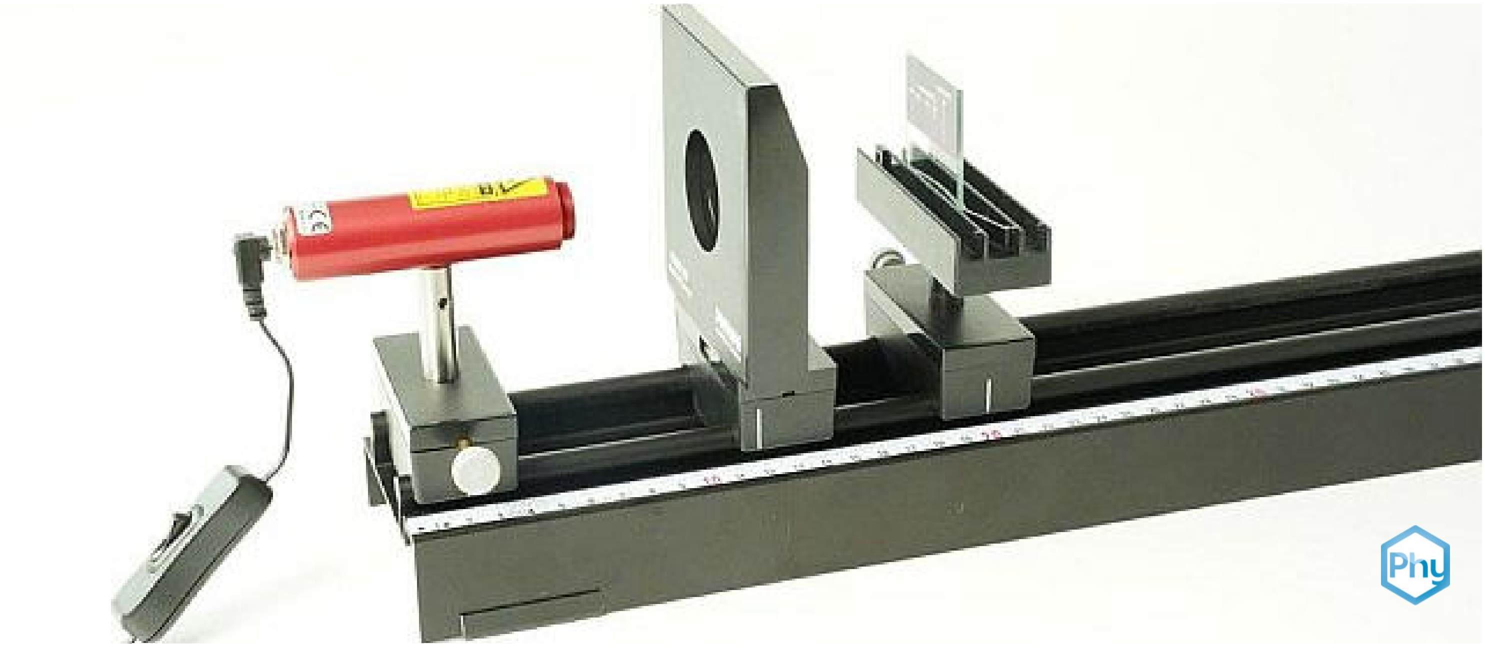
Diffraction at circular obstacles and circular apertures -Poisson spot



If circular apertures are illuminated with coherent light, diffraction and interference produce alternating concentric bright and dark circles behind them. The intensity of the interference maxima decreases rapidly with increasing distance from the centre. If the circular openings are exchanged for circular apertures, similar interference patterns appear. Brightness is always observed at every location on the centre axis of the geometric shadow area.

