

LAB 8 – POLARIZERS AND WAVEPLATES FALL 2016

Objective This is the first lab on polarization. We will introduce how to measure and change the polarization state of light using polarizers and wave plates.

PRELAB

You are given a laser of unknown linear polarization, a glass microscope slide (index ~ 1.46), and a mount that can rotate the glass slide about one axis. Utilizing only these components, design an experiment to determine the polarization of the laser. (*Hint: Re-read the book or notes on the Brewster's angle.*) You may assume that the laser is linearly polarized either in the plane of the optical table or normal to it.

(4 Points)

PART I POLARIZATION

Discussion If a laser is linearly polarized, its polarization state can be determined using reflective properties of dielectric interfaces.

Experiment Set the laser at the far end of the table, and level the beam to the table. Using the microscope slide and the procedure you designed in the prelab, determine the polarization of the laser and also determine the index of refraction of the glass slide. *Hint: You may need to estimate some angles.*

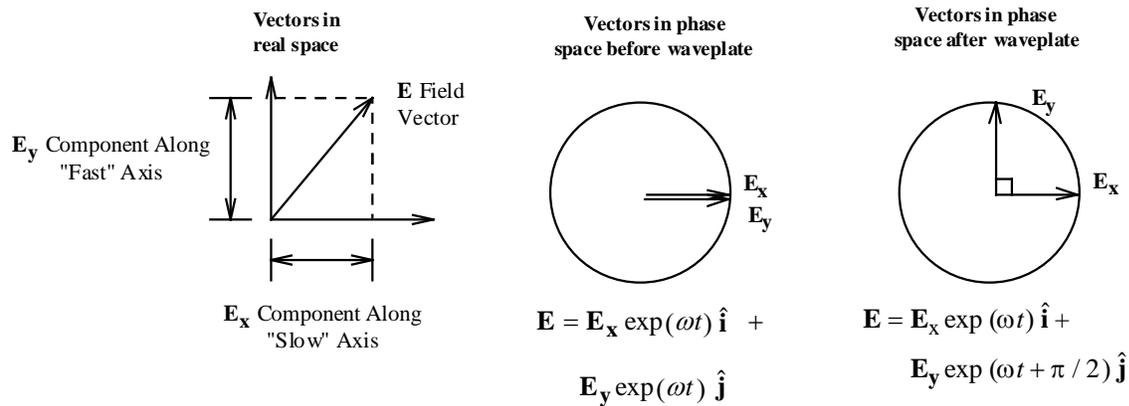
(3 points)

After you have determined the polarization-state of the laser, verify it using a linear polarizer. Measure the extinction ratio of the polarizer (i.e. the ratio of the maximum light to the minimum light) using the power meter (or detector plus ammeter). If you are confused on how to do this, see the TA. The polarizer's axis is marked on the back-side of the device.

(3 points)

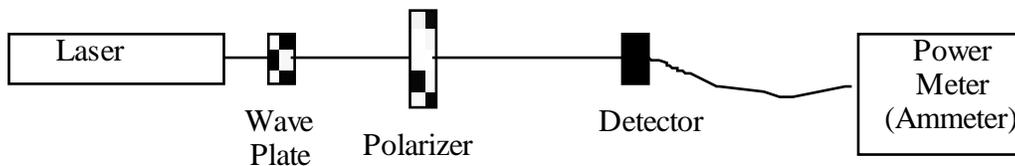
PART II $\lambda/4$ WAVE PLATE

Discussion Quarter wave plates work by delaying the phase of the polarization component along the slow axis E_x by $\pi/2$ relative to the component along the fast axis E_y . The resultant vector addition of the two components can yield circularly polarized light. In order for the wave plates to produce circularly polarized light, the axes of the wave plate must be positioned at exactly $\pi/4$ radians (45°) relative to the direction of polarization. A diagram of how the wave plate works is shown below. We are assuming that we start with linearly polarized HeNe light.



Experiment

- 1) Set up the figure below. Do not place the wave plate in the holder yet. The polarization components should be in graduated rotation mounts.



- 2) Set the polarizer so that a minimum amount of light is detected.
- 3) Set the $\lambda/4$ wave plate in the holder and rotate it until the light is again a minimum. At this point the polarization of the laser is along one of the axes. Note the orientation of the wave plate in the holder. (The fast axis is marked on the waveplate, and this does not necessarily correspond to the zero-degree mark on the mount.)
- 4) Noting where the wave plate is on the marked scale, rotate the wave plate 45° .
- 5) Record the initial reading of the polarizer and then rotate the polarizer in roughly 10° increments for 180° recording the output intensity. Plot your results in polar plot format. **(4 points)**
- 6) Insert a second $\lambda/4$ wave plate between the first plate and the polarizer. Now rotate it until you obtain minimal transmission. (Call this Position I.) At this point you have “undone” the 90° phase shift. Another rotation of 90° to the second wave plate results in a 180° phase shift and maximum transmission. (Position II.)
- 7) Testing polarization upon reflection Remove the second wave plate and place a mirror in its place. Set the mirror at a slight angle, roughly 10° . Move the polarizer to the beam reflected from the mirror and insert the second wave plate between the mirror and the polarizer. Rotate the second wave plate to Position I and Position II from Step 6 and from these measurements, determine the state of polarization of circularly polarized light upon reflection. Be sure to use the detector head

as needed. Repeat for a microscope slide. Is there any difference between the reflected polarization from the microscope slide and the mirror?

