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Nonlinear Optical Properties of Pyronin B Dye by Z-scan Technique Using Q-Switched Pulsed Nd: YAG laser

***S. Kumaresan[1], M. Basheer Ahamed[2],**

[1]Department of Physics, GKM College of Engineering & Technology , Chennai-63, India.
[2]Department of Physics, BS Abdur Rahman University, Chennai-600048, India.

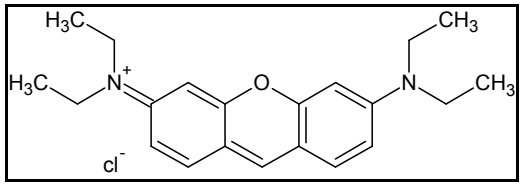
Abstract : Nonlinear optical properties of Pyronin B dye was studied by z- scan technique using Q switched pulsed Nd: YAG laser of wavelength 532nm.The dye was prepared in various concentrations 0.3mM,0.4mM and 0.5mM respectively. The dye exhibited negative nonlinearity and saturation absorption in closed and open aperture z-scan measurements. Nonlinear refractive index and nonlinear absorption coefficient were measured in closed and open aperture z-scan. The third order nonlinear susceptibility (χ^3) was measured in the order of 10-8esu.This results showed that the dye Pyronin B is very suitable for applications in optical devices.
Key Words: Z-scan; Nonlinear refractive co-efficient, nonlinear absorption co-efficient, Third order nonlinear susceptibility, Negative nonlinear, saturation absorption.

Introduction

Nonlinear optical materials are used in various technological fields such as optical signal processing devices, optical limiting and optical data storage (1-5). Z-scan technique is an effective technique to measure the third order nonlinear optical properties of dyes. In this the closed and open aperture curves results are used to calculate both the nonlinear refractive index and nonlinear absorption coefficient. Negative nonlinearity is shown as peak followed by valley in the closed aperture curve. The Q-switched pulsed Nd: YAG laser is used as source of excitation in this method. Pyronin B dye whose absorption maximum is 555nm and it is very suitable for the study of third order nonlinear optical properties studies using z scan technique (6-9).

Materials and methods

The Pyronin B dye was purchased in Sigma Aldrich Company and the sample was dissolved in ethanol in different concentrations 0.3mM, 0.4mM and 0.5mM. The organic structure and chemical formula as shown in Fig.1.



Chemical Formula: $C_{21}H_{27}ClN_2O$
Fig. 1Organic structure of pyronin B dye

UV-VIS Absorption spectra

The sample Pyronin B was prepared at low concentration of 0.01mM and the absorption spectrum was recorded by using the spectrophotometer (VARIAN COMPANY). The absorption maximum of this dye was observed as 555nm as shown in Fig.2.

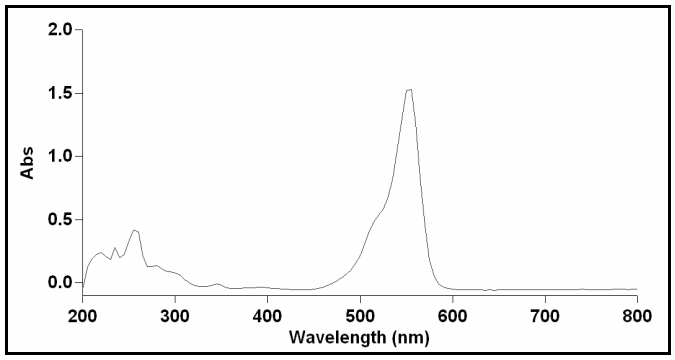


Fig.2Absorption spectra of dye pyronin B

Experimental technique

The experimental arrangement of z-scan technique is as shown in Fig.3. A Q- switched pulsed Nd: YAG laser (QUANTA RAY: Model Lab–170-10) of absorption wavelength 532nm is used as a source. The sample (dye solution) is taken in the cuvette of 1mm thickness. A convex lens of focal length f=10cm is used to focus the laser light on the sample. The far field and closed aperture of z-scan measurements are observed using detector. The digital power meter (EPM2000 Coherent Molectron USA makes) recorded the output power. The cuvette is moved forward and backward along the horizontal direction(-z to +z-axis). In the open aperture z-scan, the lens totally collects the laser beam and makes it fall on the sample and transmitted (10).

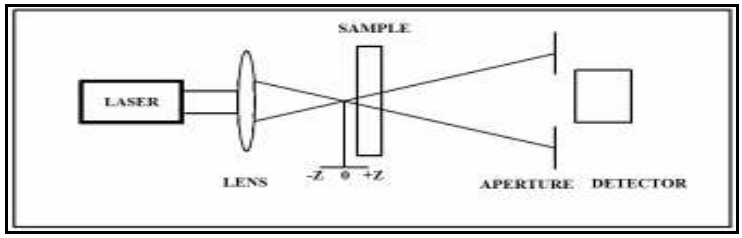


Fig.3 Experimental setup for Z-scan Instrument

Results and discussions

In this z-scan technique experimental results using Pyronin B dye, the nonlinear refractive index (n_2) and nonlinear absorption coefficient (β) values are calculated. The closed aperture z-scan curve is as shown in Fig.4