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/6492ad6a81696d00027328c8

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General information

Application

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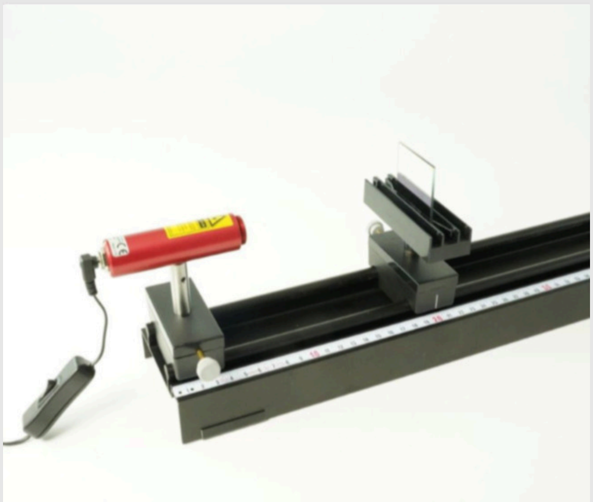

Experimental setup

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

Diffraction at circular apertures leads to a profound consequence for the resolving power of optical instruments. For example, the mount of the objective lens of a microscope acts as a diffractive circular aperture.

Two closely neighbouring objects can still be observed separately with a microscope only 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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Other information (1/2)

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Prior knowledge

It should already be known that diffraction and interference occur at openings as well as at obstacles. For this, it is a good idea 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 of elementary waves that interfere with each other.

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

Other information (2/2)

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Learning objective

Interference takes place both at pinholes and at circular apertures. On the central 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 spot.

Tasks

- Observe and compare the interference patterns
- Comprehending the derivation of Poisson's stain
- Calculating the diameters of the pinholes

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Safety instructions

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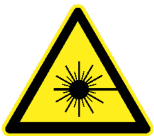

It is essential to ensure that you do not look directly into the laser beam.

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

Theory

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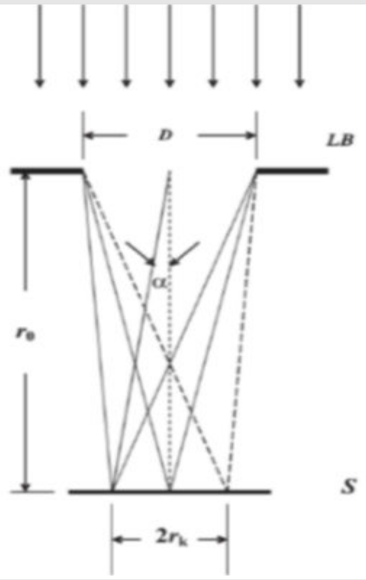
If a plane wave front is disturbed by an obstacle, elementary waves emanate from all locations of the disturbance according to Huygens' principle and interfere with each other by superposition.

From the edge of a circular obstacle, the diffracted rays emanate in phase. When superimposed somewhere on the central axis, these rays are also always in phase due to their identical paths. Thus there is always brightness on the central axis.

If the diffracted beams have different paths, they can constructively or destructively interfere with each other depending on the path difference. Because of the radially symmetrical geometry, the interference pattern consists of concentric light and dark circles.



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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	Mount with scale on slide mount	09823-00	1
4	Lens, mounted, f -50 mm	08026-01	1
5	Plate mount for three objects	09830-00	1
6	Screen, with diffracting elements	08577-02	1
7	Screen, metal, 300 x 300 mm	08062-00	1
8	Barrel base expert	02004-00	1
9	Vernier calliper stainless steel 0-157mm, 1/20	03010-00	1
10	Measuring tape, l = 2 m	09936-00	1
11	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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Setup and procedure

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Set-up

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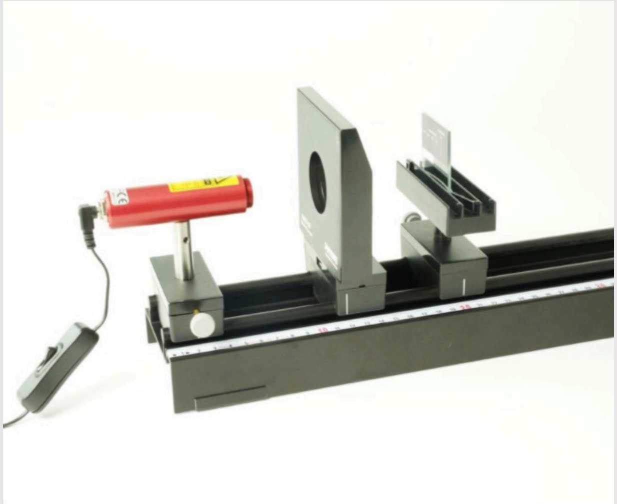

Experimental setup

The tabs for holding the components are placed on the optical bench as shown in the illustration, with the tally marks on the following positions.

