INTERFERENCE OF LIGHT
Practical 6
STUDY OF TEMPORAL COHERENCE OF RADIATION

1 Introduction

To observe a steady-state interference picture, light waves must be coherent. Coherent light waves can be obtained from a light source with a thin glass plate. In that case an interference pattern is formed by two parts of a wave incident on a plate: a wave reflected from the first face of the plate and a wave reflected from the second face. However, an interference picture in a thin glass plate can only be observed in "white" light if the thickness of the plate is small enough, of the order of a few micrometers.

The radiation of any real light source does not represent an infinite sinusoidal wave. In that case it is convenient to use the concept of wave pulses of some finite length, the so called coherent wave trains. Individual trains are incoherent. In the case of a plate, interference is possible if two parts of the same train "meet", despite the difference in optical paths because of the thickness of the plate. The longer the train length, or the coherence length of the radiation, the thicker the plate that can be used to observe an interference pattern. In other words, the interference pattern can only be observed if the path difference does not exceed the coherence length of the radiation.

The coherence length is related to the spectral range of radiation. The narrower spectral range (the more monochromatic the radiation is), the greater the coherence length.

In high-precision optical measurements light is sufficiently monochromatic ($\Delta\nu \ll \nu$), and the coherence length

$$l \approx \lambda^2/\Delta\lambda. \qquad (1)$$

The corresponding propagation time is called the coherence time

$$\tau = l/c. \qquad (2)$$

If you determine the optical path difference at which the interference pattern disappears, you can estimate the coherence length of the radiation, as well as the spectral range (the degree of its monochromaticity). These quantities characterize the temporal coherence of the radiation.

In Practical 6, it is proposed to use one of the classical interference schemes, Newton's rings (see the description of Practical 5). In contrast to the traditional scheme, the setup makes it possible to measure accurately the optical path difference between interfering light beams. Because of this, it is possible to estimate the temporal coherence of radiation produced by various light sources.

The objective of Practical 6: study the effect of temporal coherence of radiation from various light sources and estimate the spectral range of the radiation.

2 The experimental setup

Instruments: a microscope, a lens in a special frame for the microscope objective, an incandescent lamp, gas discharge lamps (mercury and sodium), glass filters.

Here, you need to use an incandescent lamp with a filter, a mercury lamp and a sodium lamp as sources of radiation.

It is necessary to become acquainted with the description of Practical 5 (Newton's rings). Referring to Fig. 1, the difference between the experimental setup, proposed in this Practical, and the traditional one is as follows. The lens L, from the lower surface of which the light wave 1 is reflected, is fixed in a special frame, which is put on the microscope objective. The glass plate II, on the surface of which wave 2 is reflected, lies on the stationary table of the microscope. After loosening screw B with the rim and lowering the lens before it comes in contact with the plate, it is possible to obtain a clearly visible interference pattern localized in the plane of contact of the lens and plate. After securing screw B and lifting the microscope tube with a micrometer screw, you can change the gap between the lens and the plate, Δ. Namely, this value Δ determines the optical path difference between interfering waves 1 and 2:

$$\Delta = 2h + \lambda/2. \tag{3}$$

If one neglects the additional path difference because of the difference in the reflection conditions of the waves at the glass-air and air-glass boundaries, it can be assumed that

$$\Delta \approx 2h. \tag{4}$$

Using the scale of the micrometer screw, it is possible to measure the gap size h and, consequently, the optical path difference Δ with a precision of 1μm.

