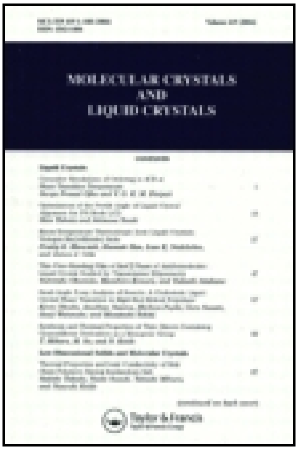

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Experimental Evidence of Dark Periodic Lattices in Nonlinear Liquid Medium

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Experimental Evidence of Dark Periodic Lattices in Nonlinear Liquid Medium

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In this work experimental measurements showing formation of dark periodic lattices in negative nonlinear liquid medium are reported. These lattices were formed by the propagation of periodic patterns through a nonlinear liquid media. These periodic patterns were induced by interference of three plane waves. Here three interesting cases showing the evolution of bright into dark periodic lattices are reported. In the first case periodic lattices formed by dark spots were observed. In the second case a periodic lattice formed by a set of stripes was observed. Finally in the third case a periodic lattice showing a combination of stripes and dark spots is reported.

Keywords: nonlinear optics; nonlinear self-action; optical lattices

INTRODUCTION

Nonlinear periodic structures or nonlinear photonics lattices have been studied extensively in photorefractive crystals [1,2]. Their principal attractive is open new ways to manipulate the propagation of light taking advantage of discrete and photonic band gap effects. To form a periodic structure in a photorefractive crystal is necessary to induce

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periodic refractive index modulation. This can be optically induced by several methods such as interference of several plane waves [3,4], by using amplitude mask [5,6], by waveguides [7,8], by applying external electric field [9] and by employing gratings [10].

Several approaches for control light propagation through engineered periodic structures have been predicted and demonstrated experimentally in recent years. For instance some of these approaches are: Manipulation of linear light propagation such as refraction and diffraction [9]; Nonlinear effects such as harmonic generation, stimulated scattering, and nonlinear self-action [11]. Furthermore the nonlinear response of the material offers opportunities for dynamic tenability based on the light intensity [12]. The interplay between nonlinearity and periodicity represents a unique way to efficiently manipulate light with light which can be used for optical switching and for signal processing applications. One of the principal lines of research in periodic structures deals with the propagation of spatial solitons in periodic structures with different nonlinearities of the medium [13]. However, the problem of propagation of bright periodic structures of beams in negative nonlinear medium has not been extensively analyzed.

In this work we study experimentally the propagation of bright periodic structures of light trough a medium with negative refractive index of the medium. Here a set of three interesting experimental observations showing formation of one and two dimension dark periodic lattices are reported. As a propagation medium we used a nonlinear liquid. These results suggest that bright spots of light can be coupled in either one or two directions by controlling the power, the geometry and the period of the input periodic lattices. Moreover the lattice dark zones are self-focused due to the negative nonlinearity. In consequence, periodic structures with different geometries and periods can be formed. We report three cases of dark photonic lattices which depend on the geometry selected.

EXPERIMENTAL SETUP

Our experimental setup is based in the periodic pattern induced by interference of three plane waves (Fig. 1a) explained in [14]; the initial beam is divided into two plane waves by Bs1. One plane waves is directed to M1 while the second wave to Bs2. Bs2 divide the wave into other two waves, one of them directed to Bs3 and the other to M2. To Bs3 interfere the wave reflected by M1 and one of the waves from Bs2, here the first interference pattern of two plane waves is produced. This pattern interferes in Bs4 with the second wave coming from Bs2 and

