Spectroscopic Study of (*E*)-2-(2-hydroxybenzylideneamino) Phenol Crystal and Study Nonlinear Optical Properties of It

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ABSTRACT

The spectral characteristics and the nonlinear optical properties of the (E)-2-(2-hydroxybenzylideneamino) phenol crystal has been determined the spectral characteristics are studied by recording their absorption and FTIR and x-ray spectra. The nonlinear optical properties were measured by z-scan technique, using Q-switched Nd: YAG laser with 532 nm wavelength. The results showed that the optimum concentration is responsible for increasing the absorption. The obtained nonlinear properties results of the (E)-2-(2-hydroxybenzylideneamino) phenol showed a negative nonlinear refractive index and tow photon absorption. All the nonlinear optical parameters are linearly dependent with concentration.

Keywords: linear optics; nonlinear optics; concentration effect; Z-Scan technique

INTRODUCTION

Research on liquid crystal has been involved in chemistry, physics, Biology, electric and electronic engineering and many other fields. Most of this research has been reported by the universities and research institutions. The study of liquid crystals began in 1888 by Australian Botanist F. Reinitzer [1]. The discovery of liquid crystals is thought to have occurred nearly 150 years ago although its significance was not fully realized until over a hundred years later. Around the middle of the last century Virchow [2]. Later, in 1877, further investigations of this phenomenon were carried out by the German physicist O. Lehmann who observed and confirmed, using the first polarized optical microscope designed by him, the existence of "crystals which can exist with softness that one could call them nearly liquid" [3]. S.L. Gomez et al are study the nonlinear optical properties of thermotropic and lyotropic liquid crystals probed by the Z-scan technique [4]. Thermotropic liquid crystals of azomethine derivatives were synthesized and characterized using various spectroscopic methods. The nonlinear optical properties of these liquid crystals were studied using z-scan technique with 7 ns pulse duration at 532 nm Studied by D.M. Rao et al[5]. Mojca Jazbinsek, Lukas Mutter, and Peter Gunter study the recent progress in the development of photonic applications based on the organic crystal 4-N, N-dimethylamino-4'-N'-methyl-stilbazolium tosylate (DAST)[6]. Liquid crystals (LCs) are a special class of soft materials characterized by so called mesophases where they flow like an isotropic liquid yet possess a long-range orientational order and a complete or partial absence of positional order of building units which can be individual molecules or their aggregates [7].

T. Seideman An introductory review of the cholesteric blue phases is presented. The emphasis is on the basic concepts of the theoretical framework and the recent achievements of theory and experiment [8].

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THEORETICAL METHOD

Liquid Crystals

Definition [1]

Liquid crystals are substances that exhibit a phase of matter that has properties between those of a conventional liquid, and those of a solid crystal. For instance, a liquid crystal (LC) may flow like a liquid, but have the molecules in the liquid arranged and oriented in a crystal-like way. There are many different types of LC phases, which can be distinguished based on their different optical properties (such as birefringence). When viewed under a microscope using a polarized light source, different liquid crystal phases will appear to have a distinct texture.

Synthesis of (E)-2-(2-Hydroxybenzylideneamino) Phenol [9]

(*E*)-2-(2-Hydroxybenzylideneamino) phenol was synthesized according to literature procedure, in a 50 ml round bottomed flask 2-hydroxybenzaldehyde (salicylaldehyde) (1.0 g, 8.18 mmol) and 2-hydroxyaniline (0.89 g, 8.18 mmol) were mixed and dissolved in 25 ml of absolute ethanol, 1 drop of hydrochloric acid was added and the mixture was refluxed for 4 hours.The mixture was cooled, then decanted into a 50 ml round bottomed flask and the solvent was evaporated under reduced pressure. The solid crude product was recrystallized from ethanol to give the pure (*E*)-2-(2-Hydroxybenzylideneamino)phenol (1.57 g, 7.36 mmol; 90%).(*E*)-2-(2-Hydroxybenzylideneamino)phenol was synthesized by the condensation reaction of salicylaldehyde and 2-hydroxyaniline the Molecular structure of (*E*)-2-(2-Hydroxybenzylideneamino) phenol is show in figure (1)**.**

