Contents

1. Tasks

- In the first experiment the lattice constant of a sine grid is to be measured.
- Then the lattice constant and the resolutions of five grids with different lattice constants shall be determined.
- For the first of these we then shall calculate the aperture function with the measured intensities of the interference maxima and a period of the aperture function shall be drawn.
- Then the property between the width of the slit and the lattice constant shall be derived.
- Finally the intensity distribution of a ultrasound wave grid shall be measured depending on the voltage of the the quartz moves with. These results shall be compared tho the Raman-Nath-theory and the sound wavelength in iso-octan is to be determined.

2. Theoretical basics

2.1. Sound and Ultrasound

Sound waves are transverse waves. This means, that they need a medium in which they can oscillate, but they don't transport any mater. This means, that the transportation of information happens by changes of density distributions. The sound frequency we can hear is between 16 Hz and 20 kHz (for a child) [Ger, p.194]. The sound with a higher frequency (until 10 GHz) is called ultrasound. This gets used by ships, dolphins and bats for the detection of obstacles or in medicine as a noninvasive imaging process. Another application is to clean for example glasses in a water bath that gets put in to motion by ultrasound. With its help we will create a phase lattice in our experiment.

2.2. Diffraction

Diffraction describes the phenomena, that light can also change its direction if there is neither a cause for reflection or for refraction. But what is needed for this is some kind of slid, double slid or lattice. There are two possible setups in order to gain diffraction: the Fresnel and the Fraunhofer setup. For the first one the light and the lattice are close enough, so that the bending of the wave front has to be taken into account. The Fraunhofer setup is the one we are going to use in our experiment. In this the source of the light is far enough away from the lattice, so that there is a parallel light bundle. We are going to achieve this with lenses. The two main conditions for diffraction are, that the slid is much broader than the wavelength and that the projection of the diffraction mustn't be looked at (i.e. measured) near the lattice [Lef]. There are two descriptions of the diffraction: the Bragg- and the Raman-Nath-diffraction.

2.2.1. Bragg-diffraction

Here the condition in order to get interference maxima is, that the difference in the way of two waves has to be an integer multiplication of the wave length. A schematic picture of the Bragg-diffraction is shown in figure 1.

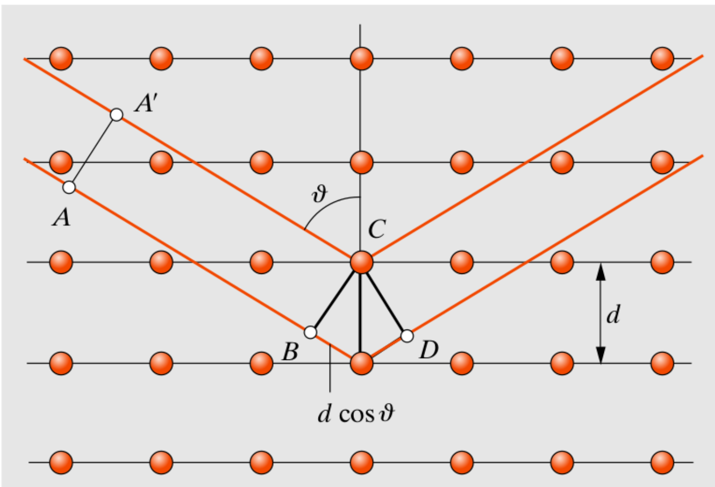

Figure 1: Illustration of Braggs-law
[Ger, p.830]

Mathematically this is described by the formula

$$k\lambda = 2d\sin(\Theta) \qquad (k = 1,2,3,...)[\text{Ger}, p.8.30].$$

With this theory it is possible to explain the amplitude of the first order intensity maximum of the interaction between light and a sound wave. In order to get just one maximum, the sound beam has to be rather wide, the frequency and the amplitude must be short. This gives for the Bragg-relation

$$k\lambda = 2\Lambda \sin(\Theta).$$

For different, but similar conditions there is diffraction into higher intensities, that can't be explained by this, but the Raman-Nath-theory is able to predict and describe them.

2.2.2. Raman-Nath-theory

The development of the Raman-Nath-theory was necessary, because in 1932 the scientists Debye & Sears and Lucas & Biquard independently found, that there are higher orders at the diffraction of light with artificially generated elastic waves [Pie]. The angle Θ at which there are maxima of the m$^{\text{th}}$-order of intensity is

$$\sin(\Theta) = \pm m \frac{\lambda}{\Lambda} \text{ [Koe].}$$

λ is the wavelength of the light and Λ the wavelength of the sound waves. This geometry can be seen in figure 2.

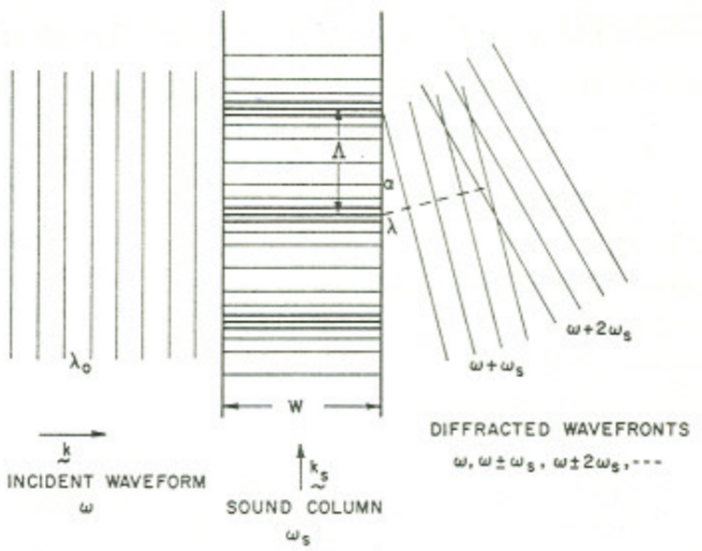

Figure 2: Schematic drawing of the Raman-Nath-diffraction [Pie].

