LABORATORY MANUAL FOR

NEWTON'S RING METHOD

Background Coherent sources of light, Concept of Interference, Interference by division of wave front and amplitude, Interference in thin films, Newton's ring apparatus.

Aim: To determine the wavelength of sodium light by Newton's Ring method.

Apparatus: A nearly monochromatic source of light (source of sodium light), a plano-convex lens C, an optically plane glass plate P, an optically flat glass plate G inclined at an angle of 45°, a travelling microscope with measuring scale and a spherometer.

Theory:

- Condition for formation of bright and dark fringes:

When a parallel beam of monochromatic light is incident normally on a combination of a plano-convex lens C and a glass plate P, as shown in fig.1(a), a part of each incident ray is reflected from the lower surface of the lens, and a part, after refraction through the film between the lens and the plate, is reflected back from the surface of glass plate. These two reflected rays are coherent, hence they will interfere and produce a system of alternate dark and bright rings (see fig.1(b)) with the point of contact between the lens and the plate at the center. These rings are known as Newton's rings.

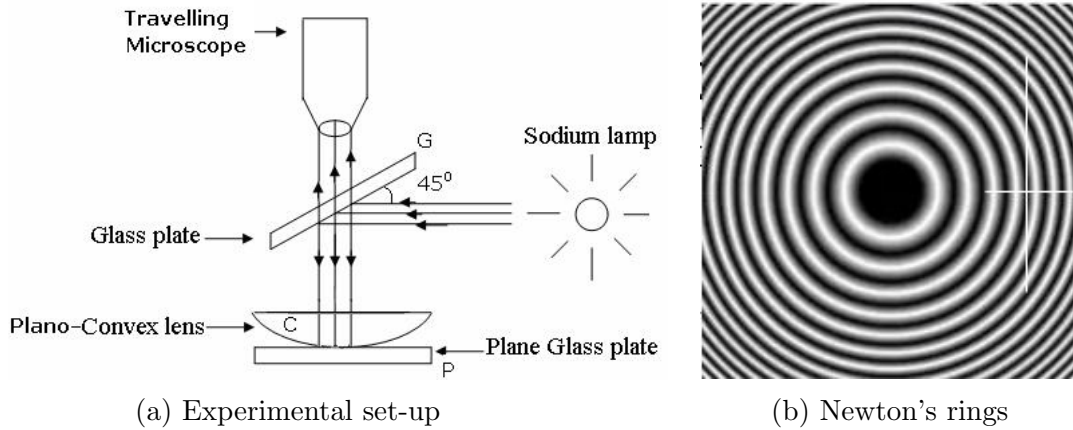(a) Experimental set-up   (b) Newton's rings

Figure 1

In general, the path difference between the reflected light beams which are undergoing interference (for oblique incidence) is given by

$$\Delta = 2\mu t cos\theta - \frac{\lambda}{2},\tag{1}$$

where additional path difference of $\frac{\lambda}{2}$ is because one of the interfering beam is reflected from film to glass surface. Also, θ is the angle of incidence.

For normal incidence $\theta=0°$ and hence, the path difference will be

$$\Delta = 2\mu t - \frac{\lambda}{2}.\tag{2}$$

In the interference pattern bright fringe will be formed if the path difference is equal to integral multiple of wavelength of light, *i.e.*,

$$\Delta = 2\mu t - \frac{\lambda}{2} = n\lambda; \quad n = 0, 1, 2, 3...$$

$$\Rightarrow 2\mu t = (n + \frac{1}{2})\lambda; \quad n = 0, 1, 2, 3... \tag{3}$$

For intensity minima (dark fringe), $\Delta = (n + \frac{1}{2})\lambda$, and thus,

$$2\mu t = n\lambda. \quad n = 0, 1, 2, 3... \tag{4}$$
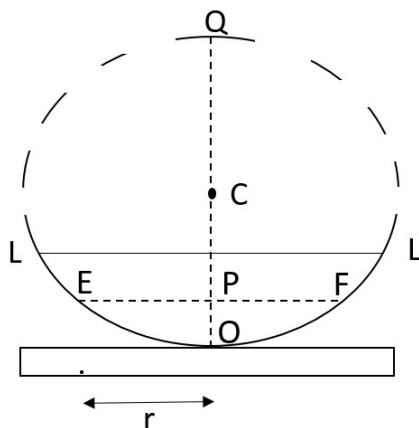
- Relationship between ring diameter and wavelength:

Figure 2

In fig.2, let LOL$'$ is the plano-convex lens placed on glass plate. Plano-convex lens appears as part of circle of radius R. Here, radius R is known as radius of curvature of plano-convex lens.

