The role of the photorefractive effect in ultrafast laser-assisted poling in $LiNbO_3$

Y. J. Ying[1], C. E. Valdivia[2], R. W. Eason[1], and S. Mailis[1]
1) Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK
2) Centre for Research in Photonics, University of Ottawa, Ottawa, Ontario K1N 6N5 Canada

Abstract: *Light assisted poling (LAP) in $LiNbO_3$ is examined under the "light" of the photorefractive effect for both CLN and Mg:CLN. Experimental results suggest that photo-induced space charges are responsible for the effect.*

Introduction

Light assisted poling (LAP) is a method for ferroelectric domain engineering in lithium niobate (LN) where intense light is used to reduce the coercive field (E_c) locally hence resulting in a preferential domain inversion upon the application of an external *E*-field [1-4]. It has attracted some interest recently due to the large E_c reductions, up to two orders of magnitude (for MgO doped LN) [5]. It has been recently reported that the effect can also occur in a latent fashion in congruently melting LN (CLN) crystals [6]. In ***latent-LAP*** the application of the external *E*-field is delayed with respect to the irradiation. The effect has been seen to fade with time as revealed by measurements of the domain inverted area as a function of the delay between illumination and subsequent *E*-field application shown in figure 1. The experimental points correspond to the area of latent-LAP domains produced with different illuminating laser intensities and an external E-field of 8 kV/mm. While the absolute domain-inverted area is seen to be a function of the illuminating intensity, the dynamics of the inverted domain area reduction with increasing time delay between illumination and *E*-field application remains essentially the same as seen in figure 1. The latency of LAP combined with the decay of the coercive field reduction in congruently melting LN is reminiscent of the behavior of the space charge field in the photorefractive effect which is formed under the influence of optical irradiation and which decays slowly (in the case of CLN) in the dark or under the influence of uniform illumination. Furthermore, the refractive index change which is associated with the photo-induced space charge field provides an excellent tool for monitoring the dynamics of the space charge distribution and the associated fields.

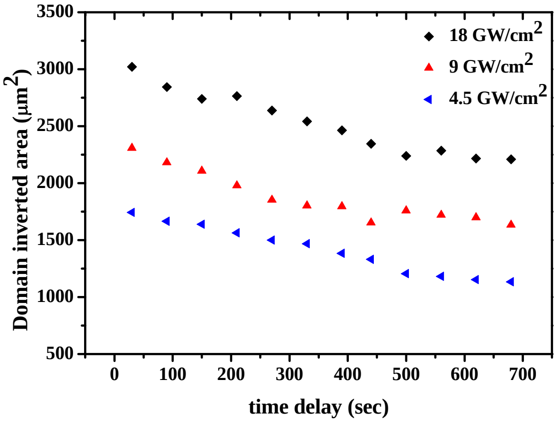

Figure 1. Latent-LAP domain inverted area, for different laser intensities, as a function of the time delay between laser exposure and E-field application.

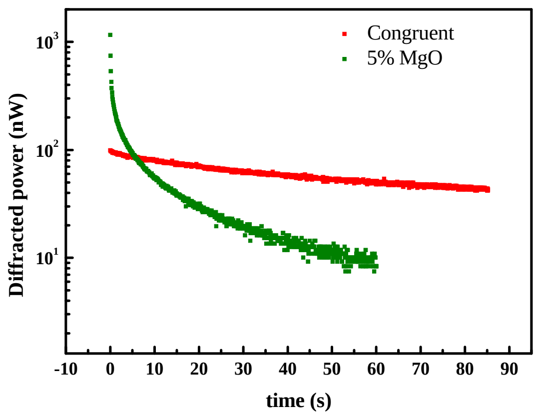

Figure 2. Photorefractive grating decay in congruently melting (red trace) and 5% MgO doped (green trace) LN crystals for the same HeNe probe laser power (3.5 mW)

Experiments and discussion

An interferometric setup was used for grating recording in various LN crystals. An ultrashort-pulse laser (150fs, 250kHz, 400nm) was used for the grating recording mainly due to the plethora of relevant LAP data (both simultaneous and latent) already existing and available for comparison. The influence of the probe beam power and wavelength on the grating decay rate was investigated and the results will be presented. A plot of the decay of a photorefractive grating which was recorded, under identical conditions, in congruently melting LN and 5% MgO doped crystals of the same thickness is shown in Figure 2. A straight comparison of the two decay curves reveals that a) the grating in MgO doped crystal decays much faster than the congruent one and b) the grating saturation level (represented by the first point in each curve) is one order of magnitude higher in the MgO doped crystal. The large dark conductivity in MgO doped crystals is responsible for the fast decay of any photo-induced space charge field which explains the absence of LAP latency in MgO doped crystals while the slow decay observed in congruently melting crystals justifies the observed LAP latency in these crystals. Additionally the difference in the value of the saturated diffraction efficiency reflects the level of the coercive field reduction for each crystal in LAP. Both observations suggest a strong link between LAP (both simultaneous and latent) and the photo-induced space charge which is responsible for the photorefractive grating.

[1] M.C. Wengler, M. Muller, E. Soergel, K. Buse, Appl. Phys. B, **76**, 393 (2003)
[2] V. Dierolf, and C. Sandmann, Appl. Phys. Lett. **84**, 3987 (2004)
[3] C. L. Sones, M. C. Wengler, C. E. Valdivia, S. Mailis, R. W. Eason, and K. Buse, Appl. Phys Lett. **86,** 212 (2005)
[4] Y. Zhi, D. Liu, W. Qu, Z. Luan and L. Liu, Appl. Phys. Lett. **90**, 042904 (2007)
[5] C. E. Valdivia, C. L. Sones, S. Mailis, J. D. Mills, and R. W. Eason, Ferroelectrics, **340,** 75 (2006)
[6] S. Mailis, C. E. Valdivia, C. L. Sones, A. C. Muir, and R. W. Eason *CLEO-Europe* CE7-2-THU (2007)