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PAPER

Investigating the optical nonlinear properties and limiting optical of eosin methylene blue solution using a cw laser beam

Qusay M A Hassan, C A Emshary and H A Sultan

Department of Physics, College of Education for Pure Sciences, University of Basrah, Basrah, Iraq

E-mail: qusayali64@yahoo.co.in

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Abstract

Diffraction patterns and Z-scan methods are used to measure the nonlinear refractive index, NRI, of the eosin methylene blue in the solvent ethanol using a continuous wave laser beam of 473 nm wavelength. Experimental results of the former and latter methods showed the appearance of rings and the self-defocusing SDF effect respectively, and these results may be due to phase modulation. It is demonstrated that the eosin methylene blue solution have a high NRI. Also the limiting optical properties of the sample are investigated. It is observed that the sample has the optical limiter properties OLPs. It is proved that the origin of the OLPs is thermal. The NRI and threshold limiting values of the eosin methylene blue solution are -1.1×10^{-8} cm^2 W^{-1} and 12 mW, respectively. A thermal lens model and the Fresnel–Kirchhoff integral are used to calculate the self-defocusing and the diffraction ring patterns results respectively.

1. Introduction

Nonlinear optics (NLO) studies the phenomena that result from the modification of the optical properties of matter when it interacts with intense coherent light. Normal light does not have enough intensity to enhance these modifications; only laser light is intense enough to modify these properties of the material [1]. Post the discovery of this branch, the optical nonlinear properties of the materials gained special interest by many researchers and scientists around the Globe. These properties have a number of applications in the photonics field and optical devices. The materials which possess high nonlinear optical properties, NOPs, and fast response times proved that they can be used as optical limiting [2–21], optical switching [22–24], optical phase conjugation [25], optical bi-stability [26–29], optical data storage [30–33], etc. So before we test the possibility of using the material in any of these applications we must first study the NOPs of the material. Currently, there are several techniques that can be used to study these properties such as ellipse rotation [34], degenerate four-wave mixing [35], interferometry [36], diffraction patterns [37], thermal lens [38] and Z-scan [39, 40]. The first three techniques are sensitive and require sophisticated experimental devices. As for diffraction ring patterns, DRPs, is sensitive and require simple experimental components. However, this method requires the appearance of DRPs in the far-field of a laser beam having a Gaussian extent traverses through the sample, since the calculation of the nonlinear refractive index, NRI, is proportional to the number of rings formed. The problem of this method lies in that not all materials lead to ring patterns generated when a laser beam traverses through so that this method cannot be used for all materials. The latest pioneered method, the Z-scan, is characterized as simple, easy, sensitive, and has the ability to determine the NOPs of materials with high accuracy. The ring patterns and Z-scan methods have been used by many researchers over the past three decades; especially the Z-scan to study the NOPs of inorganic, organic, and semiconductors materials in the liquids phase and solid film phase [41–46].

The search for materials act as optical limiters, OLrs, under irradiation with low power continuous wave (CW) laser beams is the target of the present study. To protect the human eyes and photosensitive components against the high laser beam intensity OLrs are used. The human eyes needs this device because it can be damaged when it is exposed to CW, sub-Watt laser beams even for short times. To achieve the objective of this study, the proposed material must have high NOPs. Since organic materials have such properties, we choose the organic