Lithium Niobite on Silicon High Speed Spatial Light Modulator

Sivan Trajtenberg-Mills[1,*], Mohamed ElKabbash[1,*], Cole Brabec[1], Christopher Panuski[1], Ian Christen[1], Dirk Englund[1]
[1]Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, USA
**equal contributor*
Author e-mail address: (sivantra@mit.edu)

Abstract: We present a device of thin film lithium niobite integrated on a CMOS backplane, enhanced by a high quality factor guided mode resonance. The device offers GHz speed and megapixel degrees-of-freedom spatial light modulation.

1. Introduction

The quest for developing a high-speed spatial light modulator (SLM), able to control the phase or amplitude of light at GHz speeds, has drawn a growing amount of attention over the past few years [1]. The growing interest is driven by several application: quantum computing [2], where atom or ion qubit implementations require addressing qubits at timescales shorter than their decoherence time; imaging through scattering media, where GHz speed modulation can allow non-invasive in vivo imaging [3]; and LiDAR applications that require very high speed scanning of an input source. High speed modulation can also be used for holography (for live three-dimensional holograms) and acceleration of optical neural networks [4]. Existing technologies for spatial light modulation are either slow (with rates <1 KHz for commercial devices) or inherently not scalable (demonstrations rarely exceeding a few pixels). Developing an SLM with mega pixels and at high speeds > 1GHz remains an unachieved goal.

Here, we demonstrate a high-speed SLM through two-dimensional electric field patterning of a lithium niobate (LN) thin film. We mimic the successful commercial liquid crystal on silicon (LCoS) architecture but replace the slow liquid crystal layer with thin film LN, which has a high-speed electro-optic response. A high-quality factor (>1000) guided mode resonance (GMR) enhances the amplitude and phase modulation from the induced electro-optic index variation. The GMRs were designed for high quality factor and high field overlap, to maximize the effect. By integrating the photonic device with a CMOS backplane, we present a scalable approach for GHz speed and mega-pixel SLMs.

2. GHz speed modulation

To demonstrate high-speed modulation, we fabricated a square-lattice two-dimensional photonic crystal on a Silicon Nitride (SiN) thin film (100 nm) deposited on a LN on insulator substrate with a silicon handle. The photonic crystal excites several GMR resonances which we measured using a cross polarization reflection setup to eliminate direct reflection (Figure 1(a)). We fabricated Au electrodes aligned orthogonal to the c-axis of the LN film with a gap = 30 μm.

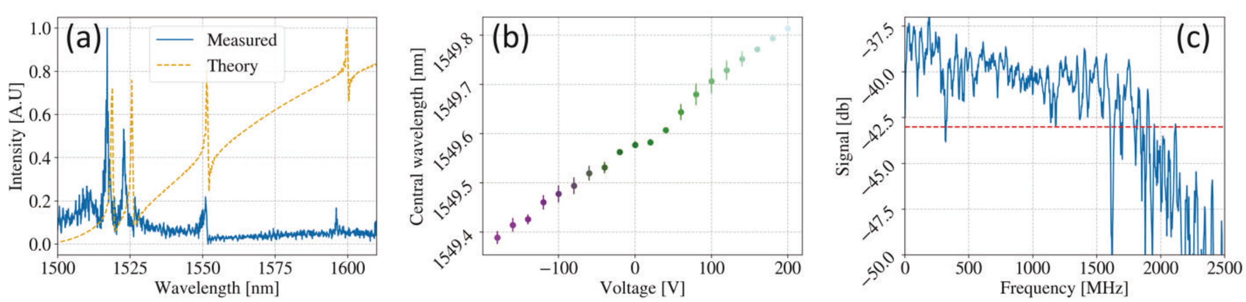

Figure 1: SLM demonstration showing GHz speed modulation. (a) Measured (Blue, solid) and theoretical (Yellow, dashed) reflection intensity per wavelength. (b) Resonant shift for different applied voltages. (c) Modulated signal, with 3db cutoff frequency at ~1.6 GHz.

The measured reflectance is fitted with a Fano-shaped waveform to extract the peak wavelength, phase and quality factor. We focus on the first TE mode, as it has the largest field overlap (by design) with the LN film. The quality factor for the TE mode is ~1500 at 1548.4 nm.

We measured the resonance shift (Figure 1(b)) of the of 0.4 nm for voltages ranging from -200V to 200V. We measured modulation speed using 1V of input power and measured cutoff modulation frequency of ~1.6 GHz as can be seen in Figure 1(c). The roll-off frequency is determined by the bandwidth of the photodetector (Thorlabs, APD450C).

2. Mega-pixel SLM:

To create a Mega-pixel and high speed SLM, we integrate our photonic crystal-LN photonic device with a CMOS backplane. Figure 2(a) shows the device stack where a CMOS backplane with 2 million pixels (acquired from Jasper Display Corp. [5]) is epoxy bonded to the photonic crystal-LN device. We also scale our fabrication method by creating the 2D photonic crystal through interference lithography. Figure 2b shows a photograph of a 1 cm^2 photonic crystal patterned on a SiN film on LN thin film substrate. An SEM image of the 2D photonic crystal shows the 2D photonic crystal. Figure 2(c) shows the epoxy bonded device that is then wirebonded to a ribbon cable which can be controlled through a microcontroller similar to existing Liquid Crystal on Silicon SLMs.

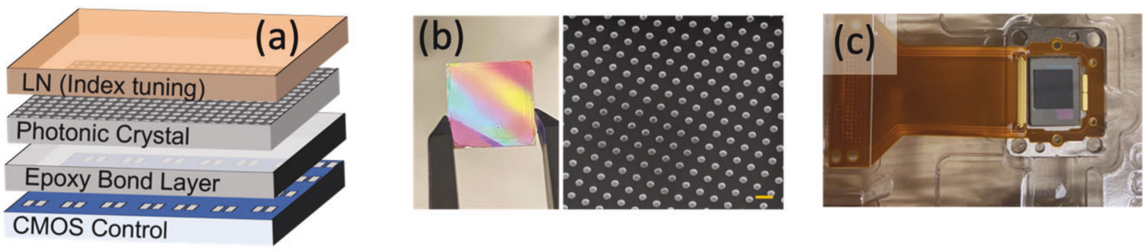

Figure 2: LNoS architecture and fabrication. (a) Design stack. (b) Photonic crystal layer, fabricated by interference lithography – left shows the entire 1cm^2 sample, right shows a microscopic image of the fabricated sample (yellow line marks 1 micron). (c) Complete bonded LNoS sample.

To conclude, we demonstrated a scalable architecture for high-speed spatial light modulators. We measured > GHz speed modulation for a simple test device and proved scalability to mega pixel apparatus by bonding to a CMOS backplane. This approach represents a major step towards scalable quantum control and high-speed optical computing, neural networks, and accelerators.

3. References

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