Optical Limiting Behavior of Congo red Dye Under CW Laser

Hussan Ali Badran, Allya J. Jerry

Abstract— The optical limiting properties for solution of Congo red dye in the solvent Dimathyl sulfoxide (DMSO) is reported. Experiments are performed using the diode laser beam at 532 nm wavelength and 40mW power. Measurements were performed using two continuous wave (CW) laser beams. The effects of concentration of the sample on the optical limiting properties have been investigated. The optical limiting behavior is investigated by measuring the transmission of the samples. A mechanism for the optical limiting is given.

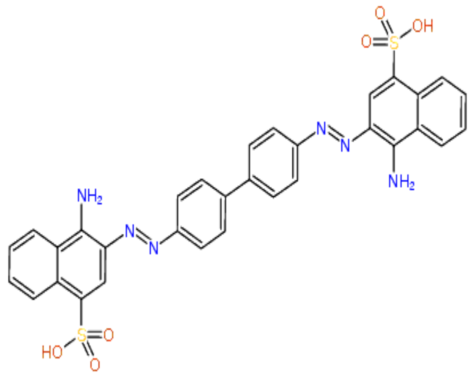
Index Terms— **optical limiting, dye , CW laser, Threshold power.**

I. INTRODUCTION

With the rapid development of new laser technology, the optical limiting materials for the protection of optically sensitive devices and human eyes from laser damage in both civilian and military applications have received significant attention in recent years [1,2]. An optical limiter strongly attenuates the laser beam of high intensity whereas it is completely transparent at lower light intensities. Ideally, the laser beam transmitted through the limiter rises linearly with input power and saturates to a constant value at high power at which the transmittance is fifty percent. Above the threshold, the output power is clamped to the saturated value which depends on the material. The optical limiter is a device used to protect the human eye, optical sensor, electronic devices and other optical devices against the high intensity of the laser light. OL is designed to have a linear transmission below threshold for low level light inputs, and a constant transmission above threshold for high power, thus it becomes safe to the eye, optical sensors and to the electronic devices [3]. The material must possess special characteristics to show the optical limiter action such as high optical damage threshold, high linear transmittance at low input power and a low threshold value [4,5]. Optical limiters, whose filtering action is instantaneously activated by the incoming intense light represents a valid solution for the protection of sensors. In this case, the incoming intense light alters the absorptive and refractive properties of the materials in such a way that the resulting transmitted intensity is greatly reduced [6-8]. Optical limiters based on reverse saturable absorption (RSA) are very transparent for weak light and get opaque for the intense light. Moreover, if only RSA occurs, the quality of the vision can still be maintained during the process of optical limiting (OL) [9].The aim of the present work is to improve the optical limiting properties for dye to obtain better optical limiting properties as the results on the optical limiting properties of an organic dye, Congo red dye dissolved in DMSO solvent using a continuous wave (CW) laser was reported. The threshold values of the samples are determined. The dependence of threshold value on various parameters is also investigated.

II. EXPERIMENTAL TECHNIQUE

The Congo red dye was purchased from Aldrich and used without any purification. Fig.1 shows the molecular structure of Congo red dye.



Figurer 1: Molecular structure of Congo red dye.

The UV–visible absorption spectrum of Congo red dye in the solvent Dimathyl sulfoxide (DMSO) was recorded using a Cecil Reflected- Scan CE 3055 Spectrophotometer. The optical absorption of the Congo red dye with concentration 0.04, 0.05, 0.06 and 0.07 mM shows an absorption peak at 529 nm as shown in Fig. 2.
The spectrum of the optical absorption was computed from the absorbance data. The absorption coefficient (α) was obtained directly from the absorbance against wavelength curves using the relation [10-15]

$$\alpha = \frac{2.303A}{L} \qquad (1)$$

where A and L are the absorbance and thickness of the cell respectively.

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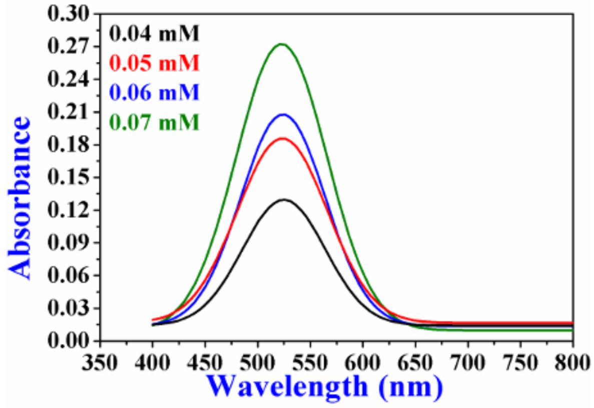

Figure 2: Absorption spectra of the Congo red at different concentrations.

The values of absorption coefficient (α) at wavelength 532 nm for Congo red in solvent DMSO with different concentrations have been calculated using Eq. 1 and the results are given in Table 1.

Table 1: Absorption coefficient of Congo red at 532 nm wavelength.

