Report

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Abstract

This report covers the realization of the Michelson's Interferometer experiment which consisted in the measurement of a laser beam length and the air refraction index. Such measurements are achieved by measuring the changes of the interference pattern when waves with different phases overlap. In this experiment will be causing the pattern of the interference rings to change by varying the distance of the mirrors that reflect the beams trough a millimeter screw, therefore we will know the displacements between the sources(distance mirrors moved) and we can calculate the wave length. The vice-verse process can be made, measuring the displacements knowing the wave length. Therefore the interferometer has many applications such as detection of gravitational waves and astronomical measurements.

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1 Introduction

In general, an interferometer is an optical instrument that produces optical interference. The Michelson interferometer became well known for its use by Albert Michelson and Edward Morley in the famous Michelson-Morley experiment (1887) in a configuration which would have detected the earthâs motion through the supposed luminiferous aether that most physicists at the time believed was the medium in which light waves propagated. The null result of that experiment essentially disproved the existence of such an aether, leading eventually to the special theory of relativity and the revolution in physics at the beginning of the twentieth century. The Michelson Interferometer has also been used to provide evidence for the special theory of relativity, to detect and measure hyperfine structure in line spectra, to measure the tidal effect of the moon on the earth and to provide a substitute standard for the meter in terms of wavelengths of light. s of light, among many other applications [1] [2] In order to facilitate the learning and understanding of this instrument we decided to create a didactic webpage about the topic.

2 Equipment

- He–Ne Laser(wave length=0,6328 mm);
- Beam splitter
- Lens
- 2 Mirror
- Micrometer screw
- Vacuum pump with pressure gauge;
- Vacuum cell
- Screen/White paper

3 Experimental Procedure

The lab experiment can basically be divided in two parts. The first on where is determined the wave length of the laser beam trough the relation between the distances of the mirror displacements and the changes on the interference rings.

- Part A–Determination of the laser beam wave length
  1. Remove the divergent lens if it is in front of the laser beam. Turn on the laser;
  2. Put in the beam splitter at an angle of 45° with respect to the beam axis, and adjust its tilt to make the two beams parallel to table;
  3. Verify if the mirrors are perpendicular to the beam axis and check that the rays are incident on the two mirrors E1 and E2 and on the target;
  4. Use the fixed mirror adjusting screws to overlap the two beams on the target;
  5. Put the lens at the laser output and orient it so that the fringed pattern is visible;
  6. Set the micrometer to zero;
  7. Slowly move the movable mirror using the micrometer screw and go counting the number of fringes that are happening in the target. Move the mirror in the distance necessary to observe 20 bands;
  8. Reset the micrometer and and repeat the procedure 7 five more times. record the measurements;
  9. Calculate the mean value of d and the standard deviation of the measures;
  10. Use equation (5) to calculate the laser wavelength and the associated error.

- Part B–Determination of the air refraction index
  1. Insert the glass chamber in the path of one of the interferometer beams;
  2. Remove the divergent lens and align the two beams again;
  3. Connect the manual vacuum pump tube to the chamber; lowly vary the pressure in the chamber and go counting the fringes of interference;
  4. Stop, each time you pass 3 fringes and record the manometer reading;
  5. Proceed until the gauge value checks at 40 cm Hg ($\approx$ 0.526 bar); note that the value read gauge corresponds to the difference in pressure between atmospheric pressure and chamber.
  6. Record the measurements made and plot the variation of the refractive index with the pressure variation.
  7. Perform a linear regression to determine the slope of the curve a and the ordinate at source b.
  8. Determine the associated uncertainties. Note that in these measurements the uncertainty originates in the pressure measurement $\triangle$P. The uncertainty in the value of n will be $\triangle$n = $|$a$\triangle$P$|$.
  9. Determine the value of the refractive index of the air $n_{ar} = 1 + b$.
  10. Compare the result obtained with the real value n = 1,00029.

4 Results and Discussion

Through the procedure we realize six different measurements of distance after register the shifting of 20 fringes (table 1). With this results we can calculate the average value of the measurements through the arithmetic method (equation (1)) and the deviation trough equation (2).

With these values we can calculate the wave length of the beam utilizing equation (2), obtaining the value indicated on the table, and as we can observe it differs a lot from the expected value (Table 1). The reason that could be behind this that the count of the fringes about the distance moved with the micrometer was made wrong . Along with the measurement and uncertainty errors the calculated value for the wave length was much smaller than the expected.

The air refraction index experiment was not realized therefore there aren't any measurements to present.

All the calculations where made considering air refraction index n=1 and for 20 counts of fringes($\triangle$m = 20).

