# VL-O2: DETERMINATION OF THE RADIUS OF CURVATURE OF A LENS BY NEWTON'S RINGS EXPERIMENT

**Objectives:**

- To study the interference of light by observing the formation of Newton's rings.
- To determine the radius of curvature of a plano-convex lens for a particular monochromatic light.

**System requirements:**

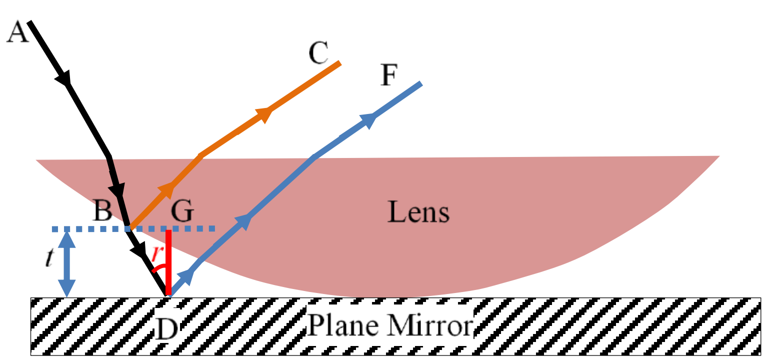
Computer (Desktop/Laptop), Operating systems: Windows, Newton's rings_vle (zipped) File.

**Advise:**

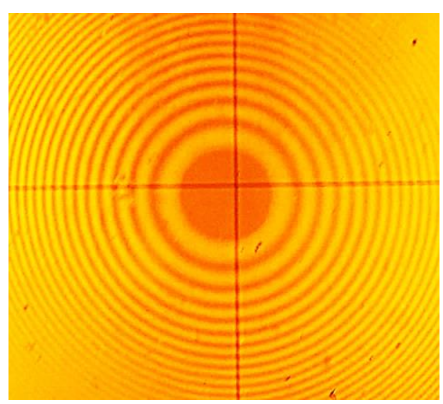
Students are advised to follow the **procedures written in this manual very strictly,** while performing the experiment. **Do not try to explore anything else in the experiment.**

**Theory:**

A parallel beam of monochromatic light AB is incident at point B on a curved surface of a plano-convex lens placed on a plane mirror, as shown in Fig. 1(a). One portion of the incident light is reflected from the glass-air boundary, say from point B and goes along BC direction. The other part is transmitted through the air film along BD. It is again reflected from the glass-air boundary, say from point D along DF direction. These two reflected rays BC and DF from the top and bottom of the air film are produced through division of amplitude from the same incident ray AB and are, therefore, coherent. Hence, they will interfere and produce a system of alternate dark and bright rings, as shown in Fig. 1(b). These rings are known as Newton's rings.




(a)



(b)

Fig. 1: (a) Schematic diagram of light rays in Newton's rings experiment. (b) Newton's rings.

The optical path difference ($\Delta$) between the rays BC and DF is given by

$$\Delta = 2\mu t cosr - \frac{\lambda}{2} = 2t - \frac{\lambda}{2} \dots\dots\dots\dots\dots (1)$$

Where, $t$ is the thickness of the air film, $r$ is the angle of refraction (the angle between the refracted ray BD and normal BG). Here, for normal incident, $r$ = 0° and therefore, $cosr = 1$; in case of air, the refractive index, $\mu = 1$.

According to the condition of interference,

For bright rings, $2t - \frac{\lambda}{2} = n\lambda$ (where $n = 1, 2, 3 \dots$), i.e., $2t = (2n + 1)\frac{\lambda}{2}$ ………… (2)

For dark rings, $2t - \frac{\lambda}{2} = (2n + 1)\frac{\lambda}{2}$ (where $n = 1, 2, 3 \dots$), i.e., $2t = n\lambda$ ………….. (3)

