EXPERIMENT 12

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PHY 115L

INTRODUCTION

In this experiment I sought to learn how to operate a Michelson interferometer. Using the interferometer, I set out to observe the concentric ring interference pattern of two point sources, as well as how this pattern changes in response to changes in path length difference between the two sources. I then set out to measure the wavelength of the helium-neon laser with the interferometer. Finally, I sought to measure the index of refraction of air, exploiting the precision of the apparatus to determine its small deviation from the vacuum index of refraction.

RESULTS

Interference of Two Point Sources:

In this section, I used the Michelson interferometer to split one incident laser beam into two interfering virtual sources which I then observed on a screen at 90° to the incident beam. The pattern I observed was a set of concentric circular dark and light bands forming a bullseye. Depending on the path length difference of the two virtual sources, determined by the position of the interferometer mirrors, the bullseye was either observed at its center or off to the side of the center.

I was able to observe the fringes approach the center as I translated one of the mirrors forward a small amount. I was also able to observe the fringe spacing decrease as I moved the mirror perpendicular to the incident beam forward (towards the splitter). The fringe spacing changed since the path length of the mirror being moved forward got closer and closer to the path length of the fixed mirror, i.e. the path length difference got smaller. In my apparatus, I was unable to make exactly one fringe fill the entire view, but in theory this would mean the virtual sources were exactly coincident.

Measurement of the Laser Wavelength:

I now used the fringes of the interference pattern to determine the wavelength of the laser. Specifically, I counted the number of fringes crossing a specific spot on the screen as I moved one of the interferometer mirrors forward a measured amount. My results are as follow in table 1.

Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Trial | Mirror displacement (m) | | Number of fringes | | Laser wavelength (nm) | |
| 1 | 0.00004 | 0.000003 | 25 | 1 | 640 | 50 |
| 2 | 0.000085 | 0.000003 | 50 | 2 | 680 | 40 |

The reported wavelength of a helium-neon laser is 632.8nm, so both of my calculated wavelengths agreed with the true value. Unfortunately, the measurements were relatively noisy since their precision was limited by counting interference fringes by eye as well as imperfect linearity of the mirror translation screw.

Index of Refraction of Air:

To measure the index of refraction of air, I placed a small, transparent chamber in front of one of the interferometer mirrors. By filling this chamber with a variable amount of air, I would be able to observe changes in the interference pattern on the screen based on the relative change in phase due to refraction of the light beam. I initially closed the valve in the chamber such that air could be removed but not added, and then evacuated a measured amount of air from the chamber. I then slowly released the valve, allowing the chamber to regain full atmospheric air pressure (101.3 kPa) while counting the number of fringes that passed. I took the wavelength of the laser to be the reported value of 632.8nm and the width of the chamber was reported as 38.5mm. From these known values and measurements, I calculated the index of refraction using the relation for N observed fringes, atmospheric pressure , and evacuated air pressure . My measurements and calculations are as follow in table 2.

Table

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Trial | P0 (Pa) | ΔP (Pa) | | Number of fringes | | λ (nm) | L (mm) | Observed index of refraction | |
| 1 | 101300 | 21500 | 50 | 24 | 0.1 | 632.8 | 38.5 | 1.00093 | 0.005 |
| 2 | 101300 | 20000 | 50 | 22 | 0.1 | 632.8 | 38.5 | 1.00092 | 0.005 |

The reported index of refraction of air is 1.00029, which is within experimental uncertainty of my calculations. However, this is unsatisfactory since the experimental error is an order of magnitude larger than the change in index of refraction from vacuum to air, and therefore the method of measurement doesn’t permit sufficient precision. This experimental error comes from fluctuations in the pressure meter of the chamber as well as from counting fringes by eye.

SUMMARY

I successfully learned to use a Michelson interferometer while two point source diffraction in this experiment. I was able to observe the characteristic bullseye interference pattern and the changes in the pattern as a response to changes in path length difference and relative phase. I also succeeded in measuring the wavelength of the helium-neon laser using the interferometer, although I failed to produce the desired precision. I then used the interferometer to measure the index of refraction of air by passing one of the interferometer’s produced virtual sources through a chamber of variable air pressure. In doing so, I was able to fulfill each of the objectives outlined in the introduction. A question for a future experiment could be if it is possible to observe a 3-dimensional diffraction.