Diffraction at circular apertures

Task and equipment

Information for teachers

Additional Information

Diffraction from circular diffraction objects must produce diffraction patterns in the form of concentric circles.
Students should be able to anticipate this result on the basis of their knowledge of diffraction from a narrow slit or obstacle gained in previous experiments. Thus, they should use this experiment to verify and confirm their assumptions.

Suggestions for Set-up and Performance

The laboratory should be well darkened because the diameter of the circular opening acting as light source must be very small and consequently the light beams will be of low intensity. This complicates adjustments to the setup which are essential for an accurate result.
To prepare the diaphragm aperture with d = 0.1 mm a piece of card is cut to size and perforated in the centre with the tip of a fine needle. The diameter of the hole should be not larger than 0.1...0.15 mm. This must be checked with the micrometer eyepiece of the observation lens.

Remark

The students might find a quantitative relationship between the diameter of the diffraction aperture and the diameter of the 1st intensity through. However, this will only be possible if they succeed in measuring the diffraction patterns resulting from the diffraction diaphragms with d = 1 mm and d = 0.1 mm, and this is by no means easy with the available resources and lightning conditions.

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Task

What kind of interference patterns are found when light is diffracted from a narrow apertures?

Investigate the interference patterns created when light is diffracted from a circular opening of small diameter, and on the basis of these patterns work out the wavelength of red light.

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	Bottom with stem for light box	09802-10	1
5	Diaphragms, d 1, 2, 3, 5 mm	09815-00	1
6	Lens on slide mount, f=+50mm	09820-01	1
7	Slide mount for optical bench	09822-00	2
8	Mount with scale on slide mount	09823-00	1
9	Aperture, d 0.4mm	08206-04	1
10	Lens on slide mount, f=+300mm	09820-04	2
11	Plate mount f.3 objects	09830-00	2
12	Measuring magnifier	09831-00	1
13	Diaphragm holder, attachable	11604-09	1
14	Measuring tape, l = 2 m	09936-00	1
15	Colour filter set, additive (red, blue, green)	09807-00	1
16	Meter scale for optical bench	09800-00	1
17	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
19	Cardboards 200x300mm,black,10 pcs	06306-01	(1)
Additional material			
18	Scissors		1
20	Pin or sewing needle, d≤ 0.5 mm		1

Set-up and procedure

Set-up

- Make a diaphragm (50 x 50 mm) with a circular aperture of approx. 0.1 mm diameter in the centre.
- 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 (Fig. 7).

Fig. 7

- Attach the diaphragm holder with the prepared aperture diaphragm to the mount (Fig. 8) and set up the mount with scale at approx. 9.5 cm (Fig. 9).

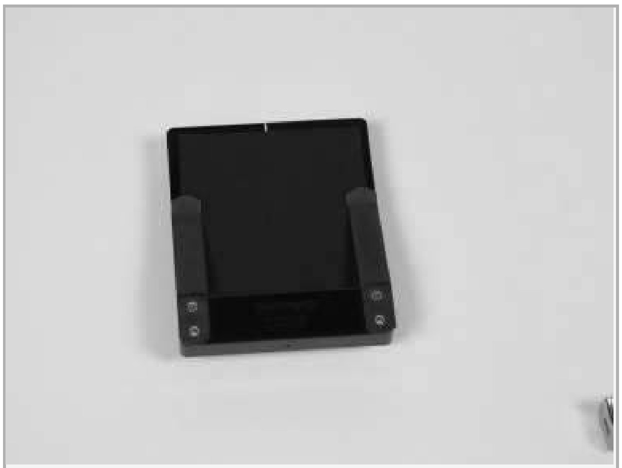

Fig. 8

Fig. 9

- Position one lens with *f* = +300 mm at 40 cm and the other at the right-hand end of the optic bench (Fig. 10).

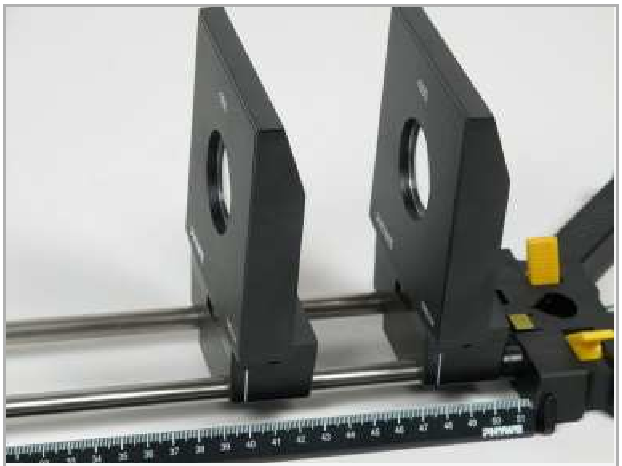

Fig. 10

- Place the slide mount with the plate holder between these two lenses (Fig. 11).

Fig. 11

- Position the second slide mount with the plate mount and the observation lens about 30 cm to the right of the optic bench (Fig. 12).

