Study of the optical properties R6G doped polymer PVA for different thicknesses

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الخلاصة

يهدف هذا البحث الى دراسة الخواص البصرية الخطية واللاخطية لصبغة الرودامين الليزرية في مذيب الميثانول لمختلف الاسماك من الصبغة والبوليمر (2, 4, 6, 8, 10, 29 مايكرومتر) في تركيز 1×10^{-6} مول/ لتر. وتم دراسة الخواص البصرية اللاخطية مثل معامل الانكسار اللاخطي ومعامل الامتصاص اللاخطي باستعمال تقنيه المسح على المحور الثالث في جزءين، الجزء الاول وضع فتحه امام الكاشف (الفتحة المغلقة) لايجاد معامل الانكسار اللاخطي، والجزء الثاني رفع الفتحة (الفتحة المفتوحة) لايجاد معامل الامتصاص اللاخطي، واستخدم طولين موجيين (532,1064) نانومتر.

الكلمات المفتاحية

الخواص البصرية الخطية واللاخطية لصبغة الرودامين، معامل الإنكسار الخطي واللاخطي، تقنية المسح على المحور الثالث، الفتحة المغلقة، الفتحة المفتوحة.

Abstract

This paper is aimed to study linear and nonlinear optical properties of polymer doped with laser dye R6G in solvent methanol of different thickness (2, 4, 6, 8, 10, 29 µm) in concentration ($1x10^{-6}$ mole/liter).

To study non-linear optical properties as refractive index (and absorption coefficient (β) by using Z-Scan technique in two parts, one part put aperture in front of the detector (close aperture) to find the non-linear refractive index, in second part remove the aperture (open aperture) to find non-linear absorption coefficient, and using two wavelength 532, 1064 nm.

Keyword

linear and nonlinear optical properties, dye R6G, non-linear refractive index, Z-Scan technique.

1. Introduction

Nonlinear optics is the interaction of light with materials. In the discovery of lasers with high intensity when they fall on the middle transparent there is a change in the optical properties such as refractive index, absorption, polarization, and this is called nonlinear properties [1]. To study the non-linear optical properties by using the simplest method is called Z-Scan technique a simple experiment and a sensitive method for measuring the sign and magnitude of the non-linear refraction and non - linear absorption for solids and liquids is Z-Scan technique developed by Sheik-Bahae et. al. in 1989 [2]. The data of experimental were recorded gradually through moving simple alone axis (z) and measuring the transmission of the samples in each position (z) [3], as shown in Fig.(1) [4].

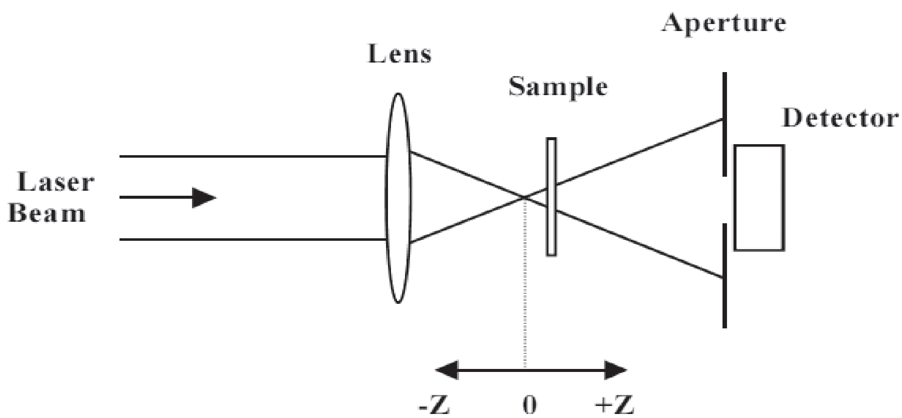

Fig.(1): Z-Scan set up There are two types of Z-Scan technique close aperture to calculate the non-linear refractive index in Fig.(2)

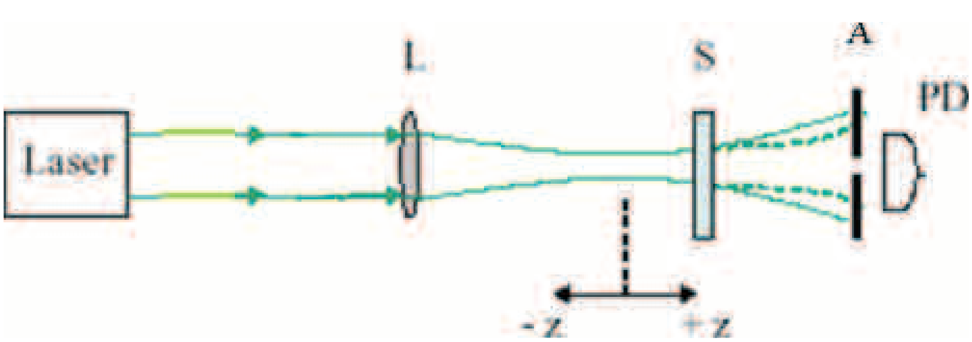

Fig.(2): Z-Scan technique close aperture [2]

