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Non-linear Properties Measurement for Liquid Solution of α- Chlorophyll Dissolved in Acetone

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***Abstract*— The spectral properties and Z- scan technique were used to study the nonlinear absorption coefficient (β) and nonlinear refractive coefficient (n2) of α- Chlorophyll dye solutions. A (100 mW) Neodymium- doped Yttrium Garnet (Nd: YAG) continuous laser (CW) with second harmonic generate at wavelength (532 mW) was used to evaluate open and closed z-scan setup. It is shown that the n_2, β, and $\chi^{(3)}$ is of the order of 10^{-12}, 10^{-2} and 10^{-10} respectively.**

***Index Terms*— Photovoltaic; Solar System Design; Optimization; HOMER; Baghdad City**

I. Introduction

CHLOROPHYLLS are aromatic heterocyclic compound belong to porphyrins molecules family, it consists of four pyrrole molecules all linked with methane group. This natural dye appears captivating nonlinear optical characteristics.

Attention to the materials that possess the properties of nonlinear optical increased because of their multiple applications in all- optical (switching, communications, power limiting), optoelectronic and photonic devices [1], so many organic compounds with delocalized electron systems have been prepared to obtained nonlinear susceptibilities more than inorganic materials [2], also it shows very high nonlinear coefficients due to their large variety at high intensities [3].

The Z-scan technique, originally proposed by Sheikh-Bahae et al, is based on the principles of spatial beam disfiguration and give naivety and very high sensitivity for measuring both the nonlinear refractive index and nonlinear absorption coefficient [5,6].

The z-scan technique has fast consent by nonlinear optics group as a standard technique due to its varied advantages. Device set up has a simple alignment, under particular conditions; it is possible to sequester the nonlinear refractive index and nonlinear absorption. Each of them, amount and the sign, can be determined [7].

In Z-scan technique looks at the central part of the beam, either in the eclipse z-scan (EZ-scan) it is possible to increase the sensitivity significantly by replacing the apertures as in Z-scan with disks which hamper the central part of the beam and shows light leaking around the edges such as Eclipse, and also the sample is scanned along the Z-axis of a focused beam like the method which used in the z-scan [8].

This research work is a fruit of continues works in the Energy and Renewable Energies Technology Center in University of Technology, Baghdad-Iraq [11-67].

II. Experimental Work

A. *Material and Instruments:*

Used parsley was purchased from a local market, and the Chlorophyll dye was extracted according to the method used by N. Yamauchi and T. Minamide (1985).

Extracted α -Chlorophyll dye have the chemical formula ($C_{55}H_{72}MgN_4O_5$) and molar mass (893.51 g/mol).

Acetone have the chemical formula (CH_3COCH_3) and molar mass (58.08 g/mol) with purity (99 %), from Gainland Chemical Company (UK), was used as a solvent to prepared different concentrations (3.6552 $*10^{-3}$, 7.3105 $*10^{-3}$, 1.09651 $*10^{-2}$, 1.4620 $*10^{-2}$, and 7.3104 $*10^{-2}$ mol/l) of the dye .

Absorption spectrum of liquid samples was carried out by Spectrophotometer T60 supplied from the English company (Instruments).

B. *EZ-scan technique:*

A continuous laser Neodymium-doped Yttrium Garnet (Nd: YAG) at wavelength (532 nm) with (90 mw) (MHHL-532-100 mw) was used as the source for the EZ-scan technique which supplied from Changchun company. The laser of Gaussian beam profile focused by a convex lens of focal length, (f = 30 cm), to produce a beam waist of (85 μm), and diameter of dick about (1.5 cm). The diffraction length, Z_R was found to be (42mm).The experimental setup used is shown in figure (1).

