Precision Interferometer

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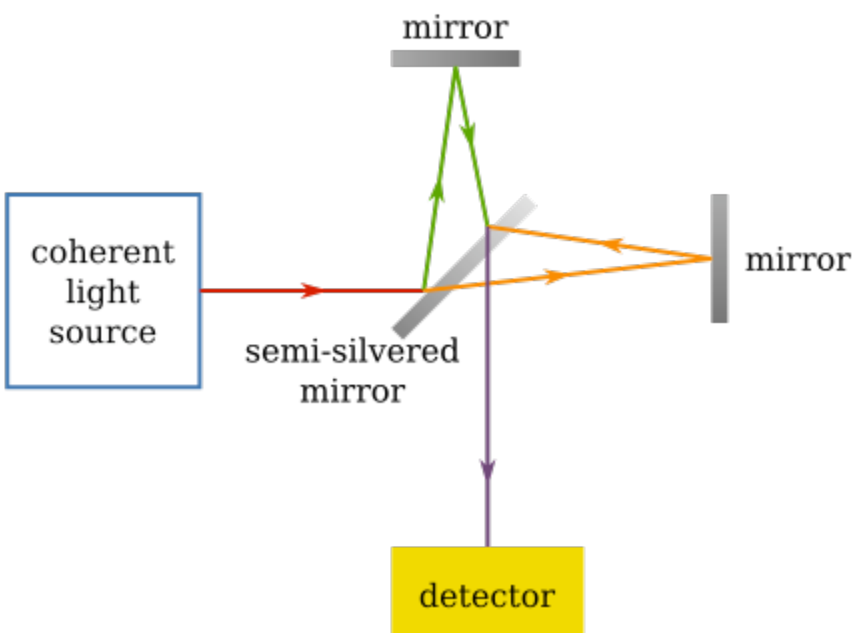
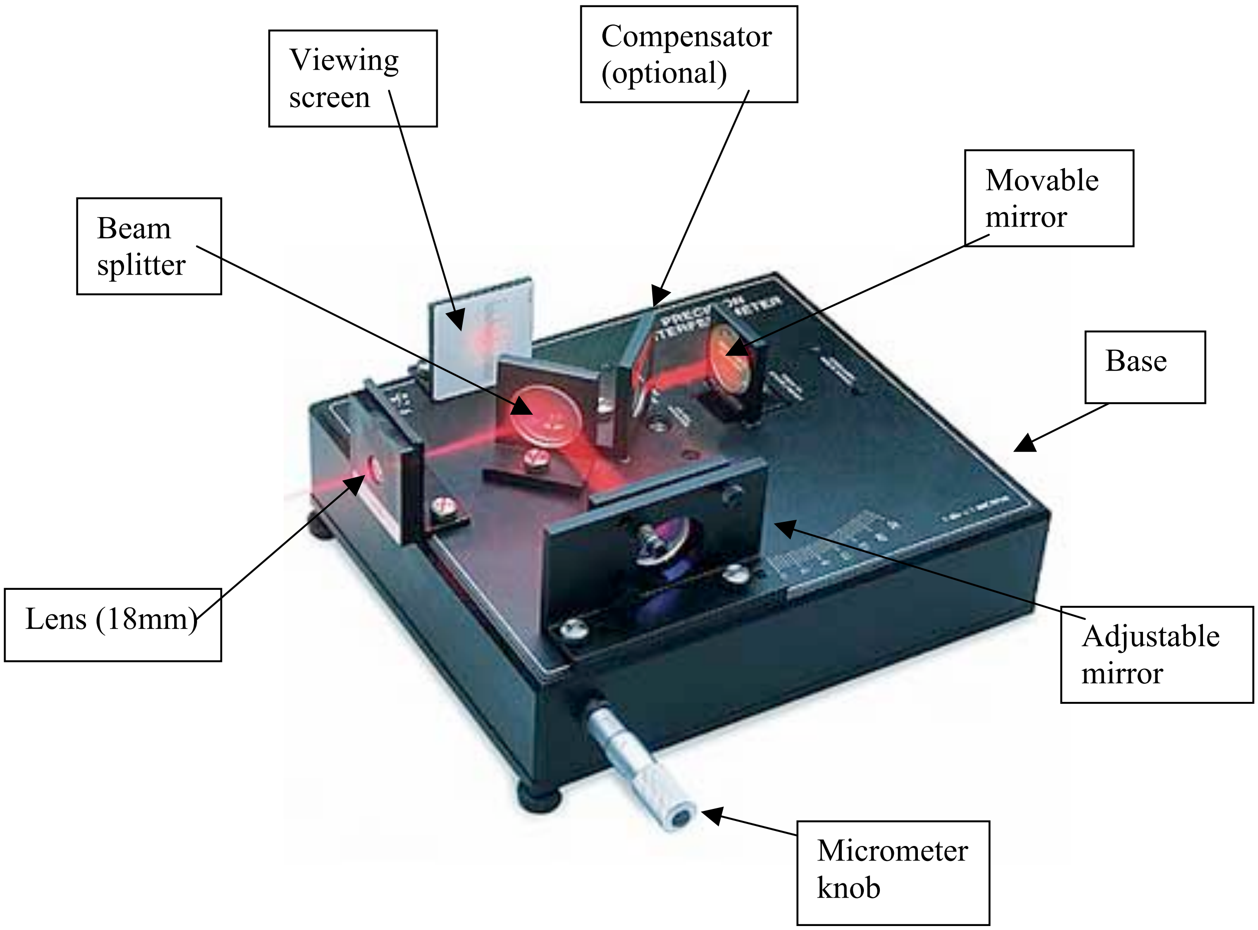
Introduction

