Optics Communications 335 (2015) 218–223

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

# Triphenylmethane dye-doped gelatin films for low-power optical phase-conjugation

T. Geethakrishnan [a,*], P. Sakthivel [b], P.K. Palanisamy [c]

[a] Department of Physics, University College of Engineering Villupuram, Villupuram 605103, Tamilnadu, India
[b] Organic Chemistry Division, School of Advanced Sciences, VIT University, Vellore 632014, Tamilnadu, India
[c] Centre for Laser Technology, Department of Physics, Anna University, Chennai 600025, Tamilnadu, India

ARTICLE INFO

*Article history:*
Received 4 September 2013
Received in revised form
8 September 2014
Accepted 10 September 2014
Available online 22 September 2014

*Keywords:*
Optical phase conjugation
Four-wave mixing
Induced holographic gratings

ABSTRACT

We have studied degenerate four-wave mixing (DFWM) based optical phase-conjugation (OPC) in few triphenylmethane (Acid blue 7, Acid blue 9, Acid blue 1 and Methyl green) dye-doped gelatin films using a 633 nm He–Ne laser radiation of total power 35 mW. Phase-conjugate (PC) reflectivity from the dye films was measured by varying the experimental parameters such as incident angle between the pump-probe beams in the DFWM geometry, dopant concentrations of the gelatin film, probe beam intensity and read-out beam intensity. The maximum PC reflectivity was observed in the Acid blue 7, Acid blue 9, Acid blue 1 and Methyl green sensitized gelatin films were 0.22%, 0.24%, 0.07% and 0.13%, respectively. The origin of the mechanism of the PC wave generation from these dye films is also reported.



## 1. Introduction

Organic dyes fixed in a solid matrix have been recently of great interest in realizing nonlinear optical interactions such as two-wave, three-wave mixing, optical phase-conjugation [1–3] and so on. Dyes having a strong absorption of laser light and a long lifetime of their triplet state can generate the phase-conjugate (PC) waves even at low light intensities. Organic dyes embedded in polymers also have been used as media of holographic recording and permanent optical memories. In phase-conjugation or degenerate four wave mixing (DFWM), the diffracted (fourth) beam propagates anti-parallel to the object (probe) beam with very unusual image-transformation properties. The new (PC) beam exactly retraces the path of the probe beam, and any phase aberrations, which occurred to the object beam, are canceled out in the diffracted wave as it again passes through the same aberration source. Therefore, by using four-wave mixing in dynamic medium, high quality optical beams can be double-passed through a poor quality or temporarily fluctuating optical systems with no loss in beam quality [4].

Organic dyes have emerged as materials with good potential for optical phase-conjugation because of their large third-order optical nonlinearity [5]. Optical phase-conjugation has been demonstrated in a number of organic materials [6–21]. A real-time image processing has been described using degenerate four-wave mixing in thin films of polymethylmethacrylate doped with disperse red 1 [22]. Polymethylmethacrylate (PMMA) doped with methyl red can generate the phase-conjugate wave due to DFWM and holographic process while the another composition, the methyl red doped gelatin, can generate the conjugate waves only through the DFWM process [23]. Optical phase-conjugation in disperse red and methyl red doped in polystyrene films have also been reported [24]. Diffraction from the grating formed by the two coherent beams of light, which can be demonstrated in dyes, can be used to measure the properties of the grating. Further, large nonlinear optical susceptibilities resulting from the nonlinear response of organic molecules have been reported for the case of single crystals of organic molecules [25], organic molecules in liquid solution [26], and for organic molecules doped into various solids [27–29].

Many of the studies reported above have used either high power pulsed or continuous wave lasers. However, to the best knowledge of the authors, only few papers discussed about the feasibility of using such materials with the interest of low power lasers for degenerate four-wave mixing based optical phase-conjugation [30,31]. In the present work, an attempt has been made to generate the optical phase-conjugate signals in few triphenylmethane dyes-doped thin films by employing the DFWM technique using a He–Ne laser of total power 35 mW. Further, the dependence of phase-conjugate beam reflectivity on various experimental parameters such as incident angle between the pump-probe beams, dopant concentrations, intensity of the probe beam and incident of the read-out beam were carried out.

* Corresponding author. Tel.: +91 4146 224500.
*E-mail address:* tgeethakrishnan@hotmail.com (Geethakrishnan T.).

http://dx.doi.org/10.1016/j.optcom.2014.09.033
0030-4018/

## 2. Experimental studies

### 2.1. Materials

Triphenylmethane [32] dyes form a very important class of synthetic dye. All the dyes of this series are derived from the hydrocarbon, triphenylmethane, and the tertiary alcohol, triphenylcarbinol, which are both colorless. The chromophore of this class is the quinonoid group, which may appear as C═Ar═NH (as in Baeyers's fuchsonimine) or C═Ar═O (as in Baeyers's fuchsone), where Ar – aromatic nucleus (color index 1975). Two aryl groups attached to the methane carbon atom complete the chromogen and the dyes are formed by the introduction of two or three auxochromes (primary, secondary, or tertiary amino or hydroxyl groups) usually in *para* position to the methane carbon atom.

In the present work, few triphenylmethane dyes namely Acid blue 7, Acid blue 9, Acid blue 1 and Methyl green were used to sensitize the gelatin films for realizing optical phase-conjugation at 633 nm laser radiation. All the above said dyes are of laser grade from Sigma-Aldrich and are highly soluble in water. Gelatin films were prepared from the emulsion of commercially available 10E75 holographic plates. The chemical structure and the molecular formula of the Acid blue 7, Acid blue 9, Acid blue 1 and Methyl green dyes are shown in the Fig. 1. The UV–vis absorption spectra of these dyes were studied using UV-2401 PC spectrophotometer. Acid blue 7, Acid blue 9, Acid blue 1 and Methyl green dyes, in water with 0.01 mM concentration, exhibited peak absorption ($\lambda_{max}$) at 637 nm, 630 nm, 637.5 nm and 631.5 nm, respectively, and the corresponding absorption spectra are shown in Fig. 2.

