Michelson Interferometer

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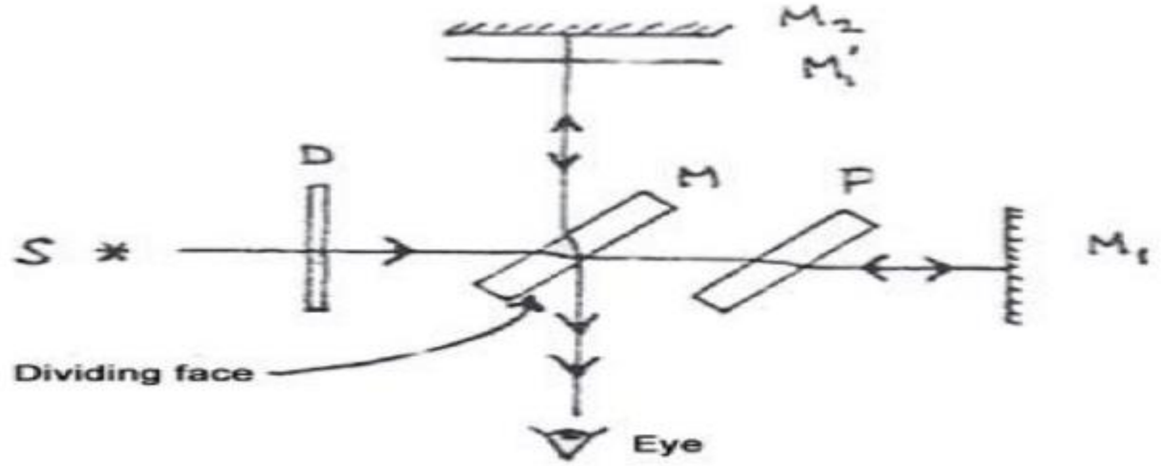
Abstract

This experiment was conducted to measure the refractive index of air, determine the dependence of the refractive index of air on its pressure, and to measure the wavelength difference of a close doublet. The refractive index of air was measured to be 1.000266 ± 9×10^{-6} by use of a mercury lamp with a mercury green filter to isolate the line of 546 nm spectral line. The refractive index of air was found to be 1.000306 ± 5×10^{-6} by calibration. It was found that the refractive index of air is directly proportional to the pressure of the air. The wavelength difference of the close band filter was found to be $2.45 \times 10^{-9} \pm 1.9 \times 10^{-10}$. The band pass of the green filter was found to be $24 \times 10^{-9} \pm 1.12\ 10^{-9}$.

Apparatus

Fig 1: Apparatus



M_1 = Mirror 1, $M_1{}'$ = Image of Mirror 1, M_2 = Mirror 2, S = Light Source, d = Diffusing Screen

Equipment as shown above was connected to rotary pump.

Theory

To **measure the refractive index of air**, the following equation was used:

$$2L(n_a - 1) = m\lambda$$

This equation was derived from the equation of the position of the interference minima in a thin film:

$$2n_{f_1}dcos(\theta_r) - 2n_{f_2}dcos(\theta_r) = Path\ Difference = m\lambda$$

Where:

n_f: Refractive Index of a Thin Film (which in this case are those of air and a vacuum)

d: Film Thickness (which in this case is equal to the length of the cell)

θ_r: Angle of reflection within the film (≈ 0)

L: Length of Cell (L= 5×10^{-2})

n_a: Refractive Index of Air

n_v: Refractive Index of a Vacuum (≈ 1)

m: Number of Fringes Observed

λ: Wavelength of Light Emitted

$$2n_{f_1}dcos(\theta_r) - 2n_{f_2}dcos(\theta_r) = m\lambda$$

$$\Rightarrow\ 2(n_a)(L)\cos(0) - \ 2(n_v)(L)cos(0) = m\lambda$$

$$\Rightarrow 2Ln_a(1) - 2(1)(L)(1) =\ m\lambda$$

$$\Rightarrow\ 2L(n_a - 1) = m\lambda$$

The average number of fringes observed (m) was found to be: 48.67 ± 1.56

The calculated refractive index of air n_a was found to be 1.000266 ± 9×10^{-6}

To **measure the refractive index of air by calibration**, the following equations were used:

$$\mathrm{k}\Delta y_n = 2n_a\Delta = 2\mathrm{L}(n_a - 1) = \lambda\, N_n$$

Where:

K: Calibration Constant

y_n: Value Measured on Micrometer_n

x_n: Horizontal Displacement of Image_n

N_n: Number of Fringes which Pass by the Pointer

which can be used to form the following equations:

$$k = \frac{N_1\lambda}{\Delta y_1}$$

&

$$n_a = \frac{\mathrm{k}\Delta y_2}{2\mathrm{L}} + 1$$

The average number of fringes observed was found to be: 31 ± 2.8

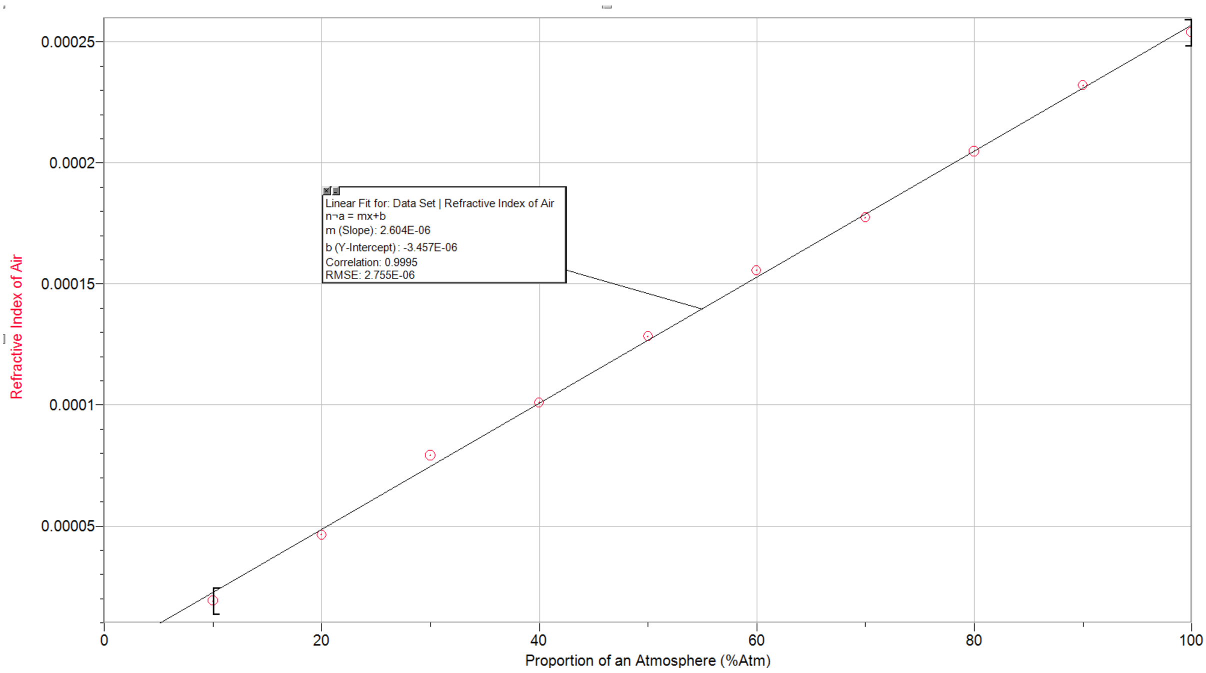
The calibration constant (k) was calculated to be: 0.34 ± 0.05

The refractive index of air was found to be: 1.000306 ± 5×10^{-6}

To **measure the dependence of the refractive index of air on its pressure**:

The value of $n_a - 1$ is taken for pressures varying from a vacuum to atmospheric pressure incrementally increasing from by 10% of atmospheric pressure and plotted against its associated pressure.

Fig 2: Plot of Refractive Index of Air Vs Pressure in Percentage of an Atmosphere



To **measure the wavelength difference of a close doublet**, the following equation was used:

$$n = \frac{\Delta y_1 \times N_1}{\Delta y_2}$$

$$\mathrm{n}(\lambda + \Delta\lambda) = (\mathrm{n} + \frac{1}{2})\lambda$$

$$\Rightarrow \ \Delta\lambda = \frac{\lambda}{2n}$$

$$\mathrm{n}{=}235.6 \pm 13.2$$

Therefore $\Delta\lambda$ was found using $[\Delta\lambda = \frac{\lambda}{n}]$ to be = $2.45 \times 10^{-9} \pm 1.9 \times 10^{-10}$

To **measure the filter band pass,** the following equation was used:

$$\mathrm{n} = 11$$

$$\Delta\lambda = \frac{\lambda}{2n}$$

$$\Delta\lambda = 24 \times 10^{-9} \pm 1.12\ 10^{-9}$$

Method

To **measure the refractive index of air,** the rotary pump was enabled while the pump valve was open, and the release valve was closed. When the pressure gauge reached one atmosphere, the pump valve was closed, and the pump was switched off. The release valve was used slowly and the number of fringes that passed the pointer was recorded. This process was repeated twice more.

