[SLM02] Light power measurement – amplitude modulator

1.Objectives：

To look for the alignment angle of the spatial light modulator; adjust the angles of the polarizer and the analyzer to convert the spatial light modulator into an amplitude modulator.

2. Introduction：

(1) Electro-Optic Effects

The study of electro-optic effects of liquid crystals is aimed atinvestigatingthe changes of light when it passes through crystals that are subjected to the effect of electric fields. For some crystals, electric fields can change the orientations of their refractive index ellipsoids, and as a result change their refractive indexes. For example, Figure 1 shows the liquid crystal alignment of a homeotropic cell. Before applying the electric field, the refractive index ellipsoid stands vertically. When light is projected from below, the cross-section of the polarization plane and the refractive index ellipsoid is a circle, thus$n_o = n_e$. This means that the liquid crystal will remain as an isotropic medium and will not affect the polarization state, no matter what the direction of the incident light's polarization state is. When an electric field is applied, molecules in the liquid crystal will slowly rotate. Consequently, the cross-section will become an ellipsoid, thus $n_e > n_o$. As the magnitude of the electric field increases, n_e will also become larger and eventually reach its maximum value when the refractive index ellipsoid is at a 90^o angle. When the liquid crystal molecules rotate because of the effect of an electric field, incident light with different polarization angles will have different refractive indexes. Different refractive indexes will in turn produce different optical paths and phase differences. Phase differences can then cause changes in the polarization state of the light. In industrial applications, polarizers and analyzers are often added on the two ends of liquid crystals to turn them into amplitude modulators or phase modulators.

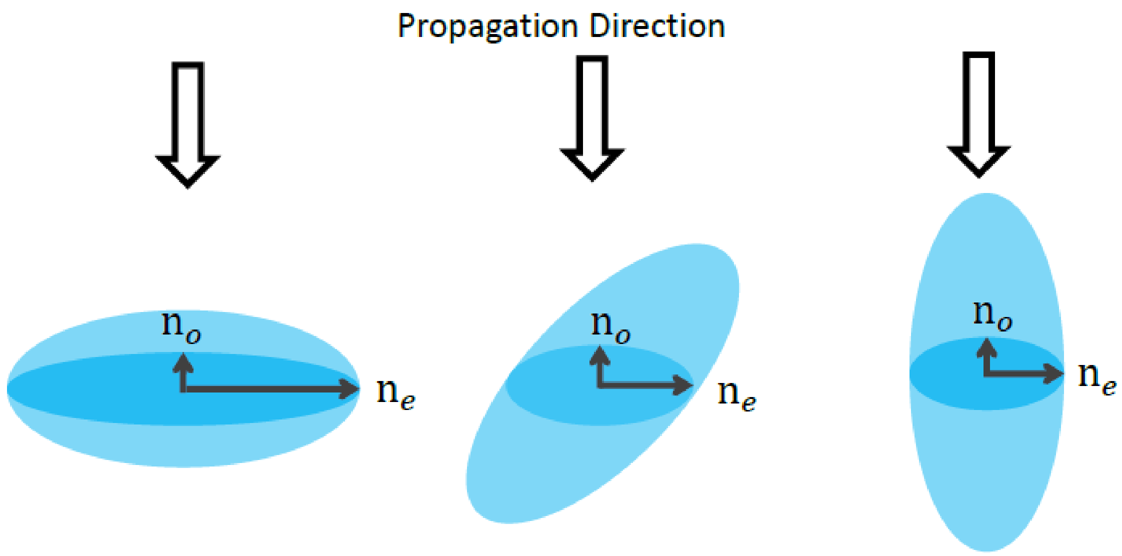

Figure 1 Changes in a Refractive Index Ellipsoid Subjected to the Effect of an Electric Field

(2) Amplitude Modulator

By adjusting the angles of the polarizer and the analyzer, we can convert a spatial light modulator into an amplitude modulator or a phase modulator. From the transmittanceof the spatial light modulator obtained previously, we know that,

$$T = \cos^2 \chi - \sin 2(\beta - \chi)\sin(2\beta)\sin^2 [\frac{\pi}{\lambda} l(n_e - n_o)] \tag{1}$$

wherein l is equal to twice the thickness of the LCoS'liquid crystal layer. When the included angle between the polarizer and the analyzer is 0°, the penetration ratio can be expressed as,

