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Third-ordernonlinear optical properties of Spatial Light Modulator

[1]Sawsan. K.saadi,[2,3]Kais. A. Al Naimee and [2]Soudad. S. Ahmed

[1]*Ph.D. student, Ministry of Science and Technology, Advanced Materials Research Directorate, Baghdad, Iraq.*
[2]*DepartmentofPhysics, Prof., College of Science, University of Baghdad, Baghdad, Iraq.*
[3]*IstitutoNazionale di OtticaApplicata -C N R, Largo E. Fermi 6, 50125 Firenze, Italy.*

Address For Correspondence:
Soudad. S. Ahmed, Department of Physics, Asst. Prof., College of Science, University of Baghdad, Baghdad, Iraq
E-mail:soudadbassam@gmail.com

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ABSTRACT

The determination of the real part of the third order nonlinear susceptibility,x^3, of Spatial Light Modulator (SLM) utilizing Z-scan technique has been presented. The nonlinear refractive index (NLR) and the nonlinear absorption coefficient(NLA) of SLM are investigated. The magnitude of NLR of SLM is found equal to0.695×10^{-7}cm^2/mw, while the magnitude of NLA is 0.0102×10^{-1}cm/mw, the pure magnitude of NLR is obtained to be as 0.139×10^{-8}.

INTRODUCTION

Spatial Light Modulator(SLM)is a programmabletri –dimensionaldevice which is based on liquid crystal(LC)arrays, its importance comes from the ability for modifying thephase of the light pattern, and the amplitude, or both, with respect to the pixelsposition (Lazarev, G.,*et al*., 2012). Technology of SLM is considered a rapidly growing field, it is a recently developed transmission method, and becomes an integral part of many optical imagingexperiments, and complex opticalapplications require several partsof optical devices (Zupancic, P.P.J., 2013; Roopashree, M.B.,).Hence, it is very useful to study the non-linear characteristics, such asthe nonlinear index (NLR) and the nonlinear absorption coefficient (NLA), of the SLM device (Askari, M.B.,*et al*., 2014).Materials that have third-order optical nonlinearitiesrecently become the fieldof an extensive scientific effort, due to theirnecessary in more extensive optical measurements (Neethling, P., 2005).Third-order nonlinear optical susceptibility,$x^{(3)}$, represents the NLR and NLA whichdenote in the real part and imaginary part respectively (Nalda, R.D.,*et al*., 2002; Abdullah1, L.A.,*et al*., 2015; Friberg, S.R. and P.W. Smith, 1987). Several methods have been utilizedto measure $x^{(3)}$(Adair, R.,*et al*., 1987; Moran, M.J.,*et al*., 1975; Owyoung, A., 1973; Maker, P.D. and R.W. Terhune, 1965; Williams, W.E.,*et al*., 1984; Bae, Y., J.J. Song and Y.B. Kim, 1982). Z-scan techniqueis the easiest and benefitsone of these methods (Shahriari, E. and W.M. Mat Yunus, 2010; tahir, D.K.,*et al*., 2012),sign via magnitude of NLR andNLA can be doing independently(Neethling, P., 2005). In this paper we report the measurement of third order nonlinear optical coefficients of aSLM by Z- scan technique.

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Experiment:

The diagram represents the Z- scan technique isshown in Fig. 1.The experiment was conducted at room temperature and the laser source is He-Ne laser withwavelength 632.8nm. A lens of focal length f=10 cm for the utilizing.