Furthermore this theory describes the intensity of the m$^{\text{th}}$-order with a Bessel function

$$I_m = J_m^2(\Delta n D \cdot 2\pi/\lambda) = J_m^2(\alpha U) \text{ [Koe].}$$

2.3. Amplitude lattice

In an amplitude lattice the index of refraction is for all slits the same. Just the amplitude of the diffracted waves gets periodically modulated. There is no phase shift. Their lattice constant K, that describes the property between the angle Θ of the direction of diffraction and the order of diffraction m, gets calculated with

$$K = \frac{m\lambda}{\sin(\Theta)} \text{ [Koe,} p.3]$$

Examples for amplitude lattices are stroke lattices, where the transmission is the same for all slits, and sine lattices, where the transmission between the slits is harmonic periodic.

2.4. Phase lattice

In this kind of lattice the transmission intensity always stays the same, but the index of refraction changes. The effect is, that there are phase shifts. In our experiment such a lattice is realised by sending a ultrasound wave through isooctan. The relation

$$\Delta n \propto \Delta \rho$$

describes, that the change of the index of refraction is proportional to the changes of the density. These changes of the density are periodic and get induced by the sound waves.

2.5. Resolution

The resolution is defined as the property between a wavelength λ and the wavelength distance $\Delta\lambda$ at which another wavelength can be seen at the diffraction. This can be rewritten, in order to depend on the number of grid lines that are shined through N and the number of maxima of the diffracting that can be seen m.

$$a = \frac{\lambda}{\Delta\lambda} = N \cdot m \text{ [Koe,} p\text{.4].}$$

2.6. Aperture function

The aperture function describes the geometry of the diaphragm plane. By taking its Fourier transformed and taking the square of the absolute value, as is described in [Koe], one gets the intensity distribution of the diffraction pattern

$$I = \left| \int_{aperture} g(\vec{k}) \cdot e^{i\vec{k}\cdot\vec{x}} d\vec{k} \right|^2 .$$

For a long single slid the aperture function is

$$g(x) = \begin{cases} 0 \text{ for } |x| > b/2 \\ 1 \text{ for } |x| \leq b/2. \end{cases}$$

From this the amplitude of the light wave function gets calculated as

$$\Phi(\Theta) \propto \int_{-b/2}^{b/2} e^{ikx\sin(\Theta)} dx = \frac{\sin(kb\sin(\Theta)/2}{kb\sin(\Theta)},$$

which is the square root of the measurable intensity distribution I.
As another example we look at the aperture function of a lattice with N lines

$$g(x) = \begin{cases} 1 \text{ for } j \cdot K \leq x \leq j \cdot K + b \text{ with } j = 0, ...N-1 \\ 0 \text{ else.} \end{cases}$$

This is a N-periodic rectangular function.
If one wants to calculate the aperture function from the Fourier transformation of the intensity distribution, it is useful to approximate the transformation with the Fourier series

$$g(x) = \sum_{j=0}^{\infty} \pm \sqrt{I_j} \cos\left(\frac{x}{K} 2\pi j\right), \tag{2.1}$$

with the amplitudes of the peaks I_j, and the lattice constant K. This gives for a sine lattice

$$g(x) = \sqrt{I_0} + \sqrt{I_1} \cdot \cos\left(\frac{x}{K} 2\pi\right),$$

with only maxima of the first order.

3. Setup

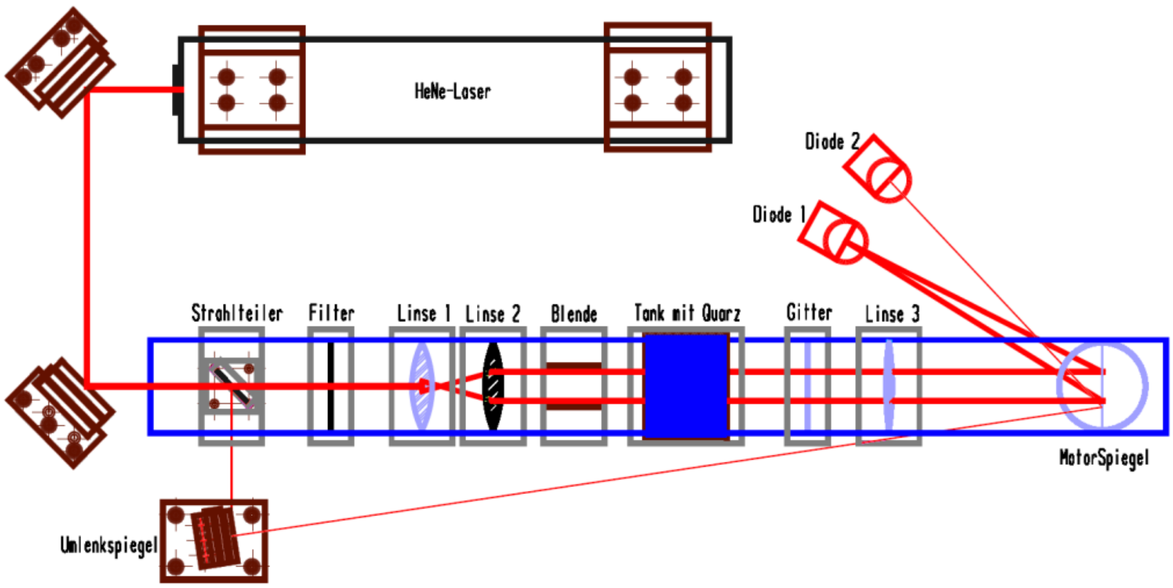

Figure 3: Setup of the experiment [Koe].

