Self-diffraction effects of Gentian violet dispersed in transparent glue films

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Abstract. We report self-diffraction effects appearing in Gentian violet dispersed in a transparent glue film. The diffraction patterns observed by us depend on laser intensity. When samples are exposed to laser irradiation for enough time, a film acts as a holographic medium.

Keywords: holography, Gentian violet, self-diffraction

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Nonlinear optics plays a major role in photonics nowadays [1]. Advances in optoelectronics and information technology encourage searching for new materials with improved nonlinear optical properties [2] for applications ranging from high-speed all-optical switches, optical commutation [3], bistability and optical limiting devices to controlling phase, polarization state or frequency of light beams in telecommunications, whereby information is coded, transported and routed optically. In particular, organic molecules have attracted much attention because of their high optical susceptibility. The apt examples are Methyl violet 2B [4], a series Hydroxy Porphyrin [5] and bismuth-based glasses [6], of which nonlinear optical properties have been studied in detail.

To become a promising nonlinear optical medium, the figures of merit of a material must provide a large and fast nonlinear response. Self-diffraction represents a common effect produced in nonlinear media under the conditions that the beam power is high enough. Self-interaction of a laser beam in a medium is due to changes occurring in its optical properties due to incident radiation. In this letter, we report on the self-diffraction of cw solid-state laser radiation from Gentian violet (GV) dispersed in a transparent glue film. These films are known to reveal nonlinear optical properties and have potential applications in holography and forward-phase conjugation. Here we analyze temporal evolution of the interference rings, process of formation of the diffraction grating, and a time interval needed for holographic recording due to changing incident radiation.

The films were prepared using a commercial GV. As a polymeric matrix, transparent commercial glue was used (Office Depot transparent glue in pen presentation). The glue was mixed with 0.1 M of GV. By using a spin-coating technique at 2600 rpm, 0.1 mL of the mixture was deposited onto a glass substrate previously treated and cleaned for a minute with a piranha solution. The inset in Fig. 1 shows a resulting sample.

Fig. 1 depicts the absorption spectra of the GV measured before and after mixing with the transparent glue. Two absorption bands are observed referred to as α-band (located at 590 nm) and β-band (located at 540 nm). It is seen that the absorption spectrum for the GV in solution reveals a maximum near 584 nm, indicating preference for a monomeric state (the α-band). However, when the GV is mixed with the glue, the β-band located exactly at 542 nm is enhanced. This hypsochromic shift indicates a preferential formation of dimers in the film. Fig. 2 illustrates schemes of an experimental setup used to analyze evolution of the interference rings (left panel) and a setup for studying a holographic recording process (right panel). The self-diffraction patterns have been obtained as shown in Fig. 3. Here the intensity profiles have been obtained while varying the laser power from 5 to 40 mW, with the steps of 5 mW.