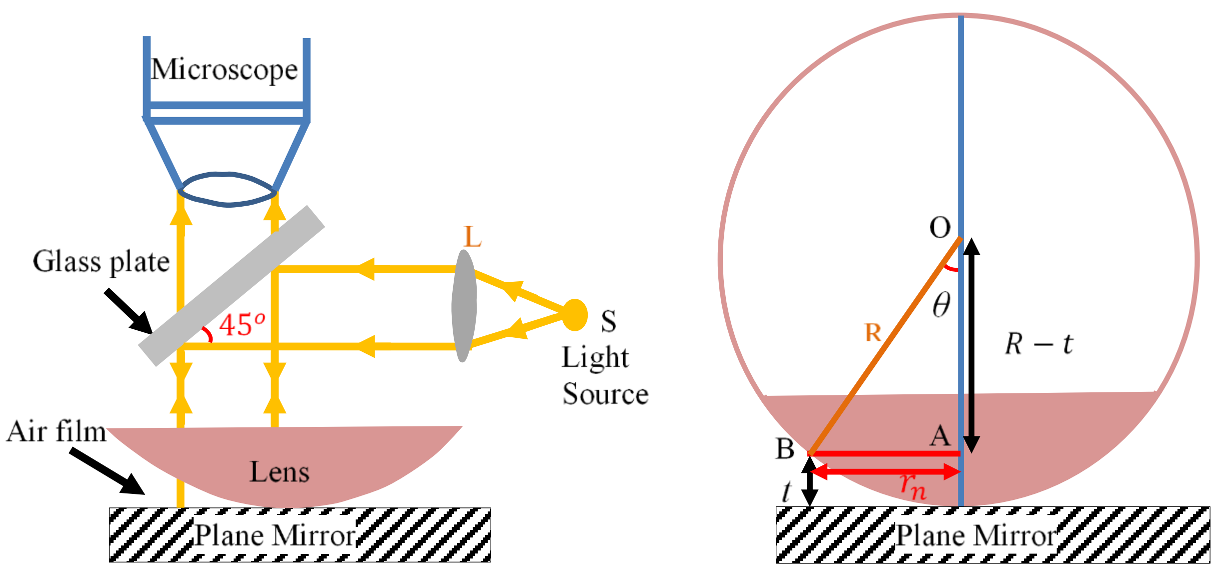



Fig. 2 (a) Fig. 2 (b)

Figure 2 (a) shows the experimental arrangement for the determination of wavelength of monochromatic light by Newton's rings. S is a source of monochromatic light. A parallel beam of light from the lens $L$ is reflected by a glass plate inclined at an angle 45° to the horizontal. Newton's rings are viewed through the eyepiece of the travelling microscope focused on the air film. Fig. 2(b) shows that the plano-convex lens appears as part of circle of radius $R$ known as the radius of curvature of this lens. If $r_\mathrm{n}$ is the radius of the $\mathrm{n^{th}}$ dark ring created for air film having thickness, $t$, then from the triangle AOB one can write,

$$R^2 = r_\mathrm{n}^2 + (R - t)^2 \dots\dots\dots (4)$$

Since $R \gg t,\ \ t^2$ can be neglected and then Equation (4) becomes

$$t = \frac{r_\mathrm{n}^2}{2R} \dots\dots\dots\dots\dots (5)$$

Combining Equations (3) and (5), one can write for dark ring, $r_\mathrm{n}^2 = R\mathrm{n}\lambda$

So, for the diameter of the $n^{th}$ ring ($D_n$), can be expressed as, $D_\mathrm{n}^2 = 4R\mathrm{n}\lambda \dots\dots\dots\dots (6)$

For the diameter of the $(n+p)^{th}$ rings $\left(D_{n+p}\right)$, $D_\mathrm{n+p}^2 = 4R(\mathrm{n}+\mathrm{p})\lambda \dots\dots\dots\dots\dots (7)$

From Equations (6) and (7), one can write

$$R = \frac{D_\mathrm{n+p}^2 - D_\mathrm{n}^2}{4\lambda\mathrm{p}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .. (8)$$

This equation can be used to find the value of radius of curvature of the plano-convex lens using Newton ring’s experiment.