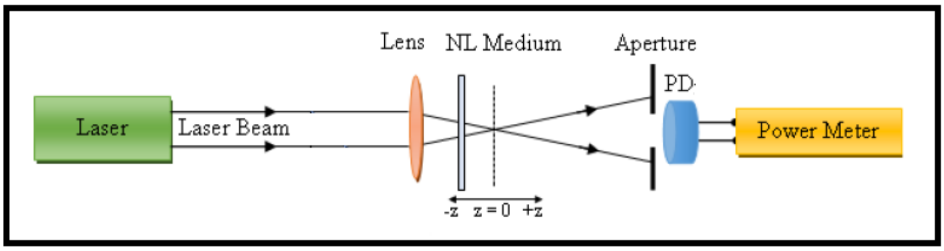
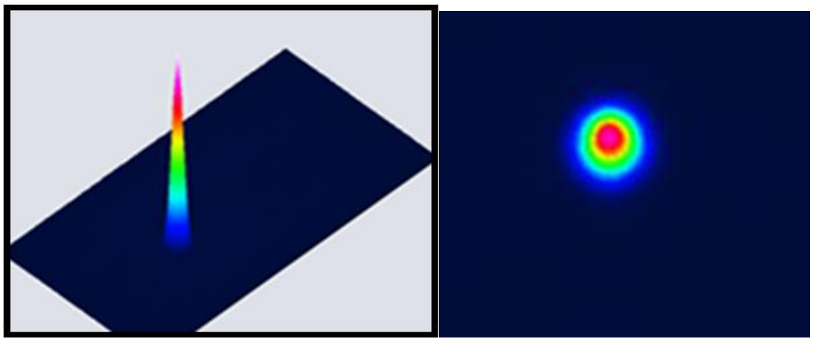


Fig.1: Schematic diagram of Z- scan setup.

The sample used in this work is the HoloEye Photonics LC2002 SLM,of 1.3 mmlength, the beam waist(w_o) at the focalpointis 0.08mm while the Rayleigh length $Z_o$is3.1 cm. The pattern of He-Ne Laser is shown inFig. 2. The OA and CA states have done respectively.



(a) (b)

Fig. 2: An intensity profile of the He-Ne laser pulse (a) 3D, and (b) 2D display.

If the transmitted light is measured through an aperture positionedafter a supplementary distance from focal point, the technique is called closed aperture (CA) Z- scan, the measurement in this manner helps to calculate the magnitude and sign of the NLR. On the other hand, if transmitted light is measured when the aperture is removed, the is called open aperture (OA) Z- scan (AL-Hamdani, A.H.,*et al*., 2015; Ule, E., 2015). In this condition, the measurement gives information about the NLA. In a Z-scan measurement, if the SLM sample is moved through the focal point of a laser beam with high intensity, the beam intensity will shows change in intensity outputdepending on propagation of a wave front distortion (Ménard, J.M.,*et al*., 2007; Poornesh, P. and S. Shettigar, 2009).

It is presumedthat LC of the SLM is thin, i.e. the sample thickness (L) is much less thanRayleigh's range $z_\circ$ **(**Nader, R.,*et al*., 2015; Munnich, M., B. Deflection, 2013**),** this permits to consider the interaction between the laser beam and the SLM to happen at only one position and not to spread out over the entire interaction length (Khurgin, J.B.,*et al*., 2015). In CA state, whenalaser beam is passed throughSLM, the refractive index of SLM will change the output intensity (Stryland, E.W.V., 1998). The phase shift ($\Delta\varphi o$) is determined by the change in outputpowerintensity between peak and valley and is given by (Neethling, P., 2005; Moran, M.J.,*et al*., 1975):

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

where ΔTp-v is the difference between peak and valley of output power, andSis the hole transmittance provided by (Nader, R.,*et al*., 2015; Stryland, E.W.V., 1998):

$$S=\left(1-exp\left(-\frac{2r_a^2}{w_a^2}\right)\right) \quad (2)$$

Wherer_a is the radius of the hole, w_a is the radius of the beam at the hole. TheSLM is placed at the focus point of the lens, and then moved along the z axis a distance of$\mp z_\circ$ which is given by the Rayleigh length $z_\circ$:

$$z_\circ = \frac{\pi w_\circ^2}{\lambda} \quad (3)$$

Wherew_0 is the beam waist. TheNLRis given by:

$$NLR = \frac{\Delta\varphi_\circ}{kI_\circ L_{eff}} \quad (4)$$

where k is the wave number, λ is the wavelength of the beam, I_o is thelaser intensity at focus given by: (Abdullah1, L.A.,*et al*., 2015; Ule, E. , 2015)

$$I_\circ = \frac{2P_\circ}{\pi w_\circ^2} \quad (5)$$

where P_0 is the laser input power. The L_{eff} is the effective length of theSLM, and given by:

$$L_{eff} = \left(1 - exp(-\alpha_\circ L)\right)/\alpha_\circ \quad (6)$$

where L is the thickness of SLM.

