Experiment 417

Diffraction and interference of light

Student should be familiar with the following theoretical concepts:

1. Fresnel and Fraunhofer diffraction.
2. Diffraction of light on a single slit.
3. Diffraction of light on grating.
4. Interference and coherence of light.

The aim of the experiment

The aim of the experiment is to examine the phenomenon of diffraction and interference of light on a system of slits and application of this effect to determine the dimensions of the slits.

Description of the phenomenon

Let a parallel beam of coherent light of wavelength λ fall perpendicularly on a system of N parallel slits, of which of width a each and with distance d between their axes. On a screen placed in distance L from the slits we see a image, where the light intensity distribution is given by the formula:

$$I(\theta) = I_0 \left(\frac{\sin \Phi}{\Phi}\right)^2 \left(\frac{\sin(N\Phi)}{\sin \Phi}\right)^2$$

where $\Phi = \frac{\pi a}{\lambda} \sin\theta$, $\Psi = \frac{\pi d}{\lambda} \sin\theta$, I_0 – illumination intensity on a screen point placed on the axis of the system light source – system of slits – screen, θ – angle of deflection.

Measurement method

The light beam from He-Ne laser (λ = 632.8 nm) falls on a diaphragm located on rotary table. Next the beam falls onto a system of mirrors which direct it to the screen. A light detector is placed in the middle of the screen.

The laser and the diaphragm may be rotated making the image move in such a way that the detector may measure light intensity in its every point. The rotation is realized by an arm driven by a screw. The rotation angle is measured by a counter counting electric impulses generated by a disk with protrusions, fastened to the screw. One impulse corresponds to angular movement of 0.2 milliradian.

The detection of light coming only from defined direction is performed by a phototransistor set in a shield with very small aperture. Relative light intensity on screen I/I_0 on the detector may be determined by measurement of current flowing through the phototransistor.

It is possible to use the following objects:

- single slits of different widths
- system of two slits
- system of two, three or four parallel slits
- single slits wedge shaped
- circular aperture (to be observed or for diameter determination)
- system of two circular apertures (to be observed)
- grid with triangular system of apertures (to be observed)
- edge (to be observed or for intensity measurements of the diffracted beam)

It is also possible to use a thin wire or a hair and determine its diameter.

Sequence of actions

1. Turn the apparatus on.

Note: The laser should not be turned off during and after the experiment.

2. Place the diaphragm with selected system on the rotary table.
3. Obtain, on the screen, a diffraction image which will stay on screen when the system is rotated.
4. Select on the diffraction image a starting point for measurements.
5. Read the detector current and corresponding rotation angle (***during the measurement the screw should be turned in one only direction!***)
6. Measure the widths of the slits and distances between their centers (using other methods, e.g. by microscope).
7. Plot the dependence of light intensity on the rotation angle.
8. Using the plots determine the widths of the slits and distances of their centers, compare the results with results of measurements by other methods.
9. Discuss the influence of size of the detector on the results obtained.

Handling of data

During data treatment it's useful to use computer programs, even Excel can be useful.

Having an initial assessment of quantities a and d characterizing the system of slits (e.g. on the basis of placement of maxima and minima in the diffraction image) it is possible to calculate the values of function $I(\theta)$ (formula 1). Then a correlation coefficient r between the calculated and measured values should be computed with the use of the spreadsheet function or by the following formula:

$$r = \frac{n(\sum_1^n x_i y_i) - (\sum_1^n x_i)(\sum_1^n y_i)}{\sqrt{\left[n\sum_1^n x_i^2 - (\sum_1^n x_i)^2\right]\left[n\sum_1^n y_i^2 - (\sum_1^n y_i)^2\right]}}$$

where: n – the number of measured points, x_i – computed value of relative intensity for angle θ_i, y_i – the measured value for this angle.

Computations should be repeated for several values of a and d, close to the initially assessed values. Select those which are best fitted, i.e. those with the greatest value of correlation coefficient.

Questions

1. Explain the difference between Fresnel and Fraunhofer diffraction.
2. Explain the Fresnel diffraction.
3. Explain the Fraunhofer diffraction.
4. Explain the phenomenon of light coherence.
5. Explain difference between interference and superposition.

Literature

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