To **measure the refractive index of air by calibration,** the mercury lamp with green filter was set up and a micrometer was moved 0.05mm and the number of fringes that passed the pointer were counted.

To **measure the dependence of the refractive index of air on its pressure**, the set up was as it was to set up the refractive index of air, but the release valve was used to measure the number of fringes that passed as the proportion of the atmosphere was released in increments of 10%. The difference in the refractive index of air from that of a vacuum was plotted against the pressure in proportion of an atmosphere.

To **measure the wavelength difference of a close doublet**, the mercury lamp with yellow filter was set up and the micrometer was used to determine the number of fringes between the first and second order of visibility and the corresponding difference in micrometer reading was recorded.

To **measure the filter band pass,** the white lamp with green filter was set up and the number of fringes between the zeroth order and order of disappearance was obtained.

Experimental Data

Temperature: 24 °C

Pressure: 101kPa

Number of Fringes Observed for Refractive Index of Air
49
50
47

Proportion of an Atmosphere (% Atm)	Number of Fringes	$n_a - 1$
10	3.5	1.91×10^{-5}
20	8.5	4.64×10^{-5}
30	14.5	7.92×10^{-5}
40	18.5	10.10×10^{-5}
50	23.5	12.83×10^{-5}
60	28.5	15.56×10^{-5}
70	32.5	17.75×10^{-5}
80	37.5	20.48×10^{-5}
90	42.5	23.20×10^{-5}
100	46.5	25.39×10^{-5}

Number of Fringes Observed for the Refractive Index of Air (By Calibration)
29
31
33

Accuracy and Error Propagation

Accuracy:

Some accuracy was lost due to having to track number of fringes and the measurements read on micrometres by human judgement which is not accurate to a high degree which creates a high degree of error.

Measurement error:

Error in Number of Fringes Observed (Δm): 1

Error in Measurement of Value Measured on Micrometer$_n$ ($\Delta\Delta y_n$): 5×10^{-6} m

Number of Fringes which Pass by the Pointer (ΔN_n): 1

Error Propagation Equations:

Error in the Average Number of Fringes Observed: $\Delta\bar{\mathrm{m}} = \sqrt{\frac{(\sum_{\mathrm{n}=1}^{\mathrm{N}}(\bar{m}-m_n)^2)}{\mathrm{N}-1}}$

Error in the Calibration Constant: $\Delta \mathrm{k} = \sqrt{(\frac{\Delta N_1}{N_1})^2 + (\frac{\Delta\Delta y_1}{\Delta y_1})^2}$

Error in the Refractive Index of Air (By Calibration): $\Delta n_a = \sqrt{(\frac{\Delta \mathrm{k}}{\mathrm{k}})^2 + (\frac{\Delta\Delta y_2}{\Delta y_2})^2}$

Error in the Number of Fringes (For Close Doublet): $\Delta n = \sqrt{(\frac{\Delta\Delta y_2}{\Delta y_2})^2 + (\frac{\Delta\Delta y_1}{\Delta y_1})^2 + (\frac{\Delta N_1}{N_1})^2}$

References

http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/soapfilm.html

Appendices

Fig 1: Apparatus

Fig 2: Plot of Refractive Index of Air Vs Pressure in Percentage of an Atmosphere

Results and Conclusion

The refractive index of air was measured to be 1.000266 ± 9×10^{-6} by use of a mercury lamp with a mercury green filter to isolate the line of 546 nm spectral line. The refractive index of air was found to be 1.000306 ± 5×10^{-6} by calibration. The difference between these refractive indices and that of the expected value of 1.0003 are passible. It was found that the refractive index of air is directly proportional to the pressure of the air. The wavelength difference of the close band filter was found to be $2.45 \times 10^{-9} \pm 1.9 \times 10^{-10}$. The band pass of the green filter was found to be $24 \times 10^{-9} \pm 1.12\ 10^{-9}$. Overall, the value of the refractive index and relevant properties the properties of the close band green filter were investigated and demonstrated to varying degrees of accuracy.