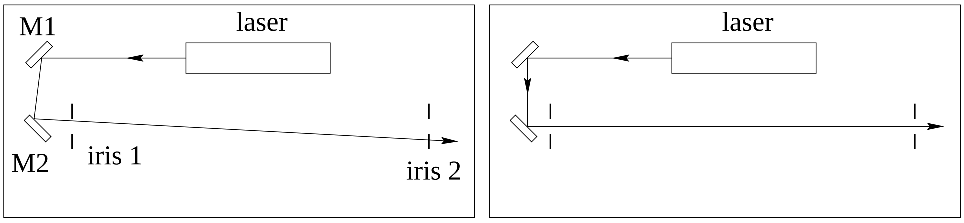
Experiment 1: Reflection, refraction, and optical power

In the beginning of this laboratory session, your assistant will introduce the equipment in the optics laboratory, and explain some basic experimental practices.

Walking the beam

A commonly used technique to align a laser beam is to steer it with two mirrors mounted on adjustable mirror mounts. Consider a situation where you want the laser beam to propagate along a particular direction defined by two points in space. Place two irises to mark these points. Adjust the first mirror (M1) to center the beam on the closer iris (1) first. Then adjust the second mirror (M2) to center it on the farther iris (2); this will make the beam off-center on the first iris. If you iterate between these two adjustments a few times, the beam path will converge to the desired direction.



1 Specular and diffuse reflection

When a light beam strikes a surface, a portion of the light is reflected. If the surface is smooth (surface irregularities smaller than the wavelength of light) then the reflection is *specular*. In other words, specular reflection occurs at polished mirror-like surfaces. If the surface is rough (surface irregularities larger than the wavelength of light) then the reflection is *diffuse*. In other words, diffuse reflection occurs at dull surfaces.

Observe the difference between specular and diffuse reflection of the He-Ne laser beam from an aluminum mirror, a glass plate, a piece of paper, and the skin of your hand.

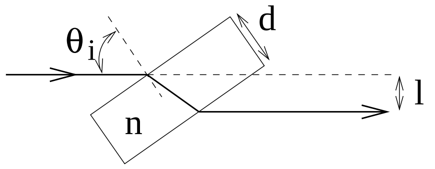
2 Angles of incidence and reflection

Specular reflection at a surface obeys the law of reflection: the reflected wavevector lies in the plane of incidence; the angle of reflection equals the angle of incidence.

Verify the law of reflection for one incidence angle of your choice using an aluminum mirror and the He-Ne laser. (Use the angle measurement rotation base and magnetically mounted components in this and the following parts.) Repeat with the glass plate instead of the mirror. Note the multiple reflections when using the glass plate.

3 Index of refraction

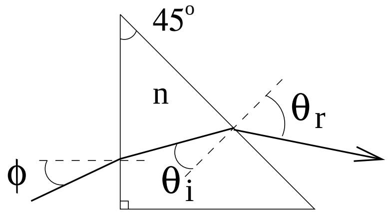
A light beam is refracted upon passing from one medium to another with a different index of refraction. Snell's law relates the angles of incidence and refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$. When a light beam passes through a parallel plate, it undergoes a lateral shift due to refraction, as shown in the figure. **Derive an expression** to find the refractive index n of a parallel plate of thickness d from a measurement of the lateral shift l at angle of incidence θ_i. Find the refractive index of the 19 mm thick acrylic plate at $\lambda_0 = 633$ nm using data obtained at three different angles of incidence. (Note that the refractive index of an optical material usually depends on the wavelength.) Discuss your results.



4 Total internal reflection

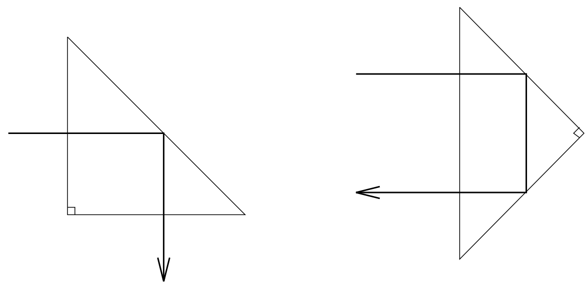
When a light beam is incident on a low refractive index medium from a high refractive index medium, total internal reflection occurs if the angle of incidence exceeds the critical angle $\theta_c = \sin^{-1}(n_2/n_1)$. The critical angle can be measured with the use of a prism as shown in the figure. **Derive an expression** that relates ϕ to the critical angle $\theta_i = \theta_c$ when $\theta_r = 90°$.

Find the refractive index of the glass prism by measuring the critical angle for total internal reflection. Discuss your observations for angles of incidence less than and greater than the critical angle.



5 Reflection in prisms

Total internal reflection facilitates the use of prisms as light reflectors. Two such arrangements are shown in the figure. These are called the right angle prism and Porro prism, respectively. Implement these arrangements to reflect the He-Ne laser beam. Note that there is no dispersion associated with either of these reflection schemes. Look at your own eye with the Porro prism; compare this with a reflection from an ordinary mirror.



6 Optical power

Measure the output power of the He-Ne laser with the optical power meter. To do this, hold the power meter head in an arrangement similar to that shown in the figure on page 4, and place it in the beam path. Remove the filter in front of the power meter head during this measurement. (This filter allows you to make *relative* power measurements without being affected by the room lights.) Familiarize yourselves with the operation of the power meter. Make sure that the *zero* of the power meter is properly adjusted before each measurement. Make the same measurement with the filter attached to the power meter head. What is the power transmittance of the filter at 633 nm? What do you think its transmittance is at 550 nm?