The setup is shown in figure 3. The light we use comes from a He-Ne-laser and has a wave length of 632.8 nm. The beam splitter separates a part of the light from the main beam. This separate light is used in order to trigger an oscilloscope. The main beam gets broadened up and made parallel again by two lenses ($f = 50$ mm and $f = 100$ mm). Behind them there is an aperture. This is followed by the grid respectively the isooctan which oscillates because of ultrasound waves. Finally there comes another lens ($f = 300$ mm), that projects the parallel light beam on a mirror, that gets rotated ($f = 12.5$ Hz) by a motor. From this mirror the light of the main light beam and the separated one hit two photo diodes, that give the signal to an oscillator. Furthermore there is a screen and a vernier caliper for adjusting the beam and measuring distances between diffraction maxima.

4. Procedure

In the first exercise the lattice constant of a sine lattice was to be calculated. For this we took all parts out of the optical path, except for the grid and the screen. Then we measured the distance between the maximum zeroth order and the maxima of the first order for different distances between the grid and the screen.
Then we put all the parts back into the optical path. This time we used five different grids and a reference grid for which we measured the intensities of the diffraction orders.
After the final grid had been used, we put the isooctan back in. Finally we measured the intensity distribution of the diffraction at the ultrasound wave grid, depending on the voltage, that drives the oscillation of the ultrasound oscillating crystal.

5. Data analysis

The evaluation of the measured data was done with Python. In the following some plots don't have error bars. That's due to the fact that they are either too small to be visible or they were intentionally omitted for the sake of clarity.

5.1. Sine lattice

The goal of the first exercise is to measure the lattice constant of a sine lattice. For this we measured the distances between the lattice and a screen on the left and on the right. For each chosen distance we then measured the distance between the 0^{th}-order and the 1^{st}-order maximum. Of these we took the mean. With the formulas

$$\tan(\theta) = \frac{x}{d}$$

and

$$K = \frac{n\lambda}{\sin(\theta)},$$

it is possible to calculate the lattice constant. The results are shown in table 1. The errors result from the reading off errors of the experimenters which were caused by the difficulty to place the vernier caliper on the right spots and read the values of.

d_l [cm]	d_r [cm]	$\overline{d}$ [cm]	x_l [cm]	x_r [cm]	$\overline{x}$ [cm]	θ [rad]
5.4 ± 0.1	5.6 ± 0.1	5.475 ± 0.005	4.8 ± 0.3	4.6 ± 0.3	4.73 ± 0.05	0.712 ± 0.005
4.6 ± 0.1	4.8 ± 0.1	4.690 ± 0.005	4.1 ± 0.3	3.9 ± 0.3	4.00 ± 0.05	0.706 ± 0.006
4.0 ± 0.1	4.1 ± 0.1	4.005 ± 0.005	3.4 ± 0.3	3.3 ± 0.3	3.32 ± 0.05	0.691 ± 0.007
3.4 ± 0.1	3.5 ± 0.1	3.450 ± 0.005	3.0 ± 0.3	2.7 ± 0.3	2.86 ± 0.05	0.691 ± 0.008
2.5 ± 0.1	2.6 ± 0.1	2.525 ± 0.005	2.3 ± 0.3	2.1 ± 0.3	2.23 ± 0.05	0.723 ± 0.010

Table 1: Values for lattice constant of a sine lattice.

By taking the mean of the angles ($\Theta = (0.705 \pm 0.003)\,\mathrm{rad}$) we get the lattice constant

$$K = (0.986 \pm 0.002)\,\mu\mathrm{m}.$$

5.2. Lattice constant for five optical grids

The data collected from the oscilloscope in form of .csv files, is in dimensions of divisions. Therefore each value needs to be multiplied with the adjusted value.
Because the x-axis of the oscilloscope is in seconds, we first need to find a conversion between time and distance. We do so, by measuring a reference lattice, for which we know the lattice constant. By plotting the time positions relative to the 0^{th} order maximum against the theoretical value for $\sin\theta = \lambda \cdot m/K_{ref}$ we assume, that we will get a linear relation. The errors on the time position come from the oscilloscopes own uncertainty of 3 % on the x-axis and the read-off errors by the experimenters, which we choose as $0.001\,\mu\mathrm{s}^{\dagger}$. The uncertainty from the oscilloscope is not significant enough compared to the read-off error and therefore gets omitted.

†More precisely it is the thickness of the lines, because we used Python to print us the positions of the maxima.

