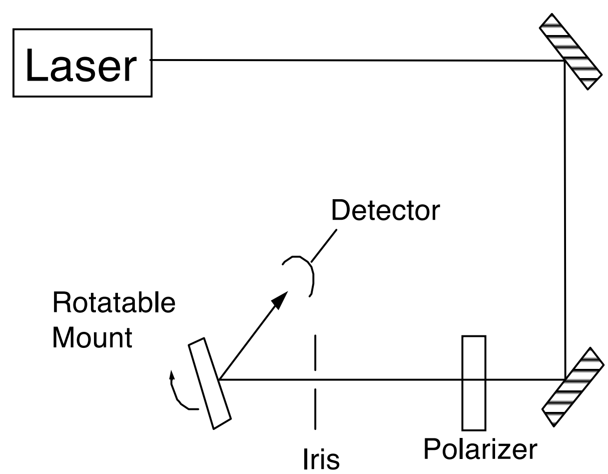
PH 481/581 **Physical Optics** **Winter 2014**

Laboratory #2 **Week of January 20**

Read: pp. 111-124 and 495-497 of "Optics" by Hecht
Do: 1. Experiment II.1: Reflection
2. Experiment II.2: Transmission
3. Experiment II.3: Refraction
4. Experiment II.4: Fresnel zone plate

In the next two experiments we will study the reflection and transmission of laser light incident upon a dielectric. The goal of this experiment is to measure the reflectance and transmittance coefficients of both parallel and perpendicular polarization, and then find the Brewster's angle of glass, verifying the Fresnel equations. The text uses the subscripts || and ⊥ for parallel and perpendicular to the plane of incidence, respectively. Another common notation is to label them P (parallel to the plane of incidence) and S (Senkrecht, German for perpendicular to the plane of incidence). We will use this notation here.

Experiment II.1: Reflection from Glass



The goal of this experiment is to find and measure the Brewster angle and to measure the reflectance of glass for S and P light.

A disc of glass, ground on one side, will serve as our sample dielectric. We will use the polished surface for our experiment. The ground surface on the back face serves to prevent internal reflection so that we only have one reflection. The rotational stage allows for precise control of the rotated angle. The rotatable mount also helps to ensure that the rotation axis lies on the reflecting surface, which is important so that the laser beam remains on the glass surface as the sample is rotated, especially at large angles.

A schematic for the general layout to be used in these experiments is shown in the above figure. Position the glass reflector in the third arm of your standard laser configuration (the optical rail is not necessary here). Allow room for several other components before and after the reflector. The laser polarization should be adjusted so that it is at approximately 45˚ with respect to vertical; this will allow you to use another polarizer to change easily between S and P polarization. The laser polarization is along the diameter of the laser tube that intersects the power cord leaving the back of the laser. Adjust the laser beam so that it covers the glass reflector as grazing (~90 degrees) incidence is approached. If you place an adjustable iris in the laser beam and aperture the laser down, then you will be able to take data closer to grazing incidence. **It is your job to find the polarization of the laser and coinciding transmission axes of the polarizers used.**

To find the Brewster angle θ_B, rotate the reflector so that the incident angle $\theta_i \approx 55^\circ$ and view the reflected beam on a card. Adjust the polarizer to minimize the brightness of the reflected beam. Change the angle of incidence and plane of polarization alternately to achieve precise extinction, in which case the incident light is pure P polarized and $\theta_i = \theta_B$; *note the setting of the polarizer.* From your measurement of θ_B, derive a value for the index of refraction *n* of the glass.

To measure the reflected laser power, you will use a Thor Labs photodetector mounted on your magnetic base so you can easily move it across the table. You can then average voltage readings on the oscilloscope. Make sure to decrease the intensity of the laser before you take measurements so you do not saturate the detector (you can do so by implementing another polarizer prior to your other polarizer). You must be careful to make sure all of the laser beam hits the detector (you may need a lens to accomplish this). Check that you can position the detector repeatedly and obtain the same results. Ambient light in the room will cause an offset in your measurement. You can measure this offset (a "baseline", or "noise level") by blocking the laser beam, but be careful to do it without changing the ambient light (i.e., the reflection of light from you or other nearby objects may be the source of noise).

Record the reflected power for both S and P polarizations for as wide a range of angles as possible. It is probably not a good idea to switch between S and P measurements at each angle; the likelihood of systematic error is high. Take special care near Brewster's angle and near grazing incidence, i.e., use smaller increments of the incident angle. Measure the laser power before the reflector for each polarization so that your data can be normalized to the incident power. **Plot your data and compare it with the theoretical Fresnel formulae using the value of *n* determined from the Brewster angle.**

Experiment II.2: Transmission through Glass

The goal of this experiment is to measure the transmittance of glass for S and P light.

A thin microscope cover slip will serve as the sample in this experiment since it will not displace the beam as the incidence angle is changed. Double sided tape works well for mounting the slips; they are disposable. If necessary, they can be cleaned with isopropyl alcohol. The detector can be mounted to the table in this experiment as it should not need to be moved.

The general experimental layout is similar to the above case, except that you are to measure the transmission instead of reflection. Start with the Brewster angle measurement again and then measure the transmitted power for S and P polarization. You may notice more "noise" in your data in this experiment, manifesting as an increase and decrease in intensity every few degrees. Examine it more closely. It is probably due to this film interference fringes caused by multiple reflection within the glass plate. We will study this effect further later in the course. You can attempt to counter this noise by watching the reflection on a card and taking data only at points where the reflection is a maximum.

Compare your data to the theoretical Fresnel formulae (remember that the light transmits through two air-glass interfaces).

Experiment II.3: Refraction

Take a thick glass (or plastic) slab and measure the angle of refraction for one angle of incidence. Calculate the refractive index of the slab.

Experiment II.4: Fresnel Zone Plate

A Fresnel zone plate has a series of annular rings, each with an outer radius given by

$$R_m = \sqrt{m} R_1,$$

where R_1 is the outer radius of the first ring (the first one is a full circle since $R_0 = 0$). Alternating rings block and transmit incident light. If a plane wave of light of wavelength λ is incident, then at a certain distance from the plate every other Fresnel zone will be blocked by the plate. This will cause a large enhancement of the on-axis light intensity. This distance is known as the first-order focal length of the plate and is given by

$$f_1 = \frac{R_1^2}{\lambda}.$$

Additional focal points will occur when there are an odd number of zones within each ring of the zone pate. These points will occur at $f_1/(2n+1)$, where n is an integer.
Use the Fresnel zone plates that are in slide mounts. Use the telescope to produce a collimated beam of laser light much larger than the outermost ring. Measure as many focal points as you can for the zone plate and determine R_1 from your data.

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Photodetector	1	Thor Labs DET1-SI
Ground glass plate	1	Edmund A44,065
Thick glass (or plastic) slab	1	
Microscope cover slip	1	Edmund A40,002
Rotation Mount	1	Thor Labs RSP1
Rotation stage	1	Thor Labs
Oscilloscope	1	
Optical Rail	1	Newport PRL-36
Rail carriage	5	Newport PRC-1
Mirror mount	2	Thor Labs KM1
Al mirror	2	Newport 10D10ER.1
Polarizer	3	Edmund A38,396
Iris (adjustable)	2	Thor Labs ID12
Filter holder	1	Thor Labs FH2
Mounting posts	8	Thor Labs P3
Voltmeter	1	Fluke 75
Cards (for laser blocking)	limitless	
Laser block	1	
Ruler	1	