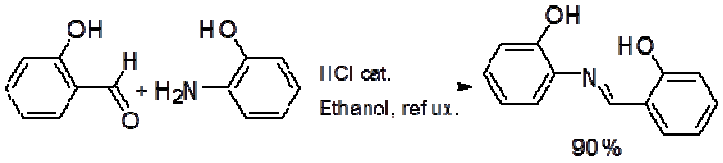

Figure 1. Molecular structure of (*E*)-2-(2-Hydroxybenzylideneamino) phenol

EXPERIMENTAL METHOD

Five concentrations were prepared for (*E*)-2-(2-Hydroxybenzylideneamino) phenol. The concentrations are ($5x10^{-4}$, $1x10^{-4}$, $8x\ 10^{-5}$, $6x10^{-5}$, $4x10^{-5}$) M. The absorption and transmittance spectra of (*E*)-2-(2-Hydroxybenzylideneamino) phenol recorded for wavelengths (200 to 599 nm)by using double beam spectrophotometer (UV-Vis-CECIL 2700,provided by optima 300 plus company) at room temperature. The schematic diagram of single beam z-Scan experiment used in the present measurement is shown in figure (2) [11]. It consists of a 30 ns Q-switched Nd: YAG laser operating at 532 nm wavelength with energy of 20 mJ. Laser pulse energy was measured by the (DPSS 1830C) detector. The laser beam passes through a lens of 30 cm focal length.

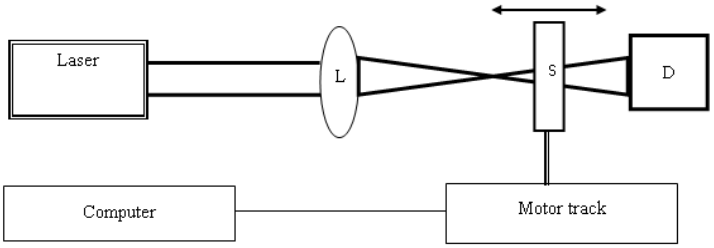

Figure 2. Schematic diagram of z-Scan experimental setup: L-Lens, S-Sample, and Detector Figure (2-3) schematic diagram of z-Scan experimental setup: L-Lens ,S-Sample, and Detector.

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There are two methods of z-Scan technique, open aperture method To obtain nonlinear absorption coefficient by using equation (6), and closed aperture to obtain nonlinear refractive index by using equation (7) Let us consider a medium subjected to an (optical) electric field E. The induced polarization (P) can be written as [10, 11, 12, 13]:

$$P = \varepsilon_\circ (\chi^{(1)}E + \chi^{(2)} : EE + \chi^{(3)} : EEE + \ldots\ldots) \ldots\ldots\ldots\ldots (1)$$

where $\chi^{(i)}$ is the electrical susceptibility of order *i* and $\varepsilon_\circ$ is the permittivity of the free space [14] .Considering centro symmetric media and keeping up to third-order terms in eq.(1), from the Maxwell's equations one obtains the refractive index n and the optical absorption α as functions of the intensity I of the incident laser beam [15]:

$$n = n_o + n_2 * E_2 / 2 = n_0 + \gamma I \ldots\ldots\ldots\ldots (2)$$

$$\alpha = \alpha_o + \beta I \ldots\ldots\ldots\ldots (3)$$

where n_o and α_o are the linear refractive index and linear optical absorption respectively, n_2 is a coefficient named the nonlinear refractive index and β is the nonlinear optical absorption coefficient.

$$\beta_1 = 2.83 * T_{min} / I_\circ * L_{eff} \ldots\ldots\ldots\ldots 4)$$

$$\beta_2 = (5.2 * T_{min} / (I_\circ * L_{eff})^2)^{1/2} \ldots\ldots\ldots\ldots (5)$$

$$\beta = \beta_1 + \beta_2 \ldots\ldots\ldots\ldots (6)$$

$$n_2 = \Delta\Phi_\circ / k * I_\circ * L_{eff} \ldots\ldots\ldots\ldots (7)$$

$$P_{peak} = E / \Delta t \ldots\ldots\ldots\ldots (8)$$

$$I_\circ = P_{peak} / \pi (w_\circ)^2 \ldots\ldots\ldots\ldots (9)$$

Where: $\Delta\Phi_\circ = \Delta T / 0.406$, $\Delta T = T_{peak} - T_{valley}$ …… (10)

