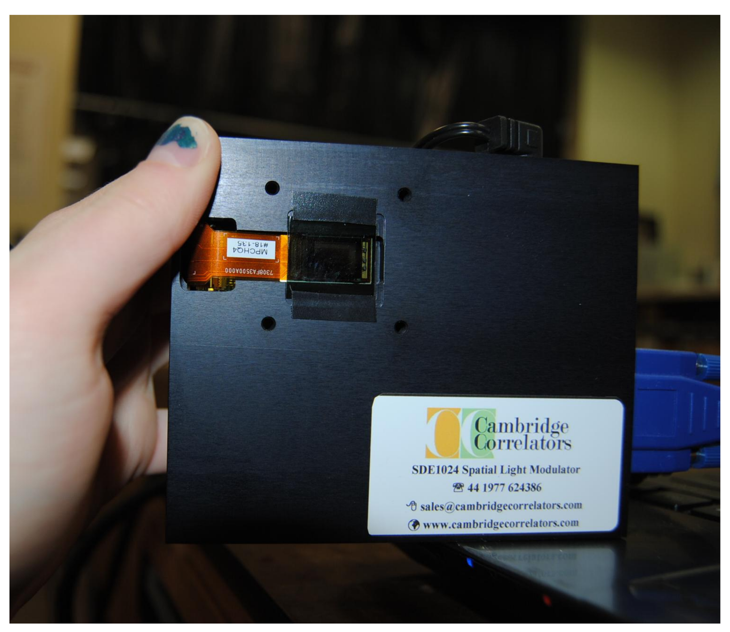
Implementing a Low-Cost Spatial Light Modulator

Rachel Sampson and John Noé
Laser Teaching Center, Department of Physics and Astronomy

Spatial Light Modulator

A spatial light modulator [SLM] is an optical device which can modify the amplitude, phase, and/or polarization of a coherent light beam. SLMs can produce structured beams with "designer" wavefronts, such as optical vortices, and have been applied to many fields of research and technology. Most modern SLMs use liquid crystals as the modulating material and hence are very similar to the LC displays found in many commercial products.

The Laser Teaching Center [LTC] recently purchased two low-cost Cambridge Correlators' SDE1024 SLMs for future use in a variety of optics projects by undergraduate and high school students. For this project, we illuminated the devices with a LM635 Collimated Laser Module from the same company, which emits a 24 mm diameter beam with λ = 635 nm. In the future, we hope to illuminate our SLMs with our argon laser (λ = 488 nm) to increase the obtainable phase range.



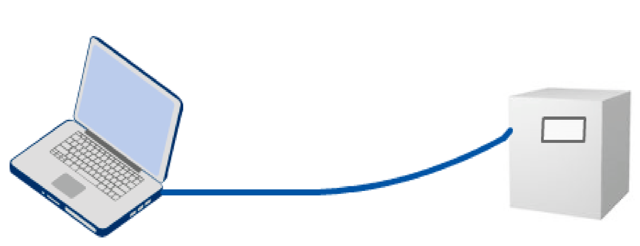
Specifications:

- Twisted Nematic (TN)
- Reflective-Liquid Crystal on Silicon (LCoS)
- Electrically-Addressed
- XGA resolution with 1024x768 9x9 μm pixels
- Bit depth: 8 bits [256 phase shift levels]
- Achievable phase range: 0.8π for red light

Programming the SLM

The display on the SLM was programmed by sending it a video signal from an auxiliary display port on the control computer. The transmitted XGA image was created using Paint or MATLAB, although a variety of graphics programs can be used.

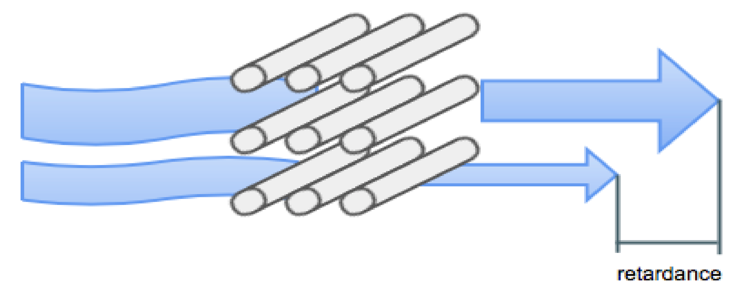
Transmitted black pixels correspond to zero voltage being applied to the liquid crystal cell, while transmitted white pixels correspond to the maximum voltage being applied.



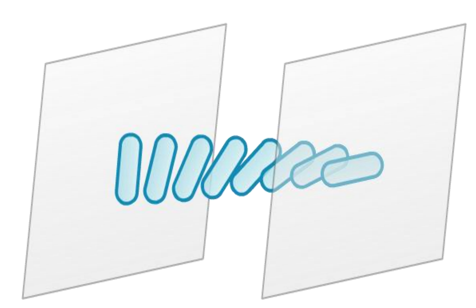
Properties of the SDE1024 SLM

Liquid crystals are rod-like molecules that occupy a state in-between liquids and solids.

They are birefringent meaning different polarizations of light can experience different indices of refraction.

