Self –Focusing and Self- Trapping of Continuous Wave Light in Neutral Red

ISSN –1817 –2695

C. A. Emshary and H.A. Badran

Physics department, Education College, Basrah University, Basrah, Iraq

((Received 25/1/2010 , Accepted 23/3/2010))

Abstract :

We demonstrate experimentally that optical beam using CW low power (7)mWatt 6328 A^0 laser beam is self-focused upon passing through organic dye cells (Neutral Red (3- amino-7-dimethylamino-2-methyl phenazine))

Keywords: Neutral red ; self- focusing ; self- trapping

Introduction:

The nonlinear interaction of laser light with different and enormous media has been of intense interest since the advent of laser from theoretical and experimental points of view [1,2] .One of the simplest nonlinear effects that can occur for a laser beam with transverse variation is the self focusing or filamentation instability .The self focusing of light in matter has long been studied , as it was one of the earliest nonlinear optical effects to be observed [3] and studied theoretically [4] since then it has been investigated in connection with the interaction of laser light with many types of solids[5] liquids [6] and gases[7] .Self –focusing is still under continuous considerations [8].

In this paper, we present the results of our observation of CW self –focusing and self trapping of a laser beam in the organic chromophore, neutral red (NR) under CW 6328A^0 laser beam produced by a solid state laser. NR (3- amino-7-dimethylamino-2-methyl phenazine); molecular structure shown in Figure (1) is a low – cost organic dye which finds many applications in biology [9] .

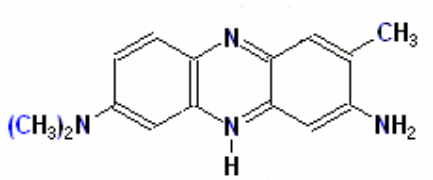


Figure (1) Molecular structure of neutral red dye molecule

The Self Focusing Process:

The details of the self –focusing effect due to an intensity dependent increase in index of refraction have been treated long ago by Kelley [10] .In the following we will give the nice picture of self focusing process given by Javan and Kelley [11] : An increase in the index of refraction with the intensity of light beam produces a decrease in phase velocity in the regions where the beam is most intense .Thus as the beam propagates the equiphase surface becomes more and more concave in the intense regions .From Huggens principle ,therefore ,the rays should move toward the region of light intensity and the intensity of the center should increase .This of course is just the opposite of what occurs in normal light diffraction .

It was predicted [10] that a light beam may be first self- trapped at any diameter and thus will not be spread. This self trapping occurs at a critical

power level P_{cr} which is independent of the beam diameter and given by

$$P_{cr} = \frac{(1.22\,\lambda)^2\, C}{512\ n_2}$$

Where λ is the laser beam wavelength, C is the velocity of light and n_2 is the nonlinear refractive index.

Experiment :

The solution sample of the dye, (NR) is prepared in distilled water. Figure (2) shows the linear absorption spectra of solution samples. The linear transmission of the solution sample was 20 % at 532nm. The linear absorption maximum (λ_{max}) of the solution (510nm) sample corresponds to the neutral form of the dye.

