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Single Beam Measurements of a Sony SVGA Liquid Crystal Spatial light modulator

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ABSTRACT

In this work, non-linear optical properties of a Sony SVGA liquid crystal spatial light modulator sample are estimated by utilizing a single beam Z-scan technique with He-Ne laser at 632.8 nm. It was found that the magnitude of non-linear refractive index (NLR) is (0.694×10^{-7} cm^2/mW) with a positive signal, demonstrates a self-focusing phenomenon, while the magnitude of non-linear absorption (NLA) for this sample is (0.0101×10^{-1} cm/mW), the pure magnitude of the NLR is (0.138×10^{-5} cm^2/mW). These results are compared with past investigations in various liquid crystals types. The obtained results showed that the sample have a high ability of originating optical limiters, switches, and

1. INTRODUCTION

Studying matters with large optical nonlinearities have lately converted the consideration of wide scientific attention, naturally because of their conceivable application in high-speed optical switching strategies, which are getting increasingly basic and ordinarily utilized [1-2]. Sony SVGA liquid crystal is a 90° twisted nematic liquid crystal, it is one of the most extensive materials and it is a fundamental part of numerous optical tricking experiments like a spatial light modulator (SLM) device [3]. It tends to be utilized in various optical applications of phase or intensity modulations, like dispersion process [4], digital holography [5], adaptive optics [6], and microscopy applications [7]. The non-linear effects of the Sony SVGA liquid crystal spatial light modulator, for instance the non-linear refractive index (NLR), and non-linear absorption (NLA), have as of late attracted much interest. A Single-beam (Z-scan) system is a significant system used for deciding the non-linear optical properties of numerous non-linear optical resources. The sample is scanned throughout the focal point (Z=0) of an excessive intensity beam, and the departing beam intensity is signed up utilizing a diminutive focal length lens with a reliably short Rayleigh length [1, 8].

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As the sample has moved through the focused beam, it started performing as a positive lens, Figure (1), thus adapting the noticed beam intensity. This effect rises as the sample moved near the focus because of increasing intensity.

This maximum in transmission (peak) will drop to the lowest (valley) as the sample is moving further and the beam deviates because of the negative lensing by the sample. The diagram will be inverted when the sample has a positive NLR [2].

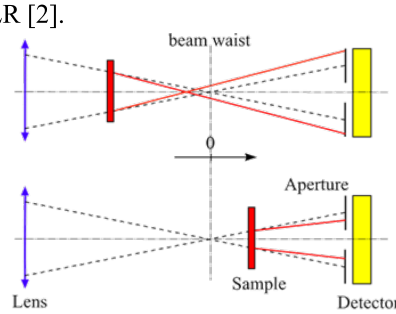

Fig .1: Z-scan process to vary the intensity of the laser beam, when the sample is moving along a focused beam. Laser intensity varied continuously with maximum at the focal point. Dashed line: laser beam transmission deprived of a sample. Solid line: intensive by a sample beam [2].

The non-linear optical properties of most liquid crystals have been investigated in some previous studies [8-13]. In this work, the non-linear optical properties of the Sony SVGA liquid crystal sample are examined by using the Z-

Scan technique. The NLA and NLR are determined by two manners, open and closed apertures. These factors offer a significant evidence about the properties of the material [14]. In closed aperture manner, the distance between the top and bottom of the output power ΔT_{P-V} was assumed by [15]:

$$\Delta T_{P-V} = 0.406(1 - S)^{0.25} |\Delta \emptyset_{\circ}| \qquad (1)$$

Where ($\Delta\emptyset_{\circ}$) is the non-linear variance of the sample phase, and S is the whole transmission. The NLR is given by:

$$NLR = \frac{\Delta\varphi_{\circ}}{kI_{\circ}L_{eff}} \qquad (2)$$

Where k is the wavenumber, λ is the wavelength of the laser, $I_{\circ}$ is the laser intensity of focus, and L_{eff} is the active length of the taster. The Variation (as a function of propagation) of laser intensity through the taster in an open aperture manner is given by:

$$\frac{\partial I}{\partial z} = -\alpha(w)I - NLA(w)I^2 - \gamma^2 - O(I^4) \qquad (3)$$

