Diffraction at multiple slits

Task and equipment

Information for teachers

Additional Information

This experiment should demonstrate to the students that light, when it is diffracted at *n*-fold slits, *n* - 1 secondary minima and *n* - 2 secondary maxima occur regularly between two adjacent primary maxima. Those are clearly visible, especially between the primary maximum of 0th order and the primary maximum of 1st order.
Furthermore, the students should recognize that the intensity of the secondary peaks decreases with increasing number *n* of slits, and that in case of the transmission grating it is negligible. On the other hand, the intensity of the primary peaks increases with increasing n and is extremely high when using the transmission grating.
In this way the experiment will facilitate the understanding of the way a transmission grating works.

Suggestions for Set-up and Performance

This experiment can be set up and performed under normal light conditions.
We recommend beginning the investigation with the 4-fold slit (alternatively you can start with the 3-fold or 5-fold slit but not with the double slit) to give the students a clearer idea of the observations required in this experiment.

Remarks

One way of explaining the occuring of secondary maxima and minima to the students is as follows:
when light is diffracted at a slit an intensity minimum will occur e.g. when the wave trains diffracted at a certain angle at adjacent slits display a path difference of λ / 2. Point out that other path differences can also results in extinction. For instance, three wave trains each having a mutual path difference of λ / 3 ($\Delta_1 = \lambda / 3$; $\Delta_2 = 2\lambda / 3$) will cancel out each other.

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Task

How does the diffraction pattern change when the number of diffraction slits is increased?

Examine the diffraction patterns created by 2, 3, 4 and 5 slits (multiple slits) of identical width and compare them with the diffraction pattern of a grating.

Student's Sheet

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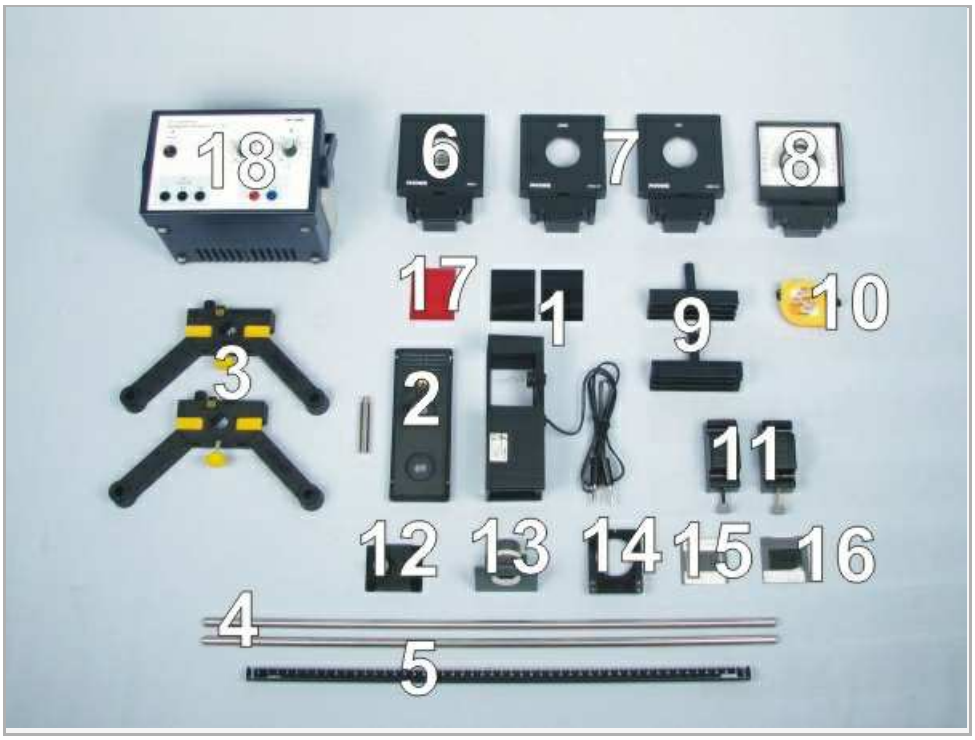
Equipment



Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-10	1
3	Support base, variable	02001-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
5	Meter scale for optical bench	09800-00	1
6	Lens on slide mount, f=+50mm	09820-01	1
7	Lens on slide mount, f=+300mm	09820-04	1
8	Mount with scale on slide mount	09823-00	1
9	Plate mount f.3 objects	09830-00	2
10	Measuring tape, l = 2 m	09936-00	1
11	Slide mount for optical bench	09822-00	2
12	Slit, adjustable.up to 1 mm	11604-07	1
13	Measuring magnifier	09831-00	1
14	Diaphragm holder, attachable	11604-09	1
15	Diffraction grating, 4 lines/mm	08532-00	1
16	Diaphragm, 4 multiple slits	08526-00	1
17	Colour filter set, additive (red, blue, green)	09807-00	red filter
18	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
-	Cardboards 200x300mm,black,10 pcs	06306-01	(1)

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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

- ssemble 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 tight fitting cover in front of the lens (Fig. 6).

