gap for the crystal, which has different cross sections [19].

Bismuth silicate oxides crystals consolidate the features of energetic insulation and broad hiatus semiconductors, whose power gap is equal to 3.4eV at a temperature equal to 2.4K [1]. some of the features of these crystals are they have a rapid response to optical refraction within the visual domain [2-5], have good photoelectric properties and rise visual action [6,7]. Bismuth silicate oxides crystals used as wave amplifiers, self-pairing systems, 3D interferometers, optical detectors and other 3D imaging devices [8,9]. It is also used in surface ultrasound [10] and electromagnetic searchlight [11,12]. These crystals are used in the registration, transformation and stock pilling of data [13]. The stimulated absorption of photons that happened in the photorefractive crystal is the outcome of the illumination by laser beams. The effect of radiation on the inner installation of bismuth silicate oxide crystals related to the transfer of the energy of the electrons that affected on absorption of light. The time and expansion of this conduct are greatly influence on the energy levels and properties of the crystals. Extreme properties are often overlooked in semi-stationary experiments due to their low life , when the exposure intensity is weak [14]. In some cases, the induced absorption of different times may extends from seconds to several days. This group of crystals show in the long run, the effects of light absorption that have been studied since the 1990s [15]. In the period from 1991-1993 Martin wrote on practical experiments on the Photochromic effect appears clearly in the photorefractive crystals due to its high sensitivity to radiation laser in the visible spectrum and that the effect of radiation appears at the visible and ultraviolet spectrum on these crystals results in the photochromic effect [24,25]. The resulting spectrum due to the induced absorption has properties based on the type and concentration of impurities and crystalline defects [20,26]. The absorption of the bismuth crystal of silicon oxide was related to the levels of crystal energy gap. The first process that electrons are induced from the valence band to the conduction band then to the levels in the energy gap ,the second process shows that the electrons back to the valence band where the electrons remain at some levels for several hours and the third process the electrons return to the valence [27,28]. Lasers devices that used for the illumination of the crystal typically operate within limit of pico and nano second of pulses laser where spectral properties are obtained [29].

2. Theoretical Calculations

In order to explain the practical results, a theoretical model was proposed, which uses a complex system of energy levels in the prohibited energy gap for bismuth silicate oxides crystals as is clearly shown in figure (1). As is the case, the location and duration of electrons at levels depends on the installation of crystalline defects and the concentration of impurities. In the study of photoinduced absorption the focus was on the induction and resettlement of electrons. The photon absorber phenomenon was induced by the induction of electrons from the valence band and its transition to the conduction band and then back to the levels of the energy gap called the traps. The energy gap width is equal to 3.4eV, so there is no direct transmission of the electrons from the valence band .This requires increasing the power of the laser radiation. We can use different types of theoretical models to validate the practical results. Here we used the four-level model, Figure (1) represents levels of energy in the crystal.

The equations used to find the absorption coefficient were solved by the mathcad14 program are given by following.

$$\frac{\partial}{\partial t}N_0 = (I_1)^2B + N_1I_1S_1 + N_2I_1S_2 - R_{41}N_0(N_1 + N_2 + N_3) - R_{43}N_0(M_3 - N_1) \quad ..(1)$$

$$\frac{\partial}{\partial t}N_1 = -N_1I_1S_1 + R_{43}N_0(M_3 - N_1) - R_{32}N_1(M_2 - N_2) - R_{31}N_1(N_1 + N_2 + N_0) \quad ..(2)$$

$$\frac{\partial}{\partial t}N_2 = -N_2I_1S_2 + R_{32}N_1(M_2 - N_2) - R_{21}N_2(N_1 + N_2 + N_0) \quad ..(3)$$