4.1 Tables and Equations

Table 1: Registered measurements

Measurement	d(μm)	Average(μm)	Deviation(μm)	λ calculated(μm)	Expected λ(μm)
1	$10 * 10^3$	$11.6667*10^3$	$0.816497*10^3$	166.67	632.8
2	$12 * 10^3$				
3	$12 * 10^3$				
4	$12 * 10^3$				
5	$12 * 10^3$				

$$Average_{-v}alue = \frac{\sum_{i=1}^{n} measured\_value_i}{n-1} \tag{1}$$

$$d = \sqrt{\frac{(\sum_{i=1}^{n}(measured\_value_i - average\_value))^2}{n-1}} \tag{2}$$

$$\frac{n}{\lambda_o} 2d = \triangle m \tag{3}$$

5 Webpage

In scope of the lab experiment we opt to create a a webpage in the didactic intention for future students or any person who want to understand or perform the Michelson's interferometer experiment. The reason we chose a webpage is that we saw it as a more dynamic mean of learning which most people feel more comfortable with and more accessible.

5.1 Structure

With the intention of making the webpage more user-friendly we opt for a structure resourceful on multimedia content. The site takes form of a continuous page document where the content is organized in different sections placed in the best chronological order to facilitate the user's understanding. In the home page for the site is a video explaining succinctly the experiment, the procedure and the theory behind it, this way a user who enters the webpage for the first time will have a general idea of the content it will find there. There is a main tap always attached on the top of the screen that allows users to access more quickly to a specific content of their will. (Fig.3)

5.2 Content

For the home page we wanted to have content that would give quickly and briefly an idea to users who attempt the page for the first time and even call their attention and curiosity to deepen in the Michelson's interferometer experiment and scroll trough the rest of the page. Therefore we choose a video of the experiment conduction in the MIT, the is demonstrated step-by-step the equipment and procedure of the experiment and then the theoretical explanation on how the interferometer works.

ragged2e Then we contextualized the experiment and talked briefly about it's historical importance, after that we passed to a more theoretical part were we explain the working principle of the interferometer, describing the physical phenomena of waves that support such principle and the equations that describe them.

After delving deeper into the theory governing this experiment, it's presented some of the main application for the Michelson's interferometer. Beginning with space and atmospheric applications we see the weight of the role that the interferometer has, as the results of its implementation and results, influences space explorations, the studies of space and upper atmosphere, and even the provisions of forecast on earth. Based on the principle of Michelson's interferometer it was developed upgraded versions of the device inclined to specific tasks, such as gravitational waves detection or Doppler widths and shifts measurements. Still in the space field, the detection of gravitational waves was a huge advance for science in the field of space, and with the Michelson's interferometer it became possible to calculate the waves origin's direction, this was made with LIGO instrument. It uses the vice versa principle of the Michelson's experiment explained here. That is instead of how we did it here, discovering the wave length by causing a know displacement, here they measure a displacement caused on the interferometer by the waves by knowing the wave length of the laser.

Other application is the Fourier-transform spectroscopy, which is a Michelson's interferometer but with only one movable mirror. It is a measurement technique whereby spectra are collected based on measurements of the coherence of a radiative source, using time-domain or space-domain measurements of the electromagnetic radiation or other type of radiation. the principle of working is basically generate a interferogram by the measurement of the mirror in many discrete positions and then converting the the interferogram into an spectrum.

For the end there is a collection of links and references to external resources who wishes to deepen his knowledge on the Michelson's interferometer, books, sites, articles. And for those who would like to replicate the experiment without the use of equipment we add a link to a simulator created by our fellow colleagues, which allows perform the experiment digitally.

5.3 Technologies and Algorithms

For the conception of the webpage we rely on to main technologies, HTML programming language, bootstrap 4.0 and some of JQuery. The website uses only front end software.

Front End

We can describe the front and back end as the exterior body and the brain of a person respectively. The front-end, also known as client-side development is the appearance of the webpage, everything involved with what the user sees, the web design, which the languages involved are normally HTML, CSS and Javascript. While the back end is the brain, responsible to make things function, update, security, databases, etc. This requires a more a deepen knowledge of programming as it involves more than just HTML and CSS but also PHP, JAVA, AJAX and C++ for example. The user doesn't see this, as it related to servers and databases.

HTML (HyperText Markup Language) is the backbone of the Web. Every website you visit is built with HTML. It takes care of all the structure and content. HTML5 is the current iteration of HTML on the Web, although sites built with older versions still run fine in your browser.

CSS (Cascading Style Sheets) is what controls the way the HTML looks on the page. CSS sets the colors, fonts, background images, and even the way the page is laid out (you can use CSS to arrange the HTML elements on a page however you want, even if itâs different than the order theyâre arranged in the HTML file). CSS3 is the current iteration of CSS on the Web, and adds a ton of features for things like basic interactivity and animations.

