Optical limiting properties of Acridine dye solution and doped PMMA, Al_2O_3 nanoparticles using Nd-YAG laser

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ABSTRACT

The optical limiting properties of three cases were studied, the Acridine dye solution , Acridine dye doped PMMA films and 5x10-^{4} Ml Acridine dye solution doped polymer with Al_2O_3 nanoparticles were measured using Q-switching Nd-YAG laser beam at 532 nm wavelength.

The optical limiting behavior is investigated at different concentrations and weight ratio. The results were observed that the important parameters for optical limiting properties are the limiting threshold of P_L (Limiting threshold) and $P_{clamping}$(limiting amplitude). They are inversely proportional to the concentration and weight ratio. From results noticed that Al_2O_3 nancomposites were the best for optical limting because they have P_L (Limiting threshold) and $P_{clamping}$(limiting amplitude) small than Acridine dye solution also Acridine dye doped PMMA. In addition, limiting threshold and limiting amplitude decreased with increasing concentration or weight ratio.

Keywords: Optical limiting, Acridine dye, polymer, Al_2O_3 nanoparticles

INTRODUCTION

Following the invention of the laser, it was recognized that intense laser beams can easily damage delicate optical instruments, and especially the human eye. Nowadays, lasers have become common in daily life and they are even being incorporated into toys. Thus, protection from lasers is not only a scientific subject but also a potential public safety issue. Over the last few decades, many scientists have sought so-called optical limiting materials that exhibit 'nonlinear extinction', i.e. strongly attenuate intense, potentially dangerous laser beams, while readily transmitting low-intensity ambient light [1].

Optical limiting is a field of growing interest owing to its application for the protection of eyes and sensors from intense laser pulses. Candidates for optical limiting materials should have low transmittance for strong incident light, and instantaneous response over a broad spectral range. An optical limiter is a device designed to keep the power, irradiance, energy, or fluence transmitted by an optical system below some specified maximum value, regardless of the magnitude of the input[2]. It must do this while maintaining high transmittance at low input powers. The most important application of such a device is the protection of sensitive optical sensors and components from laser damage [3]. Passive optical limiters based on nonlinear refraction have been demonstrated and analyzed for a variety of materials and laser wavelengths. A common geometry is illustrated in figure (4).

LASER beam is focused into a nonlinear refractive material and then collected through a finite aperture in the far field. At high irradiance the far field beam distortion arising from the self action of the laser beam inside the medium will result in the limiting of the transmitted light through the aperture [5].

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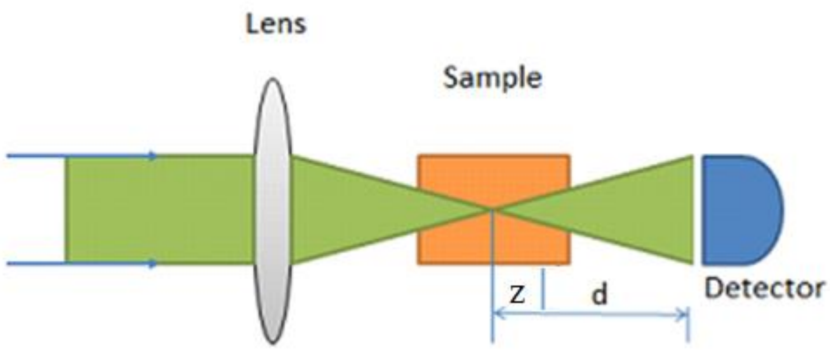

Figure 1. Schematic of the limiting geometry where Z is the distance between the focal plane in free space and the center of the sample, and d is the distance from this plane to the aperture plane .

The ideal optical limiter has the characteristics shown in figure (2) it has a high transmittance for low input fluence or energy.

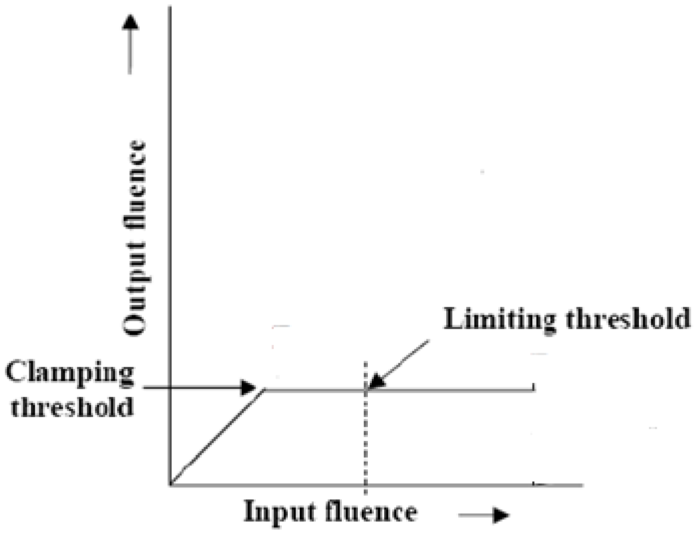

Figure 2. Schamatic representation of the behaivor of an ideal optical limiter

By plotting of the nonlinear transmittance versus the input fluence as shown in figure (3).

