reinforcement occurs, and, therefore, these regions produce bright regions. Wherever a crest meets a trough or a trough meets a crest, a gray appearance will result and each neutralizes the effect of the other and water will be practically undisturbed (fig. 28.2).

(*d*) **Diffraction** : If a part of the wave front is cut-off by an obstacle, the wave length near the edge of the obstacle advances into the region behind the obstacle. This bending of light around an obstacle is called diffraction.

In order to demons rate this phenomena, let us use a straight-wave generator and two barriers parallel to it be placed in line with an opening between them.

With periodic straight wave pulses, we observe that in the middle of the pattern beyond the opening of the wave are straight but at the sides they curve, giving the impression of circular waves orginating from the edges of the opening. This means that after passing through the opening, all the wave pulses do not propagate in its original direction and part of it is also bent. This establishes the phenomena of diffraction.

By changing the wavelength of the incident pulses, we observe that waves are strongly diffracted when they pass through an opening size comparable to their wavelength, and there is hardly any diffraction if the wavelength is very small compared to the width of the opening.

Exp. 29A. Wave length of sodium light by Newton's ring

Object

To determine the wavelength of sodium light by Newton's ring.

Apparatus

Travelling microscope, support for glass plate mclined at 45° to the vertical, short focus convex lens, sodium lamp, plano-convex lens, an optically plane glass plate and a spherometer.

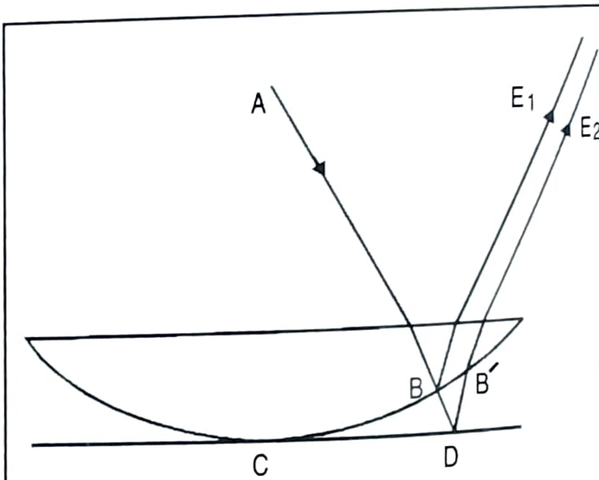

Fig. 29.1

Theory

If the convex surface of a plano-convex lens is placed in contact with a plane glass surface, a thin air-film will be formed inbetween them (fig. 29.1). The thickness of the air-film increases as one proceeds from the point of contact towards the periphery of the lens.

When a monochromatic beam of light is incident on such a lens, reflection takes place from the upper and lower surfaces of the air-film contained between the lens and the glass plate. Thus, a path-difference is introduced between the two reflected rays and consequently the fringes are produced. As the loci of points of equal thickness of the air-film are circles concentric with the point of contact, the fringes will be concentric rings with their centre at C.

Suppose the convex lens touches the plane mirror at the point E and B_1, B_2 lie on the n^{th} bright ring whose radius is r (fig. 29.2).