Where (I) is the intensity at width z, α(ω) is the linear absorption coefficient, NLA(ω) is the non-linear refraction coefficient, γ is the absorption coefficient of the third-order, and $O(I^4)$ is the absorption coefficient of fourth-order. The NLA is given by:

$$NLA = \frac{2\sqrt{2}\,\Delta T}{I_{\circ}L_{eff}} \qquad (4)$$

Where ΔT is the top value at open aperture curve. Optical limiters are the gadgets used for sensor protection against laser pulses. The perfect optical limiter has the characteristics that have a high linear transmission for low input power [16]. The employed of a perfect optical limiter is shown in Figure 2. By determining the non-linear properties of materials, these materials could be recognized as likely optical limiters [17].

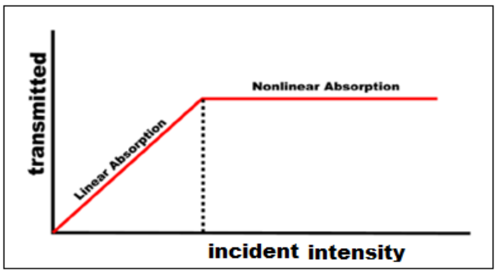

Fig. 2: A diagram illustration of the transmission through an ideal optical limiter [17], as the incident light intensity increases, the transmitted light reaches a threshold value at which point it is clamped.

2. EXPERIMENTAL SETUP

The experimental arrangement is shown in Figure (3). The experiment was performed at room temperature utilizing He-Ne laser operating at 632.8nm wavelength and output power (5mW). The sample under investigation is moved through the focus of a laser beam, and the beam radius (or the on-axis intensity) is measured at some point behind the focus as a function of the sample position. A computerized stepper motor had been used to move the sample along the z- axis with steep (10 μm). The beam was intensive using a positive lens, f =10 cm, the outputs intensity had been measured by a Metrologic 45-230 optical detector working at 2W with calibration accuracy 500-900 nm 20%. The measured laser intensity is ($I_0 = 4.27\times10^3$ W cm^{-2}).

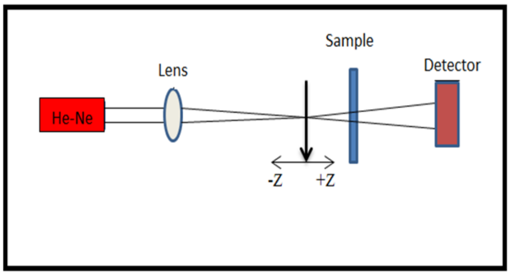

Fig.3: Experimental setup.

The sample used in this work is the SVGA liquid crystal spatial light modulator, of 1.3 mm length, the beam waist (w_o) at the focal point is (8×10^{-2}) mm while the Rayleigh length (Z_o) is 3.1 cm. The open and closed aperture states have done respectively.

3. RESULTS AND DISCUSSION

Figure (4) explains the sample behavior for the closed aperture manner, at first, the beam of He-Ne laser, shows low NLR at (Z < 0). When the sample is becoming closer to the focus, the beam intensity is increasing, producing self-focusing, so a collimated beam is obtained at the aperture. This effect is increased when the sample is moved near the focus because of increasing laser beam intensity. The laser beam intensity is decreasing at (Z > 0) until it reach a minimum rate.

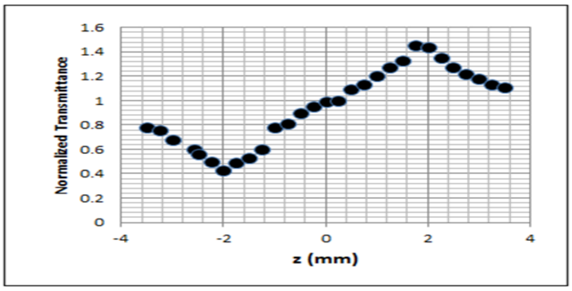

Fig. 4: The Normalized transmittance curve of the NLR in closed aperture measurements.

