Michelson's Interferrometer

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1 Abstract

The Michelson interferometer is used to measure things like the refraction index and wavelength of light. In this experiment, the wavelength of light beams produced by a He-Ne laser source and a Na lamp was measured using a Michelson interferometer. The interference pattern has been investigated for two sources, and the various fringe possibilities have been noted as a variable for the separation of two mirrors. The experiment's concentric circular fringes of equal inclination are examined to determine the light beams' wavelength.

2 Equipments:

- Michelson's Interferometer setup
- Screen
- a He-Ne laser and a Sodium Lamp
- grounded glass plate

3 Theory

3.1 Interference

Albert Michelson created an Interferometer, which was used to detect luminiferous ether in the late 19th century. The experiment uses it to measure the wavelength of light and is based on the interference of light. A beam splitter divides a source beam into two parts which form an intereference pattern on a screen upon getting reflected back from 2 mirrors. The setup is shown in Figure 1.

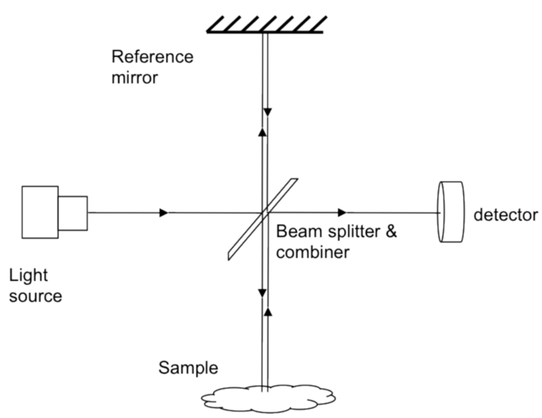


Figure 1: Michelson Interferometer

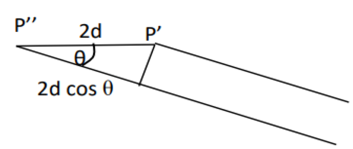
The interference can be of two types:

1. **Constructive interference:** When the path difference is a multiple of the wavelength. This is the case when the path difference is a multiple of the wavelength, i.e. $\Delta d = n\lambda$.
2. **Destructive interference:** When the path difference is not a multiple of the wavelength. This is the case when the path difference is not a multiple of the wavelength, i.e. $\Delta d = (n + \frac{1}{2})\lambda$.

3.2 Types of Fringes

The fringes observed are of the following types depending on the orientation of the mirrors:

- **Concentric circular fringes (fringes of equal inclination):** This occurs when the image of mirror M_2 as seen through the beam splitter is exactly parallel to the mirror M_1 or simply when M_2 is perpendicular to M_1. Since the width of the air film between the image and M1 is constant, the fringes are formed depending on the inclination of the reflected and incident rays. If the angle is say, θ, then the ray reflecting from the further away mirror will travel a extra distance of $2d \cos \theta$ as shown in figure below.



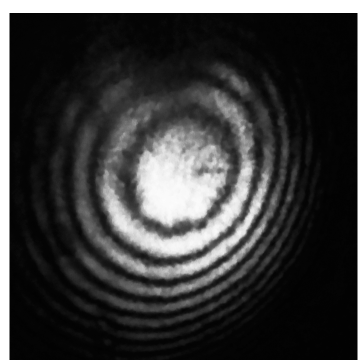


Figure 2: Circular fringes for He-Ne Lazer

Therefore bands will be formed for the same inclination of light rays which corresponds to circular fringes. In the experiment we will deal with circular fringes for the two light source. As we change the path difference between the mirror from $d(2d = n\lambda)$, say N fringes appear or disappear near the centre (that is inclination $\theta = 0$. This implies:

$$2(d + \Delta d) = (n + N)\lambda$$
$$2\Delta d = N\lambda \quad (1)$$

It is because each fringe corresponded to a particular multiple of wavelength. The images of the circular fringes formed in the experiment for He-Ne laser are shown below.

