Related topics

Intensity, Fresnel integrals, Fraunhofer diffraction.

Principle and task

Monochromatic light is incident on a slit or an edge. The intensity distribution of the diffraction pattern is determined.

Equipment

Laser, He-Ne 1.0 mw, 220 V AC	08181.93	1
Photocell, selenium, on stem	06750.00	1
Multirange meter with amplifier	07034.00	1
Dry cell, 1.5 V	11620.34	6
Lens holder	08012.00	1
Lens, mounted, f -50 mm	08026.01	1
Slit, adjustable	08049.00	1
Screen, metal, 300×300 mm	08062.00	1
Diaphragm with slit	09816.02	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	3
Meter scale, demo. l = 1000 mm	03001.00	1
Bench clamp, -PASS-	02010.00	1
Measuring tape, l = 2 m	09936.00	1
Connecting cord, 750 mm, red	07362.01	1
Connecting cord, 750 mm, blue	07362.04	1

Problems

1. Measurement of the width of a given slit.
2. Measurement of the intensity distribution of the diffraction pattern of the slit and
3. of the edge.

Set-up and procedure

The experimental set up is as shown in Fig. 1. The divergent lens of focal length –50 mm is placed in front of the laser to expand the beam. An inner edge of the slit which is fully open serves as the edge. The distance between lens and slit is 75 mm. The laser power is adjusted to 1 mW.

For diffraction at the slit the laser beam is directed symmetrically onto the vertical closed slit edges. The metal screen with the tape scale stuck to the middle, is set up at a certain distance (e. g. 3 m).

The slit is opened and the slit width is calculated from

$$b = \frac{2m + 1}{2 \cdot \sin \alpha_m} \cdot \lambda$$

where

$$\sin \alpha_m = \frac{x_m}{\sqrt{x_m^2 + r^2}}$$

b = slit width

m = serial order of the maximum from the centre outwards

x_m = distance of the m^{th} maximum

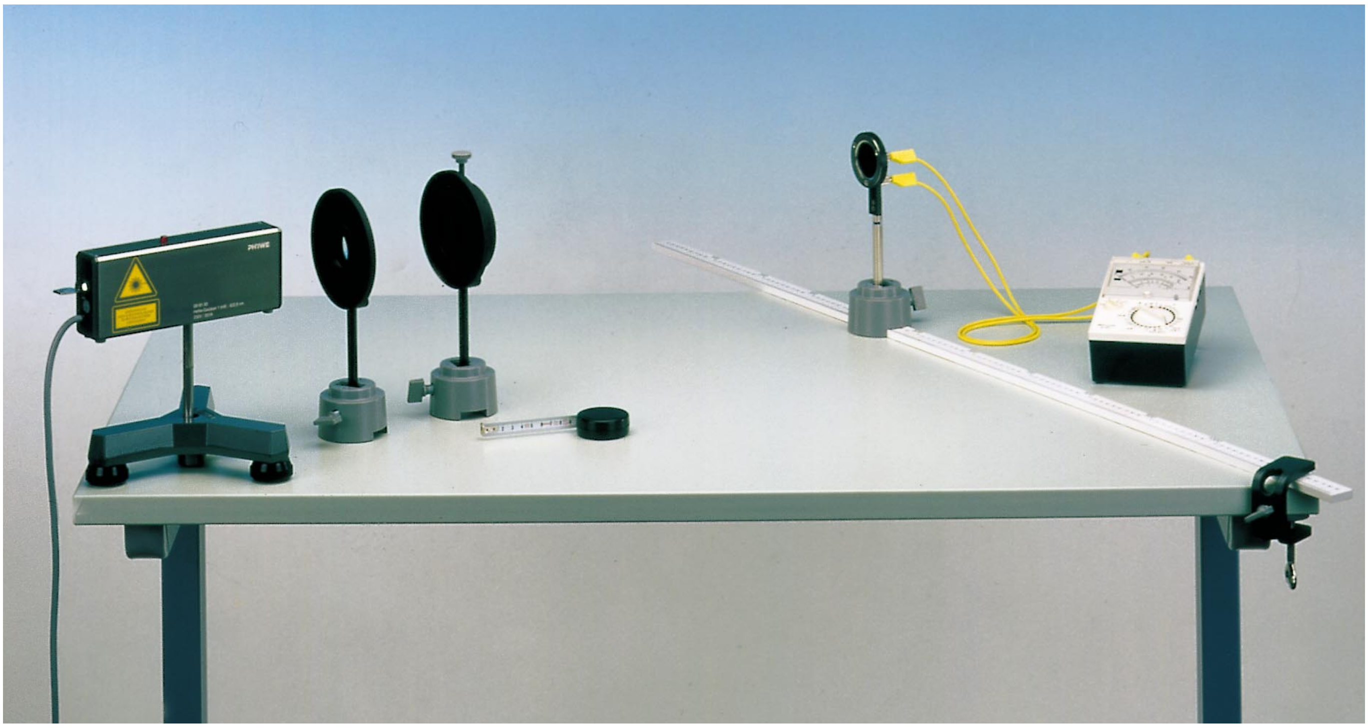
r = distance between the slit and the screen

