

3. Newton's Rings

Background

Coherent light
Phase relationship
Path difference
Interference in thin film
Newton's ring apparatus

Aim of the experiment

To study the formation of Newton's rings in the air-film in between a plano-convex lens and a glass plate using nearly monochromatic light from a sodium-source and hence to determine the radius of curvature of the plano-convex lens.

Apparatus required

A nearly monochromatic source of light (source of sodium light)

A plano-convex lens

An optically flat glass plates

A convex lens

A traveling microscope

Theory

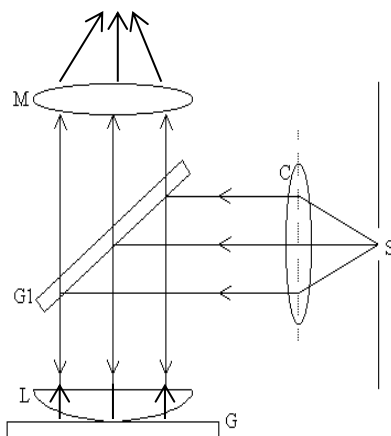


Fig. 1 Experimental set-up to observe Newton's ring

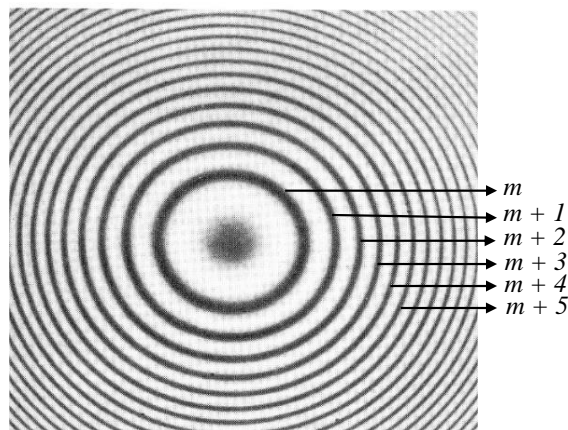


Fig. 2. Newton's rings of order $(m + n)$, wherein $n = 0, 1, 2, \dots$

When a parallel beam of monochromatic light is incident normally on a combination of a plano-convex lens and a glass plate, as shown in Fig.1, a part of each incident ray is reflected from the lower surface of the lens, and a part, after refraction through the air film between the lens and the plate, is reflected back from the plate surface. These two reflected rays are coherent, hence they will interfere

and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the center. These rings are known as Newton's ring (Fig. 2).

For normal incidence of monochromatic light, the path difference between the reflected rays (see Fig.1) is very nearly equal to $2\mu t$ where μ and t are the refractive index and thickness of the air-film respectively. The fact that the wave is reflected from air to glass surface introduces a phase shift of π . Therefore, for bright fringe

$$2\mu t = \left(n + \frac{1}{2}\right)\lambda; \quad n = 0,1,2,3, \dots \quad (1)$$

and for dark fringe

$$2\mu t = n\lambda; \quad n = 0,1,2,3, \dots \quad (2)$$

For n^{th} (bright or dark) ring (see Fig. 3), we also have

$$\frac{D_n^2}{4} + (R - t)^2 = R^2 \quad (3)$$

where, D_n = the diameter of the n^{th} ring and R = the radius of curvature of the lower surface of the plano-convex lens. On neglecting t^2 , equation (3) reduces to

$$D_n^2 = 8tR \quad (4)$$

From equations (1) and (4), we get,

$$D_n^2 = 4 \left(n + \frac{1}{2}\right) \frac{\lambda R}{\mu} \quad \text{for } n^{\text{th}} \text{ bright ring.} \quad (5)$$

Similarly, from equations (2) and (4), we obtain

$$D_n^2 = \frac{4n\lambda R}{\mu} \quad \text{for } n^{\text{th}} \text{ dark ring} \quad (6)$$

While performing the experiment, the number of rings very close to the center is unknown. To avoid the difficulty arising from this, we start from a distinctly visible ring whose order m is unknown and we start counting the rings $n = 0, 1, 2, \dots$, from here.

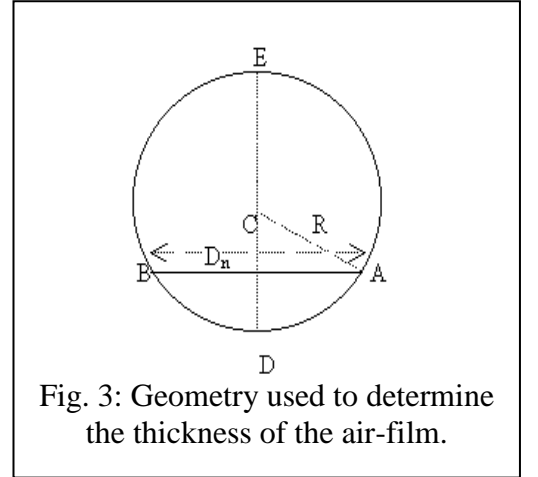
Now, the diameter of the n^{th} dark ring is given by

$$D_n^2 = \frac{(n+m)4\lambda R}{\mu} = n \frac{4\lambda R}{\mu} + \frac{4\lambda Rm}{\mu} \quad (7)$$