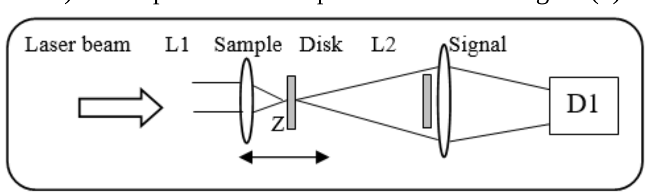

Fig. 1: Experimental arrangement for the EZ-scan

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In order to calculate the absorption coefficient (**β**) from the experimental observations, we have done the curve fitting by numerically calculating the normalized transmittance [9]:

$$T(Z) = \Sigma_{m=0}^{\infty}\left[\frac{[-q_0(z)]^m}{(m+1)^{\frac{3}{2}}}\right] \quad (1)$$

Where**:**

$$q_0(z) = I_0 L_{eff}\,\beta / [1 + (\frac{z}{z_0})^2] \quad (2)$$

, and

$$L_{eff} = \frac{1 - e^{-\alpha_{0L}}}{\alpha_0} \quad (3)$$

L_{eff} is the effective length of the sample, **L** is the thickness of the sample, **α** is a linear absorption coefficient, and $\mathbf{I_0}$ is the intensity of the laser beam at the focus (z = 0).
The nonlinear refraction $\mathbf{n_2}$ can be calculated using simple expression [3]:

$$n_2 = \Delta\Phi_0 / I_0 L_{eff}\, k \quad (4)$$

Where:

$$\Delta T_{PV} = 0.68(1-S)^{-0.44}\left|\Delta\Phi_0\right| \quad (5)$$

III. Results and Discussion

A. Absorption &Transmittance spectra of Chlorophyll a dye:

The absorption and transmittance spectrum was studied for five different concentrations ($3.6552 *10^{-3}$, $7.3105 *10^{-3}$, $1.09651 *10^{-2}$, $1.4620 *10^{-2}$,and $7.3104 *10^{-2}$ mol/l) of the dye in acetone solvent at room temperature as shown in figure (2,3) respectively , absorption peak located at (660nm-675nm) and the intensity of the peak increases with increasing of the chlorophyll concentration.

B. Nonlinear optical properties:

The α-Chlorophyll dye in acetone solvent at various concentrations (mol/l), for the incident power P_{in} = 90 mw, was evaluated by the measurements of EZ-scan. Figure (4) shows the tow photon absorption for the dye solution by the open EZ-scan curve. And also The transmission at the focus decreases with increasing sample concentration. Figure (5), shows the closed aperture EZ-scan data, and indicates that the sign of the refraction nonlinearity is positive, i.e. self-focusing and negative (de focusing) with increase the concentration. Where the defocusing effect for the α-Chlorophyll dye in solvent shown in figure (5) is attributed to a thermal nonlinearity resulting from the absorption of radiation at 532 nm [10]. From table (1), it has been observed the nonlinear absorption coefficient and nonlinear refraction index, increase with the concentration increase; this may be attributed to the fact that the number of dye molecules increases as the concentration increases, more particles are thermally agitated resulting in an enhanced effect [11].

IV. Conclusion

Our experiments show that the fast contribution of the α-chlorophyll dye to the overall nonlinearity is relatively. The nonlinear optical properties behavior of safranin α-chlorophyll dye have been studied. Both NLA and NLR increase with increase the concentration of α- chlorophyll dye. The origin of optical nonlinearity observed in the cw regime is attributed to the thermal variation of refractive index in the medium.

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Table 1: Linear and nonlinear properties of α-Chlorophyll dissolved in acetone at different concentration.

