Measurements in physical optics

Electromagnetism and Optics Laboratory
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Contents

Chapter 1

Introduction and motivation

I Summary of experiments performed

1. Using a Fabry Perot Interferometer and a LASER we measure:-
   - the wavelength of laser light.
   - the separation between two mirrors.
   - the free spectral range.
2. Using a Fabry Perot Interferometer and a sodium vapour lamp we:-
   - determine the wavelength of sodium light.
   - measure the difference in the wavelengths between the D1 and D2 lines of Na.
   - Find the fractional order at the centre of the fringe system.
3. Using Michelson Interferometer and a LASER we measure:-
   - the wavelength of laser light.
   - the refractive index of a given glass plate.
4. Using Michelson Interferometer and a sodium vapour lamp we:-
   - determine the wavelength of sodium light.
   - determine the difference in the wavelengths between the D1 and D2 lines of Na.
   - measure the thickness of givem mica sheet.

Chapter 2

Experimental set-ups and relevant theory

I Fabry Perot Interferometer with laser

Apparatus:

- Optical Breadboard
- Diode Laser
- Laser mount
- Etalon
- Screen
- Detector

Theory: Fabry – Perot Interferometer consists of two plane mirrors (M1, M2) mounted accurately parallel to one another, with a spacing d between them. This arrangement is called Fabry – Perot etalon. The inner surfaces of mirrors are coated with partially transparent films of high reflectivity. The plates themselves are made slightly prismatic in order to avoid disturbing effects due to reflections at the outer uncoated surfaces.

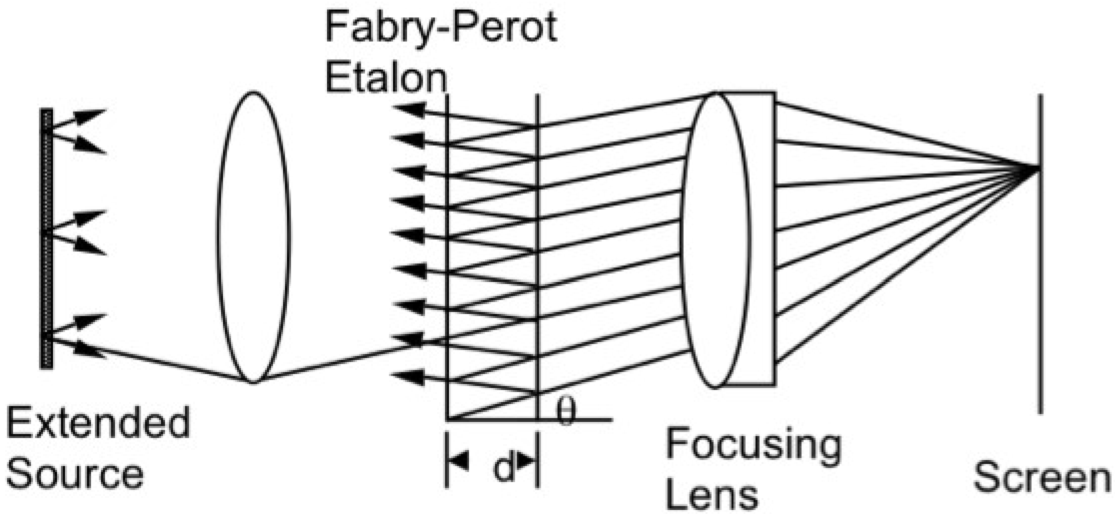
Determination of wavelength of LASER light:
For mth order bright ring at the centre we have,

$$2d = m\lambda$$

$$2(d + \frac{\lambda}{2}) = m\lambda$$

each time d increases by $\lambda/2$, one fringe crosses the center of view. If the total displacement of the movable mirror be $(y_2 - y_1)$ for N bright rings to cross the center, we have,

$$0.5N\lambda = y_2 - y_1$$



$$\lambda = \frac{2(y_2 - y_1)}{N}$$

Determination of distance between the plates of Fabry Perot Etalon (d):
Let X_m be the distance of m^th order bright fringe from the central one, D is the distance between the source and the screen.

$$tan\theta_m = \frac{X_m}{D} - \theta_m$$

when D is very large Hence,

$$cos\theta_m = \frac{1}{1 - \frac{X_m^2}{D^2}}$$

For bright fringe we know the required condition is

$$2dcos\theta_m = m\lambda$$

Hence,

$$m = \frac{2d}{\lambda}[cos\theta_m - cos\theta_{m+1}]$$

$$= \frac{2d}{\lambda}\Big[\Big(\frac{1}{1 - \frac{X_m^2}{D^2}}\Big) - \Big(\frac{1}{1 - \frac{X_{m+1}^2}{D^2}}\Big)\Big]$$

$$= \frac{d}{D^2\lambda}X_n^2$$

where $X_n^2 = X_{m+n}^2 - X_m^2$
Therefore,

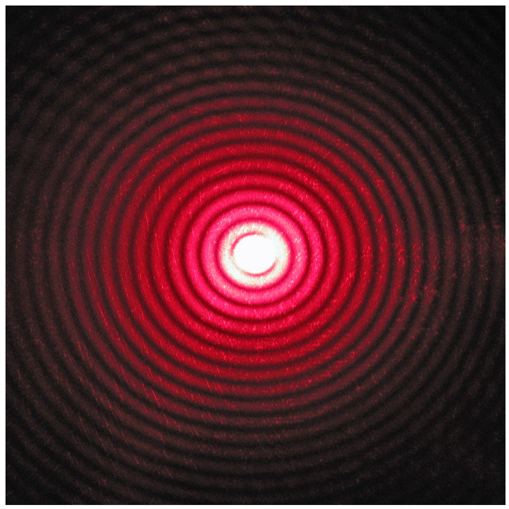
$$d = \frac{mD^2\lambda}{X_n^2}$$

To measure the free spectral range(FSR)

Free Spectral Range (FSR) is the spacing in optical frequency or wavelength between two successive reflected or transmitted optical intensity maxima or minima of an interferometer.

$$\mathrm{FSR} = \mathrm{c}/2\mathrm{d}$$

d = distance of separation of two mirrors. Free Spectral Range is inversely proportional to plate reading d. So increase of resolving power obtained by increasing plate separation is accompanied by proportionate reduction of spectral range.

