J. Indian Chem. Soc.,
Vol. 96, January 2019, pp. 45-47

Insight into nonlinear third order susceptibility measurement and optical limiting nature of 8-hydoxyquinolinium hydrogen fumarate single crystal

G. Ahila[a], G. Vinitha[b] and G. Anbalagan[c*]

[a]Department of Physics, Presidency College, Chennai-600 005, India

[b]Division of Physics, School of Advanced Sciences, Vellore Institute of Technology (VIT), Chennai-600 127, India

[c]Department of Nuclear Physics, University of Madras, Chennai-600 025, India

E-mail: anbu24663@yahoo.co.in

Manuscript received online 01 September 2018, accepted 09 October 2018

The NLO third order characteristics for 8-hydroxyquinolinium hydrogen fumarate (8HQF) compound were estimated by a diode pumping second harmonic CW Nd:YAG laser (532 nm) by utilizing Z-scan method. The resultant value with its magnitude for nonlinear refractive index was 8.64×10^{-8} cm^2 W^{-1}, nonlinear absorption coefficient was 0.08×10^{-4} cm W^{-1} and the third order nonlinear susceptibility was found to be 15.28×10^{-6} esu. A negative nonlinearity of 8HQF proves it to be a self de-focusing nature and this to be the reason for exhibiting optical limiting nature.

Keywords: Z-scan, self de-focusing, optical limiting.

Introduction

A delve into new materials having advanced properties is being a crucial area for present researchers. There is an ample interest for finding out the materials experiencing high nonlinearity for all optical switching devices and applications towards sensor protection, telecommunication and integrated optics[1,2]. Organic NLO systems are such materials which overthrow the instinctive constraint for attaining nonlinearity over inorganic material. Organic 8-hydroxyquinoline plays as proton donor so that can form diversified charge transfer complexes and that complexes are well recognized for its optical NLO properties. Typically aromatic compounds which releases electron act as donor substituent group and which readily gains the electron act as acceptors. A material is considered as a good optical limiter when two of its properties exhibit materials nonlinear absorption coefficient and its nonlinear index of refraction. These two parameters acquired through Z-scan experiment, changes the intensity of light in a nonlinear way which passes through the medium. Hence on measuring these characteristics of nonlinear materials they can be identified as possible optical limiters.

Franklin *et al*. had already reported the structure of the combining precursor's 8-hydroxyquinoline and fumaric acid[3]. Although they have uncharted its NLO properties of third order and its optical limiting nature. Therefore the thermally prompted optical linearity through a diode pumped Nd:YAG (532 nm, 50 mW) of 8HQF is meticulously examined by Z-scan experiment. Furthermore, the properties of optical limiting build on self defocusing effect are investigated in detail.

Z-Scan experiment:

In the present experiment, 8HQF crystal having 1 mm thickness was irradiated by a laser beam of 50 MW continuous wave having 532 nm diode which is pumped by Nd:Yag laser and was keenly focused by a lens having focal length 3.5 cm. The crystal is adjusted and translated between a axial direction to differentiate the intensity of laser falling on to the surface of the crystal. The transmittance received from beam of an aperture is noted through a photo detector where a digital meter is connected to it. The delineation diagram intended with the recorded data illustrating closed aperture and open aperture are shown in Fig. 1.

The interaction in-between the Gaussian beam and the exterior surface of the crystal provokes a spatial differentiation in refractive index and thus it results in distortion in beam propagation. Therefore the normalized transmittance recorded with open aperture and by closing the aperture reveals the absorption and refraction in nonlinear manner re-

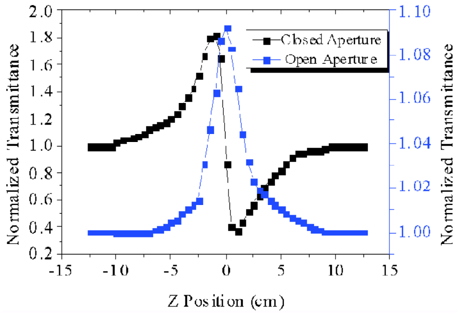

Fig. 1. Closed and open aperture for 8HQF crystal.

spectively[4]. The Fig. for closed aperture obtained from Z-scan shows a peak which is just pursued by a valley and therefore specifying it to be negative which is known to be self defocusing. This happens in reason to local discrepancy of refractive index with temperature. The open aperture portrays that at high intensity the absorption is saturated near to the focus. $\Delta T_{p\text{-}v}$ is an expression which represents the deviation betwixt the normalized transmittance of peak and valley as a function of $\Delta\phi_0$ as given below:

