Diffraction at a system of circular apertures of equal size

Task and equipment

Information for teachers

Additional Information

The students should recognize that, just as in diffraction from a slit grating (a system of equidistant slits of equal width), diffraction occurs from a system of equal diameter.
All the circular apertures produce the same diffraction pattern because they all have (approximately) the same diameter. The superposition of all these diffraction patterns creates the concentric circles observed in the experiment, the diameter of which is dependent on the wavelength of the light employed - providing that all other aspects of the setup remain unchanged -, and these circles reflect the arrangement of the holes in the diaphragm.

Suggestions for Set-up and Performance

The experiment can be performed in a semi-darkened room. It is essential for the success of the experiment to carry out most careful adjustments.
Preparing the diaphragms with their holes of (as far as possible) equal diameter is fairly time-consuming. For this reason, we recommend doing this preparation work before the lesson. Cut out of black card (order no. 06306-01) 4 squares 50 x 50 mm. When perforating the card with a needle, use a cardboard backing to produce equal-sized holes. Instructions for making the diaphragms:
As far as possible, the holes should be of (equal) diameter approx. 0.1 mm.
Diaphragm 1: 1 hole in the centre of the diaphragm
Diaphragm 2: 10 to 15 holes in a straight line through the centre of the diaphragm parallel to one side
Diaphragm 3: approx. 10 x 10 holes arranged in a square, grid size 1 mm
Diaphragm 4: approx. 100 holes at random, average gap between holes approx. 1 mm.
When making diaphragms 2 and 3 we recomment putting graph paper on top of the card squares. To prevent slipping during perforation, fix them together with tape.
The diaphragm should be clearly numbered as set down in the students' worksheet.

Remark

Thin aluminium foil is more suitable than card to produce diaphragms with holes that are as equal in size as round as possible. Once made, it is expedient to frame the diaphragms in slide frames so that they can be kept and used again in future experiments.

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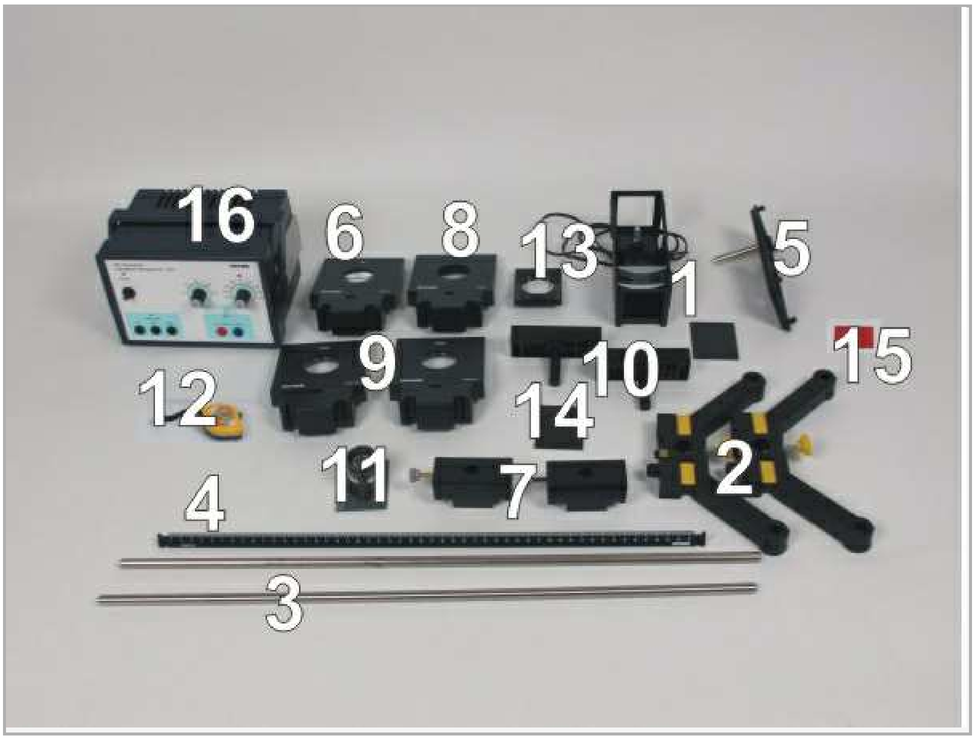
What kind of interference patterns are found behind a system of circular apertures of equal diameter?

Direct a narrow beam of light of circular cross-section onto a diaphragm perforated by identical holes of small diameter. Investigate the interference patterns created when, firstly, these holes are arrayed at regular intervals, and secondly, when they are arrayed at random.
With the aid of the diffraction patterns calculate the diameter of the holes.

Equipment



Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Support base, variable	02001-00	1
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
4	Meter scale for optical bench	09800-00	1
5	Bottom with stem for light box	09802-10	1
6	Lens on slide mount, f=+50mm	09820-01	1
7	Slide mount for optical bench	09822-00	1
8	Mount with scale on slide mount	09823-00	2
9	Lens on slide mount, f=+300mm	09820-04	2
10	Plate mount f.3 objects	09830-00	1
11	Measuring magnifier	09831-00	1
12	Measuring tape, l = 2 m	09936-00	1
13	Diaphragm holder, attachable	11604-09	2
15	Colour filter set, additive (red, blue, green)	09807-00	1
16	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
14	4 different diaphragms with circular holes		

Set-up and procedure

Set-up

- Set up the optic bench with the two support rods and the support base and place the scale in position (Fig. 1 and Fig. 2).


