Optics

Wave optics

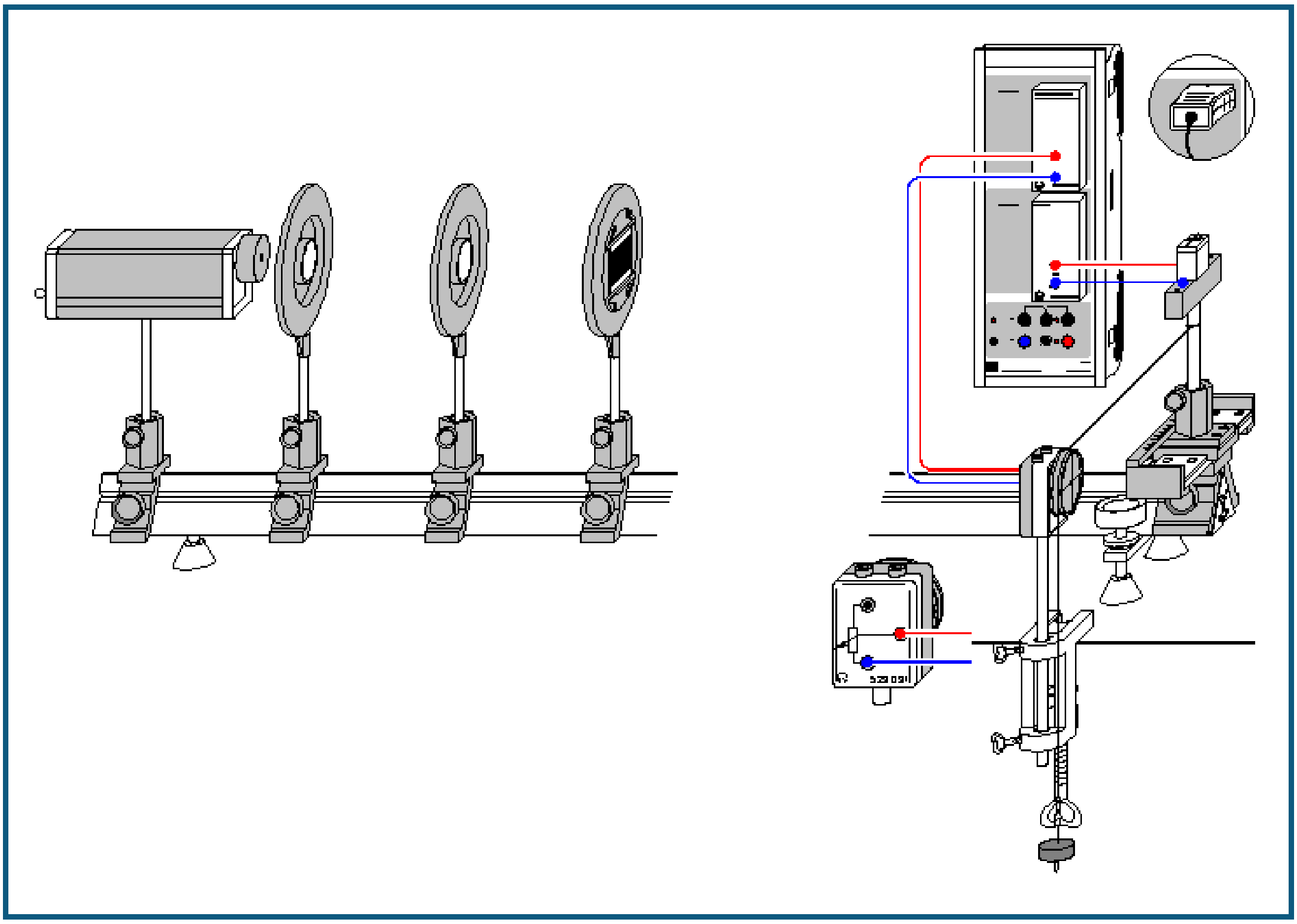
Diffraction

Diffraction at a double slit and multiple slits - Recording and evaluating with CASSY

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Diffraction at multiple slits



can also be carried out with Pocket-CASSY

Be careful when experimenting with the He-Ne laser

The He-Ne laser meets the requirements according to class 2 of EN 60825-1 "Safety of laser equipment". If the corresponding notes of the instruction sheet are observed, experimenting with the He-Ne laser is safe.

Never look into the direct or reflected laser beam.

No observer must feel dazzled.

Experiment description

Diffraction phenomena always occur when the free propagation of light is changed by obstacles such as iris diaphragms or slits. The deviation from the rectilinear propagation of light observed in this case is called diffraction.