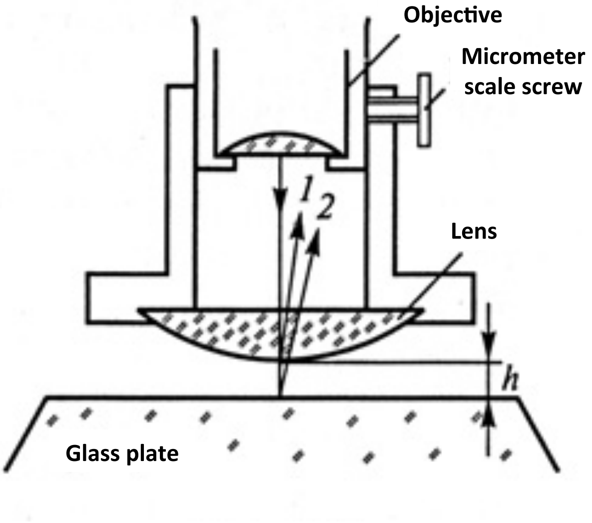

Figure 1: A schematic of the experimental setup.

3 Measurements and data processing

Before proceeding with the measurements, you should adjust the experimental setup, following the procedures below:

1) Put the lens holder on the microscope lens, fix it with a screw and carefully move down the microscope tube until a very small ($\sim$ 0.5 mm) distance between the lens and the glass plate. After that, loosen the frame and let the lens slide down smoothly onto the plate.
2) Install the light source (an incandescent lamp) against the opaque-window and achieve uniform illumination of the field of view. It can be carried out conveniently without the eyepiece of the microscope. The correctness of the adjustment can be checked by changing the aperture of the diaphragm of the illuminator: this operation should not change the symmetry of the illuminated spot.
3) Without fixing the rims, gently move the tube of the microscope until the interference pattern appears in the field of view. Fix the position of the tube with a micrometer screw. If the contrast of the picture is not sufficient, the illumination from the incandescence lamp should be reduced. It can be changed by decreasing of the diaphragm aperture (the latter operation serves as an additional test of the correct position of the lamp).
4) When observing through the microscope, carefully fix the rim on the microscope objective not to knock down the achieved adjustment. Carefully move up the microscope tube with a micrometer screw. Upon this the rings of the interference pattern will "run", towards the center. Move down the tube and restore the original picture. After that start your measurements.

Task 1.

Obtain a picture of Newton's rings in "white" light. Use the incandescent lamp without a filter. Determine the gap at which the interference pattern disappears.

Task 2.

Repeat measurements with a red filter.

What is the difference between the observed picture and the previous one?

Using the scale of the micrometer screw, measure the gap size h at which the interference pattern disappears. **Important remark**: The assessment of situations "the picture is still visible" and "the picture is no longer visible" is quite subjective, so it is useful to repeat the procedure several times.

Calculate the coherence length l of the radiation under study and the corresponding width of the spectral range $\Delta\lambda$. The mean values of the wavelengths of the radiation sources are indicated in the specification.

Task 3.

Investigate the temporal coherence of the radiation of the mercury lamp with a filter and the sodium lamp in the same way (the parameters of the lamps: the current is of the order of 1A).

The results of the measurements and calculations can be presented in the form of a table. The table must include the numbers of scale divisions n of the micrometer screw, the dimensions of the gap h, l and $\Delta\lambda$ for each source.

Draw a spectrogram in a suitable scale (about 1 mm = 1 nm). This spectrogram must show radiation bands in the spectrum of visible light that are occupied by the radiation of each of studied sources.

4 Questions

1) Derive the conditions of interference minima/maxima that appears at a given point of the field.
2) Is it possible to observe an interference pattern when you use a glass plate a few centimeters-thick and the best source in your experimental setup?
3) Can the light sources listed be considered coherent: (a) two incandescent lamps; (b) a lamp and its reflection in a mirror; (c) two slits illuminated by one lamp; (d) two lasers?
4) What are possible reasons for the difference in the level of temporal coherence of the radiation from an incandescent lamp and a gas-discharge lamp?
5) Estimate the maximum order of the interference maximum for the cases: (a) an interference pattern produced by an incandescent lamp (b) a mercury lamp.
6) What role does the spatial coherence of radiation play in the observation of interference patterns?
7) Propose a method that allows you to use the experimental setup in this practical for measurements of small displacements.