$$T_p = 1 - \sin^2 (2\beta)\sin^2 [\frac{\pi}{\lambda} l(n_e - n_o)] \tag{2}$$

The transmittance will change as the polarizer rotates. When the polarizer and the alignment angle lie in the same direction or perpendicular to each other, i.e. β = 0 or β = 90°, the maximum amplitude transmittance is achieved. These two angles just happen to match the directions of the extraordinary axis and the ordinary axis respectively. The latter one does not change the refractive index by an applied voltage. Therefore, by rotating the polarizer after entering the diffraction pattern, we know when the ratio of the diffraction light to the 0-order reflective light is at its maximum, it is where β = 0; and when the diffraction light disappears, it is where β = 90°. Thus, we can use this feature to find the alignmentangle of the spatial light modulator. After finding the alignment angle of the spatial light modulator, set the angle between the polarizer and the alignment axis at 45°, and the angle between the polarizer and the analyzer at 90°. We then have,

$$T_A = \sin^2 [\frac{\pi}{\lambda} d(n_e - n_o)] \tag{3}$$

The transmittance changes in the form of a sine-squared function and creates different gray level effects. By adding a lens in the back; and calculating the object distance, the image distance, and the magnification power by using the lens maker's formula, we can make a simple projection system.

3. Materials：

Laser、Mirror、Spatial filter、Lens、Beam splitter、Spatial Light Modulator (SLM)、Target、Polarizer、Power meter、Screen.

4. Procedure：

(1) Calibration

1. Setup instruments as shown in Figure 2. Make sure that the light emitted by the laser runs parallel to the surface of the table. Also make sure that the light beam passes through the center of each component and it enters each component perpendicularly.
2. Place the block between the mirror and the beam splitter.
2. Place the cross target in front of the screen.
3. Adjust 2 screws behind SLM until the dark cross is in the center of the rectangle as shown in Figure 3.