- **Curved fringes (fringes of equal thickness):** This occurs when the mirror M1 and M2 (or its image as in previous point) are inclined at an angle such that the width between the two forms a wedge. Hence the fringes will be common for the path difference of a particular thickness leading to curved (hyperbolic) to straight line fringes as shown in figure below.

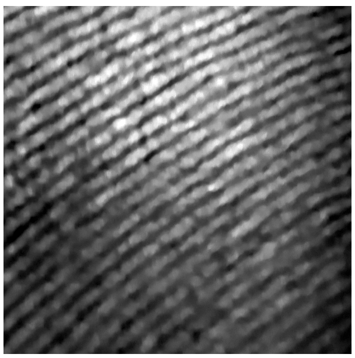


Figure 3: Straight line fringes

- **Straight line fringes:** When M_1 and virtual image of M_2 intersect, straight line fringes are obtained around the point of intersection. The path difference along the line of intersection is zero and therefore, is same for all the wavelengths. The images are shown below.

4 Observation

4.1 He-Ne Laser

$m = 0.01mm$
$n = 0.0001mm = \Delta(\Delta d)$
$d_1 = 1m + 0n = 0.01mm$

N	m	n	d_i (mm)	Δd (nm)	λ (nm)	$\Delta\lambda$ (nm)
2	1	5	0.0105	500	500.0	100.0
4	1	12	0.0112	1200	600.0	50.0
7	1	23	0.0123	2300	657.1	28.6
9	1	29	0.0129	2900	644.4	22.2
11	1	35	0.0135	3500	636.4	18.2
13	1	45	0.0145	4500	692.3	15.4
17	1	60	0.016	6000	705.9	11.8
22	1	83	0.0183	8300	754.5	9.1
23	1	89	0.0189	8900	773.9	8.7
Average Wavelength =					662.7	29.3

Table 1: Data for He-Ne laser

4.2 Sodium Lamp

$d_1 = 16m + 0n = 0.16mm$

N	m	n	d_1	Δd (nm)	λ (nm)	$\Delta\lambda$ (nm)
5	16	15	0.1615	1500	600	40.0
15	16	48	0.1648	4800	640	13.3
30	17	2	0.1702	10200	680	6.7
50	17	52	0.1752	15200	608	4.0
75	18	29	0.1829	22900	610.7	2.7
105	19	12	0.1912	31200	594.3	1.9
Average Wavelength =					622.2	11.4

Table 2: Data for sodium lamp

in Table 1 and Table 2 $\Delta d = d_2 - d_1$ and $\lambda = \frac{2\Delta d}{N}$

5 Error Analysis

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

$$\therefore \Delta\lambda = \lambda\frac{\Delta(\Delta d)}{(\Delta d)}$$

Using this formula we calculated the $\Delta\lambda$ in Table 1 and Table 2.

$$\boxed{\lambda_{He-NeLaser} = 662.7 \pm 29.3\ nm}$$
$$\boxed{\lambda_{NaLamp} = 622.2 \pm 11.4\ nm}$$

Comparing with the literature data: error in $\lambda_{He-NeLaser}$ is 4.72% and error in λ_{NaLamp} is 5.58%.

6 Discussion

- **Error in Observations:** We asumed the value of N to be absolute while calculating the error. This is because, uncertainty in calculating N can be solely due to random error. We cannot be sure about how much the value of ΔN can be. So we are reporting our value asuming there is no error in N.

- **Error in Equipments:** The fine adjustment knob (for m) has a very large backlash. Although we took the readings by rotating the knob only in one direction (that's why we didn't include it in the error analysis), I noted the value for fun: $\Delta n = \pm 47$.

References

[SPS, 2022] SPS (2022). Lab manual. *Website*. `https://www.niser.ac.in/sps/sites/default/files/basic_page/Study%20of%20polarization%20of%20light.pdf`.