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A green ultrasound-promoted synthesis, experimental, theoretical, and nonlinear optical properties studies of benzylidenehydrazono thiazolidin-4-one derivative

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Abstract

The sonochemical synthesis, structural analysis, theoretical calculations, and the nonlinear optical (NLO) discovery of benzylidenehydrazono thiazolidin-4-one derivative **8**, that is, (*Z*)-ethyl-2-((*Z*)-2-((*E*)-(4-chlorobenzylidene)hydrazono)-4-oxo-3-phenylthiazolidin-5-ylidene) acetate ($C_{20}H_{16}ClN_3O_3S$), are detailed. The ^1H and ^{13}C NMR data, melting point (m.p), infrared spectrum (IR), mass spectrum, and UV–visible spectrum measurements are used to confirm the authenticity of the synthesized derivative **8**. The geometrical structural optimizations and theoretical properties of the synthesized compound are performed using density functional theory (DFT). The NLO properties of the synthesized derivative **8** are studied under continuous wave (cw) 473-nm laser beam via conducting the closed (C)- and open (O)-aperture (A) Z-scan techniques where the nonlinear refractive index (NLRI) and the nonlinear absorption coefficient (NLAC) are obtained, viz. 1.79×10^{-7} cm^2/W and 2.72×10^{-3} cm/W, respectively, and an optical limiting (OLg) threshold of 13 mW is obtained.

Keywords Thiazolidinone · Nonlinear properties · Z-scan · Optical limiting

Introduction

Since the discovery of the ruby laser in 1960 by Maiman (Maiman 2010) and when Franken et al. published the first experiment on the frequency doubling of the ruby 6943 A^o wavelength (Franken et al. 1961), nonlinear optics (NLO) have entered new era, so that new simple approaches, viz. diffraction patterns, thermal lens, and lately the Z-scan, are used to examine the nonlinear properties of so many available materials (Emshary et al. 2021; Khalaf et al. 2022) and newly synthesized materials (Abdullmajed et al. 2022; Almashal et al. 2020). Among the various new extensively studied materials are inorganic (Gradoff 2012) and organic materials (Hassan et al. 2022). The change in a medium refractive index due to the presence of coherent optical fields leads to a number of NLO phenomena, viz. optical data storage (Manickasundaram et al. 2011), switching (Faisal et al. 2022), modulation (Yang et al. 2022), and limiting (Hassan and Manshad 2019). The interplay, in the spatial domain, between propagating beam divergence and the fast optical response leads to a wide range of self-action behaviors, viz. soliton formation, self-trapping, and spontaneous pattern formation (Strombom et al. 2012). The spatial distortion of the laser beam through the passage in a nonlinear medium might lead to the Z-scan technique. This technique became popular to obtain simultaneously the magnitude and the sign of the nonlinear refractive index (NLRI) and the nonlinear absorption coefficient (NLAC) that are related to the real and imaginary parts of the nonlinear susceptibility.

To protect the human eyes and sensors against high laser beam intensity in pulse or continuous wave fashions, NLO materials can be used in the design of a device that works on the limiting of the transmitted laser beam power. Such a device, named an optical limiter (OL), was designed by predicting and studying an ideal OL whose properties are shown in Fig. 1, where (i) represents the case of linear transmission in the absence of nonlinearity behavior, while (ii) is the case of the presence of nonlinearity. In general,

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