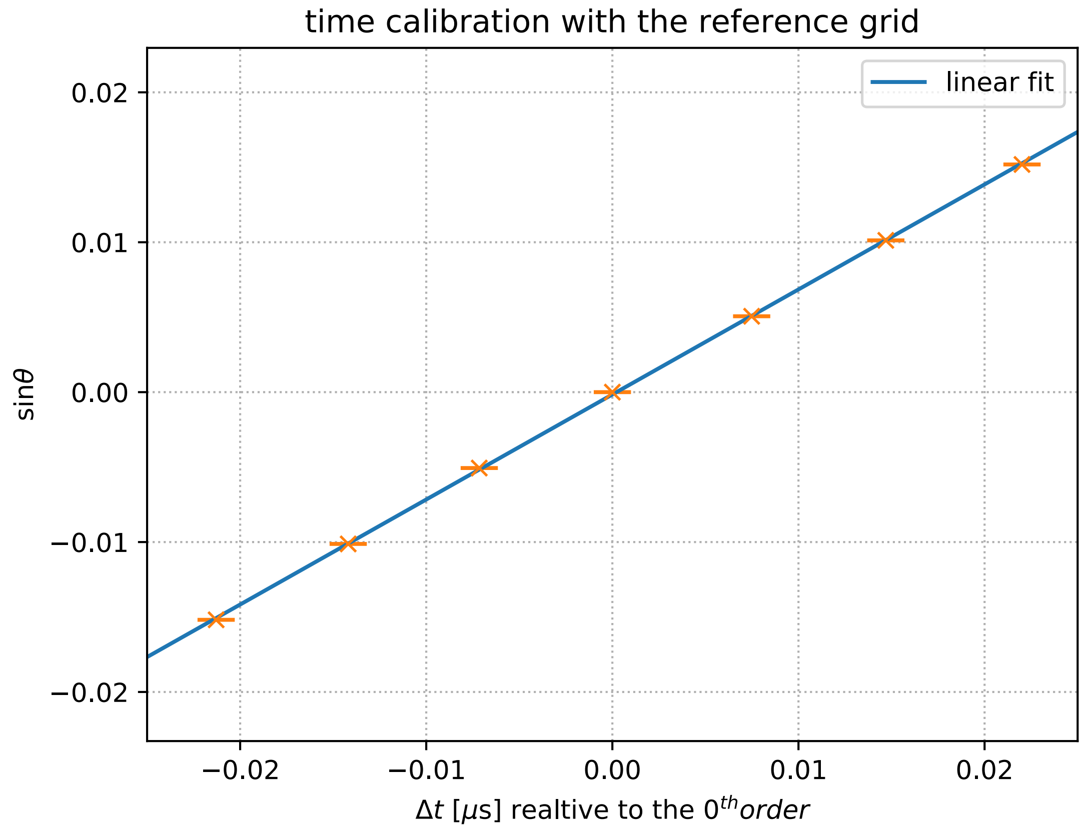

Figure 4: Time calibration from the reference lattice.

Looking at figure 4 we can see the linear correlation we expected. Fitting a function $ax+b$ we get the relation

$$\sin\theta = ax + b,$$

where x is actually t. We get

$$((0.701 \pm 0.003)\,\mu\mathrm{s}^{-1}) \cdot t + (-0.000\,16 \pm 0.000\,04) = \sin\theta. \tag{5.1}$$

With that time calibration we can start to calculate the lattice constants K for each lattice. For each lattice we will get a few different K's (one for each maxima). Those values are joined together to one for each lattice using the weighted average.
To get the lattice constants we use

$$K_i = \frac{m_i \lambda}{\sin\theta_i},$$

and

$$s_{K_i} = K_i \cdot \sqrt{\left(\frac{s_a}{a}\right)^2 + \left(\frac{s_b}{b}\right)^2 + \left(\frac{s_t}{t}\right)^2},$$

where s_a and s_b are the errors on the fitted function and are calculated via the square root of the diagonal elements of the covariance matrix.

For the lattices we get

$$K_{G_1} = (137.2 \pm 0.8)\,\mu\text{m}$$
$$K_{G_2} = (36.4 \pm 0.4)\,\mu\text{m}$$
$$K_{G_3} = (109.5 \pm 0.6)\,\mu\text{m}$$
$$K_{G_4} = (81.5 \pm 0.7)\,\mu\text{m}$$
$$K_{G_5} = (54.5 \pm 0.4)\,\mu\text{m}.$$

5.3. Aperturefunction for G1

To get the aperturfunction for the first lattice we use equation 2.1. We need the amplitude/intensities of each maxima. Here the error on the amplitude is the 3 % uncertainty from the oscilloscope, because it is more significant than the read-off error we choose.

$$I_0 = (1679 \pm 50)\,\text{mV}$$
$$I_1 = (97 \pm 3)\,\text{mV}$$
$$I_2 = (57 \pm 2)\,\text{mV}$$
$$I_3 = (33.2 \pm 1.0)\,\text{mV}$$

Here, the intensity for the left and the corresponding one on the right were averaged, except for the last one, because there was only a maximum at the right side.
Using those values the aperturefunction is plotted for 3 periods in figure 5.

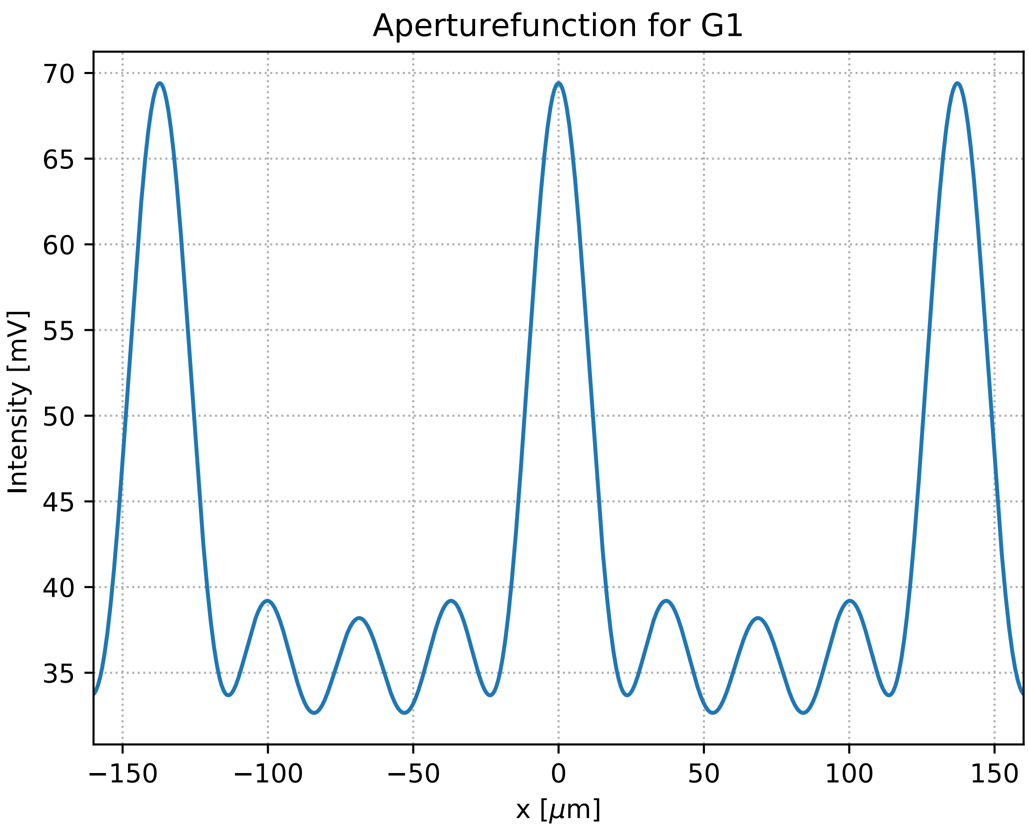

Figure 5: The calculated aperturefunction for the lattice G1 plotted in 3 periods.

