Study of the optical limiting properties of Ethidium Bromide under CW laser illumination

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Abstract— **The optical limiting properties of Ethidium Bromide dye in double distilled water was investigated using 532 nm cw solid state laser (SDL) as a light source. The variation in the output power was studied as a function of input power for four different concentrations, and for two different aperture sizes and the influence of all these parameters on the threshold limit and output clamping power was analyzed. All these experimental results show that this dye is a promising material for applications in various optical limiting devices.**

Index Terms— **cw laser, optical limiting, saturated output, Ethidium Bromide.**

I. INTRODUCTION

Optical limiting (OL) material is a kind of nonlinear optical material that can limit the transmitted light intensity to a maximum value, namely, render transparency to weak signals and opaqueness to strong signals. Such materials can protect sensitive photodetectors (including optical sensors and human eyes) from undesired high-intensity radiation hazards. Therefore, OL materials have received considerable attentions due to growing needs for optical techniques [1,2]. For an ideal OL material, it should exhibit a high, linear transmission below a certain ''limiting" threshold, and above this threshold the transmission becomes highly nonlinear. Besides, this material should be capable of switching back and forth between the two states in quick response to external optical signals [3]. Thus far, researchers have made great efforts to search for such OL materials [4–6]. More recently, several materials and device configurations have been proposed and developed to meet this challenge [7]. Among new materials, organic and organometallic compounds with nonlinear optics (NLO) properties have emerged as promising candidates [8–15] for the limiting of the laser radiation intensity because of their large nonlinearities, inherently fast response time, broadband spectral response and ease of processing. In order to protect optical systems and human eyes from debilitating laser effects, the intensity of incoming laser light has to be opportunely reduced [16]. 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. 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).

In this report, the OL effects of the Ethidium Bromide dye (EtBr) in double distilled water were investigated experimentally. The variation in the output power was studied as a function of input power for four different concentrations, and for two different aperture sizes. The results show that EtBr is a promising alternative for use as a limiter.

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II. UV-VISIBLE SPECTROSCOPIC

The UV-Vis (Ultraviolet-visible) absorption spectra for the Ethidium Bromide dye solvent in double distilled water was recorded using Cecil Reflected- Scan CE 3055 reflectance spectrometer. The molecular structure of the Ethidium bromide dye and the linear absorption spectrum of the dye dissolved at 1, 2, 2.5 and 3 mM concentrations is shown in Figure-1. Also it can be seen from the Figu.1 that the absorbance of the sample increases with increasing the concentration due to the increase in the number of molecules per unit volume, so the absorbance will be increased.

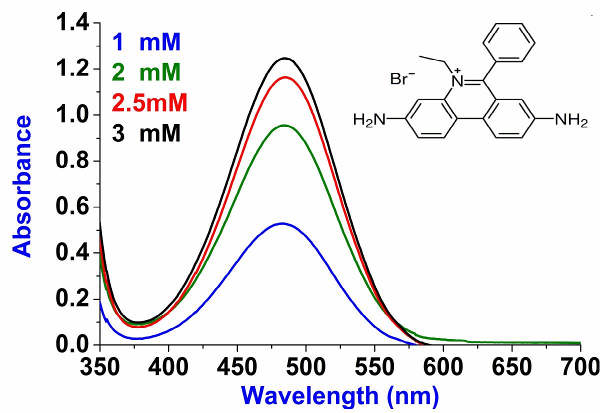

Fig 1. Chemical structure and absorption spectra of dye with different concentration.

III. EXPERIMENTAL RESULT

The limiting effect of the Ethidium Bromide dye solvent in double distilled water was studied by using a 50 mW solid state CW laser at 532 nm. The experimental set-up for the demonstration of optical limiting is shown in Figu. 2. 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 EtBr. 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.