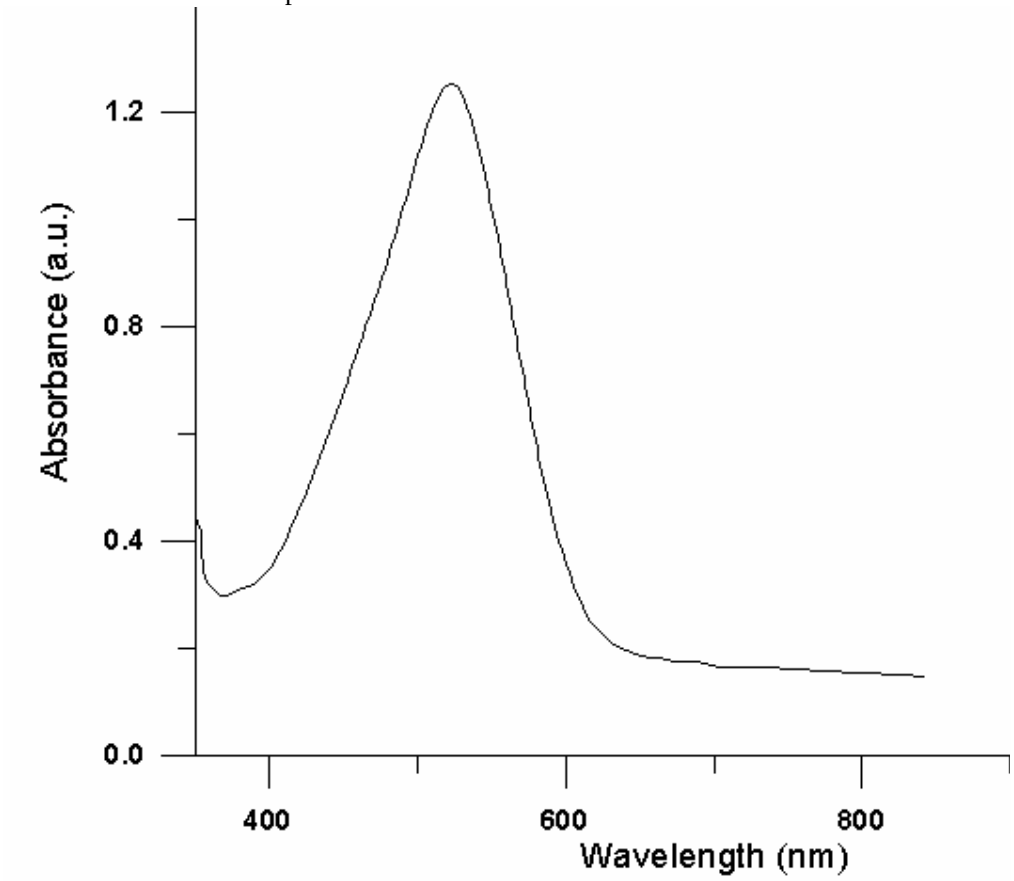


Figure (2) Absorption spectra of neutral red dye solution sample

The basic apparatus which is expanded to 10 mm using two positive lenses of proper focal lengths is sketched in Figure (3). A 6328A^0 CW laser beam of 2mm diameter which is expanded to 10mm (which reduces the intensity from

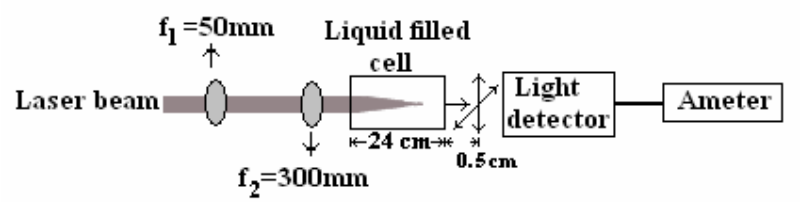


Figure (3) Experimental setup of self focusing effect.

0.22292 to $8.917x10^{-3}\frac{watt}{cm^2}$,)near the face of the liquid – filled cell. The power laser measured using a power meter type HNJG-1,8sc1,GB/ T7676-9 and the output beam transverse profile was recorded using light emitting diode LED detector on a traveling microscope that moves transverse to the direction propagation (z-axis) in the X and Y axises .A Digital canon 24mx3399 camera replaces the light detector used to photograph the output beam**.** Solutions of various concentration of liquid were prepared by dissolving the same quantity of the substance in different amounts of distilled water.

Results :

Figure (4) represents the transverse distribution of the TEM_{00} beam leaving just outside the cell for two cases (a) without the liquid and with liquid (b) .It is clear that the beam has shrunk in the transverse direction with respect to the propagation .

