Low driving voltage optical switch based on nematic liquid crystal waveguides embedded in poly(dimethylsiloxane)

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We present a photonic switch made of liquid crystals infiltrated in poly(dimethylsiloxane) slides. The device can switch near-infrared wavelengths with an extinction ratio above 16dB in either outputs by applying a voltage below 1.8 V.
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1. Introduction

Photonic devices made by using liquid crystals (LC) have been very attractive in the past few years because of the effective electro-optical effect, which allows to apply small voltages to control light confined in optical channels [1]. LC can be effectively used either as a core of optical waveguides [2,3] or as an overlayer [4], electrically controlled by applying an electric field. LC can be infiltrated in Poly(dimethylsiloxane) (PDMS) channels to make LC:PDMS optical waveguides, where light can be confined in a LC core, by using a reproducible and low cost fabrication process [5].

2. Optical switch structure

LC:PDMS waveguides electrooptically controlled by using coplanar electrodes can be effectively used to make optical switches based on zero-gap directional couplers. Figure 1a sketches the top view of a device based on a zero-gap directional coupler made of two input single mode optical LC:PDMS waveguides. In the central bimodal region, whose cross-section is reported in Figure 1b, the zero-th order and the first order optical mode interfere constructively either into one output waveguide or in the other one. The optical power can be routed by applying an in-plane electric field to the LC E7 in the bimodal region, thus controlling its refractive index, through coplanar electrodes.
The optimized dimensions of the bimodal section are 3 μm high, 3 μm wide and 500 μm long. Two incoming single mode waveguides, with 3 μm high and 1.5 μm wide were designed.

3. Results and conclusions

Beam propagation was used to design the structure. Values of the ordinary refractive index of 1.5 and the extraordinary refractive index of 1.69 at the wavelength of 1550 nm for the NLC E7 were employed. The output power at both output waveguides P_{out1} and P_{out2} was calculated along with the extinction ratio of the switch, defined as $10\text{Log}(P_{out2}/P_{out1})$ in dB, for different values of the refractive index of the NLC E7. The minimization of the Oseen-Frank equation was adopted to calculate the NLC orientation, the corresponding refractive index and the required voltage [3]. As shown in Figure 2, a cross-state with an extinction ratio of 16 dB was obtained for an applied voltage of 1.62 V corresponding to a LC refractive index equal to 1.6. A bar-state of the switch with an extinction ratio of about -18 dB was obtained instead for an applied voltage of 1.76 V corresponding to a refractive index equal to 1.627. A voltage below 1.8 V to switch LC through coplanar electrodes was experimentally validated.

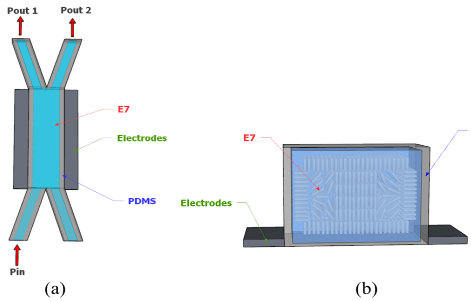

Fig. 1 (a) Top view of a zero-gap directional coupler with coplanar electrodes. (b) Cross section of the bimodal waveguide.

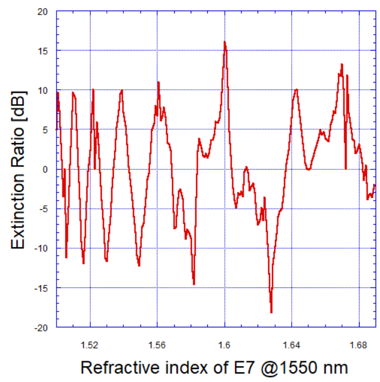

Fig. 2 Extinction ratio of the output of a zero-gap directional coupler switch versus LC refractive index.

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