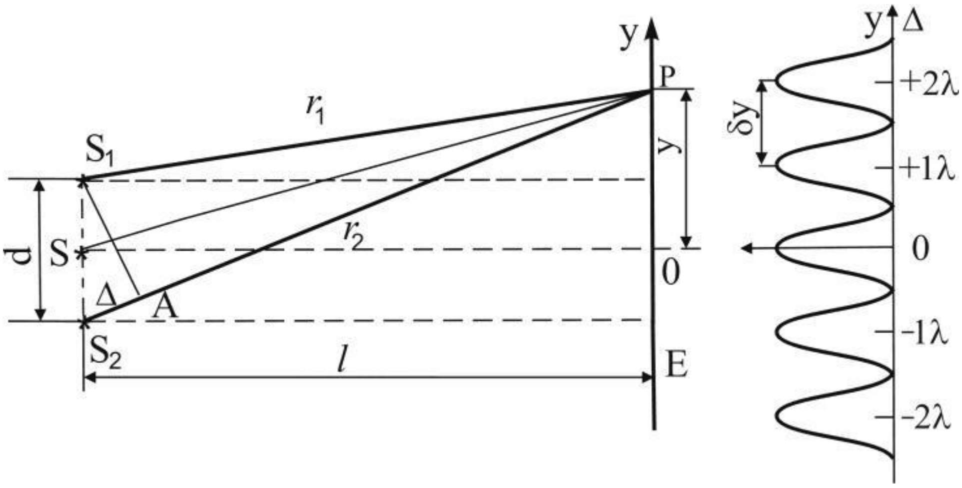
Laboratory work № 75

Study the phenomenon of light interference using Frenel's biprism

Work goal: familiarizing with interference pattern obtaining with the help of Fennel's biprism. Determination of wavelength.

Interference is a phenomenon of light waves superposition when lights strengthening is observed in arias while lights weakening is observed in other one. They are coherent is necessary condition for wave interference. Waves are coherent if they propagate in the same direction and phase's difference of oscillation induced by them constant in time. Sources radiating coherent waves are called also coherent. ` Natural light sources are not coherent. Their radiation is aggregate emissions of separate atoms which are not consistent in phase. To obtain coherent waves optical schemes are used in which radiation from one sources divided into 2 beams making them meet (for example on the screen) when they passed different optical path.

` ` Figure 1 shows principal scheme of interference obtaining. S_1 and S_2 are virtual images of source S. They play role of coherent sources.



Result of addition of oscillation coming into screen point P from these sources depends on optical path difference of these beams $\Delta = r_2 - r_1$.Right part of the figure demonstrates the light Intensity I within interference pattern which shown by the screen . Let distance between sources S1 and S2 is *d* and distance between sources and screen is *l*, so that *l*>>*d*. If angles of triangles S_1S_2A and SPO are small then we obtaining an expression for optical path difference.

$$\Delta = \frac{d}{l} y, \qquad (1)$$

where y is distance from point P to O one where O is middle of the screen and P is observation of interference.

If the path difference equal to the integer number of wavelengths than light waves perform maximum. Mutual reinforcement within point P. Waves experience weakening if path difference Δ is equal to half of integer number of wavelength.

Condition of constructive interference $$\Delta = 2k\frac{\lambda}{2} = k\lambda. \qquad (2)$$

Condition of destructive interference $$\Delta = (2k+1)\frac{\lambda}{2}, \qquad (3)$$

where k=0± 1, ± 2, ± 3,… is order of constructive interference or destructive interference(integer number) λ is wavelength .

Figure 1 shows that in the center of the screen interference pattern (Point O) path difference is equal to zero(k=0). That is why in the point O of the screen maximum (light line) is always available. Up and down from it light and dark lines are alternated. When S is illuminated by polychromatic (white light) then each wave radiation has its own interference pattern. Since light path difference is proportional to wavelength λ. In this connection constructive interference is painted. Only zero-order maximum remains white (for all wavelength k=0).