Concentration.	T%	Absorption (at 532nm)	Absorption coefficient α $(cm)^{-1}$	Nonlinear absorption coefficient $(\beta)*10^{-2}$	Nonlinear phase shift $\Phi *10^{-5}$	Nonlinear refractive index (n_2) $*10^{-12}$	Nonlinear susceptibility $X^{(3)}*10^{-10}$
$3.6552*10^{-3}$	80.6	0.097	2.23391	2.032	0.00489	0.03736	4.7920
$7.3105*10^{-3}$	67.1	0.196	4.51388	2.657	0.00302	0.12726	6.2666
$1.0965*10^{-2}$	67.8	0.191	4.39873	2.676	0.07939	0.34081	6.3122
$1.4620*10^{-2}$	69	0.157	3.61571	2.850	0.1454	0.73226	6.7207
$7.3104*10^{-2}$	33.2	0.476	10.96228	3.403	1.13059	2.59398	8.0254

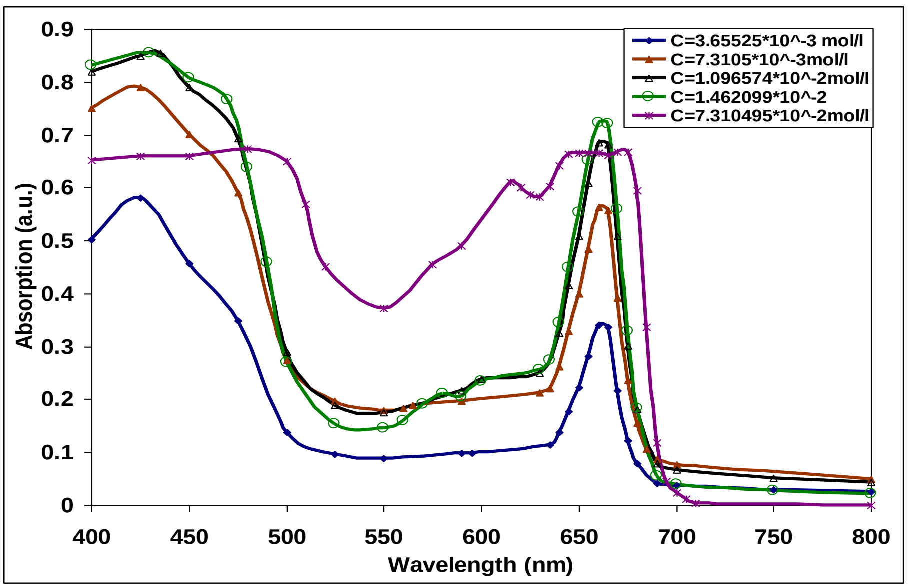


Fig. 2: Absorption of α-Chlorophyll in acetone at different concentration.