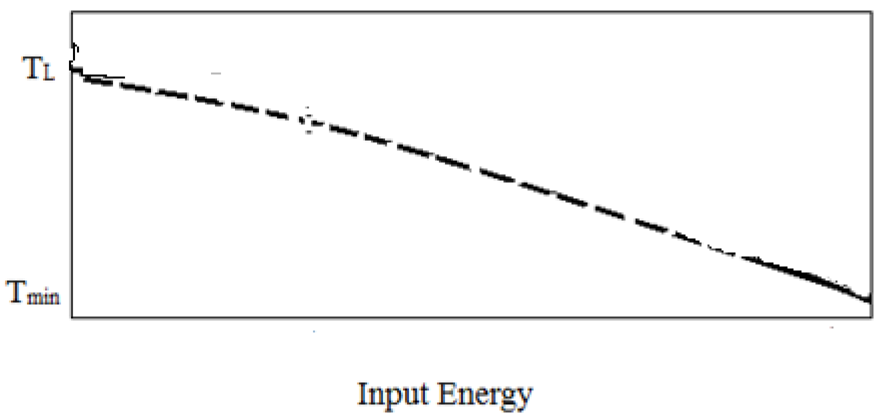

Figure 3. Transmittance output of an ideal optical limiter as a function of the input fluence or energy

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FOM is an important quantity which is represented the performance of a limiting system or device is characterized by some type of figure of merit (FOM) .Commonly FOM is equal to [6]:

$$FOM = T_L/T_{min} \qquad (1)$$

Which states that a large linear transmittance combined with a low minimum transmittance is desirable.

From figure (3) one can estimate the O.D which is defined as the optical density which is equal to

$$OD = \log_{10}(T_L/T_{min}) \qquad (2)$$

Preparation Of The Samples

A concentration of $1x10^{-3}$ M l Acridine dye solution in ethanol solvent was prepared. The powder was weighting using an electronic balance type (BL 210 S) Germany having a sensitivity four digits.

$$W = \frac{M_W \ x \ V \ x \ C}{1000} \qquad (3)$$

where

W weight of the dissolved dye (gm)

M_w molecular weight of the dye (gm/mol)

V the volume of the solvent (ml)

C the dye concentration (mol/l)

Different concentrations were provided according to the following equation:-

$$C_1 V_1 = C_2 V_2 \qquad (4)$$

where

C_1 primary concentration

C_2 new concentration

V_1 the volume before dilution

V_2 the volume after dilution

Five concentrations were prepared for Acridine dye solution .The concentrations are ($1x10^{-3}$, $5x10^{-4}$, $1x10^{-4}$, $5x10^{-5}$, $1x10^{-5}$)Ml

Dye doped polymer films were fabricated by casting block method. The solution of the polymer is prepared by dissolving the required amount of polymer (7 gm in 100 ml of chloroform solvent). A desired amount of dye solution was added to polymer solution and stirred by a magnetic stirrer at room temperature to get a uniform mixture. Films were shaped by drying the mixed polymer dye solution on a glass block at room temperature. The Acridine dye/Al_2O_3 nanoparticlesl /PMMA films were made by casting block method. The compound added to $5x10^{-4}$ M Acridine dye solution. Different weight of Al_2O_3 nanoparticles powder (0.1, 0.2, 0.3) wt % were added separately and stirred by magnetic stirrer at room temperature to get a uniform mixture. The Acridine /Al_2O_3 /PMMA films were framed by allowing the mixing to dry on a glass block at room temperature.