Where: $k = 2\pi / \lambda$ …… (11)

k: is the wave number, λ: is the wavelength of the beam. n_2: the nonlinear refractive index of the material, I_0: the intensity of the incident beam at focus, $\Delta\Phi_\circ$: the nonlinear phase shift and L_{eff} the effective length of the material

$$L_{eff} = (1-e^{-\alpha oL}) / \alpha_o \ldots\ldots\ldots\ldots (12)$$

L: the sample length, α_o: linear absorption coefficient.

RESULTS AND DISCUSSION

FTIR Spectra Results

FTIR spectrum of (*E*)-2-(2-Hydroxybenzylideneamino) phenol is shown in Figure (3).

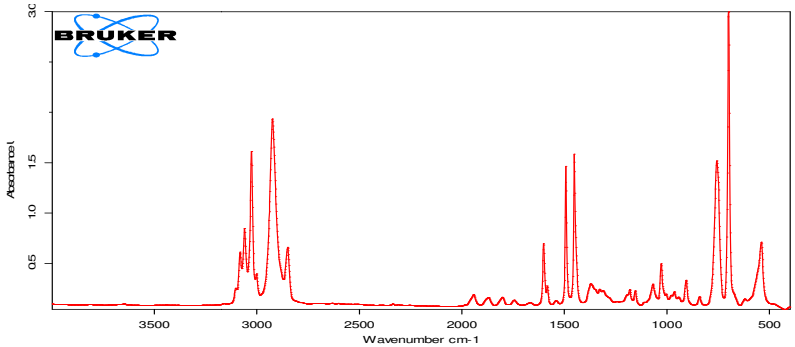

Figure 3. FTIR spectrum of (*E*)-2-(2-Hydroxybenzylideneamino) phenol

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X-Ray Diffraction Measurement

X-Ray measurements were done for (*E*)-2-(2-Hydroxybenzylideneamino) phenol and all filler weight ratio in composite. (*E*)-2-(2-Hydroxybenzylideneamino)phenol x-ray diffraction spectrum is shown in Figure (4). This figure represents the amorphous nature of these (*E*)-2-(2-Hydroxybenzylideneamino) phenol.

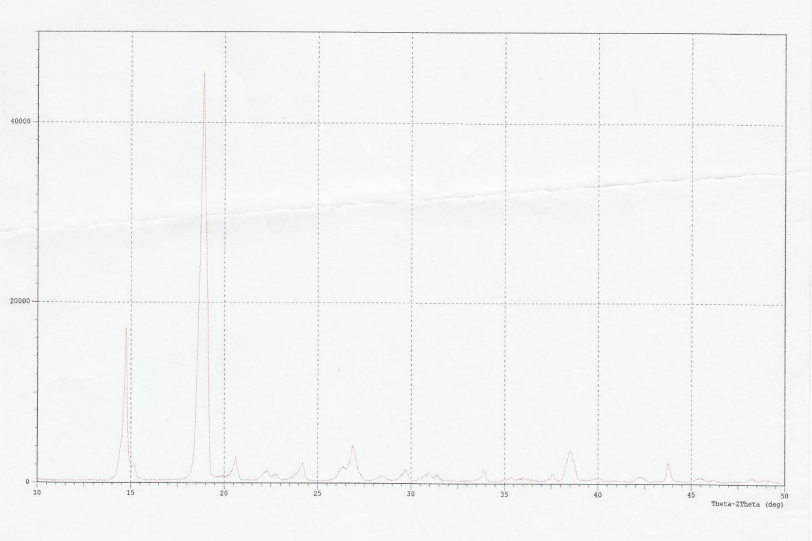

Figure 4. X-Ray diffraction pattern of (E)-2-(2-Hydroxybenzylideneamino) phenol

The Linear Optical Properties

UV-VIS absorption spectra was obtained for (*E*)-2-(2- Hydroxybenzylideneamino) phenol. The behavior is shown in Figure (5)