Thomas Young, an English genius and polymath, dabbled in many subject areas and was fluent in Latin and Greek and was familiar with French, Italian, Hebrew, German, Chaldean, Syriac, Samaritan, Arabic, Persian, Turkish and Amharic. Young was the first to make use an interferometer in his famous single slit experiment. He used this experiment to provide evidence for the wave nature of light. Then in 1881, Albert A. Michelson invented the Michelson Interferometer. He built this to measure the ether, which was thought to be the medium through which light and other electromagnetic waves propagate through space. Using his interferometer, Michelson had a beam of light pass through a silvered mirror (called the beam splitter) set at a 45 degree angle to the incoming light source. This split the beam of light in two reflecting 50% of the light to one mirror and 50% to another mirror. One mirror was perpendicular to the beam splitter and the other mirror was directly behind the beam splitter. The light beams reflecting off the two mirrors then were reflected back to the beam splitter on the back side of it and came together on the detector. See diagram below:



Methods

The apparatus we used to measure the wavelength of light of the laser is called a Precision Interferometer and is pictured below.



The interferometer works by shining a laser through the lens and it then hits the beam splitter, which true to its name, splits the one beam in two. One beam goes through the beam splitter and hits the movable mirror and is deflected back to the opposite side of the beam splitter which is then deflected onto the viewing screen. The other beam is deflected from the beam splitter onto the adjustable mirror and is deflected onto the viewing screen. When the two beams come together on the viewing screen (which has millimeter tick marks on it), they create an interference pattern in which the laser beam appears as fringes and the crests and troughs of the wave are visible. When the micrometer knob is turned, it causes the movable mirror to move very minutely. The distance the movable mirror moves is recorded in micrometers on the micrometer knob. The tick marks on the knob that represent micrometers are scaled in such a way that they can be counted by the naked eye.

