Diffraction at a double slit

If monochromatic light hits a double slit, intensity minima and maxima appear behind it on a screen, from whose positions the slit width and its slit centre distance 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/64915eaefdb49d0002e01483

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General information

Application

Experimental setup

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

The slit width and the slit centre distance 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 a double slit 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 and slit centre distance 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 gap width and the gap centre distance of a gap.

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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)

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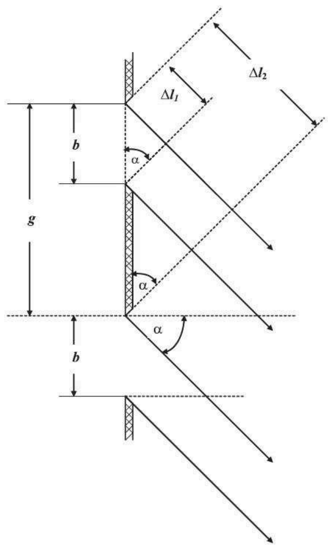
If a laser beam falls on a double slit with the slit center distance g and the width b, the beam in the double slit area can be thought of as divided into two bundles of rays, as shown on the right, which are at the angle α are inflected.

The marginal rays of the single slit have the path difference Δl_1. If this is an integer multiple of the wavelength λ, these rays interfere destructively. The single slit always produces darkness in the interference pattern if the general relationship applies:

$$\Delta l_1 = k * \lambda = b * \sin\alpha; k = \pm1, \pm2, \pm3, \ldots \quad (1)$$



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Theory (2/3)

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Now, however, the rays of the two slit bundles also interfere with each other. The corresponding edge rays of the double slit have the path difference Δl_2.

If this is an odd multiple of $\lambda/2$ then there is also a canellation.

Thus, one has additional darkness in the interference image at

$$\Delta l_2 = \frac{2m+1}{2} * \lambda = g * \sin\alpha; m = 0, \pm1, \pm2, \pm3, \ldots \quad (2)$$

If r is the distance between the double slit and the sufficiently distant collecting screen S and $x_{k,m}$ are the distances of the minima from the center, then:

$$\sin\alpha_{k,m} = \frac{x_{k,m}}{\sqrt{x_{k,m}^2 + r^2}} \approx \frac{x_{k,m}}{r} \text{für } x_{k,m} << r \quad (3)$$

Theory (3/3)

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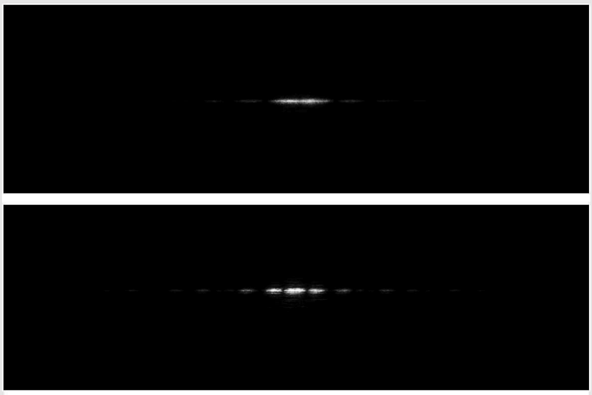
From (1) and (2) follows:

$$x_k = k\frac{\lambda * r}{b} \text{or } x_m = \frac{2m+1}{2} * \frac{r\lambda}{g} \quad (4)$$

The width of the central maximum of the individual slit (distance between the minima lying symmetrically to the center) is $2\lambda * r/b$. The equidistant maxima of a double slit with the same b have the width $\lambda * r/g$. Thus, the central maximum of the single slit of

$$\frac{2\lambda * r}{b} / \frac{\lambda * r}{g} = \frac{2g}{b} \quad (5)$$

interspersed with additional maxima.



Diffraction pattern of a slit and a double slit with equal slit widths

above: Cleavage: $b = 0,2mm$; below: Double slit: $b = 0,2mm$ and $g = 0,3mm$

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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, 4 double slits	08523-00	1
5	Diaphragm, 3 single slits	08522-00	1
6	Screen, metal, 300 x 300 mm	08062-00	1
7	Barrel base expert	02004-00	1
8	Measuring tape, l = 2 m	09936-00	1
9	Diodelaser, red, 1 mW, 635 nm	08761-99	1

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Additional material

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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

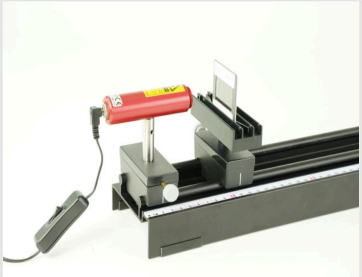
The experimental setup is as shown in the figure.

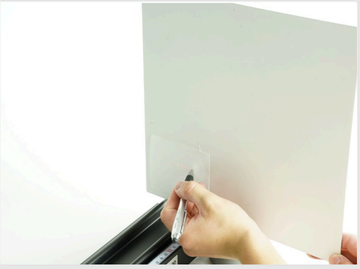
The tally marks of the tabs for holding the components have the following positions on the optical bench.

- Slider with diode laser at $2cm$
- Slider with plate mount and inserted fascia with double columns at $11cm$

The barrel base with screen is located at a distance $r \leq 3m$ to the double slit diaphragm.

Procedure





A sheet of typewriter paper is attached to the screen, whose surface normal points in the direction of the optical axis. The aperture with the double slits is aligned in the plate holder in such a way that each double slit is completely irradiated by the laser light. One determines the positions of the minima for different double slits. For comparison, a corresponding measurement is carried out on a single slit with the same slit width.

It is advisable to mark the positions of the minima with a water-soluble felt-tip pen and to determine their distances $2x$ with a ruler to $0.5mm$ exactly. The distance r between the slit diaphragm and the screen is to be determined using the measuring tape.

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Evaluation

Evaluation (1/3)

With the help of the exemplary recorded data (shown on the right in the tables), the gap width can be b and the gap centre distance g calculate as follows:

As already shown in theory, the following applies to x_k resp. x_m :

$$x_k = k\frac{\lambda * r}{b} \text{bzw. } x_m = \frac{2m+1}{2} * \frac{r\lambda}{g}$$

By rearranging the equations according to b resp. g results:

$$b = \frac{k * \lambda * r}{x_k} \text{bzw. } g = \frac{(2m+1) * r\lambda}{2 * x_m}$$

Minima of the double slit

$\pm m$	$2x_m/mm$
0	8,6
1	25,5
2	40,0
3	59,0
4	75,0

Maxima of the single slit

$\pm k$	$2x_k/mm$
1	41,0
2	81,0
3	123,0

Double slit: $b = 0,1mm; g = 0,25mm$

Single gap: $b = 0,1mm$

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Evaluation (2/2)

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Calculated results from the sample data:

$\pm m$	g/mm
0	0,246
1	0,248
2	0,264
3	0,251
4	0,253

$\pm k$	b/mm
1	0,103
2	0,104
3	0,103

What does this stand for b ?

- Gap centre distance
- Gap width
- Wavelength

Evaluation (3/3)

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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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Slide	Score / Total
Slide 16: Multiple tasks	**0/2**
Slide 17: Solve formula correctly	**0/1**

Total 0 / 3

Solutions Repeat

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