# Hidden surface photorefractive gratings in a nematic-liquid crystal cell in the absence of a deposited alignment layer

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Received September 1, 2005; revised December 23, 2005; accepted January 6, 2006; posted February 3, 2006 (Doc. ID 64534)

We have carried out studies of photoinduced diffraction in a homeotropically aligned liquid-crystal cell on indium tin oxide with no alignment layer deposited between the electrodes and the liquid crystal. We have observed diffractive components from both persistent hidden gratings and transient gratings formed in the presence of a dc electric field and two coherent pump beams. Our experiments suggest that these persistent hidden gratings are due to a light-induced modulation of the surface charge of adsorbed species that is hidden by diffusion of bulk charge to screen the surface charge in the absence of an applied field. The applied field removes the screening charge, revealing the hidden surface-bound charge modulation. This persistent hidden grating can be manipulated by the application of light and/or a dc electric field. Dynamics and other properties are studied and described. © 2006 Optical Society of America

*OCIS codes:* 050.1950, 190.5330, 240.6670.

## 1. INTRODUCTION

Photorefraction in liquid crystals (LCs) has attracted significant attention, since it is characterized by strong optical nonlinearities at low light intensities and voltage.[1–22] The photorefractive effect in a LC cell can be initiated by light-induced charge generation in both the cell volume and the LC-orienting layer as well as in the LC-aligning layer interface. In volume-mediated photorefraction, the incident optical-intensity grating generates photocharges in the LC bulk that migrate and diffuse within the LC to set up various dc space-charge fields.[1–5] These space-charge fields create a torque on the LC director, forcing its reorientation and hence changes of the orientation of the refractive index ellipsoid.

In surface-mediated photorefraction, the spatially modulated light field results in a modulation of the electric field either in the aligning layer itself[7,10–12,20–22] or at the interface between the LC and the aligning layer.[14–16] In the first case photoconductive aligning layers are applied. According to Refs. 20–22, in these experiments the photoexcited charges are trapped in the dark areas at the insulated polymer surfaces, and the resulting space-charge field reorients the LC in the cell. This increases the electric field in the LC bulk, causing a spatially modulated reorientation of the director in the cell. This effect is reversible, and the gratings disappear after termination of the incident light. In the second case, the photorefraction is controlled by the processes in the interface between LC and aligning surfaces, both of which can be nominally insensitive to light. Pagliusi and Cipparone[15,16] observed surface-mediated photorefraction in planar-oriented LC E7 in the cells whose surfaces were covered by indium tin oxide (ITO) electrodes and rubbed polymer layer of polyvinyl alcohol (PVA) above. The observed phenomenon was attributed to an accumulation of charges, initially presented in the LC, near the polymer surface owing to an external dc field and following light-induced modulation of these charges. The modulation of the charge distribution was suggested to be due to photoinduced injection of carriers from the electrode through the aligning polymer to the LC and successive recombination with ions accumulated on the opposite side of the interface.[17] The resultant spatially modulated electric field induces a reorientation of the director in the bulk and the grating recording. The photorefractive gratings reported by Pagliusi and Cipparone[15,16] occurred only during irradiation. If the origin of the photorefraction involves photoinduced injection of carriers from ITO, this effect should be rather universal and one that is especially effective in the cells made from two ITO electrodes with no deposited aligning layers.

Other characteristics of surface-mediated effect were found by Zhang *et al.*[14] in homeotropic 5CB LC cells with nominally light-insensitive aligning layers. It was observed that the recorded grating persists several hours and even days despite the disappearance of diffraction af-

 