Solving (1) and (2) we obtain coordinates of constructive interference Y_{max}

$$Y_{max} = \pm k\frac{l}{d}\lambda. \qquad (4)$$

The *width of the interference fringes δy* is a distance between centers of neighboring maximums or minimums

$$\delta y = y_{k+1} - y_k = \frac{1}{d}\lambda. \qquad (5)$$

(5) may help to determine wavelength λ .

$$\lambda = \frac{d}{l}\delta y. \qquad (6)$$

This laboratory work apply Frenel’s biprism to obtain interference pattern (fig.2)

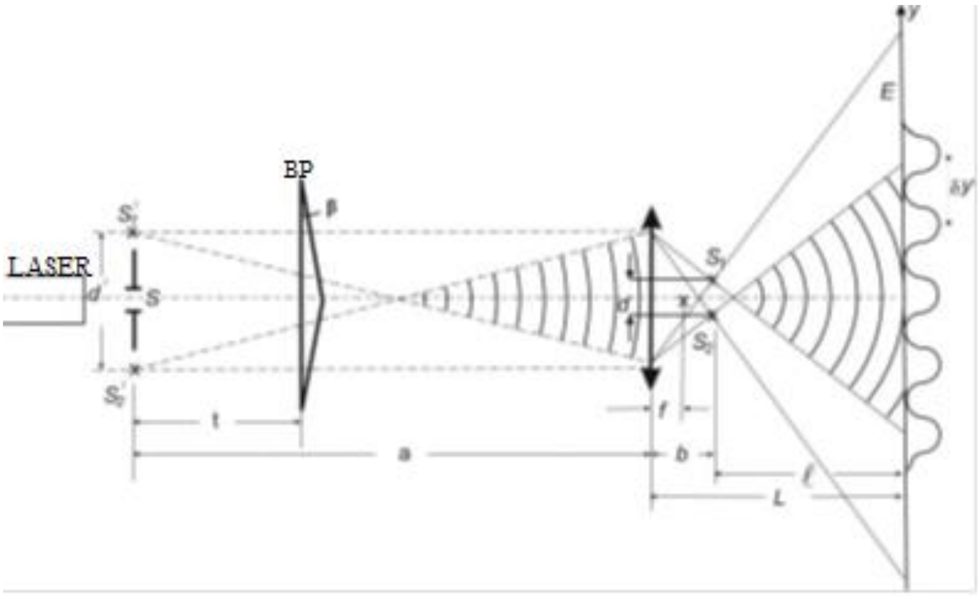


fig.2

Frenel's biprism (FB) is 2 prisms with small refracting angles (β≈(30-40)') with stacked bases and manufactured as one piece. Laser light gets on the narrow rift *S* located parallel to the refracting edge of biprism and which play roll of the light sources in this experience. Micrometer controls it weight. Radiation passed through the rift is refracted by both prisms at the distance *t* from the rift. As a result two cylindrical waves are formed like emanating from *virtual sources* S_1' and S_2' which oscillations occur in the same phase and hence they are *coherent*. In the space right of the biprism wave overlap forming *interference zone* (shaded area left of the lens).

Place converging lens with focal length *f* between BP and screen. In the space of imaging lens(right from it) we obtain a real image of the 2 sources S_2 and S_1 located at the distance *b* from the lens and at the distance *l* from the screen. They create interference pattern on the screen SC in the form of alternating light and dark fringes being is a maximums and minimums of intensity.