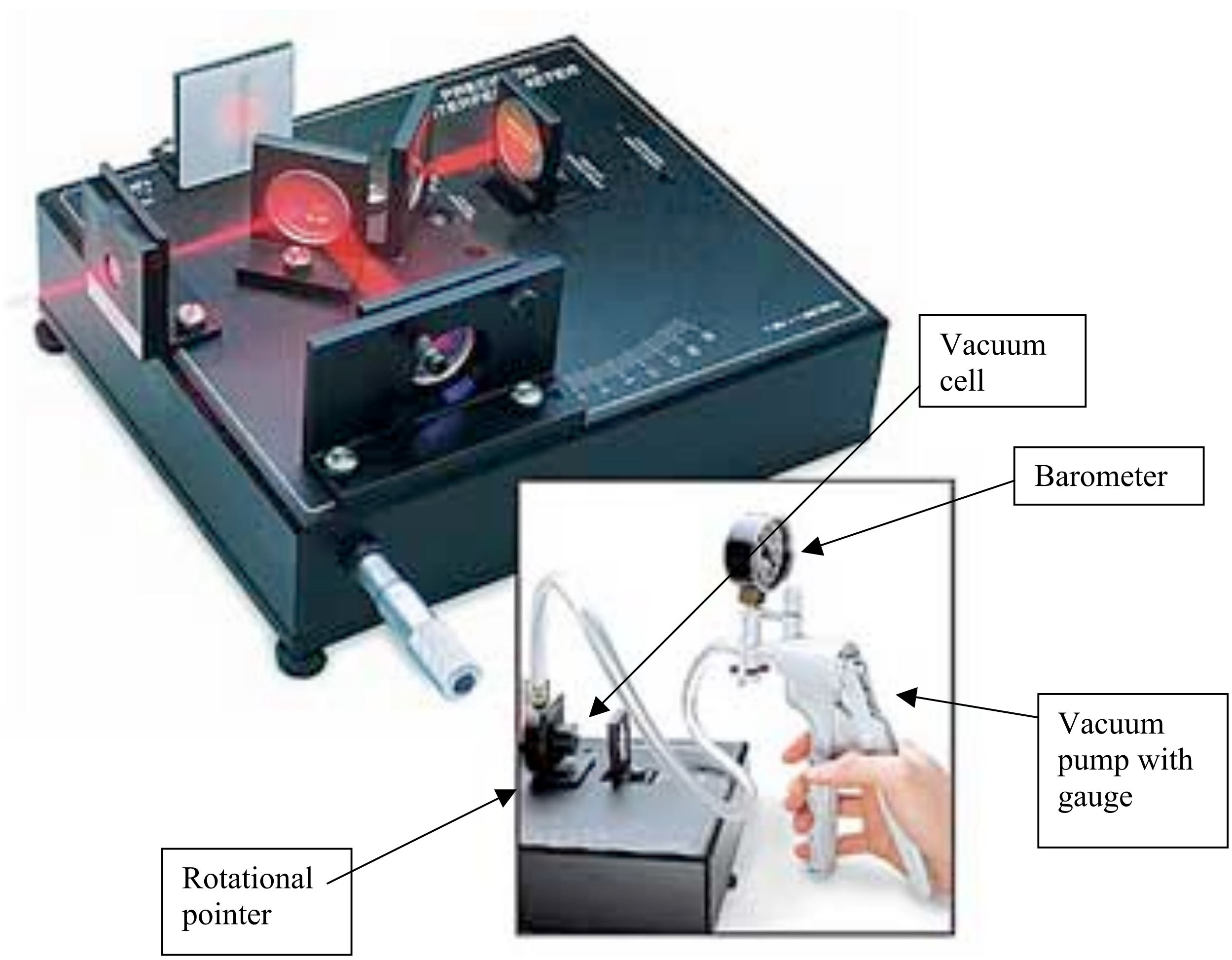
Experimental Procedure 1:

We had the interferometer set up in the Michelson mode, which is shown above. The compensator was not used though. We initially set the micrometer to 50μm and turned it one turn counterclockwise to get rid of the backlash, which set the micrometer knob to 75μm. Backlash is present in all mechanical devices and occurs when you change the direction of movement. In our case, we were going from clockwise when we reset the micrometer knob, to counterclockwise when we were counting the fringes.

We aligned one of the fringes with a tick mark on the viewing screen and then turned the knob which caused the fringes to pass the tick mark and counted to a predetermined number of 25. After we completed our 25th turn we recorded the final micrometer reading. We repeated this procedure two more times. Our data are summarized in a table in the results section below.

Experimental Procedure 2:

For experiment two, we placed a rotational pointer (after much effort for a sought after picture, our search proved to be in vain) between the movable mirror and the beam splitter.



Then we attached the vacuum cell to the magnet backing of the rotational pointer and hooked the air hose of the vacuum pump up to the air hole of the vacuum cell. We recorded the initial reading on the pressure gauge which was the atmospheric pressure. Then we slowly pumped the air out of the vacuum cell, which caused the fringes on the viewing screen to start moving and we counted them as they passed a specified point on the viewing screen. We counted until all the air was pumped out of the vacuum cell and the needle on the pressure gauge stopped increasing and we subsequently recorded the final reading of the pressure.

Results

Experiment 1

	Trial 1	**Trial 2**	**Trial 3**
d_m	8µm	8µm	10µm
N	25	25	25
Initial	75µm	75µm	75µm
Final	83µm	83µm	85µm
λ	6.4E-7	6.4E-7	8.0E-7

In the table above d_m is the distance that the movable mirror moved toward the beam splitter according to the reading of the micrometer. N is the predetermined number of fringes we counted that passed our marker on the viewing screen as we turned the knob. "Initial" was the initial reading on the micrometer knob before we started counting the fringes. "Final" was the reading on the micrometer knob when we reached N fringes. Lambda, λ, is the wavelength of the laser beam that we were trying to measure. We calculated lambda using the equation, $\lambda = (2d_m)/N$. We averaged our three results and obtained a value of 6.93E-7. Our percent error was only 9.5%.

