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Space-charge waves in a $Bi_{12}TiO_{20}$ photorefractive crystal

Ivan Oliveira[1,*] and *Varese S.* Timóteo[1]

[1]Laboratório de Óptica, Faculdade de Tecnologia - UNICAMP, Limeira-SP, Brazil.

Abstract. We studied space-charge waves caused by the competition between holes and electrons in an undoped $Bi_{12}TiO_{20}$ photorefractive crystal and generated during holographic recording with a 532 nm wavelength laser light and the reflection geometry. A non-linear relation between the velocity of the resonant space-charge waves and light intensity, as well as the photovoltaic effect, is demonstrated. The experimental data is in good agreement with the theoretical model reported here.

1 Introduction

Space-charge waves are eigenmodes of the spatial and temporal oscillations of charge density and in sillenite crystals such as $Bi_{12}TiO_{20}$ (BTO) they appear in the form of running holograms [1–4]. This phenomenon has applications in some areas, such as image processing [5] and material characterization [6]. In this work we study space-charge waves in a BTO photorefractive crystal in the presence of hole-electron competition and the photovoltaic effect.

2 Theory

The following theory is based on the two-photoactive centers model, which assumes the existence of two distinct photoactive centers: one for electrons and another for holes [7, 8]. In addition to the hole-electron competition, the photovoltaic effect and the influence of light intensity on photoactive centers are also taken into account. The simultaneous presence of electron-hole photoactive centers gives rise to a coupled system of equations and, under certain conditions, this system can be solved analytically. In this case, and with a moving interference pattern of velocity v, the space-charge field is given by

$$E_{sc}^{st} = E_{\text{eff1}} \frac{1-\kappa_{21}-iKv}{(1-i\tau_{\text{sc1}}Kv)(1-i\tau_{\text{sc2}}Kv)-\kappa_{12}\kappa_{21}} + E_{\text{eff2}} \frac{1-\kappa_{12}-iKv}{(1-i\tau_{\text{sc1}}Kv)(1-i\tau_{\text{sc2}}Kv)-\kappa_{12}\kappa_{21}} \quad (1)$$

with $j = 1, 2$ related respectively to electrons and holes. The other parameters E_{effj}, τ_{scj}, κ_{12}, and κ_{21} are respectively the effective field, the time constant of the build-up of the space-charge field, and the coupling constant of the hole-electron pairs. These parameters depend on the photovoltaic field E_{ph}, on light intensity, and on other parameters that characterize the material. In the fringe-locked running holograms condition, $\Re\{E_{\text{sc}}\} = 0$ (real part of Eq.(1)) [6], it is found that the velocity of the space-charge waves is derived as

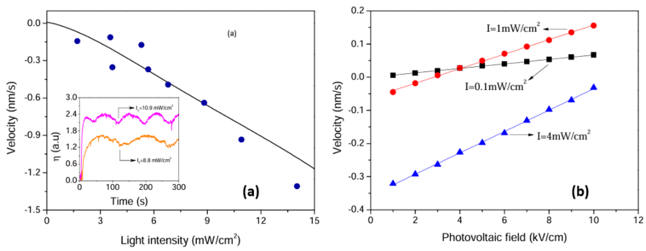
$$v = v(l_{sj}, L_{Dj}, \phi_j, E_{ph}, I). \quad (2)$$

l_{sj} and L_{Dj} being the Debye and the diffusion lengths respectively, ϕ_j the quantum efficiency for photoelectron generation, E_{ph} the photovoltaic field and I the light intensity.

*e-mail: ivan@ft.unicamp.br

3 Experiments and Results

The two-wave-mixing fringe-locked running-hologram [6] experiment was carried out using the reflection geometry, in the absence of an external electric field, with a λ= 532 nm wavelength laser light in a 1.5 mm thick nominally undoped $Bi_{12}TiO_{20}$ crystal. The figure 1(a) shows the velocity of space-charge waves as a function of light intensity. The inset shows the diffraction efficiency during holographic recording for different light intensities. The line represents Eq.(2) from the theoretical model with the parameters given in table 1(c).



Parameters	Electron	Hole
l_{s0} (nm)	50	160
L_{D0} (nm)	155	400
ϕ	0.20	0.003
E_{ph} (V/m)	1.0×10^5	

(c)

Figure 1: Space-charge wave velocity *versus* light intensity (a). The inset shows the diffraction efficiency during recording time for different light intensities. Space-charge wave velocity computed with Eq.(2), for fringe locked conditions, *versus* the photovoltaic field magnitude (b). The parameters that represent the experimental data are shown in table (c).

4 Conclusions

The results presented in this work show that the velocity of the space-charge waves of the photorefractive crystal depends not only on light intensity but also on the photovoltaic field. The oscillations of the diffraction efficiency do not indicate damping, at least during recording, as shown in Fig.1. The amplitude of these oscillations may be associated with the influence of light intensity on the formation of the space-charge electric field generated by the space-charge waves.

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