In OA condition, the aperture is removed to allow all the light to reach the detector.when the SLM gets closer to the focal point, the output power will be at maximum value, and therefore the absorption rises as well and the NLA could be measured.Thedecreasingof laser intensity throughSLMisgiven by (Neethling, P., 2005):

$$\frac{\partial I}{\partial Z} = -\alpha(w)I \quad (7)$$

Where α is a constant, the solution of this equation is:

$$\mathrm{I}(Z) = I_\circ e^{-\alpha(w)z} \quad (8)$$

where I_0 is theintensity of incident Laser beam, $\alpha(\omega)$ is the linear absorption coefficient, z is the distance traveled by light in the sample and I(z) is the intensity at thickness z. In nonlinear matter, hence equation (8) willbe include high order intensity terms:

$$\frac{\partial I}{\partial z} = -\alpha(w)I - NLA(w)I^2 - \gamma^2 - O(I^4) \quad (9)$$

where $NLA(\omega)$ is the third-order coefficient (i.e. the NLAcoefficient), $\gamma(\omega)$ is the three-photon absorption coefficient and $O(I^4)$ is the four-photon absorptioncoefficient, the NLAis given by (Ule, E. , 2015; Stryland, E.W.V., 1998):

$$NLA = \frac{2\sqrt{2}\,\Delta T}{I_\circ L_{eff}} \quad (10)$$

where ΔT is the peak value at OA of the Z-Scan curve. It is importance to notice that data of OA state is independent on to CA state (Hosseini, S.A.,; Hussein, I. and S. Abdulkareem, 2014).

RESULTS AND DISCUSSION

III.1 Nonlinear Refractive Index Coefficient Measurements (NLR):

The CA z-scan technique allows us to conclude the sign and magnitude of the NLR.At the focus point the intensity oflaser beam is calculated to beI_0 = 199.04mW mm^{-2},and the linear wholeof transmittance is 0.9. As the SLM is passages through the beam focus (Z = 0), self-focusing or defocusing modifies the wave front phase, thereby varyingthe detected beam intensity. Theoutput behavior of the SLM in Fig. 3 shows the positive z-scan profile whichbeginning far from the focus (Z < 0),the laser beamintensity is low and the nonlinear refraction is negligible,in this state, the detect transmittance remainsconstant (i.e., Z-independent)and a minor spot size with a minimum transmittance at CCD camera is producedas shown in Fig.3 (a-b).As the SLM is shiftedtowards the focus, Fig.3 (c), intensityincreases, leading to self-lensing in the SLM tend to collimate the beam on the aperture placed in front of the detector, and thus a higher transmittance passes through the aperture. This effect increases as the SLM is moved towards the focus, Fig.3 (d-e), due to the intensity increases. This maximum in transmittance will drop to a minimum, Fig.3 (f), as the SLM is moved further and the beam diverges as a result of the negative lensing by the SLM. The transmittance through the aperture will again return to the linear values as the sample is moved further from the focus (Z > 0).