5.4. Ratio of slit width and slit distance

We use the just calculated aperture function to calculate the slit width to slit distance ratio. To do so we need the slit width, which we can get from the full width at half maximum from our aperturefunction

$$FWHM = (22 \pm 1)\,\mu\text{m}.$$

With that and the lattice constant we can calculate the lattice distance

$$d = K_{G_1} - FWHM = (137.2 \pm 0.8)\,\mu\text{m} - (22 \pm 1)\,\mu\text{m} = (115.2 \pm 1.3)\,\mu\text{m}.$$

The error we calculate via Gaussian error propagation

$$s_d = \sqrt{\left(\frac{s_{K_{G_1}}}{K_{G_1}}\right)^2 + \left(\frac{s_{FWHM}}{FWHM}\right)^2}.$$

With that we can calculate the ratio with

$$p = \frac{FWHM}{d} \qquad \text{and} \qquad s_p = p\sqrt{\left(\frac{s_{FWHM}}{FWHM}\right)^2 + \left(\frac{s_d}{d}\right)^2}.$$

We get

$$p = 0.191 \pm 0.009.$$

5.5. Ratio of slit width and lattice constant

We also calculated the ratio of the slit width (FWHM) and the lattice constant (K). With Gaussian error propagation we get

$$q = \frac{FWHM}{K_{G_1}} = 0.160 \pm 0.007.$$

5.6. Resolving power

Now we want to calculate the resolving power of our lattices:

$$a = N \cdot m_i = \frac{d_{\text{Laser}}}{K_{G_i}} \cdot m_i,$$

and

$$s_a = a \cdot \sqrt{\left(\frac{s_{d_{\text{Laser}}}}{d_{\text{Laser}}}\right)^2 + \left(\frac{s_{K_{G_i}}}{K_{G_i}}\right)^2}.$$

We get

$$a_1 = 175 \pm 29$$
$$a_2 = 330 \pm 55$$
$$a_3 = 192 \pm 32$$
$$a_4 = 258 \pm 42$$
$$a_5 = 331 \pm 57.$$

5.7. Ultrasound wave lattice

In this experiment we changed the voltage which drives the ultrasound waves. The used voltages are shown in table 2 .

Measurement	Voltage [V]
1	10.09
2	9.14
3	8.26
4	7.92
5	7.38
6	6.49
7	5.59
8	4.08
9	3.33
10	2.35
11	1.33
12	0.00

Table 2: Voltage at which we measured.

The data for each measurement can be found in the appendix. Figure 6 shows them all together in one picture.

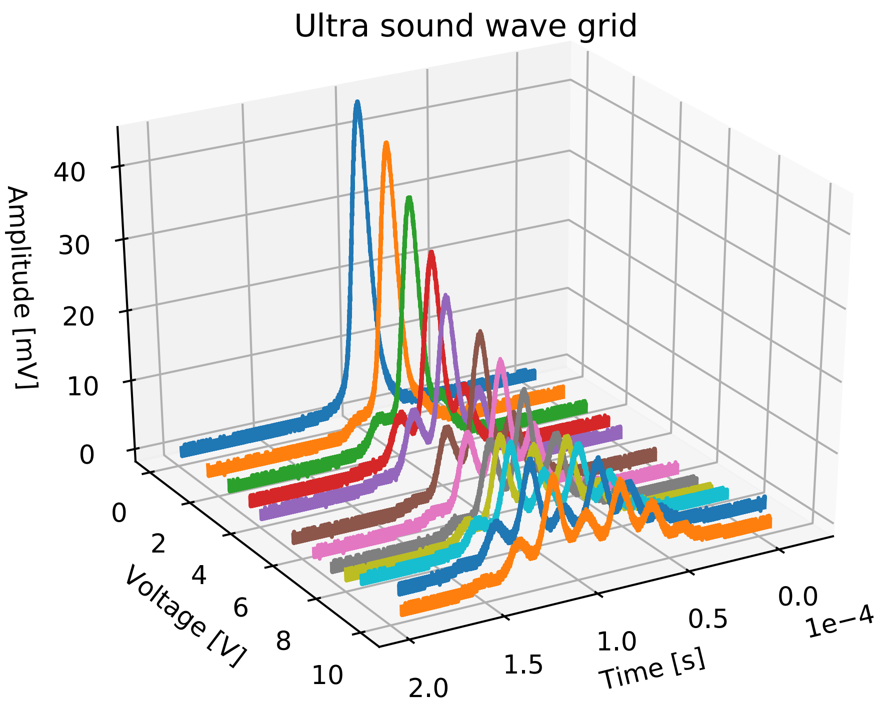

Figure 6: Measured data of the diffraction pictures for the phase lattice.