Concentration mM	Absorbtion	α (cm^{-1})
0.04	0.127	2.924
0.05	0.182	4.191
0.06	0.202	4.652
0.07	0.264	6.079

III. Results and Discussions

A cw solid state laser (SDL) was used as a light source. The wavelength of the laser is 532 nm. The experimental set-up for the demonstration of an optical limiting effect is shown in Fig. 3. The laser beam was focused normally into the sample by a positive lens with a focal length of +5 cm. In the case of the sample solution, a 1 mm quartz cell was used to contain the solution of Congo red in the solvent Dimathyl sulfoxide (DMSO). The sample could be moved back and forth along the direction of the optical axis in order to change the position of the focal point of the lens with respect to the sample. A variable beam splitter (VBS) was used to vary the input power. An aperture A of variable diameter is used to control the cross-section of the beam coming out of the sample. This beam is then made to fall on the photo detector (PD). The input laser intensity is varied systematically and the corresponding output intensity values are measured by the photo detector that is connected to a power meter (Field Max II-To+OP-2 Vis Sensor). In order to avoid cumulative thermal effects, data were collected in the single shot mode. The experiments were performed at room temperature.

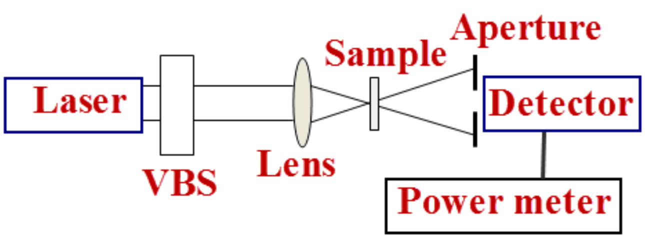

Figure 3: Experimental set-up for an optical limiting effect.

3.1 Optical limiting as a function of concentration

The dependence of optical limiting on the sample concentration is studied for different sample concentrations by using the configuration shown in Fig.3. Since these samples show absorptions at 522 nm, SDL laser at 532 nm is used in this study. In this experiment the sample was placed behind the focal point of the lens and the aperture size was set to be 5mm in diameter. The optical limiting curves for the sample solution with different concentrations is shown in Fig. 4. The output power rises initially with an increase in input power for all the samples, but after a certain threshold value the sample starts defocusing the beam, resulting in a greater part of the beam cross-section to be cut off by the aperture [16,17]. Thus the transmittance recorded by the photo-detector remains reasonably constant showing a plateau region and is saturated at a point defined as the limiting amplitude. i.e., the maximum output intensity, showing obvious limiting property [18].

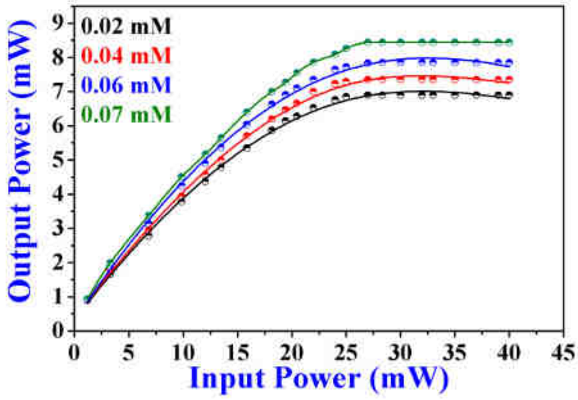

Figure 4: Optical limiting of Congo red with different concentrations

Figure 5 show the normalized transmission curves as a function of the incident input power for different concentrations of sample solution. The optical limiting abilities are quantitatively different. The optical limiting thresholds (T_H) for the sample solutions are measured and they are given in Table 2. It is well known that the concentration plays a very important role in the optical limiting action [19,20]. The optical limiting effect is enhanced and the transmittance decreases with increasing concentration. This is because a sample with high concentration has more molecules per unit volume participating in the interaction during the nonlinear absorption processes [21-23]. So the optical limiting responses of the low concentration samples are generally much weaker than those of the high concentrated samples, while high concentrated samples exhibit strong optical limiting within the range of this study [24,25]. However, the concentration of the sample should be chosen carefully in order to reach the concentration threshold, which is an important factor in the investigation of optical limiting.

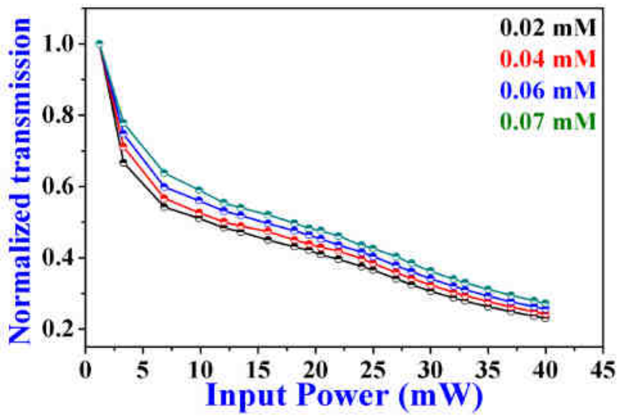

Figure 5 Normalized transmission curves of optical limiting.

Table 2: Optical power limiting threshold for the Congo dye solution.

Concentration mM	T_H *(mW)*
0.04	10.7
0.05	12.4
0.06	15.5
0.07	18

CONCLUSION

It is evident that the optical power limiting effect depends on the concentration of the Congo dye and increases with increasing the dye concentration, while the power limiting threshold decreases with increasing the dye concentration. At high Congo dye concentrations, the output power reached a plateau at low input power and the dye medium exhibits strong optical power limiting effect. The power limiting effect was observed in the Congo dye and is affected by the variation of the concentration. These advantages give an indication that the Congo dye is a promising material for potential applications in nonlinear optical devices such as photonic and signal processing device

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