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RESULTS AND DISCUSSION:

The optical limiting behavior of Acridine dye for three cases Acridine dye solution, Acridine dye solution doped PMMA polymer while the last case was $5x10^{-4}$ Ml of Acridine dye solution doped PMMA polymer with (0.1,0.2 and 0.3) wt % of Al_2O_3 nanoparticle. All cases were studied by using Q – switching Nd-YAG laser at wavelength 532 nm with 19.7 mJ. The first case; Acridine dye solution at different concentrations ($1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$)Ml were shown in Figure (4)

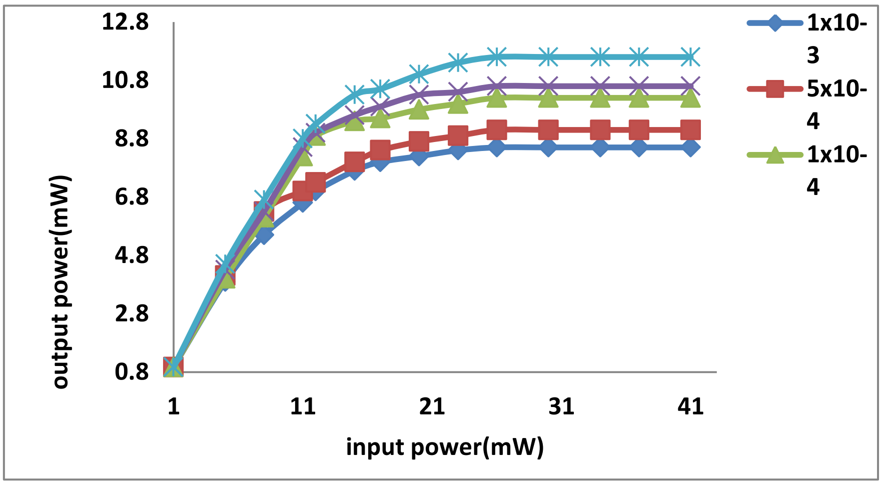

Figure 4. Optical limiting behavior of Acridine dye solution at different concentrations

From figure (4), we noticed the output power as a function of the incident power. It was increased with increasing incident power until the limiting threshold where the output power is constant in spite of the incident power increasing, the values of P_L (Limiting threshold) are (26,25.9,25.7, 25.5 and 25.3) at concentrations ($1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$) Ml respectively and the values of $P_{clamping}$(limiting amplitude) are (11.6,10.6, 10.2, 9.1 and 8.5) mW at same concentrations respectively .

For the second case, Acridine dye doped PMMA polymer films at the concentrations ($5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$) Ml were shown in Figure (5).

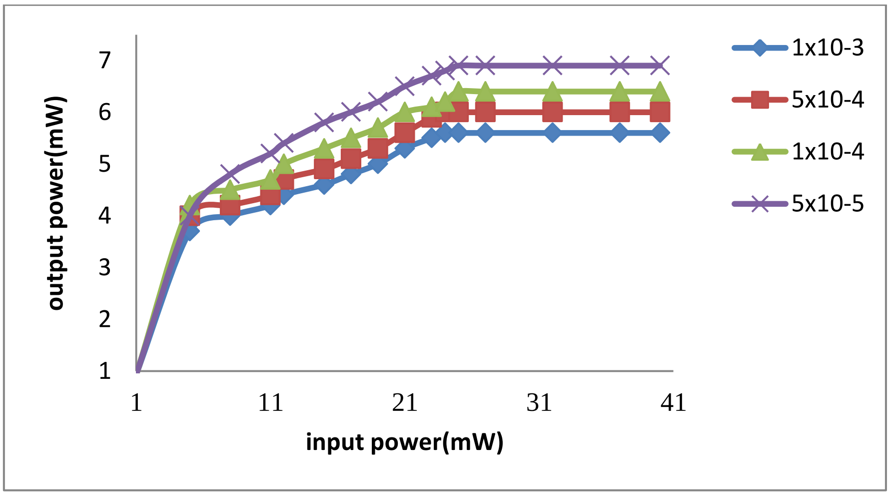

Figure 5. Optical limiting behavior of Acridine dye doped PMMA at different concentrations

From figure (5),we noticed the values of P_L (Limiting threshold) are (24.2 , 24 ,23.8 and 23.6) mW at concentrations($5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$) Ml respectively and the values of $P_{clamping}$(limiting amplitude) are (6.9, 6.4, 6 and 5.6) mW at same concentrations respectively.

For the last case, $5x10^{-4}$ Ml Acridine dye doped PMMA at (0.1 , 0.2 and 0.3) wt% Al_2O_3 nanoparticles weight ratio was shown in figure(6).

