Spatial Light Modulators : liquid cristals

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Objectives

In this study, we calibrate a SLM and study its optical properties before using the device with synthetic holograms.

- Understand polarization shifts.
- Calibrate the phase / grey-level.
- Use a grating to separate diffractions orders.
- Reconstruct an image encoded with Gerchberg-Saxton's algorith.

LCD plates

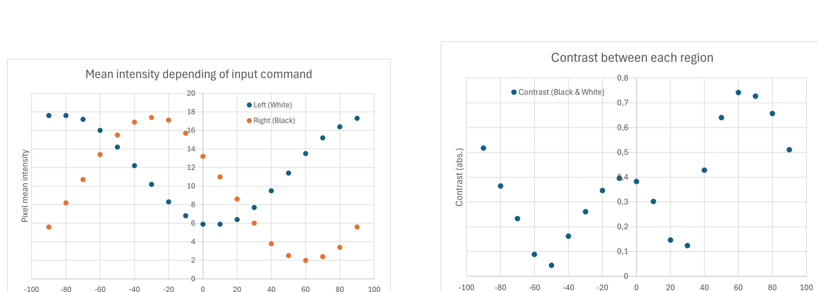
Liquid Cristal Display (LCD) modulate a back-scattering light in order to display a desired pattern onto the screen, resulting in the polarization of the light emitted by the device. While this is a widely used application of liquid cristals, the ability to shape beams are widely used in applied optics.

MEMs vs LCD

If MEMs devices can only modulate light in amplitude, liquid cristals can be configured to modulate both amplitude and phase of a lightbeam. Polarization of light is the characteristic that a liquid crystal modifies.

Amplitude modulation

The first step is to measure the "Twist" angle of the SLM. The effect of the *SLM* on the polarization is a rotation of $R = -90°$, equal to the "Twist" angle. The black command rotates the polarization (by $90°$) and the white command corresponds to zero voltage unaffecting the liquid cristals.



(a) Intensity of each region (b) Contrast between regions

Figure: Intensity and Contrast resulting of a black and white command

The evolution of the intensity, converted into grayscale by the camera, follows a $\cos^2(\theta)$ law. Indeed, Malus' law states that for a polarizer:

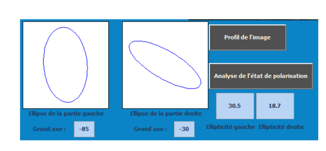
$$\frac{I(\theta)}{I_0} = \cos^2(\theta) \qquad (1)$$

Ellipticity

We have:

$$\varepsilon = \arctan\left(\frac{E_{\min}}{E_{\max}}\right) = \arctan\left(\sqrt{\frac{I_{\min}}{I_{\max}}}\right) \qquad (2)$$

Command	Black	White
Max Intensity	17,4	17,6
Min Intensity	2	5,9
Ellipticity (rad)	0,32687	0,524826
Ellipticity (°)	18,72829	30,07033



(a) Ellipticity (computed) (b) Ellipticity (software)

Figure: Ellipticity measurement

Gray level linearity

The response of the SLM is not linear between the applied and measured gray levels. However, for higher gray levels starting from 140, the response becomes linear.

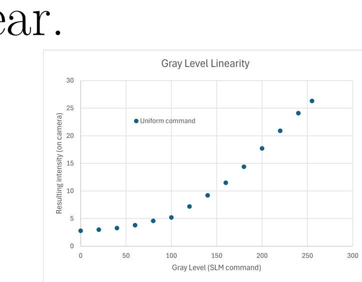


Figure: Linearity of commanded intensity

Separation of diff. orders produced by gratings

Blased mask : If the modulation depth is less than 2π, the measurement of respectively, order 0 an order 1:

$$A_0 = \left|\frac{\sin\left(\frac{\Phi_M}{2}\right)}{\frac{\Phi_M}{2}}\right|^2 \qquad A_1 = \left|\frac{-\sin\left(\frac{\Phi_M}{2}\right)}{\frac{\Phi_M}{2}+\pi}\right|^2 \qquad (3)$$

Rectangular mask : here

$$A_k = \frac{2}{k^2\pi^2}\cdot(1-\cos(\Phi_M)) \qquad A_0 = \frac{1}{2}(1+\cos(\Phi_M)) \qquad (4)$$

For a maximal phase shift of $\Phi_M = 2\pi$, only order 0 is non-zero. Conversely, for a phase shift depth $\Phi_M = \pi$, order 0 is null. Because the SLM modulates the phase approximately between 0 and $\pi/2$ rad the blased grating is more appropriate. Moreover, the rectangular mask would introduce more artifacts, due to its large harmonic constituents here.

