Contents

1. The Michelson Interferometer (Pasco OS-8501 version)

1.1. Precautions

1. Avoid touching all optical surfaces on the interferometer, because minute scratches can impair the clarity of the interference image. For instructions on cleaning the optical surfaces, see the Maintenance section in the Pasco manual for this apparatus.
2. Your alignment will not stand up to bumping any optical elements including the laser.
3. Do not use the vacuum chamber with a compressor; it is not built to withstand positive pressures.
4. The micrometer dial can be loosened too far causing the small ball-bearing to fall off then end of the adjustment structure. Make certain you are aware of how this can occur so that the situation can be avoided[1].

1.2. Laser Safety

This experiment makes use of diode and/or Helium-Neon lasers. Lasers can cause retinal damage if used improperly. ***In order to avoid this, never look into a laser and its output beam***. This means you must be aware of the beam's location. If the beam is being reflected, refracted or split, you must also know the path of those beams.

The lasers in this lab are Class II[2] which are not harmful normally, unless a person deliberately stares into the beam. Laser protective eye-wear is normally not necessary as the person will usually look away or close their eye. Flash blindness can occur. Any focusing or concentrating of the beam could increase the risk to one's eyes.

1.3. Equipment

Pasco OS-8501 interferometer, air cell, vacuum pump, diode laser, Pasco optical bench, clamps, brass stock rail

1.4. Introduction

The PASCO scientific Model OS-8501 Michelson Interferometer is a precision instrument capable of measuring the wavelength of visible, monochromatic light with an accuracy of better than 5%. With the included vacuum chamber, it can also be used for precise measurements of the index of air refraction. Please observe the following cautions.

To measure the index of refraction of air, a vacuum pump is required with a built-in gauge. It allows precise control of the vacuum level when counting fringes. However, the vacuum chamber can be used with any pump that can be connected by a 1/4 inch (0.64 cm) I.D. (inner diameter) tube.

1. Interferometer base: built-in micrometer and leveling feet, movable mirror, beam splitter, three point adjustable fixed mirror, Vacuum cell for measuring the index of air refraction, beam expanding lens with component holder, fitted case

[1] Consult with your lab instructor.
[2] output power $\leq$ 1mW, visible wavelengths only

2. Light source: To operate the Michelson Interferometer you will also need a monochromatic light source, preferably a laser. We recommend the PASCO 0.5 mW He-Ne Laser (Model OS-9171), but any low power laser that operates in the visible range will work. For optimum ease of alignment, the level of the beam should be 1.5 inches (3.8 cm) above the bench top. Leveling screws on the interferometer allow the height to be adjusted.

3. The PASCO Optics Bench can function as an aid in aligning the interferometer. It simplifies the alignment procedure and the magnetic pads on the bench top hold the laser and interferometer firmly in position once the system is aligned. A 1.0 m Optics Bench can be purchased separately (Model OS-9103). A 70 cm optics bench is included as an integral part of the PASCO scientific Introductory Optics System (Model OS8500).

1.5. Theory of Operation: Interference and Interferometer Theory

A beam of light can be modeled as a wave of oscillating electric and magnetic fields. When two beams of light meet in space, these fields add according to the principle of superposition. At each point in space, the electric and magnetic fields are determined as the vector sum of the fields of the separate beams.

In 1881, some 78 years after Young introduced his two-slit experiment, A.A. Michelson designed and built an interferometer using a similar principle. Originally Michelson designed his interferometer as a method to test for the existence of the ether, a hypothesized medium in which light could propagate. Due in part to his efforts, the ether is no longer considered a viable hypothesis. Michelson's interferometer has become a widely used instrument for measuring the wavelength of light, and for using the wavelength of a known light source to measure extremely small distances in for example, IR spectrometers and milling machines.

Pasted Layer

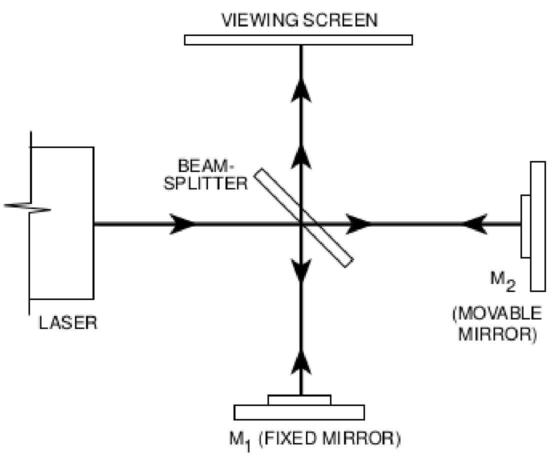


Figure 1.1.: Basic Michelson interferometer optics

Figure 1.1 shows a diagram of a Michelson interferometer's basic parts. A beam of light from the laser source strikes the beam-splitter. The beam-splitter is designed to reflect 50% of the incident light and transmit the other 50%. The incident beam therefore splits into two beams; one beam is reflected toward mirror M1, the other is transmitted toward mirror M2. M1 and M2 reflect the beams back toward the beam-splitter. Half the light from M1 is transmitted through the beam-splitter to the viewing screen and half the light from M2 is reflected by the beam-splitter to the viewing screen.