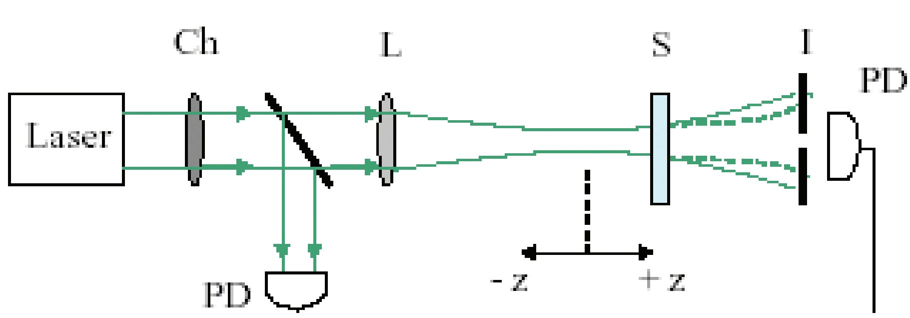

Fig.(3): Z-Scan technique open aperture [5]

And open aperture to determine the absorption coefficient in Fig.(3)

The rhodamines are based structurally on xanthenes [6] and the wavelength region (500-700 nm) and are generally efficient [7], R6G chloride have a high efficiency when used as an effective media in dye lasers, R6G chloride is a red powder has chemical formula C_{27} H_{29} CLN $2O_3$ with highly soluble and has characteristic molar mass (479.02 g/mole), the structure of R6G is shown in Fig.(4).

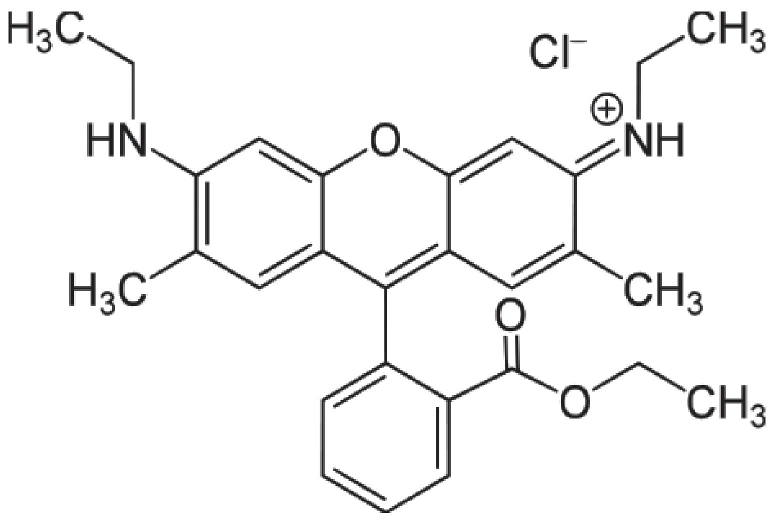

Fig.(4): the structure of R6G

Polyvinyl alcohol (PVA) is important polymeric materials and has many properties such as relative low cost, dielectric material and good charge storage capacity [8, 9], the structure of PVA in Fig.(5).

Table (1): Properties of PVA [11]

Appearance	White powder
Melting point	230
T g (dry film)	(75-85)
Stability to sunlight	Excellent

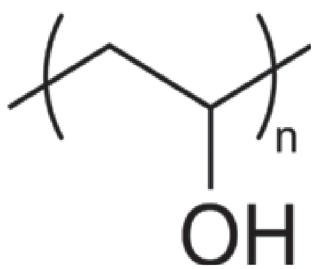

Fig.(5) polyvinyl alcohol [10]

2. Experimental

2. 1. Sample preparation

The powder of R6G dye is accurately weighted.

