The study of nonlinear optical properties of rhodamine B dye and TiO_2 nanoparticles doped in PMMA polymer

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Abstract

In this research, A thin film of Rhodamine B dye and TiO_2 Nanoparticles doped in PMMA Polymer has been prepared by a casting method. The sample was spectrum absorption by UV-Vis. The nonlinear optical properties were measured by Z- scan technique using Nd:YAG laser with (1064 nm) wavelength. The nonlinear refractive index (n_2) and nonlinear absorption coefficient (β) were estimated for the thin film for different energies of the laser, n_2 and β were decreased with increasing intensity of incident laser beam. Also, the type of β was two-photon absorption and n_2 negative nonlinear reflective.

Key words

Rhodamine B dye, TiO_2, nonlinear optical properties.

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دراسة الخواص الضوئية اللاخطية لصبغة رودامين وجزيئات التيتانيا النانومترية المشوبة لبوليمر البولي مثيل ميثا أكريليت

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الخلاصة

تم في هذا البحث تحضير غشاء رقيق من البوليمر PMMA المشاب بصبغة الرودامين B ودقائق نانويه من المركب TiO_2 (ثاني اوكسيد التيتانيوم). وقد تم قياس اطياف الامتصاص باستخدام مطياف المدى المرئي – فوق البنفسجي (UV-Vis). كما تم قياس الخواص البصرية واللاخطية باستخدام تقنية المسح على المحور الثالث Z- scan بواسطة ليزر نيديميوم – ياك ذا الطول الموجي 1064 nm. حيث تبين منها وجود معامل انكسار لاخطي (n_2) ومعامل امتصاص لاخطي (β) في الغشاء تحت الدراسه ولطاقات مختلفة من شعاع الليزر. وقد انخفضت قيمتا n_2 و β مع زيادة شدة شعاع الليزر المستخدم. كما اتضح ان β من ذوات امتصاص فوتونين وان n_2 من ذوات معامل الانكسار اللاخطي السالب.

Introduction

Rhodamine B dye belongs to the xanthine family. It is one of the most commonly used in various spectroscopic Studies [1]. Poly (methyl methane acrylates) are polymers of the esters of methacrylic acids. It is commonly called acrylic glass or simply acrylic [2]. The oxide nanoparticles synthesized by several methods appears more and more useful because these nanoparticles have good electrical, optical and magnetic properties that are different from their bulk counterparts [3]. Titania nanoparticles have received much interest for applications such asoptical devices, sensors, and photocatalysis [4, 5]. Incorporating dye molecules into solid matrices have resulted in significant advances towards the development of practical tunable solid-state lasers. The use of a synthetic polymer host presents advantages as

these materials show much better compatibility with organic laser dyes and are amenable to inexpensive fabrication techniques. These polymers provide an opportunity for the production of active elements that can effectively control the characteristics of laser radiation. [6]. Dye-doped polymers find applications in the fields of modern photonic technology apart from its use as an alternative to solid state laser media. [7]. The Z-scan technique is a simple, sensitive and popular experimental method to measure nonlinear optical prosperities (NLO) of materials. There are two parts of the Z-scan: closed aperture and open aperture. Closed aperture Z-scan helps to measure the sign and magnitude of both real & imaginary part of reverse saturable absorption (RSA) depending on the pump intensity and on the absorption cross section at the excitation wavelength [8]. Open aperture Z-scan helps to measure the nonlinear absorption coefficient ß2.

Materials and methods

All materials used without further purification. Rhodamine B supplied from Lambda Physik and used withoutfurther purification, Polymethacrylate (PMMA) from ICI company. The solvent used was Chloroform: From Lab-Scan Ltd. Analytical Sciences HPLC, Dublin Ireland. Titanium dioxide (Tio_2) from Aldrich nanopowder 25 nm particle size (99.7%) trace metals basis Sample. The Rhodamine B dye/ Tio_2 nanoparticles /PMMA film was made by casting block method. The solution of the polymer was prepared by dissolving 7gm PMMA polymer in 100ml of chloroform solvent. The compound added to the Rhodamine B dye solution of concentration $1x10^{-4}$ mol/liter. The percentage weight of Tio_2 nanoparticles powder (0.1) wt% was added separately and stirred by a magnetic stirrer at room temperature to get a uniform mixture. UV-vis absorption spectrum was recorded using a SHIMADZU UV-1800 spectrophotometer. UV-Vis absorption solution was measured in a 3 mL quartz cuvette over wavelength range 190-1100 nm.

