Experiment No. 3

NEWTON'S RINGS

I. OBJECTIVE

To determine the radius of curvature of a lens by Newton's rings method.

II. APPARATUS

Newton's rings apparatus (microscope, beam splitter, plano-convex lens, optical flat, XY translation stage), source of nearly monochromatic light (sodium vapor lamp).

III. THEORY

Newton's rings are an interesting illustration of the phenomenon of interference of light by amplitude division and can be formed by placing a convex or plano-convex lens of a large radius of curvature on a plane glass plate and using monochromatic light from an extended source at near normal incidence (Figure-1). The air gap between the lower curved surface of the lens and the glass plate possesses a radial symmetry about the point of contact. When it is illuminated normally with monochromatic light, localized circular interference fringes are formed which are loci of points of equal thickness. These circular fringes are called Newton's rings and their formation can be explained in terms of interference of light rays reflected from the lower surface of the convex lens and the flat upper surface of the glass plate, as shown in Figure-1. Consideration of the optical path difference between these two rays (for a thin lens with extremely small curvature and rear normal incidence) leads to interference conditions.

Conditions for observed interference:

$$2t \approx 2n\,(\lambda/2): \text{ Dark fringe}$$

$$2t \approx (2n + 1)\,(\lambda/2): \text{ Bright fringe}$$

Where, t is the air gap at the point of consideration.

It can be easily seen from Figure-1 that if the radius of the nth bright fringe is r_n and R is the radius of curvature of the lower surface of lens, then

$$R^2 = r_n^2 + (R - t)^2$$

$$\text{Or, } t \approx t_n^2 / 2R \text{ (neglecting } t^2\text{)}$$

Substituting this, in the interference condition for the nth bright fringe, we get,

$$r_n^2 = (2n + 1)\, \lambda R / 2$$

which leads to the diameter of the nth bright fringe

$$D_n^2 = 2\,(2n + 1)\, \lambda R \qquad (1)$$

Similarly, the diameter of the nth dark fringe is given by,

$$D_n^{'2} = 4n\lambda R \qquad (2)$$

Usually, due to imperfectness of the contact between the two surfaces at the centre of the of the lens, the exact order of fringes cannot be ascertained. However, the difference in diameters of two bright (or dark) fringes of order n_1 and n_2 are related by

$$\left| \frac{D_{n_1}^2 - D_{n2}^2}{n_1 - n_2} = 4\lambda R \right| \qquad (3)$$

IV. EXPERIMENTAL SETUP AND APPARATUS DETAILS

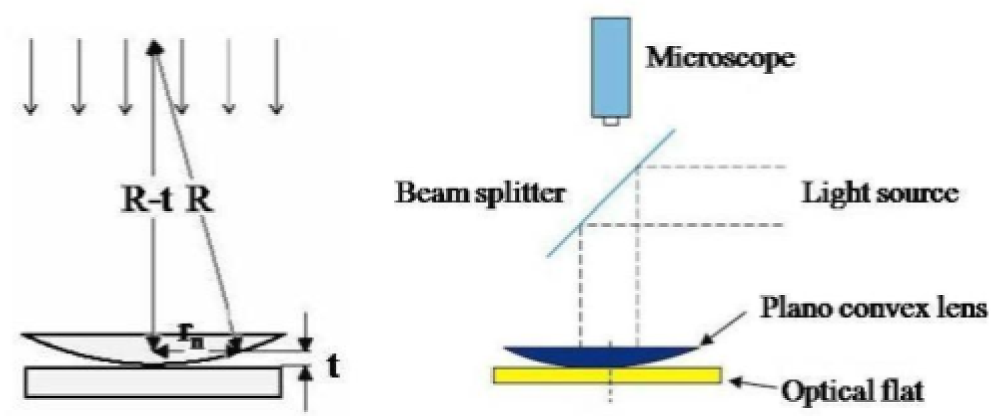

Figure 1: Schematic of Newton's Rings experiment

As shown in the schematic (Figure-1), rays from an extended source (sodium lamp) are reflected from the beam splitter inclined at 45^0 to the vertical and fall nearly normal on an air gap between a thin plano convex lens and a clean optical flat with a black background. The rays reflected from the upper and lower surfaces of the air gap are transmitted through the beam splitter and received by the microscope attached with a XY translation stage. With the help of micrometers attached with the XY stage, the microscope can be moved along X and Y directions. The apparatus is provided with an adjustment screw for the beam splitter. The plano convex lens is mounted in a holder provided with three adjustment screws. Four different wavelength LEDs are also provided. The actual apparatus is framed in Figure-2.

