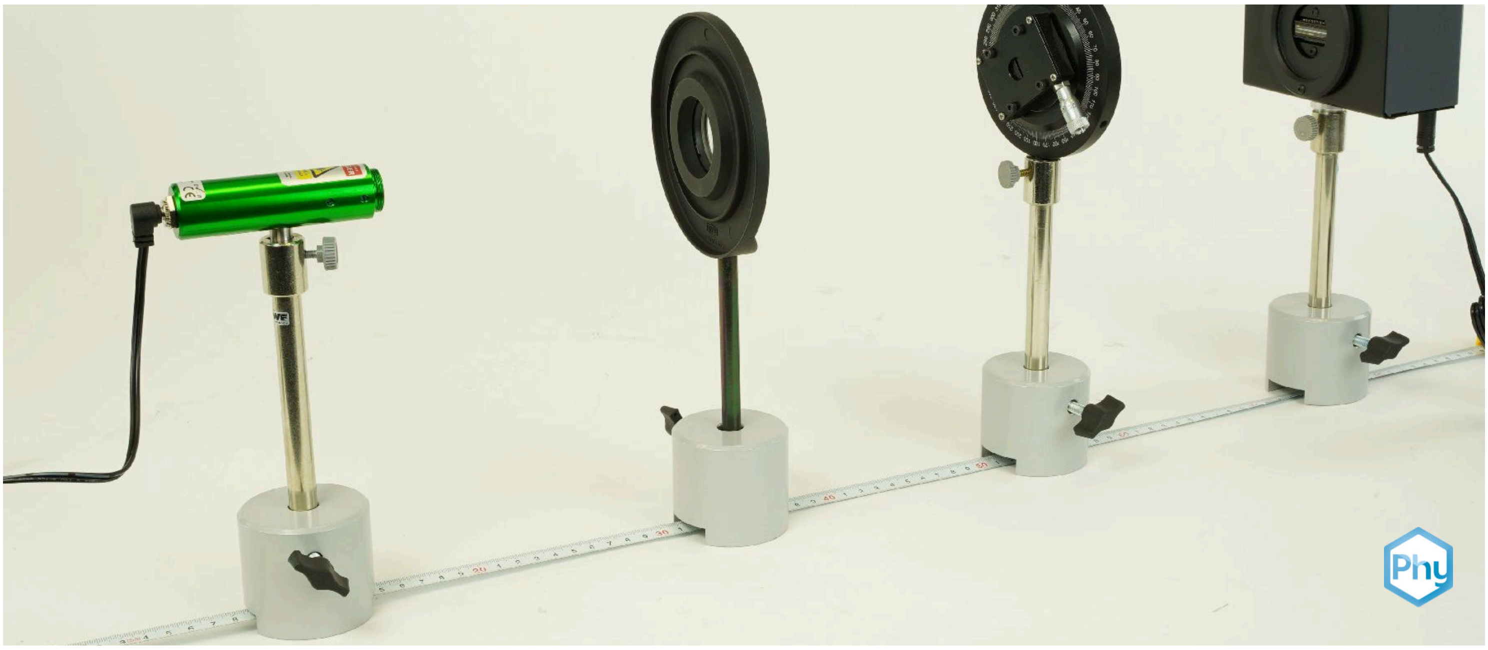
Diffraction of light at a slit and an edge



Physics | Light & Optics | Diffraction & interference

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

This content can also be found online at:

http://localhost:1337/c/60aaa21f5a74d1000344261e

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General information

Application

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Setup

Diffraction refers to various phenomena that occur when a wave encounters an obstacle or opening. It is defined as the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture. The diffracting object or aperture effectively becomes a secondary source of the propagating wave.

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Other information (1/2)

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Prior knowledge

The prior knowledge required for this experiment can be found in the theory section.

Scientific principle

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

Other information (2/2)

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Learning objective

The goal of this experiment is to investigate the diffraction of light.