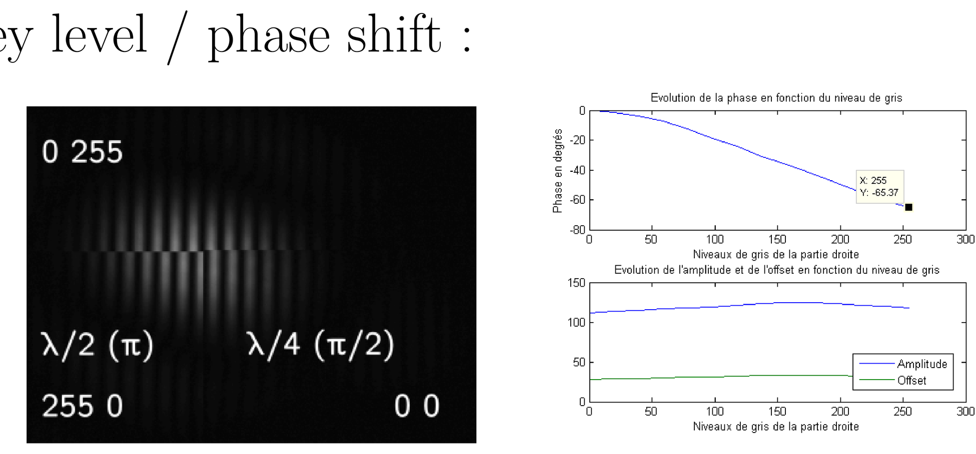
Phase modulation

One can retrieve the pixel pitch with the help of the diffraction formula and the spacing between to bright orders on the detector's plane. We have

$$sin(\theta) = \frac{\lambda}{pp} = \frac{\Delta x}{f'}\Big|_{Fourier\ Plane} \qquad (5)$$

Since we measure $\Delta x = 306$ px, and since the pixel pitch of the camera is 5,2 µm, we compute a pixel pitch equal to 47 µm. The difference with the datasheet is due to the padding of liquid cristals in x and y axis.

Phase calibration : We introduce two holes according to Young's experiment after the SLM, and oberve fringed interferences overlayed onto each diffraction orders. This phase shift respond to the input command and we compute a calibration of the grey level / phase shift :



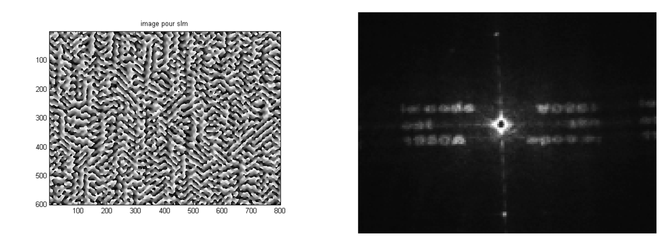
(a) Phase shift with command input (b) Linearity of commanded intensity

Figure: Phase shift with input command and calibration

We observe linearity starting at grey level of 60, and the phase shift only goes from 0 rad to $3\pi/4$ rad approximately. This will produce artifacts in the diffraction produced by the SLM in the case were the input command was computed on the 0 rad to 2π rad range.

Synthetic holograms

The ultimate goal of this study was to reconstruct the image of a picture encoded with Gerchberg-Saxton's algorithm onto a Spatial Light Modulator



(a) Gerchberg-Saxton's encoding (b) Fourier's plane (shifted)

Figure: Reconstruction of a picture (shifted)

Conclusion

We calibrated the SLM interms of phase modulation for a given grey level command, and understood the impact of phasemodulation total range on the influence of artifacts on the final image, and the role of gratingsto separate overlayed duplicated images between diffraction orders

References

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