OPTICS
INTERFERENCE
Practical 5
NEWTON'S RINGS

1 Introduction

Placing a plano-convex lens on a polished glass plate, one can observe an interference pattern in the form of concentric rings, which are called Newton's rings after Newton, who initially observed such interference pattern. The radii of the rings can be related to the parameters of the interference scheme. Indeed, if the light falls normally to the surface of the glass plate, then the optical path difference Δ between the ray reflected from the spherical surface at the point M (Fig. 1.) and the ray passing through the point M after reflection from the plate is given by the following relation

$$\Delta = 2h_k + \frac{\lambda}{2}, \qquad (1)$$

where h_k - the thickness of the air gap in the given place (think about the reasons for the appearance of an additional path difference of $\lambda/2$).

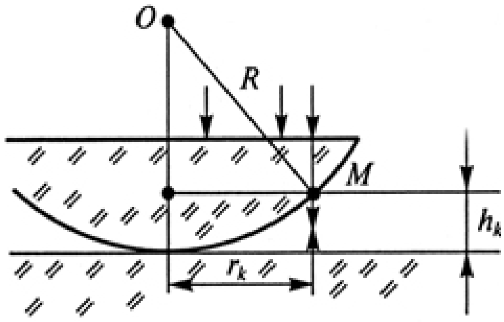

Fig.1.

Under the condition $R \gg h_k$, one can derive the squared radius of the ring with the index *k*:

$$r_k^2 = 2Rh_k. \qquad (2)$$

For a dark ring with index *k* (an interference minimum of the *k*-th order), the optical path difference at the point M is

$$\Delta = (2k-1)\cdot\lambda/2; \; k = 1, 2, \ldots \, . \qquad (3)$$

From equations (1), (2) and (3), one can obtain the radius of curvature of the lens as following:

$$R = \frac{(r_k^2 - r_i^2)}{((k-i)\lambda)} = \frac{(d_k^2 - d_i^2)}{(4(k-i)\lambda)}, \qquad (4)$$

where *k* and *i* are the ordinal numbers of the dark rings in reflected light, which count from the center of the interference pattern (for the central dark spot *k* = 1).

2 Experimental setup

Experimental setup is depicted on the Fig. 2a. The experimental setup for the observation and measurements of Newton's rings was assembled on the basis of a microscope, the subject stage of which was replaced by a special holder 6 for mounting and moving the lens and the plate (Fig. 2b). The studied lens 1 is inserted into the movable round frame 5. By changing the height of this frame above the stage with special screws 3, it is possible to make the studied lens touch the glass plate in the holder. The displacement of the holder required for measurements is carried out with the aid of the screw 4. The value of this displacement is measured on the scale of the micrometric indicator 7 with the accuracy of 0.01 mm. A small displacement of the table in the transverse direction (a precise tuning the microscope to the center of the interference pattern) is achieved with the help of the screws 2. The picture of Newton's rings is observed in reflected light. To do this, use the so-called opaque illuminator - a translucent glass plate, mounted in the microscope tube.