The equation by which the photinduced absorption coefficient was found are given as following:

$$\alpha := \frac{h\omega(N_1S_1 + S_2N_2)}{2\pi} \quad ....(4)$$

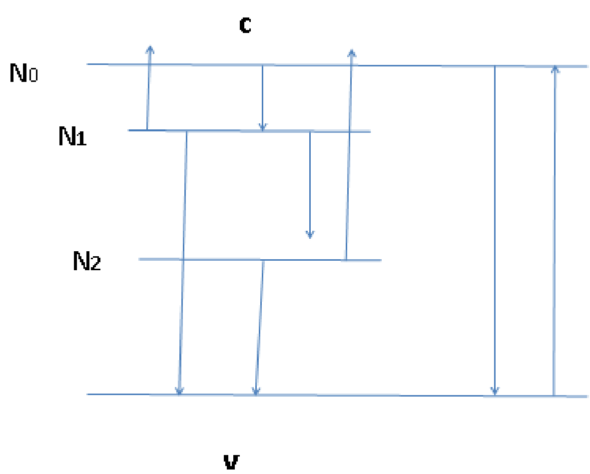

Figure (1) Energy levels in the bismuth silicate oxide crystal ($Bi_{12}SiO_{20}$)

Where N_0 is the concentration of electrons in the conduction band, N_1, N_2 the concentration of electrons in the levels of the traps in the forbidden gap ,M_2 and M_3 represent the total concentration of the levels. B represents the absorption factor for two photons, S_2, and S_1 representing the cross sections of ionization at the levels (traps) in the forbidden gap.R_{41}, R_{43}, R_{32}, R_{31} and R_{21} represent the coefficient of localization of electrons and gaps in energy levels, while I_1 represents the intensity. Theoretical calculations obtained using numerical analysis by the mathcad program to distribute electrons in the conduction band and the levels (traps) in the forbidden gap of bismuth silicate oxides crystal were shown in figure (2). The values used for the coefficients were as follows: S_2 = 48.5, S_1 = 98.99, B =9898.102, $R_{32} = 3.10^{-3}$, $R_{31} = 10^{-3}$, $R_{21} = 10^{-4}$, $R_{43} = 3.10^{-6}$, $R_{41} = 10^{-7}$. Figure 2a shows the time-induced absorption coefficient. When the time is 100s, the highest absorption coefficient records 420cm^{-1}. This means that the irradiation power is high which the photoinduced absorption to begin to descend and then returns and stabilizes at 290. It is clear that the absorption in the bismuth silicate oxide crystal increases by increasing the intensity of the radiation. The change in the concentration of electrons in the conduction band under the effect of the irradiated radiation exposed to the crystal was shown in figure2b where the increase in concentration was observed over time. The contribution of the concentration of electrons at the levels in the forbidden energy gap and their effect on the induced absorption was shown in figure 2c and 2d. From these two figures we can observe a kind of stability of the concentration of electrons in these two levels.

This indicates that the electrons remain of the mentioned levels for a period of time, where we observe from figure 2c that they increase and stabilize them, while from figure 2d we can notice the increase of concentration of electrons and then their decrease and stability. The proposed theoretical model involved the absorption of one photon from the secondary level in the forbidden gap , the absorption of two photons from the valence band and transition to the conduction band. This model shows the dependence of absorption coefficient on the powers used for exposure crystal and on the wavelengths used to excite electrons at energy levels. Figure 3 shows the calculation of the absorption coefficient theoretically using different wavelengths and using different irradiation powers. The connected line shows the theoretical calculation of the absorption coefficient using wavelengths of 520nm and 500nm while the points represent the practical calculation of absorption in the crystal. The absorption coefficient increased by increasing the radiation power and decreasing the wavelength used in irradiation, this agreed with equation 4 above.