Position of the rift, biprism, lens and screen are fixed on the optical bench. We know that image plane sources located right of the lens (fig. 2). Thus *l* and *d* parameters in (6) should be connected with easily measured geometrical quantities in the experimental device. Thus application of lens formula $\frac{1}{a}+\frac{1}{b}=\frac{1}{f}$ (If object plane position is specified) can help to determine position of object image plane too where S_1 and S_2 are sources.

$$b=\frac{af}{a-f} \qquad (7)$$

From this formula we can also find the distance l from them to the screen

$$l=L-b=L-\frac{af}{a-f} \quad (8)$$

Where L is a distance between lens and screen

Transversal magnification $d'/d=a/b$ of lens allows also to express distance *d* between sources S_1 and S_2 through the distance d' between their imaginary images S_1' and S_2'. The later parameter is determine from the ratio (see appendix)

$$d'=2\,t\,(\,n-1\,)\,\beta \quad (9)$$

Where t is the distance from rift to screen, β is refracting angle of biprism, n is index of refraction. Thus

$$d = 2\,t\,(n-1)\,\beta\,f\,/\,(a-f) \quad (10)$$

where β have to express radians.

Substituting value *l* from (8) to (6) we obtain an expression to calculate wavelength.

$$\lambda = \frac{d(a-f)}{L(a-f)-af}\,\delta y. \quad (11)$$

From equation (11) we see that we must measure weight of the interference pattern δy and geometrical parameters of device *a*,*L*,*t* to determine wavelength λ.

Description of the experimental device

Instruments and accessories, optical bench, helium-neon laser, gap with regulated weight, Frenel's biprism, collecting lens, screen.

The experimental device is going on the optical bench under schemes (Figure 3). Elements of optical systems installed in reuters with pointers to reference their position on the bench. Refractive angle of prism β= 40'. The refractive index of it is n=1,518, focal length lenses *f* = 35 mm.

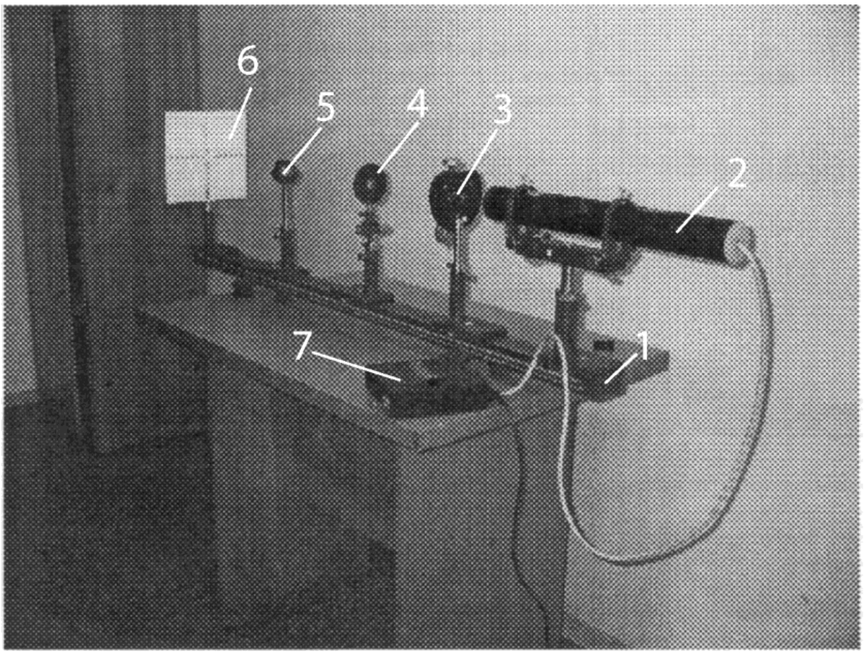


Figure 3. Scheme of experimental device.

1 - optical bench;

2 - helium-neon laser;

3 - rift with regulated width;

4 - Frenel's biprism;

5 - collecting lens;

6 - screen with two scale;

7 – Source Supply laser.

Tasks. Determination of the distance between the coherent light sources and wavelength of light.

1 Biprism 4 set on the bench so that its edge of obtuse angle to be parallel to the rift 3 and stayed at a distance t ≈20 cm from it.