This figure shows asymmetry because of the contrary behavior of the sample when it is placed before and behind the focal plane of the lens. It is not just the phase shift, but the difference in the curving of the wavefronts on either side of the focus. The experimental data of ΔT_{p-v} is obtained to be (0.07). The obtained $\Delta\varphi o$ is (0.172), the NLR utilizing eq.2 is found to be (0.694×10^{-7} cm^2/mW), where L_{eff} is equal to (1.3) mm. The positive sign of the NLR indicates that the sample displays self-focusing process. In the open aperture manner, Figure (5), the obtained curve begins to drop until it reaches the minimum value (T_{min}) of 0.9 at the focal point, (Z=0).

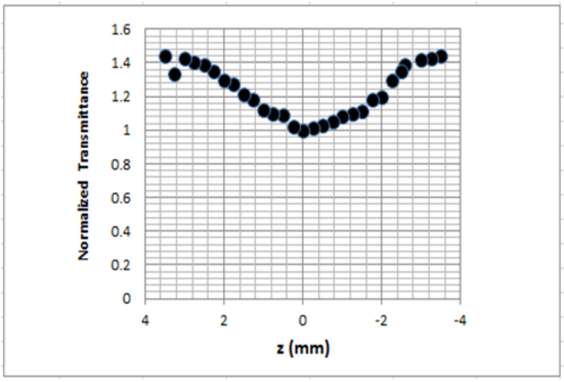

Fig.5: NLA experimental curve of open aperture manner single beam experiment.

When there is no NLA , the Z-scan curve must be symmetric around the origin of the Z-axis. However, in practice, the Z-scan curve usually has a large asymmetry. The reason for this phenomenon for thermal-optic non-linear mechanisms. (Except for experimental error). The measured value of the NLA is equal to (0.0101×10-1 cm/mW). Both the NLR and the NLA arise very sovereign of each other; this allows the abstraction of the virtuously refractive single beam documents, Figure (6). The pure magnitude of the NLR obtained to be as (0.138×10^{-5} cm^2/mW).

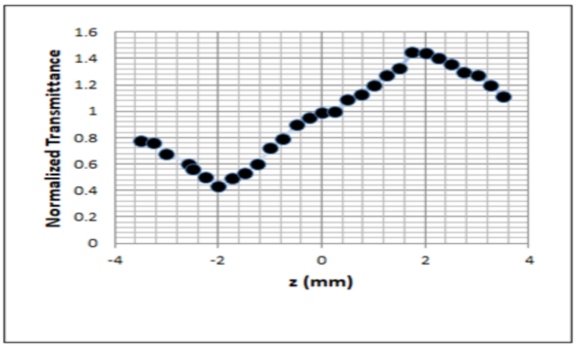

Fig. 6: Virtuously normalized transmittance of the NLR curve.

The obtained results are compared with other results for different liquid crystal subjects [8-13] and shown in table (1).

Table 1: the NLR and NLA values of different liquid crystal samples at different wavelengths of light sources obtained by [8-13].

sample	NLR (cm^2/mW)	NLA (cm/mW)	Wavelength of the incident beam (nm)
B1+RB	6.5056×10^{-10}	1.3199×10^{-3}	473
B1	3.5018×10^{-10}	1.2549×10^{-3}	473
RB	2.8167×10^{-10}	1.2147×10^{-3}	473
B2+RB	2.4629×10^{-10}	1.1733×10^{-3}	473
B2	2.0581×10^{-10}	1.1120×10^{-3}	473
Di	3.4750×10^{-10}	1.1946×10^{-3}	473
TN	1×10^{-12}	________	842
LC (E7)	-1.74×10^{-6}	________	632.8
E7	1.0895×10^{-5}	0.03491	1550
MLC 6241-000	-9.0208×10^{-6}	0.551292	1550
25%E7+75%ML	-7.8166×10^{-6}	0.857065	1550
50%E7+50%ML	-4.2183×10^{-6}	0.759502	1550
75%E7+75%ML	-6.2521×10^{-6}	0.935574	1550
SLM	9.927×10^{-8}	0.286	532
SLM	12.965×10^{-8}	0.0249	632.8
SVGA	0.694×10^{-7}	0.0101×10^{-1}	632.8

It was observed that our study is a convergence with most of these materials and a distance with others by calculating Absolute Error (AE) for these previous results utilizing the NLC program, Figures (7), and (8).