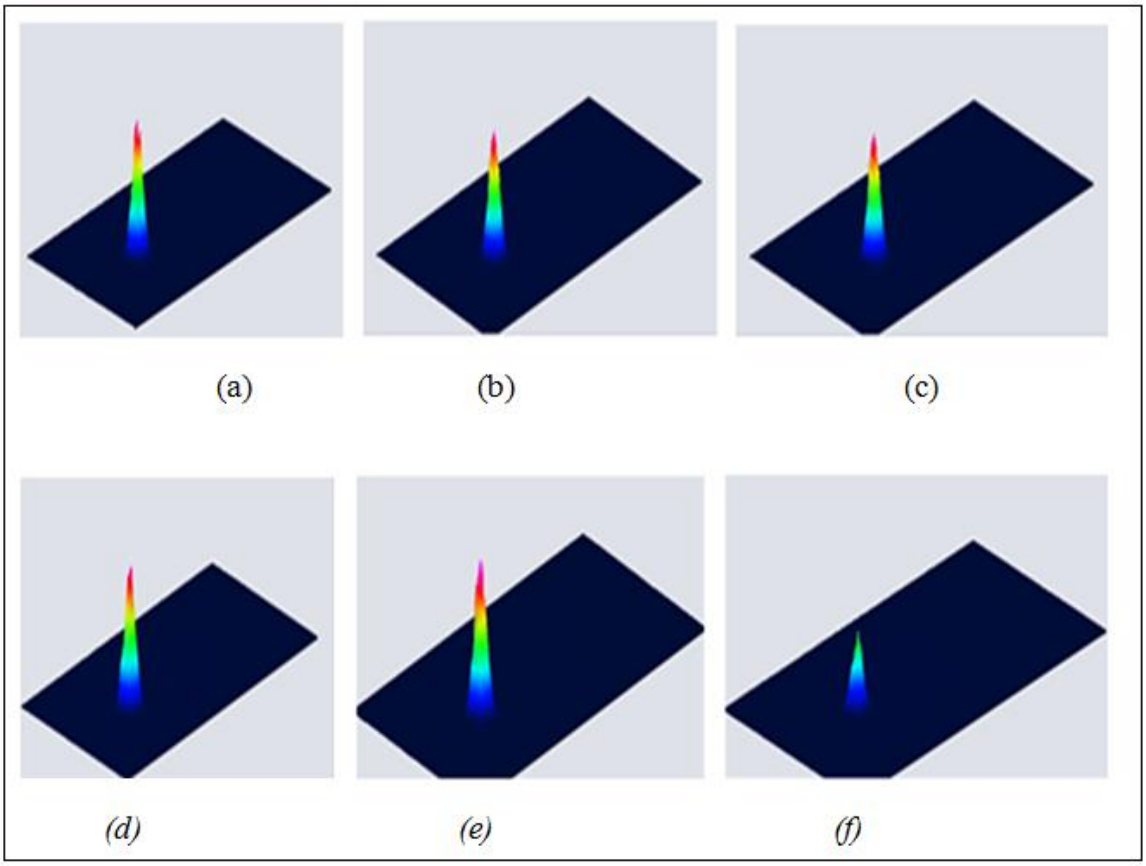


Fig. 3:3D display, diffraction patterns of the SLM for closed aperture state,the face of the SLM was imaged onto a camera through a pinhole that passed only the first diffraction orders produced by the SLM, when it is moving along different distances:(a) z=-2mm, (b) z=-1mm, (c) z=0mm, (d) z=.05mm, (e) z=1mm, (f) z=3mm.

The obtaineddata of the SLM for the CA caseis shown in Fig. 4.From these results we notice that the sign of NLR of the SLM is positive and the magnitude of the NLR coefficient is $0.695\times10^{-7}cm^2/mw$.

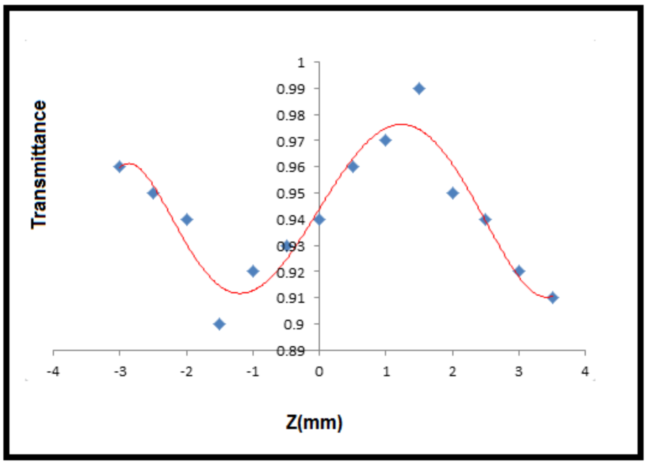


Fig.4: The Z- Scan experimental data of closed aperture state for theSLM shows a positive NLR.The transmittance increase when SLM is move far from the focus, and the behavior shows decreases as SLM is shifting close to focus.

The values obtained from CAstateforSLMare listed in Table 1.