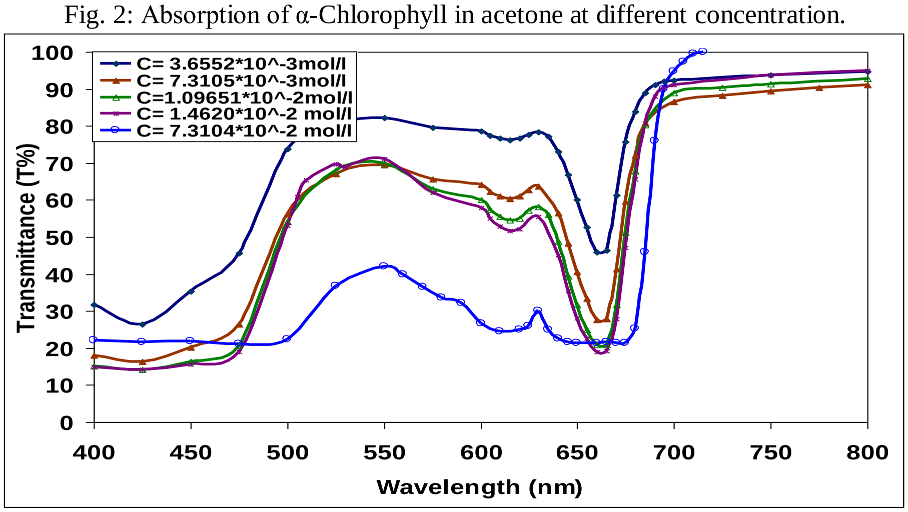
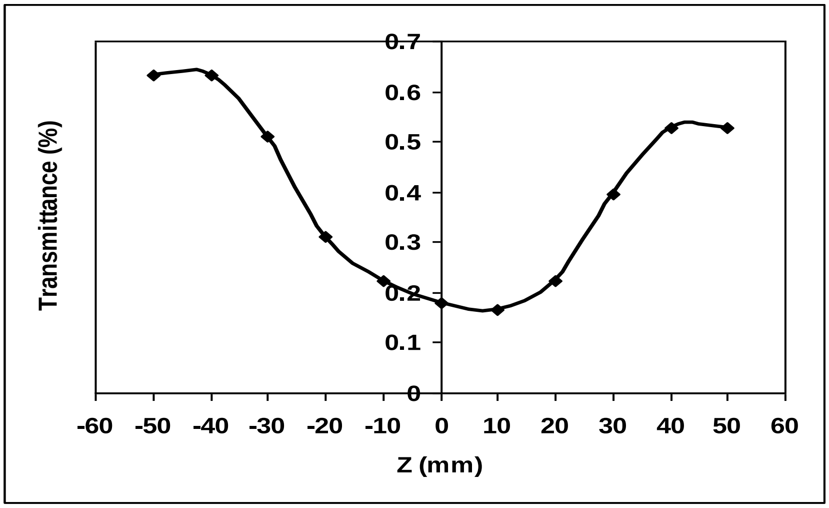
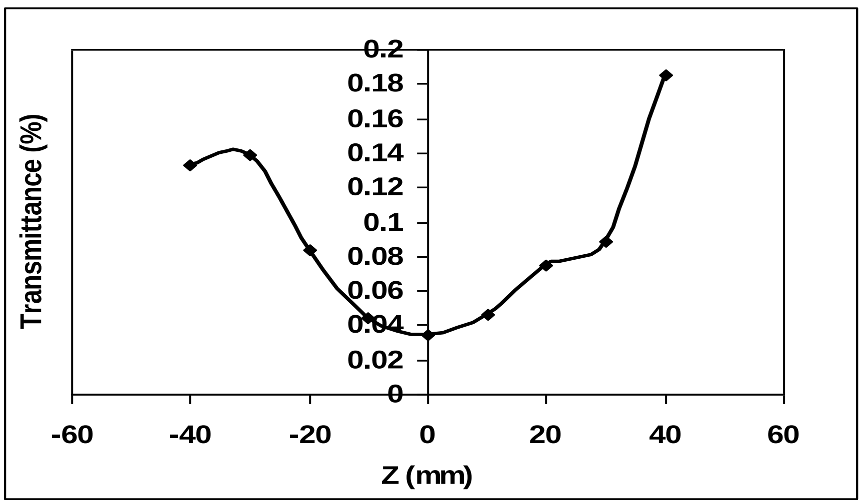


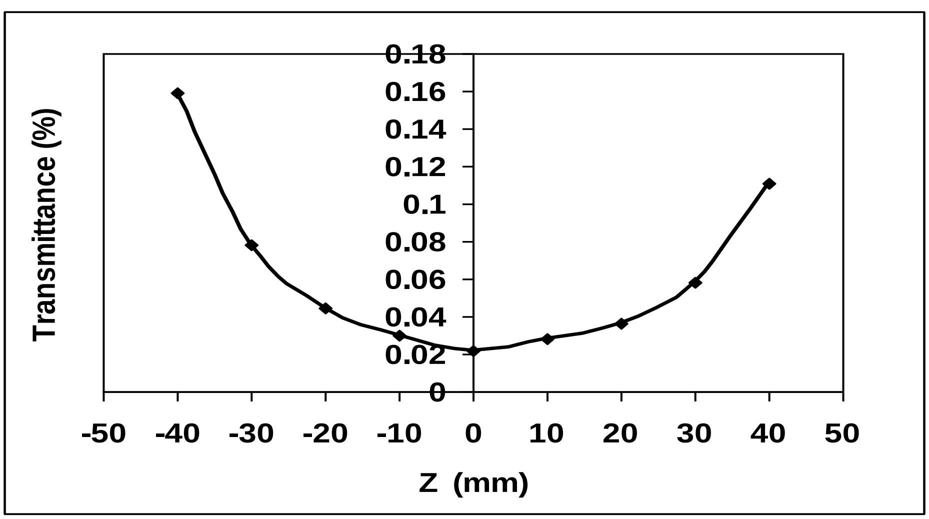
Fig. 3: Transmittance of α-Chlorophyll in acetone at different concentration.