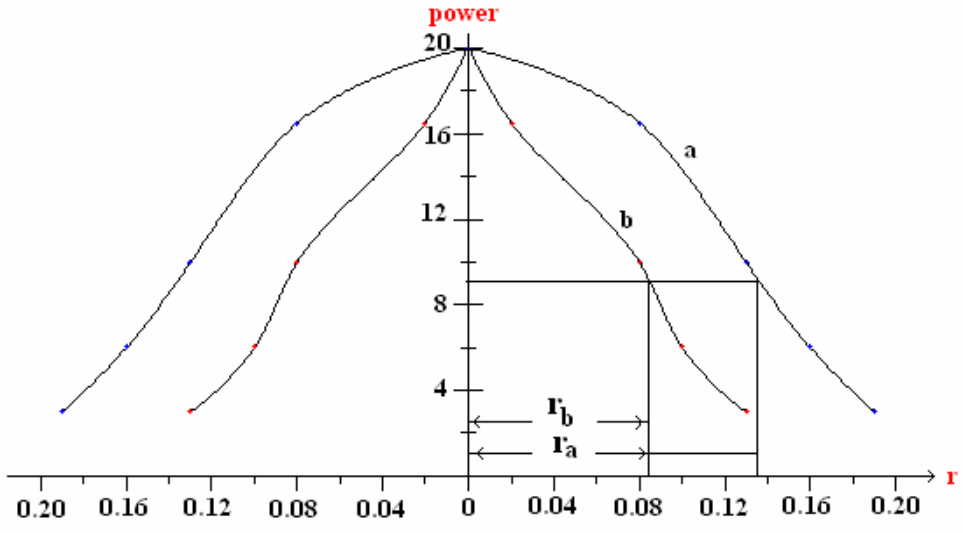


Figure (4) Transverse distribution of the TEMoo mode for Empty(a) and filled cell(b)just outside the cell

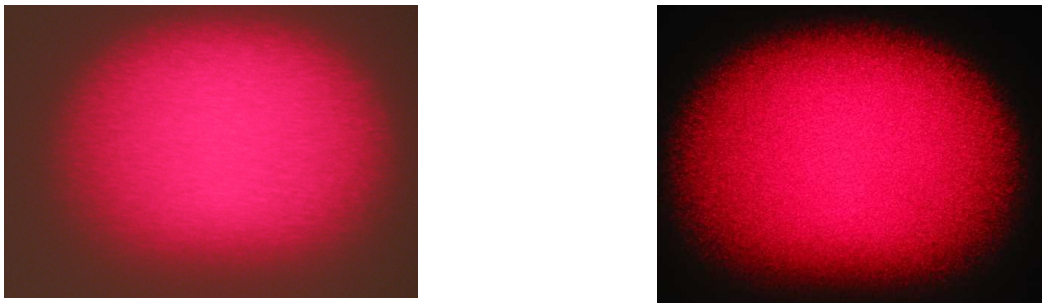
Figure (5) is photographs for the beam transverse area near the input face of cell (a) , for the beam just leaving the empty cell(b) and for the beam just leaving filled cell (c). Figure (6) is another photograph taking from side and along the cell showing the reduction of laser beam diameter as it traverses cell.

It is known that the indices of the refraction of all optical materials which are dependent to greater or lesser degree on the intensity of the optical field .This intensity dependent index of refraction is usually expressed as

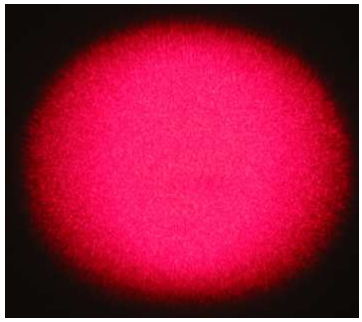
$$n = n_0 + n_2\left(\frac{E^2}{2}\right)$$

Where n_0 is the back ground refractive index of the medium, E is the peak amplitude of the electric field .If the optical frequency , ω , is far removed from any resonance absorption line of the medium (which is the case of the present work) ,then the nonlinear index , n_2 , can arise from one of the following mechanisms :1) molecular orientation Kerr effect .2) molecular redistribution or liberation ,3) third –order nonlinear electronic polariziblity , 4) electrostriction , and 5) thermal changes.

