Laser-induced optical nonlinearities in Orange G dye: polyacrylamide gel

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Abstract: We observed multiple diffraction rings of a continuous-wave solid-state laser beam from an Orange G dye doped polyacrylamide gel. The number of rings increases almost exponentially with increasing input power and the concentration of the samples. The refractive index change, Δn, and effective nonlinear refractive index, n_2, were determined from the number of observed rings. We obtained good values of $\Delta n \sim 0.004\,788$ and $n_2 = 10^{-5}$ cm^2/W. Variation of refractive index with temperature (dn/dT) and figure of merit (H) are found to be 1.01×10^{-4} 1/°C and 0.45×10^{-4}, respectively. This large nonlinearity is attributed to a thermal effect resulting from linear absorption.

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Résumé : Nous avons observé des anneaux de diffraction multiple du faisceau continu d'un laser état solide utilisant un gel polyacrylamide dopé au colorant Orange G. Le nombre des anneaux augmente presque exponentiellement avec la puissance d'entrée et avec la concentration des échantillons. Nous avons déterminé le changement d'indice de réfraction Δn et l'indice de réfraction non linéaire effectif n_2 à partir du nombre d'anneaux observés. Nous avons obtenu de bonnes valeurs de $\Delta n \sim$ 0,004 788 et $n_2 = 10^{-5}$ cm^2/W. Nous trouvons que le taux de variation thermique (dn/dT) et la figure de mérite (H) sont respectivement 1,01 × 10^{-4} 1/°C et 0,45 × 10^{-4}. Cette forte non linéarité est attribuée à un effet thermique résultant d'une absorption linéaire.

[Traduit par la Rédaction]

1. Introduction

There has been a great need for nonlinear optical materials that can be used with low-intensity lasers for applications such as phase conjugation, image processing, and optical switching [1]. The propagation of a laser beam in nonlinear media with intensity-dependent refractive index and absorption coefficient is accompanied by a variety of interesting phenomena. Among these are self-focusing and self-defocusing, self phase modulation, spatial ring formation, and beam break up [2]. The spatial ring formation is based on the Freedericksz effect [3, 4] in an optical field due to the passage of light in a nonlinear medium where a change in the orientational order appears if the intensity is above a certain threshold; such effect takes place owing to the dielectric torque exerted by light on the molecule. Depending on the polarization of the excitation light, this effect may be of first or second order. The resulting electromagnetic field and molecular orientational states for strongly coupled light media is second-order transition when light is linearly polarized, whereas it is first-order transition when using circularly polarized light. The nature of the ring pattern depends on the power of the laser beam (i.e., the electric field), the polarization of the incident light, the angle between the director of the oriented medium (molecule) and the wave-vector of the incident radiation, and the temperature and thickness of the medium. Polyacrylamide gel [5] has a soft flexible nature; special optical properties that allow for the use of high-resolution imaging to analyze the structure. A range of stiffness values can be achieved. The gel's response to changes in temperature, osmolarity, and hydration make it important to monitor the experimental atmosphere and constantly maintain suitable experimental conditions when working with polyacrylamide gels.

In this paper, we give the result of the experimental study of the ring system that appears in Orange G dye doped polyacrylamide gel as a result of the passage of a green light beam of wavelength 532 nm for two specific concentrations.

2. Experimental procedure

2.1 Preparation of materials

The samples of Orange G dye: polyacrylamide gel were prepared from 1-phenylazo-2-naphthol-6,8-disulfonic acid disodium salt (Orange G) dye (Sigma-Aldrich) and polyacrylamide (average M_w = 10 000 g/mol, Sigma-Aldrich) by dissolving (1 g, 2.2 mmol/L) Orange G dye in 50 mL distilled water, and (0.1 g, 1.4 mmol/L) polyacrylamide dissolved in 50 mL distilled water, then the Orange G dye solution and the polyacrylamide solution were mixed. The mixture was stirred at room temperature (RT) for 50 min to inter all Orange G dye molecules within polymer chains, then the solu-

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