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Fig. 3

Fig. 4

Fig. 5

Fig. 6

- Insert the red filter into the other well of the light box (Fig. 7).

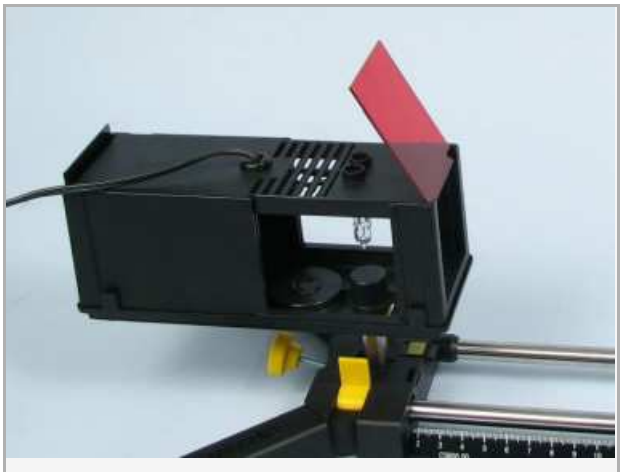

Fig. 7

- Insert the adjustable slit (light aperture) into the diaphragm holder (Fig. 8, Fig. 9) and attach this to the mount with scale (Fig. 10).

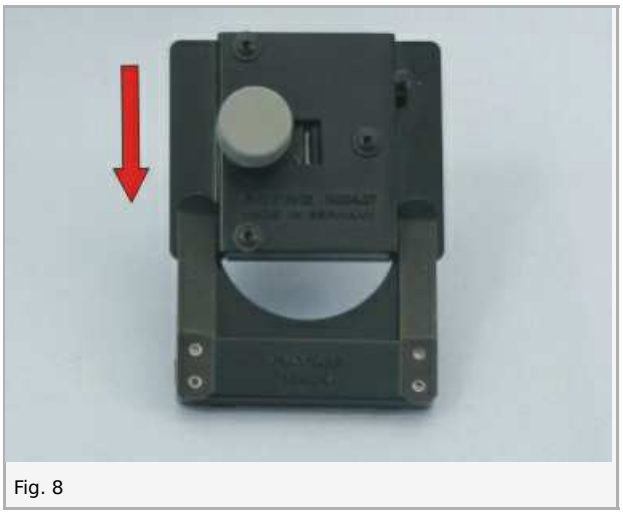

Fig. 8

Fig. 9

Fig. 10

- Position the lens with f = +50 mm at about 6 cm on the optic bench and the mount with scale at about 9.5 cm (Fig. 11).

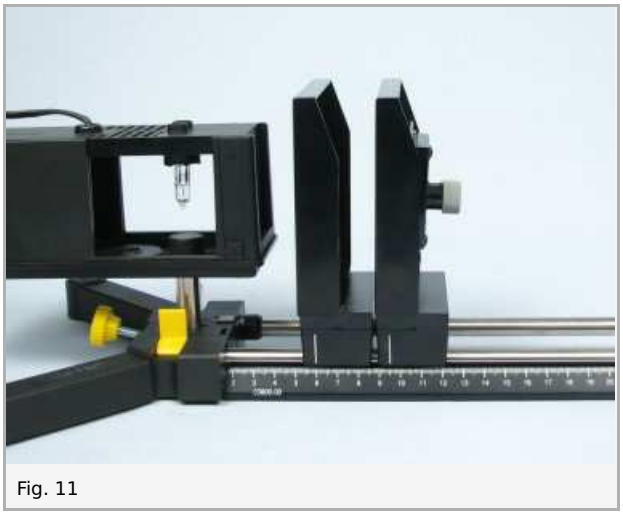

Fig. 11

- Place one of the lenses with f = +300 mm at about 40 cm and the other lens with f = +300 mm at the right-hand end of the optic bench. Just in front of the second lens position a slide mount holding a plate mount (Fig. 12).

Fig. 12

- Position the other slide mount with plate mount holding the measuring magnifier approx. 30 cm to the right of the optic bench (Fig. 13).

Fig. 13

Procedure

- Connect the light box to the power supply (12 V~) and switch it on (Fig. 14).

