Study the Non-Linear Properties of Rhodamine C Dye Dissolved in Different Solvents.

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***Abstract*— This research is a part of a series of studies being carried out to study the linear and nonlinear properties of Rhodamine C dye. The nonlinear properties was measured using " Z-scan technique" to compute the value of " nonlinear refractive index" and " nonlinear absorption coefficient" of Rhodamine C solution at the concentration of (1 *10^{-5} mol./l) at ambient temperature by using of six different solvents.**

The tests results indicate that the absorption peak for Rh C is eminent in (545-555) nm. The non-linear refractive index value is negative, which means that the peak permeability is higher than the permeability of the valley and the sample behaves as a negative lens that disperses the laser beam. The value of absorption intensity is highest in the case of dye dissolved in distilled water and the lowest value in dichloromethane.

***Index Terms*— Rhodamine dye, nonlinear property, z-scan, optical properties.**

I. Introduction

Energy and related issues remain of paramount importance to all countries of the world. The low levels of production and the delivery of energy to the citizens inevitably cause the low standard of living of many segments of society [1, 2]. Therefore, countries rely on a large part of their budgets to produce energy and increase the welfare and comfort of their citizens [3]. Most of the energy today is generated from fossil fuels (coal, crude oil and natural gas) [4]. The burning of fossil fuels causes high pollution rates for air, water and land, so the shift to environmentally friendly green fuels has become a necessity [5].

The shift to renewable energy needs to market new ideas to citizens and reformulate energy pricing. One of the most important sources of renewable energy is solar energy, which is a clean energy available most days of the year in most regions of the world in addition to it is free [6, 7]. There are many important applications of solar energy in practical life. For example, water can be heated for residential and industrial use using water heaters, storage systems, and also using salt gradient solar ponds [8-11]. Drinking water can also be produced using solar distillers [12, 13]. In addition it can be used to heat air using air heaters or Trombe Walls [14-17]. The production of electricity can be through the use of solar chimney [18, 19], concentrated power plants [20, 21], and photovoltaic cells [22-25].

All of the above applications depend on the solar radiation and its degree of intensity [26]. It varies according to the day of the year and during the same day and is influenced by air conditions such as relative humidity [27], wind speed [28], degree of purity of air and shading [29, 30].

Nonlinear optics is defined as a study of the effects and phenomena that occur when a system response is based on an optical field that is nonlinear focused on the optical field strength [31].

The photophysics of materials exposed to high-intensity laser light and the effects of nonlinear optical are interesting behaviors that have wide application areas such as optical electronics, but the materials currently used are facing many problems that determine their applications. Organic and organometallic dyes exhibit in wide ranges of wavelengths, but its thermal light stability is limited, and is often used in dilute solutions [32].

Solutions of laser dyes also work as plural sources of tunable radiation with numerous applications in various fields. nevertheless, great optical field output from refraction in the this medium can leads to intense wave front malformation of increasing the optical beam, so it is limiting the operation of high power laser dyes[33].

"Nonlinear optical" characteristic usually perform via a simple procedure called "Z-scan technique"; through which the amount of the "nonlinear refractive index" and the "nonlinear absorption coefficient" are calculated [34, 35].

In this work, spectral data and "nonlinear optical" attributes of Rhodamine C (RC) dissolved separately in different solvent (acetone; dichloromethane; methanol; ethanol; 2-propanol; distilled water) were studied.

II. Experimental Setup

A. Materials &Devices :

Rhodamine C (Diethyl-m-amino phenolphthalein); (HIMEDIA) India Company, where used in this research and dissolved separately in: (Acetone, Dichloromethane, Methanol,

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Ethanol, 2-Propanol) analytical grade 99.9% and Distilled water to prepare a solution of concentration ($1*10^{-5}$ mol. /l) at room temperature.

Absorption and transmittance spectrum of samples are listed from the UV-Visible Spectrophotometer (T60) (PG Instruments Limited).

Refractive indexes of the solutions are resulted from the use of Refractometer (Bellingham and Stanley Ltd, Tunbridgewells, ABBE60, England); Table (1).

The Z-scan experiments for different solutions were achieved by employ "CW Nd: YAG laser" at wavelength (532 nm) as a rule for an excitation origin using lens with focal length equal to (10cm) , and a diameter of the pin hole about 1.5 mm.

Table (1): Refractive index of ($1*10^{-5}$mol/l) Rhodamine C solution at 20 °C.