Although CW laser beam is used in this work, the low power and the low absorption of laser beam used as can be deduced from fig. (2) indicates the absence of the cause number (5) mentioned above .Since the beam is not uniform and the first three causes need high power input beam ,we might believe that the electrostriction is the main cause of the present results shown above.



a **b**



c

Figure (5) photographs of the beam transverse area near the input face of cell (a), for the beam just leaving the empty cell (b) and beam just leaving filled cell (c).

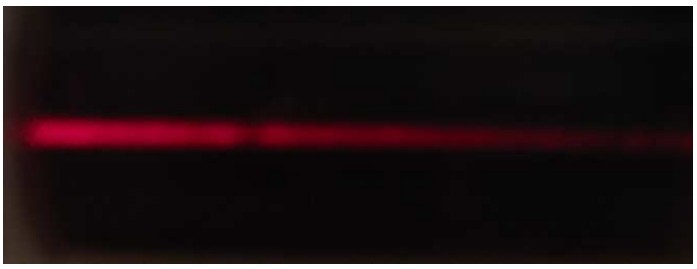


Figure (6) Experimental demonstration of self-focusing propagation in the cell of netural red dye molecule.

Conclusion :

In this paper we reported an experimental investigation of optimal conditions for observed self-focusing of an optical beam using CW low power propagation in the cells of netural red dye molecule. The use of low power visible laser beam can cause self trapping as well as self focusing as a result of the passages in the cell containing (3-amino-7-dimethylamino-2-methyl phenazine) .

References

1- P.Meystre and M.Sargent, Elements of Quantum Optics, 4th Edition, Spring-Verlay .Berlin Heidelberg (2007).
2- R.W.Boyd , Nonlinear Optics , 3th Edition, Rochester, New York (2007).
3- J.H.Marburger , Self – Focusing ,Theory , Progress in Quantum Electronics, 4th Edition ,35-110 ,J.H.Sanders and S.Steholm ,Pergamon Press , Oxford (1975).
4- Y.R.Shen, Self –Focusing: Experimental, ibid, 4, 1-34 (1975).
5- T.Y.Chang , Fast Self Induced Refractive Index Changes in Optical Media : a survey ,Optic Engineering .20 .220-232 (1981).
6- C.A.Emshary ,Self Focusing of Visible Light in CS_2 Liquid ,Basrah J.Sci.19,85-90 (2001).
7- I.A.Alsaidi , D.J .Biswas ,C.A.Emshary and R.G.Harrison , Self Socusing of CO_2 Laser Radiation in NH_3 Gas , Optical Communication ,52,336-338 (1985).
8- W.Koechner ,Solid State Laser Engineering 6th Edition ,Revised and Update Spring Series in Optical Sciences Springer Science and Business Media ,Inc (2006).
9- Mathew George ,C.I.Muneera,C.P.Singh ,K.S.Bindra and S.M.Oak,Z-Scan Studies and Optical Limiting on Nanosecond Laser Pulses in Neutral Red Dye, Optics and Laser Technology 40 , 373-378 (2008) .
10- P.L.Kelley, Self –Focusing of Optical Beams, Phys.Rev.Let, 15, 1005-1008 (1965).
11- A.Javan and P.L.Kelley, Possibility of Self Focusing Due to Intensity Dependent Anomalous Dispersion, IEEE JQE, QE2, 470-473 (1965).

التركيز والاصطياد الذاتي للضوء المستمر في مادة Neutral Red

جاسب عبد الحسين مشاري و حسين علي بدران

قسم الفيزياء – كلية التربيه – جامعة البصره – البصره – العراق

الخلاصه

برهنا عمليا باستخدام حزمة من ضوء ليزرمستمره واطئة القدره بحدود 7 ملي واط وبطول موجي قدره 6328 أنكستروم على وجود تركيز ذاتي لتلك الحزمه في خليه تحتوي صبغه كيميائيه من مادة

(3- amino-7-dimethylamino-2-methyl phenazine) Neutral Red