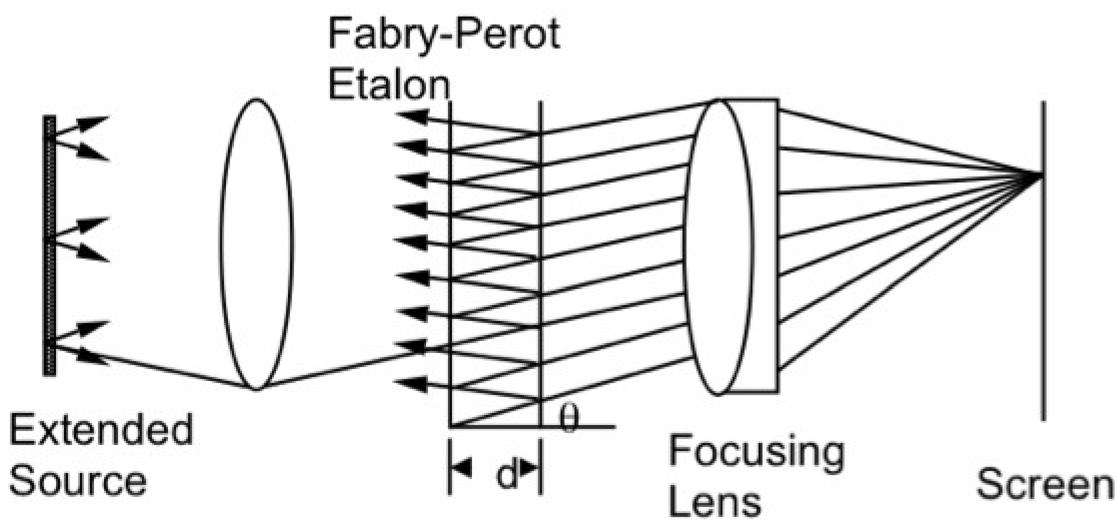


II Fabry Perot Interferometer with Sodium Lamp

Apparatus:

- Fabry Perot Interferometer
- Sodium Vapour Lamp
- Very small circular aperture

Theory:



It basically consists of two glass plates of which the inner surfaces are made plane, accurately parallel and thinly silvered. The outer surfaces (uncoated) are made to have a small angle away from the coated surfaces (helping to throw away the unwanted fringes formed due to multiple reflections in the plate itself. The thickness of the film (between the two plates) can be varied. Concentric circular fringes of equal inclination are obtained on the screen after multiple internal reflections between the plates.
Determination of wavelength of Na light:
For m th order bright ring at the centre we have,

$$2d = m\lambda$$

$$2(d + \frac{\lambda}{2}) = m\lambda$$

each time d increases by $\lambda/2$, one fringe crosses the center of view. If the total displacement of the movable mirror be $(y_2 - y_1)$ for N bright rings to cross the center, we have,

$$0.5N\lambda = y_2 - y_1$$

$$\lambda = \frac{2(y_2 - y_1)}{N}$$

Determination of wavelength separation of Na lines (D1 and D2):
The separation (d) between the plates is adjusted until the ring systems of two wavelength coincide. Under this condition concordance occurs. For first concordance
$2d_1 = m_1\lambda_1 = \left(m_1 + \frac{\lambda}{2}\right)\lambda_2$
$m_1 \rightarrow$ order of λ_1 at centre.
For the next concordance,
$2d_1 = m_2\lambda_1 = \left(m_2 + \frac{\lambda}{2}\right)\lambda_2$
$m_2 \rightarrow$ order of λ_1 at centre.
$2(d_2 - d_1) = (m_2 - m_1)\lambda_1 = (m_2 - m_1)\lambda_2 + \lambda_2$
$\rightarrow m_2 - m_1 = \frac{\lambda_2}{\lambda_1 - \lambda_2}$
$\Delta\lambda = \lambda_1 - \lambda_2 = \frac{\lambda_1\lambda_2}{2(d_2-d_1)} = \frac{\lambda_{av}^2}{2(d_2-d_1)}$
Finding fractional order at the centre of the fringe system:
The axis of the lens is usually normal to the plates, and the bright fringes, corresponding to integral values of m, are then circles with common centre at the focal point for normally transmitted light. At this point, m has max.value:

$$m_0 = m_1 + e$$

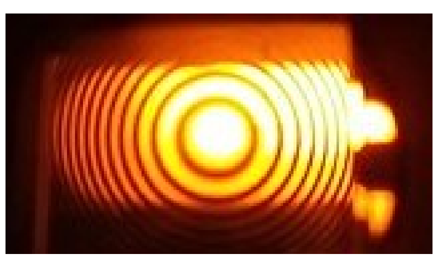
where m_1 is integral order of the innermost bright fringe, and e, having value less than unity is the fractional order at the center. The angular radius θ_p of the p^{th} bright fringe from the center, when θ_p is not too large is

$$\theta_p = \frac{1}{n}\sqrt{\frac{n'\lambda_0}{d}}\sqrt{p - 1 + e}$$

when n=refractive index of the air outside the plates and n'=refractive index of the air between the plates.
The diameter Dp of this fringe is then given by,

$$D_p^2 = (2f\theta_p)^2 = \frac{4n'\lambda_0 f^2}{n^2 d}(p - 1 + e)$$

where f id the focal length of the lens

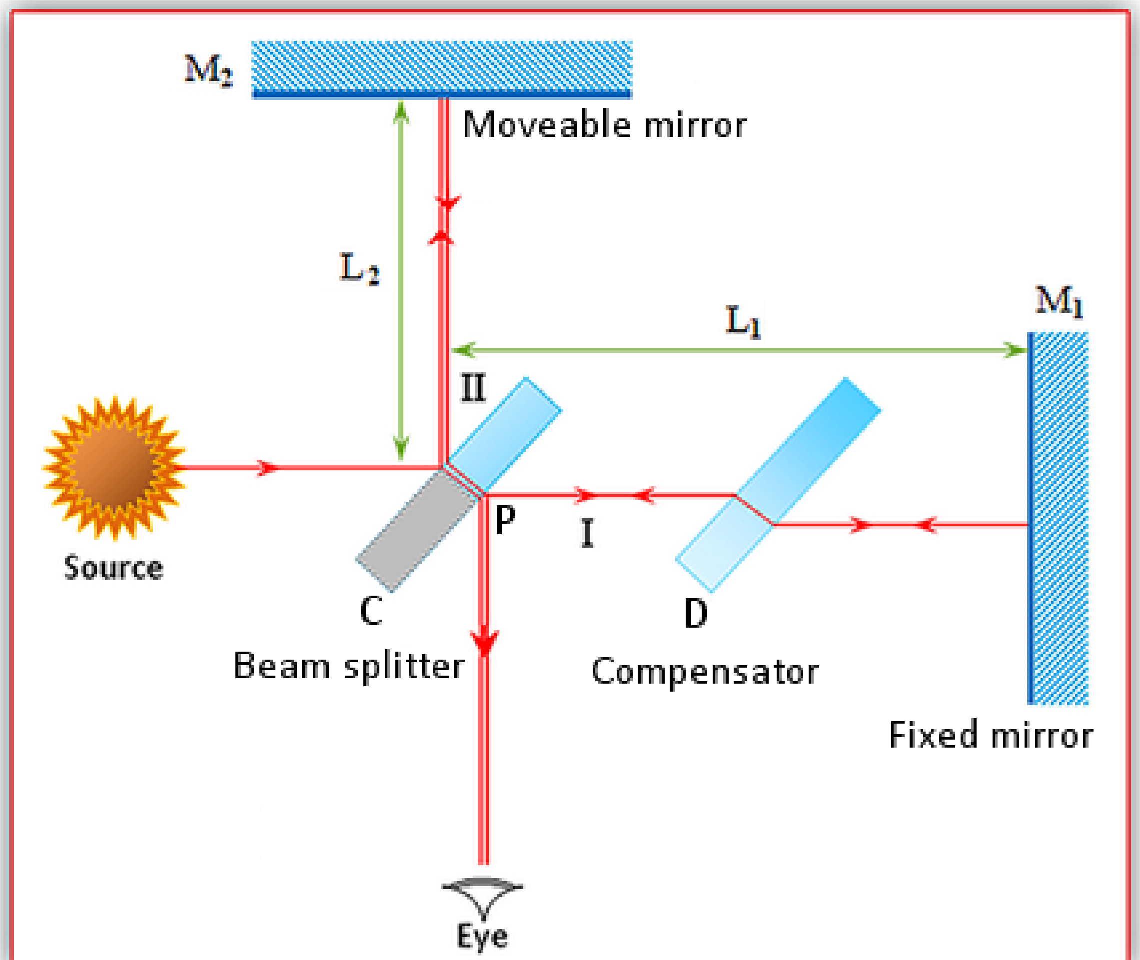


III Michelson Interferometer with laser

Apparatus:

- Optical Breadboard
- Diode Laser
- Laser mount
- Beam-splitter mount
- Mirror mounts
- Screen
- Detector
- Counter

Theory:



M_1 and M_2 are two plane mirrors silvered on the front surfaces. They are mounted vertically on two translation stages placed at the sides of the optical platform. Screws are provided at the back of the holders, adjustment of which allows M_1 and M_2 to be tilted. M_1 can also be moved horizontally by a micrometer attached to the M_1 holder. BS is a 50%-50% beam-splitter, which is a planar glass plate slightly silvered on one side. It is mounted vertically and at an angle 45^o to the direction of incident light. When light from laser is allowed to fall on BS, one portion, beam A, is transmitted through BS to M_2 and the other, beam B is reflected by BS to M_1. Beam A returning from M_2 is reflected at the back of BS to reach the screen, and beam B after getting reflected from M_1 passes through BS to reach the screen. If λ is the wavelength of laser light and D is the change in the separation between the mirrors M_1 and M_2 that occurs for 'n' fringes to collapse or evolve then

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

The optical path lengths of one of the light paths will change if a glass plate is inserted into it. As the glass plate is rotated, the length of glass in the path will increase and therefore the number of wavelengths in that path will increase. This will change the interference pattern. The refractive index of the glass plate can be calculated from the number of interference fringes shifted during the rotation of the glass plate through some angle θ. The refractive index of the glass plate is then given by:

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

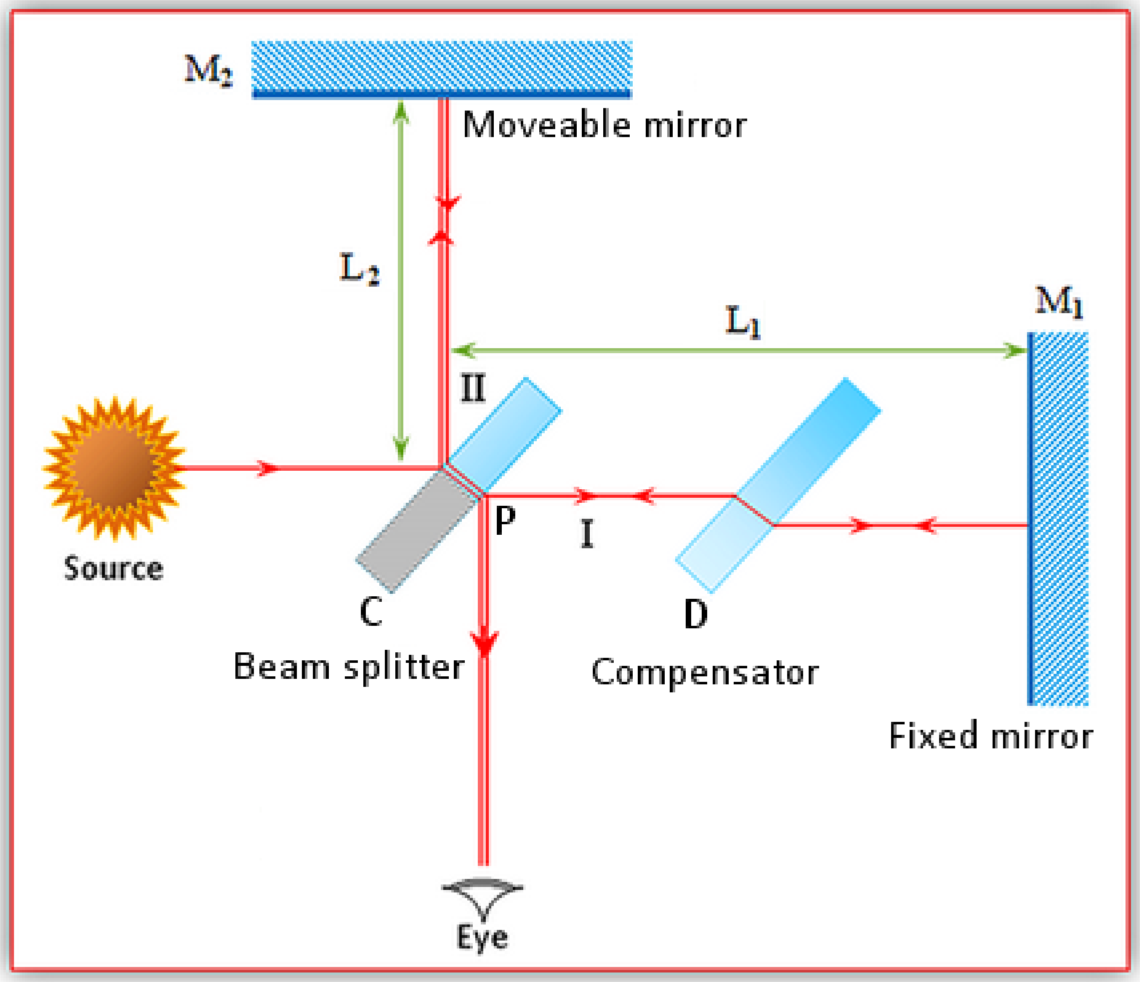
Where, N = number of shifted fringes; θ = the angle of rotation; λ = the wavelength of light used; t = thickness of the glass plate.

IV Michelson Interferometer with Na Lamp

APPARATUS:

- Michelson Interferometer
- Sodium Vapour Lamp
- White Light source
- Mica Sheet

THEORY:



M_1 and M_2 are two plane mirrors silvered on the front surfaces. They are mounted vertically on two translation stages placed at the sides of the optical platform. Screws are provided at the back of the holders, adjustment of which allows M_1 and M_2 to be tilted. M_1 can also be moved horizontally by a micrometer attached to the M_1 holder. BS is a 50%-50% beam-splitter, which is a planar glass plate slightly silvered on one side. It is mounted vertically and at an angle 45^o to the direction of incident light. When light from the lamp is allowed to fall on BS, one portion, beam A, is transmitted through BS to M_2 and the other, beam B is reflected by BS to M_1. Beam A returning from M_2 is reflected at the back of BS to reach the screen, and beam B after getting reflected from M_1 passes through BS to reach the screen.

The average wavelength of Na light,

$$\lambda_{av} = \frac{2\Delta d}{\Delta n}$$

where, Δd = distance moved by M1
Δn = no. of fringes collapsed at the centre.

The difference in wavelength of Na doublet (D1,D2) is

$$\Delta\lambda = \frac{\lambda_{av}^2}{2d}$$

where, d = distance between 2 positions of maxima in coherent
λ_{av} =mean wavelength between positions of maximums.