However, if the two beams of light originate from the same source, there is generally some degree of correlation between the frequency and phase of the oscillations of the two beams. At one point in space the light from the beams may be continually in phase. In this case, the combined field will always be a maximum and a bright spot will be seen. At another point the light from the two beams may be continually out of phase and a minima, or dark spot, will be seen.

Thomas Young was one of the first to design a method for producing such an interference pattern. He allowed a single, narrow beam of light to fall on two narrow, closely spaced slits. Opposite the slits he placed a viewing screen. Where the light from the two slits struck the screen, a regular pattern of dark and bright bands became visible. When first performed, Young's experiment offered important evidence for the wave nature of light.

Young's slits function as a simple interferometer. If the spacing between the slits is known, the spacing of the maxima and minima can be used to determine the wavelength of the light. Conversely, if the wavelength of the light is known, the spacing of the slits could be determined from the interference patterns.

In this way the original beam of light splits, and portions of the resulting beams are brought back together. The beams are from the same source and their phases highly correlate. When a lens is placed between the laser source and the beam-splitter, the light ray spreads out. An interference pattern of dark and bright rings, or fringes, is seen on the viewing screen, as shown in Figure 1.2[3].

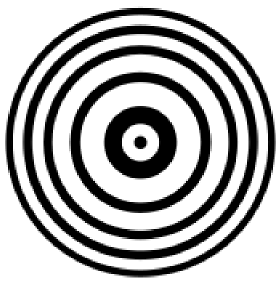


Figure 1.2.: Interference pattern

Since the two interfering beams of light were split from the same initial beam, they were initially in phase. Their relative phase when they meet at any point on the viewing screen, therefore, depends on the difference in the length of their optical paths in reaching that point. By moving mirror *M2*, the path length of one of the beams can be varied. Since the beam traverses the path between *M2* and the beam-splitter twice, moving *M2* $1/4$ wavelength nearer the beam-splitter will reduce the optical path of that beam by $1/2$ wavelength. The interference pattern will change; the radii of the maxima will be reduced so they now occupy the position of the former minima. If *M2* is moved an additional $1/4$ wavelength closer to the beam-splitter, the radii of the maxima will again be reduced so maxima and minima trade positions. However, this new arrangement will be indistinguishable from the m original pattern.

By slowly moving *M2* a measured distance d_m, and counting m, the number of times the fringe pattern is restored to its original state, the wavelength of the light, λ can be calculated as:

$$\lambda = \frac{2d}{m} \tag{1.1}$$

If the wavelength of the light source is known, the same procedure can be used to measure d_m.

1.6. Operation

The Pasco OS-8501 Michelson Interferometer is shown in Figure 1.3. The alignment of the beamsplitter and the movable mirror *M2* is easily adjusted by loosening the thumbscrews that attach them to the interferometer. The fixed mirror *M1* is mounted on an alignment bracket. The bracket has two alignment screws to adjust the angle of the mirror.

The movement of *M2* toward and away from the beam-splitter is controlled and measured using the micrometer knob. **Each division of the knob corresponds to $1\mu m = 1 \times 10^{-6} m$ of mirror movement.**

[3] Do not be concerned if your pattern shows irregularities or has fewer fringes. As long as fringes are clearly visible, measurements will be accurate.

Pasted Layer

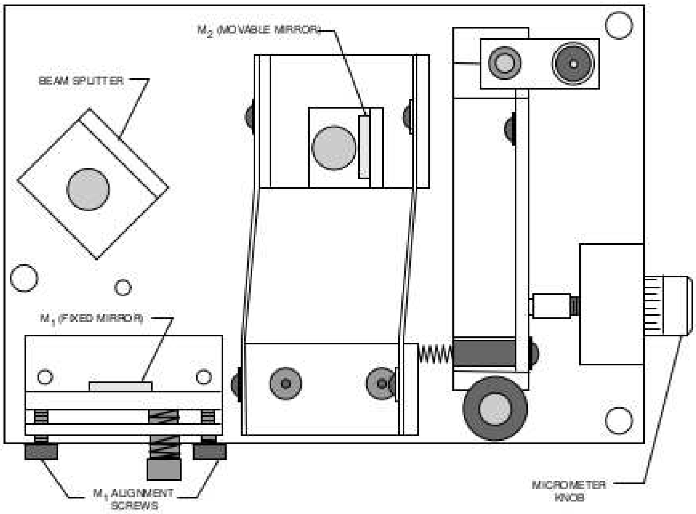


Figure 1.3.: Pasco Interferometer

To measure the wavelength of light, the movement of *M2* must be measurable for distances on the order of 10^{-6} meters. Just as important is as the mirror moves, its reflective surface must remain perpendicular to the axis of the incident light beam.

A taut-band carriage is used to maintain the alignment of the reflective surface of *M2* as it moves. The mirror is mounted in a cradle that is fixed to two semi-rigid aluminum bands. With this set-up the mirror is free to move, but its movement is constrained to a line parallel with the beam axis.

Pasted Layer

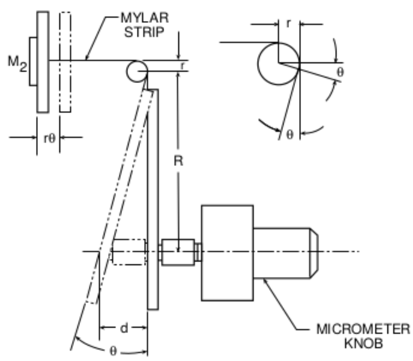


Figure 1.4.: mirror movement mechanism

The micrometer mechanism controls and measures the movement of *M2*. The cradle of *M2* is attached to a mylar strip that is attached to a lever arm. The displacement of the lever is controlled with the micrometer knob.

