Polarization independent microsecond electro-optic switch

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An inexpensive and fast electro-optic shutter is fabricated and demonstrated. The device works independently of the polarization state of the incoming light beam. Modulation between 3% and 60% transmission is obtained within a wavelength range of 50 nm with a response time of 20 µs. The working wavelength can be chosen from the visible to the near infrared according to the targeted application.

Chiral nematic liquid crystals (CLC) exhibit a helical arrangement of the molecules with a periodicity that ranges from a few hundred nanometers to several micrometers[1]. Similar to a distributed Bragg reflector (DBR), the periodicity of a CLC acts as a 1D Photonic Band Gap (PBG). When an unpolarized light beam is incident on a uniform CLC layer along the helical axis, the circularly polarized light of the same handedness as the chiral helix is reflected. Thus, a CLC cannot reflect more than 50% of normally incident unpolarized light.
In previous work we have demonstrated wavelength-tuning of the PBG of a CLC layer using an applied voltage. This resulted in a fast response (tens of microseconds) and tuning over a broad wavelength range, with high reproducibility and without deformation or degradation [2]. For many applications however it is unacceptable that the device only reflects about half of the unpolarized light. It is desirable to have a switchable photonic band gap with fast response irrespective of the polarization state of the incoming light beam.
In order to obtain switching from full reflection to full transmission in a certain wavelength range, we have used the method which is depicted in Figure 1. The set up includes two partly polymerized chiral nematic liquid crystals (PPCLC) and a half wave plate. The light with Right handed Circular Polarization (RCP) and with a wavelength in the PBG is reflected by PPCLC1 while the Left handed Circular Polarization (LCP) is transmitted. LCP light is converted to RCP by the zero order half wave plate. Then the RCP light is reflected by PPCLC2. This reflected light travels through the first PPCLC as it is converted to LCP. The photonic band gap is tuned by applying the same voltage signal over both PPCLCs.

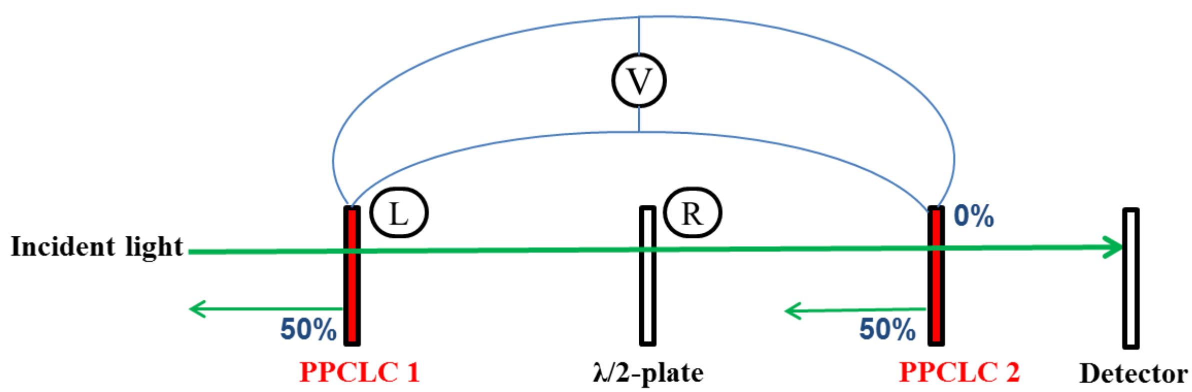

Fig.1 Schematic drawing of the device operation to modulate unpolarized incident light.

The transmission spectra of the samples are measured as a function of the electric field. Measurements are performed for different orientations of the linear polarizer which is placed before the device. No noticeable difference is measured in the transmission spectrum when varying the angle of the linear polarizer, which

means that the device works for unpolarized light. The blue shift of the PBG is 50 nm as shown in Fig. 2a. Instead of using the device as a wavelength tunable reflector, we believe that the most interesting application is a fast shutter for a particular wavelength. The contrast ratio is defined as the ratio between the transmissions of a full PPCLC-λ/2-PPCLC device for zero and high electric field for a specific wavelength. The obtained contrast ratio is 20 while the transmission in the center of the PBG is practically independent of the applied electric field and less than 3%. These measurements confirm that the field-tuning of the PBG keeps the uniform helical order which is usually not the case for polymer-based CLC switches [3]. The applied electric field can be generated by commercially available amplifiers. Due to the very limited current, the power consumption is low.
The response time of the device with right band edge at 875 nm is measured with a set of light emitting diodes (850 nm wavelength, FWHM 35 nm) and a silicon photodiode for the detection. When the voltage is off, the wavelength of the light emitting diodes is inside the photonic band gap and the incident unpolarized light is strongly reflected by the device as shown in Figure 2b. By applying an electric field, the PBG shifts to smaller wavelengths. In this state the wavelength of the light emitting diodes (850 nm) is above the PBG and the light can propagate through the device. The 10–90% response time is 20 µs for switching between zero and a block wave electric field signal with amplitude 150 V/µm and frequency 1 kHz. These switching times are much shorter than in previously reported work [4].

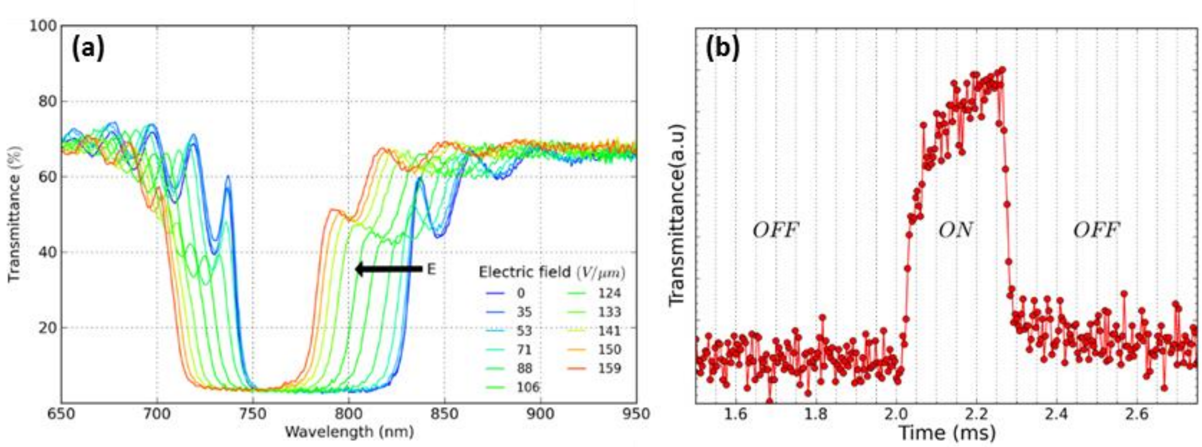

Fig. 2 a) Transmission spectra for unpolarized light b) Switching of the transmission for light with 850 nm wavelength for a block wave electric field (150 V/µm, 2 kHz) for a full PPCLC-λ/2-PPCLC device with two 8 µm thick PPCLCs.

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