(4a) open aperture - for 3.6552*10^{-3} mol/l



(4b) open aperture - for 7.3105*10^{-3} mol/l



(4c) open aperture - for 1.09651*10^{-2} mol/l

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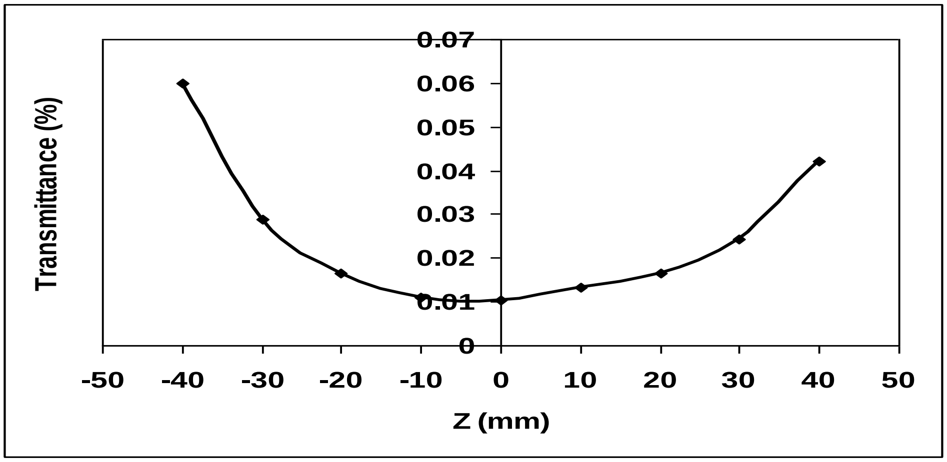
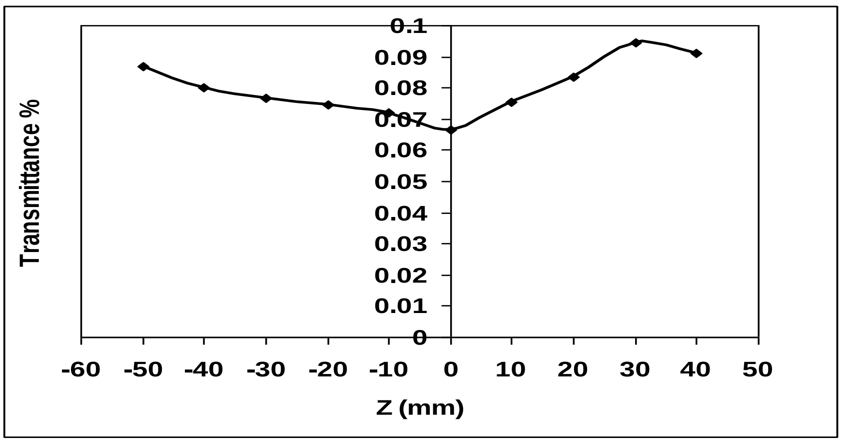
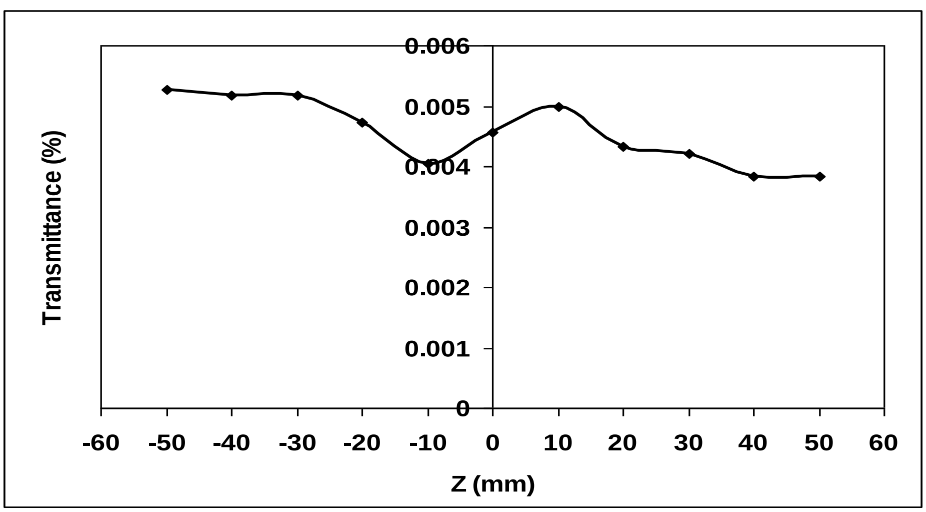