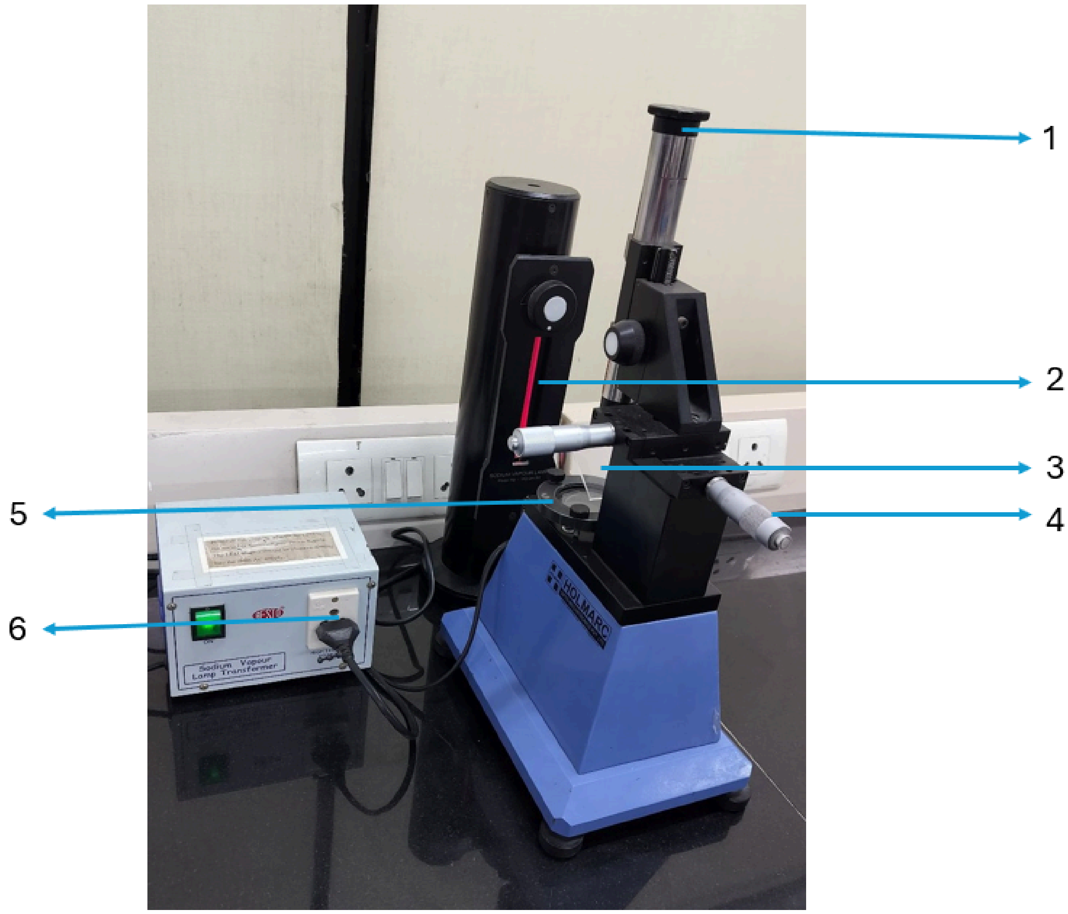

Figure 2: Apparatus for Newton's rings experiment

1.	Microscope Eyepiece	5.	Beamsplitter
2.	Sodium lamp	6.	Power supply for sodium lamp
3.	Beam Splitter		
4.	Micrometer		

V. PROCEDURE

(1) Clean the optics provided for the experiment with iso propyl alcohol. Place the optically flat disk in the region of depression near the objective of the microscope. Keep the planoconvex on top of the optically flat disk (there should only be a point contact between the flat disk and the convex side of the plano-convex lens) for the interference pattern to be formed. Insert the Beam splitter into the holder and fasten the screws. Switch on the Sodium vapor lamp, wait for a couple of minutes for the lamp to reach its maximum intensity and place the lamp in front of the microscope. Change the declination of the beam-splitter to 45° with respect to the direction of the light (when the beam splitter is adjusted to 45°, the field of view will have maximum illumination). Now the focusing of the image has to be done by either increasing/decreasing the distance of the microscope tube from the object, by adjusting the focusing knob behind the microscope. After a focused image (with the circular fringe system in view) is obtained, make sure the crosswire seen in the view is oriented along the direction of motion of the travelling microscope.

(2) With the fringe system in view, by using the micrometer screws coincide the intersection of the crosswire system with the center of the fringe pattern. At this stage, if any micrometer is turned then you will observe that the ring pattern shifts.

(3) Position the microscope in such a way that one of its crosswire touches the rings tangentially and make sure that it is possible to traverse through 20 rings completely by turning the micrometer screw in one direction only.

(4) Move the crosswire to one of the larger but sharp bright or dark rings (say mth).

Remember that ‘m’ may not represent the order of the fringe. It is just the ring no. assigned with respect to the smallest well defined ring which is called the 1^{st} ring. Usually, measurement can be started with the 20^{th} ring (m = 20) or so. Position the crosswire carefully at the centre of the width of this ring and note down its position (X_m) using micrometer. Next by turning the fine movement