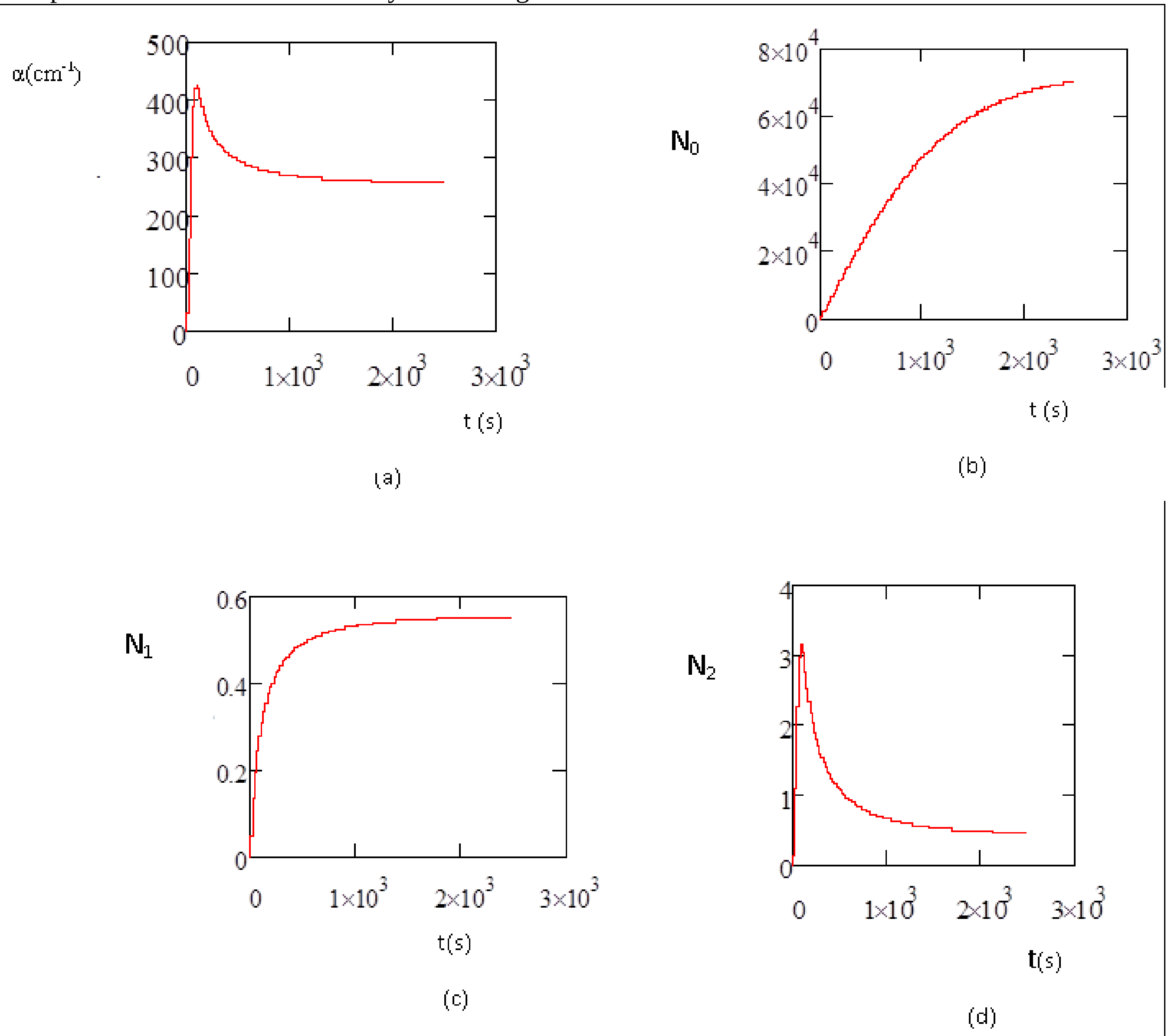

Figure (2): The photoinduced absorption coefficient in bismuth silicate oxides crystal with time (a), the concentration of electrons N_0 with time in the conduction band (b), the concentration of electrons N_1 with time at the level in the forbidden gap near the conduction band (c) Concentration of electrons N_2 with time at the level in the forbidden gap near the valence band (d).

effective optical absorption of crystals with an edge absorption of 403nm. The laser dose was 500J / cm^2 and at all irradiation stage the exciting wavelength was changing with the

same as the average power of the radiation was 8mW. The absorption spectra were recorded on the spectrometer device. The induced absorption was determined by the difference between the crystal spectra before and after the irradiation. From figure 4 and figure 5 we can notice that the absorption spectra at that irradiation with different wavelengths varies from 450nm to 1000nm.