Solutions of concentrations ($1x10^{-4}$, $5x10^{-4}$, $1x10^{-5}$, $1x10^{-6}$ and $5x10^{-6}$ mole/liter) in methanol solvent were prepared by

$$w = \frac{Mw*V*C}{1000} \text{……….. (1)}$$

where

W: weight of the dissolved dye (gm)

Mw: molecular weight of the dye (479. 02 gm/mol)

V: the volume of the solvent (ml)

C: the dye concentration (mol/l)

The prepared solutions were diluted according to the following equation:

$$C_1 \chi V_1 = C_2 \chi V_2 \text{……….. (2)}$$

where

C_1: primary concentration

C_2: new concentration

V_1: the volume before dilution

V_2: the volume after dilution

Dye R6G doped polymer PVA

Dye doped polymer films were fabricated by casting method, the solution of the polymer is prepared by dissolving the amount of polymer (0. 7 gm in 10 ml of water solvent).

2. 2. Results and discussions:

To study the linear and nonlinear optical properties of the R6G and PVA films of different thicknesses.

2. 3. Spectra of absorption and fluorescence:

The Spectra of absorption and fluorescence for films R6G and PVA in methanol for different thickness (2, 4, 6, 8, 10, 29 μm) of the polymer ($1x10^{-6}$ mole/liter) concentration are shown in Fig.(6) and Fig.(7).