- Slider with diode laser at 2cm.
- Slider with plate mountand inserted aperture with diffraction objects at 20cm.

For the investigation of diffraction at circular apertures, it is advantageous to use the diverging lens $f = -50mm$ to enlarge the diffraction image . This is inserted into the mount with scale between the laser and the diffraction object at approx. 13cm.

The aperture with the diffraction objects is inserted into

Procedure

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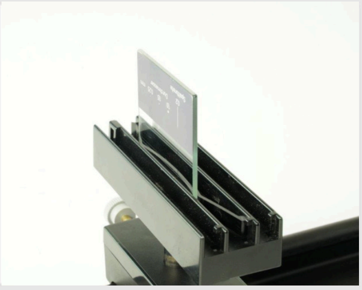

A sheet of paper is attached with adhesive tape to the screen whose surface normal points in the direction of the optical axis. The room is darkened.

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

Now concentric circles can be observed on the screen. To determine the diameters, the minicircles are marked on the sheet.

The distance between the diffraction object and the screen is determined with the tape measure. The diameters of the circles are determined with the calliper.

The circular apertures are then illuminated and their interference patterns can be observed on the screen.

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Evaluation

Evaluation (1/3)

The mathematical treatment of diffraction at circular obstacles is very complex and demanding. Therefore, the conditions for the first three dark circles are given here without any derivation. If D is the aperture diameter, α is the diffraction angle and λ is the wavelength of the incident light, the following applies to the cancellation:

$$\sin\alpha_1 = 1.22\frac{lambda}{D}; \quad \sin\alpha_2 = 2.232\frac{\lambda}{D}; \quad \sin\alpha_3 = 3.238\frac{\lambda}{D} \qquad (1)$$

If r_k denotes the radii of the minimum circles and r_0 is the distance of the diffraction object to the observation screen, then $r_0 || |r_k : \sin\alpha \approx r_k/r_0$. With this relation and (1) one finally gets from the first three dark circles for the diameter of an aperture:

$$D = 1.22\frac{r_0 * \lambda}{r_1} = 2.232\frac{r_0 * \lambda}{r_2} = 3.238\frac{r_0 * \lambda}{r_3} \qquad (2)$$

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Evaluation (2/3)

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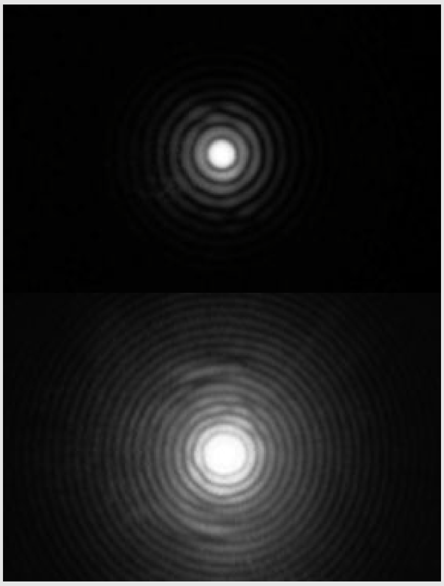

Calculate the diameters of the pinholes and check your result. How much does your result deviate?

Results

Evaluation (3/3)

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What happens as the diameter of the aperture increases?

- ☐ There are more maxima to be seen.
- ☐ The intervals between the maxima become smaller.
- ☐ The diameter of the central maximum becomes smaller.

Check

What is the principle called after the diffraction patterns of pinhole and circular apertures are identical except for the central maximum?

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

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Slide	Score / Total
Slide 15: Multiple tasks	**0/4**

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