Optical limiting studies and saturated output of continuous wave laser in Fluorescein solution

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***Abstract*— Optical limiting performances in Fluorescein with different concentration of 2, 4, 6 and 8 mM are investigated by using 473 nm continuous wave (cw) laser. The optical limiting behavior is investigated via transmission measurement through the sample at different concentrations. The investigation shows that the optical limiting capability is concentration dependent. The results showed that the sample has obvious optical limiting effect. 8 mM concentration has the best limiting effect among the four concentrations chosen. It is also found that the threshold value of optical limiting is affected by sample absorption coefficient. The Fluorescein exhibits good optical limiting properties in solution.**

***Index Terms*— Optical limiting, Laser, Fluorescein, limiting thresholds**

I. INTRODUCTION

Organic molecules with large third-order optical nonlinearities continue attracting attentions because of their potential application in optical communications, optical storage, optical computing, harmonic generation, all optical switching, optical limiting, eye and sensor protection, etc. [1,2]. Among all the nonlinear optical (NLO) properties applications, optical limiting (OL) is one of the most promising in practice, such as the protection of human eyes and optical sensors [3,4]. Several mechanisms could lead to optical limiting behaviour, such as reverse saturable absorption (RSA), two-photon absorption (TPA), nonlinear refraction and optically induced scattering [5,6]. In RSA, the absorption coefficient increases with increasing light intensity. Optical limiters based on RSA are very transparent for weak light and get opaque for the intense light.

Investigations of optical limiting performance have attracted considerable attention because of the increasing demands in laser protection against laser threats to sensors and human eyes. One major approach to laser protection is through the use of optical limiters. The present challenge is to develop new nonlinear optical materials with stronger optical limiting properties [7–9]. Typical optical limiting materials include carbon black suspension [10,11], carbon nanotube [12–15], azo dye [16-19], metallophthalocyanines [20] and metal clusters [21,22].

Recently, because of the rapid progress in synthetic chemistry, various metal nanoparticles and material [23-34] have been considered as potential optical limiting materials.

Here we report on the experimental investigation of the optical limiting properties of an organic compound, namely Fluorescein has been experimentally investigated by using continuous wave solid state laser SDL as excitation source at 473 nm wavelength. The organic compound which is used in this study are considered to be promising materials, mainly because they offer many advantages such as high damage threshold, easy molecular design, architectural flexibility, low cost and good process ability to form optical devices. Moreover, this organic compound has good solubility in chloroform.

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II. EXPERIMENT

A. Preparation of Sample

Fluorescein, with molecular formula= $C_{20}H_{12}O_5$ and molecular weight =332.31 gmmol^{-1}, has been selected for our experiments. The chemical structure of Fluorescein is shown in Fig. 1. The solution sample of the Fluorescein was prepared as follows: 0.5 g of the sample powder was dissolved in 10 ml of chloroform, the organic solution was stirred at room temperature for 30 min and then the solution was filtered through a 0.2 mm syringe filter.

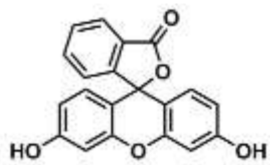

Figure 1 Chemical structure of Fluorescein.

B. UV-Visible spectroscopic studies

The linear UV-Vis (Ultraviolet-visible) absorption spectra for the Fluorescein in solvent chloroform was recorded using Cecil Reflected- Scan CE 3055 reflectance spectrometer. The optical absorption for the Fluorescein in the solvent chloroform with different concentrations, 2, 4, 6 and 8 mM, respictivily, shows absorption peak at 461 nm as can be seen in Fig. 2. Also it can be seen from the Fig. 2 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.

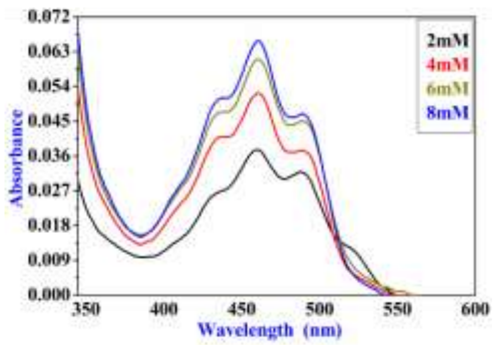

Figure 2 Linear absorption spectra of Fluorescein solution with different concentrations.

C. The absorption coefficient

The spectrum of the optical absorption was computed from the absorbance data. The absorption coefficient (α) has been obtained directly from the absorbance against wavelength curves using the relation [35-38]

$$\alpha = 2.303A/L \quad (1)$$

where L is the sample thickness and A is the absorbance. The values of absorption coefficient (α) at wavelength 473 nm for Fluorescein solution with different concentrations have been calculated using Eq. 1 and they are given in Table 1.