RC dissolved in:	acetone	dichloromethane	distilled water	methanol	ethanol	2-Propanol
n at 20 °C	1.33464	1.42554	1.36059	1.330725	1.3629	1.377565

III. Result and Discussion:

A. *Absorption spectrum:*

The absorption and transmittance spectrum of Rhodamine C dye solutions separately in (acetone, dichloromethane, distilled water, methanol, ethanol, isopropanol) at fixed concentration ($1*10^{-5}$ mole/l) can be represented in figures (1, 2, and 3). Parameters of absorption maximum peak wavelength intensity and full width at half maximum (FWHM) are listed in Table (2). The absorption peak for Rh C is eminent in (545-555) nm.

Table (2): Absorption (wavelength, intensity) and full width at half maximum (FWHM) of ($1*10^{-5}$mol/l) Rhodamine C in selected solvents.

RC in selected Solvent :-	ABS-Maximum Peak wavelength (nm)	ABS intensity (a.u.)	Full Width Half Maximum (nm)
Dichloromethane	554	0.311	16.94054
Acetone	555	0.413	22.02601
Methanol	545	0.392	24.4671
Ethanol	545	0.592	20.3479
2-Propanol	552	0.784	6.20209
Distilled water	552	1.089	32.58196

B. *Nonlinear properties:*

Z-scan which was using by M. Sheik-Bahae et al. [36] was used for evaluating the nonlinear absorption coefficient β, and the nonlinear refractive index of the samples. Figure (4) evident the "open aperture Z-scan" for Rhodamine C in (a) acetone, (b)dichloromethane, (c)methanol, (d)ethanol, (e)2-propanol,and (f)distilled water.

The "nonlinear absorption coefficient (β)" was specified via [37-40]:

$$q_o(Z) = \frac{I_O L_{eff} \beta}{1 + \frac{Z^2}{Z_O^2}} \quad (1)$$

Where:

I_0: laser beam intensity at focus z =0, L_{eff}: sample effective thickness, Z: sample position.

Whereas the nonlinear refraction (n2) value was deduced from:

$$n = \frac{\Delta\Phi_o}{I_O L_{eff} K} \quad (2)$$

Where:

ΔΦO: is the nonlinear phase shift, k: is the wave number.

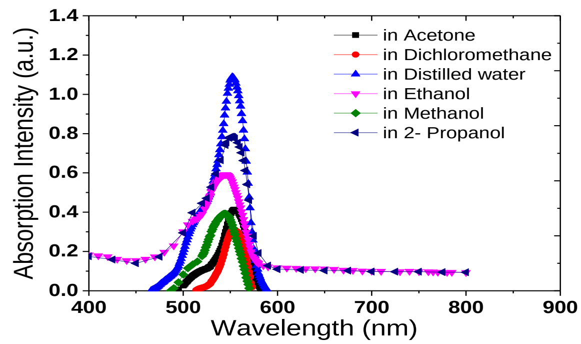


Figure (1): Absorption spectrum of Rhodamine C at fixed concentration (1*10-5mol/l) in different solvent.

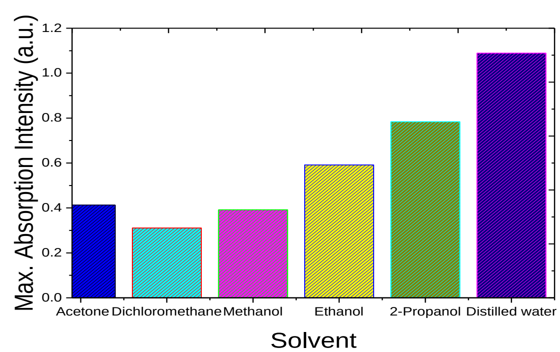


Figure (2): Maximum absorption intensity of Rhodamine C at fixed concentration (1*10-5mol/l) in different solvent.

The "nonlinear absorption coefficient" of Rhodamine C dye shows that the dye has the behavior of two photon absorption; figure (4a) (4e), due to change in laser intensity which results from a change in the intensity of the laser that moves across the waist of the beam on a dye sample. While it behaves as saturation absorption; figure (4b) (4c) (4d) (4f).

Closed aperture curve; figure (5b) (5c) (5d) (5f) shows that the non-linear refractive index value is negative (valley-peak), ((self-defocusing) i.e. the peak transmittance is higher than the valley transmittance because the sample behaves as a negative lens that disperses the laser beam. As for the figure (5a) (5e), the non-linear refractive index value is positive, (peak-valley), meaning that the sample behaves like a lens that collects the laser beam. Figure (6), (7) shows the Relationship between kind of solvent and (non-linear refractive index; (β) nonlinear absorption coefficient) respectively of Rhodamine C at fixed concentration (1*10^{-5}mol/l).