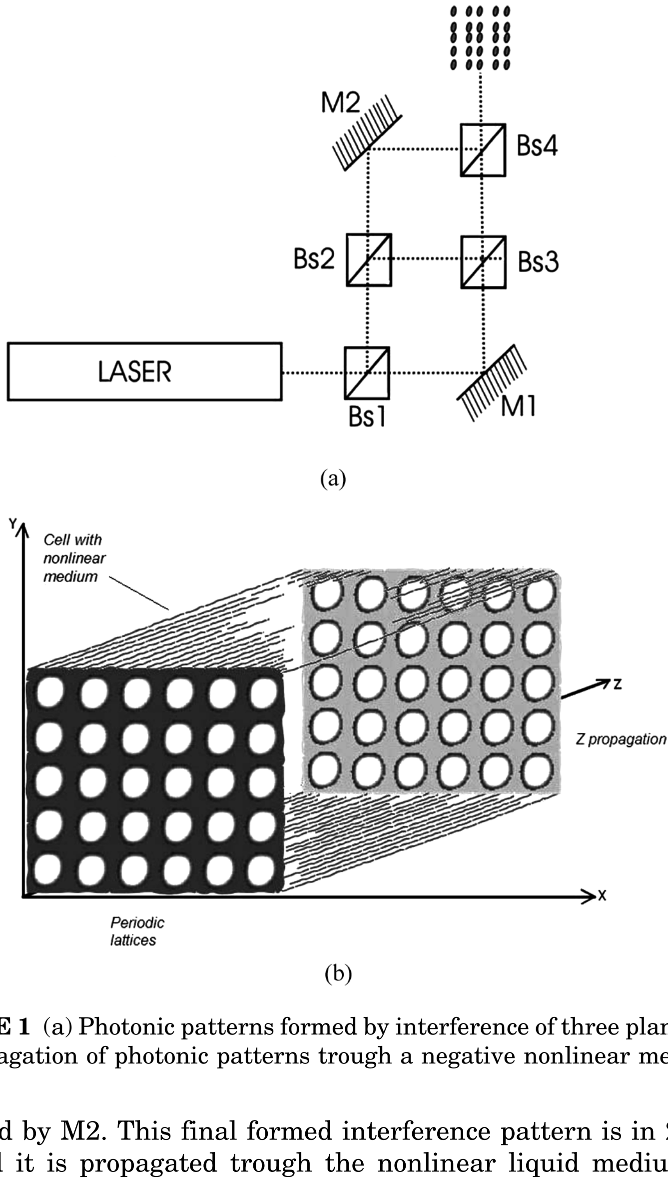

FIGURE 1 (a) Photonic patterns formed by interference of three plane waves. (b) Propagation of photonic patterns trough a negative nonlinear medium.

reflected by M2. This final formed interference pattern is in 2D (Fig. 1b) and it is propagated trough the nonlinear liquid medium (type Kerr).

In this experiment, an Ar-ion CW laser (514 nm) was used as a light source; the nonlinear liquid media was prepared using acetone with rhodamine R6G (30 g/l) contained in a cell of 1 cm of length. The images of the periodic patterns at the input and the output faces of the liquid cell were captured with a frame grabber and a CCD camera.

EXPERIMENTAL MEASUREMENTS

Case 1 – Dark Photonic Lattice

The geometry of bright periodic pattern in two dimensions (2D) formed by the interference of the three plane waves is shown in Figure 2 in the output face of the cell. To obtain the pattern shown in Figure 2 we used 127 mW of power. In this case the periodic pattern is formed by a set of ellipses with major and minor axes of length 648 and 372.5 μm respectively. In this pattern of ellipses, the major axes form a set of parallel lines with angle of 59.32° respect to the x-axis with period of 677.28 μm. Similarly ellipses minor axes form a set of parallel lines with angle of 149.32° respect to the x-axis and period of 507.87 μm.

The periodic pattern shown in Figure 2 was launched to the cell containing the nonlinear medium. After the power was incremented until 186 mW where each bright spot was coupled between neighbors due to the selected geometry and the phase change of each spot which is induced by the intensity. In this case elliptic geometry favors the interaction of energy between close neighbors while the dark spots are self-focused due to negative nonlinearity of the rhodamine [15–17]. Hence dark periodic lattices were formed as shown in Figure 3.

Case 2 – 1D Dark Photonic Lattice

The second case is very interesting and corresponds to the formation of one dimension dark periodic lattice. For this case the selected pattern

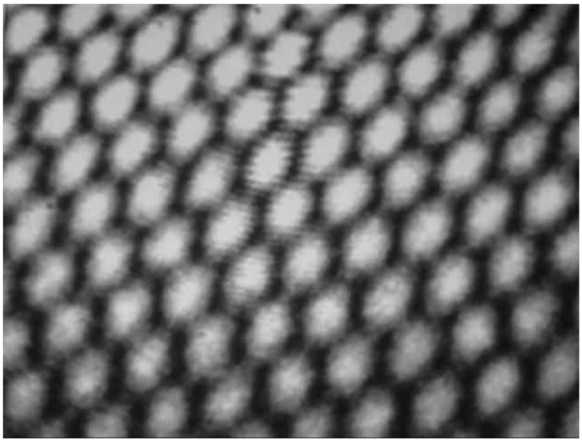

FIGURE 2 Recorded periodic pattern with elliptical bright spots at the cell input face.

