OPTICS
INTERFERENCE
Practical 9
DETERMINATION OF THE WAVELENGTH OF THE LIGHT WITH SPLIT LENS AND DOUBLE PRIZM

1 Introduction

To observe interference of light, a number of schemes are used. Such schemes usually divide a light beam from one source into two beams (by means of reflection or refraction) and forced those beams to meet again after they have traveled along different optical paths. Such interference schemes are based, in particular, on Billet split lens and Fresnel double prism.

Split lens is a thin positive lens, cut in half. Half-lenses are displaced (in the plane of the lens) relative to each other so that two spatially separated optical centers are obtained. In this case, half-lenses give two imaginary or real images of the source S, which serve as coherent light sources S_1, and S_2 (Fig.1a).

Double prism consists of two prisms with small refractive angles, which located very close to one another. The light beam incident on the double prism from the slit, due to refraction in the double prism, is divided into two intersecting beams, as if emanating from two imaginary images of the slit S_1, and S_2, (Fig. 1b). In the region of intersection of the beams behind the prism, an interference pattern will be observed.

Knowing the distance between the sources *d*, the width (bandwidth) of the interference fringe *x* and the distance from the sources to the screen *L*, one can determine the wavelength of the light in accordance with the known formula

$$\lambda = \frac{\Delta x \cdot d}{L}, \left(L \gg d\right)$$

2 Experimental setup

On the optical bench, the illuminator (incandescent lamp with condenser) and the slit diaphragm playing the role of the source are arranged in series. The small width of the slit provides the necessary spatial coherence. A sufficiently high degree of temporal coherence of radiation is achieved by means of a light filter that cuts out a relatively narrow frequency interval from the emission spectrum. The frame with replaceable filters is located directly behind the slit diaphragm. Split lens or double prism in the frame, allowing for the necessary adjustment and adjustment, is installed into a special holder. To observe the interference pattern, as well as to measure the bandwidth and distances between coherent sources, an ocular micrometer is used. In the case of working with a double prism, an auxiliary convex lens is placed in front of the micrometer. The distances between the plane of the source images and the plane of observation of the picture are measured using a ruler.

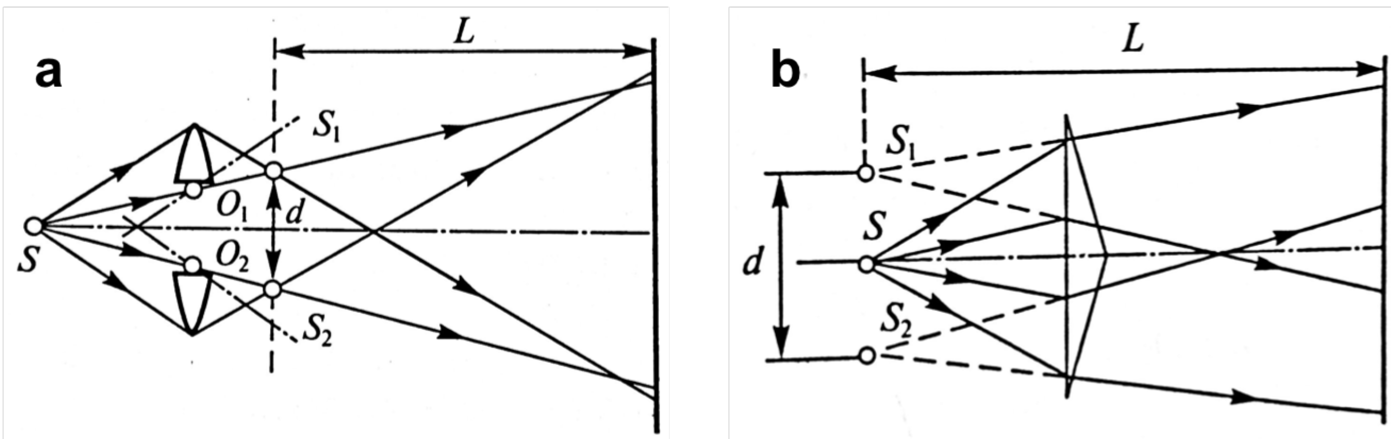

Fig. 1. a - the setup scheme with the Billet split lens; b – the setup scheme with the Fresnel double prism.

3 Measurement and data processing

Task 1. Split lens setup adjustment.

Observation of an interference pattern using split lens (see Fig. 1a) requires careful tuning of the experimental setup. To observe an interference pattern, one need to ensure that the optical system is centered: the slit diaphragm should be located along the diameter of a bright and uniformly illuminated circle - the cross section of the light beam; the axis of the light beam must pass exactly between the halves of the split lens and through the ocular micrometer.