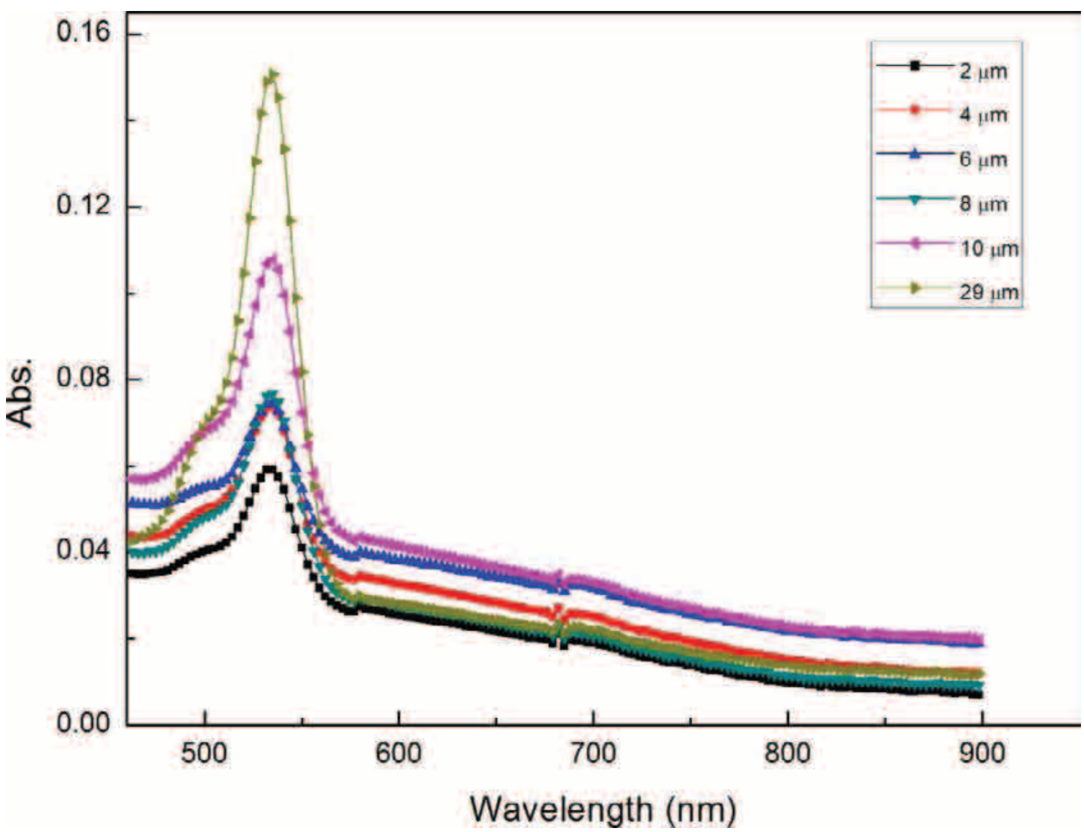

Fig.(6): spectra of Absorption for different thickness

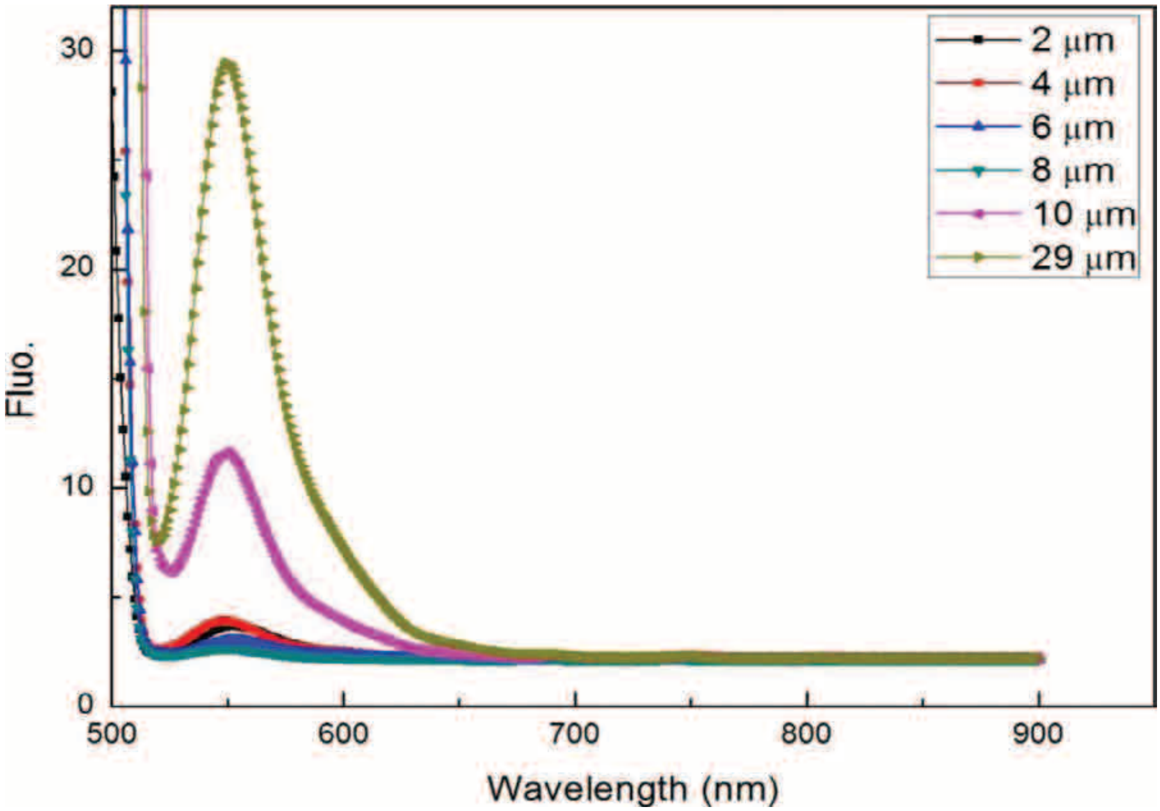

Fig.(7): spectra of Fluorescence for different thickness

2. 4. Linear 0ptical properties:

The linear absorption coefficient of R6G and PVA was determined for both wave lengths using the formulae [12].

$$\alpha_0 = \frac{1}{t} ln \frac{1}{T} .... (3)$$

Where (t) is the thickness of sample and T is the transmittance, and the extinction coefficient is obtained interns of the absorption coefficient,

$$K = \frac{\lambda \alpha_0}{4\pi} .... (4)$$

Table (2): Linear optical properties for R6G and PVA in different thickness and concentration (1x10-6 mole/liter).

t (µm)	T% 532 nm	α_0 cm^{-1}	n	T% 1064 nm	α_0 cm^{-1}	n	K × 10^{-7} 532 nm	K × 10^{-7} 1064 nm
2	87. 2634	681. 2	1. 7056	99. 689	15. 57	1. 0822	28853. 38	1318. 99
4	84. 4413	422. 78	1. 8187	99. 212	19. 78	1. 1342	17907. 56	1675. 63
6	84. 2724	285. 2	1. 8254	98. 915	18. 18	1. 1595	12080. 13	1540. 09
8	83. 913	219. 24	1. 8399	98. 689	16. 49	1. 1768	9286. 28	1396. 92
10	78. 1746	246. 23	2. 0769	98. 435	15. 77	1. 1949	10429. 49	1335. 93
29	70. 9455	118. 36	2. 4029	97. 714	7. 97	1. 241	5013. 34	675. 17

2. 5. Nonlinear optical properties:

Z-Scan technique close aperture to determine the T_p and T_v

Where T_p is the maximum transmittance and T_v is the minimum transmittance

The non-linear refractive index was measured by the formula [13]

$n_2 = \Delta\O_0 / I_0 L_{eff} k$……….. (5)

where $\Delta\O_0 = \Delta T_{p\text{-}v} / 0.406$. ……….. (6)

Where $\Delta\O_0$ is the nonlinear phase shift

$\Delta T_{P\text{-}V} = T_P - T_V$……….. (7) [13]

$k = \frac{2\pi}{\lambda}$……….. (8)

$I_0 = 2p / \pi w_0^2$……….. (9) [14]

I_0 is intensity of th laser beam at the focus (Z = 0)

P: power of laser beam

W_0: the beam radius at the focal point

$L_{eff} = (1 - exp^{-\alpha_0 t}) / \alpha_0$……….. (10) [13], L_{eff}:the effective length of the sample, t: is the sample thickness, α: linear absorption coefficient.

from the open aperture Z-scan data, the nonlinear absorption coefficient is estimated [13]

$\beta = \frac{2\sqrt{2}}{I L_{eff}} \Delta T$……….. (11)

Where ΔT is the one peak value at the open aperture Z-scan curve.

