Diffraction and Interference

Preparations

Read the textbook chapters 16.4 and 16.6, 35.2 and 35.3, and 36.1 through 36.5. Then solve the following problems and read through the entire instruction. Proper solutions are to be handed in before you start your lab.

1. At http://www.walter-fendt.de/html5/phen/singleslit_en.htm you will find an applet simulating light passing through a single slit. You can vary the wavelength of the light λ and the slit-width a.

a) Choose the largest wavelength and a slit-width that is half of the largest possible. At which angles do the light intensity become zero? Note that you can study both the diffraction pattern and the intensity profile, as well as change all parameters either via sliders or by entering values manually.

b) Select wavelength λ = 550 nm. How big should the slit-width a be, if the central maximum is to range from -45 ° to + 45 °?

c) Describe and explain what happens when you let the slit-width a approach zero (at λ = 550 nm).

2. The light from a mercury lamp passes a filter where all wavelengths except 546.1 nm are absorbed. The light passing the filter is made parallel using a lens and then sent through a single slit. The diffraction pattern is studied on a screen 7.00 m from the slit, see figure 1. Use the intensity profile to determine the width a of the slit as accurately as possible.

Answer: a = 22,6 µm (±0,5 µm depending on how you measure)

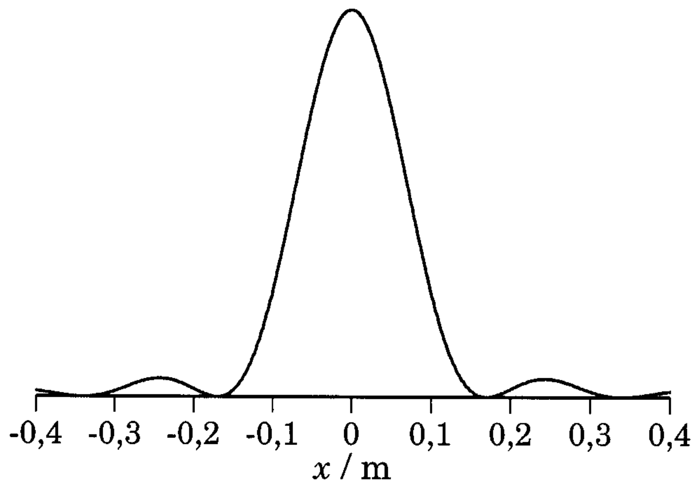


Figure 1. Light intensity distribution on a screen after diffraction in a slit.

3. Parallel light from a red He-Ne-laser (λ = 632.8 nm) is incident on a number of slits. All slits are of the same width and at the same distance apart. The intensity distribution on a screen 10.0 m away is shown in Figure 2.

a) How many slits are illuminated?

b) How big is the slit separation d?

c) What happens to the intensity distribution if one of the outer slits is covered? Sketch a figure similar to that below.

d) How much lower will the intensity of the central peak (of **c**)) be compared to the figure below?

Answer: b) 50 µm, d) The intensity is reduced by 36 %.

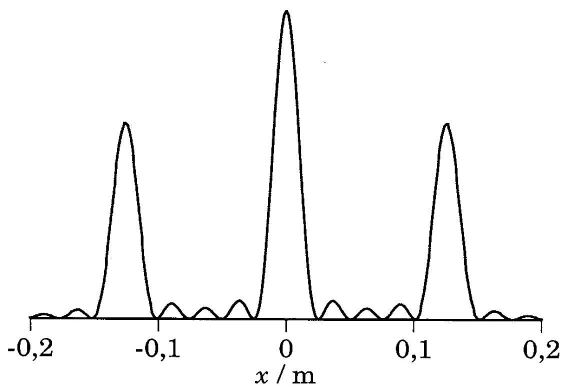


Figure 2 Intensity distribution when light from multiple slits interfere. Each slit also gives rise to a diffraction pattern, as shown in the figure.

During this lab-exercise you will study diffraction and interference phenomena of light, sound and microwaves. These phenomena all belong to what we call wave-optics. Here the explanation model for light is built on wave-properties, unlike geometrical optics where wave properties are neglected.

1 Examination of micrometer-size distances using a He-Ne laser

When small objects are illuminated with a laser, their size can be determined by studying the diffraction and interference patterns. In this experiment you use a He-Ne laser with a very well defined wavelength.

a) Illuminate a variable slit. Study the diffraction pattern on a screen a few meters away. Describe and explain what you see.

b) Determine the width a of a fixed slit. Then use the same method to determine the diameter of a hair. Describe the diffraction patterns in both cases. Can you explain why the slit and hair create a similar pattern of diffraction?

c) Determine the slit-distance d of a double slit by studying the interference-pattern.

Be sure to measure thoroughly! Make as much use of the screen as possible, and measure from min to min or max to max on each side of the central maximum.

2 Determination of the wavelength of a diode laser

Use the light from a He-Ne laser (with a well-known wavelength) to determine the number of lines per millimeter of an unknown grating.

Then use this grating to determine the unknown wavelength of a diode laser.

3 Examination of micrometer-size distances using a sodium-lamp and a spectrometer

Use one of the spectrometers and illuminate the collimator slit with the sodium-lamp. Place the fixed slit you used in experiment 1 on the spectrometer table so that the light hits the slit at an angle of 90°. Make sure the collimator slit is relatively small. Describe what you see and determine the slit-width of your fixed slit by determining the angles for which you have light minima. How to read the scales is described in the lab instruction for Geometric Optics. Compare your result to experiment 1.

Measure the slit width using a microscope and a micrometer scale. Do your measurements agree?

