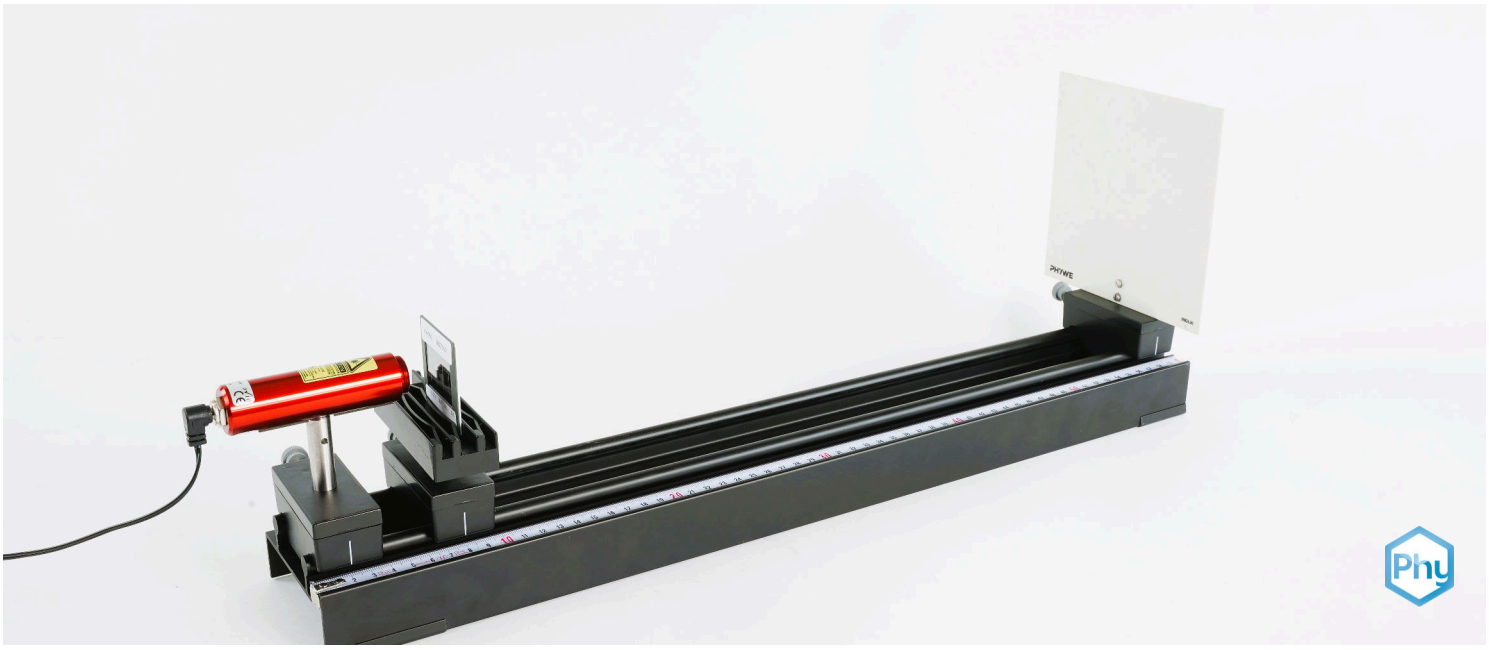
Diffraction at a double slit with laser



If monochromatic light strikes a double slit, intensity minima and maxima appear behind it on a screen, from the positions of which the slit width and its slit centre distance can be determined for a known wavelength.

Physics > Light & Optics > Diffraction & interference

Difficulty level	Group size	Preparation time	Execution time
easy	-	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6729fb9326998c000267a32c

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Teacher information

Application

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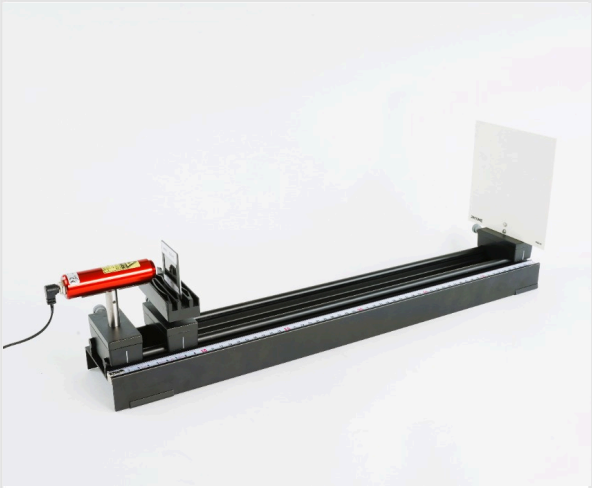

The experimental setup

If monochromatic light hits a double slit, an interference pattern with intensity maxima and minima appears behind it on a screen. Based on their positions, the slit width and the slit center distance can be determined for a known wavelength.

Diffraction often occurs in everyday life for light and sound waves. For example, when light falls on narrow posts, it is observed that their shadows have blurred edges. This phenomenon is due to diffraction effects. Slits and bars with the same thickness behave in the same way.

