Diffraction at a slit

If monochromatic light hits a narrow slit, intensity minima and maxima appear behind it on a screen, from which positions the slit width can be determined at a known wavelength.

Physics > Light & Optics > Diffraction & interference

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/647c850ed59fde0002e27e64

General information

Application

Experimental setup

When monochromatic light hits a narrow slit, an interference pattern with intensity maxima and minima appears behind it on a screen.

The slit width can be determined from their positions at a known wavelength.

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Other teacher information (1/2)

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Prior knowledge

To understand this experiment, students should already be familiar with the wave behaviour of light. For illustration purposes, it can be helpful to show interference of water waves beforehand.

Principle

A laser beam shines through an aperture with single slits and creates an interference pattern on a screen behind it.

The interference pattern can be used to read off the intensity minima and maxima and, if the wavelength is known, the original slit width can also be determined.

Other teacher information (2/2)

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Learning objective

If we look at the interference pattern of a slit, we see that the maxima and minima are equally spaced.

In addition, the central intensity maximum is twice as wide as the other maxima. If one compares the interference patterns of the different slits with each other, it can be seen that the distances between the maxima and minima increase with decreasing slit width.

Tasks

- Observing the interference patterns on the screen.
- Marking the positions of the maxima and minima on the screen.
- Determination of the slit width of a slit.

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Safety instructions

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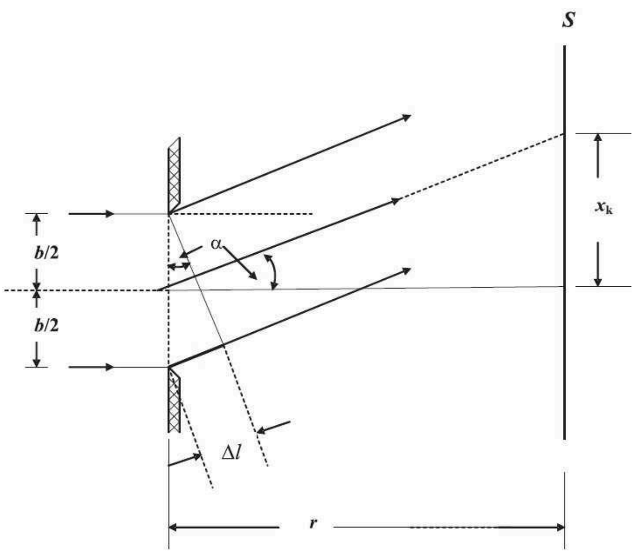
It is essential to ensure that you do not look directly into the laser beam.

The general instructions for safe experimentation in science lessons apply to this experiment.

Theory (1/3)



If a laser beam falls on a slit of width b, the beam in the slit area can be thought of as divided into two equal sub-beams, as shown on the left.

If after diffraction by the angle α the path difference $\Delta l/2$ between an edge and a central ray is an integer multiple of $\lambda/2$, then they interfere destructively. This path difference also exists between each ray of one half of the slit and a corresponding ray of the other half of the slit.

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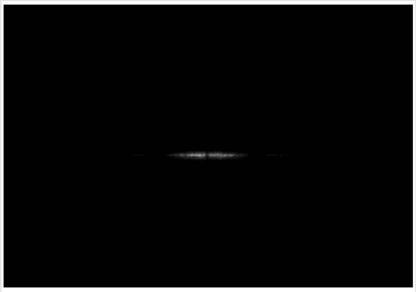
Theory (2/3)

There is always darkness in the interference pattern if the relation for Δl applies:

$$\Delta l = k * \lambda = b * \sin\alpha; k = \pm 1, \pm 2, \pm 3, \ldots \quad (1)$$

If r is the distance between the slit and the sufficiently distant collecting screen S and if x_k is also the distance of the kth minimum from the center, then:

$$\sin\alpha_k = \frac{x_k}{\sqrt{x_k^2 + r^2}} \approx \frac{x_k}{r} \text{for } x_k << r \quad (2)$$



Theory (3/3)

From (1) and (2) it follows for x_k:

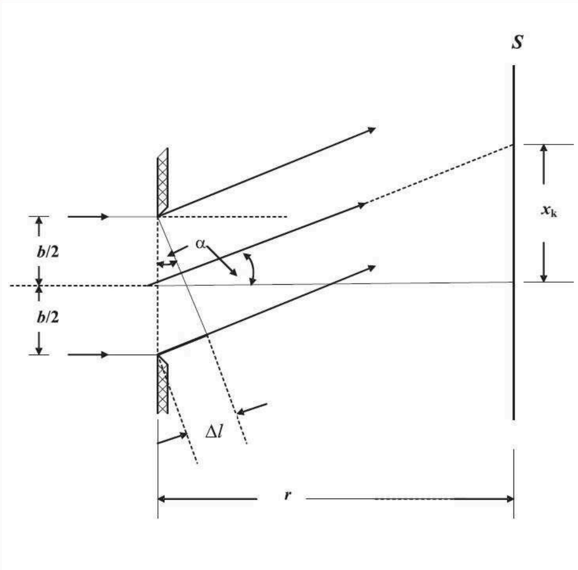
$$x_k = k\frac{\lambda * r}{b} \quad (3)$$

Brightness maxima result for the angles

$$\sin\alpha_m = \frac{2m+1}{2} * \frac{\lambda}{b}; m = \pm 1, \pm 2, \pm 3, \ldots \quad (4)$$

