Newton's Rings

Apparatus:
Travelling microscope, sodium vapor lamp, plano-convex lens, plane glass plate with mount, magnifying lens.
Purpose of experiment:
To observe Newton's rings formed by the interference produced by a thin air film and to determine the radius of curvature of a plano-convex lens.
Basic methodology:
A thin wedge-shaped air film is created by placing a plano-convex lens on a flat glass plate. A monochromatic beam of light is made to fall at almost normal incidence on the arrangement. Ring-like interference fringes are observed in the reflected light. The diameters of the rings are measured and the radius of curvature of the convex lens determined.

I Theory

The phenomena of Newton's rings is an illustration of the interference of light waves reflected from the opposite surfaces of a thin film of varying thickness. The two interfering beams, derived from a monochromatic source, satisfy the coherence condition for interference. Ring-shaped fringes are produced by the air film existing between a convex surface of a long focus plano-convex lens and a plane of glass plate. When viewed with white light, the fringes are coloured.

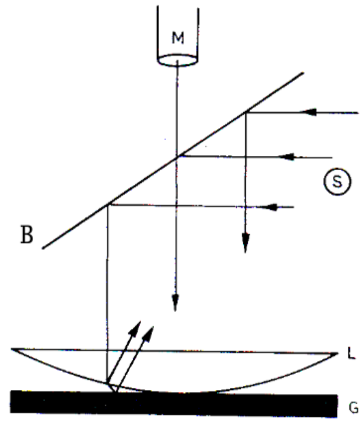

Figure 1:

When a plano-convex lens (L) of long focal length is placed on a plane glass plate (G), a thin film of air is enclosed between the lower surface of the lens and upper surface of the glass plate (See Fig. 1). The thickness of the air film is very small at the point of contact and gradually increases from the centre out-wards. A horizontal beam of light from a monochromatic source falls on a 45 deg glass plate B. A part of the incident light is reflected towards the air film enclosed by the lens L and plate G. The reflected beam from the air film is viewed with a microscope M. Interference takes place between the beams reflected at the lower surface of the lens and the upper surface of the plate G, and bright and dark circular fringes are observed.

For normal incidence, the optical path difference between the two waves is nearly $2\mu t$, where $\mu$is the refractive index of the film and t the thickness of the film. Here an extra phase difference of π occurs for the ray reflected from upper surface of the plate G because the incident beam in this reflection goes from a rarer to a denser medium. Thus the conditions for constructive and destructive interference are (using μ= 1 for air),

$$2t = m\lambda, \quad m = 0, 1, 2, ... \text{ (for minima)} \tag{1}$$

$$2t = \left(m + \frac{1}{2}\right)\lambda \quad m = 0, 1, 2, ... \text{ (for maxima)} \tag{2}$$

For the air film enclosed between the spherical surface and the plane surface, points of equal thickness form circular concentric rings. Thus, if r_m is the radius of the m^{th} order dark ring (see Fig. 2) $r_m^2 = (2R-t)t$, where R is the radius of curvature of the spherical surface. $m = 0$ corresponds to the central dark spot. Now R is of the order of $100cm$ and t is at-most $1cm$. Therefore $R >> t$. Hence $(R-t)^2 + r_m^2 = R^2 \implies r_m^2 = (2R-t)t$ which, neglecting the t^2 term, gives, $2t = \frac{r_m^2}{R}$. Substituting the value of $2t$ in eq. (1) gives the radius for the m^{th} order dark ring,

$$m\lambda \approx \frac{r_m^2}{R} \implies r_m^2 \approx m\lambda R, \quad m = 0, 1, 2, ... \tag{3}$$

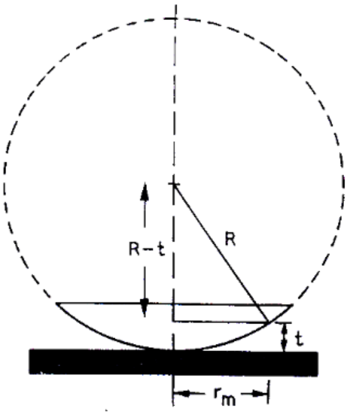

Figure 2:

From eq.(2) the radius r_m of m^{th} order bright ring is obtained as

$$\frac{r_m^2}{R} = \left(m + \frac{1}{2}\right)\lambda \implies r_m^2 = \left(m + \frac{1}{2}\right)\lambda R \tag{4}$$

hence the radius of the rings is given by, $(m = 0, 1, 2, ...)$

$$r_m = \sqrt{m\lambda R} \quad \text{for dark rings} \tag{5}$$

$$r_m = \sqrt{\left(m + \frac{1}{2}\right)\lambda R} \quad \text{for bright rings} \tag{6}$$

With the help of a traveling microscope, we can measure the diameter D_m of the m^{th} order dark ring which satisfies

$$D_m^2 = 4m\lambda R \tag{7}$$

The radius of curvature R can be calculated from the knowledge of the wavelength λ.

II Setup and procedure:

1. Clean the plano-convex lens and glass plate thoroughly. Place the lens over the plate with the curved face below, and fix in the mounting frame provided. Do not tighten too much or the lens will break. Place this on the wooden mount below the 45^o plate and bring under the travelling microscope.

2. Switch on the monochromatic light source. Let the beam fall horizontally on the 45^o plate.

3. Focus the microscope on the rings with the cross-wires at the center. The horizontal cross-wire must be parallel to the direction of travel of the microscope.

4. Now move the microscope to focus on say, the 20th order dark ring on one side of the centre. Set the crosswire tangential to one ring as shown in Fig 3. Note down the microscope reading. (Make sure that you correctly read the least count of the vernier in mm units).

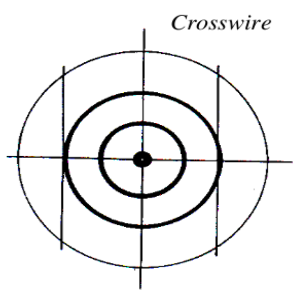

Figure 3

5. Move the microscope to make the crosswire tangential to the next ring nearer to the centre and note the reading. Continue with this process till you pass through the center. Take readings for an equal number of rings on the other side of the centre.

Precautions: *The thickness of the rings decreasees as you go towards the outer edge of the pattern. In order to minimize 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. *If you place the cross wire tangential to the outer side of a particular ring on one side of the central spot, then the cross wire should be placed tangential to the inner side of the same ring on the other side of the central spot. (See Fig. 3)*

3. *The traveling microscope should move only in one direction.*

III Exercises and Viva Questions:

1. What is the medium that causes the interference in this experiment? Why are the interferences effects due to the glass plate and the lens ignored?

2. Explain why the interference rings are circular in shape.

3. Why do the rings get closer as the order of the rings increases?

4. Show that the difference in radius between adjacent bright rings is given by $\Delta r = r_{m+1} - r_m \approx \frac{1}{2}\sqrt{\frac{\lambda R}{m}}$ for $m >> 1$

5. Show that the area between adjacent ring is independent of m and is given by $A = \pi\lambda R$ for $m >> 1$

6. Is the central spot dark? What would be the reason for not obtaining a dark central spot in the experiment?

7. What is the medium that causes the interference in this experiment? Why are the interferences effects due to the glass plate and the lens ignored?

7. What would be the shape of the rings if a wedge shaped prism were kept inverted on the glass plate?

8. What will be the effect of using a plano-concave lens in the experiment? Derive the expression for the radius of bright and dark fringes.

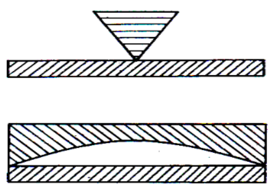

Figure 4

9. What would be effect of using white light instead of a monochromatic light?

10. Why is it necessary to use a lens of large value of R in this experiment?

References:

1. *Physics*, M. Alonso and E.J. Finn, Addison Wesley 1992.

2. *Fundamental of Physics*, D. Halliday, R. Resnick and J. Walker, John Wiley & Sons, New York, 2001.