NEWTON'S RINGS **Exp-3**

Purpose

- To demonstrate Newton's rings in transmitted light as a system of interference rings between a flat glass plate and a planoconvex lens.
- To determine the bending radius of the planoconvex lens by measuring the Newton's rings when illuminating with the coming light of the Hg spectrum.
- To investigate the dependency of the Newton's rings on the wavelength of the light by illuminating with monochromatic light from the mercury spectrum.

Related topics

Coherent light, phase relationship, path difference, interference in thin films, Newton's ring apparatus.

Theory and Evaluation

In creating Newton's rings, a very slightly curved convex lens is placed so that it touches a flat glass plate. This forms a wedge of air with one spherically curved boundary surface. When this arrangement is illuminated with normally incident parallel light, concentric interference rings are formed around the point at which the two surfaces touch. We can observe these interference rings both in reflection and in transmitted light.

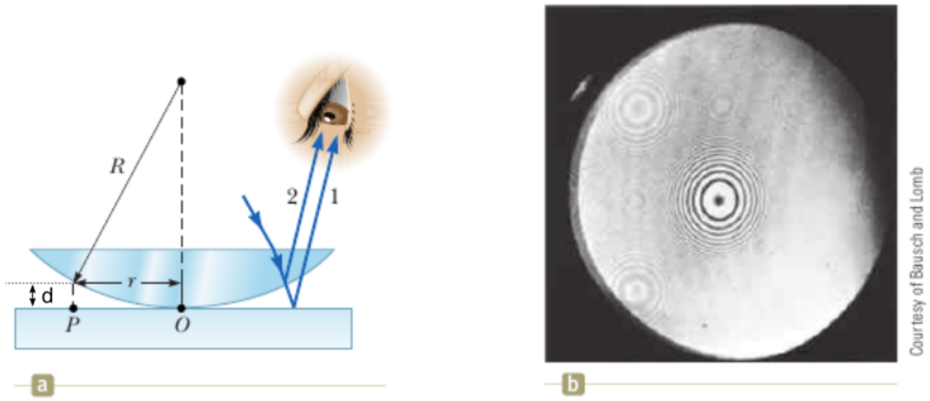

Figure 6: a) The combination of rays reflected from the flat plate and the curved lens surface gives rise to an interference pattern known as Newton's rings. (b) Photograph of Newton's rings [17]

The radius of the rings changes depending on the wavelength of the light. The distances between the interference rings are not constant, as one of the boundary surfaces of the "air wedge" is curved.

In Figure 7, a light wave L coming from the left strikes an air wedge with the thickness d between two glass plates. The partial wave T_1 is reflected at the left-hand boundary surface between the glass plate and the air wedge. The partial wave T_2 passes through the air wedge. The reflection of partial wave T_3 at the right-hand boundary surface occurs in conjunction with a phase shift, as this involves reflection at a medium with a higher refractive index, i.e. optically denser. Partial wave T_4 is first reflected at the right-hand boundary surface and then at the left-hand boundary surface, and its phase shifts each time. Additional partial waves, here represented with T_5 , are created by multiple reflection in the air wedge, with the corresponding phase shifts. We can now observe the interference of the partial waves T_1 , T_3 and further partial waves in reflection, and T_2 , T_4 and further partial waves in transmitted light. The

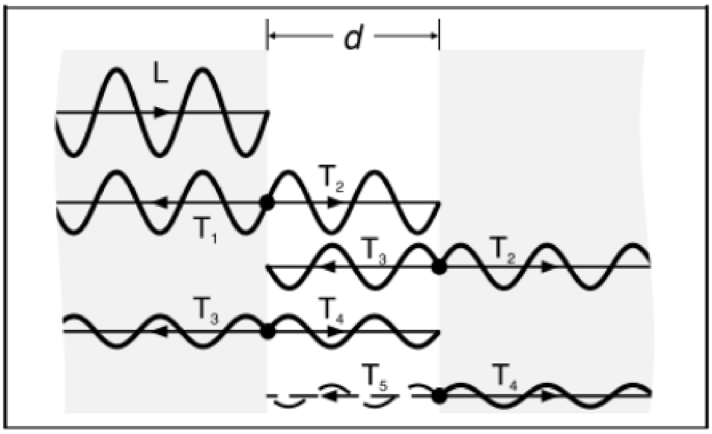

Figure 7: Calculation of optical path difference through lens-air gap-glass system [14]

path difference Δ between T_2 and T_4 is 2 d. But the condition for constructive interference in air wedge is [14]

$$2d \;=\; \left(m \;+\; \frac{1}{2}\right) \lambda_n \qquad m \;=\; 0,\; 1,\; 2,\; \ldots \tag{6}$$

The general equation for destructive interference in air wedge is

$$2d \;=\; m\; \lambda_n \qquad m \;=\; 0,\; 1,\; 2,\; \ldots \tag{7}$$

This condition takes into account two factors: (1) the difference in path length for the two rays (the term $m\lambda$) and (2) the 180° phase change upon reflection (the term $1/2\ \lambda_n$).

It is because like the reflected pulse on a string undergoes a phase change of 180° when reflected from the boundary of a denser string or a rigid support, but no phase change occurs when the pulse is reflected from the boundary of a less dense string or a freely-supported end. Similarly, an electromagnetic wave undergoes a 180° phase change when reflected from a boundary leading to an optically denser medium (defined as a medium with a higher index of refraction), but no phase change occurs when the wave is reflected from a boundary leading to a less dense medium.