Suppose r is the radius of some n^{th} bright ring having thickness t. Using the property of circle, from fig.(2), we can write

$$EP \times PF = PO \times PQ,$$
$$\Rightarrow r_n^2 = t \times (2R - t),$$
$$\Rightarrow r_n^2 = (2Rt - t^2).$$

Since $R >> t$, t^2 can be neglected therefore

$$r_n^2 \simeq 2Rt, \tag{5}$$

by using Eq.(4) and Eq.(5), we have

$$r_n^2 = \frac{n\lambda R}{\mu}. \tag{6}$$

Using $r_n = \frac{D_n}{2}$, we can write following relation for diameter of nth, ring

$$D_n^2 = 2r_n^2 = \frac{n\lambda R}{\mu}. \tag{7}$$

The diameter of some $m^t h$ dark fringe will be

$$D_m^2 = \frac{m\lambda R}{\mu}. \tag{8}$$

Subtracting Eq.(7) and Eq.(8), we can write following relation

$$\lambda = \frac{D_n^2 - D_m^2}{4R(n-m)}\mu. \tag{9}$$

Above equation is used to find the wavelength of monochromatic light using Newton ring's method, in which material of refractive index μ is immersed between plano-convex lens and glass plate.

If air is enclosed as thin film having $\mu=1$, then Eq.(9) becomes

$$\lambda = \frac{D_n^2 - D_m^2}{4R(n-m)}. \tag{10}$$

The radius of curvature, R is calculated by spherometer (see fig.3) using following relation

$$R = \frac{l^2}{6h} + \frac{h}{2}.$$

In above, l is the mean length of the three sides of equilateral triangle formed by joining the tips of three outer legs and h represents the height of the central screw above or below the plane of the outer legs.

Procedure: The experimental set-up used for the experiment is shown in fig.1(a).

1. Level the travelling microscope table and set the microscope tube in a vertical position. Find the vernier constant (least count) of the horizontal scale of the travelling microscope.

2. Clean the surface of the inclined glass plate G, the lens C and the glass plate P. Place them in position as shown in fig.1(a) and as discussed in the description of apparatus. Place the arrangement in front of a sodium lamp so that the height of the center of the glass plate G is the same as that of the center of the sodium lamp.
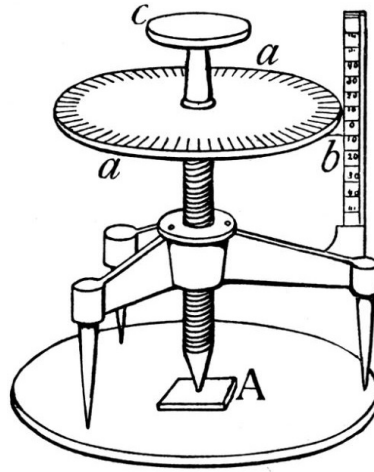
Figure 3: Spherometer.

3. Adjust the position of the travelling microscope so that it lies vertically above the center of lens C. Focus the microscope, so that alternate dark and bright rings are clearly visible.

4. Adjust the position of the travelling microscope till the point of inter-section of the cross wires (attached in the microscope eyepiece) coincides with the center of the ring system.

5. Slide the microscope to the left till the cross wire lies tangentially at the center of the 20th dark ring. Note the reading on the vernier scale of the microscope. Slide the microscope backward with the help of the slow motion screw and note the readings when the cross-wire lies tangentially at the center (see fig.1(b)) of the 18th, 16th, 14th, 12th, 10th, 8th, 6th, and 4th dark rings, respectively. [Observations of first few rings from the center are generally not taken because it is difficult to adjust the cross-wire in the middle of these rings owing to their large width.]

6. Keep on sliding the microscope to the right and note the reading when the cross-wire again lies tangentially at the center of the 4th, 6th, 8th, 10th, 12th, 14th, 16th, 18th, and 20th dark rings, respectively.

7. Remove the plano-convex lens C and find the radius of curvature of the surface of the lens in contact with the glass plate P accurately using a spherometer.

