Diffraction at circular aperturer with laser

If circular openings are illuminated with coherent light, concentric light and dark circles alternate behind them due to diffraction and interference. The intensity of the interference maxima decreases rapidly with increasing distance from the centre. If the circular apertures are replaced by circular apertures, similar interference patterns appear. Brightness can always be observed at any location on the centre axis of the geometric shadow area.

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/6729fbaa26998c000267a358

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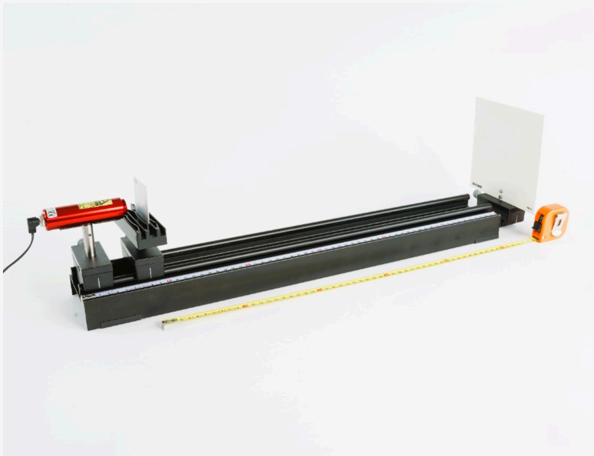
Teacher information

Application


The experimental setup

If circular openings are illuminated with coherent light, diffraction and interference create alternating concentric light and dark circles.

This phenomenon can become visible in everyday life, for example when you look through a circular hole in a blind or a leaf towards the light.

Two closely neighbouring objects can only be observed separately with a microscope if the central brightness maximum of the diffraction image of one object coincides with the first minimum of the diffraction image of the other object.

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Application

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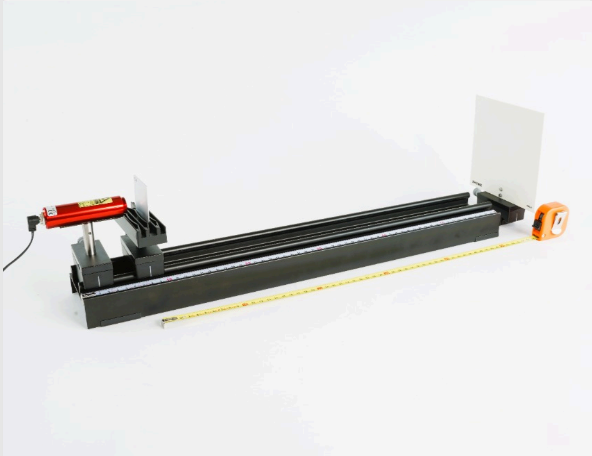

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Other teacher information (1/3)

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Prior knowledge

It should already be known that diffraction and interference occur both at openings and at obstacles. It is therefore advisable to carry out the experiment "Diffraction at a bar - Babinet's theorem" beforehand.

Principle

When pinholes or circular apertures are illuminated with coherent light, the edge of the respective object is the starting point for elementary waves that interfere with each other.

On the centre axis of the object, these elementary waves each have a path difference of zero, so that there is a brightness maximum for both the pinhole and circular apertures.

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Other teacher information (2/3)

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Learning objective

Interference takes place at both pinholes and circular apertures. On the centre axis of the diffraction objects, the interfering elementary waves have a path difference of zero, so that there is also an intensity maximum in the geometric shadow space behind circular apertures. This is called a Poisson's spot.

Tasks

The students investigate the interference patterns that occur when light is diffracted by a circular hole of small diameter. With their help, the wavelength of red light is to be determined.

Other teacher information (3/3)

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Notes on setup and procedure

The experiment room should be well darkened because the circular aperture acting as the light source may only have a small diameter and therefore low-intensity light beams must be used.

To produce the perforated panel with $d = 0.1$ mm, a piece of cardboard is cut to size and pierced in the centre with the tip of a needle that is as thin as possible. The hole diameter should be 0.1...0.15 mm, but not larger.

Remark

A quantitative correlation between the diameter of the diffractive aperture and the diameter of the 1st intensity minimum can be found by the students if they succeed in producing the diffraction images for the apertures with $d = 1$ mm and $d = 0.1$ mm to be measured

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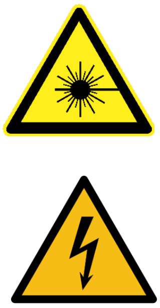
Safety instructions



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.

Student information

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Motivation

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The aperture of a camera

Light is the range of the electromagnetic spectrum that is visible to humans. Diffraction objects can be used to observe a special phenomenon of light - the ability to interfere - which indicates the wave character of light. One of these objects is the circular aperture, such as the aperture of a camera.

