Low power optical phase conjugation in dyes embedded in polyvinyl alcohol films

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Received 26 July 1988.
0003-6935/90/040449-02$02.00/0.

Low power optical phase conjugation in polyvinyl alcohol films embedded with saturable dyes is reported. Phase conjugate reflectivity achieved is higher than that obtained in the case of similar gelatin films.

Low power optical phase conjugation (OPC) in dyes embedded in thin films has been recently suggested and demonstrated by a few authors. Silberberg and Bar-Joseph[1] have used the dyes eosin and erythrosin in gelatin films. Fluorescein has been studied by Fujiwara and Nakagawa[2] in gelatin films and by Kramer *et al.*[3] in boric acid glass. Few reports on the studies of nonlinear optical properties of dyes doped in polyvinyl alcohol (PVA) have appeared so far.

Todorov *et al.*[4] studied the photoinduced anisotropy of methyl orange doped in PVA films for transient polarization holography. Their results indicate that PVA films can be a good matrix for observing nonlinear effects as well. Another work on the optical properties of dye doped PVA films has been reported by Paschenko *et al.*[5] in which they studied the fluorescence characteristics of acridine orange in PVA films. To our knowledge, no reports have appeared discussing the use of PVA films for OPC applications.

We have recently investigated the possibility of using polymer films embedded with saturable xanthene dyes for low power cw OPC. In this Letter, we report our observation of OPC in PVA films embedded with the following dyes: eosin; erythrosin B; and Rose Bengal. We also discuss the effects of photochemical damage and washout due to vibrations. We found these effects to be very severe, but none of the above authors has studied these aspects carefully.

Of the different dyes which we used, erythrosin B was found to give the strongest OPC signals. Films were prepared from microscopy grade dyes and commercial grade polymers. The polymer was dissolved in warm distilled water, and dye was added, poured onto glass slides, and allowed to dry slowly. The resulting films had a thickness of the order of a few tens of microns and good uniformity. Experiments were performed at the 514.5-nm line of the Ar-ion laser and set in the usual counterpropagating geometry applied for cw operations.[6] No optical isolator was used. Homemade aluminum coated mirrors and beam splitters were used. The powers of the pump beams differed by ~20%. The probe beam was ~9% of the stronger pump beam and incident at an angle of ~10° to the pump beams. Because of ghost images the probe beams as well as the phase conjugate (PC) beam showed dark fringes across the beam. Therefore, for the sake of detection, the PC beam was allowed to fall on a scatterer, and the scattered intensity was monitored using a photomultiplier tube (PMT). For reducing noise, the probe beam was chopped using a mechanical chopper, and the PMT signal was monitored using a lock-in amplifier.

Figure 1 shows a comparison of the lock-in amplifier signals from erythrosin B, one in a gelatin film and the other in a PVA film, both recorded in the same setup. Both samples

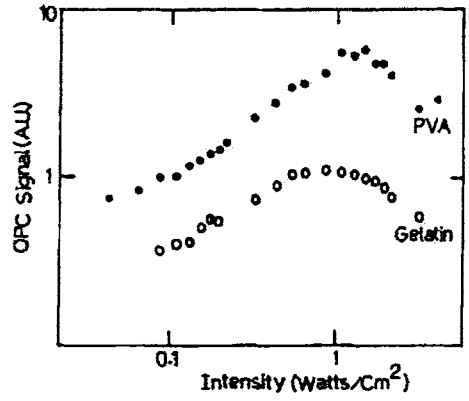

Fig. 1. OPC signal vs intensity for erythrosin B in PVA (●) and gelatin (○) films.