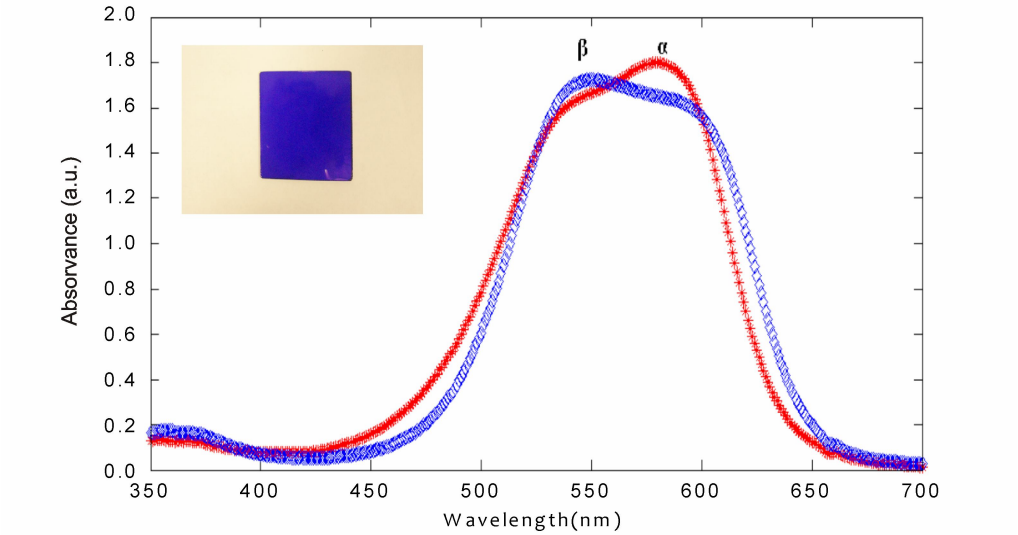


Fig. 1. UV-VIS spectra of GV in solution (*) and GV mixed with transparent glue (◊). α-band is peculiar for a monomeric state and β-band for a dimeric one. The inset corresponds to a picture of GV and transparent glue film placed over a glass substrate.

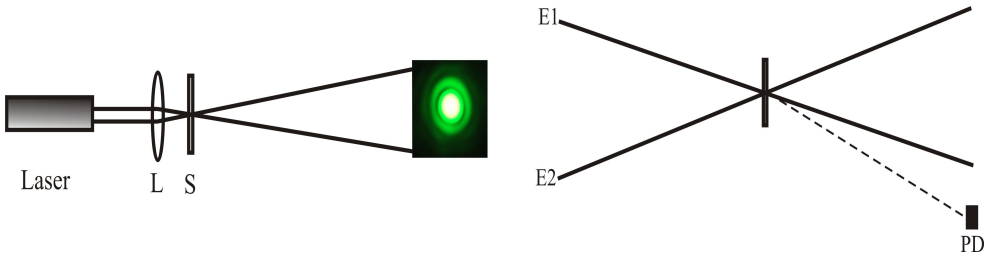


Fig. 2. Experimental setups used to study diffraction patterns (L is a lens and S a sample – see the left panel) and holographic recording (E1 and E2 are interfering beams, and PD a photodetector – see the right panel).

The self-diffraction patterns and their profiles for three different laser intensities are also shown in Fig. 3. These profiles demonstrate that a bright diffraction ring gradually becomes thicker from inner to outer side, and the light energy is mainly concentrated inside the outermost ring. Such behaviour corresponds to that observed earlier for divergent Gaussian beams passing through self-defocusing media. Notice that, in general, self-defocusing media have a negative optical nonlinear birefringence Δn [7, 8]. The number of concentric rings increases with increasing incident laser power, thus allowing us to establish relationships between the laser power and the number of rings [9].