The relation between refractive index and thickness of mica sheet is

$$t = \frac{\Delta d}{\mu - 1}$$

where, t = thickness of mica sheet
μ =refractive index of mica

Chapter 3

Experimental results and analysis

I Fabry Perot Interferometer with Laser

Calibrating the micrometer attached to the movable mirror M1.
The movable mirror mount is mounted on a translation stage. The micrometer shaft actuates a lever arm which pushes the translation stage carrying the mirror. To make proper measurements it is first necessary to obtain the calibration factor or reduction ratio R, which gives the correspondence between the distance d' moved by the micrometer screw and the actual motion D of the mirror M1. Here 10 microns (= 0.01 mm) on the thimble of the micrometer (= 1 division) is equivalent to 35 microns on the translation stage, i.e., when we move one step on the micrometer, the mirror is moved 0.35 microns. Hence

$$R = 0.35/10 = 0.035$$

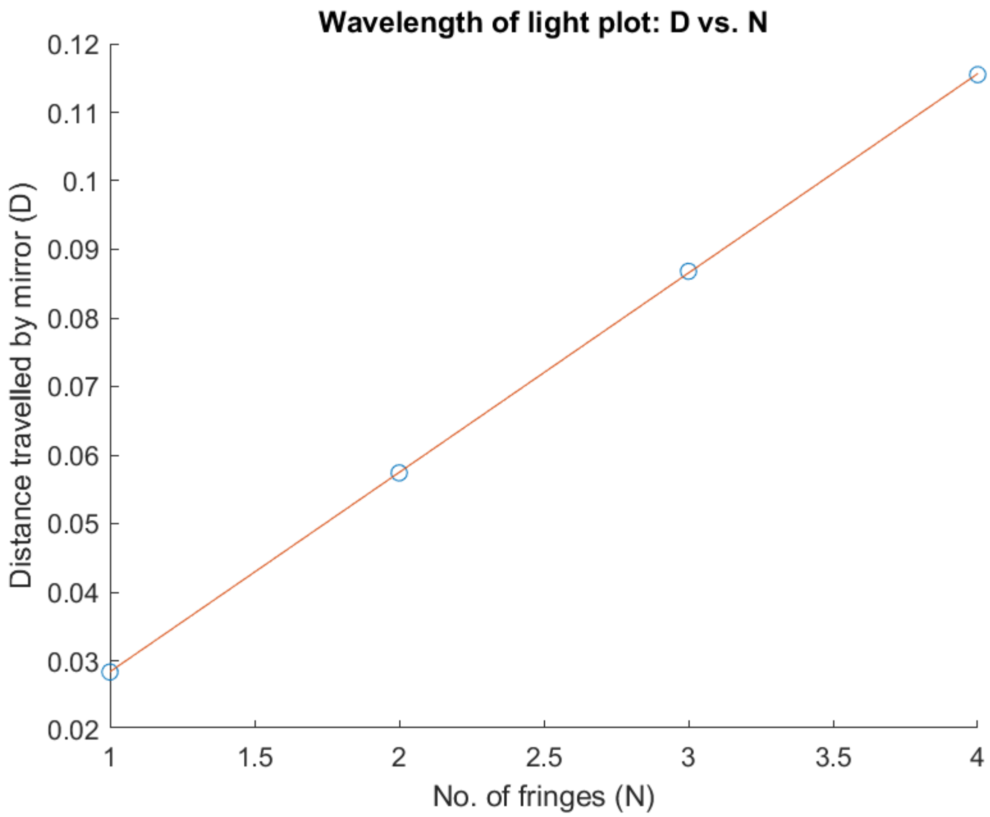
Thus D in eq (1) becomes:

$$D = 0.035 * d'$$

Determination wavelength of the laser light.
Least count of the micrometer attached to the movable mirror:-
Value of 1 small division of the main scale = 1mm
Pitch of the screw = P = 0.5mm
Total number of divisions on the circular scale = N = 50
Least count of micrometer = P/N = 0.5/50 = 0.01mm

Data for the distance D moved by the movable mirror for number of fringes to evolve/collapse

No of fringes appear/collapse (N)	Initial micrometer reading (y1)	Final micrometer reading (y2)	d (mm) (y2-y1)	D (mm) =d*0.035
100	3.5	4.31	0.81	0.028
200	1.96	3.6	1.64	0.057
300	1.5	3.98	2.48	0.087
400	1.0	4.3	3.3	0.116



Slope of the plot = 0.0291
Wavelength of light = 581.7 nm

Data to measure the diameter of the rings.
Taking m=0.

Fringe No.	Value of Xm+n (mm)	$X_n^2 = X_{m+n}^2 - X_m^2 (mm^2)$
0	0	0.00
1	3.4	11.56
2	5.3	28.09
3	6.81	46.38
4	8.18	66.91
5	10.05	101.00
6	10.94	119.68

$$d = \frac{mD^2\lambda}{X_n^2}$$

Distance between the source and the screen (D) = 55 cm.
Slope of X_n^2 vs. n plot: 20.599 mm^2
$d = \frac{D^2\lambda}{slope} = 8.54mm$

Determination of the separation between two mirrors and FSR

Slope	Distance D	Wavelength of the source (λ)	Mirror Separation $d = \frac{D^2\lambda}{slope}(mm)$	FSR $= \frac{c}{2d}$
20.599	55	581.7	8.54	3.51×10^{10} Hz

II Fabry Perot Interferometer with Sodium Lamp

Calibrating the micrometer attached to the movable mirror M1.
The movable mirror mount is mounted on a translation stage. The micrometer shaft actuates a lever arm which pushes the translation stage carrying the mirror. To make proper measurements it is first necessary to obtain the calibration factor or reduction ratio R, which gives the correspondence between the distance d' moved by the micrometer screw and the actual motion D of the mirror M1. Here 10 microns (= 0.01 mm) on the thimble of the micrometer (= 1 division) is equivalent to 12 microns on the translation stage, i.e., when we move one step on the micrometer, the mirror is moved 0.12 microns. Hence

$$R = 0.12/10 = 0.012$$

Thus D in eq (1) becomes:

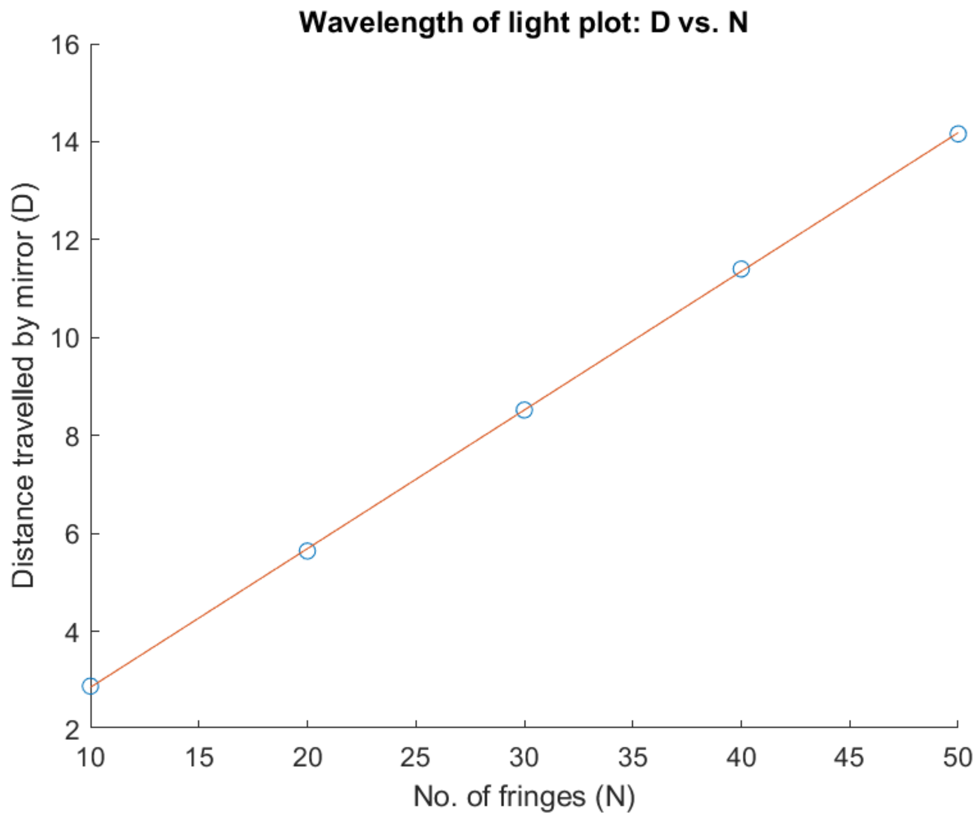
$$D = 0.012 * d'$$

Determination of the wavelength of the Sodium Lamp.
Smallest division of the linear scale= s = 0.5mm
Pitch of the screw = p = 0.5mm
Number of divisions on the circular scale = N = 50
Least count of instrument = l.c. = p/N = 0.01mm
Scaling factor for measuring displacement of the mirror : 0.012

Data for the distance D moved by the movable mirror for number of fringes to evolve/collapse

No of fringes appear/collapse (N)	Initial micrometer reading (y1)	Final micrometer reading (y2)	d (mm) (y2-y1)	D (μm) =d*0.012
10	1.50	1.74	0.24	2.88
20	1.50	1.97	0.47	5.64
30	1.50	2.21	0.71	8.52
40	1.50	2.45	0.95	11.40
50	1.50	2.68	1.18	14.16

Slope of the plot = 14.16 μm
Wavelength of light = 566.4nm



Measurement of wavelength separation.

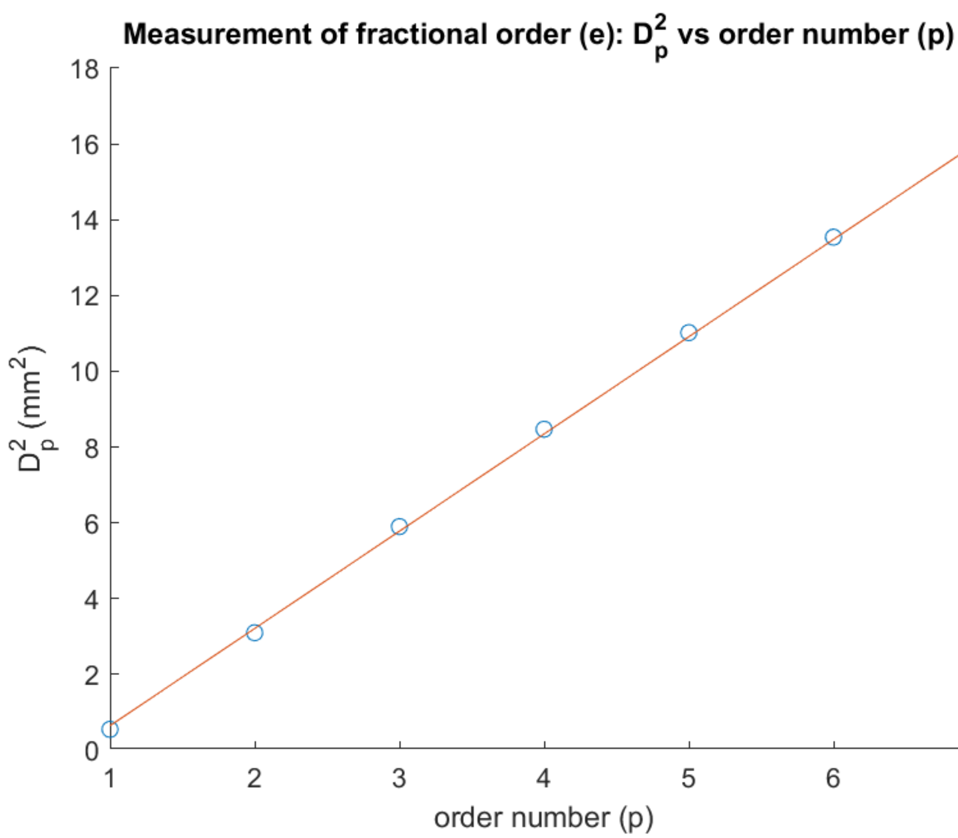
Initial micrometer reading (y1)	Final micrometer reading (y2)	d (mm) (y2-y1)	$\Delta\lambda$ (nm) $= \frac{\lambda_{av}^2}{2(d_2-d_1)_a v}$
1.29	3.22	1.93	0.693
3.22	5.16	1.94	0.689
5.16	7.07	1.91	0.700
7.07	9	1.93	0.693
9	10.91	1.91	0.700
10.91	12.81	1.9	0.704
12.81	14.74	1.93	0.693
14.74	16.63	1.89	0.707
16.63	18.51	1.88	0.711

The average difference in wavelength of Na D1 and D2 lines obtained for $\lambda_{av} = 566.4$ nm

$$\Delta\lambda = 0.699nm.$$

Determination of ring diameter.

Order No.	Read. at left edge (D_1) in cm.	Read. at right edge (D_2) (cm)	Diameter $D = D_1 - D_2$ (cm)	D^2 (mm^2)
1	6.941	7.015	0.074	0.55
2	6.89	7.066	0.176	3.10
3	6.848	7.091	0.243	5.90
4	6.833	7.124	0.291	8.47
5	6.811	7.143	0.332	11.02
6	6.797	7.165	0.368	13.54
7	6.78	7.178	0.398	15.84



To measure the fractional order (e)

From the plot D_p^2 vs order number (p),

The x-interecept = 1-e = 0.7486

Therefore, e = 0.2514.