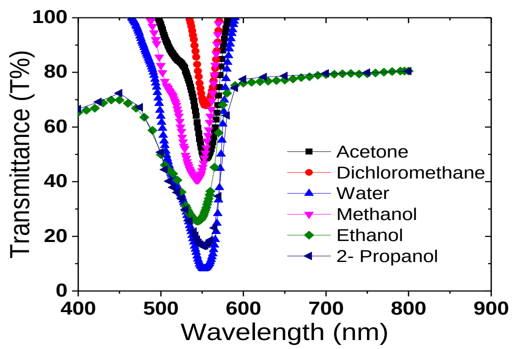
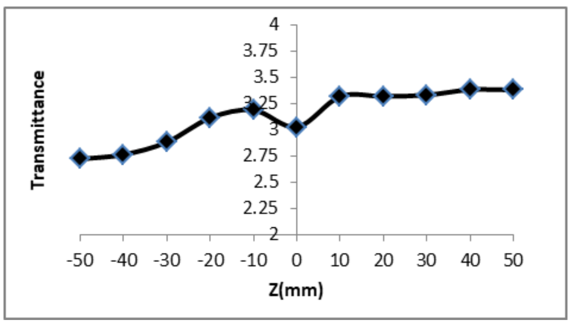
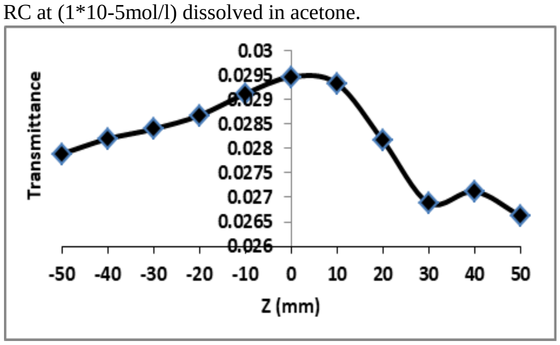


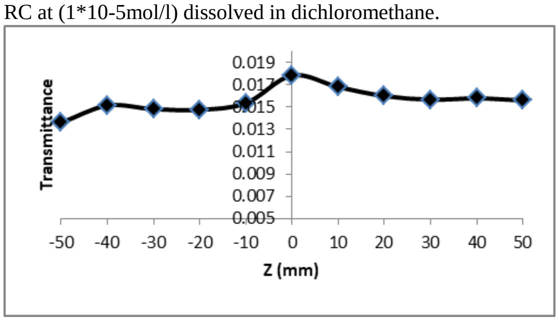
Figure (3): Transmittance spectrum of Rhodamine C at fixed concentration (1*10-5mol/l) in different solvent.



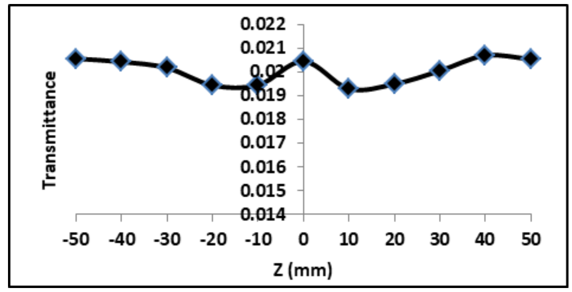
(4a): RC at (1*10-5mol/l) dissolved in acetone.



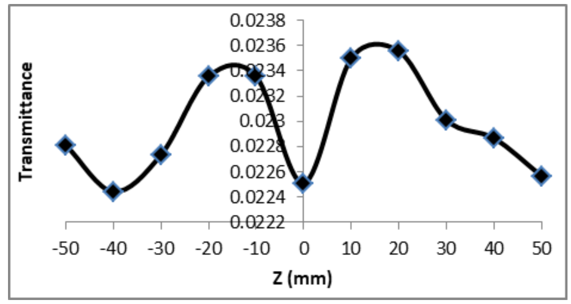
(4b): RC at (1*10-5mol/l) dissolved in dichloromethane.



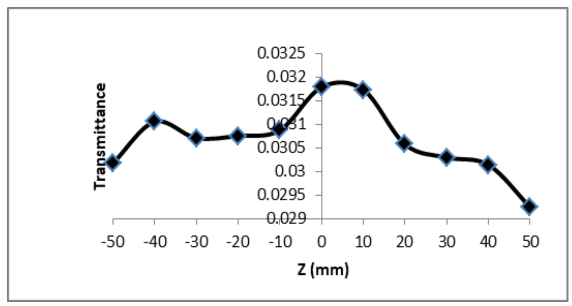
(4c): RC at (1*10-5mol/l) dissolved in methanol.