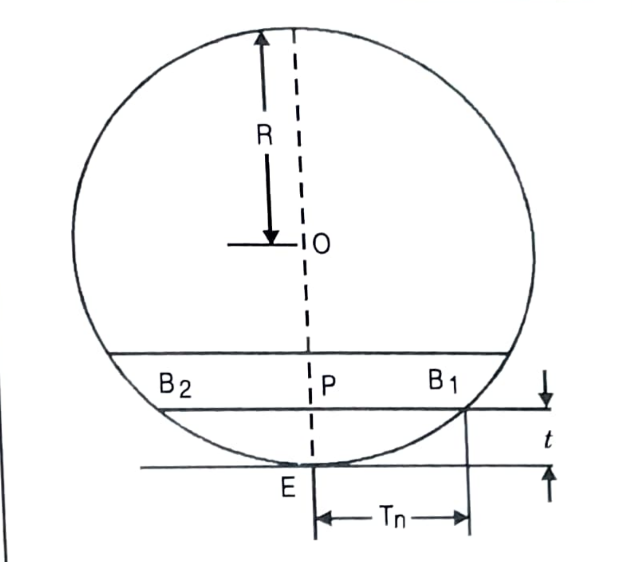

Fig. 29.2

Let R be the radius of curvature of the curved surface of the lens. The thickness t of the air-film at the point is given by

$$(B_1P)^2 = EP(2R - EP)$$

$$\therefore \quad r_n{}^2 = t(2R - t)$$

$$\text{or} \quad t = \frac{r^2 n}{2R} \qquad ...(1)$$

approximately since R is fairly large compared to t.

With this thickness of the film at the point, bright ring will occur if

$$2\mu t \cos(\alpha + \theta) = (2n + 1)\frac{\lambda}{2} \qquad ...(2)$$

where μ is the refractive index of the film, α and θ are respectively the angle of refraction for the ray into the film and the angle of the film and n, any integer.

Equation (2) can be simplified by putting $\mu = 1$ (for an air-film), $\alpha = 0$ (for normal incidence of the rays) and $\theta = 0$ using a lens of large radius of curvature, whence

$$t = \frac{(2n+1)\lambda}{4} \qquad ...(3)$$

Substituting the value of t from eqn. (1), the radius of the n^{th} bright ring (r_n) can be written as

$$r_n^2 = \frac{(2n+1).\lambda R}{2} \qquad ...(4)$$

$$\therefore \quad d_n^2 = 2(2n+1)\lambda R \qquad ...(5)$$

(d_n = diameter of the n^{th} bright ring).

Similarly, for $(n + m)^{th}$ bright ring,

$$d_{n+m}^2 = 2\{(2(n + m) + 1)\}\lambda R \qquad ...(6)$$

$$\therefore \quad \lambda = \frac{d_{n+m}^2 - d_n^2}{4Rm} \qquad ...(7)$$

Equation (7) remains the same also for dark rings.

This equation can now be used for the determination of wave length of the source. The advantage of this equation over eqn. (5) can be cleary visualised. From theoretical considerations, at the point of contact, the thickness of the air-film is zero and as a result, in a reflected system a central *dark ring** of zero order is formed. In actual pracuice, due to dust particles between the lens and the plate or due to some imperfections in their surfaces, the thickness at the point of contact may not be zero. As a consequence, any other order of dark ring may be formed at the centre and thus the measurement of diameter for the n^{th} bright ring will be inaccurate.

Procedure

(*i*) The experimental arrangement is made as shown in fig. 29.3. Light from a sodium lamp is rendered *approximately parallel*** by a short focus convex lens and is then reflected downwards by a plane glass held at 45° to the vertical. The portion of the light reflected from the plane glass falls normally on a plano-convex lens placed on the optically plane glass plate and the reflected light is received by a travelling microscope.