Fig. 14

- Move the measuring magnifier along the optical axis until the light aperture (adjustable slit) is sharply focussed on the observation plane.
- Attach the diaphragm with 4 multiple slits to the right-hand mounting of the plate mount between the two lenses (Fig. 15). Move the multiple slit with $n = 4$ into the optical axis and cover the other slits with tight-fitting covers (Fig. 16).

Fig. 15

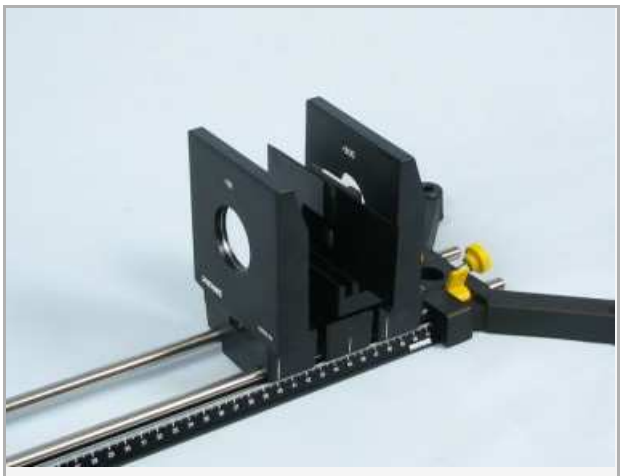

Fig. 16

- Observe the diffraction pattern. If necessary, readjust the arrangement to ensure that the light aperture and the multiple slit are parallel, that the multiple slit is evenly (symmetrically) illuminated and that the light aperture is adapted to its optimum width.
- Examine the diffraction pattern for possible **secondary** intensity peaks (maxima) and troughs (minima) which occur between the expected maxima known as **primary** maxima.
- Ascertain the number of secondary peaks (maxima) and troughs (minima) and enter your results in table 1 in the report. Estimate the intensity of the primary and secondary maxima (using the distinction high, medium, low or very low) and also enter your results in table 1.
- Replace the multiple slit (n = 4) consecutively by the multiple slits with n = 2, 3 and 5 and proceed as described above.
- Leave the width of the light aperture unchanged and replace the diaphragm with multiple slits by the grating with 4 lines / mm (Fig. 17).

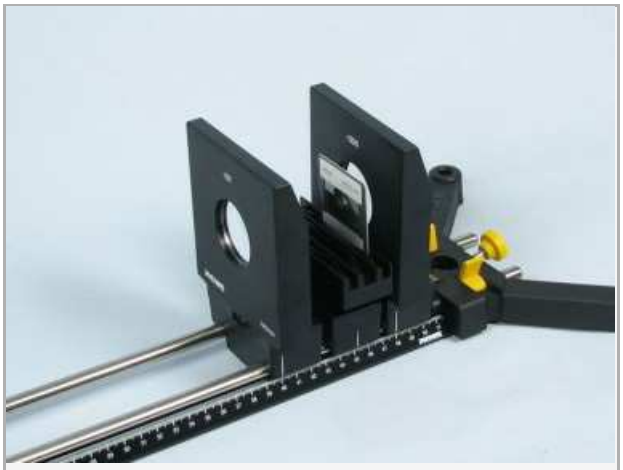

Fig. 17

- Cover the grating with two tight-fitting covers so that, to start with, a wide area of the grating positioned symmetrically to the optical axis remains uncovered (Fig. 18).

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Fig. 18

- Move both tight-fitting covers symmetrically to the optical axis to reduce the utilised area of the grating (thus decreasing the number of illuminated diffraction slits); at the same time observe the diffraction pattern.
- Describe your observation and note your description in the report.

- Switch off the power supply.

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Report: Diffraction at multiple slits

Result – Table 1

Record all measured values in the table. Write "very low", "low", "medium" or "high" for the intensity of peaks.

Number *n* of slits	Number of:		Intensity of:	
of multiple slit	secondary peaks	primary peaks	secondary peaks	primary peaks
2	$1_{\pm 0}$	$1_{\pm 0}$	-	very low 1
3	$1_{\pm 0}$	$1_{\pm 0}$	high 1	low 1
4	$1_{\pm 0}$	$1_{\pm 0}$	medium 1	medium 1
5	$1_{\pm 0}$	$1_{\pm 0}$	low 1	high 1

Result – Observations

Note down your observations made during using the diffraction grating:

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Evaluation – Question 1

When light is diffracted, what correlation exists between the number of secondary peaks / troughs on the one hand and the number *n* of the slits of the multiple slit on the other hand?

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Evaluation – Question 2

Summarize the results of the experiment with the multiple slits and the grating.

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