Table 1: The experimental results for SLM at CA state.

material	$\Delta T p - v$	$\Delta \emptyset$	NLR($\frac{cm2}{mW}$)
SLM	0.07	0.172	0.695×10^{-7}

III.2 Nonlinear Absorption Coefficientmeasurements (NLA):

Nonlinear absorption coefficientof the SLM is determined utilizingOA z-scan measurements.Thetransmittance of SLM in the second diffraction orders is presented as well as the zero order diffraction orders of SLMas shown in Fig.5, this behavioris due to the SLM structure, where it contained arrays of pixelated LC.

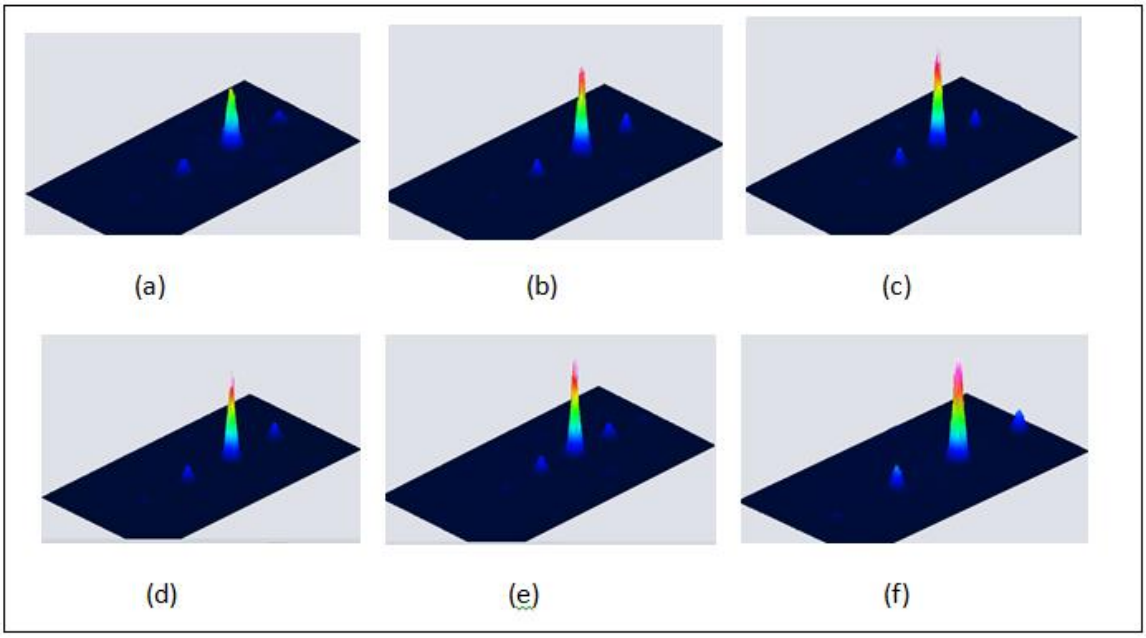


Fig. 5: Diffraction patterns of the SLM, the second order diffraction appears with the zero order diffraction for open aperture Z- Scan experimental, (a) z=0mm, (b) z=1mm, (c) z=2mm, (d) z=-0.5, (e) z=-1, (f) z=-2.

The performance of transmittance started linearly at different distances from the far field of the SLMposition (-Z). At the near field, the transmitted curve begins to decrease until it reaches the minimum value at the focal point(atZ=0). The transmittancebegins to increase toward the linearperformance at the far field of the SLM position (+Z). Thevariation of the intensity in this condition is produced by two photon absorption in the SLM movements across beam waist, as shown in Fig.6. The value of NLAof the SLM is calculated by using equation (10) to be5.29×10^{-3} cm/mW.