Suppose the micrometer knob is turned so it pushes the lever in by a distance d (see Figure 4). The angle of the lever arm changes by an amount θ such that $d = R \tan\theta$, as shown. Since the angle change is always small, $R \tan\theta = \mathrm{R}\theta$, to a close approximation. This change in the lever arm angle causes the mylar strip to be pulled further around the lever post by an amount $r\theta$, where r is the radius of the lever post. The mirror is therefore pulled away from the beam-splitter by the amount $r\theta$.

In this way, a relatively large displacement of the lever $d = R\theta$ results in a much smaller displacement of the mirror $d_m = r\theta$. By selecting appropriate values for r and R , the motion of *M2* is controlled so that each division on the micrometer dial corresponds to $1\mu m$ of mirror movement.

1.7. Aligning the Interferometer

The interferometer alignment will be complete and possibly demonstrated. The following alignment procedure is for those using a PASCO scientific Optics Bench. If you are not using an Optics Bench, tape a straightedge to a flat level surface. The straightedge will provide a substitute for the alignment rail of the optics bench.

1. Loosen the thumbscrew that holds the beam-splitter and rotate the beam-splitter so it is out of the beam path of the laser as shown in Figure 5. Then loosen the thumbscrew that holds M2, the movable mirror. Adjust the rotation of M2 so the laser beam is reflected directly back toward the aperture of the laser. (The reflected beam need not be at the same height as the incident beam, but it should strike the front panel of the laser along a vertical line through the aperture.) Hold M 2 in position and tighten the thumbscrew.
2. Place the laser and the interferometer on the Optics Bench, approximately 10 - 20 cm apart (Figure 5). Be sure that the edges of both units are flush against the alignment rail of the bench. Place a viewing screen as shown. (A blank sheet of white paper taped to the cover of a book provides a convenient screen.) Turn on the laser.
3. Rotate the beam-splitter so its surface is at an angle approximately 45° with the incident beam from the laser. two sets of laser spots will be visible on the viewing screen, corresponding to the two paths that the beam takes in reaching the screen. (Each path results in more than one laser spot because of multiple reflections within the beam-splitter.) Adjust the beam-splitter so the two sets of laser spots are as close as possible, then tighten the thumbscrew to secure the beam-splitter.
4. Using the alignment screws, adjust the angle of M1 until the two sets of laser spots are superimposed on the viewing screen (the two brightest spots must be superimposed).
5. Place the lens holder on the optical bench as shown in Figure 7. Be sure its edge is flush against the alignment rail. Then place the 18 mm focal length lens on the lens holder (it attaches magnetically). Adjust the position of the lens on the holder so the light from the laser, now spread out by the lens, strikes the center of the beam-splitter. If you have performed the alignment correctly, you will see an interference pattern of concentric rings on the viewing screen. If the alignment is not just right, the center of the fringe pattern may not be visible on the screen. Adjust the alignment screws on M1 very slowly as needed to center the pattern.

1.8. Experiment: Measuring the Wavelength of Light

1.8.1. Purpose

1. To measure the wavelength of the diode laser's light.

1.8.2. Theory

In many scientific and industrial uses of interferometers, a light source of a known wavelength is used to measure incredibly small displacements of about $1\mu m$. However, if you know the distance of mirror movement, you can use the interferometer to measure the wavelength of a light source. In this experiment you will use the interferometer to measure the wavelength of your laser light source.

1.8.3. Procedure

NOTE: Whenever you reverse the direction in which you turn the micrometer knob, there is a small amount of give before the mirror begins to move. This is called mechanical backlash, and is present in any mechanical system involving reversals in direction of movement. By beginning with a full counterclockwise turn, and then turning only counterclockwise when counting fringes, you can eliminate backlash in your measurement.

1. Align the laser and interferometer as described in the preceding section, so an interference pattern of circular fringes is clearly visible on your viewing screen.
2. Adjust the micrometer knob so the lever arm is approximately parallel with the edge of the interferometer base. In this position the relationship between knob rotation and mirror movement is most nearly linear.
3. Turn the micrometer knob one full turn counterclockwise. Continue turning counterclockwise until the zero on the knob is aligned with the index mark.
4. If you are using a blank piece of paper as your viewing screen, make a reference mark on the paper between two of the fringes. You will find it easier to count the fringes if the reference mark is one or two fringes out from the center of the pattern.
5. Rotate the micrometer knob slowly counterclockwise. Count the fringes as they pass your reference mark. Continue until a predetermined number of fringes has passed your reference mark (count at least 20 fringes). As you finish your count, the fringes should be in the same position with respect to your reference mark as they were when you started to count.
6. Record d_m, the distance that the movable mirror moved toward the beam-splitter due to the the micrometer knob having been turned. Remember, each division on the micrometer knob corresponds to $1 \mu m$ of mirror movement.
7. Count another 20 fringes and record d_m. Make a table with further fringe counts and distance d_m moved. Count at least 200 fringes in groupss of 20.

1.8.4. Analysis

1. Plot of graph of fringe count as a function of mirror distance moved d_m.
2. Determine the slope with error.
3. Using equation 1.1, calculate the laser light's wavelength λ with error.