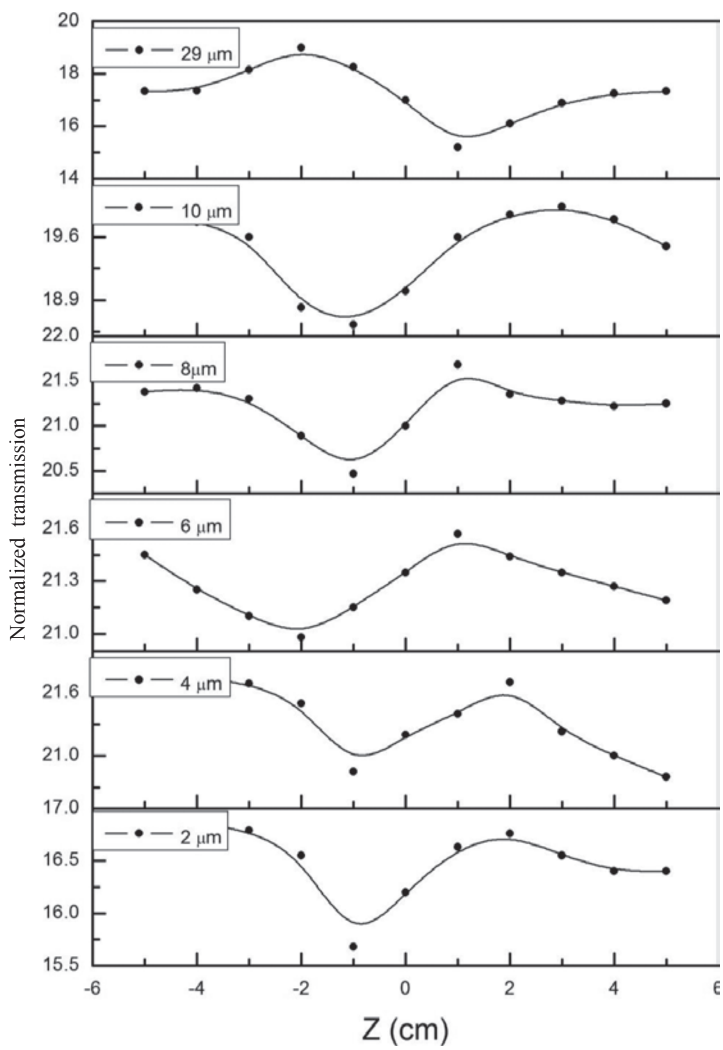

Fig.(8): Closed aperture Z-Scan for R6G and PVA in wavelength 532 nm in different thickness and concentration (1x10^{-6} mole/liter).