Equation (7) is of the form: $D_n^2 = a n + b$ (8)

A plot of n vs D_n^2 would result in a straight line of slope a .

where, $a = \frac{4\lambda R}{\mu} \Rightarrow R = \frac{\mu a}{4\lambda}$ (9)



Procedure

1. Level the traveling microscope with its axis vertical. Arrange the set-up as shown in Fig.1 and focus the microscope on the air-film. Newton's Rings will be clearly seen.
2. Adjust the glass plate G1 for maximum visibility of the point of contact of lens L with the glass plate G and hence for maximum visibility of Newton's Rings. In this orientation, G1 is at 45° to the incident beam of light.
3. Move the microscope to the right of the central dark spot (say order ' m ', this is because the central ring is often broad and may not necessarily be of zero order) and set it on the extreme tenth ($n = 10$) distinct bright ring so that the cross-wire perpendicular to the direction of movement of the microscope passes through the bright ring and is tangential to it. Record the microscope position from the horizontal scale along with its number with bright ring around the central dark spot as the first bright ring. Move the microscope to left and record the position of the next bright ring. Repeat it till you reach to the tenth bright ring on the left. From these measurements, evaluate the diameters of different rings. Repeat these measurements for microscope movement from left to right and evaluate the diameters of different rings. Determine the average diameters of different rings.

Calculation and Results

Plot a graph of n vs D_n^2 using the method of least squares. Then, from the slope of the plot and by using equation (9), the radius of curvature (R) can be calculated, given $\lambda = 5893 \times 10^{-8}$ cm and $\mu = 1$.

$$R = \frac{\mu a}{4\lambda}$$

Estimate error in R

The error in the measurement of D_n^2 can be estimated as follows:

$$\text{Let, } D_n^2 = y \quad (10)$$

$$\frac{\delta y}{y} = \frac{\delta D_n^2}{D_n^2} = 2 \frac{\delta D_n}{D_n} \quad (11)$$

Since D_n is measured by taking the difference between the two readings of a micrometer scale, the maximum error in measuring each of these quantities is twice the least count i.e., $2 LC$.

Hence,

$$\begin{aligned} \frac{\delta D_n^2}{D_n^2} &= 4 \frac{LC}{D_n} \\ \delta D_n^2 &= 4 D_n LC \end{aligned} \quad (12)$$

Evaluation of δD_n^2 for each of the experimental data points can be used to plot the error bars in the graph of n vs D_n^2 .

Next, the error in R can be obtained using equation (9):

$$\frac{\delta R}{R} = \frac{\delta a}{a} \quad (13)$$

Here, δa is to be obtained from the expression (eqn. 12) provided in the chapter '*General Instructions*' under the section 'Chi-square fitting'. Note that δD_n^2 is the square of the standard deviation of the errors associated with each measurement.

Discussion

- (i) The Newton's ring experiment can be also used to find the wavelength of a monochromatic light. In this case, the radius of curvature of the convex surface of the given lens is supplied or is determined otherwise. By employing sodium light whose mean wavelength is 5893 \AA , R can be determined from Eqn. (9), as in the present experiment. Then the same equation can be used to find the wavelength λ of any other given monochromatic light.

- (ii) R is calculated from Eq. (9). An error in the actual ring number $n+m$ does not affect the result.
- (iii) Since the first few rings near the center are deformed, they must be avoided while taking readings for the rings.
- (iv) Care must be taken not to disturb the lens and glass plate combination in any way during the experiment.

Questions

1. In the Newton's ring experiment, how does interference occur?
2. Where have the fringes formed?
3. Why are the fringes circular?
4. Are all rings equispaced?
5. Why is an extended source used in this experiment?
6. What will happen if a point source or an illuminated slit is used instead of the extended source?
7. In place of lens, if a wedge shaped film formed by two glass plates is supplied to you, will you be able to observe Newton's ring? Why?
8. How is the central spot in your experiment, bright or dark? Why?
9. Instead of reflected rays, if you look at transmitted rays, what do you expect to observe?
10. What happens with the central spot when a liquid of refractive index μ greater than that of the lens and less than that of the glass plate is introduced between the lens and the glass plate?
11. Is it possible to determine the refractive index of the liquid by this experiment?
12. What would happen to the ring if the space between lens and the plate is filled with a liquid of refractive index μ ?
13. What do you expect to see in the microscope if you use a white light source?
14. What is the difference between biprism fringes and Newton's ring fringes?
15. On which factors does the diameter of a ring depend?
16. What would happen if a glass plate is replaced by a plane mirror?
17. Why should a lens of large radius of curvature be used in this experiment?
18. Is it desirable to measure the radius of curvature of the given lens by a spherometer in the usual way?
19. What do you understand by (a) fringes of equal thickness (b) fringes of equal inclination and (c) fringes of equal chromatic order.
20. How does the sodium source, which you are using in your experiment work?

References

1. Fundamental of Optics by F. Jenkins and H. White 535 JEN/F
2. Optics by A. Ghatak 535 GHA/O
3. Optics by E. Hecht 535 HEC/O

Graph: Newton's Rings