Name
Section Number
Lab Partner's Name

Optical Micrometer

Introduction

In geometrical optics, refraction is described by Snell's Law. Refraction refers to the bending of light as it passes from one medium to another. Snell's Law will be studied in this lab. It states that

$$n_i \sin\theta_i = n_r \sin\theta_r \tag{1}$$

where n is the index of refraction of the incident or refracted material, and θ is the angle of the incident or refracted light ray measured from the normal to the surface. When the incident index of refraction is greater than the refracted index of refraction, there is a critical angle beyond which refraction can no longer take place and the beam of light is totally internally reflected. This critical angle is given by

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) \tag{2}$$

The index of refraction of a material will be measured using a semi-circular lens and equations 1 and 2.

When light passes through a rectangular piece of material of width, D, its lateral displacement, d, is given by

$$d = D\frac{\sin(\theta_i - \theta_r)}{\cos(\theta_r)} \tag{3}$$

Equation 3 presumes that the light emerging from the rectangular plate is parallel to the incident path. If there is some angle of deviation from the incident path, it can be found using

$$\theta_{dev} = \frac{d_{far} - d_{near}}{L} \tag{4}$$

where L is the distance between the two different locations where the lateral displacement is measured.

Procedure

A 632.8 nm laser mounted on an optical track at lab table number 2 will be used for all experiments. The laser is aligned on the track and the beam is projected onto a plate perpendicular to the track at the other end of the track. A piece of graph paper is used on this plate to mark the positions of laser. Between the laser and the plate is a rotating protractor. The two types of lenses can be mounted on this protractor. The protractor is aligned so that the beam passes directly over its pivot point. The distance between the pivot point and the face of the plate is measured with a meter or 2-meter stick.

Initially the semi-circular lens is mounted so that the face of the lens faces the laser. The lens is positioned so that the beam reflects back towards the laser, and the mounting apparatus is rotated so that at this position, the protractor reads 0 degrees. The initial beam position is marked with pen or pencil on the piece of graph paper. Then the protractor is rotated clockwise and counter clockwise in 5 degree increments, and the beam positions are also marked on the graph paper. The displacement of these marks is measured with respect to the initial position using calipers. The intensity of the reflected and refracted beams are also noted qualitatively as the angle changes.

The same procedure is followed where the lens is now oriented so that the round part of the lens is facing the laser. The critical angle of the lens is also measured while the beam is in this position. This is done by rotating the protractor until there is no mor refraction at the flat surface, and the beam is totally internally reflected. This is done both clockwise and counterclockwise.

Next the rectangular bar-shaped lens is placed on the protractor. The laser is again oriented so that the reflected beam returns to the laser. Again, the displacement is measured on the piece of graph paper, but this time, the protractor is turned in 10 degree increments. This is done twice. Once while the plate is close to the protractor, and once while it is far away. The distance between these measurements, *L*, is measured, as well as the thickness of the block, *D*.

Results

With the D-shaped lens mounted so that the flat part of the lens faces the laser, the index of refraction was found to be 1.5568 ± 0.0069. With the curved part facing the laser, the index of refraction was found to be 1.5495 ± 0.0017. Using the critical angle measurement, the index of refraction was found to be 1.5557 ± 0.01618. When using the bar lens with the plate located far away from the pivot point, the measured *d* divided by the calculated *d* using n =1.5566 had a mean of 1.0791 ± 0.0209. Finally, the angle of deviation of the beam was calculated for several incident angles. This deviation was typically on the order of a few hundredths of a degree. All data and calculations can be found on the attached spreadsheet.

Conclusion

Comparing two measurements of the index of refraction using the D-lens gives a t-value of 1.03. Comparing the critical angle index of refraction to the D-lens with the flat side facing the laser gives a t-value of 0.06. Comparing the critical angle index of refraction to the D-lens with

the curved side facing the laser gives a t-value of 0.38. Overall, these three measurements appear to be compatible with each other.
There were several possible sources of error in this lab. There were random errors associated with the measurements of angles, and lengths. There were also many possible systematic errors. The laser beam may not have been aligned on the track. The plate at the end of the track or the paper attached to it may not have been perpendicular to the laser. The laser may not have passed directly through the pivot point of the protractor device. Perhaps the most obvious source of error was the fact that the lenses where of low quality, and all of the laser images were fuzzy, making it quite difficult to located the true position of the beam on the graph paper.

I would improve this lab by using higher quality lenses.