Accordingly, the following applies to x_m

$$x_m = m\frac{\lambda * r}{b} + \frac{\lambda * r}{2b} \quad (5)$$



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Equipment

Position	Material	Item No.	Quantity
1	Optical profile-bench, l = 1000 mm	08370-00	1
2	Slide mount for optical bench	09822-00	3
3	Plate mount for three objects	09830-00	1
4	Diaphragm, 3 single slits	08522-00	1
5	Screen, metal, 300 x 300 mm	08062-00	1
6	Barrel base expert	02004-00	1
7	Measuring tape, l = 2 m	09936-00	1
8	Diodelaser, red, 1 mW, 635 nm	08761-99	1

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Additional Equipment

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Position	Equipment	Quantity
1	Sellotape	1
2	white sheet of paper	1

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Set-up and Procedure

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Set-up

The experimental setup is as shown in Fig. 1.

The tally marks of the tabs for holding the components have the following positions on the optical bench.

- Rider with diode laser at $2cm$
- Rider with panel holder and inserted panel with gaps at $11cm$

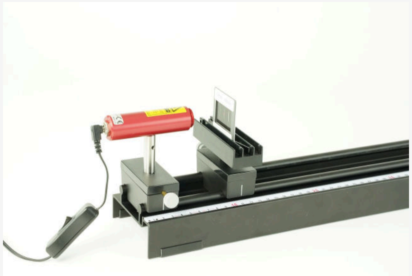
The barrel base with umbrella is located at a distance $r \geq 3m$ to the slit diaphragm.

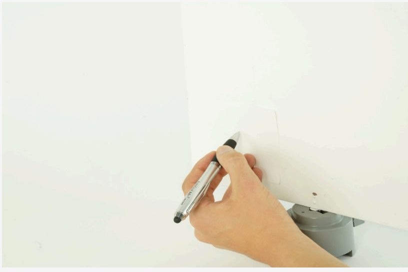
Fig. 1

Procedure

A sheet of typewriter paper is attached to the screen with its surface normal pointing in the direction of the optical axis using adhesive tape. The aperture with slits is moved in the plate holder so that one slit at a time is completely irradiated by the laser light.

Use a water-soluble felt-tip pen to mark the positions of the maxima and minima of several diffraction orders. The distance $r$between the slit diaphragm and the screen must be determined with the tape measure. Use a ruler to determine with an accuracy of $0,5mm$ the distances $2x$ of the various intensity maxima and minima.





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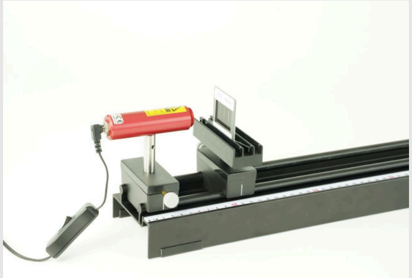

Evaluation

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Evaluation (1/4)

$\pm k$	$2x_k/mm$
1	20,5
2	40,0
3	60,0
4	80,0
5	99,0

$\pm m$	$2x_m/mm$
1	30,5
2	49,5
3	70,0
4	89,5
5	111,0

If we look at the interference pattern of a slit, we see that the maxima and minima are equally spaced.

In addition, the central intensity maximum is twice as wide as the other maxima. Comparing the interference patterns of the different slits with each other, it can be seen that as the slit width decreases, the distances between the maxima and minima increase (Fig.2).

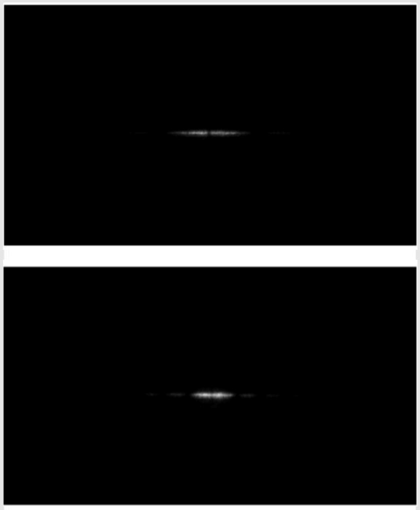

Fig. 2

Evaluation (2/4)

For a gap of the width $b = 0,2mm$ The distance values given in the table were used as examples. $2x_k$ resp. $2x_m$ and the corresponding value for the slit width was calculated with (3) or (5). From the data sheet of the diode laser, the value for the wavelength was taken as $\lambda = 635nm$ taken over.

The mean value for the gap width is obtained from the individual values:

$b = (0,203 \pm 0,002)mm; \Delta b/b \approx 1$ An inaccuracy of r at $\pm 5mm$ can be neglected when considering errors.

Calculated results from the sample data:

$\pm k$	b/mm
1	0,199
2	0,204
3	0,204
4	0,204
5	0,206

$\pm k$	b/mm
1	0,200
2	0,206
3	0,204
4	0,205
5	0,202

(Table: r = 3205 mm, gap b = 0.2 mm)

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Evaluation (3/4)

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What does this stand for b ?

- Gap width
- Wavelength
- Gap centre distance

If we look at the interference pattern of a slit, we see that the maxima and minima are unequally spaced.

- True
- False

Check

Evaluation (4/4)

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What must be taken into account so that the formula gives the correct result?

- The wavelength λ must not be smaller than 700nm.
- All given values must be converted into the base units.

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