1.9. Experiment: Measuring the Index of Refraction for Air

1.9.1. Purpose

1. Measure the index of refration of air.

1.9.2. Theory

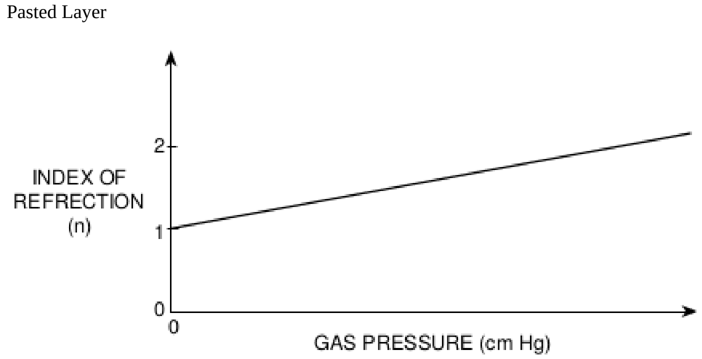
For light of a specific frequency, the wavelength λ varies according to the formula

$$\lambda = \frac{\lambda_o}{n}$$

where λ_o is the wavelength of the light in a vacuum, and n is the index of refraction for the material in which the light is propagating.

For reasonably low pressures, the index of refraction for a gas varies linearly with the gas pressure. For a vacuum, where the pressure is zero, the index of refraction is exactly one. A graph forthe refraction index as a function of pressure is shown in Figure 1.6. The measurements you make in this experiment will allow you to calculate the slope of this graph for air. From that, numerical values can be determined for the index of air refraction at various pressures.

Figure 1.6.: Index of refraction as a function of gas pressure



If a thickness t of a substance having a refractive index n is introduced into one arm of the interferometer, the optical path of that arm is increased because light travels more slowly in the substance than in vacuum, and consequently the light has a shorter wavelength since the light's frequency does not change.

In this part of the experiment an air cell is introduced into one arm and the air is nearly exhausted. With the cell at atmospheric pressure the optical path is nt, whereas it is t with a vacuum. Thus the change in optical path for 1 pass is .

$$\Delta t_{1pass} = (n-1)\,t$$

Since the light traverses the cell twice the total change in optical path is

$$\Delta t_{2pass} = 2\,(n-1)\,t$$

A change in total optical path of length λ will cause a number of fringes m to be created or destroyed, where

$$2\,(n-1)\,t = m\lambda \tag{1.2}$$

Rather than simply measuring m for complete evacuation of the air cell, measure the fringe shift as a function of pressure change. The relationship applicable is the above with the addition of ratios of temperature and pressure: $2\,(n-1)\,t\frac{273[K]}{T[K]}\frac{P[mmHg]}{760[mmHg]} = m\lambda$ or:

$$2\,(n-1)\,t = m\lambda\frac{T[K]}{273}\frac{760[mm\,Hg]}{P_{cell}} \tag{1.3}$$

where $P_{cell} = P_{room} - P_{gauge}$ is the initial cell pressure in mm Hg when fully evacuated

P_g is the varying gauge pressure reading during the measurement phase in mm Hg

P_{room} is the room pressure in the lab

T the absolute temperature of the gas in the cell in Kelvin

m is the fringe number with 0 occurring at minimum P_{cell} for our purposes.

t is the length of the air cell, to be deterimined.[4]

When P_{cell} is replaced by $P_{room} - P_{gauge}$, Equation 1.3 can be rearranged into the form of $y = (slope)x + b$ as shown in equation 2.4, where y is the fringe count m, and x is the variable pressure P :

$$m = -\frac{2\,(n-1)\,t}{\lambda}\frac{273[K]}{760[mmHg]T}\cdot P_{gauge} + \frac{2\,(n-1)\,t}{\lambda}\frac{273[K]P_{room}}{760[mmHg]T} \tag{1.4}$$

[4] $4.95cm \pm 0.05cm$ for gray Ealing apparatus, $3.81cm \pm 0.05cm$ for large black Pasco apparatus, smaller Pasco apparatus TBA

1.9.3. Procedure

NOTE: Miscounting of fringes, which is easily done, can be seen clearly on the graph and corrections made there.

1. Measure the temperature and barometric pressure of the lab. A barometer is located in the SW corner of BB2-35 and has a vernier scale allowing measurement of pressure to $^1/_{10}mm$.
2. Mount the air cell in position in the path of the beam as shown in Figure 1.7. A small hand-pump is used to reduce the pressure in the cell. Evacuate the cell as much as the pump will allow, which gives the initial minimum pressure P_{cell} at maximum P_{gauge}.
3. Leak air slowly into the air cell and count fringes m while recording the pressure readings on the gauge P_{gauge}. Collect about eight points from the lowest pressure to room pressure. This can be tricky, more than one trial can be required. Simultaneos pressure and fringe count is the goal.