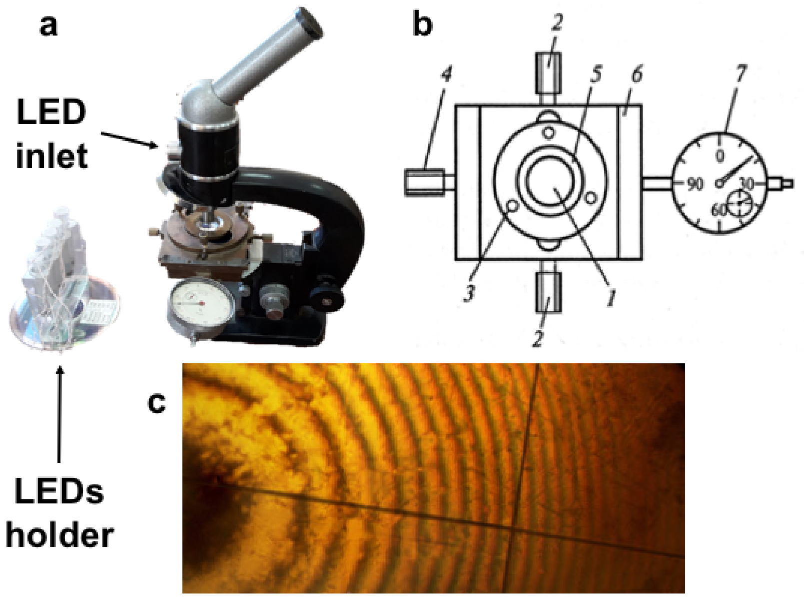

Fig. 2 a – the image of the experimental setup; b – the schematic image of the lens holder; c – the interference fringes from the white light source with the cross pointer set to the *k* ring.

The light beam from the light emission diode (LED) of a given wavelength falls on the vertical illuminator plate. Reflecting down from its translucent layer, the beam normally falls on the "lens-plate" system and is again reflected, thus ensuring the possibility of observing the interference pattern in the field of view of the microscope eyepiece.

A cross pointer (Fig. 2c) of the eyepiece is placed in its focal plane, which makes it possible to determine the displacement of the certain point of the picture relative to the optical axis of the microscope. LEDs of different colors are used as light sources.

3 Measurement and data processing

Task 1. Setup adjustment

A key condition for correct measurements is a sufficiently bright and contrasting interference pattern. The following sequence of actions allows one to obtain such a picture. Rotating the screws 3, one can lower the frame so that the lens touches the glass plate (at the point of contact of the lens with the plate, one can see a small black spot - the central minimum of the interference pattern). Lowering the microscope tube with a micrometric screw, so that the objective lens of the microscope is ~ 5 mm above the lens, and adjusting the position of the LED source, ensure that the field of view of the microscope is uniformly and brightly illuminated. On the next step, gently (slowly!) raise the tube of the microscope until the interference fringes (Fig. 2c) appear in the field of view. First find the interference fringes, then tune position of the holder with screws 4 and 2, until you see the symmetrical interference pattern relative to the cross-pointer of the eyepiece. If the contrast of the picture is not sufficient, then one can play with the position of the LED holder in the microscope (this operation serves as an additional check of the correct position of the source).

One can proceed to the measurements of the radii of the rings, after checking that a sufficient number of interference rings is observable both to the left and to the right of the central interference minimum (with good tuning, at least 20 rings should be clearly observed). To reduce the relative error of measurements, it is recommended to measure the diameters of the rings by selecting rings of sufficiently large orders (at least 5-th order or higher), for example: $k = 10$, $i = 8$.

Task 2. Measurements of the radius of curvature of the lens.

Measure radii and diameters of at least 15 rings for red and orange LEDs, at least 6 rings for green and blue LEDs, for the white light LED (440 – 640 nm) one need to observe the pattern of the Newton's rings and explain it during the defense. After measuring the radii and diameters of the Newton's rings, one need to calculate the radius of curvature of the lens R using expression (4) for at least three different values of k and i and obtain the mean value of the radius of curvature R. The wavelength for the given LED is stated on the LEDs' holder. Repeat the whole series of measurements for 4 LEDs (red – 630 nm, orange – 590 nm, green – 525 nm, blue - 470) out of 5. Record the results of measurements and calculations in a table. Estimating the errors of measurements of the radii of the rings, calculate the error of measurements for the radius of curvature of the lens R.

4 Questions

1. Under what condition will an interference maximum be observable in the reflected light at the point M (see Fig. 1.)?

2. How will the picture of Newton's rings, observed in the passing light, differ from the picture observed in the reflected light?

3. Compare the intensity of interfering light beams for two case: observations take place in passing light; observations take place in reflected light. In which cases will the picture be more contrast?

4. What will be observed if the lens is slightly raised above the glass plate? Check the answer experimentally.

5. Is it possible to use sufficiently long light sources in observations of Newton's rings?

6. How will the pattern of Newton's rings change, if one places the lens on the concave surface of the smaller curvature instead of the flat glass plate? Or if one places the lens on the convex lens with the same curvature instead of the flat glass plate?

7. How will the pattern of Newton's rings change, if the space between the lens and the plate be filled with water (the speed of light in the glass is lower than in the water)?