

## Lab 4 -- S, P Reflection from a Boundary

### I. Objective

Experimentally study reflection/ transmission of polarized light from a glass plate. Experimental determination of Brewster's Angle.

### II. Introduction

The magnitude and phase of an electromagnetic wave reflected from a boundary depends on the angle of incidence and refractive indices (ie. Snell's law). In addition, the polarization of the incident wave determines the magnitude of the reflected and refracted wave. By applying Maxwell's equations and boundary conditions to the electromagnetic waves at the boundary, one obtains (See Figure 1 for Geometry):

Figure 1

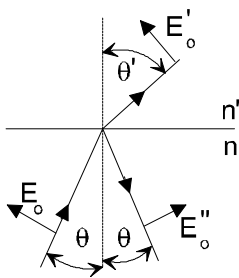
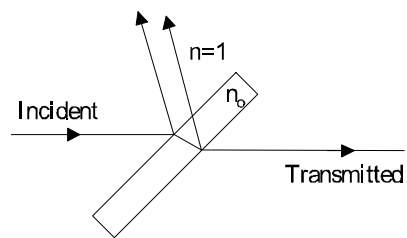


Figure 2



E perpendicular to Plane of Incidence (s polarization):

$$\frac{E_0'}{E_0} = \frac{2n \cos q}{n \cos q + n' \cos q'} \quad (1)$$

$$\frac{E_0''}{E_0} = \frac{n \cos q - n' \cos q'}{n \cos q + n' \cos q'} \quad (2)$$

E parallel to Plane of Incidence (p polarization):

$$\frac{E_0'}{E_0} = \frac{2n \cos q}{n \cos q' + n' \cos q} \quad (3)$$

$$\frac{E_0''}{E_0} = \frac{n' \cos q - n \cos q'}{n \cos q' + n' \cos q} \quad (4)$$

Where  $E_0$  is the incident wave amplitude,  $E_0'$  is the transmitted wave amplitude,  $E_0''$  is the reflected wave amplitude

Following the geometry of Figure 2 for transmission and reflection of a nonabsorbing dielectric plate of index  $n$ , the transmission coefficients through the plate (multiple reflections ignored) are

$$T_{\perp} = \left[ \frac{4n_0 \cos q \cos q'}{(\cos q + n_0 \cos q')^2} \right]^2 \quad (5)$$

$$T_{\parallel} = \left[ \frac{4n_0 \cos q \cos q'}{(\cos q' + n_0 \cos q)^2} \right]^2 \quad (6)$$

With  $\sin q = n_0 \sin q'$

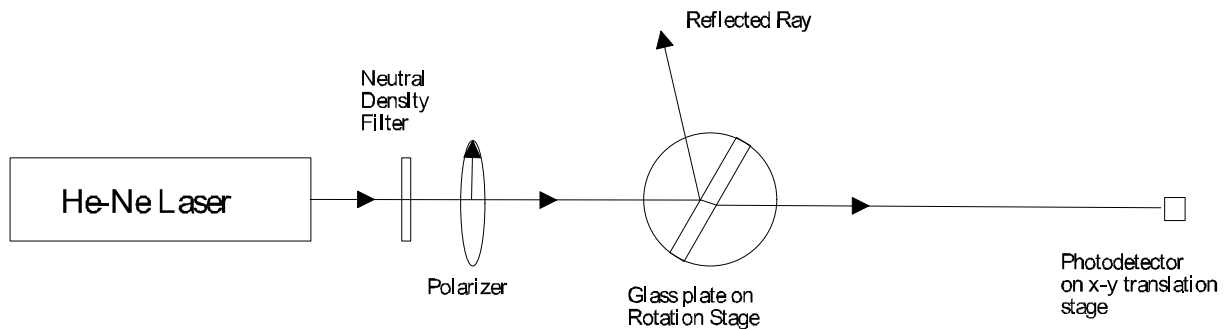
### III. Procedure

Following the schematic in Figure 3, your goal is to measure the transmission of s and p polarized light through the glass plate. The polarizer should be mounted in a rotation stage (vertical). The glass plate should be mounted in a horizontal rotation stage. Mount the photodiode in a x-y translation stage. Use a mechanical chopper and lock-in amplifier to measure the voltage on the photodiode.

a. Orient the polarizer so that only p polarized light (polarization parallel to tabletop) is incident on the waveplate. Using the light reflected by the waveplate, determine the reading on the horizontal rotation stage which corresponds to normal incidence (0 degrees). Slowly rotate the horizontal stage until you observe a distinct minimum in the REFLECTED light. Use an index card to observe the reflected light. Record the angle of incidence. This is Brewster's angle.

b. Using the photodiode, measure the transmission through the plate as a function of the angle of incidence. (Make sure detector is linear and that the light is optimized on the photodiode before each measurement!) While increments of 10 degrees from 0 to 90 degrees should be sufficient, use smaller increments when the angle of incidence is close to Brewster's angle.

Figure 3



c. Rotate the polarizer 90 degrees such that s polarized light is used. Repeat step (b) for s polarized light.

d. Remove the waveplate and measure the intensity of the incident light using the photodiode.

#### **IV. Discussion**

- a. Plot on the same graph the theoretical and experimentally measured s polarization transmission as a function of the angle of incidence. For the theory, use the index of refraction of 1.56. Repeat for the p polarization.
- b. From your plots of IV.a, explain any discrepancies between theory and experiment. In your discussion, you might think about the assumption that multiple reflections can be ignored. Is this true for every angle of incidence? What if the angle of incidence is zero?
- c. Based on your experimental data for (a), what is your experimentally determined Brewster's angle? How does it compare to the value you measured in reflection (III.a)? How do the experimental values compare with the theoretical value using an index of 1.56?
- d. Based on your experimental experience, which method (reflection or transmission) gives the most accurate measurement of Brewster's angle? Why?
- e. Derive Equations 5 and 6 from Equations 1 and 3. Remember, the light transverses TWO interfaces.