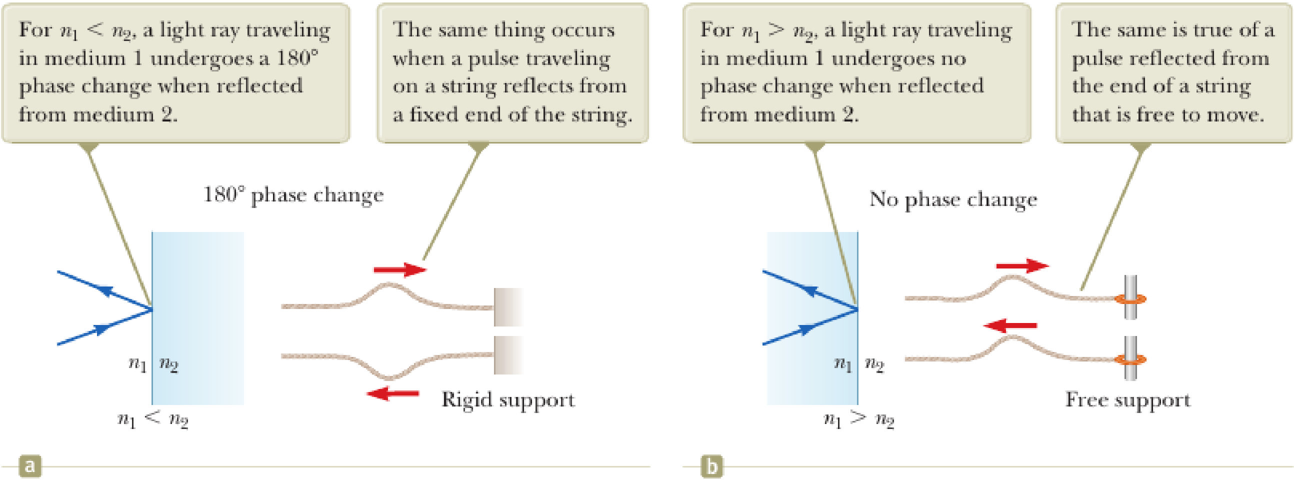

Figure 8: Comparisons of reflections of light waves and waves on strings [17]

In accordance with Fig. 6, there is a relation;

$$\begin{aligned} R^2 &= r_n^2 + (R-d)^2 \\ r_n^2 &= 2dR - d^2 \end{aligned} \tag{8}$$

In case of slightly convex lenses, d ≪ R, If we put d in Eq. 8, so that for the dark rings we would get [17];

$$\begin{aligned} r_n &= \sqrt{2\ d\ R\ -\ d^2} \\ r_n &\approx \sqrt{2dR} \\ r_n &\approx \sqrt{2\ m\ \lambda\ R} \end{aligned} \tag{9}$$

Set-up, Procedure

1. Set up the experiment in Figure 9 to determine the Newton's rings pattern.

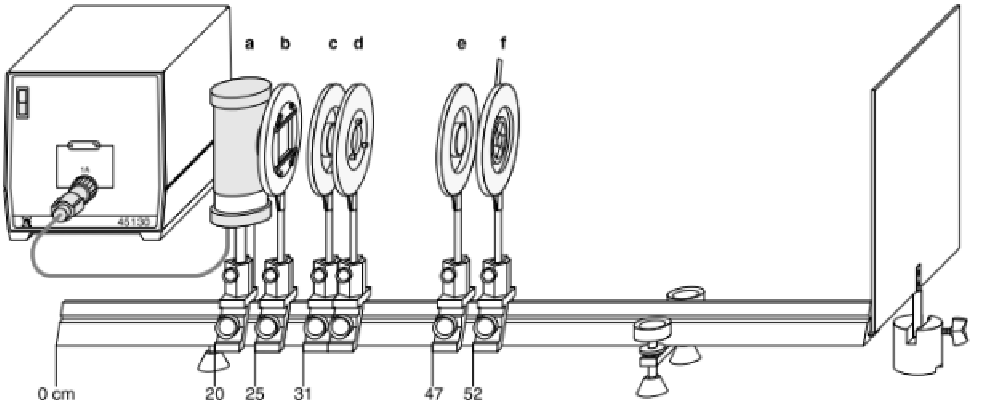

Figure 9: Experimental set-up for determining wavelength using the Newton's apparatus, (a) Hg spectral lamp (b) Object holder (c) Lens, f = 100 mm (d) Plates for Newton's rings (e) Lens, f = 100 mm (f) Iris diaphragm [14]

2. Mount the optical components on the optical bench; check their positions.
3. Place the translucent screen at a distance of 1 to 2 m.
4. Set up the holder for the "plates for Newton's rings" (d) so that the ad- justing screws face the translucent screen. Slide the optics rider as close as possible to the lens (c).
5. Place the Hg–spectral lamp in the setup and switch it on. After a warm-up phase of a few minutes (approximately 10 min), move the optics rider until the plates are optimally illuminated.
6. Vary the position of lens (e) or the translucent screen until a sharp image of the Newton's rings appears and the scale is clearly recognizable.
7. Clamp the yellow filter in the object holder. Optimize the bright-dark contrast of the Newton's rings using the iris diaphragm (f). Measure the radii r of the bright interference rings on the pattern for the yellow color filter and record in the Table below. Draw the graph which shows the the number of the bright line and the change of the ring radius.
8. Repeat the measurement with the green color filter. Interpret the graph and check the Newton's rings change with the wavelength λ.