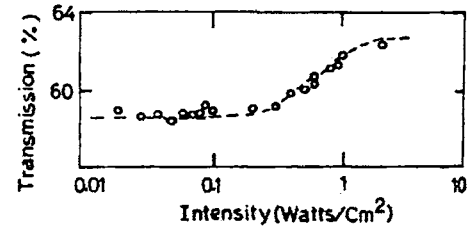

Fig. 2. Saturable absorption of erythrosin B in a gelatin film. On saturation, transmission increases from 58.8 to 62% only. The rest is unsaturable.

had an initial transmission of 4.7% at 514.5 nm, which corresponds to an absorption length ($\alpha_0 l$) of 3.06. The saturation intensities of erythrosin B in both matrices were measured to be 0.26 W/cm^2. The maximum power which we detected in the PC beam in the case of the PVA films was of the order of 10^{-7} W (measured directly using a EG&G Gamma Scientific model 460 Laser Powermeter), when the probe beam power was of 10^{-2} W. This implies a reflectivity of 10^{-5}. Reflectivities obtained from eosin and Rose Bengal were of the same order but a little less than that from erythrosin B. These values are much less compared to the reflectivity obtained from the boric acid glass films.[3] But boric acid films are difficult to prepare and handle when compared with PVA films. Also PVA films offer better uniformity than the gelatin films prepared in the same way.

As seen from Fig. 1 PC reflectivity increases with intensity up to a certain value and then decreases. This is caused not only by the inherent nature of the interaction as discussed by Abrams and Lind[8] but also by the photochemical damage occurring to the dye molecules.[7] These systems do not behave completely as saturable absorbers. There is always a good amount of unsaturable component for absorption (see Fig. 2), and this, along with the various nonradiative processes, contributes to the damage of the dye molecules. To understand how fast this happens, we studied the decay of the OPC signal in time for various values of intensities. These are plotted in Fig. 3. It is seen that the decay is very fast when intensities are high. A working level of intensity

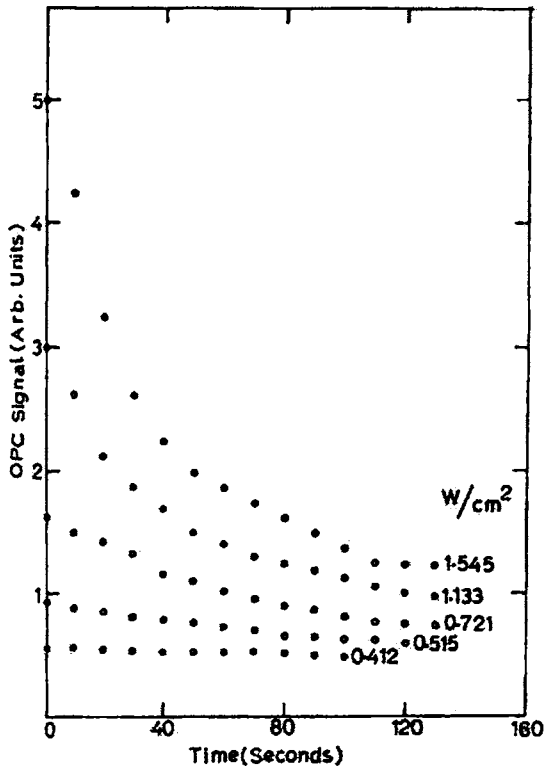

Fig. 3. OPC signal vs time for erythrosin B in a PVA film for different intensities.

which allows reasonably good OPC signals can, however, be fixed.

Although one expects an instantaneous response from a saturable absorber, in these cases, since saturation is achieved by bottle-necking at the triplet levels in a time scale of milliseconds, there is a finite rise time for the OPC signals. Washout effects due to vibrations, therefore, become detrimental. In our experiments, the OPC signals displayed on an oscilloscope showed a spiky profile due to the vibrations picked up from the floor. Although indigenous vibration-isolation techniques improved the signal profile, a high quality virbation-isolation device seemed to be necessary for eliminating the fluctuations completely.

In conclusion, we have observed OPC in polyvinyl alcohol films embedded with saturable xanthene dyes. In view of the ease of preparation and uniformity achievable, PVA films are better than boric acid glass and gelatin films in which OPC has been reported. In all these cases, photochemical damage poses problems and limits the working intensity levels to small values. Since the rise times of milliseconds are involved, washout effects are serious, and this necessitates the use of vibration isolation systems for the experimental setup.

Financial assistance from the Department of Atomic Energy and the Council of Scientific and Industrial Research, Government of India, in the form of project funds and research fellowships is gratefully acknowledged.

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