Experiment 1: Introduction to Interferometry*

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Abstract

In this experiment, you will use a Michelson interferometer and a Fabry-Perot interferometer to determine the wavelength of light emitted by a helium-neon laser.

1 Introduction

In 1881, 78 years after Young introduced his two-slit experiment, A.A. Michelson designed and built an interferometer using Young's interference principle. Originally Michelson designed his interferometer as a means to test for the existence of the ether, a hypothesized medium in which light propagated. Due in part to his efforts, the ether is no longer considered a viable hypothesis.

In general, an interferometer can be used in two ways. If the characteristics of the light source are accurately known (wavelength, polarization, intensity), changes in the beam path can be introduced and the effects on the interference pattern can be analyzed. On the other hand, by introducing specific changes in the beam path, information can be obtained about the light source that is being used. In this experiment, you'll use the interferometer, in both the Michelson and Fabry-Perot modes, to measure the wavelength of your light source. You will also investigate the polarization of your laser source.

2 Equipment

Laser (OS-9171)	Laser Alignment Bench (OS-9172)
Basic Interferometer (OS-9255A)	Interferometer Accessories (OS-9256A): Component Holder Calibrated Polarizers (2)

*Adapted from *Instruction Manual and Experiment Guide for the PASCO scientific models OS-9255A thru OS-9258A Precision Interferometer.*

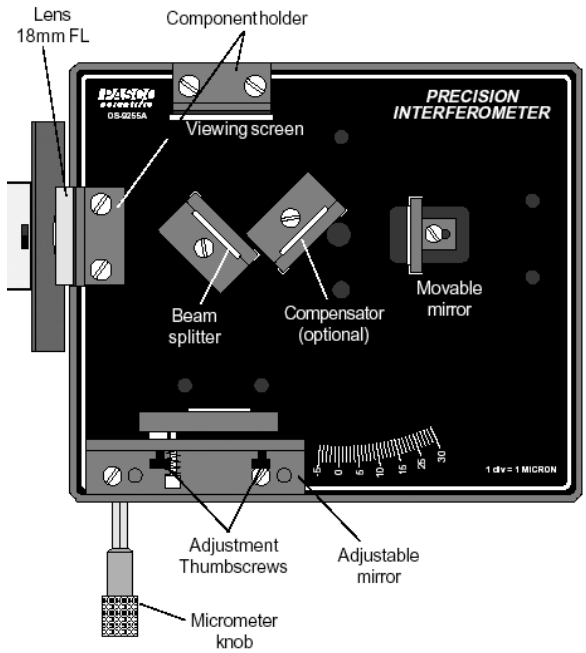

Figure 1: PASCO Precision Interferometer: Michelson Mode Setup

3 Procedure

Thoroughly read and understand the provided equipment manual *Instruction Manual and Experiment Guide for the PASCO scientific models OS-9255A thru OS-9258A Precision Interferometer* (hereafter referred to as the *Manual*) before beginning this experiment.

3.1 Michelson Mode

1. Align the laser and interferometer in the Michelson mode as described in the "Setup and Operation" section of the *Manual* (see Figure 1), so an interference pattern is clearly visible on your viewing screen.

2. Adjust the micrometer knob to a medium reading (approximately 50 μm). In this position, the relationship between the micrometer reading and the 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. Record the micrometer reading.

   NOTE: When 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 all mechanical systems involving reversals in direction of movement. By beginning with a full counterclockwise turn, and then turning only counterclockwise when counting fringes, you can eliminate errors due to backlash.

4. Adjust the position of the viewing screen so that one of the marks on the millimeter scale is aligned with one of the fringes in your interference pattern. 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 some predetermined number of fringes have passed your 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. Record the final reading of the micrometer dial.

6. Record d_m, the distance that the movable mirror moved toward the beam-splitter according to your readings of the micrometer knob. Remember, each small division on the micrometer knob corresponds to one μm (10^{-6} meter) of mirror movement.

7. Record N, the number of fringe transitions that you counted.

8. Repeat steps 3–7 at least five times times, recording your results each time.

3.2 Polarization

1. Place a polarizer between the laser and the beam-splitter. Try several polarization angles. How does this effect the brightness and clarity of the fringe pattern?

2. Remove that polarizer and place a polarizer in front of the fixed or movable mirror. Try several polarization angles. How does this effect the fringe pattern?

3. Now try two polarizers, one in front of the fixed mirror, and one in front of the movable mirror. First rotate one polarizer, then the other. Again, note the effects.