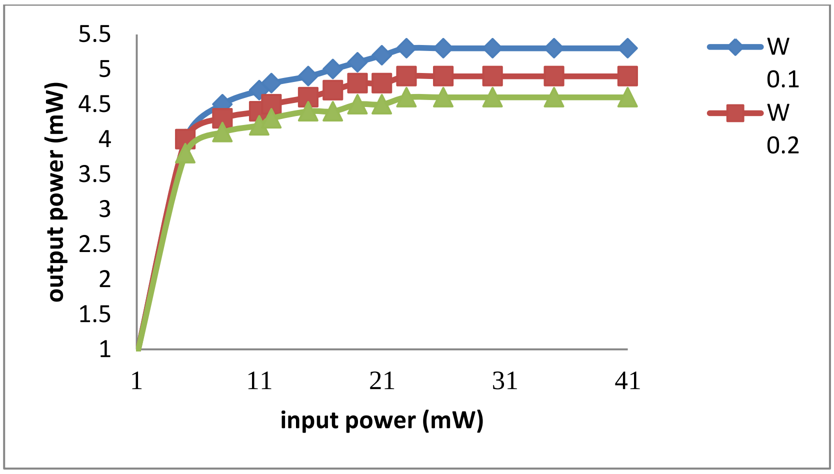

Figure 6. Optical limiting behavior of acridine dye doped PolymerAl_2O_3 with nanoparticals at different weight ratio

In figure(6), the values of P_L (Limiting threshold) are (22,8,22 and 21.8) mW at (0.1, 0.2 and 0.3) wt% respectively and the values of $P_{clamping}$(limiting amplitude) are (5.3, 4.9 and 4.6) mW at same weight ratio.

From figures (4), (5), and (6), it is observed that the important parameters for optical limiting properties are the limiting threshold of P_L (Limiting threshold) and $P_{clamping}$(limiting amplitude). They are inversely proportional to the concentration and weight ratio. From figures we noticed that Al_2O_3 nancomposites were the best for optical limting because they have P_L (Limiting threshold) and $P_{clamping}$(limiting amplitude) small than Acridine dye solution also Acridine dye doped PMMA. In addition, limiting threshold and limiting amplitude decreased with increasing concentration or weight.

Transmittance as a function of input power for the three cases were revealed.The first case, Acridine dye solution at different concentrations ($1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$) Ml were shown in figure(7).

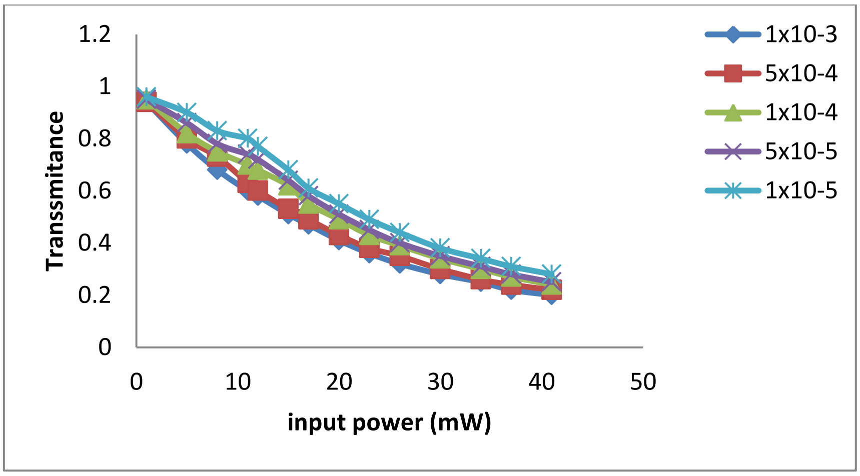

Figure 7.Transmittance output of optical limiter as function of the input power of acridine dye solution at different concentrations

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From the figure(7), the normalized transmittance decreased with the concentration.

For the second case; Acridine dye doped PMMA at concentrations($5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$) Ml were presented, figure(8) shows the normalized transmission curves as a function of incident input power.