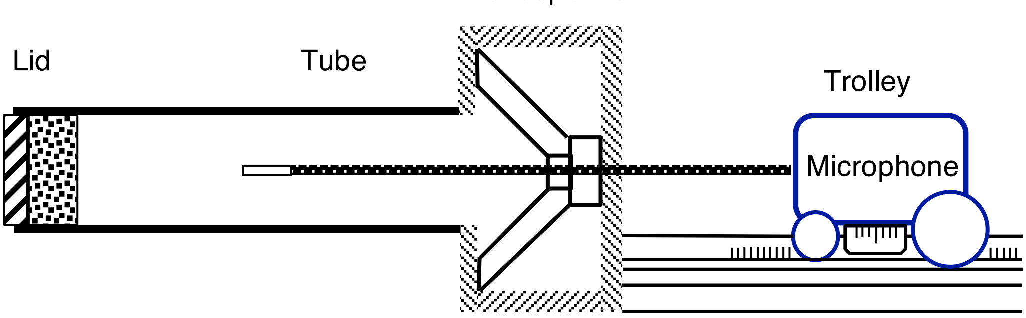
Examine the diffraction patterns created when different slit-systems are illuminated. For each slit-system, change the size of the collimator slit to make the diffraction pattern sharp. Describe what you see and try to qualitatively illustrate how the light intensity varies for the different slit-systems. Particularly note the number of secondary maxima.

4 Determination of the speed of sound by use of Kundt's tube

We will now take a closer look at the standing wave created when two oppositely directed sound waves interfere. A loudspeaker creates the sound wave, and directs it into a tube called Kundt's tube, see Figure 3 below. The sound wave propagates in the tube and is reflected at the end of the tube. The lid at the end can be removed so that it is possible to study the sound wave's reflection against both the lid and air.

The microphone, which is mounted in the "trolley", records sound pressure, which is converted into a voltage read on a voltmeter.

Adjust the speaker frequency to a resonance frequency between 400 Hz and 800 Hz. Carefully measure the sound pressure along the tube. Then plot the sound intensity, i.e. the reading of the voltmeter, as a function of the microphone's position and determine the speed of sound.



Figur 3. Experimental setup for measuring the speed of sound using Kundt's tube.

5 Phase difference between sound waves

By studying phase differences between the signal put into a loudspeaker and the signal recorded by a microphone at different distances from the speaker, one can determine the speed of sound.

Put a 3.0 kHz signal from the frequency generator on to the x-channel of an oscilloscope. The oscilloscope should show a sinusoidal function. Then connect the frequency generator to the amplifier and on to the speaker. The microphone registers the sound from the speaker, and the signal from the microphone should enter the y-channel of the oscilloscope. The oscilloscope image shows the sum of the two sine functions;

$x = A_x \sin \omega t$ and $y = A_y \sin(\omega t + \phi)$ where A_x and A_y are the amplitudes of the signals.

Convince yourself that the sum will be a straight line on the screen when $\phi = 0$ ° or 180 °. What does the sum look like when $\phi = 90$ °?

Slowly move the microphone from a position near the speaker and away. Record the microphone position each time the shape becomes a straight line - try to find 10 such positions. Use this to calculate the speed of sound.

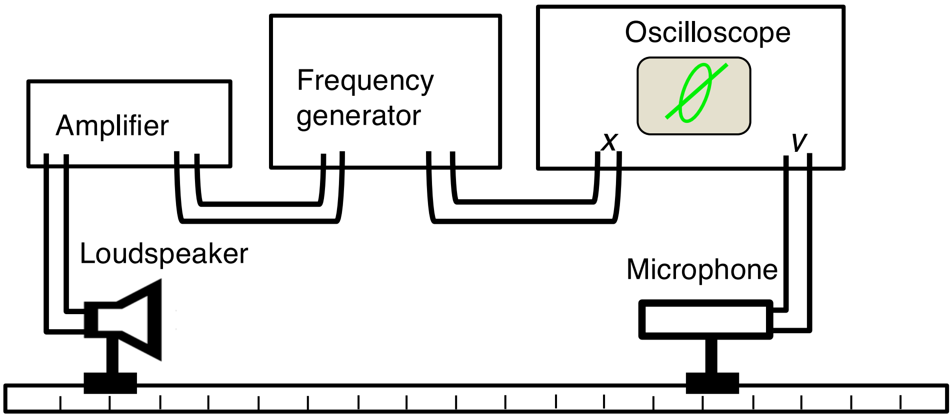


Figure 4. Experimental setup for measuring the speed of sound using phase differences.

6 Determination of the frequency of microwaves

Electromagnetic radiation within the range of 300 MHz to 300 GHz is called microwaves. We use a so-called Gunn oscillator to generate microwaves.

Set the voltage for the microwave transmitter to the value specified on the transmitter. Connect the receiver to the x-channel of an oscilloscope. The experimental setup is shown in Figure 5.

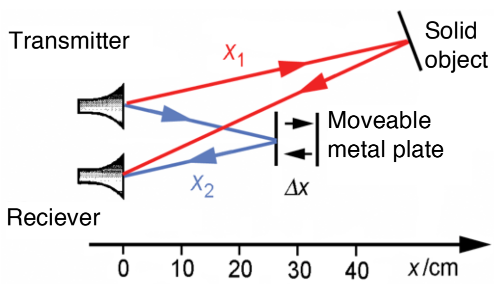


Figure 5. Experimental setup for measuring the microwave frequency.

We always detect two waves with the receiver. One wave reflected by the metal plate and one wave reflected somewhere against a solid object (e.g. walls) in the room. Consider what happens to the sum of the two waves when the metal plate is moved along the ruler, and use this to determine the wavelength and frequency of the microwaves.