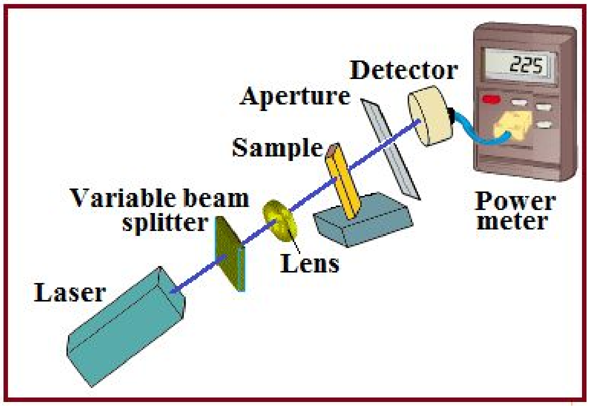

Fig. 2. Experimental set-up for an optical limiting effect.

A variable beam splitter (VBS) was used to vary the input power. An aperture 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). The photograph of the experimental set-up is shown in Figure-2. The dependence of optical limiting on the sample concentration is studied for different sample concentrations by using the configuration shown in Figure-2. 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.

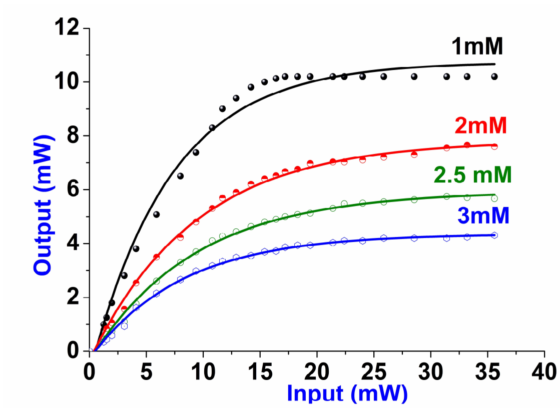

Fig.3. Optical limiting of sample with different concentrations for **a** EtBr solution.

The optical limiting curves for the sample solution with different concentrations are shown in Figure-3. 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. 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. The saturated output value at which limiting occurs for the sample solution are shown in Fig. 4 for different concentrations. It can be seen from Fig. 4 that the saturated output value decreases with an increasing concentration.

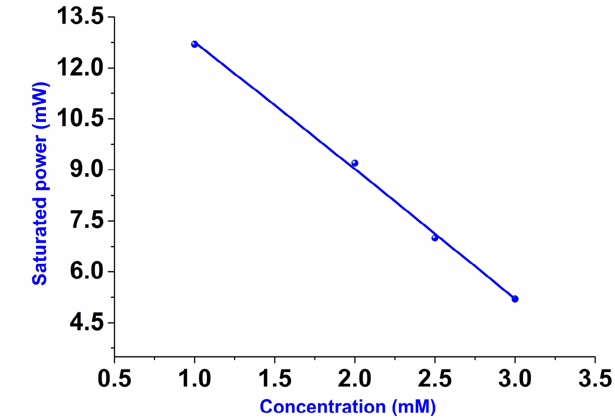

Fig. 4. Concentration dependence of saturated output value of sample for a EtBr solution.

During the process of measuring, when the input power increases, the transmitted beam is photographed from a distance far from the sample. Fig. 5 show such photographs for 6 mM concentration of sample solution when the input powers are 1.9, 4.5, 12.3, 20.5, 32.2, 37.2 and 43.3mW respectively. From the photographs a,b and c in Fig. 5 it is clear that the spot size increases with an increasing input power, which reflects the increasing output power. This explains the rapid increases in the output power for 1.9, 4.5 and 12.3mW input power in the limiting curve of Fig. 3. It can be seen from the photographs d and e in Fig. 5 that there is a small increase in the spot size. Hence, there is a little increase in the output power for 20.5 and 32.2 mW input power in the limiting curve of Fig. 3.The photographs g and f in Fig. 5 show the similarity of spot size. This means that the output power becames constant for 37.2 24 and 35 43.3 mW input power as shown in the limiting curve in Fig. 5.