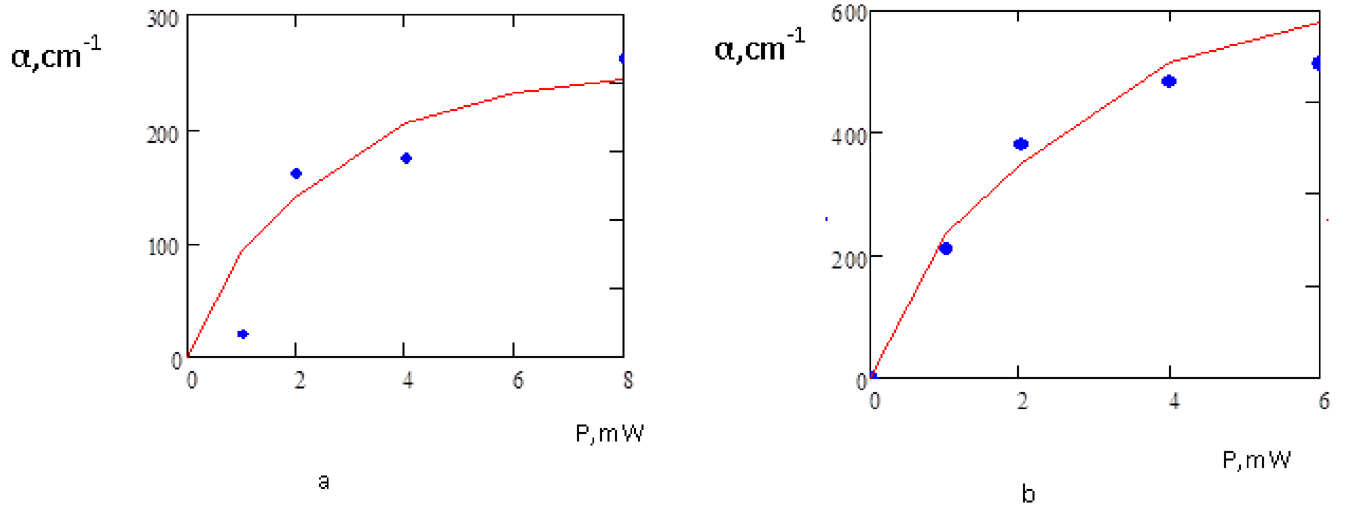

Figure (3): Absorption coefficient of bismuth silicate oxides crystal with the powers (a) radiation wavelength530nm (b) radiation wavelength 500nm.

3. Experimental Results

To study photoinduced absorption, pure bismuth silicate oxides crystal was used, which has high sensitivity properties in the visible region of the spectrum. The thickness of crystal was 2mm, for crystal irradiation was used the parametric laser pulse generator which pumps light through third harmonic of the laser Ndium Yac. The pulse width was 10ns and the spectral width is less than 1 nm. The frequency used was 10Hz and the pulse energy ranges from 1 to 10mJ depending on the wavelength generated. To ensure smooth homogenization for illumination of crystal, a diaphragm was used with a 2 mm hole. The laser pulse generator was manufactured so that the wavelength changes smoothly from 410nm to 2150nm, providing for comparison purposes ,from figure 4a, we observe that the value of the induced absorption is 2.9 when the wavelength is 520nm and becomes low when the exciting wavelength is 600nm, where it is 1.8 and so for figure 4b when the exciting wavelength is 530nm its effect becomes apparent on the induced absorption in the crystal more than with the wavelength 545nm. The photoinduced absorption coefficient(α) continues to decrease significantly when the exciting wavelength was increased. This can be seen from figure 5a when the exciting wavelengths are 580,590nm. It is also possible to observe that the effect of these two wavelengths on the photoinduced absorption process is almost identical. The absorption volume caused by the difference between crystal spectra before and after irradiation can be clearly seen in figure 5b.