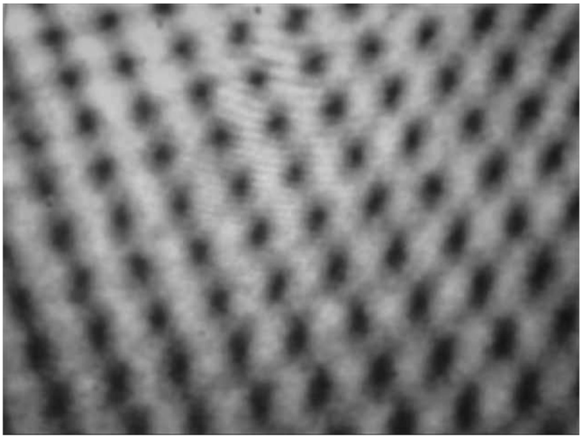

FIGURE 3 Dark photonic lattice observed at the output cell.

geometry at the input cell face was formed by elliptical bright spots as seen in Figure 4a, here the power was 52 mW. In this pattern ellipses have major and minor axes of length 336 and 262.5 μm respectively. Moreover ellipses major axes form a set of parallel lines with angle of 90° respect to the x-axis with period of 950.4 μm. Similarly ellipses

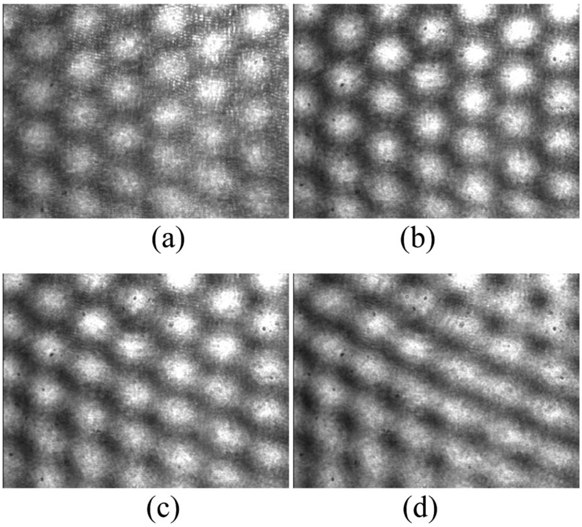

FIGURE 4 Evolution of dark photonic lattice in one dimension due to geometry selected and power.

minor axes form a set of parallel lines with angle of 0° respect to the x-axis with period of 898.1 μm. Here is seen that 6 columns are formed at the input cell face. Now when the power is increased up to 127 mW the periodic lattice observed at the output cell face has 7 columns of bright spots (Fig. 4b) due to a period change. Afterwards if the power is increased to 138 mW 1D stripe dark periodic structure is formed as shown in the central part of Figure 4c. Moreover when the power increases to 152 mW the lattice bright spots are coupled with their neighbors forming a diagonal line as shown in the central part of Figure 4d. This case is very interesting since it shows that a 2D bright photonic lattice can evolve into a 1D dark periodic lattice if the conditions for energy interchanging in two directions are satisfied. Here is important to mention that bright spots at top right corner are more intense due to the plane waves which form the interference pattern have an initial small tilt angle due to slight experimental alignment problems. Similarly the bright spots are less intense at the bottom left corner.

Case 3 – Combination of 1D and 2D Dark Photonic Lattices

The third case observed is a combination of two effects: stripes formation in 1D and 2D photonics lattices. Figure 5 shows the geometry selected in the input face of the cell, for this case the power was 211 mW. The periodic lattice is formed by vertical ellipses with 969.6 μm in major axis and 345 μm in minor axis; the ellipses form 9

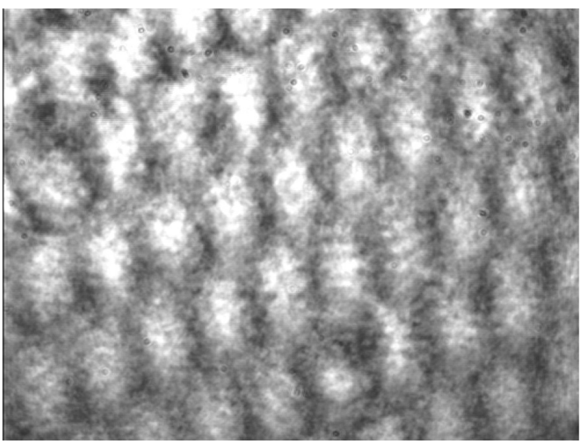

FIGURE 5 Photonic lattices at the input face of the cell, with a laser power of 211 mW.