(4d) open aperture - for 1.4620*10^{-2} mol/l



(4e) open aperture - for 7.3104*10^{-2} mol/l

Fig. 4: open aperture z-scan measurements of α-Chlorophyll in Acetone



(5a): Close aperture- for 3.6552*10^{-3} mol/l

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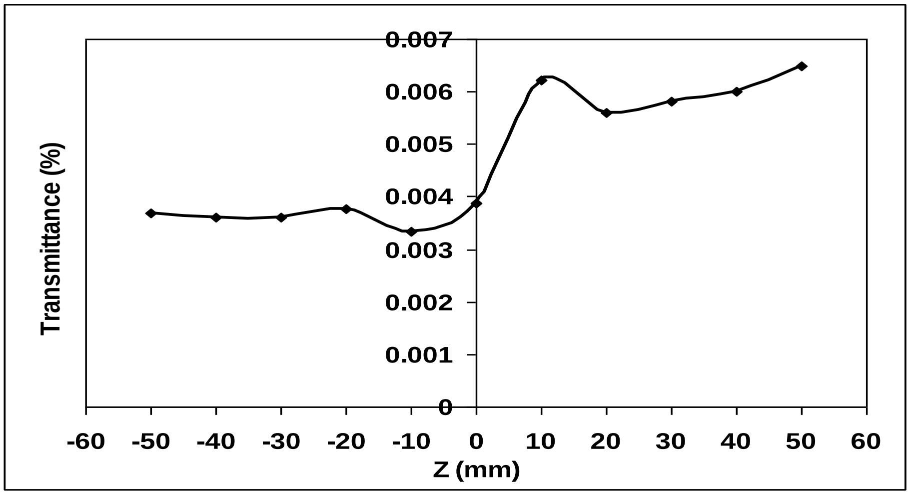
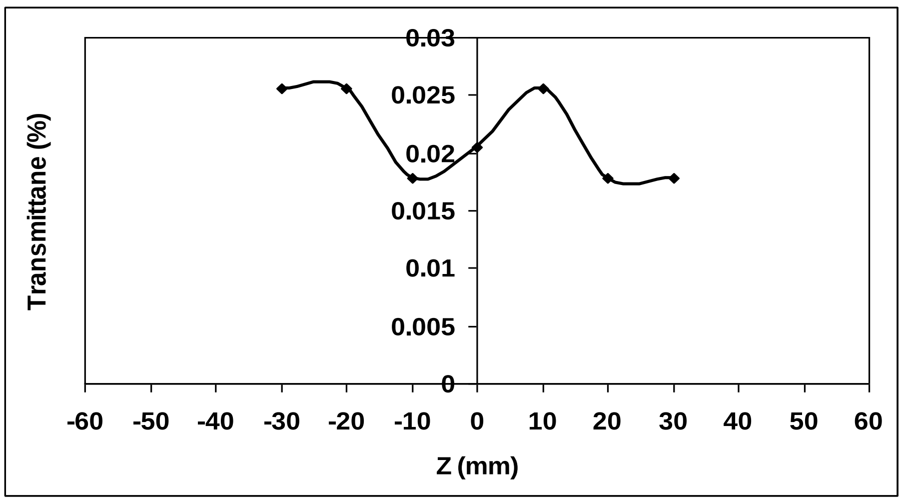
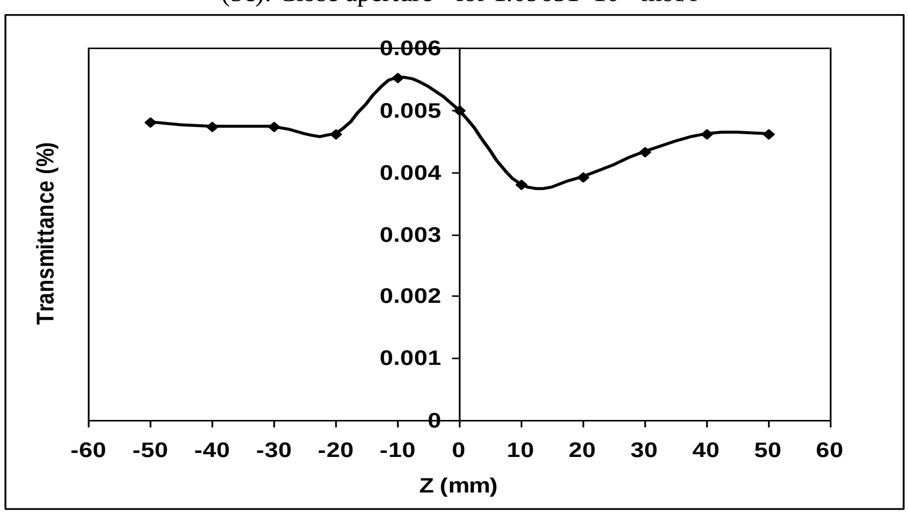


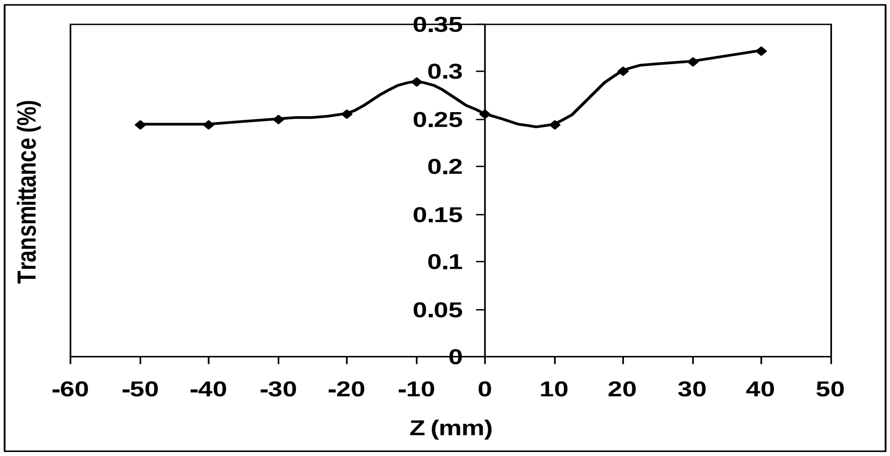
(5b): Close aperture- for $7.3105*10^{-3}$ mol/l