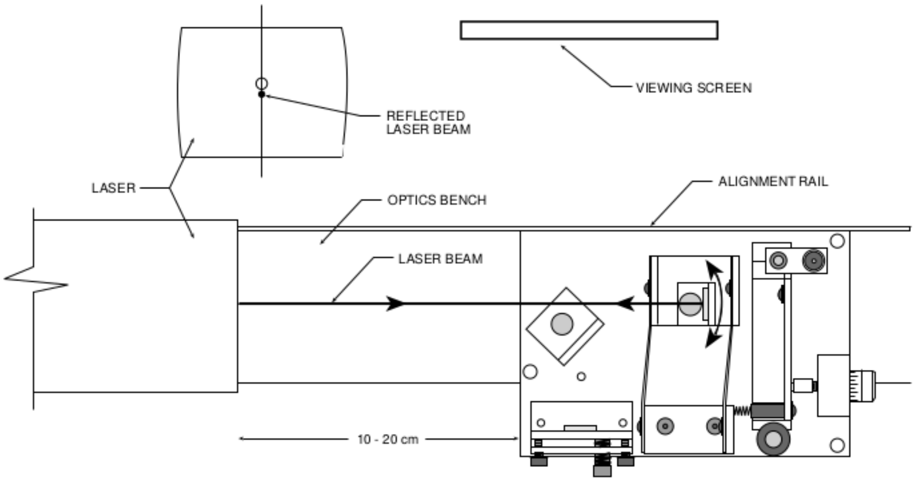
1.9.4. Analysis

1. Plot m as a function of P_{gauge}, which will yield a straight line graph with the slope:

$$slope = -\frac{2\,(n-1)\,t}{\lambda}\frac{273}{760T} \tag{1.5}$$

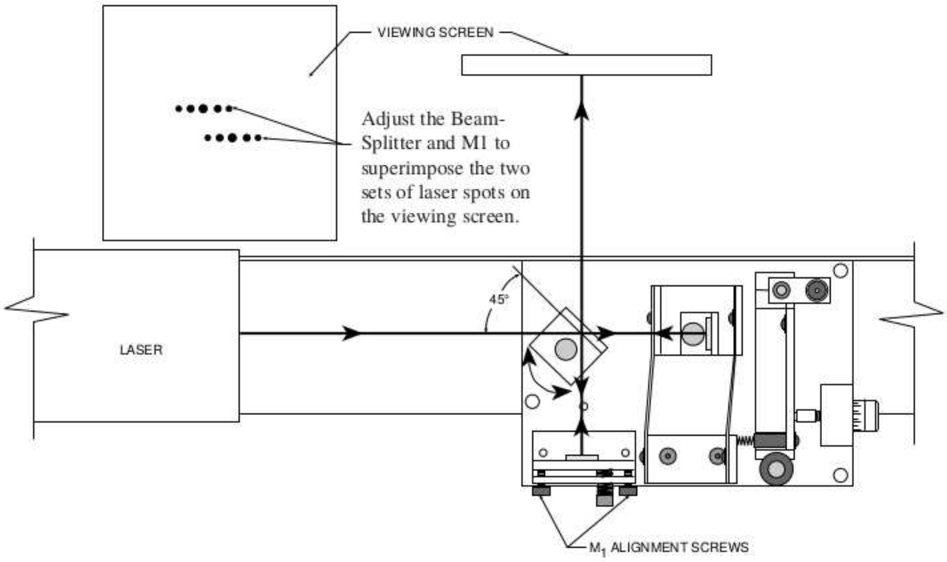
2. Determine the slope with error and use equation 2.5 to calculate a value n for air with error.
3. Determine a second value for n with error from your graph of your data. Consult equation 2.4.

Pasted Layer



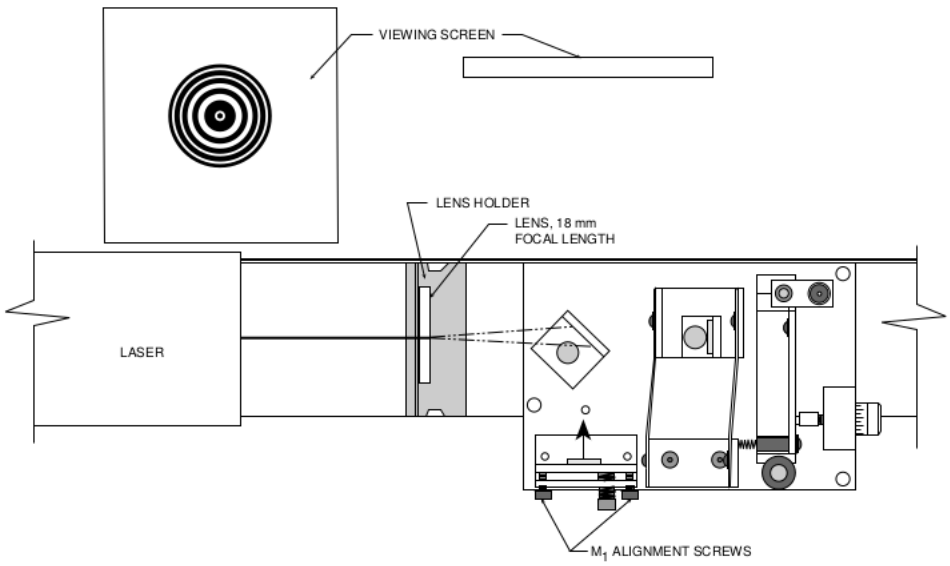
(a) Adjusting *M1*

Pasted Layer



(b) Aligning laser spots

Pasted Layer



(c) Positioning the lens

Figure 1.5.