For a rotating animation gif of figure 6 follow the link https://gph.is/2xaXnD4.
It is now our task to compare these data with the Raman-Nath-Theory. For this we compare them to the Bessel-function

$$I_m = J_m^2(\alpha U).$$

The factor α gets calculated by taking the x-value of the first minimum of the Bessel-function and dividing it by the x-value of the first minimum of the data. The data itself gets middled, for each voltage and each order, with

$$I_m = \frac{I_l + I_r}{2I_0},$$

where I_l is the maximum on the left, and I_r on the right side. We calculate the error with

$$s_I = \sqrt{\left(\frac{\partial I}{\partial I_l}\right)^2 s_l^2 + \left(\frac{\partial I}{\partial I_r}\right)^2 s_r^2 + \left(\frac{\partial I}{\partial I_0}\right)^2 s_0^2} = \sqrt{\left(\frac{s_l}{2I_0}\right)^2 + \left(\frac{s_r}{2I_0}\right)^2 + \left(\frac{I s_0}{I_0}\right)^2}.$$

The errors s_r, s_l and s_0 we choose all as 0.6 mV. The error on the voltage is 0.01 mV. The plots for the different orders are in pictures 7 to 10. It can be seen, that the measured data follows a curve similar to the Bessel-function. But it also can be seen, that there are also quiet some differences, especially for higher voltages.

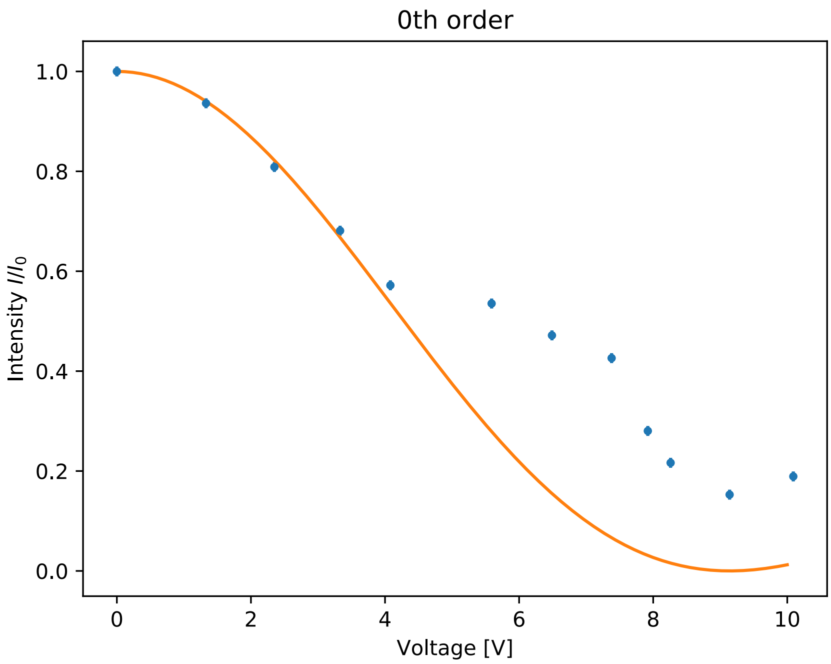

Figure 7: Bessel-function 0^{th}-order.

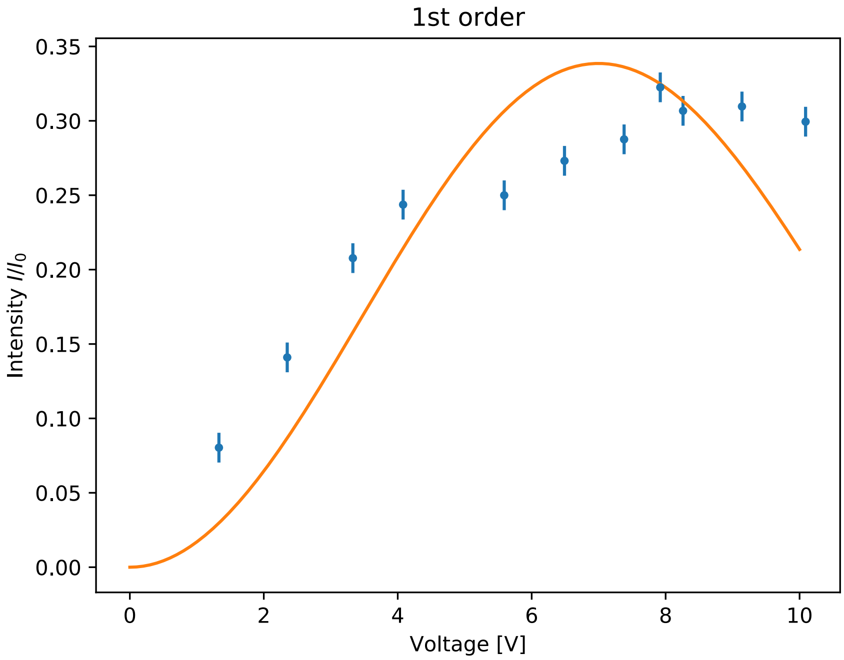

Figure 8: Bessel-function 1^{st}-order.

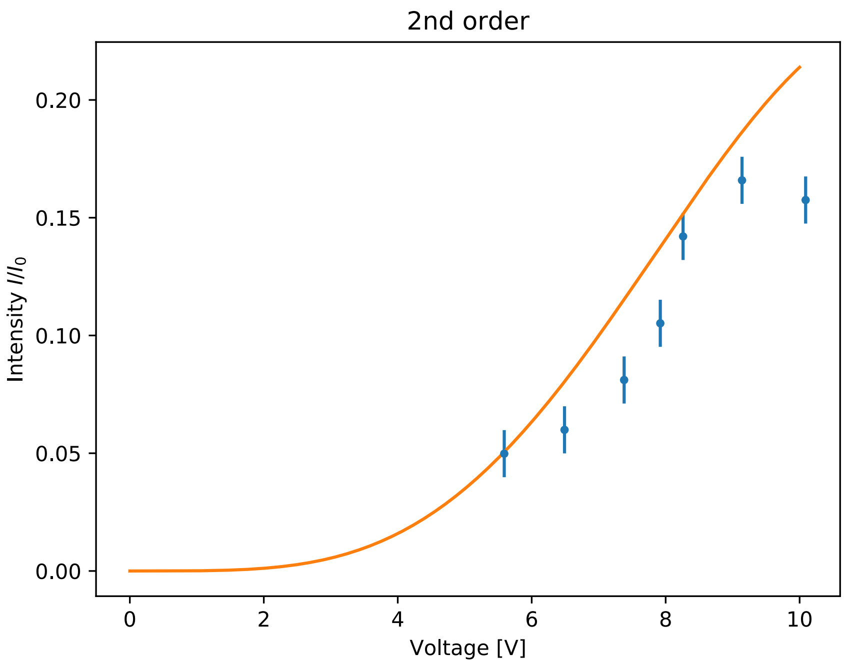

Figure 9: Bessel-function 2^{nd}-order.

