OPTICS AND LASER PHYSICS LABORATORY #3

CIRCULAR & ELLIPTICAL POLARIZATION OF LIGHT

Polarization via Birefringence

There is an asymmetry in index of refraction that exists in some materials, called birefringence. Birefringent materials are able to produce two different refracted beams of opposite linear polarization due to the existence of two different polarization dependent indices of refraction in these materials. While dichroism depended on the absorption of light to be asymmetrically dependent on polarization, these birefringent materials have low absorption in the visible range but still exhibit asymmetric crystalline structure and thus asymmetric electron-binding forces that manifest themselves in asymmetric indices of refraction. A well-known naturally-occurring example of a birefringent material is calcite, $CaCO_3$, which has a tetrahedral structure. There is usually one direction along which light will experience no asymmetry (for uniaxial birefringent crystal) and this is called the optic axis. Unpolarized light incident upon a birefringent crystal in a direction other than along the optic axis will find that each component of the E-field will encounter different indices and thus will travel with different speeds through the crystal and exit the crystal at slightly different spots. Thus, one could isolate a particular polarization by careful positioning of the incident unpolarized beam with respect to the optic axis.

Another interesting application of birefringence is the ability to produce circularly or elliptically polarized light. It is possible to cut birefringent materials in such a way as to have the direction of one index of refraction at a right angle to the direction of the other index. In this case the minimum index direction is designated the fast axis (as light will travel more quickly along this axis) and the direction of the maximum index of refraction is the slow axis. Thus light polarized linearly at 45^{o} to the axes and incident on this carefully cut sample will find that half the E-field will have a component along each birefringent axis. Half of the E-field will speed up as it traverses the sample and half will slow down. The resultant beam exiting the birefringent material will have E-field components of equal amplitude but different phase, i.e. be elliptically polarized. If one were to cut the birefringent material to be some integer number of 1/4 wavelengths thick, the exiting light would be circular as the two E-field components would be out of phase by $\pi/2$. Alternatively, if one were to introduce linearly polarized light at an angle other than 45^{o} to the axes, the transmitted beam would also be elliptically polarized. Remember, the thickness of the 1/4 waveplate must be such that the path difference between the E-field components is 1/4 wavelength.

$$d = \frac{\lambda_o}{4(n_1 \pm n_2)} \qquad \text{Eq. 3}$$

If the thickness of the plate is exactly 1/4 (λ) then it is known as a zero-order quarter-wave plate. If the thickness is an integral number of quarter waves, then it is known as a multiple-order plate.

1) View a portion of this lab write-up through a calcite crystal using the unpolarized room light reflected from the page surface. What do you see?

2) Next, produce a linearly polarized output using a dichroic sheet, bring a quarter-wave plate into the beam and observe the output. What is its polarization? Record powers of transmitted beam through dichroic sheets?

3) Consider a half-wave plate [$d(n_1 - n_2) = \lambda/2$] and how it should effect a linearly polarized beam. Draw a diagram of the shift in E-field orientation/phase. Predict its behavior and then verify it with the HeNe and polarizers.

Mystery Polarizers

There are two "mystery polarizers in the lab. Each one is made up of 2 polarizing elements laminated together. One of the elements is a linear polarizer and the other is for you to determine. The only tools you will need are the room lights, your eyes, and one or two dichroic sheets. Try all possible orientations of the two sheets. This includes rotations, order, and inversions. Record the polarization and the relative power of the light both between and after the two mystery polarizers for all orientations and relative orders of polarization elements. From these observations, answer the following question.

1) Given this experimental data, what is the mystery element in the mystery polarizers ? How is it aligned with respect to the linear polarizer?