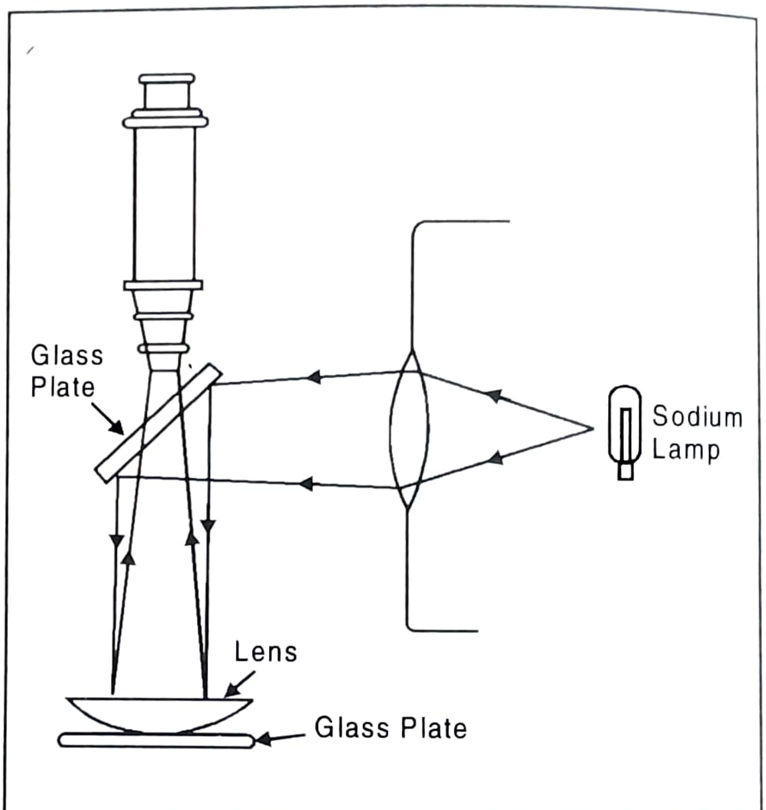

Fig. 29.3

(*ii*) The eye-piece is focussed on the cross-wire of the microscope. The microscope is adjusted over the point of contact so that the rings are distinctly seen in the field of view. For quickly obtaining the rings, the plano-convex lens is removed and the microscope is focussed on a mark on the top of the glass plate.

* Assuming the air film to be optically rarer than the media above and below it, a phase change of π or a path change of $\lambda/2$ occurs in the wave at the instant of its reflection at points in the glass plate being backed by a denser medium. At the central spot, the two rays are thus in opposite phases and a dark spot is obtained.

**If all the rays of the incident beam could be made perfectly parallel, circular fringes formed would have no width. Since in practice, the rays from an extended source can be made only approximately parallel, the fringes will have small but finite width.

(*iii*) After obtaining the rings, the microscope is set properly so that the point of intersection of the cross-wires lies on the centre of the central dark ring. The microscope is clamped and working with the fine adjustment screw the cross-wire is set tangential to 20th bright ring (say) on one side of the central dark spot, counting the central spot as zero. Now the fine adjustment screw is worked in the other direction till the cross-wire is tangential to the 15th bright ring. The reading is noted. Moving back towards the centre, the cross-wire is now set tangential to 14th bright ring and the reading is recorded. The observations are continued till 6th bright ring is reached, care being taken to see that the tangential screw is moved always in one direction to avoid any error due to back-lash. The screw is continuously worked till the cross-wire is set to the 6th bright ring on the other side of the central dark spot and the reading is noted. The process is continued and the readings are taken as the cross-wire is set on different rings till the 15th bright ring is reached. From these observations, the diameters of the various rings are calculated.

(*iv*) Next, the radius of curvature (R) of the spherical surface of the lens in contact with the glass plate is determined by spherometer.

(*v*) The observations for diameters of the rings are tabulated as shown in table [A]. The value of the squares of the diameters of these bright rings are calculated and the expression $[d_{n+m}^2 - d_n^2]$ is evaluated choosing such a value of n as to make use of all the readings. From the mean value of this expression and the value of R, the wavelength of sodium light is determined.

Observations

[A] *Determination of* $(d^2{}_{n+m} - d^2{}_n)$

No. of ring	Microscope reading		Diameter in cm	(Diameter)^2 in cm^2	$(d^2{}_{n+m} - d^2)$	m
	Left side in cm	Right side in cm				
15	...	...	...	d_{15}^2...	...	
14	...	...	...	d_{14}^2...	...	
13	...	...	...	d_{13}^2...	... ...	
...	...	...	...	....	... ...	5
10	...	...	...	d_{10}^2...	... ...	
9	...	...	...	d_9^2...	... ...	
8	...	...	...	d_8^2...	...	
7	...	...	...	d_7^2...	...	
6	...	...	...	d_6^2...		
				Mean in cm^2		

[B] *Determination of radius of curvature (R)*

Pitch of the spherometer = ... cm

No. of div. in the circular scale = ...