The nonlinear optical properties of RB Dye and TiO_2 Nanoparticles Doped in PMMA Polymer were investigated by using a Z-scan technique which is a sensitive and convenient method. The nonlinear absorption can be revealed by the study of the transmittance of the open aperture Z-scan experiment, and the nonlinear refraction can be revealed by dividing transmittance of the closed aperture Z-scan by that of the open aperture. The open and closed aperture Z-scan can be performed simultaneously. A home built Q-switched Nd: YAG laser with 30 ns pulse duration and was focused by a lens with focal length of 5 cm for different energies (131, 141,150 mJ).

Results and discussion

A. Characterization of the sample

Fig.1 shows the absorption spectrum of RB Dye and TiO_2 Nanoparticles Doped in PMMA Polymer. The absorption peak as can be shown is in the UV-visible range.

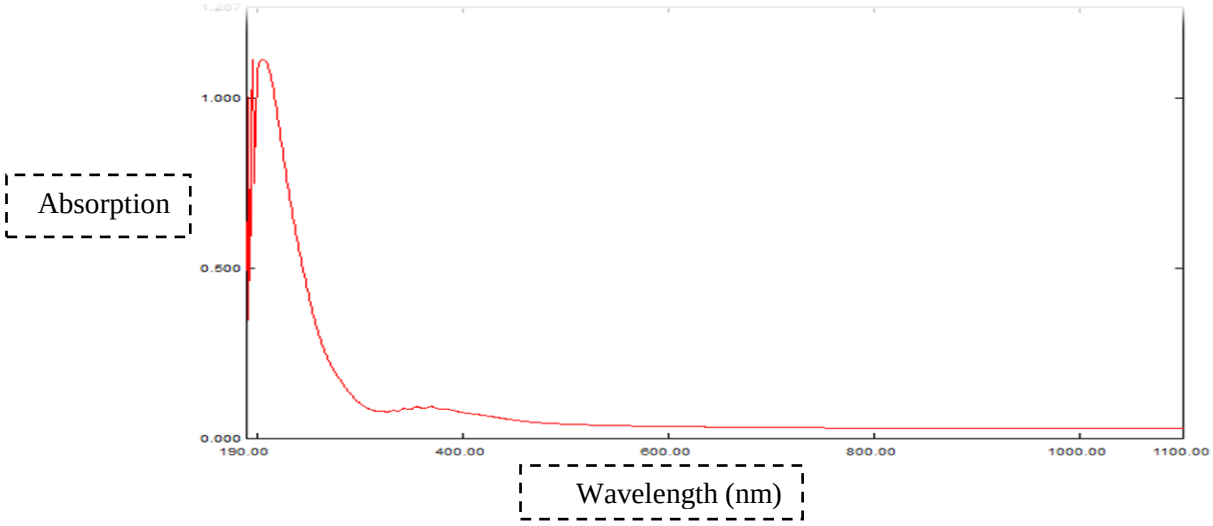

Fig. 1: UV-Vis absorption spectrum of RB dye and TiO_2 Nanoparticles Doped in PMMA polymer.

B. Nonlinear optical properties of RB dye and TiO_2 nanoparticles doped in PMMA polymer

The RB dye and TiO_2 nanoparticles doped in PMMA polymer casting method. The linear transmittance of the RB dye and TiO_2 nanoparticles doped in PMMA Polymer was 82.948 % at 1064 nm wave length. The transmittance is decreased when the sample moves even closer to the focal point, a curve with symmetrical valley and two humps are presented as shown in Fig.2 which shows the results of the Z-scan experiment at energies of (131, 141, 150mJ).