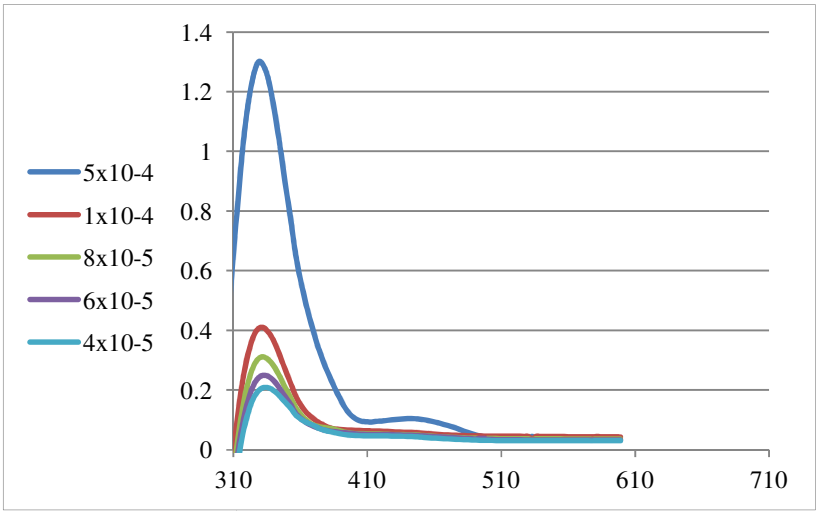

Figure 5. Absorption spectra for the different concentration of (*E*)-2-(2-Hydroxybenzylideneamino) phenol

The present results show that the absorption peaks for (*E*)-2-(2- Hydroxybenzylideneamino) phenol after different concentrations of in ethanol solvent were shifted toward the longer wavelengths with decreasing concentrations. This shift obtain due to decreasing number of molecules per volume unit at low concentrations, we show absorptance increasing with increases concentration.

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Transmission Spectra

The transmission spectra of the samples were analyzed using UV-VIS spectrophotometer. Figure (6) shows the transmission spectrum of the (*E*)-2-(2- Hydroxybenzylideneamino) phenol.

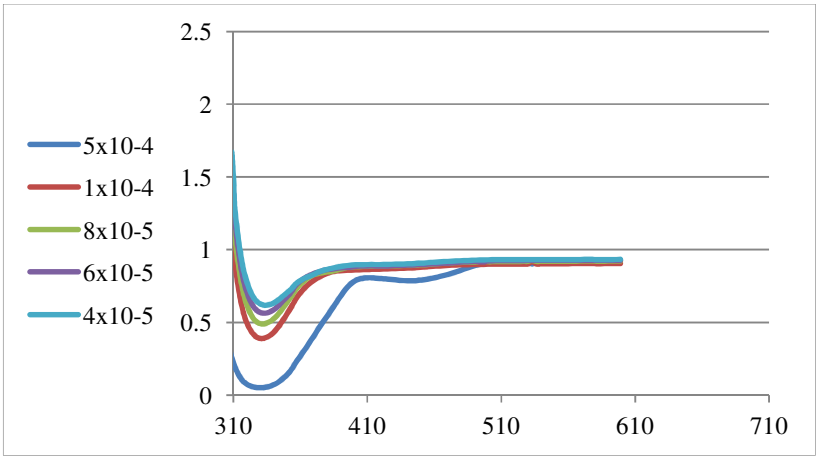

Figure 6. Transmission spectra for the different concentration of (*E*)-2-(2- Hydroxybenzylideneamino) phenol

The optical transmission of the (*E*)-2-(2-Hydroxybenzylideneamino) phenol samples are shown a variable behavior of the transmission as a function of the incident wavelength. At the wavelength 532 nm the transmission for (*E*)-2-(2-Hydroxybenzylideneamino) phenol with different concentration ($5x10^{-4}$, $1x10^{-4}$, $8x10^{-5}$, $6x10^{-5}$, $4x10^{-5}$) M .