Now, you can create a website with just HTML and CSS, but itâs JavaScript thatâs really the gamechanger (plus, itâs whatâs causing all the aforementioned blurriness). To put it simply, JavaScript lets you add in interactivity, more complex animations, and even makes it possible to build fully featured Web applications.

As we opt to a webpage page with a format of a continuous page of document, there isn't more than a page on the website. Therefore it wasn't necessary to use back end here to connect the different pages, and since we're not using any other mechanisms that would need it such as forms or login options.

Bootstrap

Bootstrap is a free and open-source front-end framework for developing websites and web applications. The reason for choosing bootstrap 4.0 as framework is that it seemed to us as the more complete free toolkit for HTML e CSS languages we're using, with a rich library of templates for typography, forms, buttons, navigation and other front ending components, and also contains JavaScript extensions.

6 Conclusion

Due to the large margin of difference between the obtained value of the wave length to the expected value, we believe that an error was committed in the process of counting the fringes. Instead of counting the transition from light center to black center in the interference rings, constructive and destructive interference respectively (fig.1)), as half fringe, we count it as one, therefore the distance moved micrometer was smaller than it should have been. Leading to calculated value beneath the expected.

We believed that thought a webpage was the best way to transmit to future students the knowledge acquired through the elaboration of this project, as it prove to be a dynamic and attractive way to display information due to the clean design and organized structure that was adopted.

7 Special Thanks

Our thanks go to the physics department professor Carlos Vinhais for helping us throughout the development of the project, from the completion of the laboratory experiment to the conception of the report, giving us feedback on our doubts and which lines should be followed for a suitable conception of this report.

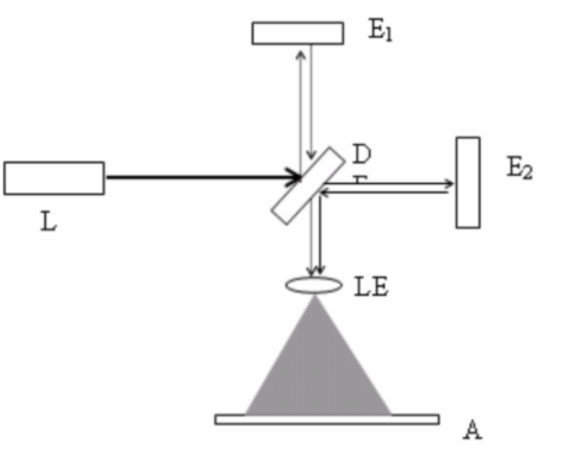

Figure 1: Assembly schematic

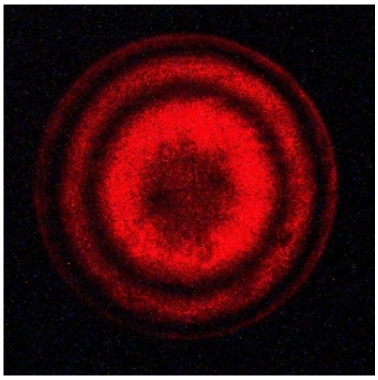

Figure 2: Interference rings

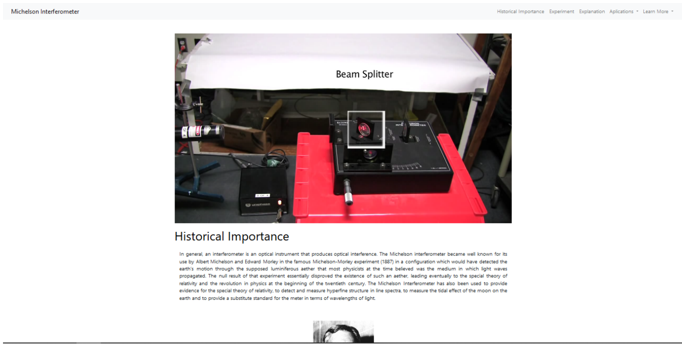

Figure 3: Webdesign 1

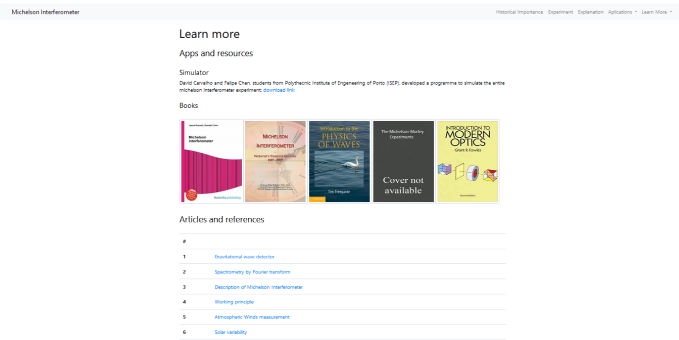

Figure 4: Webdesign 2

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