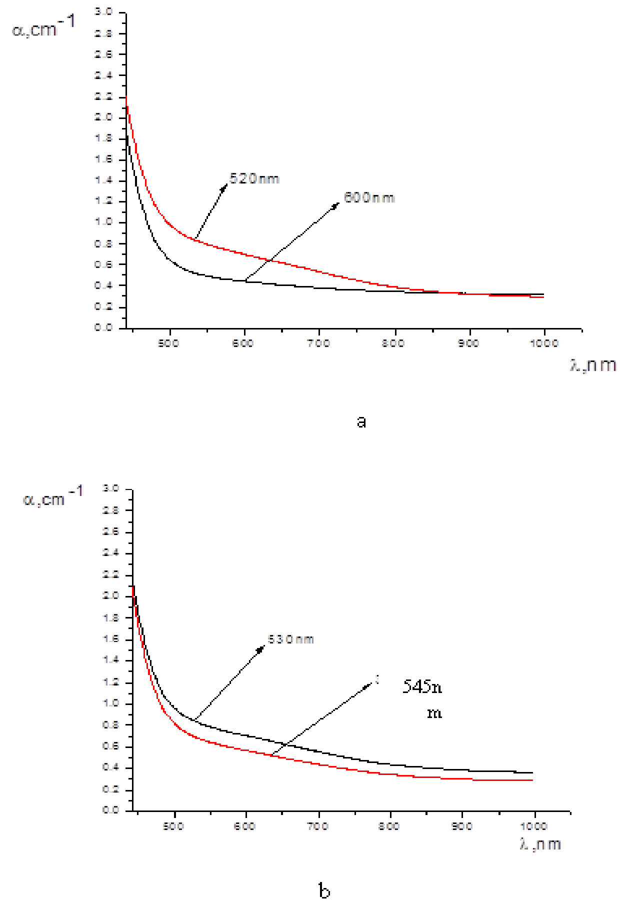

Figure (4): Absorption coefficient for BSO crystal when irradiated by wavelengths (a)520nm, 600nm, (b)530nm, 545nm.

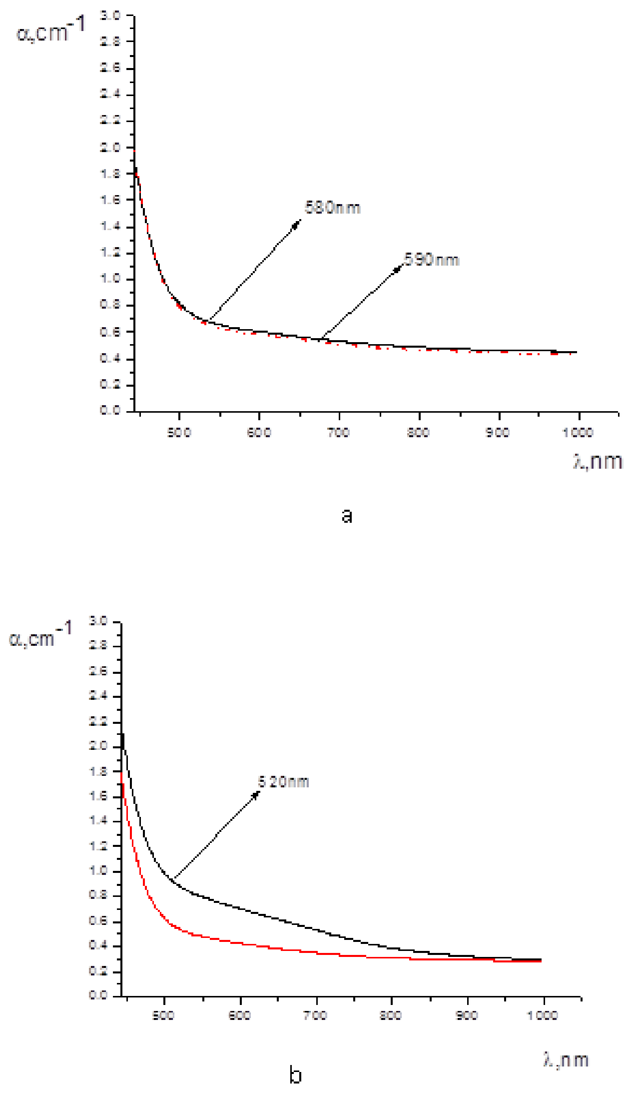

Figure (5): Absorption coefficient for BSO crystal when irradiated by wavelengths (a)580nm, 590nm, (b)520nm.

The proposed theoretical model involves the absorption of one photon from the

secondary levels defined in the forbidden gap, while absorbing two photons from the valence band to the conduction band. From the results obtained, it is clear that irradiation using 590,580nm wavelengths has a very close effect on the photoinduced absorption coefficient. This shows that increasing the wavelength value of more than these two exciting wavelengths would not affect the induced absorption process

4. Conclusions

The absorption coefficient of the $Bi_{12}\ SiO_{20}$ was increased by increasing the power of the radiation with the same wavelength used for irradiation. This has been proven practically and theoretically using the wavelengths of 500nm and 530nm. The photo induced absorption decreases as the exciting wavelength increases.

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