Pasted Layer

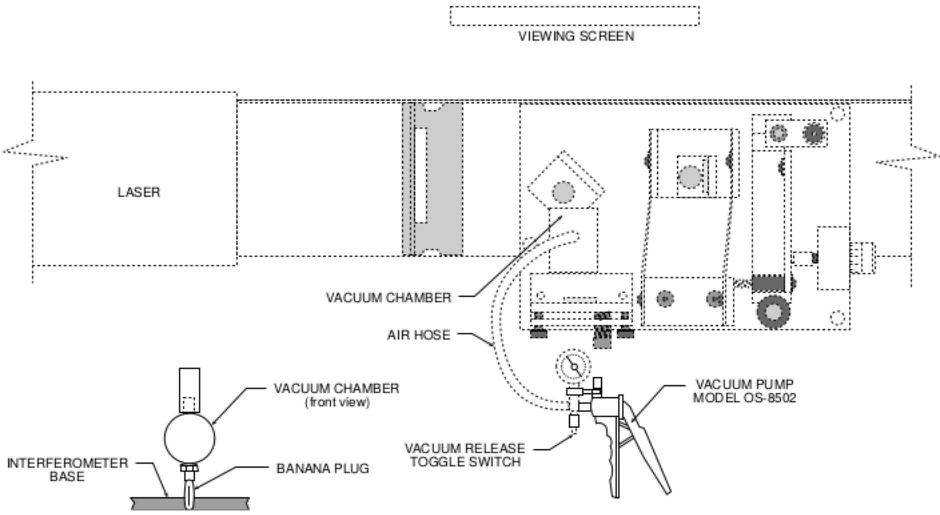


Figure 1.7.: Adding the air cell

2. The Michelson Interferometer (Older equipment version)

2.1. Laser Safety

This experiment makes use of diode and/or Helium-Neon lasers. Lasers can cause retinal damage if used improperly. ***In order to avoid this, never look into a laser and its output beam***. This means you must be aware of the beam's location. If the beam is being reflected, refracted or split, you must also know the path of those beams.

The lasers in this lab are Class II[1] which are not harmful normally, unless a person deliberately stares into the beam. Laser protective eye-wear is normally not necessary as the person will usually look away or close their eye. Flash blindness can occur. Any focusing or concentrating of the beam could increase the risk to one's eyes.

2.2. Purpose

In this experiment, the Michelson Interferometer is used

- to measure the wavelength of light from a helium-neon laser.
- to measure the refractive index of air.
- to measure the separation between the D lines in the emission spectrum of sodium.
- to detect white light fringes and measure the refractive index of glass.

The interferometer is fully described in most standard optics texts. The following are useful references: Jenkins & White, Fundamentals of Optics; Wood, Physical Optics; Shong, Concepts of Classical Optics.

Figure 2.1 shows the positions of the components in a Michelson Interferometer. A fringe pattern is observed on a screen placed at the bottom of the diagram where the light exits. If the light source is not overly bright, the fringe pattern is directly observed with the eye. Otherwise it is projected onto a screen.

2.3. Theory and Experiments

NOTE: The first two experiments use the Pasco interferometer. It is much more easily aligned than the Ealing interferometer. The Ealing interferometer is used for the second two experiments: the sodium D line measurement and white light fringes. Your lab demonstrator will show how the interferometer is adjusted. Please do not adjust the Ealing interferometer.

2.3.1. EXPERIMENT: Wavelength of light from a helium-neon laser.

Adjust the interferometer to produce circular fringes as discussed in the reference text. With the mirrors plane parallel circular fringes can be observed. If the two planes are not parallel, i.e. they form a wedge shaped air gap; the fringes look straight or are slightly curved. By recognizing the fringe pattern and the way it changes with fine adjustment of the mirror mounts, you will soon be able to set up the required fringe pattern. The light of a red HeNe laser has a wavelength of 632.8nm in vacuum. The micrometer screw on this Pasco interferometer moves the mirror 25 microns for each rotation.