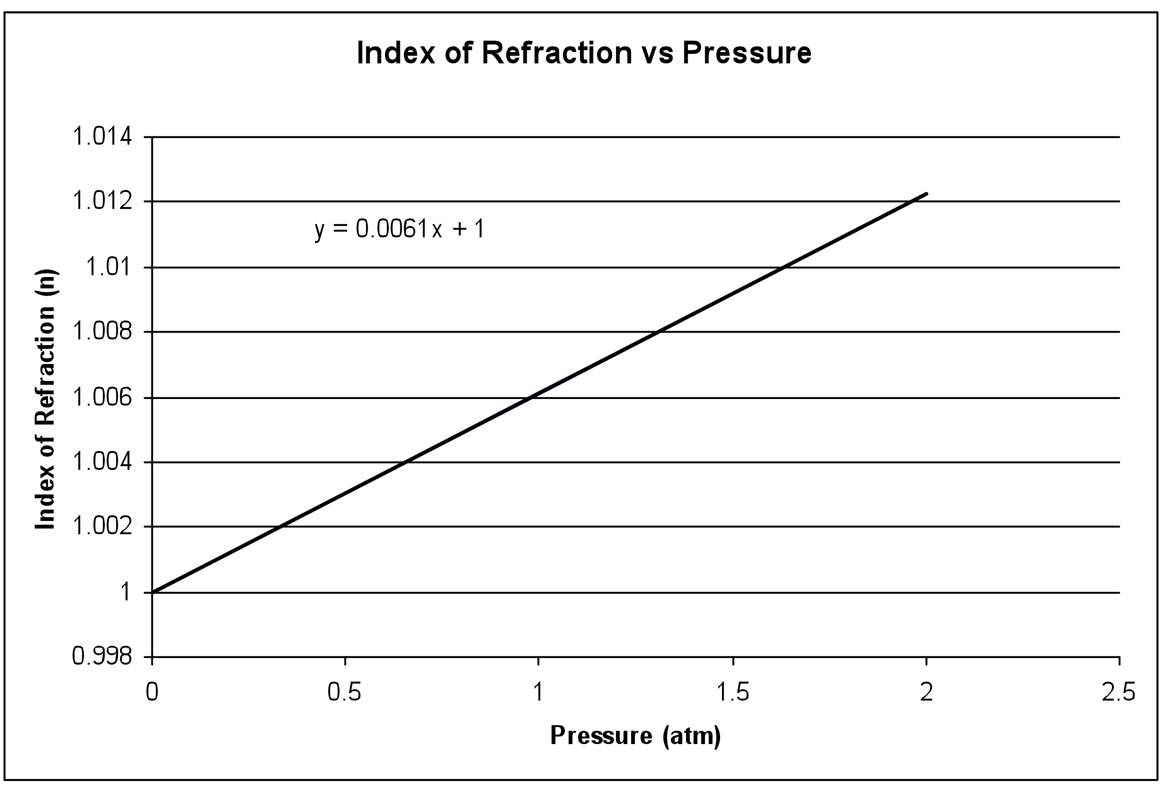
Experiment 2

P_i	40mmHg	.0526atm
P_f	65mmHg	.0855atm

In the table above, P_i = the initial reading of the barometer and P_f = the final reading of the barometer. We counted the number of fringes, N=18, until the needle inside the gauge of the barometer stopped moving due to the completer evacuation of air inside the vacuum cell. We made a graph which gave us a straight line of the index of refraction versus pressure inside the vacuum cell. Using the slope of the line we obtained the index of refraction in air. We calculated the slope using the following equation:

$$\frac{n_i - n_f}{P_i - P_f} = \frac{N\lambda_0}{2d(P_i - P_f)}$$

Which gave us a slope, m=0.00613. The index of refraction for air that we calculated was 1.00613. Our percent error is 0.58% error. A graph of this line is below.



Discussion

The most frustrating part of this lab was not having instructions in the manual on how to use the micrometer knob. We finally decided to ask the professor how to use it. After being enlightened on the instruction of knob turning and reading, we were both impressed at the ingenuity of such an invention. Another characteristic of the interferometer that captivated our attention was the turning of the micrometer knob made the movable mirror move in tiny increments.

One benefit of this experiment was that it really nailed down the notion of interference in wave patterns. From General Physics that concept seemed to be confusing until we did this lab. Actually being able to see the real data right in front of our eyes was a treat in that we could manipulate the interference pattern ourselves and see the effects. Our results were very close to the actually theoretical value for the wavelength of the laser that we used and for the index of refraction in air. We were very pleased with our percent errors recorded above. One thing that we both found surprising was being able to use the vacuum pump to make the fringes move.

Literature Cited

1. S. L. Swenson, *The ethereal aether; a history of the Michelson-Morley-Miller aether-drift experiments, 1880-1930* (Austin, University of Texas Press, 1972).

2. MS. Stony Brook. *Http://www.physics.sunysb.edu/Physics/*. Stony Brook Department of Physics and Astronomy, 1998. Web. 27 Mar. 2010. http://felix.physics.sunysb.edu/~allen/252/PHY251_Michelson.html