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Other teacher information (1/5)

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Prior knowledge

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

Principle

A laser beam shines through an aperture with a double slit and generates an interference pattern on a screen behind it.

The interference pattern can be used to read 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 you look at the interference pattern of a double slit, you can see that the maxima and minima are equidistant from each other.

Comparing the interference patterns of the different columns with column spacing g with each other, it can be seen that with increasing g the distances between the maxima and minima decrease. In addition, the wavelength λ of the laser light can be calculated.

Tasks

The students should investigate how the interference pattern changes during diffraction at the double slit as a function of the slit width, b and the column spacing g and determine the wavelength of red light.

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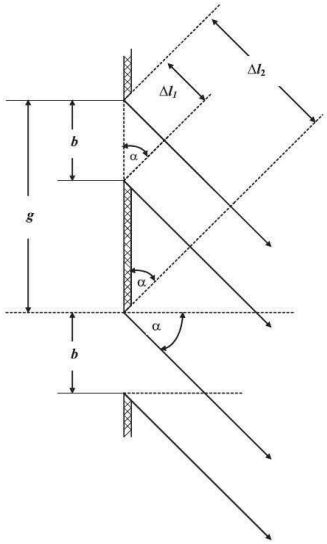
Other teacher information (3/5)

If a laser beam falls on a double slit with the slit centre distance g and the width $b$the beam in the double slit area, as shown on the right, can be thought of as being split into two beams, which are directed at the angle α be bent.

The edge rays of the single slit have the path difference Δl_1. If this is an integer multiple of the wavelength λthese rays interfere destructively. The single slit therefore always produces darkness in the interference image if the relationship applies in general:

$$\Delta l_1 = k \cdot \lambda = b \cdot \sin\alpha; k = \pm 1, \pm 2, \pm 3, \ldots \quad (1)$$



Other teacher information (4/5)

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

If this is an odd multiple of $\lambda/2$ this also constitutes cancellation.

This provides additional darkness in the interference image for

$$\Delta l_2 = \frac{2m+1}{2} \cdot \lambda = g \cdot \sin\alpha; m = 0, \pm 1, \pm 2, \pm 3, \ldots \quad (2)$$

Is r the distance between the double slit and the sufficiently distant collecting screen S and are still $x_{k,m}$ is the distance of the minima from the centre:

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

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Other teacher information (4/5)

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Other teacher information (5/5)

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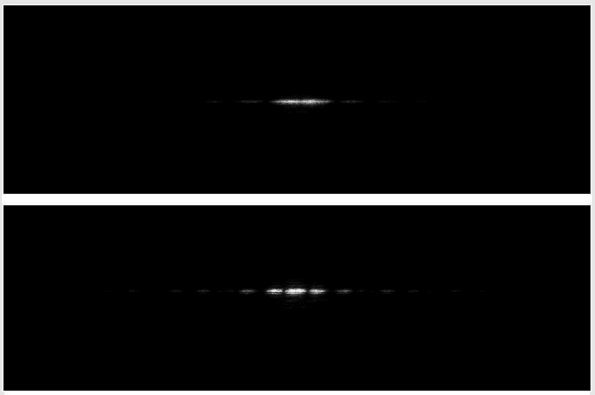
From (1) and (2) follows:

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

The width of the central maximum of the single slit (distance of the minima symmetrical to the centre) is $2\lambda \cdot r/b$. The equidistant maxima of a double slit with the same b have the width $\lambda \cdot r/g$. This means that the central maximum of the single slit of

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

interspersed with additional maxima.



Diffraction pattern of a slit and a double slit with the same slit widths

oben: gap: b = 0.2 mm; bottom: Double slit: b = 0.2 mm and g = 0.3 mm

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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.

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Student information

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Motivation

Light diffraction when looking towards the sun

Light refers to the range of the electromagnetic spectrum that is visible to humans. With diffraction objects, such as a double slit, a special phenomenon of light - the interference capability - can be observed, which indicates the wave character of light.

This phenomenon can be observed if you hold your hand in front of your eyes and look at the sun. It appears as if it is partially visible, although part of it is covered by the fingers.

But what does an interference pattern look like and what physical laws underlie it? These questions are investigated in this experiment.

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Equipment

Position	Equipment	Item no.	Quantity
1	Optical profile bench for student experiments, l = 600 mm	08376-00	1
2	Rider for optical profile bench	09822-00	3
3	Plate holder for 3 objects	09830-00	1
4	Panel with 4 double columns	08523-00	1
5	Shade, white, 150 mm x 150 mm	09826-00	1
6	Diode laser, 1 mW, 635 nm (red-3V) with short stem, l = 75 mm	08771-99	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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Setup

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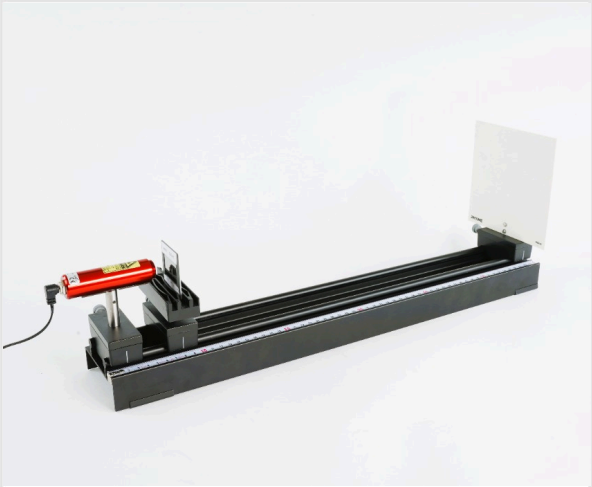

The experimental setup

The experiment is set up as shown in the illustration.

