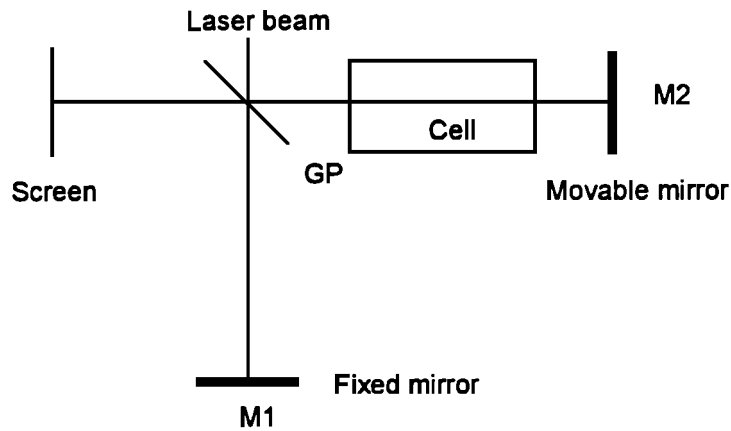


Lab 11: Index of Refraction (n) of Air

Introduction In this experiment you will measure the index of refraction of air by comparing the optical path lengths of two columns of air of equal physical length but at different pressures. The Instrument used to compare optical path lengths is the Michelson Interferometer.

Read the textbook description of the Michelson Interferometer given in our textbook, pages 977-978. In an interferometer (Figure 1) a light beam (in this case a helium-neon laser) is incident on a partially silvered glass plate (GP) placed 45° with respect to the beam. The beam is split, part of it traveling to mirror M1 at the end of the side arm. This beam is reflected by M1, returning through GP to strike the screen. The other part of the original beam goes through the glass plate and the cell to mirror M2. It is reflected by M2 through



the cell to the glass plate where it is reflected to the screen.

Figure 1. The Michelson Interferometer.

The two beams arriving at the screen produce an interference pattern. An interference pattern is normally a series of bright and dark concentric circles (Figure 2), because of the imperfections in the mirrors of our interferometers, the circles may be distorted.

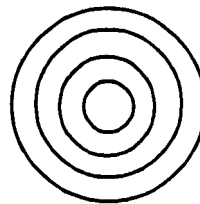


Figure 2. Ideal interference pattern.

In the bright regions of the pattern, the crests of the waves of the two beams arrive together. In the dark areas the crest of one wave arrives at the same time as the trough of the other.

If the optical path length of one beam changes by one wavelength, the interference pattern is shifted by one fringe. The optical path length is equal to nL , where n is the Index of refraction and L is the physical path length. The optical path length can be varied by changing either n or L .

In our experiment the one beam passes through the cell of length L . Because the beam passes through the cell twice, the optical path length is $2nL$. The air will be removed from this cell, changing the refractive index, n . The other beam passes through the same length of air, but with no cell in that beam, the pressure will remain constant.

If the refractive index changes by Δn , the path length changes by $2 \Delta n L$. As the air is removed, the pattern will shift by one fringe at each time the refraction index changes by an amount $\Delta n = \lambda/2L$. A shift of m fringes will occur when the refractive index changes by an amount $\Delta n = m\lambda/2L$

The refractive index for most gases is close to 1. For air and other ideal gases, the difference between the refractive index and 1 is proportional to the pressure of the gas. Thus we define the refractive index of air $n = 1 + k p$, where p is the air pressure and k is an unknown constant. When the pressure is changed, the change in the refraction index is $\Delta n = k \Delta p$. We can therefore relate the number of fringes shifted, m , to the change in pressure $\Delta p = \Delta n/k = m\lambda/2Lk$.

Therefore the unknown constant, k , is given by $k = m\lambda/2L\Delta p$.

Thus if you measure m fringes while the pressure changes by an amount Δp , you can calculate the refraction index of air at room temperature using

$$n = 1 + m\lambda p/2L\Delta p \tag{1}$$

Experiment

Warning: The Interferometer glass plate and mirrors have very sensitive surfaces. Please do not touch the mirror or the plates. Call your Instructor before making any adjustments that require you to touch any of the glass surfaces.

Aligning the interferometer: Procedure

- The laser, interferometer and screen are set up as shown in Figure 2.
- Cover the **M1** with a sheet of paper. The laser beam should go through the glass plate and cell, strike **M2**, and return through the cell and the plate to the laser.
- Adjust the location of the laser until the return beam is very close to the exit hole on the face of the laser. (WARNING: Do not look directly into the laser beam!!)

- A set of three or four dots should now be seen on the screen (Figure 3a). Now uncover **M1**.
- A second series of dots should now be seen on the screen (Figure 3b). Turn the screws on **M2** so as to superimpose the two sets of dots.
- When the correct dots are lined up, they should "shimmer," and a slight touch of the interferometer should cause the intensity of the dots to flicker.
- A small lens will be used to spread the laser beam passing through the interferometer. Place the small lens on the exit hole of the laser, adjusting the position so that the beam goes through the cell.
- If the interferometer is properly aligned, an interference pattern similar to Figure 2 should appear on the screen.
- If a series of thin circular arcs appear on the screen only a minor adjustment of the three screws on **M2** is needed. If the arcs are horizontal carefully turn the top or bottom screw. If the arcs are vertical, try the side screw. In any case, turn the screws so as to center the pattern of the circular arcs on the screen.



Figure 3. Aligning the interferometer.

Evacuating the cell and making the measurement: Procedure

- Open the air valve (counter-clockwise) a couple of turns.
- Squeeze the handle of the vacuum pump several times to evacuate the cell.
- When you have evacuated the cell to the lowest pressure you reasonably can, close the valve.
- Record the reading of the vacuum gauge. This will be the Δp value you will use in Equation (1).
- Record the room pressure, p , from the barometer in the lab.
- Concentrate on one point on the screen and open the valve slightly until the fringes move slowly.

- Count the number of fringes that pass a fixed point on the screen. Continue counting until room pressure is reached.

Calculations

- The cell length is $L = 7.056 \pm 0.005 \text{ cm}$.
- The laser wavelength is $\lambda = 632.8 \text{ nm}$.
- Calculate the refractive index of air using Equation (1).

$$n = 1 + m\lambda p/2L\Delta p \quad (1)$$

- The accepted value for dry air is at 15°C and 760 Torr is $n = 1.0002760$. Compare with your result.
- Show all of your data and calculations on a separate sheet of paper. Discuss any discrepancy between the accepted value and your value.

Questions

1. One major contribution to the uncertainty of your measurement arises from counting only integral number of fringes. If you continued to use only Integral values, would a laser with a shorter or longer wavelength give more precise results? Why?
2. The cell was measured between the Inside surfaces of the glass ends. Is there an error introduced by the glass plates? If so, what is it?