Michelson Interferometer

Experiment 8

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Contents

1 Wavelength of Laser Beam

1.1 Theory

The Michelson interferometer splits a laser beam into two paths using a beam splitter. The recombined beams create interference fringes due to the path difference between the mirrors M_1 and M_2. The wavelength λ is calculated using:

$$\lambda = \frac{2d}{N}\Delta$$

where:

- d: Mirror displacement (corrected by calibration constant Δ)
- N: Number of fringes counted
- Δ: Micrometer calibration constant (determined using a reference laser)

1.2 Calibration

- **Green laser ($\lambda = 532\,$nm):**

$$\Delta = \frac{\text{Actual displacement}}{\text{Micrometer reading}} = \frac{N\lambda/2}{d'} = \frac{20 \times 532 \times 10^{-6}\,\text{mm}}{2 \times 0.22} = 0.02418$$

1.3 Data & Calculations

Table 1: Wavelength measurements for red laser ($\Delta = 0.02418$)

Trial	N	Micrometer Divisions	d' (mm)	λ (nm)
1	20	32	0.32	774
2	20	31	0.31	747
3	30	42	0.42	678
4	40	58	0.58	698
5	40	46	0.46	556
6	40	57	0.57	690
7	60	80	0.80	645
8	60	82	0.82	663

$$\text{Average } \lambda = \frac{774 + 747 + \cdots + 663}{8} = 681\,\text{nm}$$

1.4 Result

The wavelength of the red laser is $\lambda = \boxed{681\,\text{nm}}$.

2 Refractive Index of Glass Slide

2.1 Theory

Rotating a glass slide (thickness t) changes the optical path length. The refractive index n is given by:

$$n = \frac{(2t - N\lambda)(1 - \cos\theta)}{2t(1 - \cos\theta) - N\lambda}$$

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where:

- N: Number of fringe shifts
- θ: Angle of rotation
- t: Thickness of the glass slide (assumed $t = 1.0\,\text{mm}$)

2.2 Data & Calculations

Table 2: Angle measurements and refractive index ($\lambda = 681\,\text{nm}$)

Trial	N	Left (°)	Right (°)	n
1	50	14	16	1.97
2	50	14	15	2.31
3	50	15	16	1.75

$$\text{Average } n = \frac{1.97 + 2.31 + 1.75}{3} = 1.88$$

2.3 Result

The refractive index of the glass slide is $n = \boxed{1.88}$.

2.4 Note

The higher-than-expected value ($n \approx 1.5$ for typical glass) suggests potential errors in the assumed thickness t or angular measurements.

3 Refractive Index of Air

3.1 Theory

Pressure changes (ΔP) alter the optical path length in an air cell. The refractive index n is derived from:

$$n - 1 = \left(\frac{m_{AP}}{\Delta P}\right) \frac{\lambda}{2d} P_{\text{atm}}$$

where:

- m_{AP}: Number of fringe shifts
- d: Length of the air cell (assumed $d = 100\,\text{mm}$)
- $P_{\text{atm}} = 760\,\text{mm Hg}$

3.2 Data & Calculations

$$\text{Slope } \frac{m_{AP}}{\Delta P} = \frac{20}{244.5} = 0.0818\,\text{mm Hg}^{-1}$$

$$n - 1 = \left(0.0818 \times \frac{681 \times 10^{-6}}{2 \times 100}\right) \times 760 = 0.000212$$

Table 3: Pressure and fringe shift data

m_{AP}	ΔP (mm Hg)
20	250
20	240
20	246
20	242

3.3 Result

The refractive index of air is $n = \boxed{1.000212}$, consistent with literature values ($n \approx 1.0003$).

[1]

References

[1] Daryl W. Preston and Eric R. Dietz. *The Art of Experimental Physics*. 2025. Available online.