The linear absorption coefficient (α_o) & linear refractive index (n_o) obtained from eq. (13,14)[16] and transmission spectra fig.(6). The linear refractive index and linear absorption coefficient of (*E*)-2-(2- Hydroxybenzylideneamino) phenol, listed in Table (1).

$$\alpha_o = \frac{1}{t}\ln\left(\frac{1}{T}\right) \quad \ldots\ldots\ldots\ldots \quad (13)$$

$$n_o = \frac{1}{T} + \left[\left(\frac{1}{T^2} - 1\right)\right]^{1/2} \ldots\ldots\ldots\ldots \quad (14)$$

Table 1. Refractive index and linear absorption coefficient of (*E*)-2-(2-Hydroxybenzylideneamino) phenol

Concentration Ml	*Wavelength nm*	*Linear Transmission T%*	*Linear absorption coefficient (αo) cm^{-1}*	*Linear Refractive Index (no)*
$5x10^{-4}$	532	0.90159	0.10359	1.5889
$1x10^{-4}$	532	0.91884	0.08464	1.5178
$8x10^{-5}$	532	0.92506	0.07698	1.4880
$6x10^{-5}$	532	0.92596	0.07691	1.4877
$4x10^{-5}$	532	0.93146	0.07009	1.4641

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The Nonlinear Optical Properties

The Nonlinear Refractive Index (N_2)

The nonlinear refractive index of the (*E*)-2-(2- Hydroxybenzylideneamino) phenol in different concentrations ($5x10^{-4}$, $1x10^{-4}$, $8x10^{-5}$, $6x10^{-5}$, $4x10^{-5}$) M were measured by the z-scan technique. The measurements were done at 532nm.

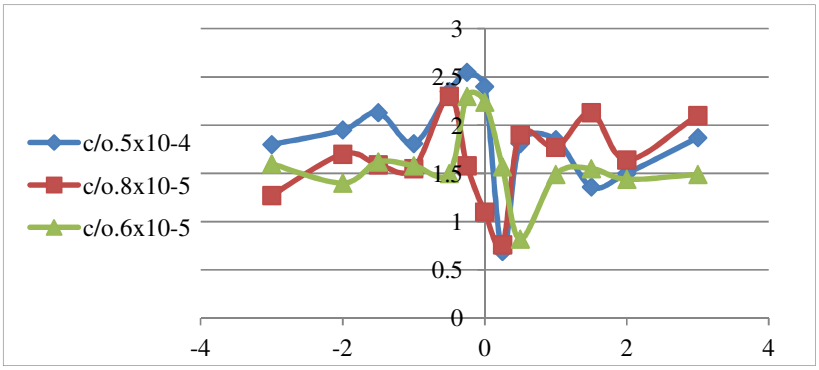

Figure 7. The closed-aperture z-scan

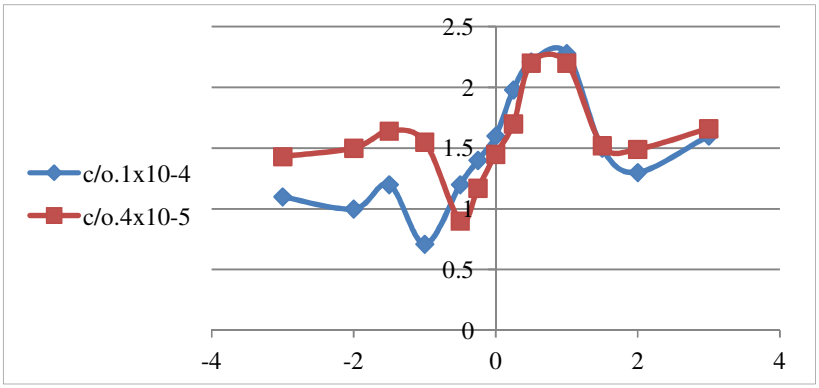

Figure 8. The closed-aperture z-scan

Table 2. Nonlinear phase shift and nonlinear refractive index

Concentration M	T_{Peak}	T_{Valley}	$\Delta\Phi$	n_2 (cm^2/Gw)
$5x10^{-4}$	2.55	0.69	8.1776	0.000139367
$1x10^{-4}$	2.28	0.71	7.2449	0.000117527
$8x10^{-5}$	2.3	0.76	7.2496	0.000115237
$6x10^{-5}$	2.3	0.82	6.9882	0.000110747
$4x10^{-5}$	2.2	1.04	5.5840	0.00009574

