PHYSICS 252   EXPERIMENT NO. 1
THE MICHELSON INTERFEROMETER

Introduction

To better understand the interferometer used by Michelson and Morley, we use a simplified version of their instrument to measure the wavelength of the laser light source used. The second part of the experiment consists in measuring the index of refraction of air by counting fringe shifts in the interference pattern.

In the interferometer pictured below, the light from a (nearly) monochromatic source is split into two beams which recombine to form a visible pattern of areas of constructive and destructive interference; i.e. bright and dark fringes. When the effective length of one of the optical paths is changed by some means, then any given point on the interference pattern shifts from light to dark or vice-versa for each half-wavelength of path length change.
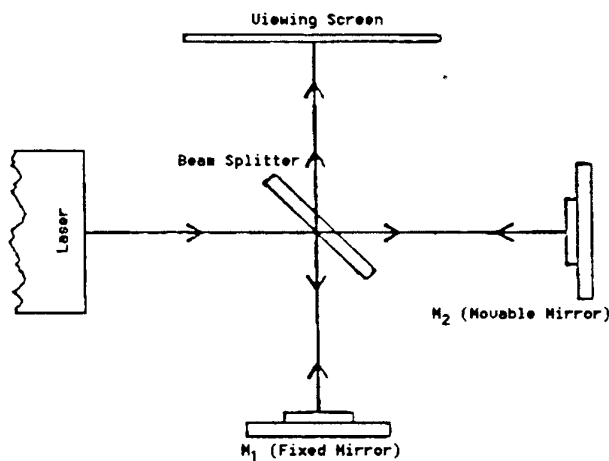
Note: the actual interference pattern will most probably be more irregular and show less fringes.

Figure 1: Michelson Interferometer
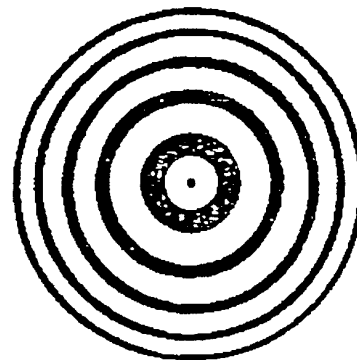
Figure 2: Interference Pattern
Note: the actual interference pattern will most probably be more irregular and show less fringes.

Alignment

Your instructor will discuss the alignment of the interferometer using a laser. BE VERY CAREFUL WITH THE EQUIPMENT AS IT IS DELICATE AND EXPENSIVE! Never

touch the mirror surfaces or bump, or drop any part of the apparatus. Consecutively, the movable mirror *M*2, the beam-splitter, the fixed mirror *M*1, and the lens holder with lens are aligned. A blank sheet of white paper taped to the cover of a book provides a viewing screen.

Whenever the laser is turned on, NEVER look directly into the beam or its reflection!

Measurement of the Laser wavelength

1. Adjust micrometer knob so the lever arm is approximately parallel with the edge of the interferometer base. Then turn the micrometer knob one full turn counterclockwise. Continue turning counterclockwise until the zero on the knob is aligned with the index mark.
2. Make a reference mark on the paper between two of the fringes.
3. Rotate micrometer knob slowly counterclockwise. Count the fringes as they pass your reference mark. Continue until 25 to 40 fringes have passed your reference mark. As you finish your count, the fringes should be in the same position with respect to your reference mark as they were when your started the count.
4. Record d_m, the distance that the movable mirror moved toward the beam-splitter as you turned the micrometer knob. Each division on the micrometer knob corresponds to 1 μm of mirror movement.
5. If the number of fringes that crossed your reference mark is *m*, the wavelength of the laser light is given by:

$$\lambda = 2 \, d_m \, / \, m$$

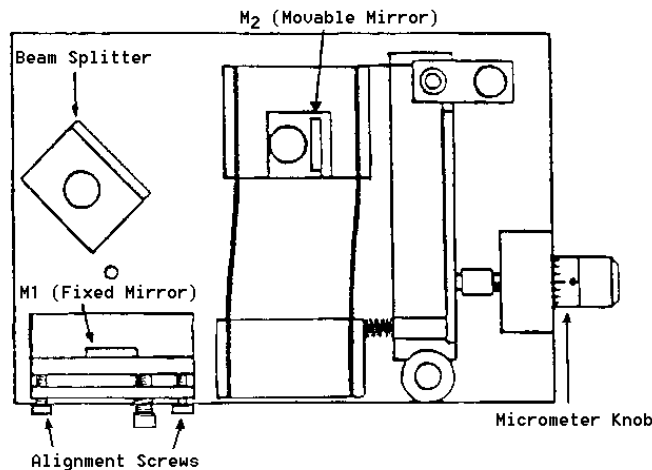Derive the above equation and calculate λ and compare to the specified value of 632.8 nm.

Figure 3: The Interferometer

Measuring the index of refraction of air

Evacuate the air cell with the small hand-operated vacuum pump provided. When the best partial vacuum is attained, stop pumping and you will find that air slowly leaks back into the cell. As the cell pressure rises, the fringe pattern will shift. One partner should count the number of fringe shifts m as time goes by, and the other should record the pressure as a function of fringe-shift number. The relationship between the pressure change Δp and the number of fringe shifts m is given by (derive!):

$$m = (n - 1) \cdot (2\,d/\lambda) \cdot (\Delta p/p_{atm}) ,$$

where λ is the light wavelength, n is the index of refraction of air at atmospheric pressure, d is the length of the air cell, p_{atm} is the current atmospheric pressure, and $\Delta p = p_{cell} - p_{initial}$, where p_{cell} is the air pressure inside the cell at the m-th fringe shift, and $p_{initial}$ the initial cell pressure. In the derivation of this expression one may assume that n depends on p as n-1 $\propto p$.

Plot m versus Δp on a graph and draw the best straight line through your data points. From the slope of this line and a knowledge of d, λ, and p_{atm} determine n. Estimate the experimental uncertainty on your measurements (by error propagation of various error sources) and compare to the literature value.

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