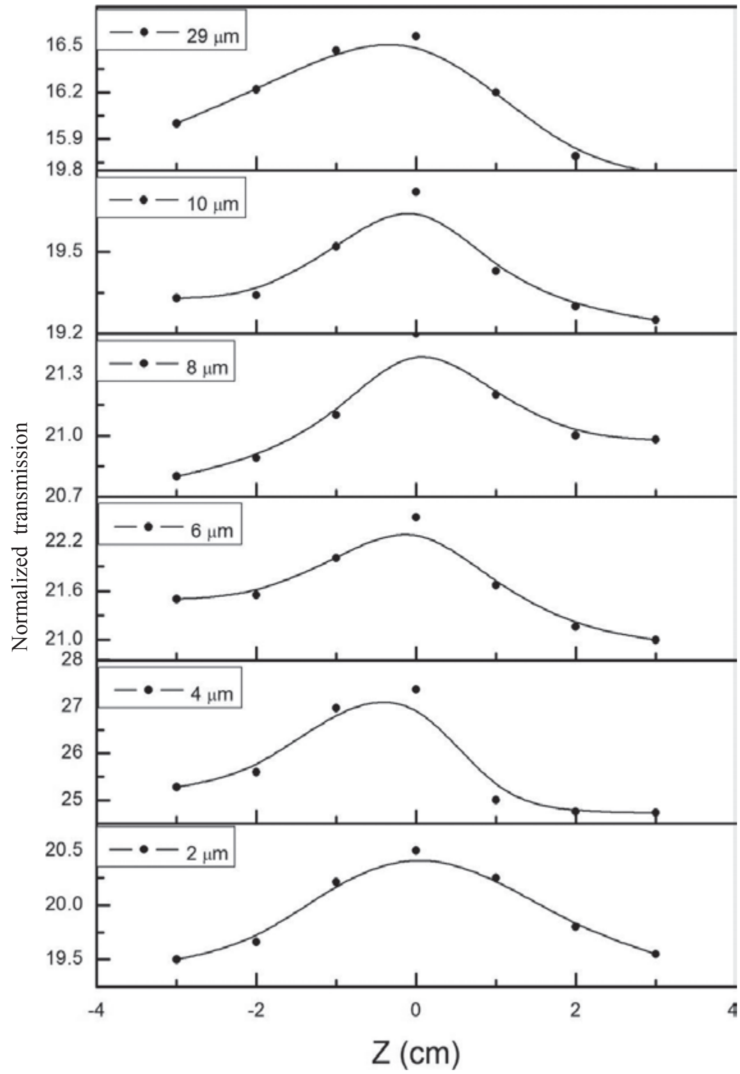

Fig.(9): Open aperture Z-Scan for R6G and PVA in wavelength 532 nm in different thickness and concentration (1x10^{-6} mole/liter).

Case 1: In $\lambda = 532$ nm and $I_0 = 49.147 \times 10^3\ mW/cm^2$

Table (3): The results of nonlinear optical properties for R6G and PVA by the Z- scan.

t(μm)	$\Delta T_{P\text{-}V}$	ΔØ (Rad)	$n_2(\frac{cm^2}{mw}) \times 10^{-7}$	T_{max}	$\beta\ (\frac{cm^2}{mw})$
2	1. 08	2. 66	24. 52	20. 5	6. 3
4	0. 85	2. 09	9. 79	27. 37	4. 3
6	0. 59	1. 45	4. 5	22. 5	2. 3
8	1. 21	2. 98	7	21. 5	1. 7
10	1. 31	3. 23	6. 28	19. 72	1. 3
29	4	9. 85	6. 9	16. 56	0. 388

From this Table it can be shown that higher nonlinear refractive index (n_2) obtained when the thickness is (2μm), we also note that the non-linear absorption coefficient (β) increases with the decreasing of the thicknesses.

