Student Name ______________________________ Date ________________

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Department of Electrical Engineering and Computer Science

6.237 Modern Optics Project Laboratory

Laboratory Exercise No. 2 **Fall 2024**

Polarization States of Optical Waves, Dielectric Reflection

To get the most out of your in-lab experience, you must come to Lab prepared (makes life easier for you and the TA and minimizes your time in the Lab). Thus, you should go through this Lab manual, complete the Pre-Lab Exercises, and answer all the Pre-Lab questions BEFORE entering the Laboratory. In your lab notebook record data, explain phenomena you observe, and answer the questions asked. Remember to answer all questions in your lab notebook in a neat and orderly fashion. No data are to be taken on these laboratory sheets. Tables provided herein are simply examples of how to record data into your laboratory notebooks. Expect the in-lab portion of this exercise to take about 3 hours. **The report for this Lab will be done as an oral presentation.**

PRE-LAB EXERCISES

PL2.1 – – Get Prepared to Start the Laboratory Exercises

Read the **entire** laboratory handout, and be prepared to answer questions before, during and after the lab session. Determine all the equations and constants that may be needed in order to perform all the laboratory exercises. **Write** them all down in your laboratory notebook before entering the Lab. This will ensure that you take all necessary data while in the Lab in order to complete the lab write-up. This preparatory work will also count toward your Lab Exercise grade.

Pre-Lab Question

Explain using electric dipole arguments and with the aid of diagrams why the light reflected from the floor wax is predominantly polarized perpendicular to the plane of incidence.

IN-LAB EXERCISES

2.1 Linear Polarizer

As was discussed in lecture, light reflected off the waxed floor tiles is predominantly polarized perpendicular to the plane of incidence. Holding the given sheet of linear polarizer close to your eye, use such reflections to determine the axis of the polarizer. Convince the T.A. that you have identified the polarizer axis.

T.A. or L.A. Signature

2.2 Two-Polarizer Diagnostic System

The setup you are given consists of a randomly polarized (unpolarized) laser beam of intensity I_0, a pair of polarizers, and a screen arranged as illustrated in Figure 1. The second polarizer is often called an analyzer. Its axis is generally oriented perpendicular (crossed) or parallel to the axis of the first polarizer.

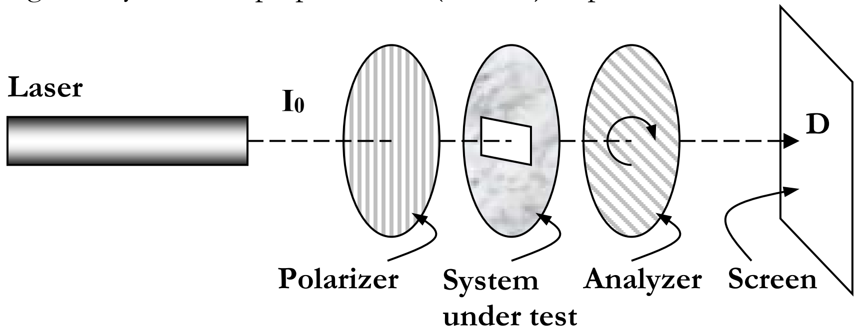

Figure 1 – Diagnostic two-polarizer system

In-Lab Assignment

With the first and second polarizers crossed in the above system, place a third sheet of linear polarizer in the system between the two stationary crossed sheets and observe the intensity of the transmitted light on the screen as you rotate the third polarizer. Make sure to record the orientation of every element in the diagnostic system in your lab notebook.

Now place a photodetector at D and record below the intensity on the screen as a function of the angle of rotation of the third polarizer. About 10 points between (and including) two adjacent intensity maxima should be sufficient. Record this chart into your lab notebook.

Angle	Relative Intensity

Post-lab Questions

(a) Explain why the intensity on the screen changes as the central polarizer is rotated?

(b) Derive the form of the theoretically expected intensity at the detector and compare it with your measurement (you may use Jones matrices for this or use basic trigonometry). Explain the discrepancy, if any.