To obtain valid images of the source slit, the split lens should be placed at some distance (usually larger than 2F) from the slit.

After preliminary alignment of the system, adjusting the position of the lenses in the frame with the appropriate screws, one should get two symmetrically arranged (relative to the vertical) and equally bright images of the slit on the auxiliary screen (a piece of paper).

At the point where the actual images of the sources are obtained, install the eyepiece micrometer and observe the enlarged images of the two sources (the distance between them should be measured after the interference pattern is obtained and the bandwidth is measured).

Move the ocular micrometer until the images of the slits overlap each other. If, in this case, no characteristic interference fringes appear in the field of view, then keep observing, while gently adjust the position of the half-lens with the screw at the top of the rim. The contrast of the resulting picture can be increased by decreasing the width of the slit. If the interference fringes are too narrow, the micrometer should be moved away or the images of the slit should be moved together with a careful rotation of the screw located on the side of the split lens frame.

Once a distinct interference pattern is obtained, the bandwidth should be measured. To improve the accuracy of the result, it is advisable to determine the length of a segment containing several bands on the micrometer scale, and by dividing the obtained value by the number of bands, find the width of the strip x.

One should move the cross pointer of the ocular micrometer very gently, since strong pressure on the micrometer body can easily lead to a shift in the field of view. During this measurement, the micrometer drum (knob) rotates only in one direction.

After recording the position of the ocular micrometer on the centimeter scale, move it to the place where the sharp images of the sources are visible, and, observing the precautions listed above, measure the distance d between them.

The distance between two positions of the micrometer (in one of which the images of the sources are considered, and in the other the interference pattern) is obviously equal to L, that is, the distance between the coherent sources and the location of the interference pattern.

Task 2. Determination of the wavelength of the light with the split lens.

Repeat the measurements of x several times and determine the average value of the bandwidth. Change the light filter and repeat the same set of measurements for another average wavelength of the light.

Put down the measured data of d and L in the table and, using the expression (1), calculate the required average wavelengths 1 and 2 for measurements with two difference light filter. Estimate the relative error and write the measurement results in the form $\lambda_{exp} = (\lambda_{aver} + \Delta\lambda)$ nm.

Task 3. Double prism setup adjustment.

If the interference pattern is observed with the help of a double prism (see Fig.1b), two imaginary images of the slit S_1 and S_2 serve as coherent sources. Due to small values to refractive angle of each of the prisms, which form the double prism, we can assume that the images S_1 and S_2 lie in one plane with a slit. This circumstance makes it easy to determine the distance from the sources to the place of observation. The optical system (a slit, a double prism, a micrometer) is centered in the same way as a system with a split lens. One need to pay attention to the position of the double prism, which should be parallel to the source slit. To get the necessary parallelism, one need to observe the source slit through the double prism (with a bare eye) and adjust the position of the rim of the double prism around the horizontal axis, until the desired parallelism is achieved (the images of the slits should be located symmetrically with respect to the vertical). The interference pattern is observed with a micrometer. If the picture is not clearly enough, slightly turn the frame of double prism. The contrast of the picture depends, of course, on the width of the slit. Measurement of the width of the strip x is carried out in the same way as in the **task 2** of the work.

To measure the distance between the sources, a convex lens is used. Using this lens, we obtain real images of the sources and measure (as in the **task 1**) the distances between them on the scale of the ocular micrometer. The distance between the imaginary sources d can be calculated by measuring the distances from the slit to the lens and from the lens to the focal plane of the micrometer (it is recommended to draw a picture, which traces the beams according to the laws of geometric optics).

Task 4 Determination of the wavelength of the light with the double prism

Make the necessary measurements to determine the wavelength. Put down the results of two series of measurements (for two light filters) into the table. After evaluating the error, record the results of two series of measurements in the form $\lambda_{exp} = (\lambda_{aver} + \Delta\lambda)$ nm.

4 Questions

1. Where should one look for an interference pattern, if the lens is cut into halves and those half-lenses are separated from each other?
2. How should one locate half-lenses to make an interference pattern unobservable?
3. Is it possible to use a lens with a strip of black paper pasted over its diameter as the split lens?
4. Give several examples of interference schemes in which the dimensions of the source can be relatively large.
5. Compare the interference patterns obtained with the proposed setups, equipped with light filters, with the interference patterns obtained in the white light.
6. What means provide a sufficient degree of spatial coherence in experiments with double prism and split lens?
7. How can one simplify the experimental setup with double prism (split lens), if radiation of a very high degree of coherence (laser radiation) is used?