λ = wavelength of the laser light

To ensure glare-free reading at the screen it is necessary to cover up the intensely bright centre of the pattern (e. g. with a pencil in a barrel base).

Caution: Never look directly into a non attenuated laser beam

Fig. 1: Experimental set-up for the diffraction of light at a slit and an edge.



For diffraction at the edge, the screen with a single slit (vertical) is stuck to the photocell with adhesive tape. The metre scale, on which a barrel base with the photocell can be moved at right angles to the laser beam, is secured at a certain distance (e. g. 3 m). The photocell is connected to the multirange-meter with amplifier (mV ≙ nA).

First of all, the intensity I_0 is measured without the edge – initially without the laser (dark value) and then with it (light value). These values must be taken into account in the evaluation.

The edge (an edge of the slit) is moved into the laser beam so that half of it is masked. This requires some care. In some circumstances, an intensity measurement can be carried out more rapidly with the slit screen lying horizontally. In this case the edge is moved into the beam until only half the voltage is recorded.

Theory and evaluation

If light of wavelength λ falls onto a slit of width *b*, each point of the slit acts as the starting point of a new spherical wave. The diffraction pattern is formed on a screen behind the slit as a result of the interference of these new waves.

If this diffraction is treated according to the Fraunhofer approximation, the intensity at point *P* on a screen parallel to the slit, using the symbols of Fig. 2, is:

$$I = c \cdot \left(\frac{\sin \frac{\pi b}{\lambda} \sin \theta}{\frac{\pi b}{\lambda} \sin \theta} \right)^2 \qquad (1)$$

c is a constant which depends on the wavelength and the geometry. Intensity maxima occur for

$$\tan \frac{\pi b}{\lambda} \sin \theta = \frac{\pi b}{\lambda} \sin \theta \, .$$

The first maximum is thus obtained for θ = 0. The following maxima occur if the argument of the tangent assumes the values:

1.43 π, 2.459 π, 3.47 π, 4.479 π, …

Intensity minima occur when

$$\frac{\pi b}{\lambda} \sin \theta = n \pi ; \; n = 1, 2, \ldots$$

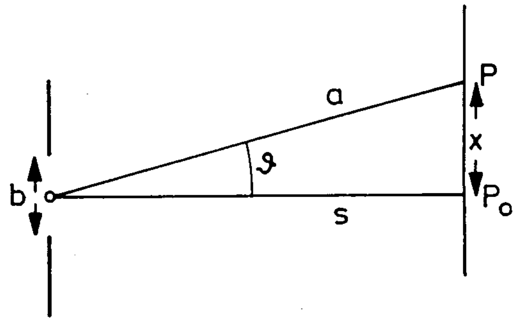
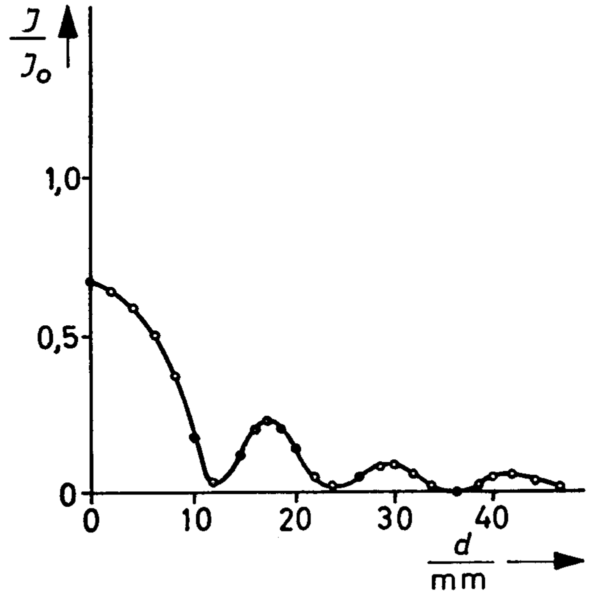


Fig. 2: Diffraction at the slit.

Fig. 3: Intensity distribution on diffraction at the slit, as a function of the position along a straight line parallel to the plane of the slit, standardised on the intensity without the slit.



where *a* >> *x*, the minima are approximately equidistand, and

$$x = n \cdot \frac{a\lambda}{b}$$

If light falls on to a slit formed by a straight edge (parallel to the *y* axis), it is diffracted. If the origin of coordinates is placed at the intersection of the connecting line *PQ* between the light source and the point of incidence with the plane of the diffraction screen, the intensity distribution of the diffraction pattern behind the diffracting edge is

$$I = \frac{I_0}{2} \left(\left(U(\omega) + \frac{1}{2} \right)^2 + \left(V(\omega) + \frac{1}{2} \right)^2 \right) \qquad (2)$$

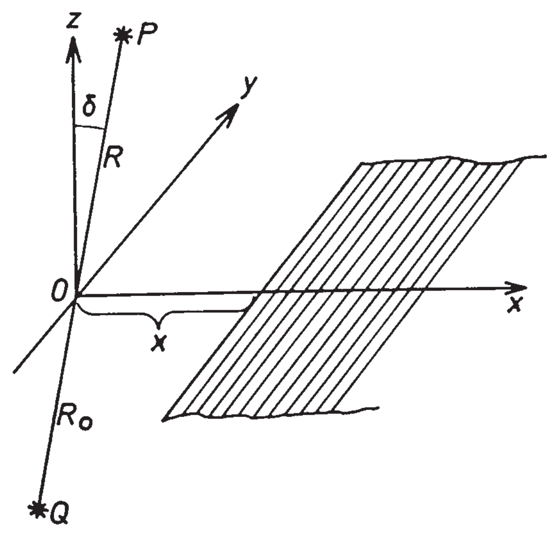


Fig. 4: Diffraction at the edge.

Using the symbols of Fig. 4 we have

$$I_0 = \frac{1}{(R_0 + R)^2} \qquad (3)$$

$$\omega = x \cdot \cos \delta \sqrt{\frac{2}{\lambda}\left(\frac{1}{R_0} + \frac{1}{R}\right)} \qquad (4)$$

U and *V* are the Fresnel integrals, defined as follows:

$$U(\omega) = \int_0^{\omega} cos\left(\frac{\pi}{2} n^2\right) dn.$$

$$V(\omega) = \int_0^{\omega} ccsin\left(\frac{\pi}{2} n^2\right) dn.$$

The intensity on the shadow side decreases regularly. On the light side the intensity exhibits maxima and minima, while the total intensity according to (3) decreases quadratically with the distance between the light source and the point of incidence.

Fig. 5: Intensity distribution on diffraction at the edge, as a function of the position on a straight line at right angles to the line connecting the light source and the edge, standardised on the intensity without the edge.