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

In the above equation sketch out the shift in phase at the focus placed on axis and the linear aperture transmittance,

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

where r_a depicts the aperture radius at the same time ω_a is the radius of laser spot back the aperture. The n_2 is represented by:

$$n^2 = \frac{|\Delta\phi_0|}{kL_{eff}I_0} \qquad (3)$$

L_{eff} is given as $L_{eff} = (1 - e^{-\alpha L})/\alpha$ with L denoting the sample's length, α as the linear absorption coefficient, at the axis of focal point z = 0, and the wave vector $k = 2\pi/\lambda$. The β is calculated from the following equation:

$$\beta^2 = \frac{2\sqrt{2}\Delta T}{I_0 L_{eff}} \qquad (4)$$

The Rayleigh length, $Z_R = kw_0^2/2$, where w_0 is the beam waist at focal spot. On obtaining the values of n_2 and β it is easier to figure out the values of real part (Re $\chi^{(3)}$) and the imaginary part (Im $\chi^{(3)}$) bestowing to the subsequent relation:

$$\mathrm{Re}\,\chi^{(3)}\,(\mathrm{esu}) = \frac{10^{-4}(\varepsilon_0 C^2 n_0^2 n_2)}{\pi}\,(\mathrm{cm^2/W}) \qquad (5)$$

$$\mathrm{Im}\,\chi^{(3)}\,(\mathrm{esu}) = \frac{10^{-2}(\varepsilon_0 C^2 n_0^2 \lambda\beta)}{4\pi^2}\,(\mathrm{cm^2/W}) \qquad (6)$$

where ε_0, c are the universal constants, n_0 is the linear refractive index of the sample and λ is the wavelength of laser beam. The susceptibility of order three nonlinearity is given by:

$$|\chi^3| = \left[\left(\mathrm{Re}\left(\chi^3\right)\right)^2 + \left(\mathrm{Im}\left(\chi^3\right)\right)^2\right]^{1/2} \qquad (7)$$

Therefore using all above equation the calculated nonlinear values of refractive index (n_2), absorption coefficient (β) was 8.64×10^{-8} cm^2/W and 0.08×10^{-8} cm/W respectively with that optical susceptibility (χ^3) of real and imaginary was 15.28×10^{-6} esu and 0.51×10^{-6} esu and total nonlinear susceptibility (χ^3) of order three is estimated to be 15.28×10^{-6} esu.

The recorded optical limiting curve for the crystal is shown in Fig. 2. The output intensity which is transmitted is found to vary in linear with respect to the intensity given as input. It is observed that it deviates near high intensity values. When power is raised further the intensity reaches threshold amplitude and thus the maximal output intensity shows the optical limiting characteristic. The maximum output power of 23.1 mW of 8HQF portrays its limiting behavior and hence can be used for application oriented to optical limiting[5] for human eye.

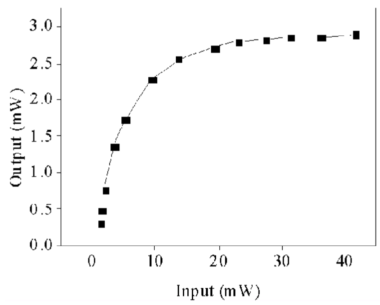

Fig. 2. Optical limiting for 8HQF.

Conclusions

The nonlinear optical response exhibited by 8HQF at low cw laser was investigated and the action of optical limiting relied on refraction in nonlinear manner is explained. The larger value of (χ^3) with the magnitude 10^{-6} esu owes to the larger delocalization promoted in charge transfer complex pattern. The nonlinearity is noted to be large and negative in reason to the illumination of cw laser. The self defocusing nature of 8HQF behaves as a good optical limiter in the low power reign as because even a 1^{-5} mW cw laser light exposed to eyes for milliseconds would harm the eyes permanently.

References

1. D. F. Eaton, *Science*, 1991, **253**, 281.
2. C. Bosshard, K. Sutter, P. Pretre, J. Hulliger, M. Flörsheimer, P. Kaatz and P. Günter, "Organic Nonlinear Optical Materials", Gordon and Breach, Basel, 1995.
3. S. Franklin and T. Balasubramanian, *Acta Crystallographica,* 2009, **C65**, o58.
4. B. Kulyk, A. P. Kerasidou, L. Soumahoru, C. Moussallem, F. Gohier, P. Frere and B. Saharaoui, *RSC Adv.*, 2016, **6**, 14439.
5. Jesby George, D. Sajan, Javeesh Alex, Arun Aravind, G. Vinitha and R. Chitra, *Opt. Laser Technol.,* 2018, **105,** 207.