OPTICS 380A
Lab 7: Waveplates and Stokes Vectors

Part A: Half-Wave Plate (HWP) and Quarter-Wave Plate (QWP)

Use two linear polarizers (one as a polarizer, the other as an analyzer), a detector and a white light source (LED lamp) for the following:

(A) Investigate the behavior of a half-wave plate. Orient the fast-axis of the half-wave plate at 45° with respect to the transmission axis of the first polarizer. Use the second polarizer as an analyzer. Looking back at the white light source, rotate the analyzer through 360° and describe what you see. What is the state of polarization of the light after passing through the half-wave plate? Next, set the fast axis of the half-wave plate aligned with the transmission axis of the polarizer. Determine the state of polarization and orientation of the transmitted light as the half-wave plate is rotated. What is the relationship between the input polarization, output polarization, and angle of the half-wave plate fast axis?

(B) Investigate the behavior of a quarter-wave plate. Orient the fast-axis of the quarter-wave plate at 45° with respect to the transmission axis of the first polarizer. Use the second polarizer as an analyzer. Looking back at the white light source, rotate the analyzer through 360° and describe what you see. What is the state of polarization of the light after passing through the quarter-wave plate oriented at this angle?

(C) Describe and carry out a simple experiment to determine which of the unknown wave plates the quarter-wave plate is, and which is the half-wave plate? Identify both the fast and slow axes of each of the wave plates. (Note that the axes can't be determined uniquely with this simple equipment.)

Part B: Optical Isolator

(D) Describe what an optical isolator is supposed to do.

(E) Describe a procedure to build one, using the quarter-wave plate, a linearly polarized laser beam, a polarizing beam splitter (PBS) and a flat mirror.

(F) Build the isolator, demonstrating that it works. Check the amount of reflected light passing back through the PBS by slightly tilting the mirror. Make a drawing showing the state of polarization at each point in the optical chain. Can you know whether or not the beam is RHC or LHC polarized? Does is matter?

(G) Measure the degree of isolation (the ratio of incident light, P_{inc} to the amount of light returned into the laser, P_{ret}) in decibels, dB as a function of angle of the fast axis of the quarter-wave plate. Use the photo detector, and make sure to subtract off any dark reading (for greatest accuracy).

$$Isolation[dB] = 10\log_{10}\left(\frac{P_{inc}}{P_{ret}}\right) = 10\log_{10}\left(\frac{V_{inc}}{V_{ret}}\right)$$

(H) Observe the red plastic material by placing it on the metallic portion of your optical table and determining the amount of reflected light. Turn the material over and repeat the observation.

(I) If it is known that the red plastic material is a combination of a quarter-wave plate and a linear polarizer, explain your observations in (H).

Part C: Stokes Vectors

In this part of Lab 7, you will take an unpolarized source (approximately collimated light from the LED you used in Lab 1), reflect it off a prism and measure the Stokes polarization vector of the reflected light. Remember that the Stokes vector contains the following components:

S0 is proportional to the amount of light in the beam being measured.
S1 is proportional to the tendency of the light to be linearly horizontally (+) or vertically (-) polarized.
S2 is proportional to the tendency of the light to be linearly +45° (+) or -45° (-) polarized.
S3 is proportional to the tendency of the light to be RHC (+) or LHC (-).

In order to measure the Stokes vector of a light beam, we can use a rotatable linear polarizer and a polarizer that is opaque to LHC. We also need a detector to measure the transmitted beam. You will take four measurements for each of three orientations of the beam. The output is measured on an oscilloscope as an AC signal from the modulated LED. The modulation frequency is about 1kHz. You will measure the peak-to-peak voltage of the scope signal, which is proportional to the power transmitted through the components.

The four measurements that you will make are the following:

V0: Measure power in the light beam before it strikes the prism.
V1: Measure power in the beam after transmitted through the polarizer oriented with a horizontal transmission axis. (The correct angle settings for the polarizer are in the lab.)
V2: Measure power in the beam after transmitting through the polarizer oriented with a +45° transmission axis.
V3: Measure power in the beam after transmitting through the circular polarizer.

The Stokes parameters are calculated from:

S0 = V0
S1 = $2*C_{lin}*V1 - V0$
S2 = $2*C_{lin}*V2 - V0$
S3 = $2*C_{circ}*V3 - V0$,

where C_{lin} and C_{circ} are calibration factors due to the fact that we are using imperfect polarizers. These factors are available in the lab.

The degree of polarization is given by

$$V_d = \frac{\sqrt{S1^2 + S2^2 + S3^2}}{S0} \quad .$$

(J) Measure the Stokes vector and determine the degree of polarization Vd for the collimated LED before it strikes the prism.

(K) Measure the Stokes vector and determine the degree of polarization Vd for the collimated LED after it reflects from the prism at a 30° angle of incidence.

(L) Measure the Stokes vector and determine the degree of polarization Vd for the collimated LED after it reflects from the prism at a Brewster's angle. (An extra 2.5 points will be added to the final percentage of the lab group members who obtain the highest Vd in this experiment.)

(M) Describe the state of polarization of (J) through (L), based on interpretation of the Stokes vector for each measurement.