III. OPTICAL LIMITING TECHNIQUE

The experimental set-up for the demonstration of an optical limiting effect is shown in Ref [39] where the observation screen is replaced by an aperture that is centered at the optical axis. A cw solid state laser (SDL) was used as a light source. The wavelength of the laser can be tuned among 473 nm. 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 Fluorescein in the solvent chlorophorm. 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. 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). Fluorescein solution with different concentrations is placed at the valley behind the focal point. The input power of the laser beam and the corresponding output power through the aperture are detected by a photodetector fed to the digital power meter. So, the characteristic curve of the output power as a function of the input power can be obtained.

The dependence of optical limiting on the sample concentration is studied for different sample concentrations by using the configuration shown in Ref [39]. In this experiment the sample was placed behind the focal point of the lens and the aperture size was set to be 5 mm in diameter. The optical limiting curve for the sample solution at different concentrations is shown in Fig. 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 [40].

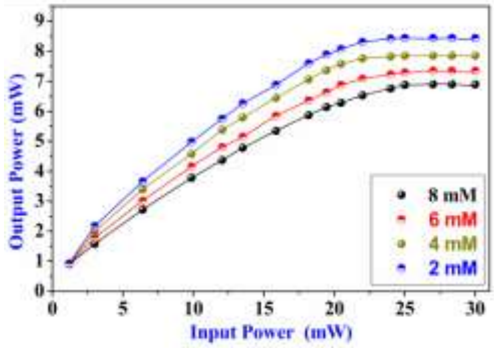

Figure 3 Optical limiting curves

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 is shown in Fig. 4 for different concentrations. It can be seen from Fig. 4 that the saturated output value decreases with an increasing concentration.

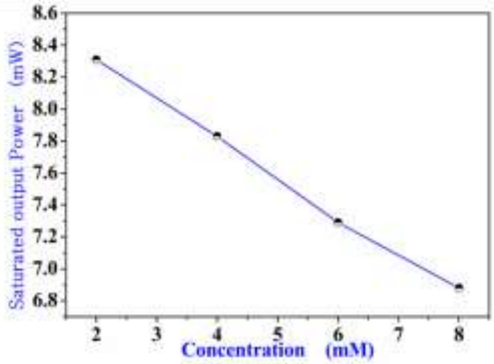

Figure 4 Concentration dependence of saturated output power.

Fig. 5 shows the normalized transmission curves as a function of incident input power for 2, 4, 6 and 8mM concentrations of Fluorescein. The optical limiting abilities are quantitatively different. The optical limiting thresholds (defined as the incident input power where the transmission reduces by 50%)are measured and they are given in Table1.

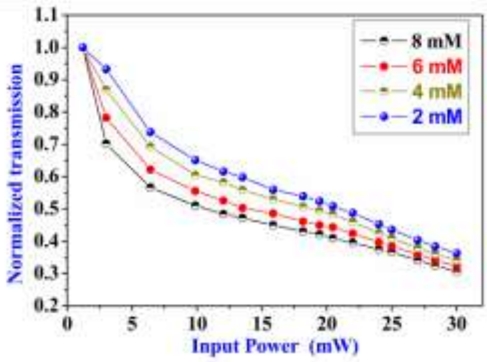

Figure 5 Normalized transmission curves of optical limiting.

It is well known that concentration plays very important role in the optical limiting action. 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. So the optical limiting responses of the low concentration sample are generally much weaker than those of high concentrated samples, while high concentrated samples exhibits strong optical limiting with the range of this study. 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 [41,42]. The limiting behavior observed in all samples is attributed mainly to nonlinear refraction. Since the samples were pumped with cw laser beam the arising nonlinearities are predominantly thermal in nature [43,44]. Due to change in refractive index of the material self-focusing and self-defocusing can be observed in the material, leading to reduction of transmittance at far field (due to distortion of spatial profile of Gaussian beam). Reduced transmittance in the far field gives better optical limiting performance.

Table 1 Optical parameters and limiting thresholds of Fluorescein.

Concentration (mM)	Absorbance	absorption coefficient (cm^{-1})	Limiting threshold (mW)
2	0.031	0.713	21.1
4	0.041	0.944	18.8
6	0.049	1.128	13.8
8	0.051	1.174	10.8

IV. Conclusion

The optical limiting performances of Fluorescein solution have been investigated at 2, 4, 6 and 8 mM concentrations, using cw laser beam at 473 nm wavelength. The results show that the optical limiting efficiency is concentration dependent. Excellent optical limiting performances with relatively good stability for Fluorescein solution have been observed until the incident input power approaches 30 mW without sample damaging. It is also found that the threshold value of optical limiting is affected by sample concentration. The experimental results show that the optical limiting threshold and saturated values of Fluorescein solution with 8 mM concentration are much lower than those of other films with 2, 4, and 6 mM concentrations. These materials can find potential applications in various optical limiting devices. The sample which is used in this study are considered to be promising materials, mainly because they offer many advantages such as available, architectural flexibility, high damage threshold, easy molecular design, low cost and good process ability to form optical devices. Moreover, this organic compound show good optical limiting properties.

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