3.3 Diffuse Light

1. Your kit should come with a diffuser, which is nothing more than glass with a rough surface. This just takes the collimated laser beam and causes the light to scatter in different directions. If your kit does not come with a diffuser, you should be able to accomplish the same results with a piece of tissue paper.

2. Place the diffuser in front of the laser and describe what happens to the diffraction pattern.

3. What happens when you put the diffuser in one of the two interferometer arms? Explain what is happening in both cases. Think about the coherence of the beam in both situations.

3.4 Matches

With a fringe pattern on the screen light a match and hold it in one of the arms just below the laser beam and describe what you see on the screen. (Its ok if the laser goes through the flame) What is happening to cause this?

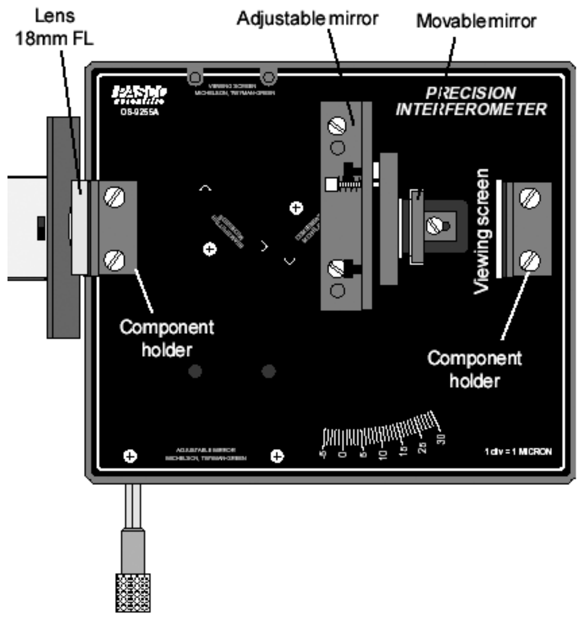

Figure 2: Precision Interferometer: Fabry-Perot Mode Setup

3.5 Fabry-Perot Mode

1. Repeat the procedure of section 3.1 using the Fabry-Perot mode of the PASCO Precision Interferometer as described in the "Setup and Operation" section of the *Manual* (see Figure 2).

4 Analysis

4.1 Calculating λ

1. For each Michelson mode trial, calculate the wavelength of the laser light ($\lambda = \frac{2d_m}{N}$) and the associated uncertainty, then average your results (remember to propagate the uncertainties).

2. For each Fabry-Perot mode trial, calculate λ, then average your results. The same formula applies. Again report all uncertainties

4.2 Polarization

1. From your observations in step 1 of the Polarization procedure, can you determine the polarization characteristics of your light source? Does it vary with time?

2. Do your observations from step 2 give you any more information about the polarization of your source?

3. From your observations in step 3, do cross-polarized beams interfere?

5 Additional Requirements

You should ensure that your laboratory report addresses the following questions.

1. Include a brief derivation for the formula you used to calculate λ for one of the interferometer setups.

2. What does the lens do and how does it cause the bullseye pattern on the screen?

3. In the calculation to determine the value of λ based on the micrometer movement, why was d_m multiplied by two?

4. Why move the mirror through many fringe transitions instead of just one? Prove this mathematically. Why take several measurements and average the results?(Think about what is happening to the uncertainties"

5. In Fabry-Perot mode, was your measured λ the same? If not, can you speculate about possible reasons for the difference? Do you have more confidence in one value as opposed to the other?

6. Compare your results with the known value of λ for a helium-neon laser (look it up if necessary). If there is a difference, to what do you attribute it? (Think about the micrometer, mirrors, etc.

7. When measuring mirror movement using the micrometer dial on the interferometer, what factors limit the accuracy of your measurement?

8. When measuring mirror movement by counting fringes using a light source of known wavelength, what factors might limit the accuracy of your measurement?

9. What role does polarization play in producing an interference pattern?

6 Useful formulas

Sample Mean:

$$\bar{x} = 1/N \sum x_i \tag{1}$$

Sample variance:

$$\sigma^2 = \frac{1}{N-1} \sum (x_i - \bar{x})^2 \tag{2}$$

Standard deviation:

$$\sigma = \sqrt{(}\sigma^2) \tag{3}$$

Propagation of uncertainties when adding or subtracting.$x = a + b$

$$\sigma_x = \sqrt{\sigma_a^2 + \sigma_b^2} \tag{4}$$

Propagation of uncertainties when multiplying or dividing $x = a \times b$

$$\sigma_x = x\sqrt{\left(\frac{\sigma_a}{a}\right)^2 + \left(\frac{\sigma_b}{b}\right)^2} \tag{5}$$