**Procedures:**

1. At first unzip **“Newton’s rings_vle (zipped)”** File. Click on the executable file **“Newton’s rings_vle”**, then a window will open as shown in Fig. 3.
2. The default option for the source of light is red. Select the yellow color of light by moving the white triangular slider (marked by 2 in the Fig. 3) and record the wavelength of the light.
3. Change the radius of the lens using the light-blue knob (marked by 3) to see the clear rings. For this, move the pointer of the knob towards left or right.
4. Change the coherence length of the light using the yellow knob at the top right-hand side (marked by 4) to observe a greater number of rings on the microscope view. For this, move the pointer of the knob towards left or right.
5. Repeat procedures 3 and 4 so that you can display at least 8 rings.
6. Move the vertical line of the eyepiece’s crosswire using the microscope movement knob at the bottom (marked by 5) on the circumference of the $8^{th}$ bright ring at the left side from the central circular dark spot. Press “zero” knob (marked by 6), which will set the reading “zero” for the $8^{th}$ ring in the left side. Record the microscope reading.

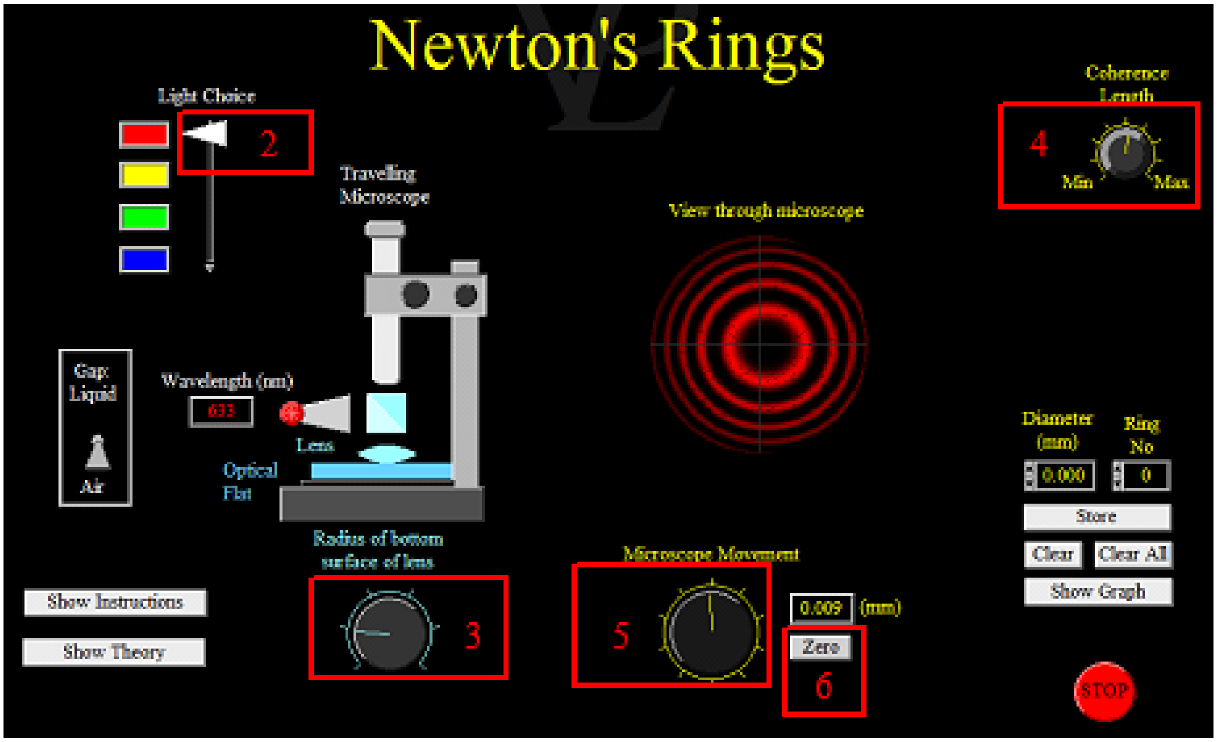



Fig. 3: Newton's rings experiment as observed in the simulation.

