电子科技大学
格拉斯哥学院
Glasgow College, UESTC

Score

Physical Experiment Ⅱ

Physics Lab Report 08

Experiment Title:	Measuring Laser Wavelength and Index of Refraction of Air by Michelson Interferometer
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Lab Date:	2018.9.13

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Abstract (About 100 words, 10 points)

The purpose of this experiment is to measure the wavelength of the laser and the index of refraction of air by using the Michelson interferometer during the experiment. We used the method of split amplitude to generate two beams to observe the motion of the interference fringes. When we rotate the wheel, the optical path difference is changed which means the interference condition (constructive and destructive) would change so that we can see the fringes move either towards or away from the center of the interference pattern. By calculating the data during rotation, we can obtain the wavelength of He-Ne laser. After that, we followed the steps before with an air cell, and recorded the readings of pressure to calculate the index of refraction of air.

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Calculations and Results (Calculations, data tables and figures; 15 points)

Data Tables

DATA TABLE 1-1 (*purpose*: to measure the wavelength of He-Ne laser)

N	0	50	100	150	200	250
d (mm)	57.868	58.140	58.384	58.543	58.762	59.050
Δd (mm)	$\Delta d_1 = \lvert d_{150} - d_0 \rvert = 0.685$		$\Delta d_2 = \lvert d_{200} - d_{50} \rvert = 0.622$		$\Delta d_3 = \lvert d_{250} - d_{100} \rvert = 0.666$	
$\Delta\bar{d} = \frac{\Delta d_1 + \Delta d_2 + \Delta d_3}{3}$ (mm)	0.6577					
$\bar{\lambda} = \frac{2\Delta\bar{d}}{\Delta m} = \frac{2\Delta\bar{d}}{3\times 50}$ (nm)	876.9					

DATA TABLE 1-2 (*purpose*: to measure the index of refraction of air)

Room temperature T= 25 ℃; Atmospheric pressure p=1.01325×10^5 Pa;

L=95.0 mm; λ_0=633.0 nm; m=60.

Trial	1	2	3
p_1 (MPa)	0.102	0.117	0.126
p_2 (MPa)	0.053	0.056	0.062
$\Delta p = \lvert p_2 - p_1 \rvert$ (MPa)	0.049	0.061	0.064
$\Delta\bar{p} = \frac{\Delta p_1 + \Delta p_2 + \Delta p_3}{3}$ (MPa)	0.057		
$n = 1 + \frac{\lambda_0}{2L}\frac{60}{\Delta\bar{p}}p$	1.0004		

Calculations

1.Compute the wavelength of He-Ne laser and its uncertainty

(1) Compute the mirror displacements.

$\Delta d_1 = \lvert d_{150} - d_0 \rvert = 58.543 - 57.868 = 0.685\text{mm}$,

$\Delta d_2 = \lvert d_{200} - d_{50} \rvert = 58.762 - 58.140 = 0.622\text{mm}$,

$\Delta d_3 = \lvert d_{250} - d_{100} \rvert = 59.050 - 58.384 = 0.666\text{mm}$,

(2) Compute the averaged mirror displacement.

$$\Delta\bar{d} = \frac{\Delta d_1 + \Delta d_2 + \Delta d_3}{3} = \frac{0.685 + 0.622 + 0.666}{3} = 0.6577mm$$

(3) Compute the wavelength of He-Ne laser.

$$\bar{\lambda} = \frac{2\Delta\bar{d}}{\Delta m} = \frac{2\Delta\bar{d}}{3\times 50} = \frac{2\times 0.6577}{3\times 50} = 876.9nm$$

(4) Compute relative error of the wavelength of He-Ne laser.

$$E_{\bar{\lambda}} = \frac{\bar{\lambda} - \lambda_0}{\lambda_0}\times 100\% = \frac{876.9nm - 633.0nm}{633.0mm}\times 100\% = 38.5\% \quad (\lambda_0\text{=633.0 nm})$$

(5) Compute the type A evaluation of uncertainty in $\Delta\bar{d}$.

$$\mu_{A_{\Delta\bar{d}}} = \sqrt{\frac{(\Delta d_1-\Delta\bar{d})^2+(\Delta d_2-\Delta\bar{d})^2+(\Delta d_3-\Delta\bar{d})^2}{n(n-1)}} = \sqrt{\frac{(0.685-0.6577)^2+(0.622-0.6577)^2+(0.666-0.6577)^2}{3(3-1)}} = \sqrt{\frac{(0.0273)^2+(0.0357)^2+(0.0083)^2}{3(3-1)}} = \sqrt{\frac{0.00074529+0.00127449+0.00006889}{3(3-1)}} = 0.000348mm$$

(6) Compute the type B evaluation of uncertainty in $\Delta\bar{d}$.

$$\mu_{B_{\Delta\bar{d}}} = \frac{\Delta_{Instr.}}{\sqrt{3}} = 0.0000289mm \ \ (\Delta_{Instr.} = 0.00005 \text{ mm})$$

(7) Compute the combined uncertainty in $\Delta\bar{d}$.