(4d): RC at (1*10-5mol/l) dissolved in ethanol.



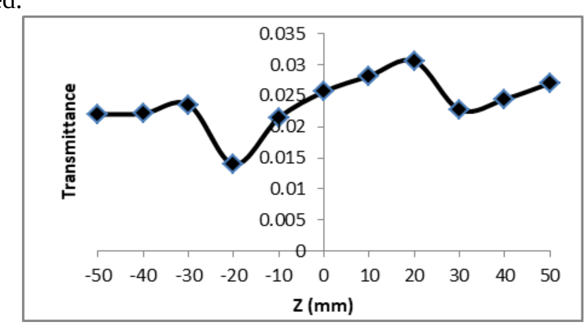
(4e): RC at (1*10-5mol/l) dissolved in 2-propanol.



(4f): RC at (1*10-5mol/l) dissolved in distilled water.

Figure (4): Open aperture Z-scan curves of RC at (1*10-5mol/l) dissolved indifferent solvent.

The different behavior of the dye in these solvents can be explained by the polarity and dielectric constant of the solvent and the dye ability to form hydrogen bonding with the solvents used.



(5A) RC AT (1*10-5MOL/L) DISSOLVED IN ACETONE.

IV. CONCLUSIONS

The linear and nonlinear optical properties of Rhodamine C dye in different solvents have been studied, we can conclude that:

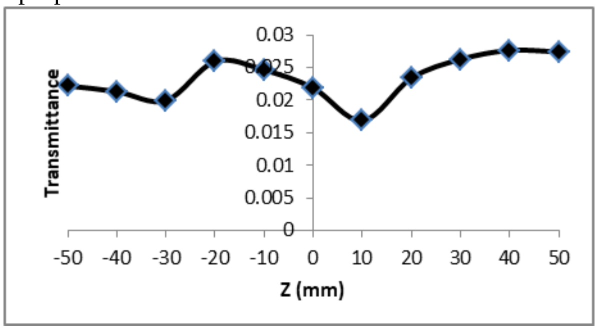
1- The value of absorption intensity is highest in the case of dye dissolved in distilled water and the lowest value in dichloromethane.

2- The value of (FWHM) can be arranged as follows: distilled water > methanol > acetone > ethanol > dichloromethane > 2-propanol.

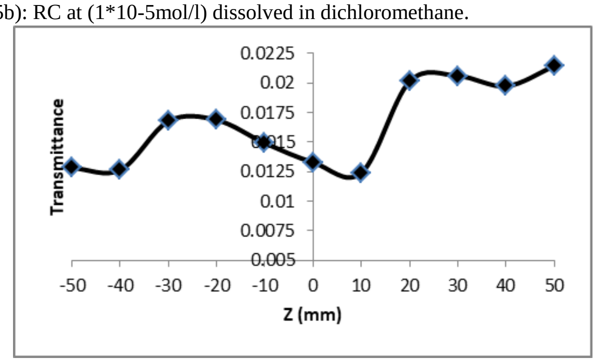
3- The value of nonlinear absorption coefficient for group (1) can be arranged as follows:

acetone > dichloromethane. , and for group (2):

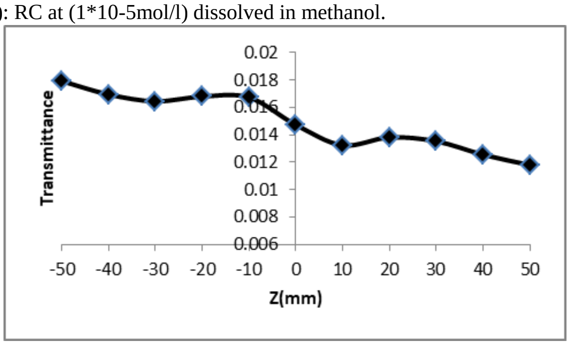
2-propanol > distilled water > ethanol > methanol.



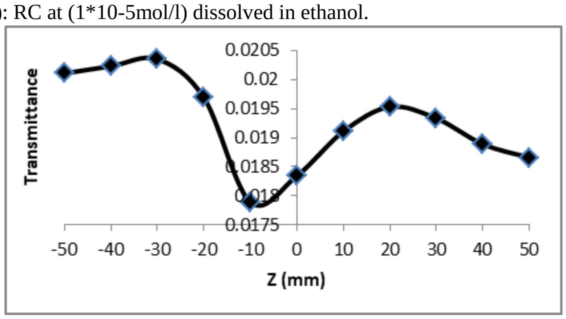
(5b): RC at (1*10-5mol/l) dissolved in dichloromethane.