2. The lens is placed at a distance L = (40 - 60) cm from the screen and fix its location.

3. Determine the width δy of interference fringes. For this measure distance y between fairly distant from each other lanes. Divide this distance on Number of pages N concluded in this section

$\delta y = Y / N$.

4. By formula (10) calculating the distance *d* between imaginary sources.

5. Repeat point 3, 4 for other values *t*, increasing it by 2 cm to *t*≈ 30 cm.

6. Build a graph of $d = f(t)$.

7. by formula (11) are calculated wavelength for all values *t*.

8. The results of measurements and calculations are entered in the table

9. Quantity $\delta\lambda$ calculated by standard statistical processing procedure of experiment data.

10. The final result is written in the form $\lambda = <\lambda> \pm \delta\lambda$ where α=…

№	t	L	a	d	N	Y	δy	λ_i	$<\lambda>$	$\delta\lambda_i$	$S_{<\lambda>}$	$\delta\lambda$	$E\%$
1													
2													
3													
4													
5													

Table

Quiz

1. What is the phenomenon of light interference?

2. What waves are called coherent?

3. What is the Frenel's biprism and what is its purpose?

4. What are the conditions for strengthening and weakening of the interference of light. Determine what will be at the points of screen where path difference of waves Δ = 2,205mkm and wavelengths λ = 0,63mkm.

5. What is the width of the interference fringes?

6. What is the difference of interference pattern, which is obtained in this study using

laser from the picture obtained in white light?

Literature

1. TI Trofimov Course of physics. M .: "Academy". 2005

2. Laboratory workshop on physics. Ed. AS Akhmatova, M .: "High School", 1980.

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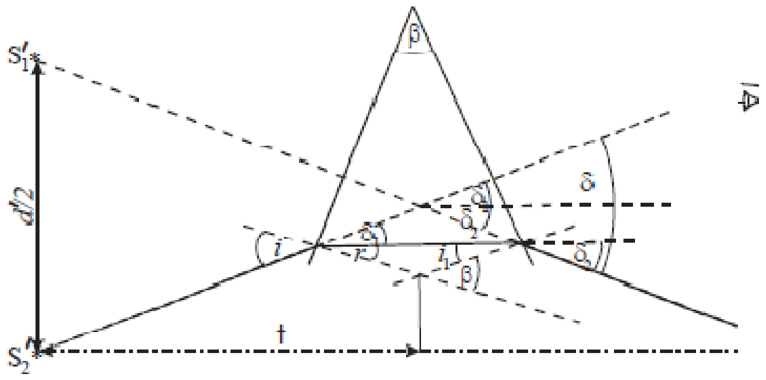
Addition

The figure shows a magnified form of optical schemes to monitor

Interference using Frenel's biprism.



According to the Law well refractionon the border of distribution of two media

sin*i*/sin*r* =n_{21} where n_{21} =n/n_b = n (1)

and n is index of refraction of material of prism(glass) .With little angle β *sini* ≈ *i*, *sinr = r.*

Then the law of refraction of light (1) takes the form i / r =n (2)

Angle slightest deflection, curved prism

From the figure and (3) that

$$\delta = \delta_1 + \delta_2 = 2\delta_1. \qquad (3)$$

$$i = \delta_1 + r = \delta/2 + r, \qquad (4)$$

$$\beta = r + i = 2r, \quad r = \beta/2. \qquad (5)$$

$$i = \delta/2 + \beta/2. \qquad (6)$$

Substituting (6) and (5) to (2), we obtain

where it appears that

$$n = \frac{\delta/2 + \beta/2.}{\beta/2} = \frac{\delta + \beta}{\beta}, \qquad (7)$$

$$\delta = (n-1)\beta. \qquad (8)$$

The figure shows that the distance *d'* between imaginary light sources with (8) is

$$d' \approx 2t\delta = 2t\,(n-1)\,\beta. \qquad (9)$$