$$\sigma_{\Delta\bar{d}} = \sqrt{{\mu_{A_{\Delta\bar{d}}}}^2 + {\mu_{B_{\Delta\bar{d}}}}^2} = \sqrt{(0.000348mm)^2 + (0.0000289mm)^2} = 0.00349mm$$

(8) Compute the uncertainty in $\bar{\lambda}$.

$$\sigma_{\bar{\lambda}} = \frac{2\sigma_{\Delta\bar{d}}}{\Delta m} = \frac{2\times 0.00349}{\Delta m} = 0.0000465mm \ \ (\Delta m=3\times 50)$$

(9) The final result of the laser wavelength.

$$\lambda=\bar{\lambda} \pm \sigma_{\bar{\lambda}}=(876.9 \pm 46.5)nm$$

2.Compute the wavelength of He-Ne laser and its uncertainty

(1) Compute changes in pressure.

$\Delta p_1=|p_{12}- p_{11}|=0.102-0.053=0.049$

$\Delta p_2=|p_{22}- p_{21}|=0.117-0.056=0.061$

$\Delta p_3=|p_{32}- p_{31}|=0.126-0.062=0.064$

(2) Compute the mean value of the changes in pressure.

$$\Delta\bar{p} = \frac{\Delta p_{1+}\Delta p_{2+}\Delta p_3}{3} = \frac{0.049 + 0.061 + 0.064}{3} = 0.057$$

(3) Compute the index of refraction of air at atmospheric pressure.

$$n = 1 + \frac{\lambda_0}{2L}\frac{60}{\Delta\bar{p}}p = 1 + \frac{633.0nm}{2\times95.0\text{mm}}\frac{60}{0.057}\times1.01325\times10^5\text{Pa} = 1.00035$$

(p=1.01325$\times$10^{5}Pa)

(4) Theoretically, the index of refraction of air at atmospheric pressure can be calculated by the following equation

$$n_0 = 1 + \frac{2.8793p}{1+0.003671\times T}\times10^{-9} = 1 + \frac{2.8793\times1.01325\times10^5}{1+0.003671\times298}\times10^{-9}$$
$$= 1.000139$$

where p is atmospheric pressure in Pa, T is the room temperature in Kelvin. Compute the theoretical value of the index of refraction of air

(5) Compute the relative error of n.

$$E_n = \frac{n-n_0}{n_0}\times100\% = 0.0211\%$$

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Conclusions (About 100 words, 5 points)

In these two experiments, we observed and calculated to get the laser wavelength of He-Ne laser and the index of refraction of air by using the Michelson interferometer. We used mirrors to reflect the light and form the path distance of the light, and counted the number of the interference pattern changes on the screen. In the second experiment, we used the Michelson interferometer with an air cell to measure the refraction of air according to the changes of pressure. To make the result of this experiment more accurate, we repeated this experiment for many times to get the mean value so that minimize the error and rotate the wheel in one direction when we count the passing fringes in order to avoid error caused by gear backlash. After the experiment, we also have become more familiar with the apparatus.

Score

Answers to Questions (10 points)

（1）Because the light is separated into 2 beams and reflected by several mirrors more than two times.

（2）We are required to rotate the wheel in one direction when we count the passing fringes, in order to avoid error caused by gear backlash.

（3）When we rotate the wheel, the optical path difference is changed which means the interference condition (constructive and destructive) would change so that we can see the fringes move either towards or away from the center of the interference pattern.

Appendix

(Scanned data sheets)

3.8.5 Experimental Data

Data Table 3.8-1 ***Purpose*: To measure the wavelength of He-Ne laser**

N	0	50	100	150	200	250
d/mm	57.868	58.140	58.384	58.543	58.762	59.050
Δd_i/ mm	$\Delta d_1=\lvert d_{150}-d_0\rvert=$ 0.685		$\Delta d_2=\lvert d_{200}-d_{50}\rvert=$ 0.622		$\Delta d_3=\lvert d_{250}-d_{100}\rvert=$ 0.666	
$\Delta\bar{d}=\frac{\Delta d_1+\Delta d_2+\Delta d_3}{3}$ / mm	0.6577					
$\bar{\lambda}=\frac{2\Delta\bar{d}}{\Delta m}=\frac{2\Delta\bar{d}}{3\times 50}$ / nm	876.9					

Data Table 3.8-2 ***Purpose*: To measure the index of refraction of air**

Room temperature $T=$ 25 ℃; Atmospheric pressure $p = 1.013\ 25\times10^5$ Pa;

$L = 95.0$ mm; $\lambda_0 = 633.0$ nm; $m = 60$

Trial	1	2	3
p_1 /MPa	0.102	0.117	0.126
p_2 /MPa	0.053	0.056	0.062
$\Delta p_i=\lvert p_2-p_1\rvert$ /MPa	0.049	0.061	0.064
$\Delta\bar{p}=\frac{\Delta p_1+\Delta p_2+\Delta p_3}{3}$ /MPa	0.057		
$n=1+\frac{\lambda_0}{2L}\frac{60}{\Delta\bar{p}}p$	1.0004		

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