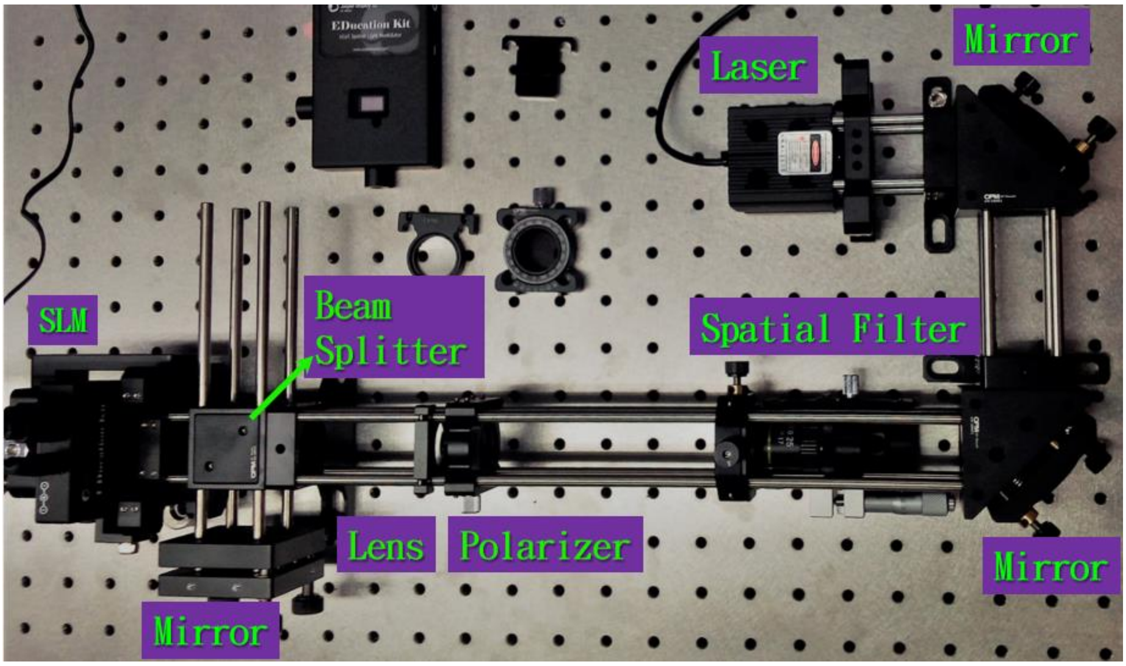

Figure 2

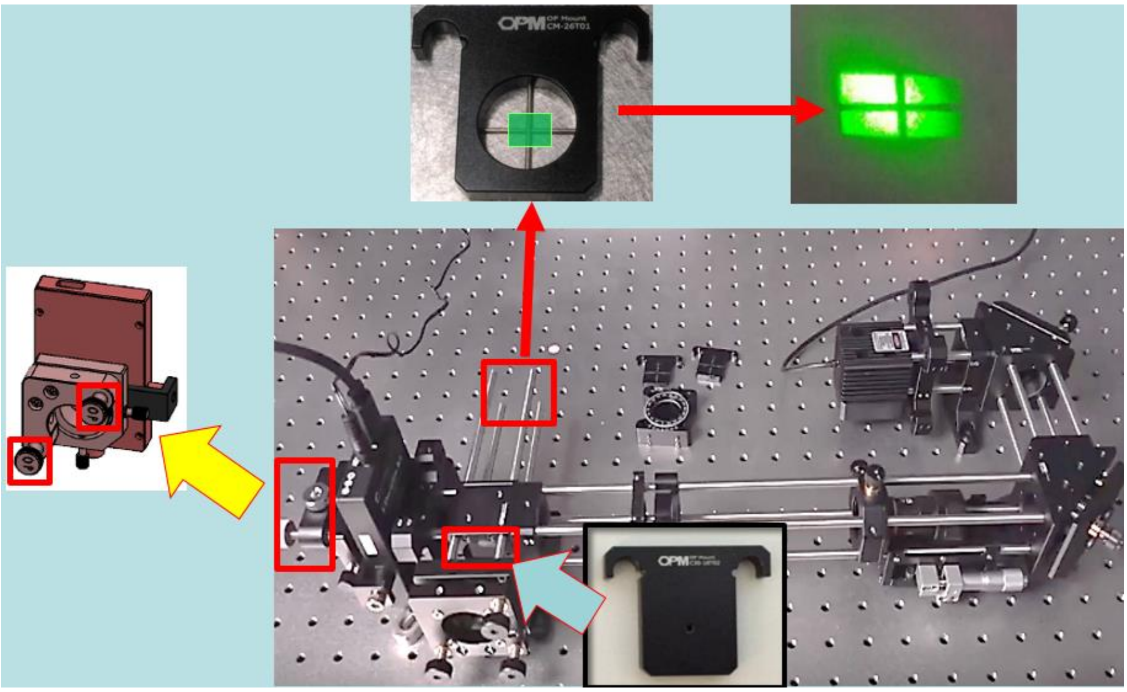

Figure 3

(2) Amplitude modulation

1. Remove the cross target.
2. Open the EDK software. Select 1 for the Monitor Index in the upper right corner. Select experiment to 4. Wavefront modulation. Select the Plane Wave tab, set the Diffraction angle to 0.168 and press the Generate button, you can see the result shown in Figure 4. Then press the Send to LCOS button to transfer the image to the SLM.