(5c): Close aperture- for $1.09651*10^{-2}$ mol/l



(5d): Close aperture - for $1.4620*10^{-2}$ mol/l



(5e): Close aperture- for 7.3104*10^{-2} mol/l

Fig. 5: Close aperture z-scan measurements of α-Chlorophyll in Acetone

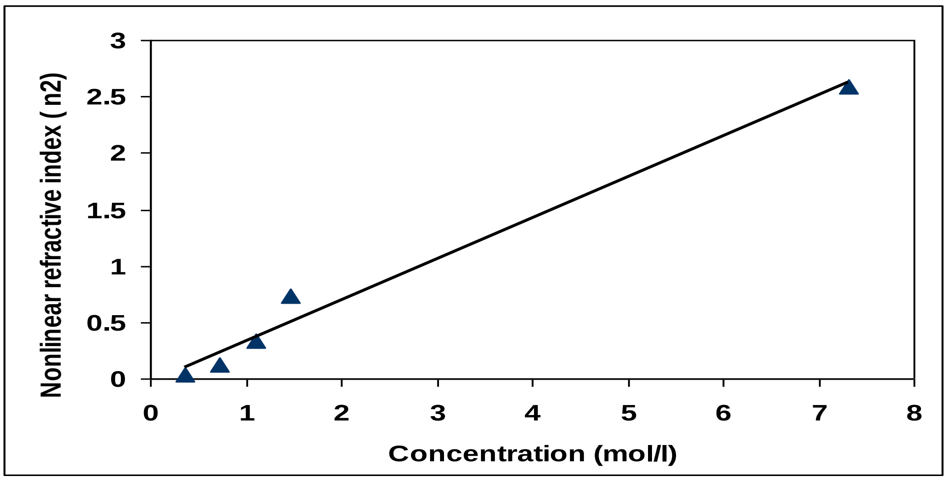


Fig. 6: Relationship between concentration and nonlinear refractive index for α-Chlorophyll dissolved in acetone.

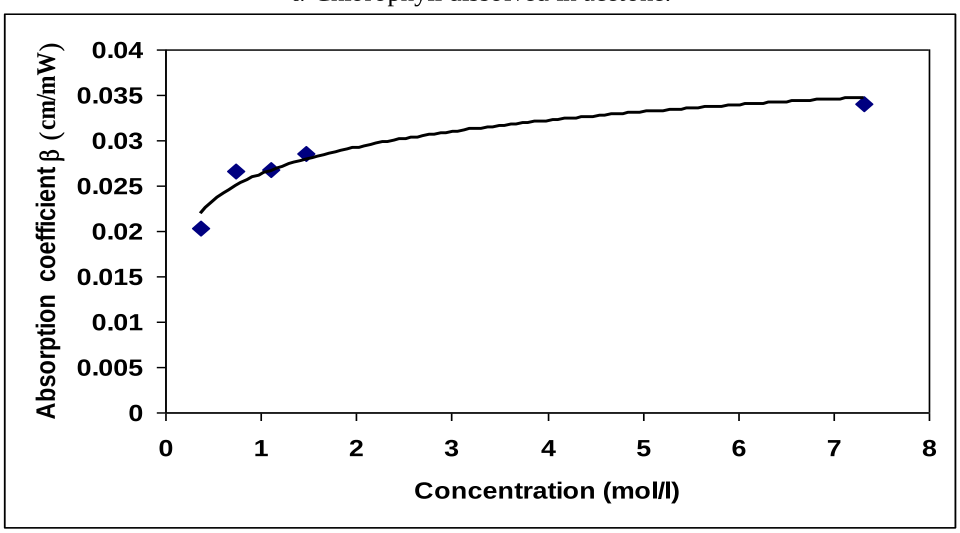


Fig. 7: Absorption coefficient Vis. concentration and for α-Chlorophyll dissolved in acetone.