Reflection, Transmission and Fresnel's Coefficients

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Brewster's angle is the angle of incidence at which ***p*** polarized light is perfectly transmitted through a transparent dielectric surface (such as glass), without any reflection. In this experiment you will find the Brewster angle by measuring the reflectance of a glass slide for ***p*** polarized light. You will also measure the reflectance for ***s*** polarized as well as light polarized at 45° with respect to the incidence plane. Furthermore Brewster's angle can be used to calculate the refractive index of the glass.

Essential pre-lab reading: "*Physics of Light and Optics*" by Justin Peatross and Michael Ware, Brigham Young University, 2013; (sections 3.1 to 3.4).

1 Test your understanding

1. Derive Fresnel's reflection and transmission coefficients, for ***s*** and ***p*** polarized light. Let's call these coefficients r_s, r_p, t_s and t_p.
2. Use Matlab (or a software of your choice) to make the following plots for air-glass interface as a function of the incident angle. Use $n_i = 1$ for air and $n_t = 1.6$ for glass. Explicitly label Brewster's angle on all of the applicable graphs.
   (a) r_p and t_p.
   (b) R_p and T_p, where $R_p = {r_p}^* r_p$ and $T_p = {t_p}^* t_p$.
   (c) r_s and t_s.
   (d) R_s and T_s, where $R_s = {r_s}^* r_s$ and $T_s = {t_s}^* t_s$.

You are provided with a simulation, named *reflectance.m*, which shows effects of changing the refractive index and the polarization on R. Use it to further understand the relation between these entities.

2 The Experiment

The laser beam from a HeNe laser is first polarized by a linear polarizer and then passed through a half-wave-plate which can rotate the angle of polarization. It subsequently passes through an iris and falls on a glass slide sample (that has been grounded from one side) which is mounted

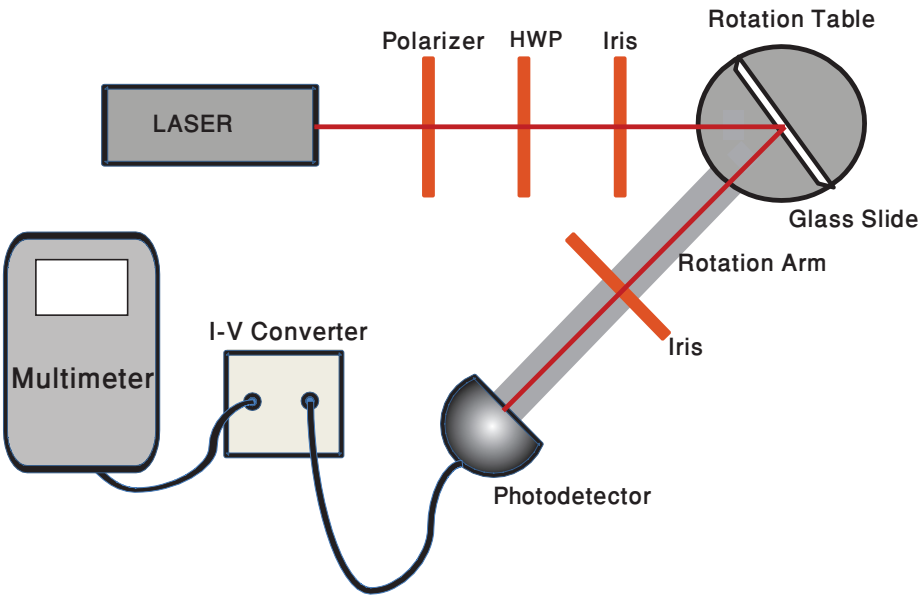

Figure 1: Schematic of the experimental setup. The red line represents the conceived path of the laser beam.

on a rotatable platform. Finally the reflected beam is measured by a photo-detector,mounted on a rotatable arm, with an iris in front of it. The photo-detector outputs current, which is first converted to voltage by an I-V converter and then displayed on a multi-meter.

Q 1. Why are we using iris in this setup? Furthermore, why is one side of glass grounded?

Turn on the laser and check the alignment. The laser should pass through the center of polarizer, half-wave plate and iris. Rotate the glass sample so that the reflected beam goes straight back into the laser. The rotatable platform can be fixed by a locking screw. Note the reading on the dial, it is the first approximate to a zero angle of incidence.

Q 2. Find the reflectance curves for $\boldsymbol{p}$, 45° and $\boldsymbol{s}$ polarizations.

To obtain $\boldsymbol{p}$ polarization orient the glass sample to approximately 58° and measure the reflected light. Then adjust the half-wave plate to minimize it. This will give you $\boldsymbol{p}$ polarized light. If the polarization of the light incident on the half-wave plate makes an angle θ with the *fast axis* of the half-wave plate, it rotates the polarization by 2θ. Figure 2 gives more detail of this process. You can now get $\boldsymbol{s}$ or 45° polarizations from $\boldsymbol{p}$ polarized light by rotating half-wave plate through 45° or 22.5° respectively.

Q 3. Why are we using a half-wave plate? Why not just rotate the polarizer to achieve required polarizations?

Q 4. Reflectance can only have values from zero to one. Therefore you need to normalize your data. At some suitable angle (e.g. 10°) use theoretically calculated value to normalize your data. Then plot your results superimposed with theoretically calculated curves. Include uncertainty bars with your data.

Q 5. Find Brewster's angle and refractive index of glass sample. Quote the uncertainty in your results.

Q 6. After use, clean the sample glass slide with cleaning solution provided to you.

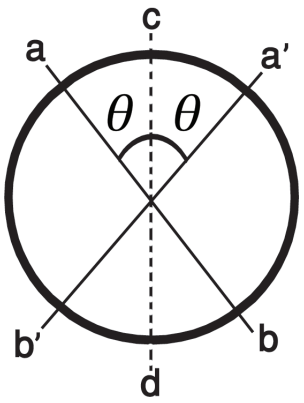

Figure 2: Conceptual working of a half-wave plate. ab is the plane of polarization of the incident light, cd is the fast axis of the half-wave plate and $a'b'$ is the plane of polarization of the transmitted light which has been rotated by the half-wave plate.