III Michelson Interferometer with Laser

Calibrating the micrometer attached to the movable mirror M1:-
The movable mirror mount is mounted on a translation stage. The micrometer shaft actuates a lever arm which pushes the translation stage carrying the mirror. To make proper measurements it is first necessary to obtain the calibration factor or reduction ratio R, which gives the correspondence between the distance d' moved by the micrometer screw and the actual motion D of the mirror M_1. Here 10 microns (= 0.01 mm) on the thimble of the micrometer (= 1 division) is equivalent to 35 microns on the translation stage, i.e., when we move one step on the micrometer, the mirror is moved 0.35 microns. Hence

$$R = \frac{0.35}{10} = 0.035$$

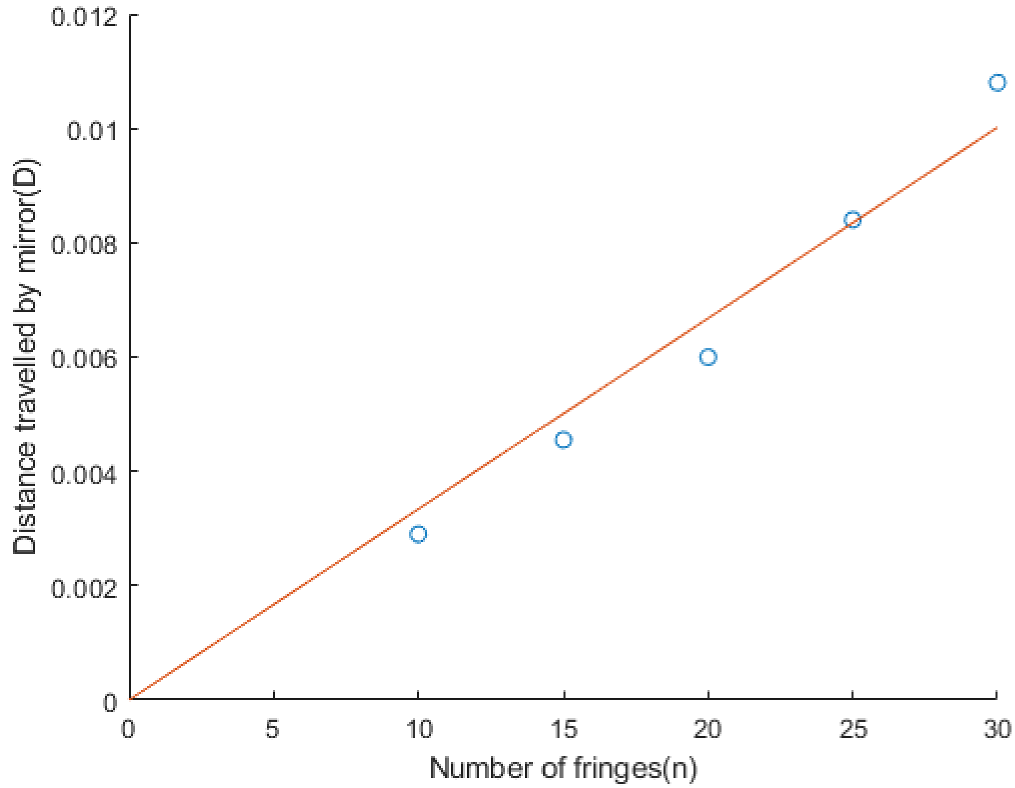
Thus D becomes

$$D = 0.035 * d'$$

Determination of wavelength of the laser light
Least count of the micrometer attached to the movable mirror:-
Value of 1 small division of the main scale = 0.5 mm
Pitch of the screw = P = 0.5 mm
Total number of divisions on the circular scale = N = 50
Least count of micrometer = $\frac{P}{N}$ = 0.01 mm

No. of fringes(n)	Initial Reading (y1)(mm)	Final Reading (y2)(mm)	d'=y2-y1 (mm)	D=0.035*d' (mm)
10	5.49	5.61	0.12	0.0042
15	5.32	5.49	0.17	0.00595
20	6.65	6.93	0.28	0.0098
25	4.94	5.32	0.38	0.0133
30	5.26	5.8	0.54	0.0189

Slope of the plot = 333.89 nm
Wavelength of laser light = 667.78 nm



The number of fringes N evolved/collapsed when the glass plate is rotated

No. of fringes(n)	Angle(in degrees)
10	6
15	8
20	10
30	12
40	13

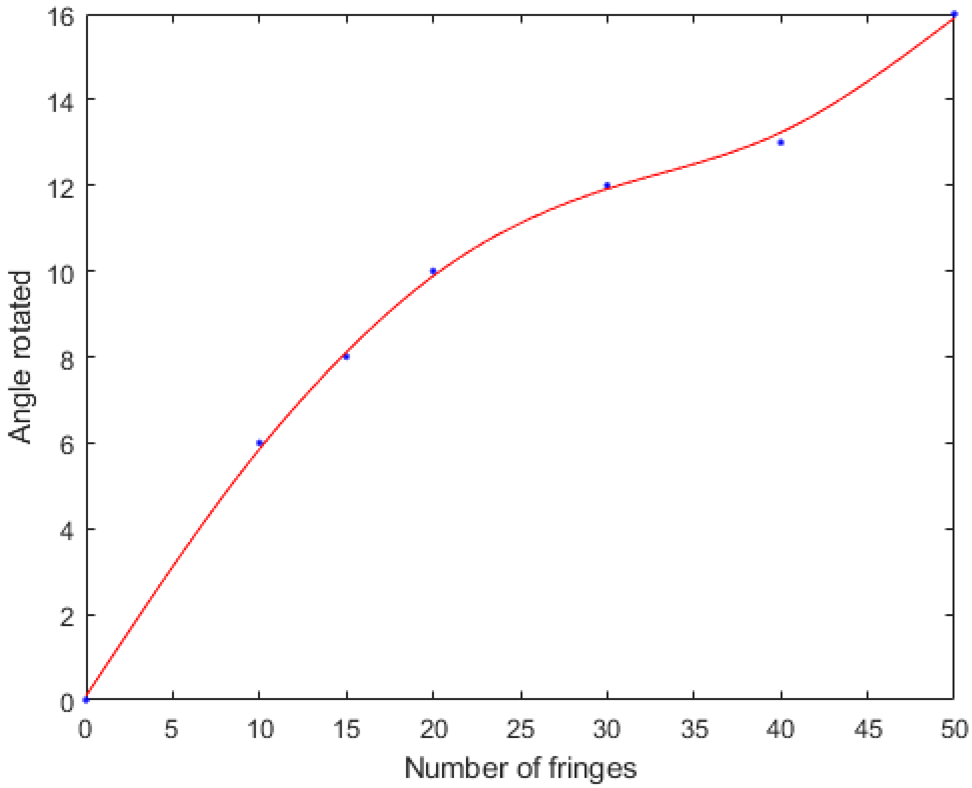


Table for Thickness of screw gauge

Serial No.	Thickness of glass plate(mm)	Average Thickness t (mm)
1	1.66	
2	1.69	1.67
3	1.67	

Average refractive index = 1.4185.

