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Liquid crystals in photonic components

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Introduction

In direct-view liquid crystal displays, the pixels dimension is in the order of 100x100 μm^2 and the liquid crystal layer does not influence the wave vector of the incident light, only the polarization state. There are several ways to obtain fast lateral variations in the incident light by using liquid crystals. One way is to realize smaller pixel sizes, in the order of only a few μm. Switchable one-dimensional optical phased arrays, based on liquid crystal between glass substrates, can be used for beam steering. Devices with two-dimensional arrays of pixels are usually based on the liquid crystal on silicon (LCOS) technology. With such spatial light modulators (SLM) in combination with laser light, Fourier images or beam steering in two dimensions can be realized [1]. When ferro-electric materials are used the switching times can be in the order of μs. Another approach is to implement the lateral variation in the structure of the substrate, in such a way that the thickness of the liquid crystal layer changes with the position. With this approach switchable Fresnel lenses can be produced.

In the above examples, the light is incident from above or below a liquid crystal layer, and we call this transversal propagation. In the following, we will focus on devices in which the light travels parallel with the liquid crystal layer, so called lateral light propagation. The interaction between the light and the liquid crystal occurs over a larger distance and many architectures become possible.

All-liquid crystal waveguides

The effective index for lateral light propagation in a liquid crystal layer depends on the tilt angle of the director, which can be modified by applying a voltage. In this way, it is possible to create waveguides in bulk liquid crystal. These waveguides can be one-dimensional (homogeneous electrodes) or two-dimensional (line electrodes).

In a one-dimensional nematic LC waveguide the TM polarized light is trapped in the region of the LC layer with the highest tilt. The number of modes in the LC slab waveguide depends on the thickness of the waveguide, the ordinary and extra-ordinary refractive indices and the tilt of the molecules. Such slab-waveguides can be used for beam steering over large angles. In bistable surface-stabilized ferroelectric cells, switching has been demonstrated using the effect of double refraction.

In two-dimensional configurations switching between two output channels has been demonstrated by changing the effective index in a bi-modal liquid crystal waveguide [2]. We have demonstrated that it is possible to deflect light using a voltage addressed two-dimensional waveguide by using strip electrodes on one substrate and a planar electrode on the other one (Fig. 1) [3]. Using light with sufficiently high power, the beam remains confined due to nonlinear self-focusing [4].

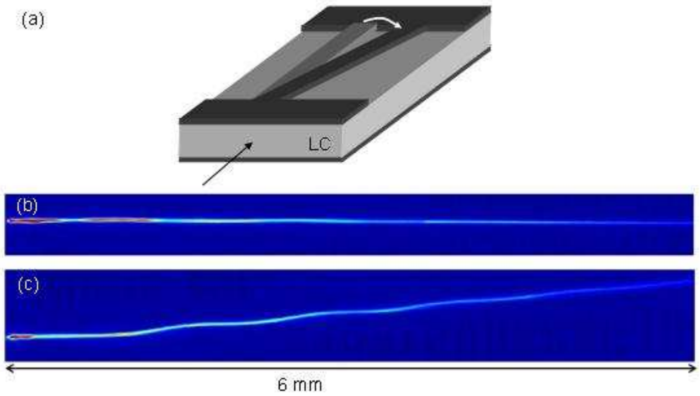

Figure 1: (a) Sketch of a configuration with a waveguide induced by a strip electrode. The direction of a soliton beam can be altered, as shown in (b) for 0° and in (c) for 6°.

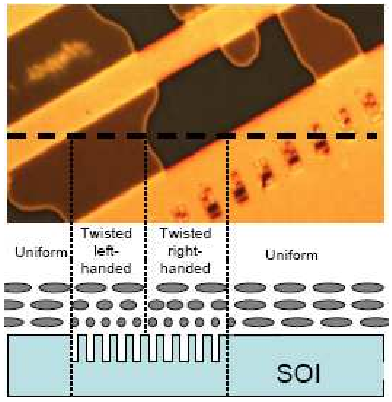

Figure 2: Photograph of LC over a number of SOI ridge waveguides. The waveguides induce alignment of the LC.

Hybrid liquid crystals waveguides

There is extensive literature on waveguide systems in which liquid crystals are used to realize tunability. In such hybrid systems, the liquid crystal can serve as the core, when it is surrounded by a low-refractive index material [5] or as (part of) the cladding. The liquid crystal can be used as an overlay material for silicon on insulator (SOI) or silica-titania glass [6] waveguides. In this configuration the substrate influences the LC alignment, as shown in Fig. 2 [7]. Typically, by applying the voltage over the liquid crystal, the effective index of the waveguide is slightly modified and this effect can be used to engineer tunable filters. In two-dimensional photonic crystal waveguides, the holes can be filled with liquid crystal to obtain tunability. The empty spaces in holey optical fibers can be filled with liquid crystal to obtain tunability [8].

Lasing in liquid crystals

Because of the selective reflection properties in cholesteric liquid crystals, it is possible to obtain lasing from dye molecules doped in LC material. Recently, random lasers and lasers based on induced gratings have been proposed.

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References

[1] Boulder Nonlinear Systems, URL: *www.bnonlinear.com*
[2] A. Fratalocchi et al., *Opt. Express* **2005**, *13*, 32-36
[3] J. Beeckman et al., *J. Opt. A: Pure Appl. Opt.* **2006**, *8*, 214–220
[4] J. Beeckman et al., *Opt. Express* **2004**, *12*, 1011-1018
[5] A. d'Alessandro et al., *IEEE J. Quantum Electron.* **2006**, *42*, 1084-1090
[6] L. Sirleto et al., *J. Opt. A: Pure Appl. Opt.* **2003**, *5*, S298-S304
[7] H. Desmet et al., *J. of Appl. Phys* **2005**, *98*, 123517
[8] T. Wolinski et al., *Mol. Cryst. . Liq. Cryst.* **2000**, *352*, 361-370