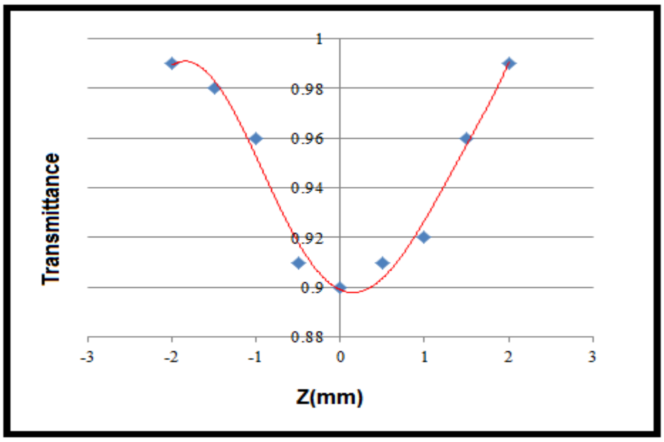


Fig.6: The open aperture Z- Scancurve of experimental datafor theSLM.

The values of obtained by OA state forSLM sample are listed in Table 2.

Table 2: Nonlinear absorption coefficient for SLM

Material	T_{min}	$NLA(\frac{cm}{mW})$
SLM	0.9	0.0102×10^{-1}

Perfect NLRis obtained by dividing the results of CA data by the results of OA data. The results are shown in Fig.7.

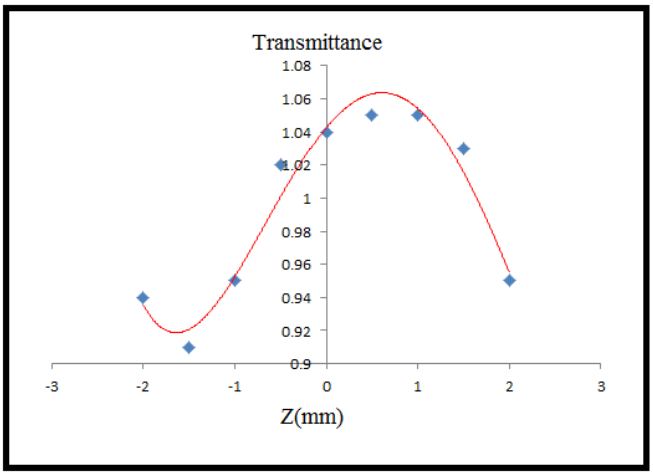


Fig. 7: Closed aperture Z-scan experimental data for the SLM by dividing CA/OA.

Theperfect third order NLR magnitude is 0.139×10-8 cm^2 /mW, and the values obtained from CA/OA forSLMare listed in Table 3.

Table 3: Nonlinear refractive index from CA/OA fitted curve for SLM.

material	$\Delta T p - v$	$\Delta\emptyset$	NLR$(\frac{cm2}{mW})$
SLM	0.09	0.344	0.139×10^{-8}

Conclusions:

The Z- scan technique is very appropriate to study the third order nonlinear optical properties,the nonlinear refractive index coefficient and the nonlinear absorptioncoefficient, of the SLM devise. It has been found that the compound shows prominent nonlinear refractive index coefficient with the positive sign indicates the focusing phenomenon, the SLM is therefore seen to be a promising material for designing optical limiters, switches and modulators.The experimentaldata from open aperture measurements showed that a two photon absorption phenomenon.

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REFERENCES

Abdullah1, L.A., S.S. Ahmed1, K.A. Al Naimee, R. Meucci, 2015. Nonlinear Optical Properties of Liquid Crystals, International Journal on Numerical and Analytical Methods in Engineering (IRENA), 3: 7-11.

Adair, R., L.L. Chase and S.A. Payne, 1987. ‘‘Nonlinear refractive-index measurements of glasses using three-wave frequency mixing’’, J. Opt. Soc. Am. B 4: 875-881.

AL-Hamdani, A.H., M.H. Mohamed and A.H. Ali, 2015. “Eclipsing z-scan measurement for mixture of dyes (R6G, RB, AND RC) in liquid and solid media”, ARPN Journal of Engineering and Applied Sciences, 10(16): .6705-6709.

Askari, M.B., P. Jalilpour, F. Ahmadi, 2014. Optical nonlinear absorption coefficient of PbSnano particles studied by the Z-scan technique, American Journal of Nanoscience and Nanotechnology, pp: 28-31.

Bae, Y., J.J. Song and Y.B. Kim, 1982. ‘‘Photoacoustic study of two-photon absorption in hexagonal ZnS’’, J. Appl. Phys., 53: 615-619.