2.3 Quarter and Half Wave Plates

In-Lab Assignment

(a) You are given one quarter-wave plate and one half-wave plate (labeled A and B) but it is not known which plate is which. Use the system in Figure 1 to: (i) find the axes of the quarter-wave plate, (ii) find the axes of the half-wave plate, and (iii) distinguish one plate from the other. Convince the T.A. that you have indeed found the axes and distinguished the two wave plates.

	T.A. or L.A. Signature

Describe the experiments you performed on the two wave plates. Tabulate the results and explain how you arrived at your conclusions. Make sure to record the orientation of every element in the diagnostic system in your lab notebooks.

Post-lab Questions

A half-wave plate can be used to convert vertically polarized light into horizontally polarized light, and vice versa. Another useful application of a half-wave plate is as a linear polarization rotator. Indeed, if linear polarized light is incident at normal incidence on a half-wave plate and the plate is rotated through an angle θ about an axis parallel with the propagation direction, the polarization of the transmitted beam is rotated by 2θ.

(a) In your lab notebook, draw diagrams and explain how a half-wave plate converts vertically polarized light to horizontally polarized light,

(b) In your lab notebook, draw diagrams and explain how and why a half-wave plate achieves polarization rotation.

Note: We are not looking for detailed calculations, but instead a detailed written description using diagrams as visual aids.

2.4 Magic Sheet

In-Lab Assignment

You are given a sheet of "magic" material, which transmits light when folded in one direction, but blocks light when folded in the other direction. Observe this for yourself. Using only linear polarizers, devise nondestructive experiments to determine the possible optical elements that constitute the "magic" material. Record your data in tabular form in your lab notebook and explain with the help of diagrams why light is blocked or passed in each experiment you perform. Show clearly how you arrive at your conclusion about the magic material.

2.5 Dielectric Reflection and the Brewster Angle

In-Lab Assignment

The Brewster angle is defined as the angle of incidence for which the reflected light intensity from a dielectric boundary goes to zero for TM polarization. This effect can be demonstrated by the experiment shown schematically below in Fig. 2.

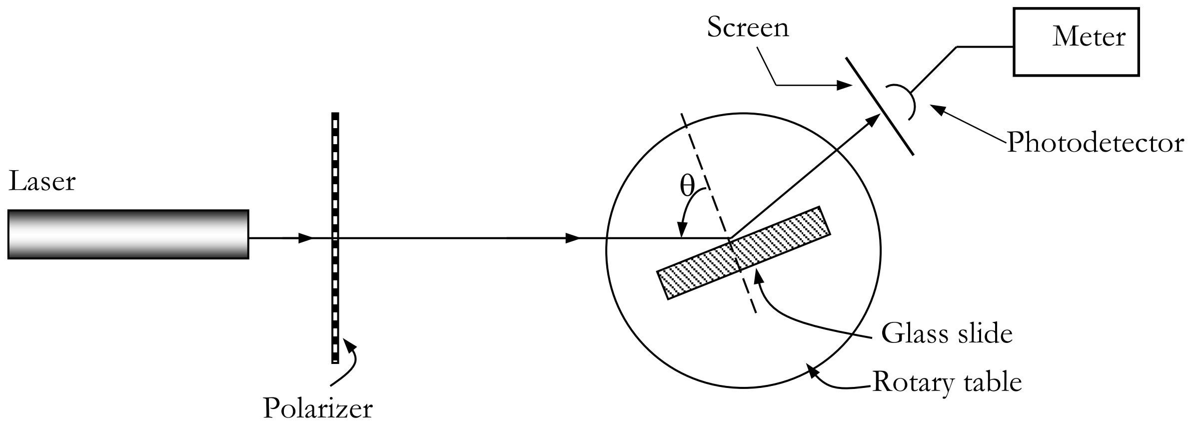

Figure 2. - Experimental setup to demonstrate Brewster's angle.

Use a randomly polarized laser beam for this experiment. Align the glass slide so that its axis of rotation is perpendicular to the laser beam. This can be accomplished by adjusting the laser or the glass slide so that at normal incidence, the reflected beam goes back close to or into the laser cavity.

