13.

Brewster angle measurement

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Objective:

1. Verification of Malus law
2. Measurement of reflection coefficient of a glass plate for p- and s- polarizations
3. Determination of Brewster angle

Theory:

When a monochromatic plane wave is incident on an interface between two materials, its **E**-field can be decomposed into two transverse components that are in a plane normal to the **k**-vector as shown in Fig. 1. The two transverse components are typically defined with respect to the plane of incidence. The component in the plane of incidence is known as p-polarized wave whereas the component normal to the plane of incidence is known as the s-polarized wave.

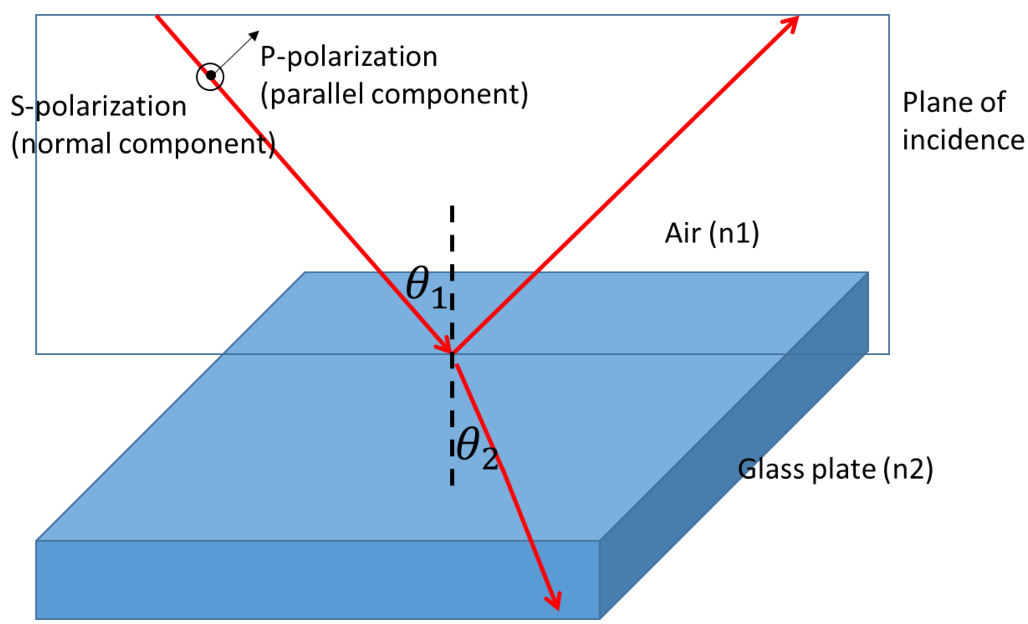


Fig. 1: Illustration of p- and s- polarization components in relation to plane of incidence.

The amplitude or Fresnel reflection coefficients for the p and s polarization components can be obtained using appropriate boundary conditions and are given by:

$$r_p = \frac{n_1 \cos\theta_2 - n_2 \cos\theta_1}{n_1 \cos\theta_2 + n_2 \cos\theta_1} \quad \text{and} \quad r_s = \frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2}.$$

Here the angle of incidence and angle of refraction are related by the Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Using the expressions for reflection coefficients and the Snell's law it is easy to show that when $\theta_1 + \theta_2 = \pi/2$ or equivalently when $\theta_1 = \theta_B = \arctan(n_2/n_1)$, $r_p = 0$. This angle of incidence is known as the Brewster angle (θ_B). The reflected wave is thus purely s-polarized whereas the transmitted wave has both polarizations. The aim of this experiment is to measure the energy reflection coefficients at air-glass interface for both p- and s-polarizations and for various values of incidence angle. The typical plots for energy reflection coefficients $R_p = |\, r_p \,|^2$ and $R_s = |\, r_s \,|^2$ are shown in Fig. 2.

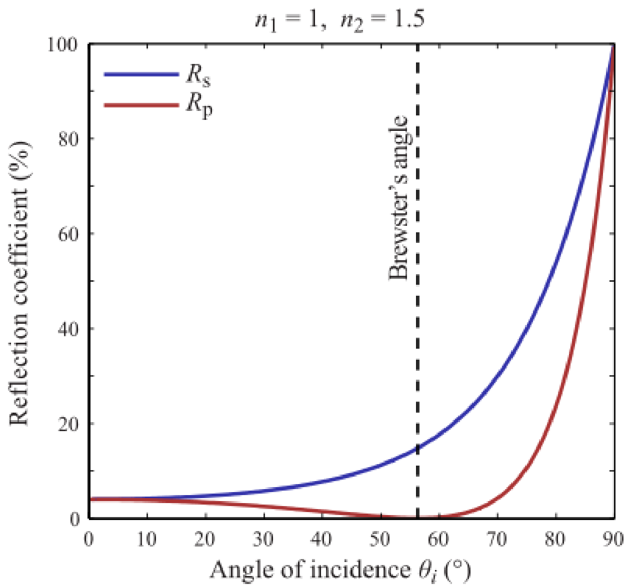


Fig. 2: Plot of energy reflection coefficients as a function of angle of incidence for p- and s-polarized light. The reflection coefficient for p-polarized wave vanishes when angle of incidence is equal to the Brewster angle.