The voltage of a photocell is measured as a function of the diffraction angle. It is observed that the diffraction pattern moves more and more into the geometrical shadow area as the slit width decreases. The measuring values recorded are compared with the prediction of a model calculation for the diffraction intensity $U \propto (\sin(\pi b/\lambda \cdot \alpha)/(\pi b/\lambda \cdot \alpha))^2 * (\sin(N\pi d/\lambda \cdot \alpha)/(\pi d/\lambda \cdot \alpha))^2$, where the slit width b, the slit spacing d, the number of slits N, and the wavelength λ enter as parameters. For small diffraction angles α, α is easily determined from the distance L between the diffraction object and the photocell and the path of displacement s of the photocell as $\alpha \approx \tan \alpha = s/L$.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	µV box	524 040
1	Current source box	524 031
	with Displacement transducer and	529 031

	Pair of cables, 100 cm, red and blue	501 46
	or	
1	Rotary motion sensor S	524 082
1	He-Ne laser, linearly polarized	471 840
1	Precision optical bench, 2 m	460 33
4	Riders, H=90 mm/B=60 mm	460 374
1	Sliding rider	460 383
1	Lens in frame, f = +5 mm	460 01
1	Lens in frame, f = +50 mm	460 02
1	Diaphragm with 3 double slits	469 84
1	Diaphragm with 4 double slits	469 85
1	Diaphragm with 5 multiple slits	469 86
1	Holder with spring clips	460 22
1	Photocell STE 2/19	578 62
1	Holder for plug-in elements	460 21
1	Bench clamp, simple	301 07
1	Fishing line, 10 m	from 309 48ET2
1	Set of 12 weights, each 50 g	342 61
1	Pair of cables, 100 cm, red and blue	501 46
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

Remark: the adjustment should be carried out in a slightly darkened room.

- Using a rider, mount the He-Ne laser to the optical bench as shown in the drawing.
- Set up the photocell at a distance of approx. 1.90 m from the laser by means of the sliding rider and the holder for plug-in elements. The photocell should be located in the middle of the sliding rider. Stick two strips of dark paper on the photocell so that an entrance slit of approx. 1 mm is left.
- Direct the laser towards the photocell, and switch it on.
- Adjust the height of the laser so that the laser beam impinges on the center of the photocell.
- Place the spherical lens with the focal length f = +5 mm in front of the laser at a distance of approx. 1 cm. The laser beam has to cover the photocell.
- Position the converging lens with the focal length f = +50 mm in front of the spherical lens at a distance of approx. 55 mm and displace it on the optical bench towards the spherical lens until the laser beam is sharply imaged on the photocell.
- Displace the converging lens on the optical bench somewhat further towards the spherical lens until the diameter of the laser beam on the photocell is approx. 6 mm. Now the laser beam should have a circular profile of constant diameter along the optical axis.
- Put the holder with spring clips on the optical bench with the diaphragm being clamped, and displace it until the distance L between the photocell and the slit diaphragm is 1.50 m.
- Fix the bench clamp with the displacement sensor to the table as shown in the drawing.
- The path of displacement s_{A1} perpendicular to the optical axis is measured via the displacement sensor at the current supply box on input A of the Sensor-CASSY.
- In order to measure the voltage, the photocell is connected to input B of the Sensor-CASSY via the µV-box.

Carrying out the experiment

- Load settings
- Set the photocell to the position -6.0 cm opposite the displacement sensor.
- Turn the wheel of the displacement sensor to the stop so that the display of the path s_{A1} is approximately -6.0 cm. If it turns out that the path measurement will lead to a wrong sign, connect the current supply box to the other arm of the displacement sensor.
- Tie a piece of fishing line to the holder for plug-in elements, wind it once around the wheel of the displacement sensor, and suspend a weight from it.
- Calibrate the zero of the path – for this place the photocell in the middle of the sliding rider (= zero of the scale or of the position of the principal intensity maxima, respectively).
- Enter the **target value** 0 cm in Settings sA1 **Correct**, and then select **Correct Offset**.
- Slide the photocell back to the position opposite the displacement sensor, and keep it there.
- If necessary, **Correct** the background brightness in the Settings UB1. For this enter the **target value** 0 mV, and then select **Correct Offset**.
- Start the measurement with ⏱ (the message **No Trigger Signal** appears).

- Displace the photocell very slowly by hand towards the displacement sensor. As soon as you pass the starting point at -5.5 cm, recording of measured values begins.
- Stop the measurement with ⏱.

Evaluation

The intensity distribution of the diffraction pattern appears already during the measurement. The measured intensity distribution can now be compared with the result of the model calculation for small diffraction angles $\alpha \approx \tan \alpha = s_{A1}/L$ by performing a Free fit. Use the following formula:

A*(sin(180*B/0.633*(x-C)/150)/(180*B/0.633*(x-C)/150))^2 *
(sin(2*180*D/0.633*(x-C)/150)/sin(180*D/0.633*(x-C)/150))^2

with

x: displacement s_{A1} perpendicular to the optical axis
A: intensity I_0
B: slit width b in µm
C: correction of the position of the principal maximum
D: slit spacing d in µm
N: number of slits (here double slit: N = 2)
L: distance between the diaphragm and the photocell (here: L = 150 cm)
λ: wavelength of the He-Ne laser (here: λ = 0.633 µm)

In this fit, the wavelength λ = 0.633 µm of the He-Ne laser has been assumed to be known and the slit width b and the slit spacing d have been determined. The other way round, the wavelength λ of the laser can be determined if the slit width b and the slit spacing d are known.

For the Free fit, always reasonable starting values for the slit width and the slit spacing should be chosen, e.g., B=200 (µm) for b=0.2 mm and D=250 (µm) for d=0.25 mm.

If the secondary maxima are not clearly seen for N > 2, the slit spacing d cannot be determined by the Free fit. In this case, the correct slit spacing d should be entered in µm as a starting value for the fit and then be kept constant (e.g. 250 for 0.25 mm).

Remark

In this experiment on diffraction of light at multiple slits, the intensity distribution is recorded manually. The measuring values can be recorded automatically with the aid of VideoCom (experiment P5.3.1.7).