IV Michelson Interferometer with Sodium Lamp

Calibrating the micrometer attached to the movable mirror M1.
The movable mirror mount is mounted on a translation stage. The micrometer shaft actuates a lever arm which pushes the translation stage carrying the mirror. To make proper measurements it is first necessary to obtain the calibration factor or reduction ratio R, which gives the correspondence between the distance d' moved by the micrometer screw and the actual motion D of the mirror M1. Here 10 microns (= 0.01 mm) on the thimble of the micrometer (= 1 division) is equivalent to 25 microns on the translation stage, i.e., when we move one step on the micrometer, the mirror is moved 0.25 microns. Hence

$$R = 0.25/10 = 0.025$$

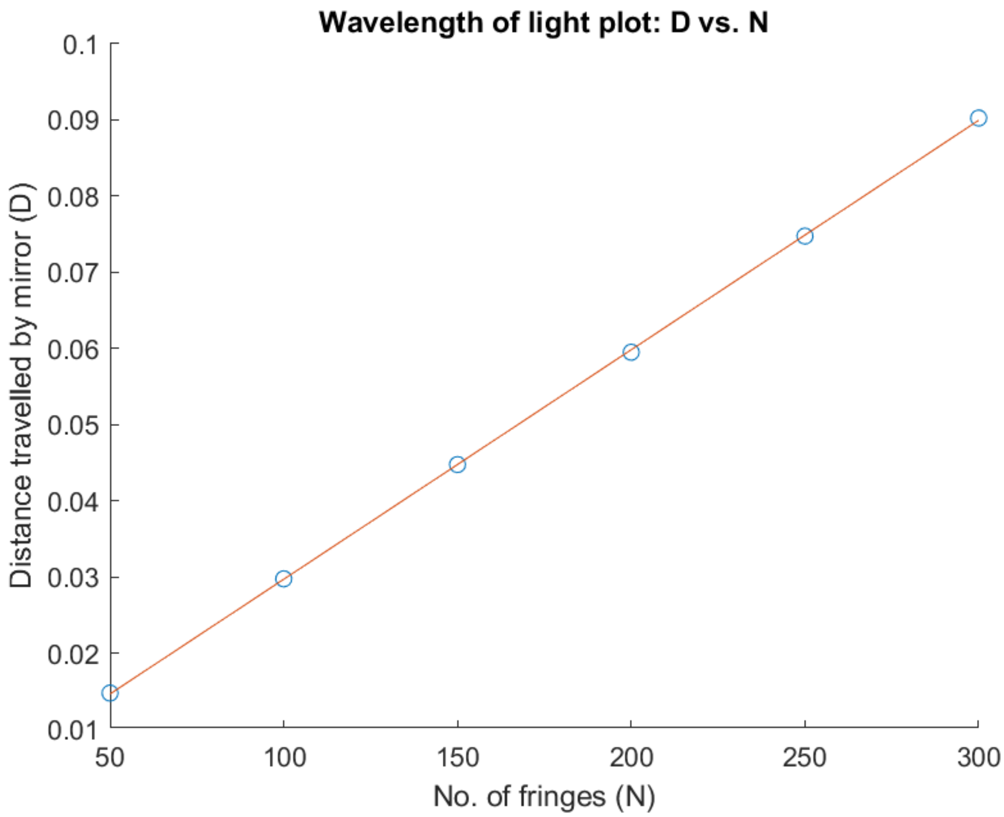
Thus D in eq (1) becomes:

$$D = 0.025 * d'$$

Determination the wavelength of sodium lamp.
Least count of the micrometer attached to the movable mirror:-
Value of 1 small division of the main scale = 0.5 mm
Pitch of the screw = P = 0.5 mm
Total number of divisions on the circular scale = N = 50
Least count of micrometer = $\frac{P}{N}$ = 0.01 mm

No. of fringes(n)	Initial Reading (y1)(mm)	Final Reading (y2)(mm)	d'=y2-y1 (mm)	D=0.0035*d' (mm)
50	12	12.59	0.59	0.01475
100	12	13.19	1.19	0.02975
150	12	13.79	1.79	0.04475
200	12	14.38	2.38	0.0595
250	12	14.99	2.99	0.07475
300	12	15.61	3.61	0.09025

Slope of the plot = 0.3013 μm
Wavelength of light = 602.56nm



Determination of the difference in wavelengths of the Na-D lines.

Initial micrometer reading (y1)	Final micrometer reading (y2)	d (mm) (y2-y1)	$\Delta\lambda$ (nm) $= 5 * 10^4 * d/N$
10.59	21.66	11.06	0.656
10.71	21.90	11.19	0.649
10.87	22.20	11.33	0.641
11.17	22.41	11.25	0.646

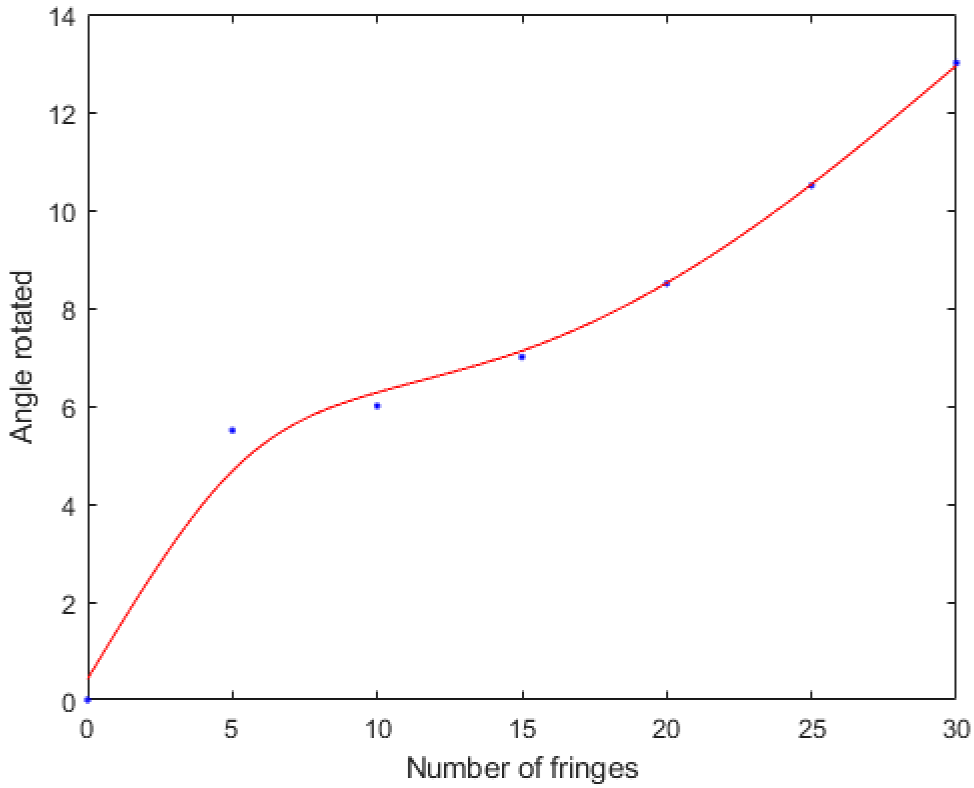
The average difference in wavelength of Na D1 and D2 lines obtained for $\lambda_{av} = 602.56$ nm

$$\Delta\lambda = 0.648nm.$$

Determination of the thickness of the given mica sheet.