Depending on the shape of the diffraction objects, the interference patterns change accordingly.

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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	2
3	Plate holder for 3 objects	09830-00	1
4	Perforated aperture, d = 0.4 mm	08206-04	1
5	Shade, white, 150 mm x 150 mm	09826-00	1
6	Measuring tape, l = 2 m	09936-00	1
7	Diode laser, 1 mW, 635 nm (red-3V) with short stem, l = 75 mm	08771-99	1

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Setup (1/2)

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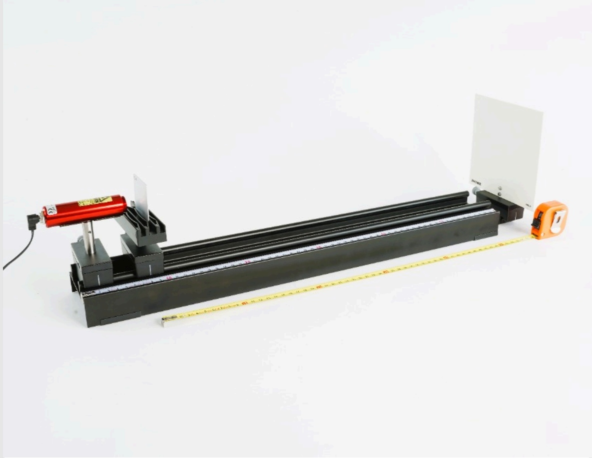

Experimental setup without diverging lens

The riders for holding the components are placed on the optical bench as shown in the figure, with the line marks in the following positions.

- Rider with diode laser at $2\ \mathrm{cm}$.
- Mount with pinhole aperture ($d\ = 0.4\ \mathrm{mm}$) with diffraction objects at $8\ \mathrm{cm}$.

To investigate diffraction at circular apertures, it is advantageous to add the diverging lens $f = -50$ mm (not included in the set) to enlarge the diffraction image. To do this, the mount with the pinhole inserted is positioned at $20\ \mathrm{cm}$ and the lens in the mount at approx. $13\ \mathrm{cm}$ is inserted.

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Setup (2/2)

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Experimental setup with diverging lens

The screen is attached to the rider and positioned at $58\ \mathrm{cm}$.

Experimental setup without diverging lens

The sunshade is attached to the rider and positioned approx. 1.5 - 4 metres away from the screen.

Procedure

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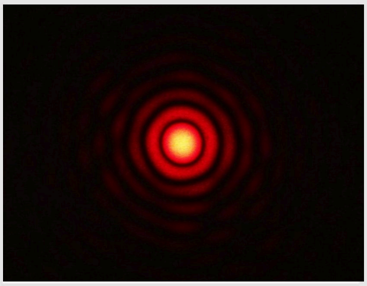

A sheet of paper is attached to the screen with the surface normal pointing in the direction of the optical axis using adhesive tape. The room is darkened.

First, the pinhole apertures are illuminated symmetrically one after the other with laser light.

Concentric circles can now be observed on the screen. To determine the diameter d_n the minima circles are marked on the sheet.

The distance r between the diffraction object and the screen is determined using the measuring tape. The diameter d_n of the circles are determined using the calliper gauge.

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Report

Task 1

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Drag the boxes into the correct fields.

The diffraction pattern consists of a red ______ and concentric, circular coloured ______, whose ______ decreases strongly outwards into outwards. Each of these circular rings contains the ______ from violet to red - seen from the common centre her .

- intensity
- circular disc
- interference fringes
- spectrum

Check

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Task 2

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Compare the diameters of the 1st intensity minima with each other and establish a relationship to the diameters of the diffraction apertures.

- Regardless of the diameter of the diffraction aperture, the diameter of the 1st intensity minimum always remains the same.
- The smaller the diameter of the diffractive aperture, the larger the diameter of the 1st intensity minimum.
- The smaller the diameter of the diffracting aperture, the larger the diameter of the 1st intensity minimum.

Check

Task 3

PHYWE

Equation of the wavelength

What is the equation for the diffraction of light at a narrow bar? Now calculate the mean wavelength of the light, assuming that this equation also applies approximately to diffraction at a narrow circular aperture.

$$\lambda = \frac{\square \cdot \square}{\square \cdot \square}$$

r	Distance diffraction slit - observation plane
d_n	Distance of the nth interference minimum from the optical axis
n	Order of the interference minimum
b	Gap width

Check

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Task 4 and 5

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What happens as the diameter of the aperture increases?

- [ ] More maxima can be seen.
- [ ] The distances between the maxima become smaller.
- [ ] The diameter of the central maximum becomes smaller.

Check

What is the principle according to which the diffraction patterns of pinhole and circular apertures are identical except for the central maximum?

- Babinet's theorem.
- Fresnel's rule.
- Lloyd's principle.

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