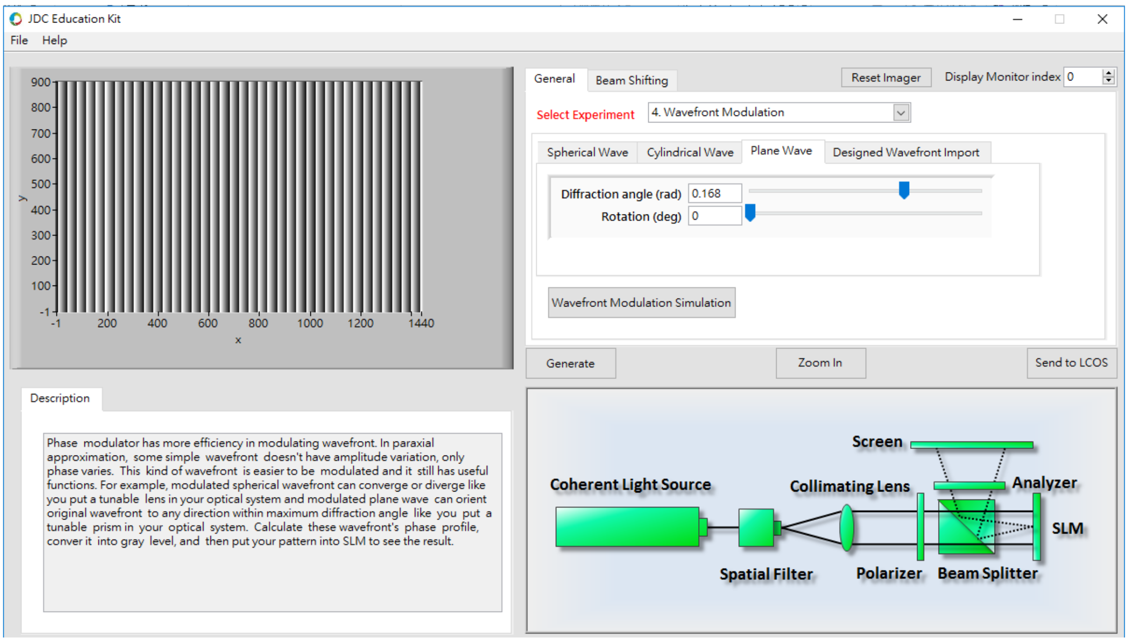

Figure 4

3. Rotate the polarizer until the bright band disappear as shown in Figure 5.
4. Adjust the polarizer to the angle identified in step 3 +45° or -45° and record that angle. (Use the laser's polarization direction to decide whether to use the positive or the negative value in order to achieve better light utilization efficiency.)

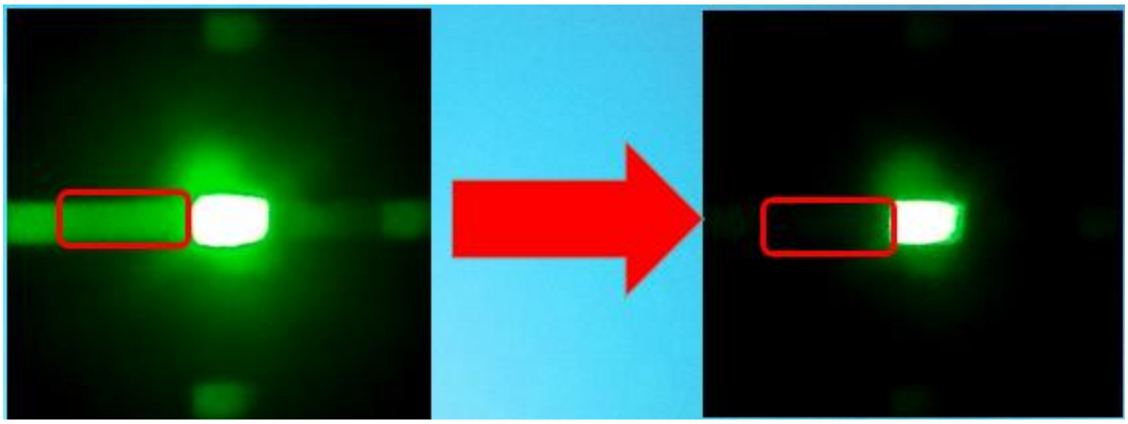

Figure 5

5. Place the block in front of SLM and analyzer in front of screen respectively. Adjust the angle of the analyzer until the light intensity seen on the screen is the lowest. Record the angle of the analyzer.
6. Place the block back to the position between the beam splitter and the mirror. Setup optical power meter and place the lens (focal length F = 12.5 cm) between the analyzer and the optical power meter. Adjust the position of the lens or optical power meter until the beam is in the range of the optical power meter. Fix the optical power meter to the table.
7. Go back to the EDK software and select 2.Amplitude modulation mode. Go to the Grayscale tab. change the grayscale value of the input image and measure the corresponding power value. Record these power values and also record the grayscale value corresponding to the minimum and maximum power.
8. Create the scatter chart of power versus grayscale in Excel.

5. Questions：

(1) When looking for the alignment angle, why is it that we were able to find two angles with the lowest contrast? Which one was the alignment angle? How did we decide?

(2) After successfully projecting the image, what changes can we observe if we rotate both the

polarizer and the analyzer for an additional 90°? Why?

(3) Following question 2, if we only rotate the analyzer for an additional 90°, then repeat step 7 in the experiment and observe the changes, what differences can we observe? Why?

6. Cautions：

(1) When adjusting the optical path, you should not sit down, and the light path must be parallel to the surface of desktop. If the laser accidentally enters the eye, it may cause blindness. When adjusting the optical path, all personnel must stand. When the optical path is adjusted and there is no need to adjust again, sit down and record the experiment, but try not to sit directly opposite the spatial light modulator.

(2) The optical power meter is a high-priced precision instrument. The laser cannot be over-focused onto the optical power meter without passing through the optical component. This may cause the optical energy per unit area to be too high, thus causing the optical power meter to burn out. In the experiment, it is only necessary to confirm whether the output image has completely entered the range of the screen of the optical power meter.

(3) The optical components used in the experiment are almost all high-priced devices. Please use them with care. Remember not to touch the mirror surface of the optical components with your bare hands. If there is any dirt, please inform the teacher or the teaching assistant. Do not wipe optical components by yourself.