Friberg,S.R.and P.W. Smith, 1987. Nonlinear Optical Glasses for Ultrafast Optical Switches, IEEE J. Quantum Electron, 23: 2089-2094.

Hosseini, S.A., A. Sharan, D. Goswami, "High Sensitive Measurement of Absorption Coefficient and Optical Nonlinearities with a Single Experimental Setup, Tata Institute of Fundamental Research", 42: 1-13.

Hussein,I.and S. Abdulkareem, 2014. "Characterization of Nonlinear Optical Properties and Optical Power Limiting of Leishman Dye Using Z – Scan Technique", Journal of Basrah Researches (Sciences),40(4): 59-67.

Khurgin, J.B., G. Sun, D.P. Tsai, 2015. "Ultrafast Thermal Nonlinearity", scientificreports, pp: 1-8.

Lazarev, G., A. Hermerschmidt, S. Kruger and S. Osten, 2012. LCOS Spatial Light Modulators: Trends and Applications. Optical Imaging and Metrology: Advanced Technologies, First Edition.

Maker,P.D.and R.W. Terhune, 1965. ''Study of optical effects due to an induced polarization third order in electric field strength'', Phys. Rev., 137: A801-A818.

Ménard, J.M., M. Betz, I. Sigal and H.M. van Driel, 2007. "Single-beam differential z-scan technique", Optical Society of America.

Moran, M.J., C.Y. Sheand R.L. Carman, 1975. Interferometric Measurements of Nonlinear Refractive-Index Coefficient Relative to CS2 in Laser- System- Related Materials, IEEE J. Quantum Electron., 11: 259-263.

Munnich, M., B. Deflection, 2013. MSc thesis, University of Central Florida.

Nader,R., A.H. Al-Hamdani, S.I. Ibrahim, R.A. AbdUllah, 2015. "Non-linear properties for Membranes of Rhodamine tincture by using Z-Scan Technique", International Journal of Application or Innovation in Engineering & Management (IJAIEM), 4: 52-57.

Nalda, R.D., R.D. Coso, J.R. Isidro, J. Olivares, A.S. Garcia, J. Solis and C.N. Afonso, 2002. Limits to the determination of the nonlinear refractive index by the Z-scan method, Optical Society of America, 19(2): 289-296.

Neethling, P., 2005. Determining non-linear optical properties using the Z-scan technique, Msc thesis,University of Stellenbosch.

Owyoung, A., 1973. "Ellipse Rotations Studies in Laser Host Materials",IEEE J. Quantum Electron, 9: 1064-1069.

Poornesh,P.and S.Shettigar, 2009. "Nonlinear optical studies on 1,3-disub stituentchalcones doped polymer films", Optical material, 31: 854.

Roopashree, M.B., A. Vyas, R. Banyal and B.R. Prasad, phase characteristics of reflecting and transmitting type twisted nematic spatial light modulator.

Shahriari,E.and W.M. Mat Yunus, 2010. "Single Beam Z-Scan Measurements of Nonlinear Refraction and Nonlinear Absorption Coefficients in Silver Nano-Fluid", American J. of Engineering and Applied Sciences, 3: 98-101.

Stryland, E.W.V., 1998. "Z-Scan Measurements of Optical Nonlinearities, Characterization Techniques and Tabulations for Organic Nonlinear Materials", Florida, pp: 655-692.

tahir, D.K., D.R. Abd-Alamire and A. Raheem, 2012. "Linear and Nonlinear optical properties of dichromate gelatin", Karbala university,college of science,physics department, 10(2): 62-69.

Ule,E., 2015. "Measurement of The Nonlinear Refractive Index by Z-scan Technique", Ljubljana".

Williams, W.E., M.J. Soileau, and E.W. Van Stryland, 1984. ''Optical switching and n2 measurements in CS2 '', Opt. Commun., 50: 256-260.

Zupancic, P.P.J., 2013. Dynamic Holography and Beamshaping using Digital Micromirror Devices, Msc thesis, Ludwig-Maximilians-UniversitatMunchen.