[1]output power $\leq$ 1mW, visible wavelengths only

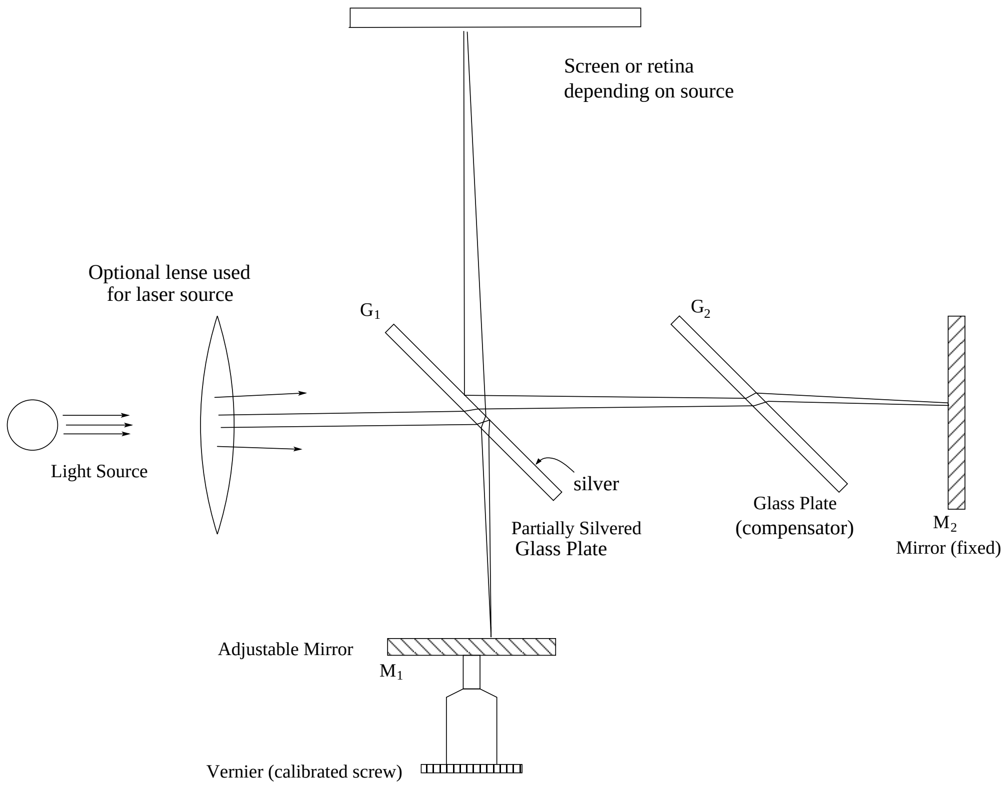


Figure 2.1.: Michelson Interferometer.

To calculate the wavelength of the source it is simply a matter of measuring the distance that one mirror moves to move the pattern one fringe, i.e. create or destroy one fringe.

For m fringes created or destroyed

$$2d = m\lambda \tag{2.1}$$

Count fringes as a function of distance moved and plot a graph d vs. m, and hence from the slope calculate λ. Measurements of d every twenty fringes, with a total fringe count of at least three hundred is a reasonable basis for measurement. You will find that the data is very precise and you will probably be able to see from the graph if you miscount.

2.3.2. EXPERIMENT: Measurement of the refractive index of air.

(See Jenkins and White, 2nd ed.., p. 249; 3rd ed., p. 256)

If a thickness t of a substance having a refractive index n is introduced into one arm of the interferometer, the optical path of that arm is increased because light travels more slowly in the substance than in vacuum, and consequently the light has a shorter wavelength (the frequency does not change).

In this part of the experiment an air cell is introduced into one arm and the air is nearly exhausted. With the cell at atmospheric pressure the optical path is nt, whereas it is t with a vacuum. Thus the change in optical path is $\Delta t_{1pass} = (n-1)\,t$.

Since the light traverses the cell twice the total change in optical path is

$$\Delta t_{2pass} = 2\,(n-1)\,t$$

A change in total optical path of will cause a number of fringes m to be created or destroyed, where

$$2\,(n-1)\,t = m\lambda \tag{2.2}$$

Rather than simply measuring m for complete evacuation of the air cell, in this experiment measure the fringe shift as a function of pressure change. The relationship applicable is the above with the addition of ratios of temperature and pressure: $2(n-1)t\frac{273[K]}{T[K]}\frac{P[mmHg]}{760[mmHg]} = m\lambda$ or:

$$2(n-1)t = m\lambda\frac{T[K]}{273}\frac{760[mm\,Hg]}{P_{cell}} \tag{2.3}$$

where $P_{cell} = P_{room} - P_{gauge}$ is the initial pressure in mm Hg

P_g is the varying gauge pressure reading during the measurement phase in mm Hg

P_{room} is the room pressure in the lab

T the absolute temperature of the gas in the cell in Kelvin

m is the fringe number with 0 occurring at minimum P_{cell} for our purposes.

t is the length of the air cell $= 4.95cm \pm 0.05cm$ for the gray Ealing cell and $3.81cm \pm 0.05cm$ for the black Pasco cell, $3.00cm \pm 0.05cm$ for gray Pasco cell.

When P_{cell} is replaced by $P_{room} - P_{gauge}$, Equation 2.3 can be rearranged into the form of $y = (slope)x + b$ as shown in equation 2.4, where y is the fringe count m, and x is the variable pressure P :

$$m = -\frac{2(n-1)t}{\lambda}\frac{273[K]}{760[mmHg]T}\cdot P_{gauge} + \frac{2(n-1)t}{\lambda}\frac{273[K]P_{room}}{760[mmHg]T} \tag{2.4}$$

Miscounting of fringes which is easily done, can be seen clearly on the graph and corrections made.

1. Measure the temperature and barometric pressure of the lab. A barometer is located in the SW corner of BB2-35 and has a vernier scale allowing measurement of pressure to $\frac{1}{10}th$ of a millimeter.
2. Mount the air cell in position in the path of the beam which is traveling to the movable mirror. A small hand-pump is used to reduce the pressure in the cell. Evacuate the cell as much as the pump will allow, which gives the initial minimum pressure P_{cell} at maximum P_{gauge}.
3. Leak air slowly into the air cell and count fringes m while recording the pressure readings on the gauge P_{gauge}. Collect about eight points from the lowest pressure to room pressure.
4. Plot m as a function of P_{gauge}, which will yield a straight line graph with the slope:

$$slope = -\frac{2(n-1)t}{\lambda}\frac{273}{760T} \tag{2.5}$$

2.3.2.1. Question

1. Determine a second value for n from your graph of your data. Consult equation 2.4.

2.3.3. EXPERIMENT: Measurement of the separation of the D lines in the spectrum of sodium.

Change to the Ealing spectrometer for the rest of the lab. The emission spectrum of sodium contains a number of lines in the visible region of the spectrum, the most intense being two closely spaced lines in the yellow-orange region.