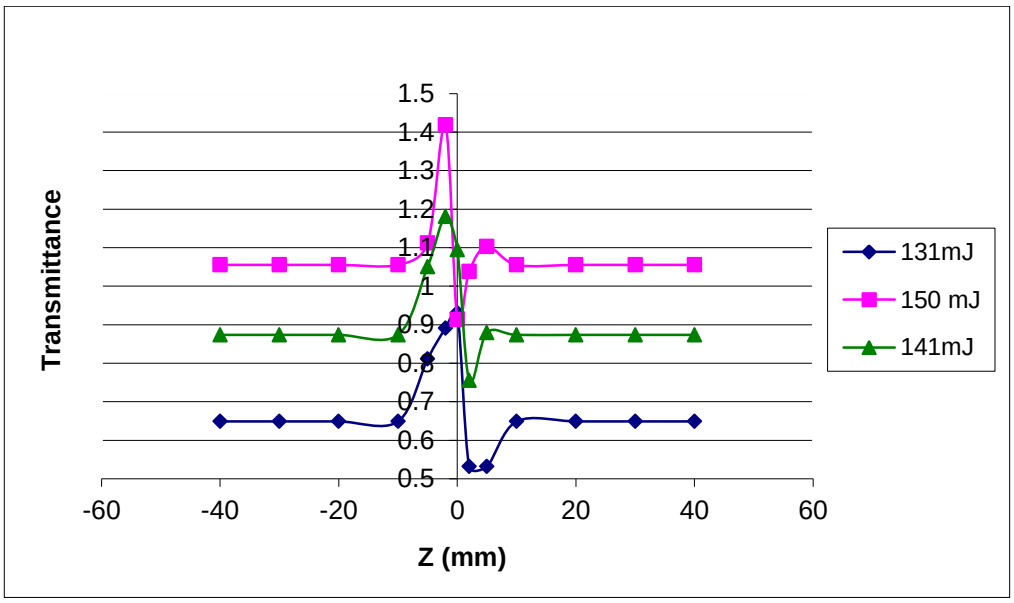

Fig. 2: Closed-aperture of sample for (131, 141 and 150) mJ at 1064nm.

For closed Z-scan of the thin films for different energies, we can observe the negative nonlinear refractive index. The figure shows all the film behaviors were self-defocusing NLR.

As seen from figures the transmittance of all samples were enhanced with increasing the intensity. Due to at the intensity increases, the population of electrons saturates the conduction band

thus blocking further excitation from valance band, hence transmission through the sample increases [9].
The nonlinear absorption coefficients β of the thin films were measured by performing the open aperture z-Scan technique. β is related to the imaginary part of the third-order optical susceptibility $\chi^{(3)}$. Open aperture-Scan that performed in this study exhibited a reduction in the transmission about the focus of the lens.

The transmittance curves ofthe thin films at different energies of 1064 nm are shown in Fig. 3. The behavior of transmittance started linearly at different distances from the far field of the sample position (-Z). At the near field, the transmittance curve begins to decrease until it reaches the minimum value (T_{min}) at the focal point, where Z=0 mm. The transmittance begins to increase with the linear behavior at the far field of the sample position (+Z).

The transmittance behavior of all previous figures are started linearly when the sample is located far from the beam waist, where the beam intensity is low; the transmission through the aperture is normalized to unity. As the sample is shifted closer to the waist, the induced nonlinear absorption and the transmittance curve begins to decrease until it reaches the minimum value (T_{min}) at the focal point, where Z=0 mm. Afterward, the transmittance begins to increase the linear behavior at the far field of the waist. In the open-aperture z-Scan, the nonlinear behavior of the transmission curves in good agreement with the result reported by Z.S.Sadik et al., Rawaa A. Farisand Zainab F. ALBawi [9, 10, 11]. In the focal plane where the intensity is greatest, the largest nonlinear absorption is observed.