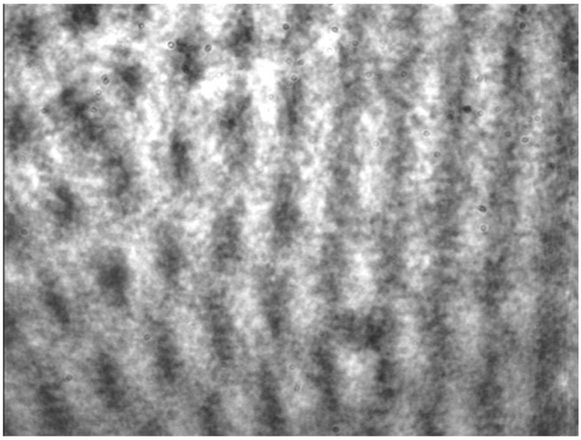

FIGURE 6 Combination of dark photonic lattices in 1D and 2D at the output face of the cell, with a laser power of 280 mW.

vertical columns with 85.4° respect x-axis. The period of the lattice is 1153.1 μm in vertical direction.

If the power is increased up to 280 mW stripes in *Y*-axis direction are formed (as shown at the right side of Fig. 6) since the bright initial spots are coupled between their neighbors in vertical direction. The major axes of the ellipses favor the interchange of energy in this direction. However, the minor axis is far from the nearest neighbor and therefore do not exist energy interchange in the horizontal direction. In addition at the left side of Figure 6 we can observe that a 2D dark lattice, very similar to the obtained in case 2, is formed. This is consequence of the tilt of the plane waves (which produce the interference patterns) and also is due to the beams used are elliptic.

CONCLUSIONS

In the present work we study experimentally how a bright photonic lattice evolves into a dark photonic lattice when it is propagated trough a negative nonlinear medium. Here three interesting cases obtained by changing the geometry, periodicity and power of the photonic lattice are reported. These preliminary experimental results show that in nonlinear liquid media the propagation of photonic lattices can form stripes lines due to self-phase modulation of the periodic lattice, dark periodic lattice in 2D, and combinations of stripes and dark periodic lattices 2D.

REFERENCES

[1] Cohen, O., Bartal, G., Buljan, H., Carmon, T., Fleisher, J. W., Segev, M., & Christodoulides, D. N. (2005). *Nature*, *433*, 500.
[2] Christodoulides, D. N., Ledererand, F., & Silberberg, Y. (2003). *Nature*, *424*, 817.
[3] Fleisher, J. W., Carmon, T., Seguev, M., Efremidis, N. K., & Christodoulides, D. N. (2003). *Phys. Rev. Lett.*, *90*, 023902.
[4] Fleisher, J. W., Seguev, M., Efremidis, N. K., & Christodoulides, D. N. (2003). *Nature*, *422*, 147.
[5] Christodoulides, D. N. & Joseph, R. J. (1988). *Opt. Lett.*, *13*, 794.
[6] Davidov, A. S. (1973). *J. Theor. Biol.*, *38*, 559.
[7] Ablowitz, M. J. & Musslimani, Z. H. (2001). *Phys. Rev. Lett.*, *87*, 254102.
[8] Sukhorukov, A. A. & Kivshar, Y. (2002). *Opt. Lett.*, *27*, 2112.
[9] Wyller, J. (2000). *Phys. D*, *157*, 90.
[10] Neshev, D., Ostrovskaya, E., Kivshar, Y., & Krolikowski, W. (2003). *Opt. Lett.*, *28*, 710.
[11] Gurdev, L., Dreishuh, T., & Stoyanov, D. (1993). *JOSA A*, *10*, 2296.
[12] Yakimenko, A., Zaliznyak, Y., & Kivshar, Y. (2005). *Phys. Rev. E*, *71*, 065603.
[13] Fleisher, J. W., Seguev, M., Efremidis, N. K., & Christodoulides, D. N. (2003). *Nature*, *422*, 147.
[14] Miroslava Cano-Lara, "*Periodic photonic arrays in nonlinear media*", Thesis master degree, FIMEE, Universidad de Guanajuato, 2006.
[15] Kozich, V. P., Marcano, O. A., Hernández, F. E., & Castillo, J. A. (1994). *Appl. Spect.*, *48*, 1506.
[16] Sinha, S., Ray, A., & Dasgupta, K. (2000). *J. Appl. Phys.*, *87*, 3222.
[17] Naga-Srinivas, N. K. M., Venugopal-Rao, S., & Narayana-Rao, D. (2003). *JOSA B*, *20*, 2470.