For General Medicine

Topic of section: Lasers

Topic of lab work: Determination of the laser radiation wavelength with help of the diffraction grating

Aim: determine the laser radiation wavelength with help of diffraction grating; determine the size of a small object with help of the diffraction image of the laser radiation on this object.

Theory:

1. Describe processes of emission and absorption in two-level quantum system.
2. Explain main difference between processes of spontaneous and stimulated emission. Specify main properties for the stimulated emission.
3. Describe the construction of laser. Explain its working principles.
4. Explain the main properties of the laser radiation.
5. Specify types of laser classification.
6. Describe lasers medical application area.

Do not look into the laser!

Practical part:

1. Measuring the wavelength of the laser

The **diffraction** of classical waves refers to the phenomenon wherein the waves encounter an obstacle that fragments the wave into components that interfere with one another. **Interference** simply means that the wavefronts add together to make a new wave which can be significantly different than the original wave. For example, a pair of sine waves having the same amplitude, but being 180◦ out of phase will sum to zero, since everywhere one is positive, the other is negative by an equal amount.

It is important to understand the physical processes that are occuring that give rise to the diffraction phenomenon. For the sake of concreteness, we will consider the diffraction of light through a diffraction grating, which is the device that we will be using in today's lab. A **diffraction grating** consists of a transparent material into which a very large number of uniformly spaced wires have been embedded. As the light impinges on the grating, the light waves that fall between the wires propagate straight on through. The light that impinges on the wires, however, is absorbed or reflected backward. At certain points in the forward direction the light passing through the spaces (or slits) in between the wires will be in phase, and will constructively interfere. Whenever the difference in pathlength between the light passing through different slits is an integral number of wavelengths of the incident light, the light from each of these slits will be in phase, and the it will form an image at the specified location. Mathematically, the relation is simple:

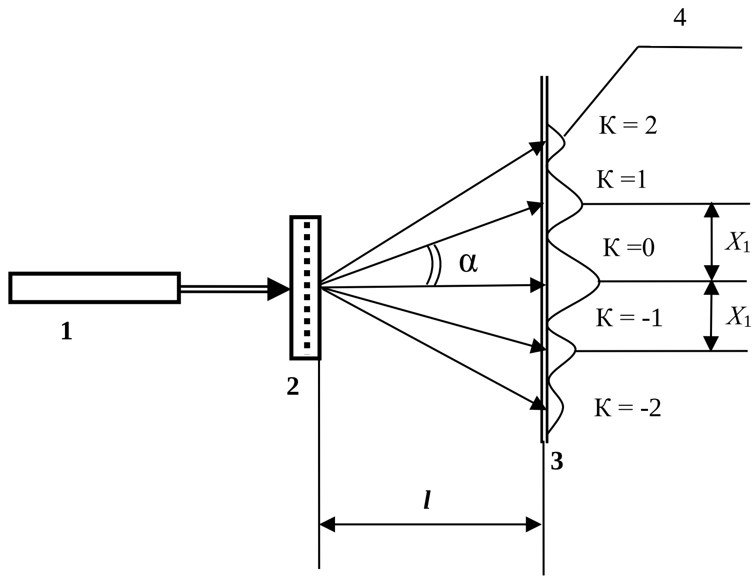
$$\boldsymbol{c} \cdot \sin\alpha = k\,\lambda,$$

where ***c*** is the grating period (distance between adjacent slits), α is the angle the re-created image makes with the normal to the grating surface, λ is the wavelength of the light, and k $(k = 0, \pm 1, \pm 2, \pm 3, \ldots)$ is an integer.

The diffraction grating that you will use today has the grating spacing is $c = 10\ \mu m$.