8. Find the diameter of the each ring from the difference of the observations taken on the left and right side of its center.

9. Take any two diameter and perform the calculations for $D_n^2 - D_m^2$ $(m{<}n)$ as directed in Table.1.

5

10. Finally calculate the value of wavelength of the sodium light source using Eq.(9).
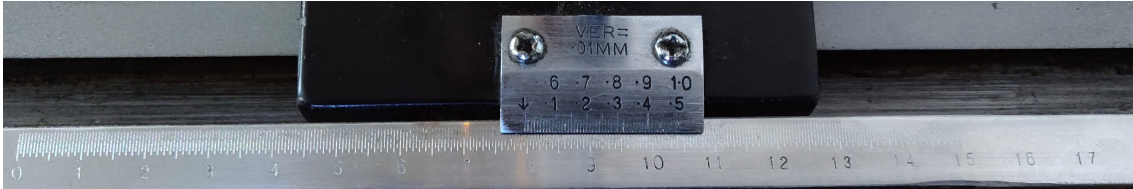
Observations:

Diameter

Figure 4: Vernier Scale of the Microscope.

1. M.S.D = ...

2. V.S.D = ...

3. Vernier constant = . . . cm.

4. μ (air) = ...

Sr. no.	Ring no. (n)	Microscope reading (cm)						D_n =L-R (cm)	D_n^2 (cm^2)	$D_n^2 - D_m^2$ (cm^2)
		Left(L)			Right(R)					
		Main	Vernier	Total	Main	Vernier	Total			
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Table 1: Measurements of the diameter of the ring.

Spherometer

1. Pitch of the screw = ... cm.

2. Number of divisions on circular head = ...

3. Least count of the spherometer =. . . . . .cm.

Sr. no.	Spherometer readings on		h (cm)	l (cm)
	convex surface	plane surface		
1.				
2.				
3.				

Table 2: Calculations of h and l.

4. The mean height h of the central screw=. . . . . cm and the mean distance between the two legs of the spherometer, l=. . . . . cm.

5. The radius of curvature R= . . . . cm.

Wavelength

Sr. no.	$\lambda = \frac{D_n^2 - D_m^2}{4R(n-m)}\mu$ (nm)
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	

Table 3: Calculations for wavelength λ.

• The mean wavelength (λ) of Sodium light is =. . . . . nm.

Results:

• Observed wavelength of the Sodium light is (λ_O): . . . . nm.

- Actual wavelength (λ_A): 589.3 nm.

- % error: $\left|\frac{\lambda_O - \lambda_A}{\lambda_A}\right| \times 100 =$. . . . . %.

Precautions: Notice that as you go away from the central dark spot the fringe width decreases. In order to minimize the errors in measurement of the diameter of the rings the following precautions should be taken:

1. The microscope should be parallel to the edge of the glass plate.

2. The mirrors should be in perfectly stable positions when reading are being taken.

3. There should be no play between the screw and the nut in which it rotates.

4. To avoid any backlash error, the micrometer screw of the travelling microscope should be moved very slowly and be moved in one direction while taking observations.

5. While measuring diameters, the microscope cross-wire should be adjusted in the middle of the ring (see fig.1(b)).

Sample viva voce questions :

1. What do you understand by the interference of light?

2. What are essential conditions for obtaining interference of light?

3. What do you understand by coherent sources?

4. Is it possible to observe interference pattern by having two independent sources such as two sodium lamp?

5. Fro the interference to happen, why two sources should be monochromatic?

6. Why are the Newton's rings circular?

7. Why is central ring dark?

8. Where are these rings formed?

9. Sometimes these rings are elliptical or distorted, why?

10. What is the difference between the rings observed by reflected light and those observed by transmitted light?

11. What will happen if the glass plate is silvered on the front surface?

12. Why do the rings gets closer and finer as we move away from the center?

13. What will happen when a little water is introduced in between the plano-convex lens and the plate?

14. How does the diameter of rings change on the introduction of liquid?

15. Can you find out the refractive index of a liquid by this experiment?

References

- F. Jenkins and H. White, *Fundamental of Optics*, TATA-McGRAW HILL.

- A.Ghatak,*Optics*, TATA-McGRAW HILL.

Note: Soft copy of this manual is available on http://www.nitj.ac.in/physics/