

Photorefractive gratings in liquid crystals with polymer doped C₆₀ layers

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Photorefractive-like liquid crystals¹, with their large diffraction efficiencies and nonlinear effects combined with thin film format, are ideal materials for integrated optics applications. Liquid crystals doped with dyes or with added photoconducting polymer layers² show high two-beam coupling gain.

The reorientation process that liquid crystal molecules undergo is induced and controlled by the application of light and electric field. There is typically more than one mechanism involved in the reorientation of liquid crystal molecules and, with careful design, the photorefractive space-charge field can play an important role. Moreover, the reorientation can also be strongly influenced by surface-mediated effects and surface-charge modulation, as well as surface anchoring.

Photorefractive liquid crystals structures with photoconductive layers on their substrates have shown to be very efficient, in particular using polyvinyl carbazole (PVK) polymer doped with photosensitiser trinitrofluorene (TNF).

However, the practical application of this structure is minimised by the toxic nature of the TNF dopant.

We have observed that efficient two-beam coupling can also be observed with PVK doped with another photosensitiser, namely fullerene C₆₀, instead of TNF. The gratings were written in 30 μm thick planar cells filled with E7 liquid crystals and using two linearly p-polarised beams at 633 nm (or 514 nm). We have measured the two-beam coupling gain ratio G defined as: $G=I_{12}/I_1$, where I_1 is the intensity of the probe beam in the absence of the pump beam I_2 and I_{12} is the intensity of the probe beam in the presence of the pump beam. We simultaneously monitored the intensity of both beams and measured the build-up of power in beam 1 and the depletion of beam 2. When we changed the polarity of the applied DC field, the direction of the energy flow was reversed.

In order to determine the efficiency of the material structure (liquid crystal-polymer-photosensitiser) we use the exponential gain parameter Γ defined as:

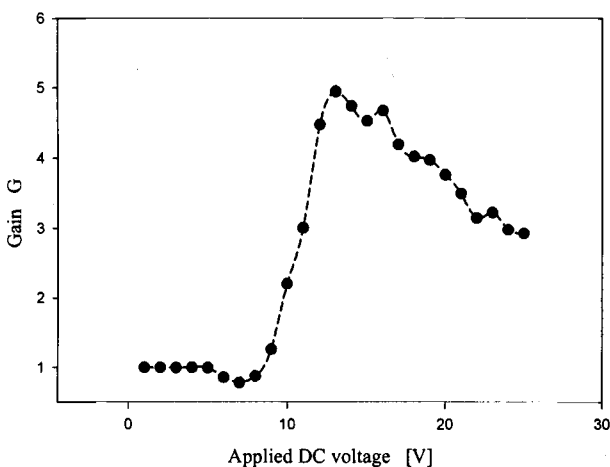


Fig. 2 Two-beam coupling gain G as a function of externally applied electric field for 30 μm thick cell

$$\Gamma = \frac{1}{d'} * \ln \frac{Gm}{m - G - 1}$$

where d' is the effective thickness of the liquid crystal, m is the incident beams intensity ratio.

Even for low grating spacings of 6 μm we achieved gain G as high as 5, giving the exponential gain parameter Γ of over 700 cm⁻¹. The results presented so far were measured at the optimum cell tilt angle of 45°, but we noted that a significant beam coupling exists for the whole range of tilt angles between 0 and 45°.

The figure shown gives an example of gain dependence on the applied voltage, with a maximum obtained for voltages around 20 V. These results were measured with very low light intensities, namely the total incident intensity was 150 μW/cm². We have observed that the net value of gain G varied very little with incident intensity, so even increasing the incident power by an order of magnitude, did not yield significant increase in the gain. However, the dynamics of the beam coupling response depended on voltage, namely at higher light intensities, the reorientation processes started at lower voltages than in the case of low incident intensity.

We also observed how reorientation is activated from the surface following light illumination. While application of an electric field tends to affect the orientation of the bulk of the liquid crystal, the photosensitive layer, covering the surface of the cell, reacts quite strongly with the incident light. Transition from planar to homeotropic alignment can then be easily observed and monitored.

Overall, liquid crystal structures incorporating PVK:C₆₀ show excellent performance and prove their suitability for coherent light amplification and patterning, details of which we will describe in our presentation.

¹ I.C. Khoo, IEEE J. Quant. Electron, **32**, pp. 525 (1996).

² S.Bartkiewicz, A.Miniewicz, F.Kajzar, M.Zagorska, Appl. Optics, **37**, 6871 (1998).