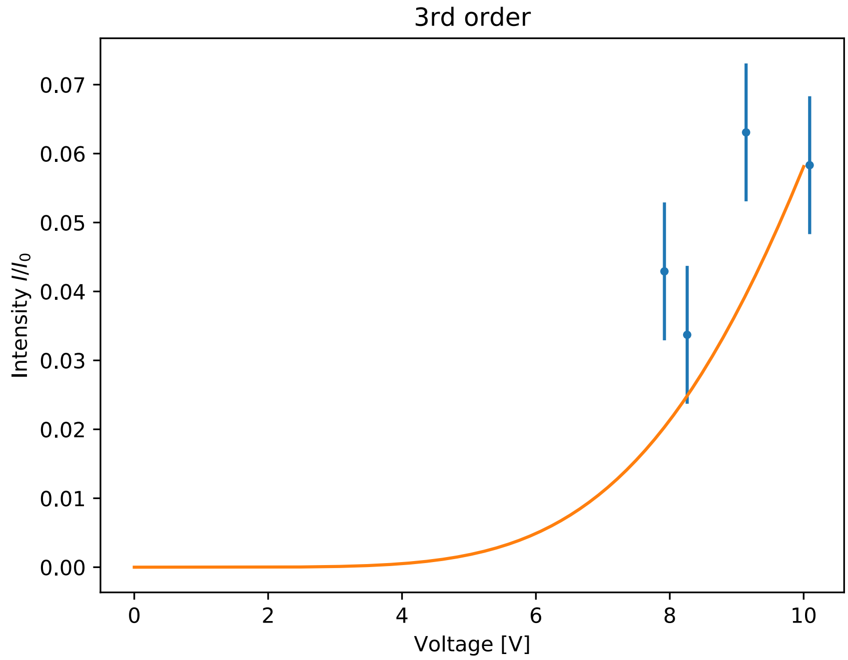

Figure 10: Bessel-function 3^{rd}-order.

The Raman-Nath-theory also allows to calculate the wavelength of sound in the medium. For this we measured the time position of the maxima of the first order.
With these times we then calculate the time differences between the maxima. After taking their average, we can use the formula

$$\Lambda = \pm m \frac{\lambda}{\sin(\Theta)} = \pm m \frac{\lambda}{a \Delta t}$$

Λ is here the wave length of sound in medium, λ that of the laser, a is the proportional coefficient from formula 5.1 and Δt the average time difference between the maxima. The error on the wavelength can be calculated with

$$s_\Lambda = \Lambda \sqrt{\left(\frac{s_a}{a}\right)^2 + \left(\frac{s_{\Delta t}}{\Delta t}\right)^2}$$

With these we get a value for the wavelength of

$$\Lambda = (0.501\,44 \pm 0.000\,02)\,\text{mm}.$$

We get the theoretical value from the speed of sound in isooctan ($v = 1111\,\frac{\text{m}}{\text{s}}$ [Lef]) by calculating

$$\Lambda_{theo} = \frac{v}{\nu}$$

where $\nu = 2265.9\,\text{kHz}$ is the average frequency we used for the sound waves. The error is calculated with Gaussian error propagation from the changes of the frequency. With this the theoretical value is

$$\Lambda_{theo} = (0.49 \pm 0.02)\,\text{mm}.$$

6. Summary and discussion

The goal of the first part was to measure the lattice constant for a sine lattice.
By measuring the positions of the maxima and the distance between the lattice and the screen we calculated

$$K = (0.986 \pm 0.002)\,\mu\text{m}.$$

With a relative error of about 0.2 % we conclude that is was a precise measurement.
In the second experiment we used five grids and tried to measure their lattice constant. We measured

$$\begin{aligned} K_{G_1} &= (137.2 \pm 0.8)\,\mu\text{m} \\ K_{G_2} &= (36.4 \pm 0.4)\,\mu\text{m} \\ K_{G_3} &= (109.5 \pm 0.6)\,\mu\text{m} \\ K_{G_4} &= (81.5 \pm 0.7)\,\mu\text{m} \\ K_{G_5} &= (54.5 \pm 0.4)\,\mu\text{m}. \end{aligned}$$

We can see, that their relative errors are all under 1 % except for K_{G_2} where it is 1.1 %. Since there are no values for the latices given, there is no comparison possible.

With the now calculated lattice constant for the first lattice, we calculated the aperture function and plotted it (see fig. 5).
With the help of that aperturefunction we now calculated the slit width to slit distance ratio, by using the full width at half maximum from our middle peak of our aperturefunction.
We got a ratio of

$$p = 0.191 \pm 0.009.$$

With the FWHM we also calculated the ratio of the slit width and the lattice constant. We calculated

$$q = \frac{FWHM}{K_{G_1}} = 0.160 \pm 0.007.$$

The next step was to calculate the resolving power of our lattices. We got

$$\begin{aligned} a_1 &= 175 \pm 29 \\ a_2 &= 330 \pm 55 \\ a_3 &= 192 \pm 32 \\ a_4 &= 258 \pm 42 \\ a_5 &= 331 \pm 57. \end{aligned}$$

We can see, that their relative error is around 16 %. Also there are now literature values so no comparison is possible. But the relatively high relative errors show, that the measurement wasn't really precise.