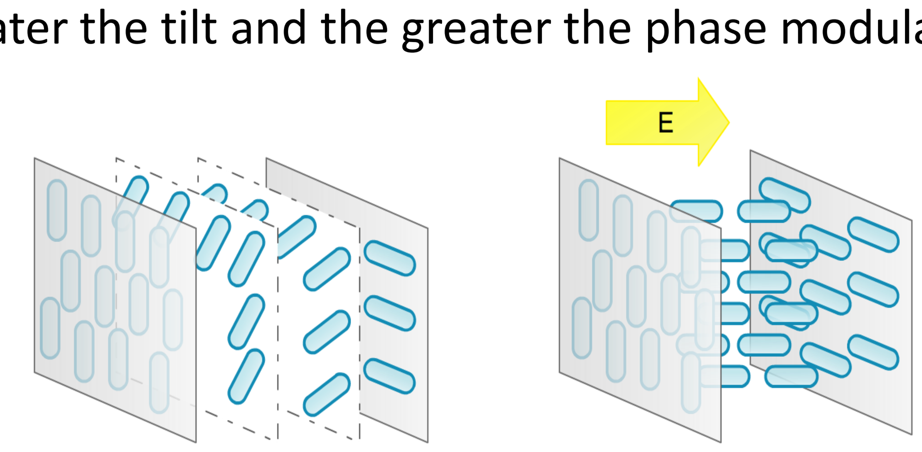


Liquid crystals can exist in a variety of configurations. One such liquid mode is *twisted nematic*. Liquid crystals are twisted nematic when the molecules are twisted into a helix with long axis of the front-most and back-most molecule usually being perpendicular. Because light is scattered along the axes of the molecules, the incident polarization follows the rotation of the helix.



Our SLMs are electrically-addressed. This means that we can modify the properties of liquid crystals pixels by applying a voltage signal to the SLM.

As the electric field is applied, the molecules tilt forward. It is this tilt that modifies the phase of the incident beam. The stronger the electric field, the greater the tilt and the greater the phase modulation



The SDE1024 is a liquid crystal on silicon [LCoS] SLM. LCoS is always reflective. Incident light travels through the liquid crystal cell and reflects off the back silicon wall. When this reflection occurs, the polarization axis of the light will be shifted 180°. In the case of twisted nematic SLM's, this shift will cause the incoming and outgoing polarization of the light to be the same with no voltage applied.

Current Results

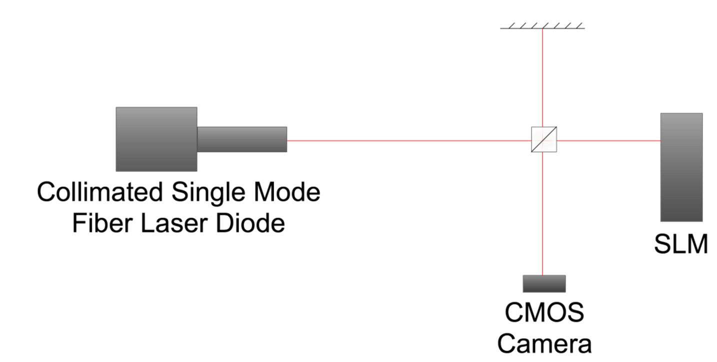
We have gotten the SLMs operational!

Using Paint and MATLAB, we were able to control the display on the SLM. We confirmed that with no voltage applied, the liquid crystals act as a zero phase plate and light enters and exits with the same polarization axis, we also confirmed that when maximum voltage is applied the SLM the polarization of the incident light is changed. We observed this by placing a linear polarizer on the face of the SLM and observing under what conditions light emerged.

We also projected circular and rectangular apertures onto the SLM. While the expected diffraction patterns were present, their quality was not very good and we hope to improve them in the future.

Future Work

This project marks the first step in investigating the properties of the LTC's SLMs In the future, we hope to characterize the phase range of the device using a Michelson interferometer.



We also hope to expand upon the blazing techniques described by Bowman et al to increase the diffraction efficiency of our device.

References and Acknowledgements

[1] Bowman et al "Optimisation of a low-cost SLM for diffraction efficiency and ghost order suppression." Eur. Phys. J. Special Topics 199, 149-158 (2011).

[2] Cambridge Correlators, "SDE1024 Spatial Light Modulator Kit", datasheet.

[3] D. Martin and S. O'Leary, "Spatial Light Modulator (SLM) Workshop," BFY Conference (2012).

[4] P.J. Collings, "Liquid crystals: nature's delicate phase of matter" (2nd ed.). Princeton, N.J.: Princeton University Press (2002).

[5] M. Bonomo, "Cambridge Correlator's low cost spatial light modulator," unpublished report (2013).

[6] M. Bonomo, "An Introduction to Spatial Light Modulators," unpublished report (2013).

We thank Marty Cohen , Jeff Davis (SDSU), and Hui Cao (Yale) for stimulating discussions, Catherine Herne (Colgate) for assistance with the MATLAB programs, and Melia Bonomo for researching and facilitating the purchase of our SLMs and diode laser module