Related topics

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

Principle

In a Newton's rings apparatus, monochromatic light interferes in the thin film of air between the slightly convex lens and a plane glass plate. The wavelengths are determined from the radii of the interference rings.

Equipment

1	Newton rings apparatus	08550-00
1	Lens, mounted, f = +50 mm	08020-01
1	Interference filters, set of 3	08461-00
1	Screen, translucent, 250 x 250 mm	08064-00
1	Lamp, f. 50 W Hg high press. lamp	08144-00
1	Power supply for Hg CS/50 W lamp	13661-97
1	Double condenser, f = 60 mm	08137-00
2	Lens holder	08012-00
4	Slide mount f. opt. pr.-bench, h = 30 mm	08286-01
1	Slide mount f. opt. pr.-bench, h = 80 mm	08286-02
1	Optical profile-bench, l = 1000 mm	08282-00
2	Base f. opt. profile-bench, adjust.	08284-00
1	Rule, plastic, l = 200 mm	09937-01

Fig. 1: Experimental set-up for determining wavelength using the Newton's apparatus.

Tasks

Using the Newton's rings apparatus, to measure the diameter of the rings at different wavelengths and:

1. to determine the wavelengths for a given radius of curvature of the lens
2. to determine the radius of curvature at given wavelengths.

Set-up and procedure

The Newton's rings experiment is set up as shown in Fig. 1. The mercury vapour high-pressure lamp with the double condenser (focal length 60 mm) fitted, the lens holder with the interference filter, the Newton's rings apparatus, the lens holder with the lens of focal length 50 mm and a transparent screen about 40 cm away from the lens are all set up on the optical bench. At the beginning of the experiment the path of the rays is adjusted, first without colour filters, until interference rings can be observed on the screen. Then the yellow filter is inserted in the lens holder and the room darkened. By turning the three adjusting screws on the Newton's rings apparatus to and fro, the plano-convex lens is set on the plane parallel glass plate so that the bright centre of the interference rings is in the mid-point of the millimetre scale projected on the screen. When making this adjustment, ensure that the lens and the glass plate only just touch. This is achieved when no more rings emerge from the ring centre when the adjusting screws are tightened up.

The radii r_n of the interference rings are measured for the various interference filters at the appropriate ordinals.

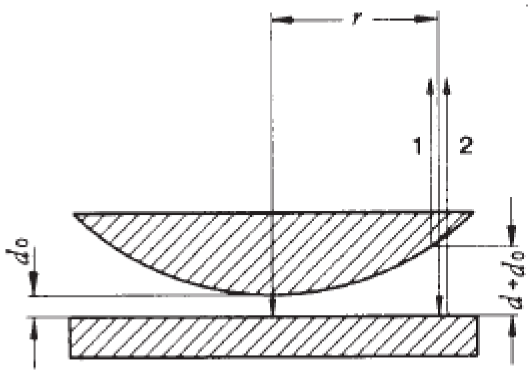

Fig. 2: Creating Newton's rings.

Theory and evaluation

If two phase-locked wave trains of the same frequency and plane of polarisation (coherent light) overlap, after travelling different paths, interference occurs. In a limited aperture angel γ, the light of wavelength λ leaving a surface of diameter a fulfils the coherency condition

$$a \cdot \sin \gamma \ll \lambda/2 \quad .$$

Interference figures whose brightness can differ in places, can occur.

“Newton’s rings” occur through monochromatic light interfering in the thin intermediate film between a convex lens and a plane glass plate. Ray 1 reflected at the underside of the lens thus interferes with ray 2 reflected at the top of the glass plate (Fig. 2).

The film of air at a distance r from the point of contact between the lens and the glass plate has a thickness $D=d\pm d_0$. As ideal contact is not present, we must take d_0 into account. d_0 is positive when, for example, there are particles of dust between the lens and the glass plate, but is can so also be negative when the pressure is greater. The geometric path difference δ' of the interfering rays is therefore:

$$\delta'=2(d\pm d_0) \quad .$$

In addition, the ray reflected from the plane glass surface experiences a phase shift π at the transition from the optically thinner to the optically denser medium. The effect of this corresponds to a distance travelled of length $\lambda/2$. In all, therefore, there is an apparent path difference