(5c): RC at (1*10-5mol/l) dissolved in methanol.

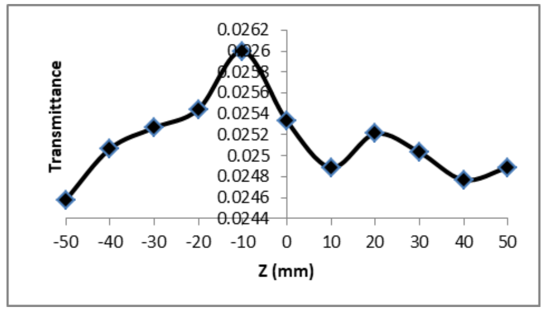


(5d): RC at (1*10-5mol/l) dissolved in ethanol.



(5e): RC at (1*10-5mol/l) dissolved in 2-propanol.

4- The value of non-linear refractive index can be arranged as follows: acetone > dichloromethane. , and for group (2): methanol > ethanol > 2-propanol > distilled water.



(5f): RC at (1*10-5mol/l) dissolved in distilled water.

Figure (5): Close aperture Z-scan curves of RC at (1*10-5mol/l) dissolved indifferent solvent.

5- Non-linear refractive index for dye dissolved in acetone, and, 2-propanol is positive, and it is negative for dye dissolved in dichloromethane; methanol; ethanol; distilled water.

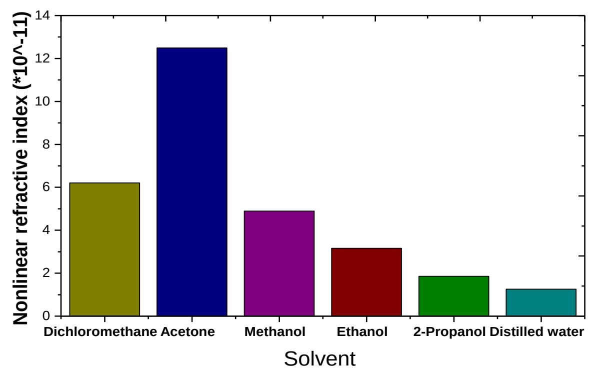


Figure (6): Relationship between kind of solvent and (n2) nonlinear refractive index of Rhodamine C at fixed concentration (1*10-5mol/l).

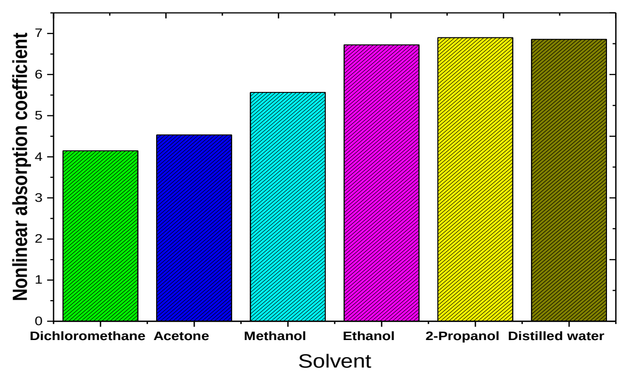


Figure (7): Relationship between kind of solvent and (β) nonlinear absorption coefficient of Rhodamine C at fixed concentration ($1*10^{-5}$mol/l).

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Table (3): Some linear &nonlinear properties of ($1*10^{-5}$mol/l) Rhodamine C in different solvents.

Solvent	Absorption intensity at 532nm, (a.u.)	α (cm^{-1})	L_{eff} (cm)	T(z)	β (cm/W)	ΔT_{pv}	$\Delta\Phi_0$ $*10^{-6}$	n_2 (cm^2/w) $*10^{-11}$
Group (1)								
Dichloro-methane	0.06	2.7636	0.0466	0.0294	4.1428	0.0090	4.8513	6.2022
Acetone	0.145	6.6787	0.0425	0.0336	4.5318	0.0166	8.8950	12.4933
Group (2)								
Methanol	0.325	14.9695	0.0351	0.0178	5.5621	0.0044	2.3811	4.0387
Ethanol	0.524	24.13544	0.0290	0.0204	6.7245	0.0034	1.8645	3.8335
2-Propanol	0.554	25.51724	0.0282	0.0225	6.8979	0.0016	0.8788	1.8574
Distilled water	0.558	25.70148	0.0281	0.0317	6.8574	0.0011	0.5937	1.2596