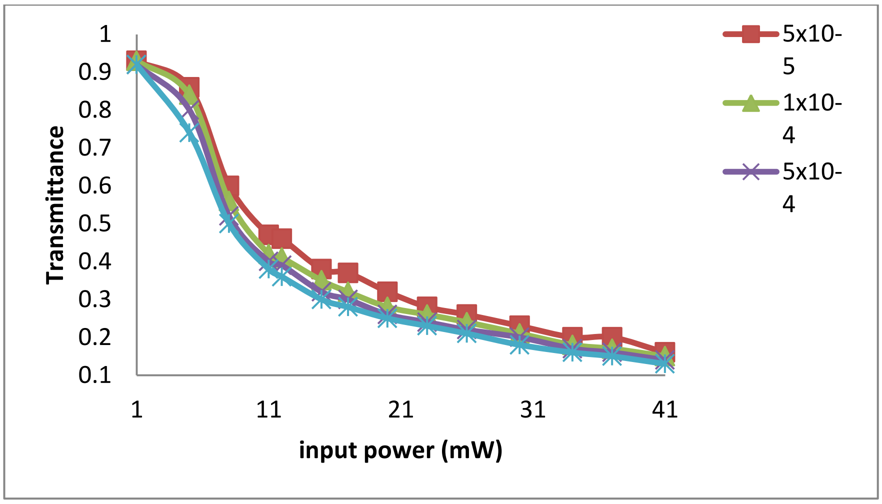
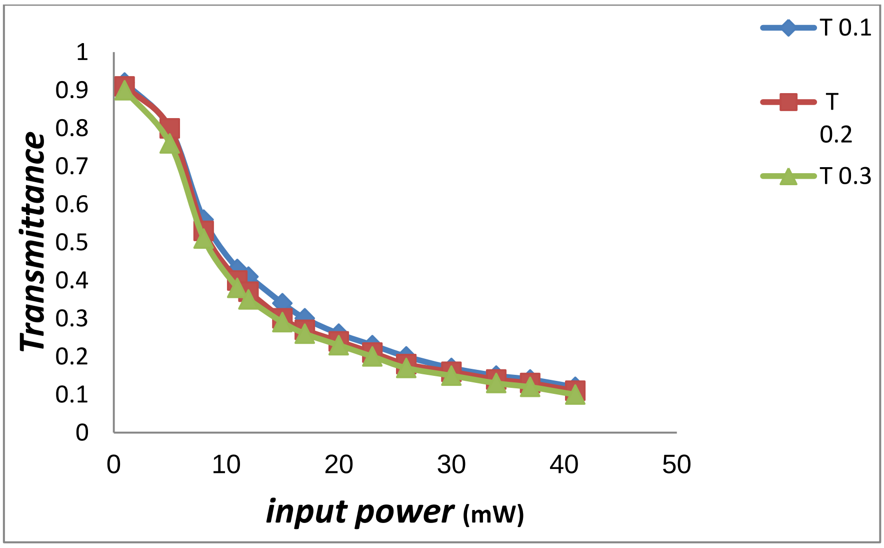


Figure 8. Transmittance output of optical limiter as function of the input power of acridine dye doped PMMA at different concentrations

For third case, $5x10^{-4}$ Ml Acridine dye doped PMMA at (0.1 , 0.2 and 0.3) wt% Al_2O_3 nanoparticles weight ratio.

Figure(9) shows the normalized transmission curves as a function of incident input power. it is behaved like the other cases.



Figure(9): Transmittance output of optical limiter as function of the input power of acridine dye doped Polymer with Al_2O_3 nanoparticles at different weight ratio

From figures (7), (8) and (9) at high concentration ,the transmission is poor .While at low concentration ,the transmission is very high.

From the values of T_{max} (maxiumum transmittance) and T_{min} (Minimum transmittance), FOM (The performance of the limiting) and O.D (optical density) can be found. Tables (1),(2)and (3) listed the FOM and OD values of the Acridine samples at 532 nm.

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Table 1. The FOM and O.D values of the Acridine dye solution at different concentrations

Concentration Ml	*FOM*	*OD*
$1x10^{-5}$	3.42	0.535
$5x10^{-5}$	3.8	0.579
$1x10^{-4}$	3.95	0.597
$5x10^{-4}$	4.27	0.630
$1x10^{-3}$	4.7	0.672

Table 2. The FOM and O.D values of the Acridine dye doped PMMA at different concentrations

Concentration Ml	*FOM*	*OD*
$5x10^{-5}$	5.81	0.764
$1x10^{-4}$	6.2	0.792
$5x10^{-4}$	6.5	0.817
$1x10^{-3}$	7.07	0.849

Table 3. The FOM and O.D values of the Acridine dye doped polymer with Al_2O_3 nanoparticles at different weight ratio

Weight Wt%	*FOM*	*OD*
0.1	7.66	0.884
0.2	8.27	0.917
0.3	9	0.954

From tables we can notice FOM and OD increased with increasing concentration and weight ratio results inscreasing number of molecules per volume at high concentration and weight ratio FOM and OD for Acridine dye doped polymer with Al_2O_3 nanoparticles large than Acridine dye solution and Acridine dye doped PMMA.

Thus Acridine dye doped polymer with Al_2O_3 nanoparticles is the best because FOM is largeht ratio.

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