The polarization state of light for incident unpolarised light at Brewster angle can be shown diagrammatically as in Fig. 3.

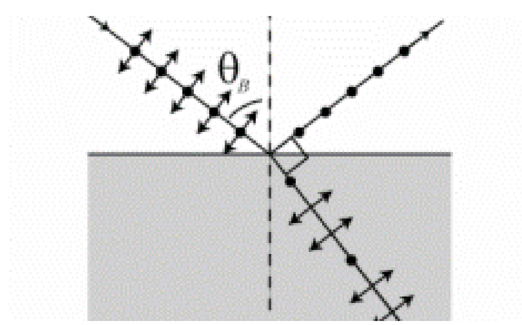
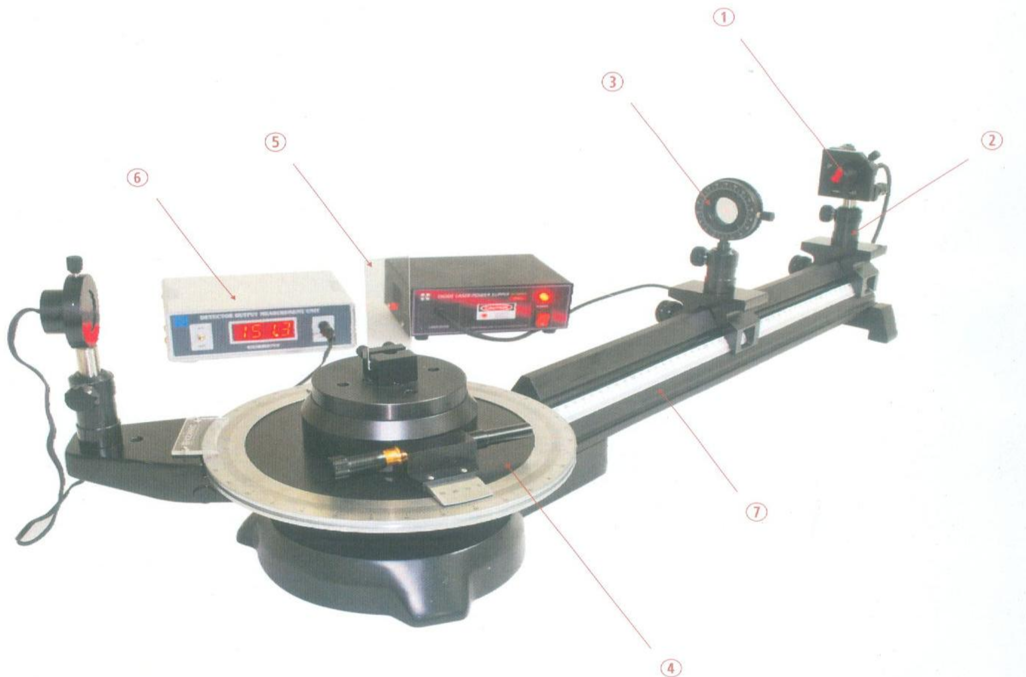


Fig. 3: Polarization state of unpolarised light incident at Brewster angle on reflection and transmission.

Procedure:

The experimental setup is shown in Fig. 4 below.



1. Diode Laser with power supply (3mW 650nm Red)
2. Kinematic Laser mount
3. Polarizer
4. Goniometer Based Detector Mount
5. Glass Slide Specimen
6. Pinhole Photo Detector with power supply
7. Optical Rail (500mm)

Fig. 4: Experimental setup for Brewster angle measurement.

1) Without the glass plate in place, first arrange the laser and the detector such that the laser illumination falls directly on the detector pinhole and you get some photocurrent from the detector.
2) Now insert the polarizer in laser path. Rotate the polarizer at 5-degree intervals and note down the detector signal. Make a plot of detector intensity vs. polarizer angle. Verify that your plot satisfies Malus law. What do you conclude about state of polarization of the laser from this plot? Is the laser polarized?
3) Now orient the pass axis of the polarizer (shown by notch on the polarizer mount) in vertical and horizontal directions. Verify that the detector readings for the two cases are approximately equal. This will ensure that the laser is oriented such that its polarization is at 45-degree angle to vertical (why?). If not, then adjust the laser mount

by rotating the laser unit. (Approximate balancing of powers for the two polarizations is important so that you do not have low signal on the detector for one of the polarizations).

4) Insert the glass slide in the central mount and identify the p- and s-polarization components with the horizontal and/or vertically polarized light states respectively.
5) Turn the polarizer such that it passes vertically polarized light. Using the goniometer arrangement find the reflected light power as a function of incidence angle. Make a plot of energy reflection coefficient vs. incidence angle. Use sufficient number of incidence angle values to get a smooth curve.
6) Repeat step (5) for horizontally polarized light.
7) Determine the Brewster angle and the refractive index of glass using your plots.
8) Find log error in estimation of refractive index.

Direct power measurement for p and s polarized light with detector:

Direct detector signal for p-polarization =

Direct detector signal for s-polarization =

<u>Representative data table for p or s polarized light:</u>

Least count of circular scale on goniometer unit =

Angle of incidence	Detector signal	Energy Reflection coefficient*

*****The energy reflection coefficient can be determined from your experiment as a ratio of the detector signals for reflected beam and the direct beam for both p and s polarizations.