The line marks of the riders for holding the components have the following positions on the optical bench:

Rider with diode laser at $2\,\mathrm{cm}$.
Rider with plate holder and inserted aperture with double slits at $8\,\mathrm{cm}$.
The screen in the rider is at a distance $r = 1.5\,\mathrm{m}$ from the double slit diaphragm. If less space is available, the screen can be placed on the bench at $58\,\mathrm{cm}$ for the slit with $g < 1.0\,\mathrm{mm}$.

Procedure

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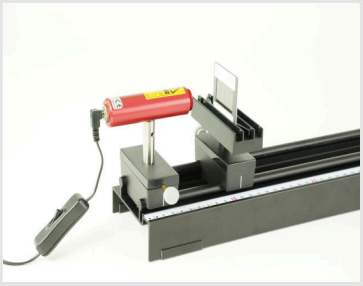

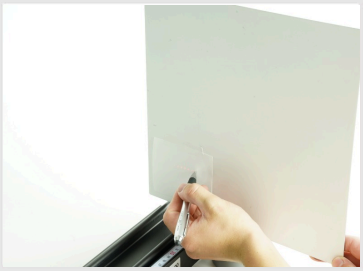

- Describe below for each slit how the interference pattern changes with the slit width b and the slit distance g.
- Move the double slit with $b = 0.2\,\mathrm{mm}$ and $g = 0.25\,\mathrm{mm}$ into the optical axis
- Determine the distance between the first interference maximum to the left and right of the middle maximum using a ruler or caliper, note the measured value and divide it by 2. The result is d_1
- Proceed in exactly the same way for the other distances d_n between the n-th and the adjacent maximum for at least $n = 3$
  Measure the distance r of the double slit from the screen with a tape measure and note it down

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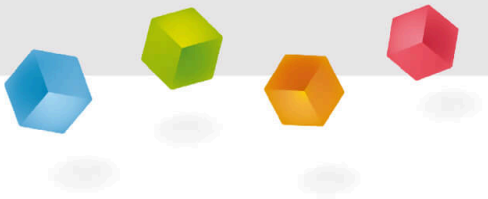

Report

Task 1 and 2

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What does b stand for in the experiments?

- Wavelength
- Gap width
- Gap centre distance

What could be possible sources of error that lead to deviations in the calculation of the wavelength? λ of the red light?

- [ ] When using a ruler or sliding caliper, the scaling error of these utensils must also be taken into account.
- [ ] When measuring the values for d_n and r reading errors lead to inaccurate measured values.
- [ ] The specified values for the gap width b and the gap distance g have a certain but unknown error.

Check

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Task 3

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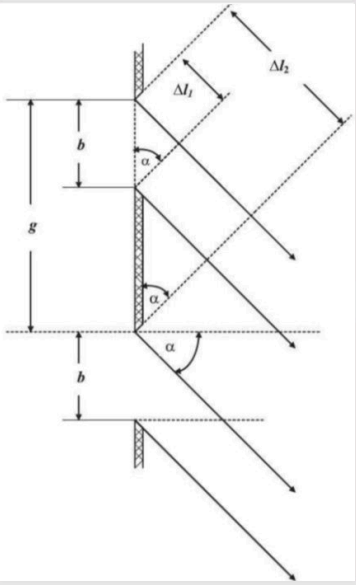

Influence of slit width b and gap distance d

The larger b at constant g is, the _____ are the interference fringes.

The larger g at constant b is, the _____ are the number and sharpness of the interference fringes and all the more _____ their distances from each other.

smaller | larger | brighter | darker

Check

Task 4

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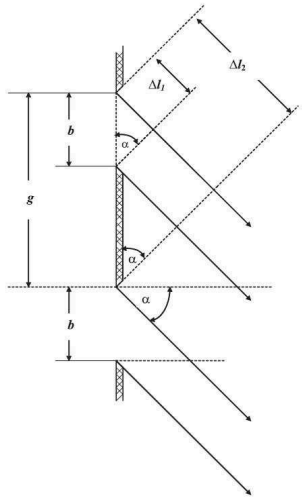

Diffraction at the double slit

Using the recorded data, the Pythagorean theorem can be used to determine the wavelength of the laser λ calculate:

$$\lambda(d_n) = \frac{d_n * g}{n * \sqrt{(d_n)^2 + r^2}}.$$

Calculate $\lambda(d_n)$ for n = 2, 3 and 4, where 1 nm = 10^{-9} m.

What is the approximate wavelength of red laser light?

$\lambda \approx$ _____ nm

550 | 640 | 700

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