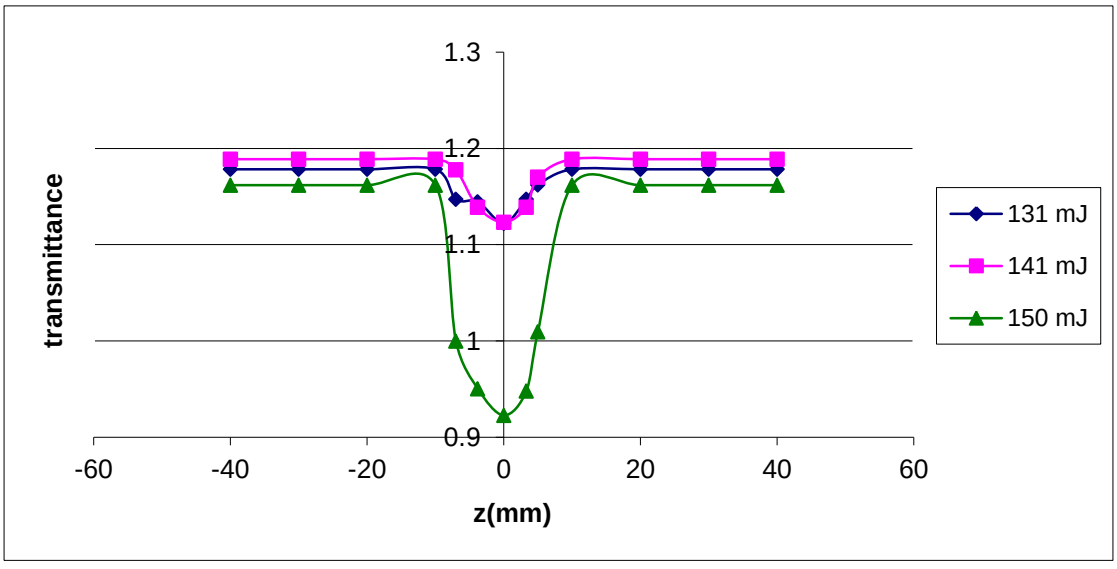

Fig .3: Open-aperture of a thin film for (131, 141 and 150) mJ at 1064 nm.

The open aperture indicates that the nonlinear absorption of the sample is two-photon absorption with different energies. From previous figures, the nonlinear absorption coefficient and nonlinear refractive indices can be estimated as tabled in the Table 1.

Table 1: The nonlinear refractive index and nonlinear absorption coefficient.

Energy mJ	n_2	*B*
131	0.10	7013.79
141	0.14	7896.195
150	0.42	10354.24

Conclusions

The nonlinear optical properties for the Rhodamine B dye doped PMMA with TiO_2 nanoparticles was studied by Z-scan technique using Nd: YAG laser at 1064 nm. The nonlinear absorption coefficient can be attributed two-photon absorption while nonlinear refractive index leads to self – defocusing in this film. And it found that the film can be active medium as dye lasers.

References

[1] N. K. M. Naga Srinivas, S. Venugopal Rao, D. Narayana Rao, J. Opt. Soc. Am. B 20, 12 (2003) 2470-2479.

[2] Harper, Charles A., "Handbook of Plastic Processes", John Wiley & Sons, 2005.

[3] H. Xu, X. Wang, L. Zhang, Powder Technol., 185 (2008) 176.

[4] O. Harizanov and A. Harizanova, Sol. Energy Mater. Sol. Cells, 63 (2000) 185.

[5] B. Li, X. Wang, M. Yan, L. Li, Mater. Chem. Phys., 78 (2002) 184.

[6] Achamma Kurian, Nibu A George, Binoy Paul, Paul, V. P. N. Nampoori, C. P. G. Vallabhan, Technique Laser Chemistry, 20 (2-4) (2002) 99–110.

[7] Sally A. Swanson, Greg M. Wallraff, Jian P. Chen, Weijie Zhang, Luisa D. Bozano, Kenneth R. Carter, Jesse R. Salem, Reymundo Villa, J. Campbell Scott, Chem. Mater, 15 (2003) 2305-2312.

[8] Steven Richard Vigil, "Nonlinear-Optical Studies Of Organic Liquids and Polymer Optical Fibers", Ph.D. Thesis, Washington State University, 2000.

[9] Zainb S. Sadik, Dhia H. Al-Amiedy, Amal F. Jaffar, Advances in Materials Physics and Chemistry, 2 (2012) 43-49.

[10] Rawaa A. Faris, Iraqi Journal of Physics, 11, 22 (2013) 64-71.

[11] Zainab F. Al-Bawi, Iraqi J. Laser, 9, 2 (2010) 9-14.

[12] Zainab F. Mahdi, Ahmed A. Ali, Iraqi Journal of Physics, 10, 19 (2012) 54-69.