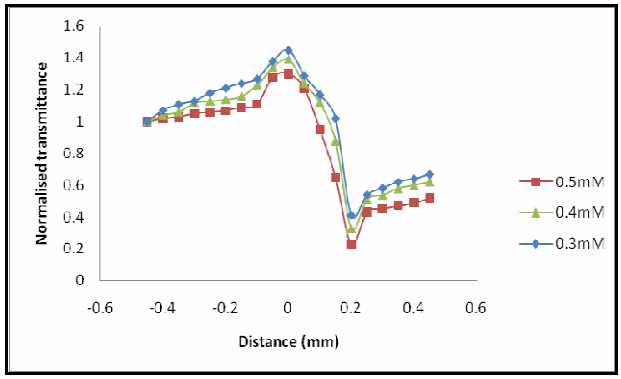


Fig.4Z-Scan closed aperture curve for pyronin B dye

In this graph drawn in various concentrations, the peak to valley of the curve denotes that the negative nonlinear refraction. This exhibits self- defocusing effect of the dye Pyronin B. The open aperture curve shown in the Fig. 5 indicates saturation absorption for the dye in ethanol and transmittance is also calculated. The calculated transmittance shows that the intensity depends on the absorption effect.

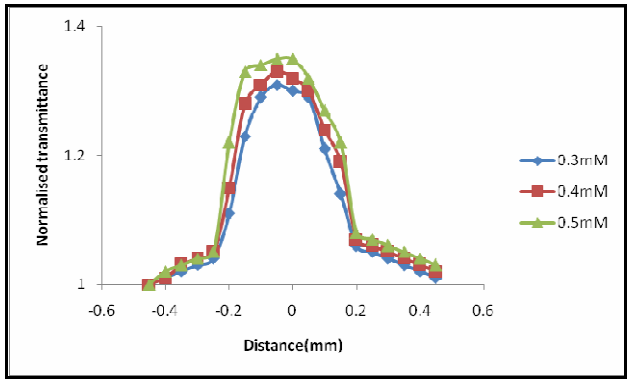


Fig.5Z-Scan open aperture curve for pyronin B dye

The difference between the normalised peak and valley transmittance is $\Delta T_{(p-v)}$ and it can be expressed as the following

$$\Delta T_{p-v} = 0.406(1-S)^{0.25} \left|\Delta\phi_0\right| \qquad (1)$$

In the open aperture z-scan all the energy transmitted by the sample and nonlinear absorption was shown. From the closed aperture z-scan results the nonlinear refractive index is calculated (11).

Nonlinear absorption coefficient (β) and nonlinear refractive index (n_2) were calculated using the following relation

$$\beta = 2\sqrt{2}\Delta T / I_o L_{eff} \qquad (2)$$

$$n_2 = \frac{\Delta\Phi_0 \lambda}{2\pi I_0 L_{eff}} \qquad (3)$$

The real and imaginary part of the third order nonlinear optical susceptibility (χ^3) are calculated using the following relations,

$$\mathrm{Re}\,\chi^3 = 10^{-4}\frac{\varepsilon_o c^2 n^2}{\pi} n_2 \qquad (4)$$

$$I_m \chi^3 = 10^{-2}\frac{\varepsilon_o c^2 n^2 \lambda}{4\pi^2}\beta \qquad (5)$$

The third order nonlinear optical susceptibility (χ^3) is given by,

$$\chi^3 = \left\{[\mathrm{Re}\,\chi^3]^2 + [\mathrm{Im}\,\chi^3]^2\right\}^{1/2} \qquad (6)$$

The experiment was repeated in various concentrations of dye Pyronin B and values of ΔT_{p-v}, n_2, β, Δn and χ3 are given in Table (1).

Table1.Nonlinear parameters of Pyronin B dye in ethanol

Concentration		ΔT_{p-v}	$n_2 \times 10^{-9}$ **cm²/W**	**β ×10⁻⁴ cm/W**	$\Delta n \times 10^{-4}$	$\chi^{(3)} \times 10^{-8}$ **(e.s.u)**
Liquid Medium	0.3mM	1.04	–1.30	–2.22	–5.98	4.06
	0.4mM	1.06	–1.33	–2.25	–6.11	4.14
	0.5mM	1.07	–1.34	–2.30	–6.16	4.19

In this experimental observations, the closed z-scan curves for pyronin B were indicated that the properties of negative nonlinearity.Z-scan open aperture curves were drawn normalised transmittance along with distance in different concentrations showed that the saturation absorption. In the negative nonlinear refractive index for closed aperture z-scan observed the defocusing effect(12-14). It was attributed to the nonlinearity resulting from the electronic polarization at the excitation wavelength. This polarization of a tightly focused beam propagating through the dye medium produces a spatial distribution of dipoles in the dye solution and consequently, a spatial variation of the refractive index which produces lensing effect and resulting in severe phase distortion of the propagating beam. This showed that the change in the refractive index due to electronic polarization effect in liquid medium.

The concentration-dependent nonlinear refractive index and nonlinear absorption coefficient were observed for these dyes. It showed that there was an increasing trend in the values of n_2, β and $\chi^{(3)}$as the concentration increased. In this result the number of dye molecules increases due to increase in concentration, electronic polarization is more resulting in an enhanced effect (15-20). The z-scan measurements indicated that the dye exhibit large NLO properties.

Conclusion

The nonlinear optical parameters of Pyronin B dye result showed that it has saturation absorption. The nonlinear refraction exhibited self-defocusing effect and electronic polarization. The closed aperture curve shows negative nonlinearity. The third order nonlinear optical susceptibility value is high under Q-switched pulsed Nd: YAG laser. This result concludes that the dye is very much suitable for the applications in optical devices.

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