Diffraction at a grating

Task and equipment

Information for teachers

Additional Information

By carrying out this experiment using transmission gratings with largely differing grating constants, the students should gain an understanding of how these affect the interference pattern.
Establishing the wavelength λ of light filtered with the red filter is a by-product of the experiment which could prompt consideration of error, since the individual measurements will result in differing values for the wavelength λ.

Suggestions for Set-up and Procedure

One advantage of this experiment is that − except for the grating with 80 lines/mm − it can be performed under almost normal light conditions.
The experimental setup is simple to adjust. The teacher should ensure that the students have selected the optimum width of the light aperture.

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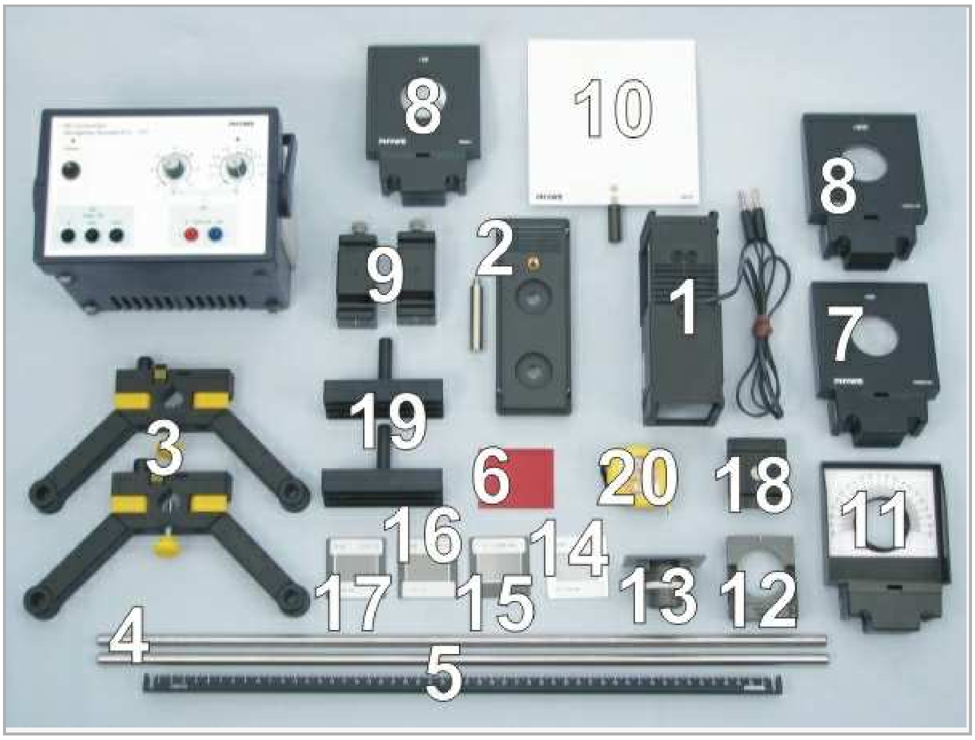
Task

How does the grating constant affect the diffraction pattern of the grating?

Using transmission gratings with different grating constants, investigate the relationship between the grating constant *g* and the distance *d* of the interference fringes.

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	Colour filter set, additive (red, blue, green)	09807-00	red filter
7	Lens on slide mount, f=+50mm	09820-01	1
8	Lens on slide mount, f=+300mm	09820-04	2
9	Slide mount for optical bench	09822-00	2
10	Screen, white, 150x150mm	09826-00	1
11	Mount with scale on slide mount	09823-00	1
12	Diaphragm holder, attachable	11604-09	1
13	Measuring magnifier	09831-00	1
14	Diffraction grating, 4 lines/mm	08532-00	1
15	Diffraction grating, 8 lines/mm	08534-00	1
16	Diffraction grating,10 lines/mm	08540-00	1
17	Grating, 80 lines/mm	09827-00	1
18	Slit, adjustable.up to 1 mm	11604-07	1
19	Plate mount f.3 objects	09830-00	2
20	Measuring tape, l = 2 m	09936-00	1
-	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
	Ruler (approx. 30 cm)		1

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

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

Fig. 7

- Attach the diaphragm holder with adjustable slit (light aperture) to the mount with scale (Fig. 8 - 10) and position the mount at 9.5 cm (Fig. 11).


Fig. 8


Fig. 9


Fig. 10

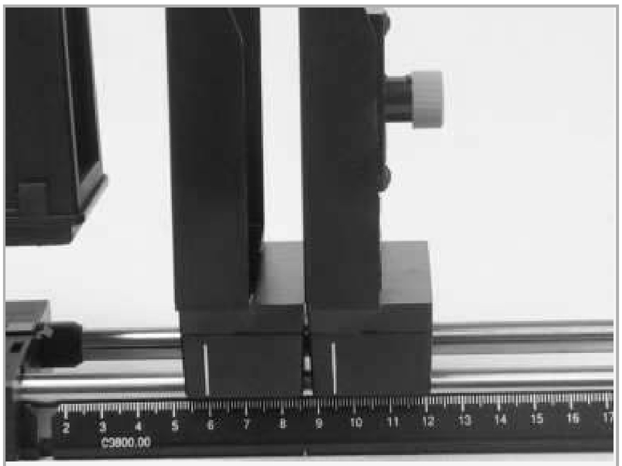


Fig. 11

- Position one lens with *f* = +300 mm at approx. 40 cm and the other one at the very end of the optic bench (Fig. 12).
- Position a plate mount on slide mount in between these two lenses (Fig. 13).