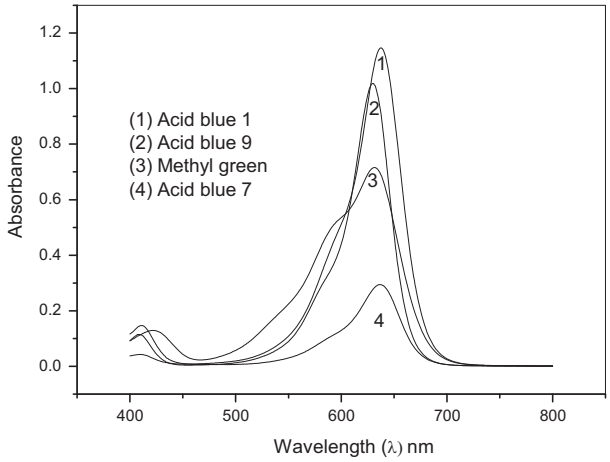


**Fig. 2.** UV–vis absorption spectra of aqueous solutions of triphenylmethane dyes.

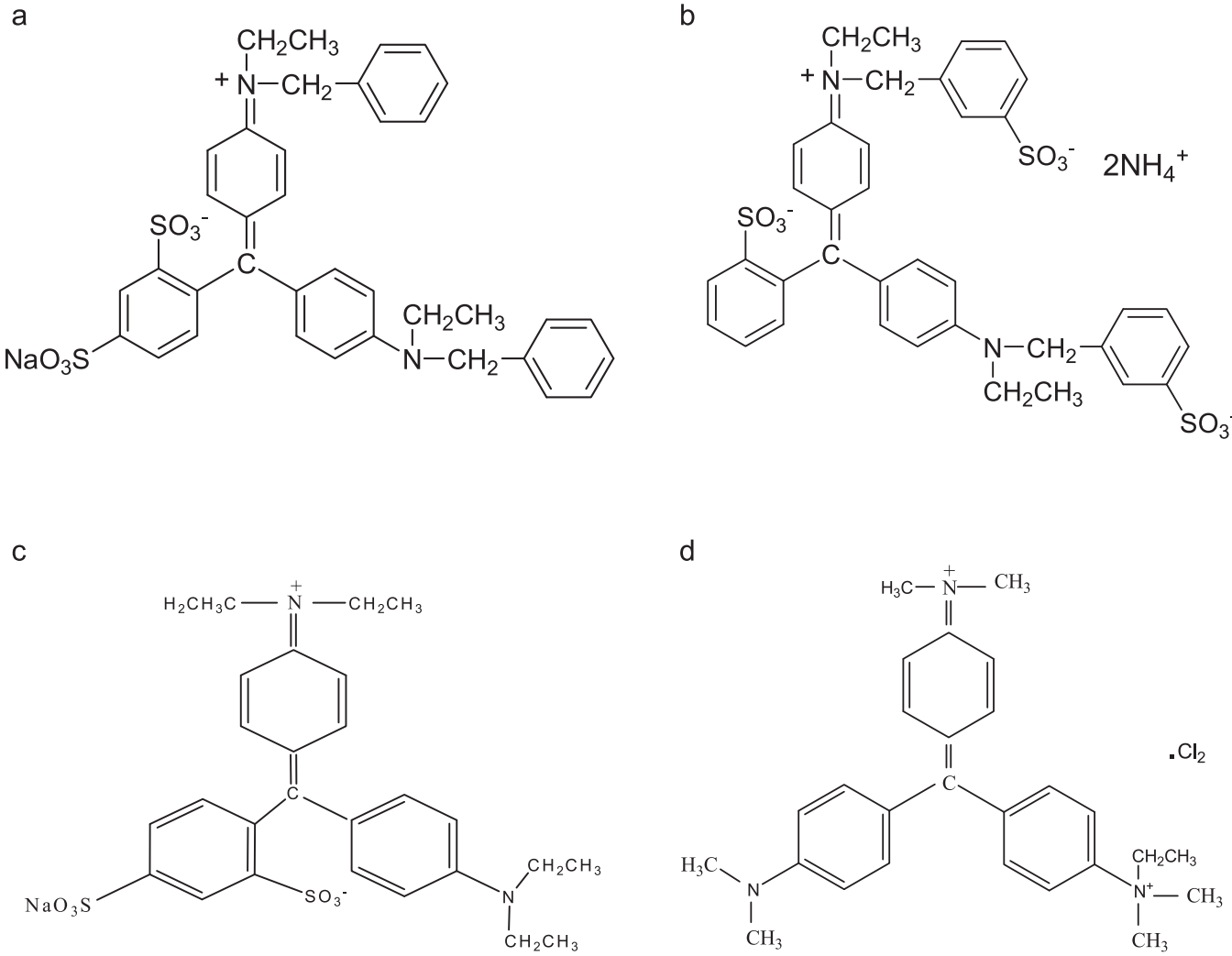


**Fig. 1.** Chemical structure and formula of triphenylmethane dyes: (a) Acid blue 7 (Molecular formula: $C_{37}H_{35}N_2NaO_6S_2$ ), (b) Acid blue 9 (Molecular formula: $C_{37}H_{42}\ N_4O_9S_3$), (c) Acid blue 1 (Molecular formula: $C_{27}H_{31}N_2O_6S_2Na$ ), and (d) Methyl green (Molecular formula: $C_{27}H_{35}C_{l2}N_3$).