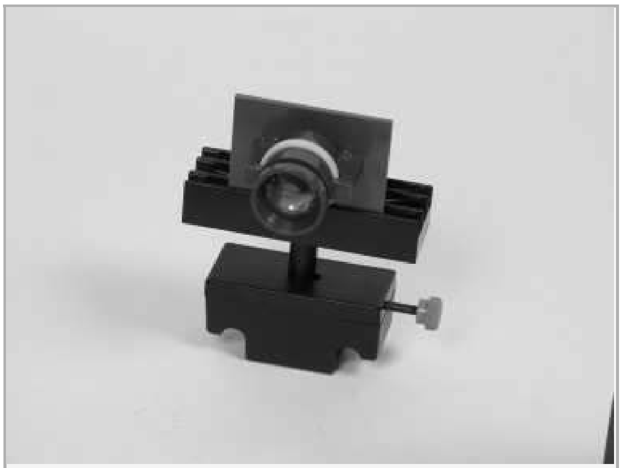

Fig. 12

Procedure

- Plug the light into the power supply (12 V~) (Fig. 13) and switch on the power supply.

Fig. 13

- Move the observation lens along the optical axis and slide along the optical axis until the diaphragm aperture (serving as light source) is sharply focused in the observation plane.
- Now attach the diaphragm aperture (d = 0.4 mm) to the plate mount between the two lenses with f = +300 mm such that the aperture is evenly and symmetrically illuminated (Fig. 14).

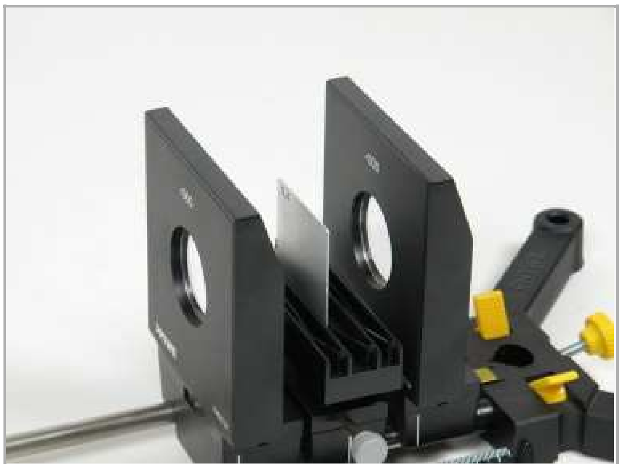

Fig. 14

- Observe and describe the diffraction patterns in the report.
- Insert the red filter into the unoccupied light well (Fig. 15).

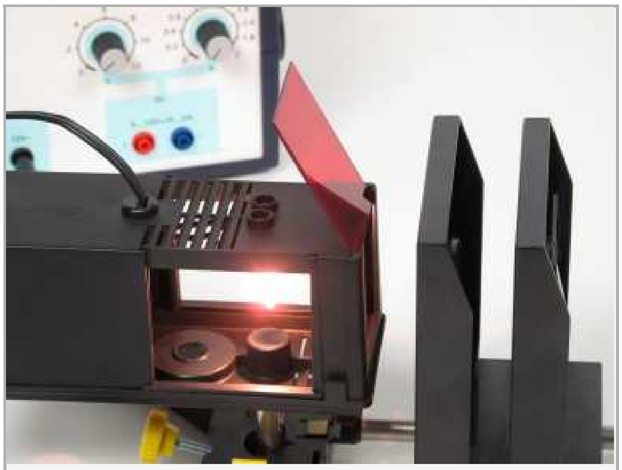

Fig. 15

- Observe and describe the diffraction patterns in the report.
- Measure the mean diameter $2r_1$ of the first intensity trough and if possible also the second intensity trough ($2r_2$). Note your results.
- Measure and note the distance e between the observation plane and the right-hand lens with f = +300 mm.
- Replace the diaphragm with d = 0.4 mm by the diaphragm with d = 1 mm and observe the diffraction pattern; now exchange the diaphragm with d = 0.1 mm for the diaphragm with d = 0.4 mm and the diaphragm with d = 1 mm for the diaphragm with d = 0.1 mm. Observe the diffraction patterns. Note your observations in the report.
- Switch off the power supply.

Report: Diffraction at circular apertures

Result – Observations 1

Describe the diffraction patterns during the first part of the experiment:

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Result – Observations 2

Describe the diffraction patterns during the second part of the experiment (insertion of the red filter):

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Result – Observations 3

Record the values:

$2r_1$ = ... mm

$2r_2$ = ... mm

e = ... cm

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Result – Observations 4

Describe the diffraction patterns during the third part of the experiment (replacement of the diaphragm):

Evaluation – Question 1

What properties must the diaphragm aperture used as the light source have in order to produce interference patterns are clearly structured?

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Evaluation – Question 2

Compare the diameter of the 1st intensity troughs and try to relate these to the diameters of the diffraction apertures.

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Evaluation – Question 3

When light is diffracted from a narrow slit the following equation applies:

$$\lambda = d_n \text{ x } b \,/(n \text{ x } e)$$

where d_n = distance of the nth interference trough from the optical axis; e = distance from diffraction slit to observation plane (in the experiment between right-hand lens f = +300 mm and observation plane); b = slit width.

Calculate the mean wavelength of the light transmitted through the colour filter, assuming that this equation can in approximation be applied to diffraction from a narrow, circular aperture.

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