Therefore wavelength of laser radiation:

$$\lambda = \frac{c \cdot \sin\alpha}{\mathrm{k}}.$$

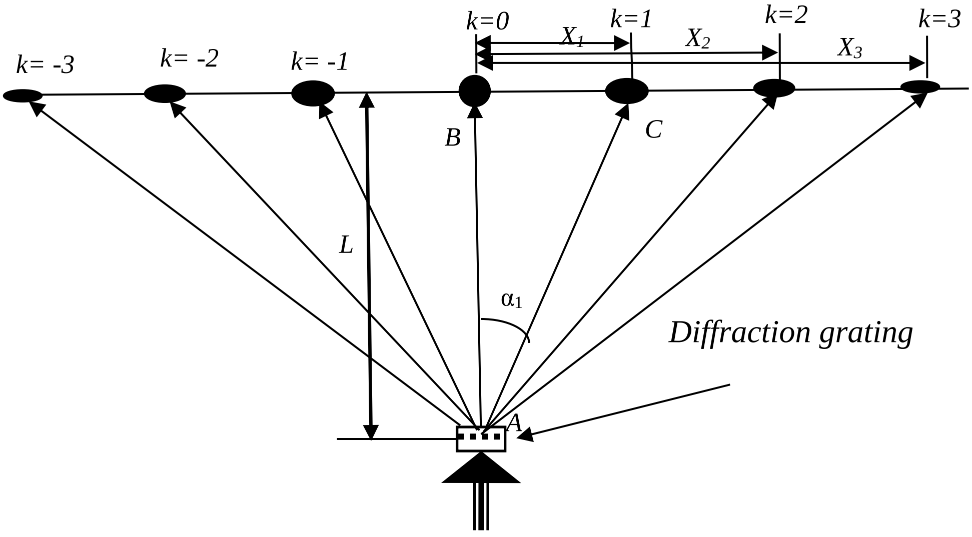


1. – laser;
2. – diffraction grating;
3. – screen;
4. – diffraction pattern.

Setup procedure:

1. Set up the laser and grating as shown in figure 2.
2. Measure the distance ***L*** between the screen and the diffraction grating.
3. Switch on the laser.
4. Measure the distance x_1 between the 1st order images appearing on the left and right sides of the center line.
5. Measure the distance x_2 between the 2nd order images appearing on the left and right sides of the center point.

On the diffraction pattern appears as individual peaks, the illumination of which



decreases with increasing distance from the central maximum.

6. According to diffraction pattern calculate sinα for ***k***=1,2,3:

$$\sin\alpha_k \approx tg\ \alpha_k = \frac{X_k}{L}.$$

7. Fill the table:

Table 1. Results of measurements

k	***c***, μm	*L* , mm	*X*, mm	tg α ≈ sinα	*λ*, μm
1	10				
2	10				
3	10				
Average value λ, μm =					

8. Calculate average wavelength.
9. In conclusion write down your result, compare it with textbook value.

2. Determination sizes of the small object

1. Install instead of diffraction grating another small-sized periodic structure, for example, hemocytometer.
2. Point the ray of He-Ne laser on this structure, achieve a clear diffraction pattern on the screen.
3. Determine the diffraction angle for 5 serial peaks.
4. Calculate the average size of periodic structure according formula:

$$\boldsymbol{d} = \lambda \frac{\boldsymbol{k} \cdot \boldsymbol{L}}{\boldsymbol{X}_{\boldsymbol{k}}}$$

Wavelength for He-Ne laser λ = 633 nm.

5. Fill the table:

Table 2. Results of measurements

k	*L , mm*	X_k*, mm*	λ*, μm*	*d, μm*
1				
2				
3				
4				
5				
Average value d, μm =				

Solve the problems:

1. The monochromatic laser radiation with a wavelength λ was used in the experiment with a diffraction grating with a period 0.01 mm. The distance between two interference maxima of the radiation of the first order on the screen, separated from the diffraction grating on the 1 m, is 138 mm. Find the wavelength of the laser radiation λ.

   Answer: 690 nm

2. The laser of power 1W with the dose of irradiation 1 J/cm^2 was used during the therapeutic procedure with time duration 2 s. Find the area of irradiated

surface.

Answer: 2 cm^2

Literature

1. Medical and biological physics for medical students, pages 201-208.