knob, move the microscope towards the centre of the ring system, each time positioning the crosswire at the centre of width of alternate rings (with decreasing ring no. m-1, m-2, ….., 2,1) and note down the corresponding positions (X_{m-1}, X_{m-2}………., X_2, X_1). After crossing over the centre of rings, continue to position the crosswire at the centre of width of the corresponding rings (at the diametrically opposite points) with increasing order and note down the positions ($X`_1$, $X`_2$, $X`_3$, ……, $X`_{m-2}$, $X`_{m-1}$).

VI. RESULTS AND CALCULATONS

(1) Tabulate ring no. (1, 2,…..,m), X_m and $X`_m$, the ring diameter $D_m$ ( $= X_m - X`_m$) and D_m^2.

(2) Plot D_m^2 (Y-axis) verses m (X-axis) on a graph paper. Use the slope S [= $(D_m^2 - D_{m-2}^2) / (m - (m-2))$] to calculate the radius of curvature (R) using eqn.3. Take $\lambda = 5893$ Å.

(3) Draw the limiting lines with slopes S_1 & S_2 and calculate the error in the slope ΔS $\left(= \frac{|S_1 - S_2|}{2} \right)$ (See section on errors). Hence, estimate the error in R $\left(\Delta = \frac{\Delta S}{S} \right)$ *R R*

VII. PRECAUTIONS

(1) Make sure that before taking measurements that it is possible to transverse through at least 20 rings or so on both sides of the centre of the fringe system.

(2) While measuring the fringe diameter, the microscope should be moved in the same direction throughout, to avoid error due to backlash.

(3) While measurements of X_m and Y_m on the two sides of the centre of the rings, make sure that the ring no. (m) is correctly assigned to the same ring on both sides (with respect to the smallest ring taken as the 1st ring).

VIII. LEARNING OUTCOMES

1. Understand the concept of interference due to division of amplitude using Newton' rings experiment.
2. Demonstrate thin film interference and determine how the interference pattern depends on the wavelength of the incident monochromatic light.

IX. REFERENCES

1. B. K. Mathur: Introduction to Geometrical and Physical Optics.

2. Ajoy Ghatak: Optics

X. QUESTIONS

1. Explain why the interference rings are circular in shape
2. Why do the rings get closer as the order of the rings increases?
3. What would be effect of using white light instead of monochromatic light?
4. What would be the shape of the rings if a wedge shaped prism is kept inverted on the glass plate?