Analysis of a vertically aligned liquid-crystal on silicon microdisplay for photonics applications

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Abstract. We present the characterization results for an analogically addressed vertically aligned liquid crystal on silicon microdisplay (VA-LCoS). We show that it covers more than 360º phase modulation range at 1550 nm, and that in the visible the range available enables the generation of multiorder DOEs. There are basically no studies dealing with the characterization of vertically aligned high resolution LCoS devices, since the ones typically found in the literature and commercially available correspond to the parallel aligned. We have also verified that the microdisplay used in this work is free from flicker, which is a very interesting feature for application where the phase stability is of the utmost importance. The results shown here represent a first step in the work underway oriented to the generation of programmable DOEs for telecommunication applications (C-band) and for the visible spectrum.

1 Introduction

Spatial modulation of light wavefronts is a very important topic nowadays, transversal to many different areas in Optics and Photonics [1]. Among the different technologies, parallel aligned liquid crystal on silicon (PA-LCoS) microdisplays have become widespread [1] and their properties have been extensively studied in the literature [2,3]. In this paper a different LCoS device, based on the vertical-alignment (VA) configuration is analyzed using a linear polarimeter measurement setup. We use a linear polarimeter configuration to calibrate its phase-shift dependence with voltage. Instantaneous measurements are also taken via an oscilloscope to analyze the existence of flicker, typically found in digital backplane LCoS devices [4]. The analysis for the application to diffractive optical elements (DOEs) is discussed, which is the one of the goals of the research lines under development in our research group.

2 Experiment and results

For the experiments, the reflective liquid crystal device is a commercial VA-LCoS display, model SLM-200 from the company SANTEC, with an antireflection coating for 450-1600nm. It is a homeotropically aligned nematic liquid crystal filled device, with 1920x1200 pixels, with 8 µm pitch and 95% fill factor and with analog addressing. We illuminate the device with the collimated beam of a 1550 nm laser (CoBrite DX2 Tunable Laser from IDPhotonics). Then, we also use a supercontinuum source, NKT EVO HP EU-4, and a wavelength selector, NKT VARIA, to probe the LCoS at other wavelengths in the visible and the near infrared.

When voltage is applied to the SLM-200, the LC director axis aligns with the rows of the pixelated device, which corresponds to the horizontal of the lab reference system. Then, we can consider the VA-LCoS as a variable linear retarder with its neutral lines along the horizontal and vertical of the lab. The LCoS is between two linear polarizers, with the input LP at +45º from the vertical of the lab (this is the X-axis in our right-handed lab reference system where the Z-axis points in the direction of the light propagation). The intensities $I^{||}$ and $I^{\perp}$ are measured respectively with the output LP parallel and crossed to the input polarizer for the reflected light. From these measurements we can extract the retardance Γ as a function of the voltage using the following expression [4],

$$\Gamma = cos^{-1}\left(\frac{I^{||}-I^{\perp}}{I^{||}+I^{\perp}}\right) \quad (1)$$

In addition, the power meter is connected to a digital oscilloscope to measure the instantaneous values for $I^{||}$(t) and $I^{\perp}$(t) as a function of time, to check the stability of the signal and the existence of flicker, typically present in many of the commercial LCoS available [1].

In Fig. 1 we show the measured retardance versus applied voltage (in gray level (GL) from the graphics card, with a 10 bits depth, i.e. from 0 to 1023, available for the SLM-200) at 1550 nm where we see that a linear retardance range of 384º is obtained, i.e. larger than 360º. We note that, as opposed to PA-LCoS devices where the maximum retardance happens when no voltage is applied,

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in the case of VA-LCoS, this is when retardance approaches to zero. Therefore, with the voltage increase (GL increase), the retardance increases. We see in Fig. 1 that there is a good linearity with the GL addressed.

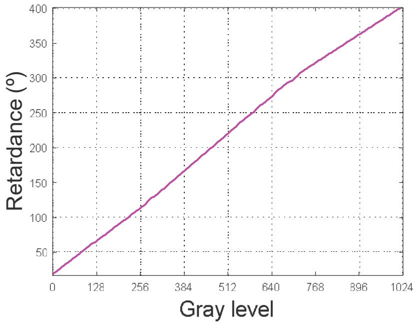

Fig. 1. Measured retardance vs. applied voltage, at 1550 nm.

In Fig. 2, we show the measurements taken with the oscilloscope for the instantaneous values for $I^{||}$ at different gray levels. We see that the signal shows no sign of flicker, simply with a very low value of residual noise. This total lack of flicker is clearly a distinctive feature when compared with digital backplane LCoS devices.

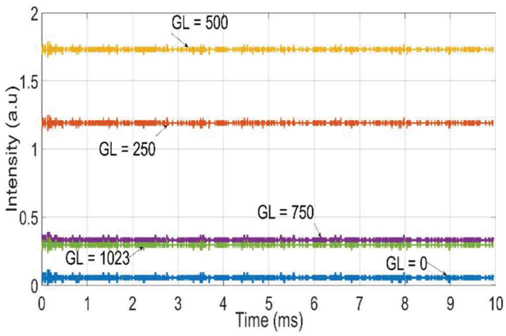

Fig. 2. Instantaneous $I^{||}$ at different gray levels, at 1550 nm.

We are also interested in evaluating the retardance range offered by the VA-LCoS in the visible. In Fig. 3 we show the retardance range at 530 nm, when applying the voltage range used previously to obtain a range of about 360º in Fig. 1 for 1550 nm. Now, we see that this corresponds to 1402º, that is, almost 4 times the typical 360º range used in programmable diffractive optics. This is interesting to produce multiorder DOEs (diffractive optics elements) [5].

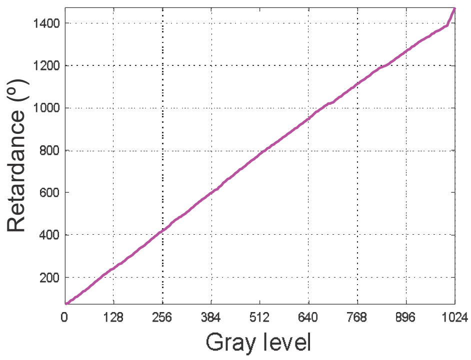

Fig. 3. Measured retardance vs. applied voltage, at 530 nm.

One of the applications of these primary results is to produce reconfigurable interconnects, i.e. programmable DOEs, with a very low cross-talk (less than 30 dB) for telecommunication applications (C-band) but also in the visible. Work is underway in this direction.

3 Conclusions

We have presented characterization results for a VA-LCoS microdisplay, which covers more than 360º phase modulation range at 1550 nm, and which is also applicable in the visible and the NIR ranges. In the visible the range available enables the generation of multiorder DOEs. It is also interesting to note, that there are basically not studies dealing with the characterization of vertically aligned high resolution LCoS devices, since the ones typically found in the literature and commercially available correspond to the parallel aligned. The microdisplay used in this work is also analogically addressed, and we have verified that is free from flicker.

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