Figure (7) has behavior z-scan. The peak-valley configuration indicates the negative sign of (n_2) and Figure (8) The valley- peak configuration indicates the positive sign of (n_2). The scan started from distance far away from the focus, the beam irradiance is low.as the sample is brought closer to focus. The beam irradiance increases, leading to diself-lensing in the sample. Table (2) shown nonlinear, phase shift and nonlinear refractive index at 532 nm[17,18].

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Nonlinear Absorption Coefficient (B)

To investigate the nonlinear absorption coefficient, at wavelength 532nm, Figure (9) shows open-aperture z-scan at different concentrations at 532nm, 2 mJ.

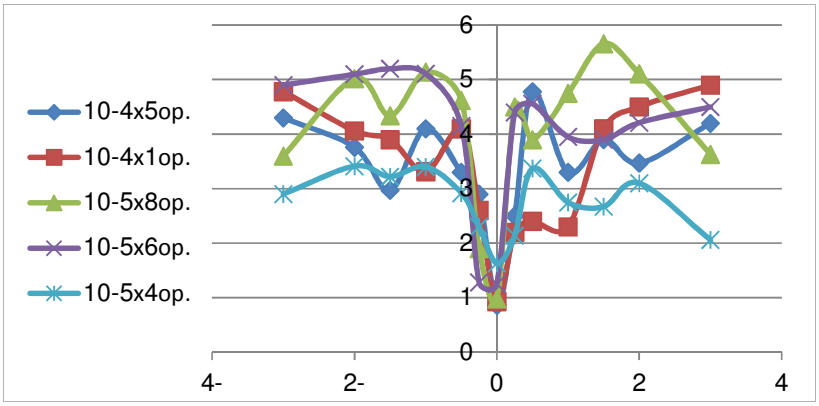

Figure 9. Open-aperture z-scan at different concentrations of (*E*)-2-(2- Hydroxybenzylideneamino) phenol

The behavior of transmittance started linearly at different distances from the far field of the sample position the sample moves through the beam focus (at z = 0), self-focusing or -defocusing modifies the wave front phase, there by modifying the detected beam intensity. To figure out how the Z-scan transmittance as a function of z is related to the nonlinear refraction of the sample, let us assume a medium with a negative nonlinear refraction index and a thickness smaller than the diffraction length of the focused beam. This can be considered as a thin lens of variable focal length. Beginning far from the focus (z < 0), the beam irradiance is low and nonlinear refraction is negligible. In this condition, the measured transmittance remains constant (i.e., z-independent), as the sample approaches the beam focus, irradiance increases, leading to self-lensing in the sample. A negative self-lens before the focal plane will tend to collimate the beam on the aperture in the far field, increasing the transmittance measured at the iris position. after the focal plane, the same self-defocusing increases the beam divergence, leading to a widening of the beam at the iris and thus reducing the measured transmittance. Far from focus (z > 0), again the nonlinear refraction is low resulting in a transmittance *z*-independent. A pre-focal transmittance maximum (peak), followed by a post-focal transmittance minimum (valley) is a Z-scan signature of a negative nonlinearity. an inverse Z-scan curve (i.e., a valley followed by a peak) characterize a positive nonlinearity, fig (8), which used to determine absorption coefficient at 532nm. This can be reported in Table (3) [19,20].

Table 3. Nonlinear absorption coefficients different concentrations of (*E*)-2-(2-Hydroxybenzylideneamino) phenol

Concentration M	T_{Valley}	*B (cm/Gw)*
$5x10^{-4}$	0.69	13.81440823
$1x10^{-4}$	0.71	14.10219444
$8x10^{-5}$	0.76	14.84276956
$6x10^{-5}$	0.82	15.72774558
$4x10^{-5}$	1.04	17.17537735

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