$$\delta=2(d\pm d_0)+\lambda/2 \qquad (1)$$

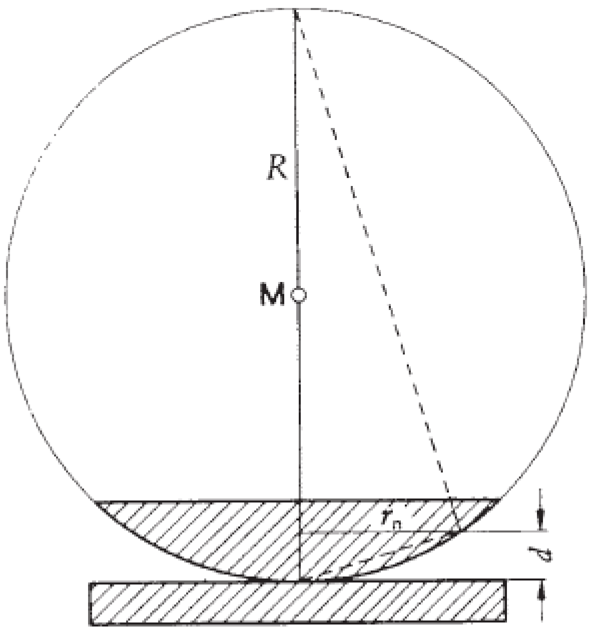

Fig. 3: Geometry used to determine the thickness d.

For the interference rings of maximum cancellation,

$$\delta=2(d\pm d_0)+\lambda/2=(n+1/2)\lambda$$

or

$$2(d\pm d_0)=\lambda n \quad . \quad (2)$$

In accordance with Fig. 3, there is a relation

$$d \cdot (2R - d) = r_n^2 \qquad (3)$$

between the radius r_n of the nth dark ring, the thickness d and the radius of curvature R of the plano-convex lens (in the ideal case $d_0 = 0$).

In case of slightly convex lenses, $d \ll R$, so that for the dark rings, using (2) and (3), we have:

$$r_n^2 = nR\lambda \mp 2 d_0 R \qquad (4)$$

For the evaluation, r_n^2 is plotted against n (Fig. 4). At the given radius of curvature, $R = 12.141\,m$, the wavelength λ of the transmitted light is obtained from the slope of the straight line:

$$\beta = R \cdot \lambda \qquad (5)$$

$$\lambda_{\text{yellow}} = 582 \pm 4\,nm$$
$$\lambda_{\text{green}} = 545 \pm 4\,nm$$
$$\lambda_{\text{blue}} = 431 \pm 4\,nm$$

At a given wavelength λ , the value of R obtained from (5) is the average value of the radius of curvature of the plano-convex lens:

$$R = 12.13\,m$$

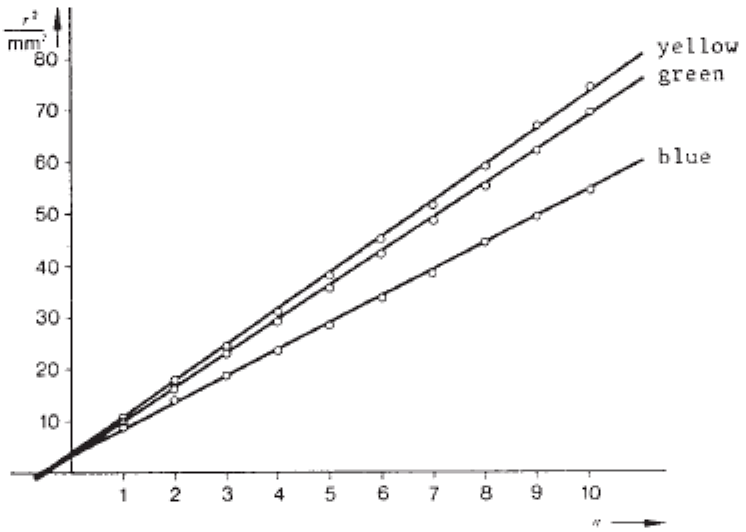

Fig. 4: Radius of the interference rings as a function of the order number for various wavelengths.

Note

In the set-up described, the Newton’s rings are observed in transmitted light. The interference rings are complementary to those in reflected light. In the latter case, therefore, the light rings are counted and not the dark ones.