In the last part of the experiment we used isooctane and ultrasonic waves as a lattice. We measured at 12 different voltages, which results in 12 different intensity distributions of the ultrasonic sound waves. The captured diffraction images are plotted in figure 6.
We then compared the collected data to the Raman-Nath-Theory. To do so we fitted n^{th} Bessel-functions to the n^{th} order maxima from our diffraction images. The results can be seen in figures 7 to 10.

As we see, the fits do not fit well with the data. In figure 7 the first 5 data points do fit. With higher voltage the points seem to have the right curve progression, but with a systematic offset. We noticed, that the whole system was more prone to vibrations, caused by footsteps or the vibrations from the rotating mirror, when a higher voltage was applied. It showed this susceptibility in form of a more and more flickering image on the oscilloscope. Also with a higher voltage is was very hard for the oscilloscope to trigger on the signal. Only with great effort it was able to trigger on the signal and not always this worked well. For those values we should have assumed higher errors.
The first order plot shows an offset for the first 4 values, the next 3, and the last two, but all with different offsets. The last third and fourth points are where the theory predicts them to be.
The second order shows the points follow the curve progression but aren't at the expected levels. The third order plot is completely meaningless. We could only measure four maxima, and their positions are only in the general area, where we would have expected them, but with big error bars.

All in all with this data we can't proof the theory of Raman and Nath, but also we can't refute it, because of how bad the measurements are (including the construction of the experiment).

The theory also lets us calculate the wavelength of our sound waves. We calculated

$$\Lambda = (0.501\,44 \pm 0.000\,02)\,\mathrm{mm}.$$

Here we had also had a theoretical value for the wavelength. It it

$$\Lambda_{theo} = (0.49 \pm 0.02)\,\mathrm{mm}.$$

We can see, that we are 73 standard deviations away from the literature value if we consider the error from a calculated wavelength. If we consider the error from the literature value we are in a $1\,\sigma$ range, but the error on the literature value is propagated from our own chosen frequency error. The calculated wavelength has a relative error of 0.004 % and the 'literature' value has a relative error of 4.1 %. The error on the calculated wavelength is obviously way too small, considering the sensitive way of measuring and the bad compensation for any vibration.
We can say that our data followed the predictions from Raman and Nath but for a proper proof of their theory we would need to measure more precise and more often.

Generally the construction could be optimised by simply adding a plate that can be placed on top of the experiment to shield the diodes from extra light. This background can be seen in our plot for the aperture function (fig. 5), where the function itself has a big offset of $\approx 30\,\mathrm{mV}$. Also it would be better if the construction would be mounted to the wall, to reduce footstep vibrations. A bigger and heavier table should accomplish similar results.

A. List of Figures

B. List of Tables

C. References

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D. Appendix

D.1. Original data

Experiment Ultraschall 5.9.18

Aufg. 1: Sinusgitter

d: Abstand Gitter-Schirm [cm]
x: Abstand 0.-1. Ordnung [cm]

Messung	dl	dr	xl	xr
~~1~~	~~5,02~~	~~5,~~		
1	5,37	5,58	4,84	4,61
2	4,61	4,77	4,08	3,92
3	3,95	4,06	3,38	3,25
4	3,40	3,50	3,00	2,71
5	2,50	2,55	2,32	2,74

$s_d = 0,1$ cm
$s_x = 0,3$ cm

Aufg 2. Amplitudengitter

Strahldurchmesser: 0,44cm Fehler: 0,1cm

Gitter	maximale Beugungs~~ordnung~~
1	10
2	5
3	7
4	7
5	7

Aufg. 5 Ultraschallwellengitter

1. Messung

Frequenz [kHz]	Spannung [V]
2266,6	0,00
2266,5	2,28
2265,8	3,64
2265,0	4,09
2264,3	4,59
2264,2	5,00
2264,1	6,04
2263,9	6,56
2263,9	7,08
2264,6	7,50
2265,2	7,99
2265,5	8,59
2266,3	9,32
2266,8	9,96
2266,8	10,06

2. Messung

Frequenz [kHz]	Spannung [V]
2259,3	0,00
2260,9	1,78
2259,4	3,11
2258,3	3,34
2259,9	4,25
2258,9	4,71
2257,9	5,78

2260,4	0,00
2261,9	1,91
2261,8	2,81

2260,7	0,00
2261,9	1,54
2262,4	2,44
2261,5	2,96
2260,2	3,37
2260,4	3,81
2259,5	5,41
2258,8	5,89
2259,0	7,05
~~2260,6~~	~~8,15~~
2261,4	8,14
2262,0	9,11
2263,3	10,01

3. Messung

2265,9	10,02
2264,7	7,66
2264,3	6,93
2265,1	6,14
2265,8	5,50
2265,6	4,55
2266,4	3,88
2266,7	3,54
2267,1	3,03
2266,1	1,86
2265,5	0,00

peak von 1. Messung außerhalb von Bild

4. Messung

Frequenz [kHz]	Spannung [V]
2266,6	10,09
2265,8	9,14
2265,2	8,26
2264,8	7,92
2264,5	7,38
2264,9	6,49
2265,4	5,59
2266,1	4,08
2267,2	3,33
2266,8	2,35
2266,8	1,33
2266,4	0,00

Aufg. 2 Amplitudengitter

Messung 2

Strahldurchmesser: 0,3 cm   Fehler 0,05 cm

Gitter	Beugungsmaxima
R	7
1	8
2	4
3	7
4	7
5	6

Allgemeine Daten: Dioden-Vorverstärker: Messbereich 1 : 10

Amplitude Oszi: ± 3 %

Linsenreihenfolge: F = 50 mm, 100 mm, 300 mm

Simona Gargiulo