(4 points)

8) Go on to Part III.

PART III OPTICAL ISOLATORS

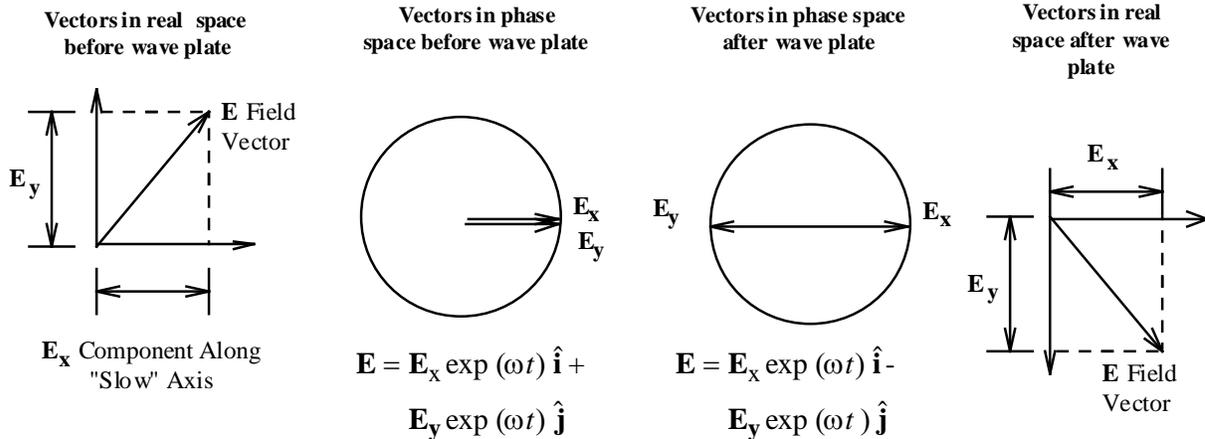
Discussion A polarizer and a $\lambda/4$ plate can be used to construct an isolator.

Experiment Design and build an optical isolator using a mirror as a retro-reflector. Optimize the isolator for output (throughput) power. Measure this power. Now, using a retro-reflecting mirror at the output, send the HeNe beam back through the isolator. Measure the power that successfully goes back through the isolator. Commercial isolators usually have the following spec provided: 10 times the log of the ratio of the back power to the forward power. Determine this value for your setup.

(4 points)

PART IV $\lambda/2$ WAVE PLATE

Discussion Half wave plates work by delaying the phase of the polarization component along the slow axis E_x by π relative to the component along the fast axis E_y . The result is that one component "changes signs". The vector addition of the two components yields linearly polarized light, and when the laser polarization is halfway between the two axes, the output light is rotated by 90° . A diagram of how the wave plate works is shown below.



Experiment

- 1) Use the same setup as for the $\lambda/4$ plate.
- 2) Set the polarizer (without the $\lambda/2$ wave plate in the holder) so that a minimum amount of light is detected.
- 3) Set the $\lambda/2$ wave plate in the holder and rotate it until the light is again a minimum.

- 4) Rotate the $\lambda/2$ plate in 5° increments up to 90° and simultaneously, using the polarizer, determine the output state of polarization by measuring the angle of minimum transmission using a linear polarizer. Plot the angle of the $\lambda/2$ plate vs. the angle of the output polarization. **(4 points)**
- 5) Go on to Part V and test the wavelength dependence.

PART V WAVELENGTH DEPENDENCE

Discussion The ability to produce exactly $\pi/2$ or a π phase shift is dependent on the material and the wavelength of operation. A $\lambda/2$ plate at one wavelength will not produce a π phase shift at another. *Note: The tunable HeNe may not be available for this part. We will identify which laser you should use if an alternative is present.*

Experiment

Repeat Part IV through procedure 4 using the yellow or green line from the HeNe.

(4 points)

QUESTIONS FOR WRITE-UP

- 1) Describe how you determined the state of polarization of the laser and estimate the accuracy of the measurement of the index of refraction of the glass slide. **(3 points)**
- 2) Using the data and the plots from Part II, determine the state of polarization after passing through the $\lambda/4$ waveplate. If it is not circular, explain any error that might have produced this result. **(3 points)**
- 3) Using the plot from Part IV, determine the angle of the output polarization state as a function of the angle the $\lambda/2$ plate is rotated. Explain. **(3 points)**
- 4) Using the plot of the detector vs. angle in Part V, determine the state of polarization of the HeNe yellow (or green) line after transmission through the $\lambda/2$ waveplate. **(3 points)**