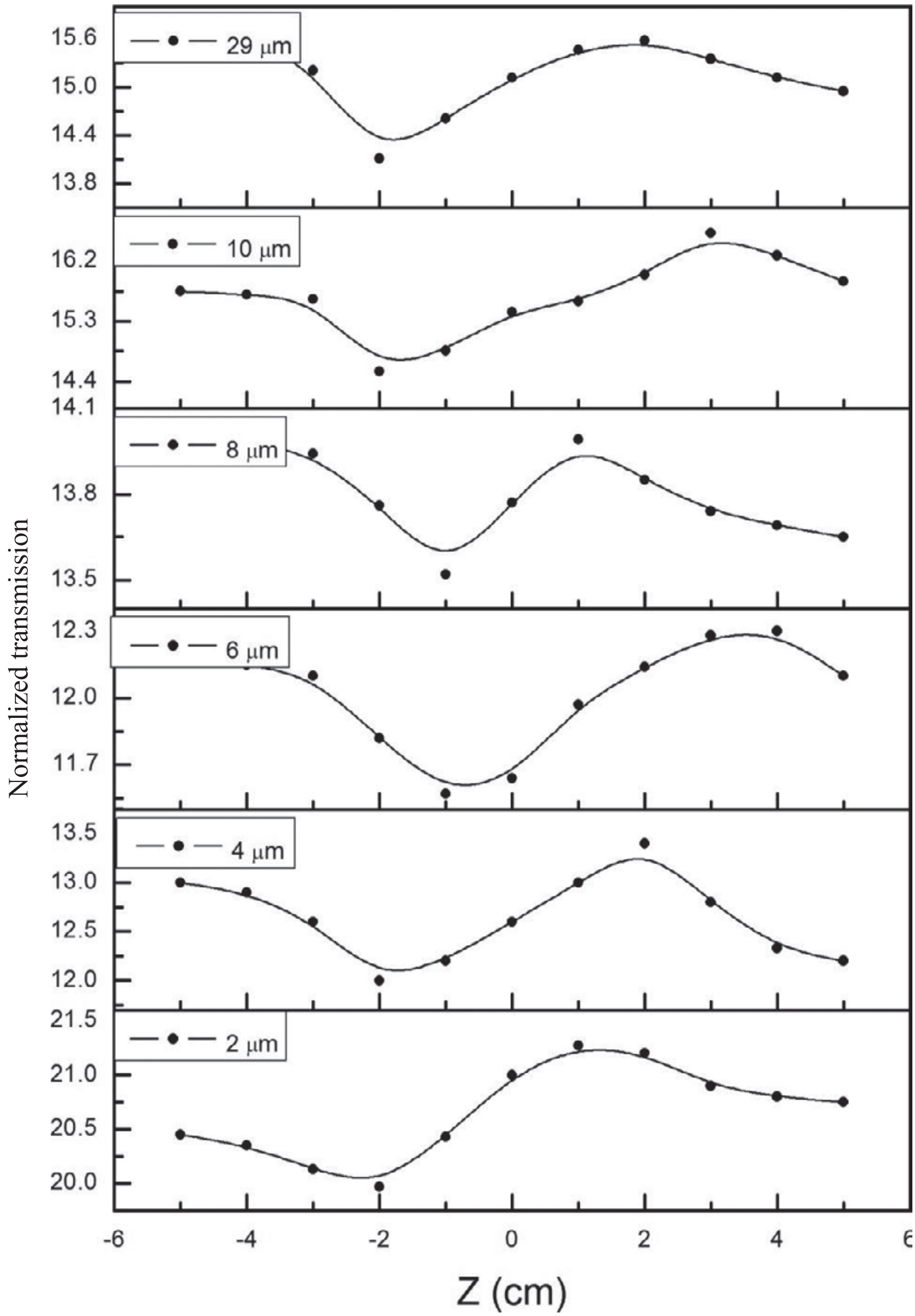

Fig.(10): closed aperture Z-Scan for R6G and PVA in wavelength 1064 nm in different thickness and concentration (1x10-6 mole/liter).