Fig. 1


Fig. 2

- Assemble the light box according to Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing away from the optic bench (Fig. 5). Insert a light-tight diaphragm into the well in front of the lens (Fig. 6).


Fig. 3


Fig. 4


Fig. 5


Fig. 6

- Attach the lens with *f* = +50 mm at 6 cm on the optic bench (Fig. 7).


Fig. 7

- Attach the diaphragm holder with the aperture diaphragm 1 (one hole *d* = 0.1 mm) to the mount and set up the mount with scale at approx. 9.5 cm (Fig. 8).

Fig. 8

- Position one lens with *f* = +300 mm at 40 cm and the other at the right-hand end of the optic bench (Fig. 9).

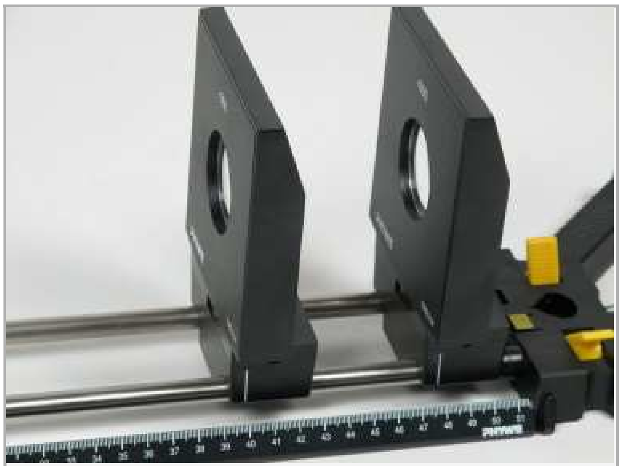


Fig. 9

- Place the slide mount with the plate holder between these two lenses (Fig. 10).

Fig. 10

- Position the second slide mount with the plate mount and the observation lens about 30 cm to the right of the optic bench (Fig. 11).

Fig. 11

Procedure

- Plug the light into the power supply (12 V~) (Fig. 12) and switch on the power supply.

Fig. 12

- Move the observation lens along the optical axis and slide along the optical axis until the image of the diaphragm aperture is sharply focused in the observation plane. If necessary, adjust the diaphragm aperture and light once more to ensure that the optical axis is set for the complete experimental arrangement.
- Now attach the diaphragm with holes arranged in a straight line (diaphragm 2) to the plate mount between the two lenses (Fig. 13).

Fig. 13

- Observe the image through the observation lens and describe it in the report.
- In place of diaphragm 2 insert diaphragm 3 with holes arranged in a sqaure grid.
- Observe and describe the ensuing image and compare it with the previous image in the report.
- Finally exchange diaphragm 3 for diaphragm 4, which has irregularly spaced holes; observe and describe the ensuing image and compare it with the previus images in the report.
- To calculate the hole diameter, select diaphragm 3 again and insert the red filter into the light well.
- Measure the diameter d_1 of the first dark circle (1st intensity trough) and, if possible, also d_2 of the second intensity trough.
- Measure the distance e between the observation plane and the lens positioned at the right-hand end of the optic bench.
- Switch off the power supply.

Report: Diffraction at a system of circular apertures of equal size

Result – Observations 1

Describe the image after the insert of diaphragm 2 in the first part of the experiment:

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Result – Observations 2

Describe the image after the insert of diaphragm 3 in the second part of the experiment and compare it with the previous image:

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Result – Observations 3

Describe the image after the insert of diaphragm 4 in the third part of the experiment and compare it with the previous image:

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Result – Observations 4

Enter the values:

$d_1 =$ .... mm

$d_2 =$ .... mm

$e =$ .... cm

Evaluation – Question 1

What correlation exists between the arrangement of the holes and the structure of the diffraction pattern?

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Evaluation – Question 2

The following equation applies to the intensity troughs of the circular diffraction patterns created when light is diffracted from circular apertures:

$$d = 1{,}22 \cdot \lambda \cdot 2 \cdot e/d_1 \text{ (1}^{\text{st}}\text{ order)} \quad \text{and} \quad d = 2{,}23 \cdot \lambda \cdot 2 \cdot e/d_2 \text{ (2}^{\text{nd}}\text{ order)}$$

d = diameter of the circular apertures of equal size, $d_{1,2}$ = diameters of the circles representing the intensity troughs of the 1st and 2nd order, *e* = distance of observation plane from the lens at the end of the optic bench, λ = wavelength of the light.

Calculate the mean diameter of the circular apertures in the diaphragm. Assume the wavelength of the red filter light to be 650 nm.

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Evaluation – Question 3

Verify the order of magnitude of your result under question 2 with the aid of the observation lens.

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Evaluation – Question 4

Why must we use **a hole** diaphragm (i.e. a diaphragm with a circular hole) in this experiment rather than **a slit** diaphragm?

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