7. Then move the cross-wire to the right direction and set it carefully on the circumference of each successive bright ring ($7^{th}$, $6^{th}$ .....$1^{st}$ rings at the left) and record the microscope readings.
8. Move the cross-wire again to the right direction and set it carefully on the circumference of each successive bright ring ($1^{st}$, $2^{nd}$, $3^{rd}$ …. $8^{th}$ rings at the right) and record the microscope readings.
9. Considering a particular ring, the difference between the right side and left side readings gives the diameter of the ring.
10. Draw a graph with the square of the diameter as ordinate and number of the ring as abscissa. The graph should be a straight line passing through the origin as shown in Fig. 4.
11. Determine the value of $D_{n+p}^2 - D_n^2$ and $p$ from the graph as shown and calculate the radius of curvature of the lens using Equation (8).

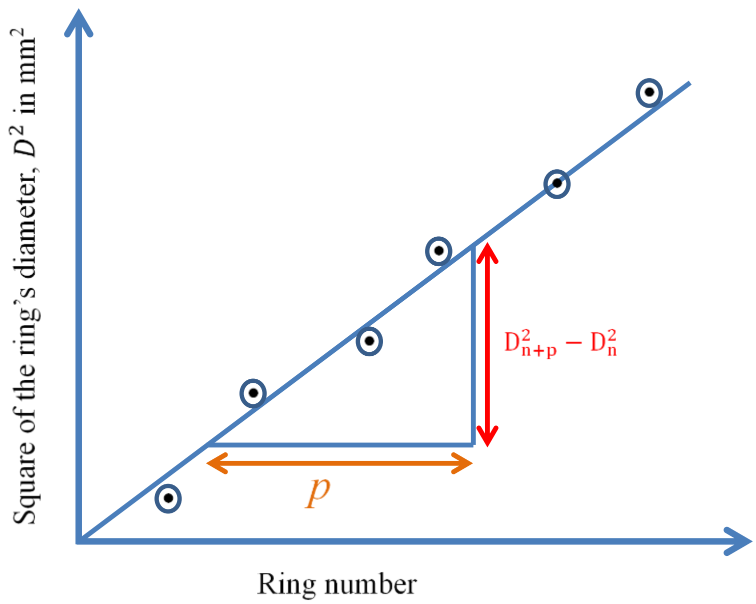



Fig. 4: Square of the diameter versus ring number graph.

**Data Collections:**

**Table 1: Data for the diameter of the Newton's rings**

| **Ring number** | **Microscope reading (mm)** | | $D_n = \mathbf{R} - \mathbf{L}$ **(mm)** | $D_n^2$ **(mm$^2$)** |
|---|---|---|---|---|
| | **Left side (L)** | **Right side (R)** | | |
| 8 | | | | |
| 7 | | | | |
| 6 | | | | |
| 5 | | | | |
| 4 | | | | |
| 3 | | | | |
| 2 | | | | |
| 1 | | | | |

**Calculations:**

From Equation (8) the radius of curvature of the plano-convex lens is, $R = \frac{D_{\mathrm{n+p}}^2 - D_{\mathrm{n}}^2}{4\lambda \mathrm{p}}$

**Result:**

Radius of curvature of the plano-convex lens =…….. cm

**Discussion:**

Based on your understanding from this experiment, answer the following questions:

1) If you change the radius of the lens with blue knob, what happens to the interference pattern?
2) If you change the coherence length of the light using the yellow knob at the top right-hand side, what do you notice? What happened to the interference pattern when a large coherence length is chosen?
3) Why are the rings circular?
4) In the Newton's rings system, the rings close to the center are quit broad, what is the reason?
5) Why the center of the rings is dark in your experiment? When the center of the rings may become bright, why?
6) Introduce a liquid in the gap between the lens and glass plate using the white switch on the left hand side. What do you notice? What does it tell you about the wavelength of light for a material of higher refractive index?