(a) Where is the plane of incidence in your experiment?

(b) With the linear polarizer aligned with its axis horizontal, and the laser beam centered on the axis of rotation of the glass slide, rotate the glass slide and **observe the intensity of the reflected beam on the screen.** Rotate the polarizer sheet by 90^0 and repeat the experiment. Copy the table below into your lab notebook. Record your observations of the **reflected beam** for each of the two polarization cases in your lab notebook.

	Horizontal Polarization		**Vertical Polarization**	
Polarization in plane of incidence	☐ Yes	☐ No	☐ Yes	☐ No
Does reflected beam intensity ever vanish?	☐ Yes	☐ No	☐ Yes	☐ No
If yes, corresponding angle of incidence	____________		____________	

(c) Now, use the photodetector to measure the reflectivity of the glass slide as a function of the angle of incidence for both polarizations. About every 5° is good enough (the most accurate measurements are obtained if measurements for both polarizations are made before the angle of incidence is changed). Record the raw data in your lab notebook in a similar fashion to the table shown below. Plot your data using a software package of your choice and paste it into your lab notebook.

TM Polarization

Angle of Incidence	Relative Intensity

TE Polarization

Angle of Incidence	Relative Intensity

<u>Post Lab Questions</u>

(a) Compute the index of refraction of the glass slide from your measurement of the angle at which the reflected beam vanishes. The wavelength of the He-Ne laser is 633 nm. Comment on the accuracy of this method of measuring refractive index.

(c) Using the refractive index calculated in part (a), compute the expected reflectivity for the glass slide and compare your computed results with your experimental results. Plot the measured and computed reflectivity for TM polarization on one graph and for TE polarization on another. Make sure to identify the points where you took data.

2.6 Total Internal Reflection System

You are given a 45°-right-angle glass prism on a rotary table and a HeNe laser set up in the arrangement shown in the Figure 3. Illuminate one of the small faces with the laser beam at normal incidence (reflection off this surface goes back into the laser cavity) and observe the phenomenon of total internal reflection.

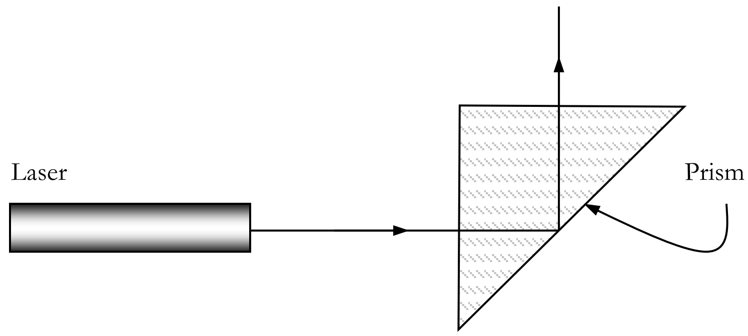

Figure 3 – Setup for observing total internal reflection using 45° - right angle prism.

Pre-Lab Questions

(a) Make a sketch of Figure 3 and indicate which direction you would have to rotate the prism to get light transmitted through the hypotenuse.

(b) Derive an expression relating the index of refraction and the rotation angle at which you should first observe light transmitted through the hypotenuse.

In-Lab Assignment

(a) Sketch the actual system used for this experiment.

Illuminate one of the small faces with the laser beam at normal incidence (reflection off this surface goes back into the laser cavity) and observe the phenomenon of total internal reflection. Slowly rotate the prism until the transmitted beam just grazes the hypotenuse of the prism.

(b) Measure the angle of rotation and use it to calculate the refractive index of the glass block. You should have come up with an equation to do this in the pre-lab exercises. Use your derived equation, while in the Lab to perform a reality check on the index of refraction.

"Two brothers bought a cattle ranch and named it "Focus." When their father asked why they chose that name, they replied: "It's the place where the sons raise meat."

-- Prof. W. B. Pietenpol, Physics Department, University of Colorado, Boulder, Colorado

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