Fringes	Angle (in degrees)
5	5.5
10	6
15	7
20	8.5
25	10.5
30	13

Average value of thickness of glass plate = 1.4067 mm



14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Angle rotated
Number of fringes

Chapter 4

Error Analysis

I Fabry Perot Interferometer with Laser

Statistical error in slope for D vs N plot = 0.926 nm
Therefore, Error in Wavelength = 1.85 nm
Wavelength of laser light (experimental) = 581.7 ± 1.85 nm (Theoretical: 632.8 nm)

Statistical error in slope for X_n^2 vs n plot = 1.346 mm^2

$$\frac{\Delta d}{d} = \frac{\Delta slope}{slope} + \frac{\Delta\lambda}{\lambda} = \frac{\Delta FSR}{FSR}$$

Therefore Δd = 8.54*(1.346/20.599 + 1.85/581.7) = 0.585
and ΔFSR = 2.41 $\times 10^9$ Hz

Separation between mirrors = 8.54 ± 0.585 mm
Free Spectral Range = (3.51 ± 0.241) $\times 10^{10}$ Hz

II Fabry Perot Interferometer with Sodium Lamp

Statistical error in slope for D vs N plot = 0.0014 μm
Therefore, Error in Wavelength = 2.77 nm
Wavelength of Sodium light (experimental) = 566.4 nm ± 2.77 nm (Theoretical: 589.3 nm)

Wavelength separation of Na D1 and D2 lines = 0.699 nm (Theoretical: 0.6 nm)

Statistical error in x-intercept for D_p^2 vs p plot: 0.076
Fractional Order (e) = 0.2514 ± 0.0191

III Michelson Interferometer with Laser

Statistical error in slope for D vs N plot = 2.34 nm
Therefore, Error in Wavelength = 4.68 nm
Wavelength of laser light (experimental) = 667.78 $\pm$ 4.68 nm (Theoretical: 632.8 nm)

Refractive index of glass plate (experimental) = 1.4185 (Theoretical: 1.5)

IV Michelson Interferometer with Sodium Lamp

Statistical error in slope for D vs N plot = 1.15 nm
Therefore, Error in Wavelength = 2.29 nm
Wavelength of laser light (experimental) = 602.6 $\pm$ 2.29 nm (Theoretical: 589.3 nm)

Wavelength separation of Na D1 and D2 lines = 0.648 nm (Theoretical: 0.6 nm)
Thickness of glass sheet = 1.4067 mm

Chapter 5

Conclusion, discussion and remarks

I Fabry Perot Interferometer with Laser

Results
Wavelength of laser light (experimental) = 581.7 ± 1.85 nm (Theoretical: 632.8 nm)
Separation between mirrors = 8.54 ± 0.585 mm
Free Spectral Range = (3.51 ± 0.241) $\times 10^{10}$ Hz

Precautions

- The micrometer must be rotated very gradually while applying a steady pressure on the thimble. The rotation should be unidirectional to avoid any back-lash error.
- Distance between and source and screen should be kept small so that diameter of fringes are large and will lead to more precise results.
- Zero error in the screw gauge should be accounted.

Sources of Error

- Multiplication factor provided was erroneous.
- To compute the diameter of the fringes, the center of the bright fringes were found out using eye-estimation.
- Error procured due to manual counting of the fringes.

Discussion
Since the counter was not working, all the counting was done manually. Manually counting required a great amount of patience and along with it brought huge error. The manual error done while counting is very erratic in nature and is not measurable.

II Fabry Perot Interferometer with Sodium Lamp

Results
Wavelength of Sodium light (experimental) = 566.4 nm ± 2.77 nm (Theoretical: 589.3 nm)
Wavelength separation of Na D1 and D2 lines = 0.699 nm (Theoretical: 0.6 nm)
Fractional Order (e) = 0.2514 ± 0.0191

Precautions

- Zero error in the screw gauge should be accounted.
- The micrometer must be rotated very gradually while applying a steady pressure on the thimble. The rotation should be unidirectional to avoid any back-lash error.
- To make the measurements more accurate, first of all the fringes should be made concentric as much as possible.

Sources of Error

- Multiplication factor provided was erroneous.
- Error procured due to manual counting of the fringes.

Discussion
To measure the difference in the wavelength of the two sodium lines, I employed the method of concordance. The trick is to turn the screw gauge over a cycle of faded fringe to sharp fringe and back to faded fringes. The distance moved by the mirror to complete one such cycle, provides us with the value of $\Delta\lambda$. But there is a catch that the transformation from faded fringes to sharp fringes occur in a continuous fashion and it is difficult to pin point a particular point and label it as perfectly faded. To overcome this problem what we did is that we moved the screw over multiple such cycles and hence with every cycle we reduced the effect of this doubt factor.
The screw gauge was particularly very sensitive in case of Fabry-Perot using Na Lamp. We were pushing the thimble of the screw gauge very slightly but still it was very easy to loose track of the count and start over again.

III Michelson Interferometer with Laser

Results

Wavelength of laser light (experimental) = 667.78 ± 4.68 nm (Theoretical: 632.8 nm)
Refractive index of glass plate (experimental) = 1.4185 (Theoretical: 1.5)

Precautions

- The micrometer must be rotated very gradually while applying a steady pressure on the thimble. The rotation should be unidirectional to avoid any back-lash error.
- Zero error in the screw gauge should be accounted.
- The reflecting surfaces of the mirror and the beam-splitter should not be touched, as the finger grease eventually causes etching and permanent damage. Also the surface should not be wiped with a tissue, as it will leave a scratch, which will give rise to scattering of light.

Sources of Error

- Multiplication factor provided was erroneous.
- Error procured due to manual counting of the fringes.

Discussion

The apparatus that we were using had some problematic components. Most notorious among them was the lens used to diverge the laser beam. We were making all possible attempts to align the laser with lens removed and as soon as we would introduce the lens all our efforts was in vain.
Fringes obtained were not circular.
The laser beam source was producing two spots instead of one making the attainment of fringes really difficult.
Since the counter was not working, all the counting was done manually. Manually counting required a great amount of patience and along with it brought huge error. The manual error done while counting is very erratic in nature and is not measurable.

IV Michelson Interferometer with Sodium Lamp

Results
Wavelength of laser light (experimental) = 602.6 ± 2.29 nm (Theoretical: 589.3 nm)
Wavelength separation of Na D1 and D2 lines = 0.648 nm (Theoretical: 0.6 nm)
Thickness of glass sheet = 1.4067 mm

Precautions

- While counting the fringes, the head should be kept fixed at a certain position because fringes do collapse/evolve by changing the point of observation.
- Zero error in the screw gauge should be accounted.
- The micrometer must be rotated very gradually while applying a steady pressure on the thimble. The rotation should be unidirectional to avoid any back-lash error.
- The reflecting surfaces of the mirror and the beam-splitter should not be touched, as the finger grease eventually causes etching and permanent damage. Also the surface should not be wiped with a tissue, as it will leave a scratch, which will give rise to scattering of light.

Sources of Error

- Fringe count kept changing due to various mechanical factors.
- Multiplication factor provided was erroneous.
- Error procured due to manual counting of the fringes.

Discussion
In the measurement of thickness of the glass plate, firstly I tried the method of concordance. That is to first place the fringe system at a position where fringes due to different lines of sodium disagree (faded fringes). Then remove the glass plate to find that the fringe system has changes. Finally the thickness of glass plate is measured by turning the fringe system back to faded point. Apparently this method works really well for thin glass plate but in our case the thickness of the glass plate was too large and it caused the fringe system to elope several cycles of concordance and hence the method failed.
In order to determine the thickness of glass plate we instead followed the method employed in the Michelson Interferometer with lasers. That is the glass plate is rotated about it's axis to cause evolution/disappearance of fringes. There is relation that relates refractive index of glass plate to that of angle rotated (θ) and Number of fringes collapsed/evolved (N).

Bibliography

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- Fundamentals of Optics - Jenkins and White.