For a single spectral line of λ_1, using the interferometer

$$2d = m_1\lambda_1$$

For a line with wavelength λ_2, a different number of fringes would pass in the same distance

$$2d = m_2\lambda_2$$

where $m_1 > m_2$ if $\lambda_1 < \lambda_2$.

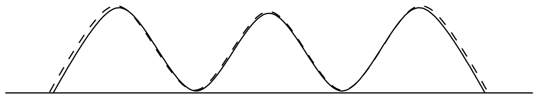


Figure 2.2.: Two fringe patterns overlapping to produce strong fringes. Note the dashed line is of slightly longer wavelength.

If the light used contains these two wavelengths the fringe pattern seen in the field of view will be the superposition of the two fringe patterns which have slightly different separations.

If the two fringe patterns align exactly in the field of view, a single fringe pattern will be observed as shown in figure 2.2.

However, if one pattern is displaced from the other by a separation equal to half the distance between maxima, then the two intensity patterns add in such a way that the field of view is uniformly illuminated, and there appear to be no fringes as shown in figure 2.3.

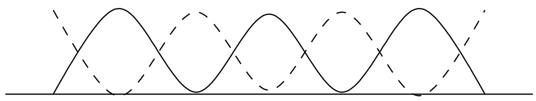


Figure 2.3.: Two fringe patterns overlapping to produce no fringes.

For two wavelengths λ and $\lambda + \Delta\lambda$, and a fringe count m and $m-1$ respectively, and for a movement of the mirror d

$$2d = m\lambda = (m-1)(\lambda + \Delta\lambda)$$

In this case d represents the distance between adjacent intensity cancellations which is a shift of one complete fringe peak (of say λ_1) relative to the other peak(s) of the λ_2 pattern. Continuing,

$$m\lambda = m\lambda - \lambda + m\Delta\lambda - \Delta\lambda$$

and solving for $\Delta\lambda$ gives

$$\Delta\lambda = \frac{\lambda}{(m-1)}$$

Since $m = \frac{2d}{\lambda}$ we have:

$$\Delta\lambda = \frac{\lambda^2}{2d} \tag{2.6}$$

if $d \gg \lambda$, which will be the case if $\Delta\lambda \ll \lambda$

2.3.4. Procedure:

1. Use the Ealing interferometer with a sodium lamp and observe fringes in the field of view. Move the mirror over a range of position and observe the visibility of the fringes.

2. Note that this Ealing interferometer's micrometer screw gauge introduces a multiplication factor of 5x, hence d is must be calculated by dividing the micrometer positions by 5. This is a result of the lever which connects the micrometer screw to the movable mirror.

3. Measure the distance between positions where the fringes seem to nearly or completely disappear. Do this for five consecutive positions and record the mirror position each time.

4. Calculate the difference between adjacent readings. This distance is d in equation 2.6. Use the four values of d to get a mean with a mean error.

5. Calculate $\Delta\lambda$ with error. In equation 2.6, λ is equal to the average of the two wavelengths in the sodium D lines = 589.29nm.

6. Look up the actual value for the two D lines in sodium and calculate their difference for comparison to your value.

2.3.5. EXPERIMENT: Refractive index of a section of glass and white light fringes.

The effect seen (canceling of fringe patterns) with the sodium D lines will occur on a very much wider scale if white light is used because the view will be the superposition of many fringe systems. If the two mirrors are positioned so that the optical paths in the two arms are exactly equal, a white light fringe system can be observed.

This is quite difficult the first time you try to do it and requires more patience than any other part of the experiment. The problem is that there is only one position where you have any chance of seeing anything, and it is not obvious whereabouts the movable mirror should be positioned. If you are unlucky you may find that you are moving the rear mirror away from the position you seek. One other problem if you scan the rear mirror too quickly, or even blink while the mirror is moving you won 't see them either. Your lab demonstrator can assist you with positioning the mirror to produce white light fringes.

This time it is not possible to use the procedure that you used with the gas, because the introduction of a large finite change of optical path causes the the fringe patterns to overlap and cancel, so you cannot count how many fringes were created or destroyed.

However, white light fringes only occur when the two optical paths in each arm are equal. Thus if you produce white light fringes with and without the solid in place, you must move the mirror to a new position which recreates white light fringes, and the distance moved will be equal to the change in optical path.

$$d = (n-1)\,t$$

where d is the distance the mirror was moved to reproduce the fringes and t is the thickness of glass measured with a micrometer, then

$$n = \frac{d+t}{t} = 1 + \frac{d}{t} \tag{2.7}$$

Thus the refractive index of the glass sample n can be determined.

2.3.6. Procedure

1. Without the round glass plate, center the white light fringe patter in your field of view. Record the position of the micrometer screw.

2. Introduce the glass plate into the arm of the interferometer which has the fixed mirror. Locate the white light fringes again. It should be perpendicular to the light's path.

3. Record the position where the fringes just appear again and the position where the fringes fade away.

4. Measure the thickness t of the glass sample with the micrometer.

5. Calculate the refractive index n of the sample.

2.3.6.1. Questions

1. Which measurement in step 3 should you use to calculate the refractive index n of the glass sample and why?

2. Why are the white light fringes occurring over such a wide range of mirror positions with the glass in place, compared to when there wasn't any glass present in the interferometer. Hint: Consider the shape of the glass.