Least count of the spherometer = ... cm

S. No.	Reading on		d in cm	D in cm	$R = \frac{D^2}{6d} + \frac{a}{2}$ in cm
	plane glass plate in cm	convex surface of the lens in cm			
1.					
2.					
3.					

It is to be noted that D is the distance between any two of the outer legs, and d is the distance through which the central leg is raised so that all the four legs may be in contact with the curved surface of the convex lens in contact with the liquid.

Calculations

$$R = \frac{D^2}{6d} + \frac{d}{2} = \ldots \text{ cm}$$

$$\therefore \quad \lambda = \frac{d_{n+m}^2 - d_n^2}{4mR} = \ldots \text{ A.U.}$$

% *error* :

Result

The wavelength of sodium light (correct to significant figures) = ... A.U.

Precautions

(*i*) The glass plate should be inclined at 45° to the vertical.

(*ii*) The radius of curvature of the spherical surface of the plano-convex lens should be of the order of 100 cm,

(*iii*) The surfaces of the lens and the glass plate in contact with it should be cleaned with rectified spirit. Unclean surfaces of the lens and the glass plate may give rise to elliptically shaped rings.

(*iv*) Before taking readings for the diameters, it should be seen that the motion of fine adjustment screw of the microscope covers all the diameters of the rings to be measured.

(*iv*) The fine adjustment screw should always be moved in one direction only to avoid the back-lash error.

(*vi*) The cross-wires should be set only on the bright rings as they provide a contrast between the cross-wires and the bright background of the ring.

An alternative method of determining λ

If a graph is plotted between d'_n on y-axis and the number of rings n on X-axis, a straight line will be obtained whose slope m is equal to $4R\lambda$. If the slope m be measured from the graph and R be determined experimentally, then λ can be calculated from the relation,

$$\lambda = \frac{m}{4R}.$$

Important points about the experiment

(*a*) The rings, which are formed in the air-film enclosed between the lens and the plate of glass, are not seen directly but after refraction through the lens. Thus, the observed diameters are not correct. The error in this method is appreciably reduced by using a thin plano-convex lens of large radius of curvature. The rings formed are nearly coincident with the surface of the lens and hence lie in its first principal plane. Their images lie in the second principal plane and hence the observed images are almost of the same size as those of the actual rings. At the same time, the lens of large radius of curvature is necessary so that (*i*) the angle of the air-film becomes small (see theory of the experiment) and (*ii*) the rings observed have then a comparatively large diameter and consequently the accuracy in the measurement of their diameters is increased.

(*b*) The rings can also be studied with transmitted light. The central spot which is dark when seen by the reflected light is bright when seen by transmitted light. The rings observed by reflected light are exactly complementary to those seen by the transmitted light.

QUESTIONS

(*i*) What do you mean by interference of light ? What are the essential conditions for observing this phenomenon ?

(*ii*) What are sources of light called and how are they produced ?

(*iii*) Why should the source be monochromatic ?

(*iv*) How are the Newton's rings formed ? Why are the rings circular ?

(*v*) On what factors, the radius of a ring depends ?

(*vi*) Where are the fringes formed ?

(*vii*) What would be your observation in transmitted light ?

(*viii*) Why is the central spot dark in your experiment ?

(*ix*) If the sodium lamp be replaced by an electric bulb, what would be the result ?

(*x*) Can this experiment be utilised for determining the refractive index of any liquid ? How ?

(*xi*) Why should you use a convex lens of large radius of curvature ?

(*xii*) Why does the fringes get closer and finer as we move away from the centre ?