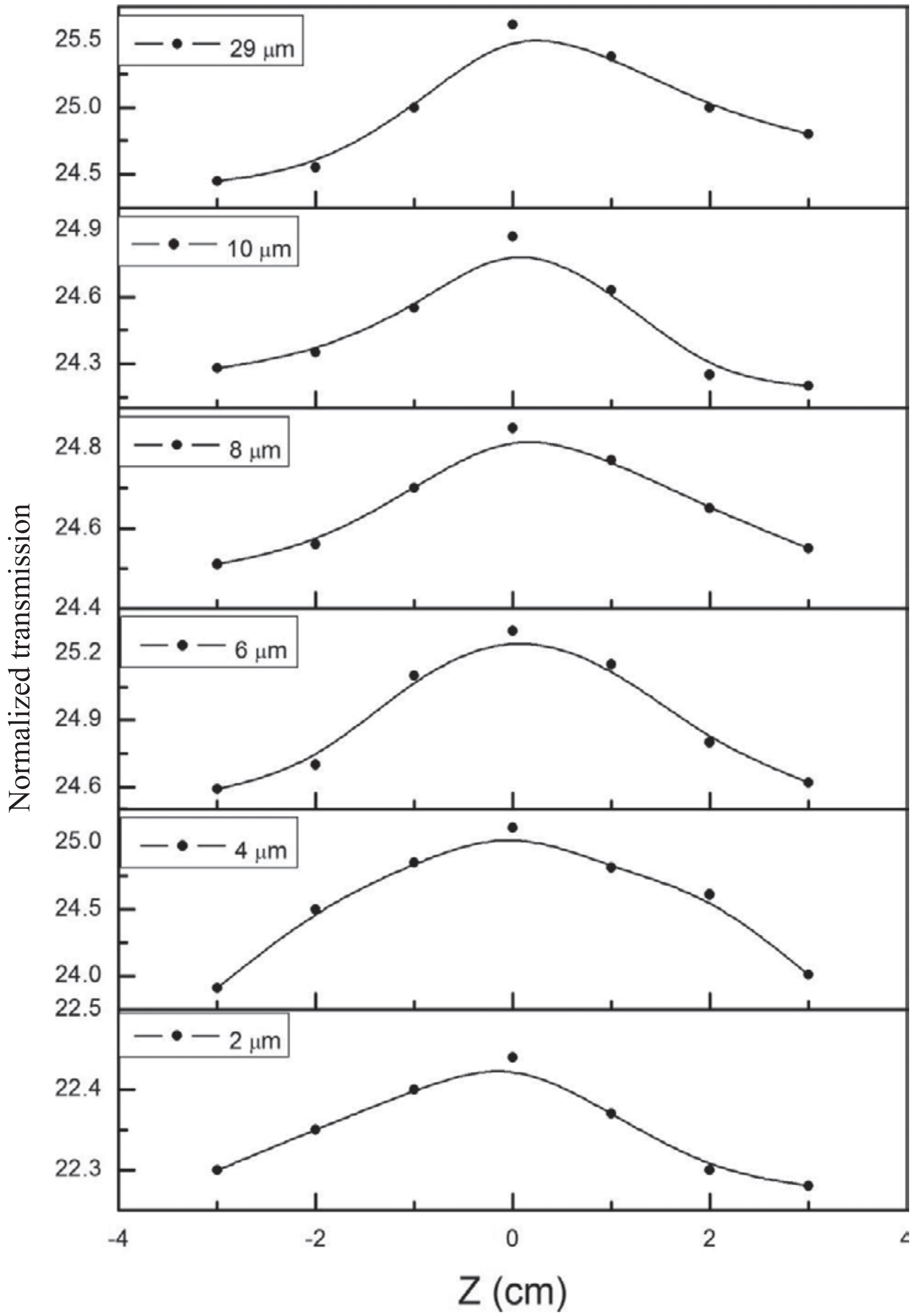

Fig.(11): open aperture Z-Scan for R6G and PVA in wavelength 1064 nm in different thickness and concentration (1x10^{-6} mole/liter).

Case 2: In $\lambda = 1046$ nm and $I_0 = 72.737 \times 10^3\ mW / cm^2$

Table (4): The results of nonlinear optical properties for R6G and PVA by the Z- scan.

t(μm)	ΔT_{P-V}	ΔØ (Rad)	$n_2(\frac{cm^2}{mw}) \times 10^{-7}$	T_{max}	$\beta\ (\frac{cm^2}{mw})$
2	1. 3	3. 2	37. 3	22. 44	4. 37
4	1. 2	2. 96	17. 3	25. 11	2. 5
6	0. 73	1. 8	7. 03	25. 3	1. 65
8	0. 47	1. 16	3. 4	24. 85	1. 22
10	2. 07	5. 1	11. 97	24. 87	0. 97
29	1. 47	3. 6	2. 9	25. 62	0. 35

This Table shows that the nonlinear refractive index (n_2) increases with the decrease of the thickness except when the value (t = 10μm), we also note that the non-linear absorption coefficient (β) increases with the decrease of the thickness.

From this Table shows that the energy gab increase with increasing the thickness.

Table (5): The results of E. g for different thickness

t(μm)	E. g
2	2. 1
4	2. 2
6	2. 21
8	2. 22
10	2. 23
29	2. 25

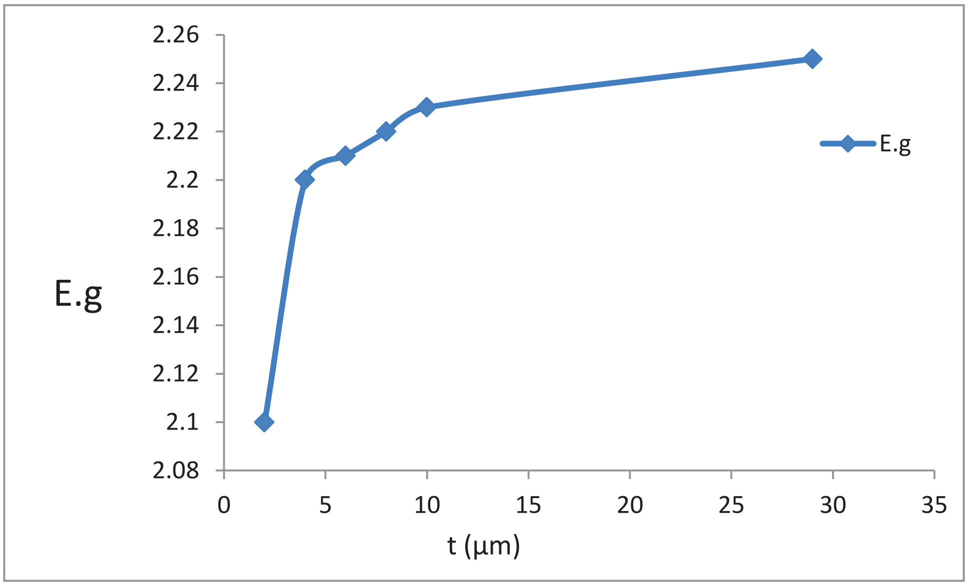

Fig.(12): Energy gab for different thicknesses

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