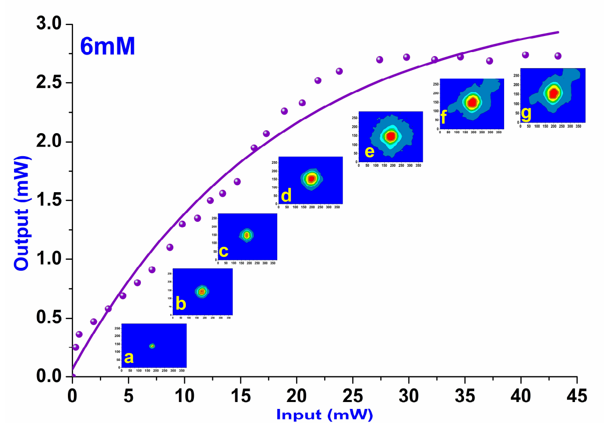

Fig. 5. Photographs of the transmitted beam spot size when the input powers are **a** 1.9, **b** 4.5, **c** 12.3, **d** 20.5, **e** 32.2, **f** 37.2 and **g** 43.3 mW for 6 mM concentration of the sample solution.

Experiments are also carried out by varying the aperture size. Fig. 6 shows the optical limiting as a function of aperture diameter obtained with sample solution for two concentrations for two aperture sizes. The sample concentrations are 2 mM and 6 mM. The wavelength of the laser used is 532 nm and the position of the sample is behind the focal point. From Fig. 6 one can see that the limiting effect changes with the diameter of the aperture. The smaller the aperture is, the lower the threshold value and the constant the output power are. The limiting amplitude of the dye solutions with 2.5 and 5mm aperture diameters for 2mM concentration are 6 mW and 8.3 mW, respectively but the limiting amplitude of the 6 mM concentration with 2.5 and 5 mm aperture diameters are 3.8 and 5.1 mW, respectively. The desired values of low threshold within the range of a few mW can be obtained by a proper choice of the aperture size, for a given experimental geometry.

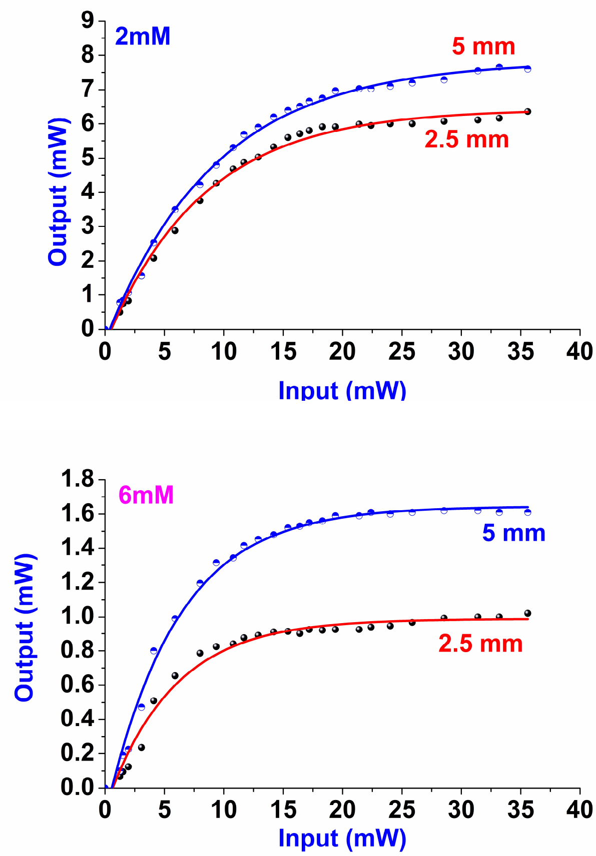

Fig. 6. Optical limiting of sample with different aperture sizes for a dye solution

CONCLUSION

We have presented the measurement results of the optical limiting performance of the Ethidium Bromide dye solvent in double distilled water, have been investigated using cw solid state laser. The variation in the output power was studied as a function of input power for four different concentrations, and for two different aperture sizes and the influence of all these parameters on the threshold limit and output clamping power was analyzed. The limiting threshold can be improved by a proper choice of design parameters such as the geometry of the configuration and the concentration of the sample, based on the actual requirements of the sensor such as the dynamic range, sensitivity and the field of view. The mechanism of optical limiting in the low power regime is found to be predominantly of a thermal origin. All these experimental results show that this dye is a promising material for applications in various optical limiting devices.

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