Fig. 12

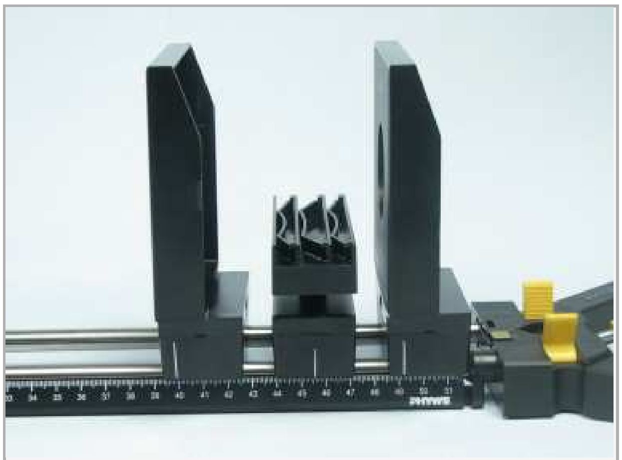


Fig. 13

Procedure

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

Fig. 14

- Position the other slide mount with plate mount and observation lens on the table approx. 30 cm away from the optic bench (Fig. 15).
- Slide the observation lens along the optical axis until the light aperture is sharply focussed in the observation lens.

Fig. 15

- Attach the grating with 4 lines/mm (g = 0.25) to the plate mount (Fig. 16).

Fig. 16

- Adjust the arrangement: light aperture parallel to the grating lines; optimum width of light aperture to ensure that interference patterns are both sharply focussed and bright enough.
- Examine the diffraction pattern.
- Insert the red filter into the well of the light box (Fig. 17) and measure the gap d between the interference fringes. Do this by measuring the distance d_n of the n^{th} fringe from the middle and divide by n. Enter your result in table 1 in the report.

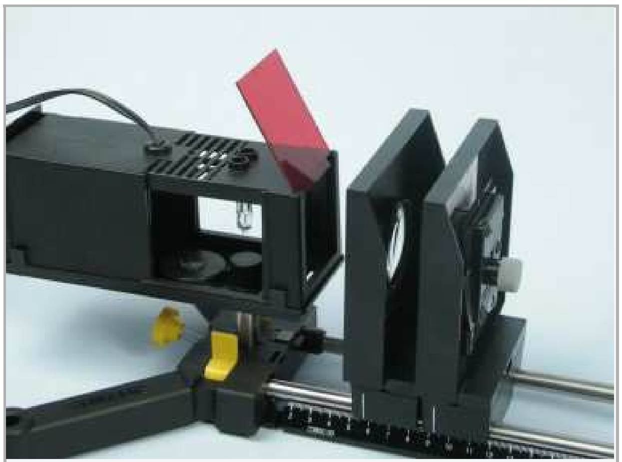


Fig. 17

- Leaving the general setup unchanged, remove the red filter and now replace the grating with 4 lines/mm by the grating with 8 lines/mm (g = 0.125 mm).
- Regard the interference patterns.
- Reinsert the red filter and measure d. Enter your results in table in the report.
- Proceed the same way with the 10 line/mm grating.
- Finally insert the grating with 80 lines/mm; in this case use the screen instead of the observation lens (Fig. 18) and measure d with a ruler.

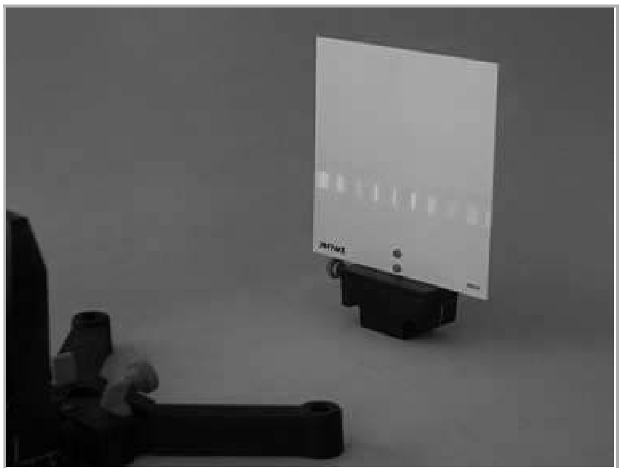


Fig. 18

- Switch off the power supply.
- Measure the distance e of the observation plane from the middle of the right-hand lens and note your result above table 1 in the report
- Describe the interference pattern for white light and how it changes with each grating. Write down your description in the report.

Report: Diffraction at a grating

Result – Observations 1

Determine the value:

$e =$ .... cm

Result – Table 1

1. Record in the measured values in table.
2. Calculate the arithmetic product of g and d and enter the values in the table.
3. Calculate the wavelength λ of the red light transmitted by the red filter used, using the formula $\lambda = g \times (d/e)$. Enter your calculated values in the last column of Table

Lines / mm	g in mm	d in mm	$g \times d$ in mm^2	λ in nm
4	0,25	1 ±0	1 ±0	1 ±0
8	0,125	1 ±0	1 ±0	1 ±0
10	0,1	1 ±0	1 ±0	1 ±0
80	0,0125	1 ±0	1 ±0	1 ±0

Result – Observations 2

Describe the interference patterns:

....

....

....

....

Evaluation – Question 1

What correlation exists between the distance *d* of the diffraction fringes and the grating constants *g* ?
(*Hint*: Find the product of *g* and *d* and enter the results in the 4th column of Table 1.)

Evaluation – Question 2

Fig. 19 shows how the nth interference fringe (brightness peak of the nth order) arises when light is diffracted at a grating.
From this figure one can also derive the equation for calculating the wavelength λ of the light used:

$\lambda = g \times (d_n/(n \times e))$ or $\lambda = g \times (d/e)$ for the interference fringe of 1st order.

Derive this equation and remember that for small angles α is valid: $\sin(\alpha) = \tan(\alpha)$.

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