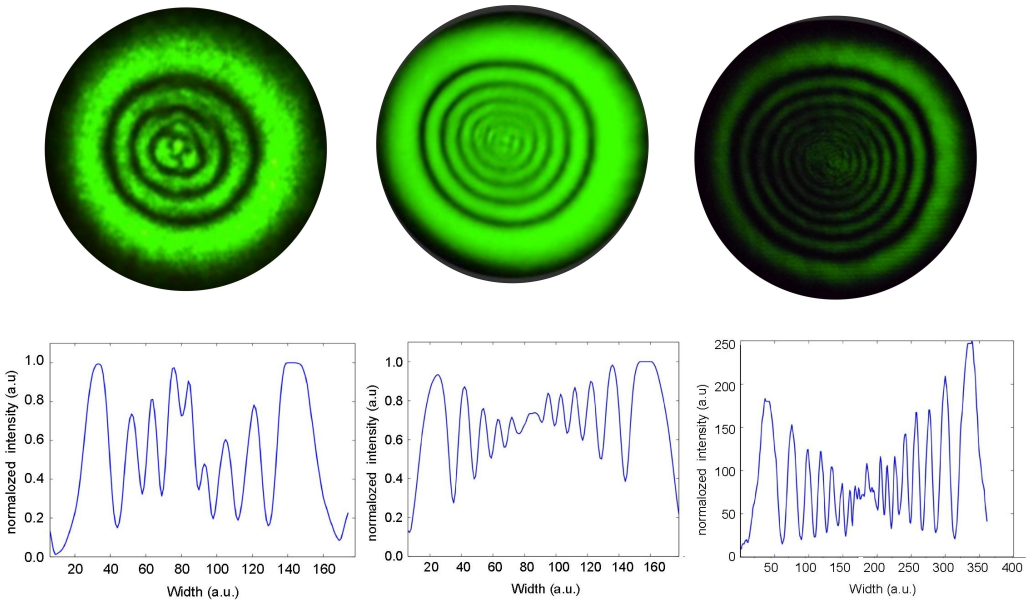
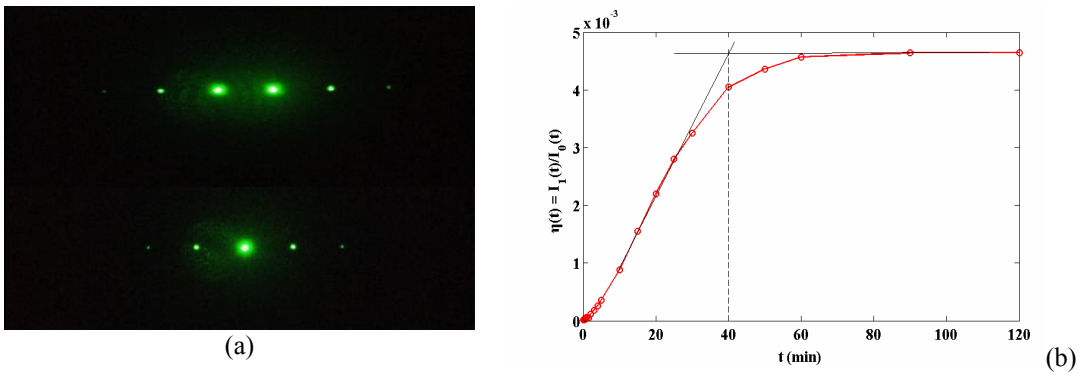


Fig. 3. Self-diffraction patterns and their profiles observed for three different laser powers: 15, 20, 25 mW respectively from left to right.

The diffraction pattern of the grating induced by interference of the two incident laser beams is shown in Fig. 4a (upper part). Here one can clearly observe the diffraction orders ±1 and ±2. If the interference process is held in a sample for some time, information about the interference pattern is recorded inside the sample. In other words, the sample is acting as a holographic medium. The interference pattern can be recovered by illuminating the hologram with a coherent light identical to one of the interfering beams (E1 or E2). While passing through the hologram, this beam collects the phase and amplitude modulations and reconstructs the wave front matching that of the object image (see Fig. 4a, lower part).

By analyzing the time evolution of the diffraction efficiency ($\eta = I_1/I_0$), we have found the recording time to be equal to $t = 40$ min (see Fig. 4b). On this basis we can conclude that the self-diffraction effects observed by us are mainly due to nonlinear absorption. As a consequence, the absorption should produce local heating and deformation in the polymeric base, allowing holographic recording. Hence, our films can provide a simple and cheap way for studying nonlinear optical effects.



(a) (b)

Fig. 4. (a) Diffraction pattern observed for two interfering beams (upper part) and diffraction pattern of holographic grating (lower part) after 40-min recording. (b) Diffraction efficiency curve (a dashed line indicates a threshold for holographic recording).

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Анотація. *В роботі повідомляється про спостереження ефекту самодифракції, який виникав у метилвіолеті, дисперговаому у плівках прозорого клею. Виявлена дифракційна картина залежить від інтенсивності лазерного випромінювання. При опроміненні зразка продовж тривалого часу лазерним випромінюванням плівка діє, як голографічне середовище.*