Tasks

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

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Theory (1/3)

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. 1, 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

$$\tan \frac{\pi b}{\lambda} \sin \Theta = \frac{\pi b}{\lambda} \sin \Theta$$

Theory (2/3)

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

$$1.43\pi, 2.459\pi, 3.47\pi, 4.479\pi, \ldots$$

Intensity minima occur when

$$\frac{\pi b}{\lambda} sin(\theta) = n\pi; n = 1, 2, 3, \ldots$$

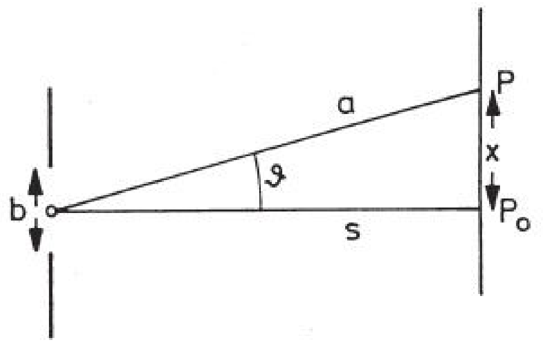

Fig 1: Diffraction at the slit

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Theory (3/3)

where a >> x, the minima are approximately equidistant, 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 camera, the intensity distribution of the diffraction pattern behind the diffracting edge is

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

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Equipment

Position	Material	Item No.	Quantity
1	Diode laser, green, 1 mW, 532 nm	08764-99	1
2	Digital array camera	35612-99	1
3	Lens holder, beam height 120 mm	08012-01	1
4	Lens, mounted, f -50 mm	08026-01	1
5	Slit, adjustable	08049-01	1
6	Screen, metal, 300 x 300 mm	08062-00	1
7	Barrel base expert	02004-00	4
8	Measuring tape, l = 2 m	09936-00	1
9	Stand tube	02060-00	1

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Setup and Procedure

Setup and Procedure (1/3)

The experimental setup is as shown in Fig. 2.

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.
For diffraction at the slit the laser beam is directed symmetrically onto the vertical closed slit edges.

The CCD camera is set up at a certain distance (e.g. 0.5 m).For deteils on usage of the CCD camera, please refer to the manual of the camera.

Fig. 2: Experimental setup

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Setup and Procedure (2/3)

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The slit is opened and the slit width is calculated from

$b = \frac{2m+1}{2 \cdot \sin(\alpha_m)} \cdot \lambda$, where

b = slit width,

m = serial order of the maximum from the centre outwards,

x_m = distance of the m^{th} maximum,

r = distance between slit and the screen,

λ = wavelength of the laser light

Caution: Never look directly into a non-attenuated laser beam!

Setup and Procedure (3/3)

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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).

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.

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Evaluation

Results (1/2)

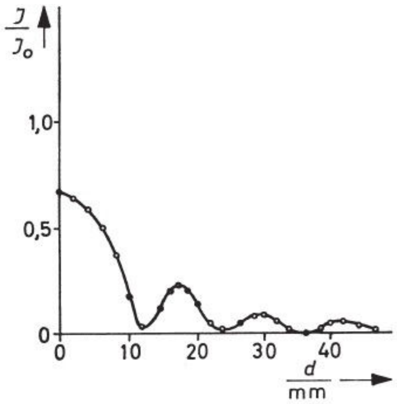

Fig 3: Intensity distribution on diffraction at the slit, as a function of the position along a straight line parallel to the plane of the slit, standardised on the intensity without the slit.

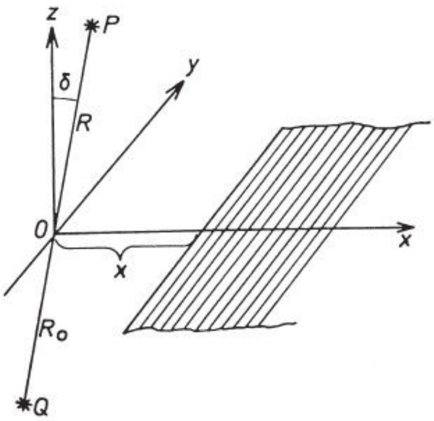

Fig 4: Diffraction at the edge

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Results (2/2)

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Using the symbols of Fig. 4 we have $I_0 = \frac{1}{(R_0+R)^2}$ (3)

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

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

$$U(\omega) = \int_0^\omega \cos\left(\frac{\pi}{2}n^2\right)\mathrm{d}n,\ V(\omega) = \int_0^\omega \sin\left(\frac{\pi}{2}n^2\right)\mathrm{d}n$$

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.

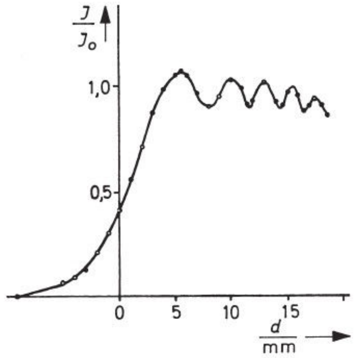

Fig 5: Intensity distribution on diffraction at the edge, as a function of the position on a straight line at right angles to the line connecting the light source and the edge, standardised on the intensity without the edge.

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