Lab 1:

FRESNEL RELATIONS and SNELL'S LAW (2 Lab Periods)

Objective Examine the refraction and reflection of light at a planar dielectric interface.

References Hecht, sections 4.4, 4.6, 4.7, 8.6

(A) Basic Equations

1. Fresnel's Equations

$$R_{\perp} = \left[\frac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)}\right]^2 \tag{1.1}$$

$$R_{\parallel} = \left[\frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)}\right]^2 \tag{1.2}$$

where R are reflection coefficients (*i.e.*, reflection amplitudes *squared*), subscripts $\perp$ and $\|$ denote polarization directions with respect to the plane defined by the propagation direction and the direction normal to the interface, and θ_i and θ_t are the angles the incoming and the transmitted beams make with the interface normal.

2. Snell's Law

$$n_i \sin\theta_i = n_t \sin\theta_t \tag{1.3}$$

where n are refraction indices.

3. Critical angle for total internal reflection

$$\sin\theta_c = \frac{n_t}{n_i} \tag{1.4}$$

4. Brewster's Angle (Polarization Angle)

$$\tan\theta_P = \frac{n_t}{n_i} \tag{1.5}$$

(B) Equipment

Polarized laser, divided circle spectrometer, semicircular piece of plexiglass, silicon photodiode detector, and power meter.

(C) LAB SAFETY: Do not look into the Laser beam. Eye injury and blindness may result.

FOR THIS EXPERIMENT, WITH THE LASER BEAM GOING THROUGH THE SPECTROMETER, DON'T LOOK INTO THE TELESCOPE OF THE SPECTROMETER.

(D) Procedure

In this experiment, we will be using a divided-circle spectrometer to measure angles between various laser beams. This instrument, shown below, is normally used with a light source illuminating the slit, a grating or prism resting on the table, and with the user looking through the eyepiece. However, for this experiment we'll use it in a different mode – with a laser beam going through the slit and collimator, reflecting/refracting off of a piece of plexiglass on the table, and then passing through the telescope. NEVER LOOK AT THE BEAM THROUGH THE TELESCOPE! Rather, you simply want to measure the angle of the beam by aligning the telescope so that the beam passes centrally through it. For this purpose, it is convenient to remove the eyepiece from the telescope, and have the beam hit a piece of tape or paper (with a central mark on it) to indicate its position. For measurements of intensities, this piece of paper can have a slit made in it to allow the beam to pass through it into the detector.

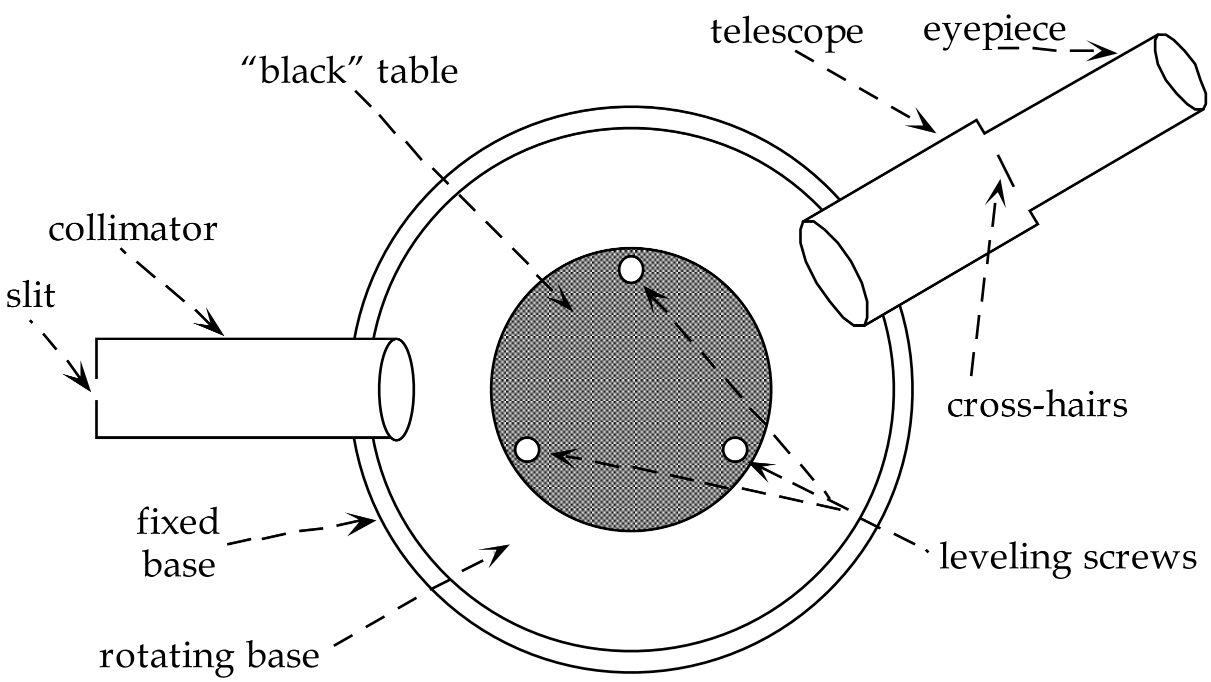

Figure 1.1: *Divided-circle spectrometer*

(E) Assignments

a. Snell’s Law

Direct the laser beam onto the planar surface of the plexiglass and note the refracted beam. Use the angular scale built into the spectrometer base to measure the angles of the incident and refracted rays.

<u>Technical hints:</u> use the surface reflection off the plexiglass to direct the Laser beam straight back onto itself. This allows you to align the laser angle vertically and to determine the zero incidence angle of the spectrometer table. Also, you can remove the plexiglass to find the zero of the refracted ray angle.

Make a plot of the appropriate quantities to verify Snell’s Law.

b. Total Internal Reflection.

Find the critical angle for total internal reflection. Measure this angle, and determine the index of refraction of the plexiglass from the result.

c. Brewster’s Angle.

Turn the plexiglass to study external reflections. Find Brewster's angle, the angle for which there is no reflected beam for light polarized in the plane of reflection.

<u>Technical hint:</u> The laser you are using is polarized, but you must find the plane of polarization. This can be done by (a) using a polarizing sheet with known plane of polarization, and/or (b) locating the zero of intensity corresponding to Brewster's angle, since this zero only occurs for the correct polarization.

Measure Brewster's angle and use it to determine the index of refraction of the plexiglass.

Compare your results for the index of refraction from Parts A, B, and C.

d. Fresnel Equations.

Use the detector and DVM to measure the intensity of the reflected beam.

Plot reflected power versus angle for each polarization and compare to theory.

<u>Technical hint:</u> The detector may have a zero offset (that is, the power meter has a nonzero reading even with zero illumination of the detector). Take care to zero that offset using the adjustment on the power meter.