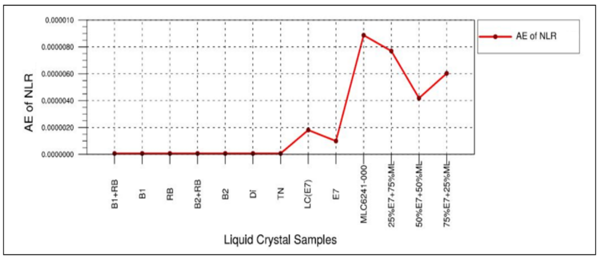

Fig.7. AE NLR of the SVGA liquid crystal sample comparison with different studies.

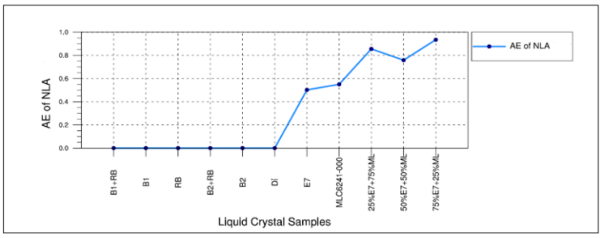

Fig.8. AE NLA of the SVGA liquid crystal sample comparison with different studies.

The optical limiting occurs when the optical transmission of a material saturates with increasing laser intensity, a property that is desirable for the protection of sensors and human eyes from the intense laser radiation. The optical power limiting property of the SVGA liquid crystal, illustrated in Figure (9), gives the optical limiting characteristics at room temperature for the sample.

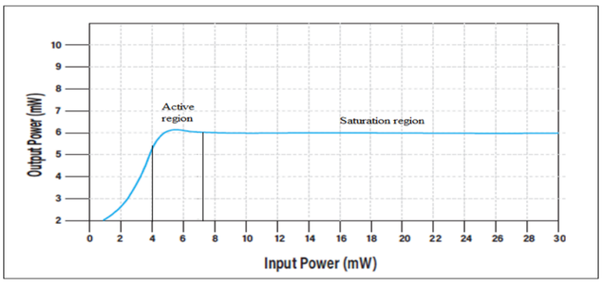

Figure 9: Practical optical limiting response SVGA liquid crystal at 632.8 nm.

The output power growths firstly with the growth in input power, but after a definite threshold significance, the sample starts defocusing the beam resulting in a larger amount of the beam cross-section being cut off by the hole. Thus, the transmittance continued sensibly constant presenting a hill area [10].

4. CONCLUSION

The non-linear refractive index (NLR) and the non-linear absorption index (NLA) of a Sony SVGA liquid crystal spatial light modulator sample have been examined utilizing the single beam (Z-scan) technique with He-Ne laser of 632.8 nm wavelength. The positive sign of the NLR is due to the self- focusing of the sample process, the amounts of NLR and NLA explain the high sensitivity and very low absorption for this sample. The obtained results were compared with previous studies for several types of liquid crystals, it was observed that our study is a convergence with most of these materials and it is a distance with others by calculating Absolute Error (AE). The sample shows a very good optical limiting behavior arising from the NLR at the given wavelength. Thus, its preparation technique will be an important aspect in optical sensing, and in different optical modulations.

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قياسات الشعاع المنفرد لمُعدِّل الضوء المكاني البلوري السائل من نوع سوني SVGA

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الخلاصة:

في هذا العمل، تم تقدير الخصائص البصرية اللاخطية لعينة مُعدِّل الضوء المكاني البلوري السائل SVGA من نوع سوني باستخدام تقنية مسح ضوئي أحادي الحزمة مع ليزر He-Ne عند 632.8 نانومتر. وقد وجد أن قيمة معامل الانكسار اللاخطي (NLR) هو (0.694 × 10-7 سم2 / ملي واط) ذو إشارة موجبة، مما يشير الى ظاهرة التبئير الذاتي، في حين أن قيمة معامل الامتصاص اللاخطي (NLA) لهذه العينة (0.0101 × 10-1 سم / ملي واط)، وكان صافي قيمة NLR هو (0.138 × 10-5 سم2 / ملي واط). تم مقارنة هذه النتائج مع نتائج دراسات سابقة في أنواع مختلفة من البلورات السائلة. أظهرت النتائج التي تم الحصول عليها أن العينة لديها قدرة عالية على إنشاء محددات، ومفاتيح، وأدوات تعديل بصرية.