Contents

1 Physical Background

1.1 Diffraction

When a wave hits an obstacle, phenomena occur that cannot be explained by reflection or refraction. These phenomena are explained by diffraction. Diffraction is described by the Huygens-Principle which claims that a wave front is the summation of an infinite number of spherical waves. Using this consideration and some further geometric deliberations one can derive a equation for the position of diffraction maxima where light passes a grid with grid constant g. This equation is given by

$$\sin(\theta) = \frac{\lambda}{g}\, m \tag{1}$$

where the diffraction order m is any whole number and λ is the wave length of the light passing the grid.

1.2 Amplitude Grating

An amplitude grating is characterized by the feature that the transmission of a propagating wave is dependent to the position where the light passes through which leads to a modulation of the wave's amplitude. The refraction index however remains constant. Considering the Huygens-Principle the change of the Amplitude causes a wave front to split up in the spherical waves it consists of which leads to interferences. This kind of grid is characterized by the grid constant g, which describes the distance between the grid lines, and the width of a grid line.

1.3 Phase Grating

Different to the amplitude grating the phase grating does not change the amplitude rather the phase of a propagating wave. So instead of modulating the amplitude in dependency of the wave's position the phase gets modulated. So the transmissivity remains constant within the whole grating.

This experiment uses a vibrating quartz crystal to produce an ultrasonic wave in a liquid filled chamber. The sound wave causes density fluctuations which leads to fluctuations of the refraction index of that liquid. These refraction index fluctuations are described by

$$\frac{\Delta n}{n-1} = \frac{\Delta \rho}{\rho_0} \tag{2}$$

where Δn is the change of the refraction index and $\Delta \rho$ is the change of the density. The dependency described by eq. (2) implies that the refraction index is described by the same periodicity as the density distribution in the liquid

$$n(x) = n_0 + \Delta n \sin\left(\frac{2\pi x}{\Lambda}\right) \tag{3}$$

where Λ is the wavelength of the ultrasonic wave in the liquid. That results in an phase grating with an periodically changing refraction index orthogonal to the direction of propagation of the light. A theory for the observable intensity distribution using phase gratings is provided by the Raman-Nath-Theory.

1.4 Fraunhofer Diffraction & The Aperture Function

The Fraunhofer diffraction equation is used to describe the intensity distribution observed with experiments where the distance between the diffracting object and the screen is large. The Fraunhofer diffraction assumes that the intensity distribution is given by the Fourier transformed of the aperture function $g(x)$ which is the function describing the transmissivity of the grating in dependency of the position. So we assume

$$I(x) = \left| \int_\sigma g(\mathbf{k}) e^{i\mathbf{k}\cdot\mathbf{r}} \mathrm{d}\mathbf{k} \right|^2 \tag{4}$$

where σ represents the integration area which is the plane given by diffraction grating. The aperture function for an single slit for example would be

$$g(x) = \begin{cases} 1, & \text{for } |x| \leq a/2 \\ 0 & \text{else} \end{cases} \tag{5}$$

For an observed intensity distribution one can approximate the aperture function by the Fourier series

$$g(x) = \sum_{j=0}^{\infty} \pm\sqrt{I_j} \cos\left(\frac{2\pi}{g} xj\right) \tag{6}$$

where the coefficients are the square root of the measured intensity peaks of order j. Since during this experiment only a finite number of peaks are measurable the aperture function can only be approximated to a certain extend. For a sine grating we get

$$g(x) = \sqrt{I_0} + \sqrt{I_1} \cdot \cos\left(\frac{2\pi}{g} x\right) \tag{7}$$

therefore only maxima of first order are formed.

1.5 The Raman-Nath-Theory

The Raman-Nath-Theory uses the Fraunhofer-Equation of diffraction under consideration of the features of a phase grating as mentioned before. For the position of the observed maxima the Theory provides

$$\sin(\theta) = \frac{\lambda}{\Lambda} m \tag{8}$$

where m is any whole number and Λ the wavelength of the ultrasonic and λ the wavelength of the used light. For the intensity distribution the following relationship applies:

$$I_m = J_m^2 \left(\frac{2\pi D \Delta n}{\lambda}\right) = J_m^2(\alpha U). \tag{9}$$

Where m is the order of the maxima, J is the Bessel-Function, D is the thickness of the phase grating medium and U is the voltage applied to the supersonic producing element.

1.6 Angular Resolution

The angular resolution of a grating a is defined by

$$a = \frac{\lambda}{\Delta\lambda} \tag{10}$$

where λ is the wavelength of the light and $\Delta\lambda$ is the difference where two wavelength can be measured separately. It can be shown that for a grating the angular resolution can be calculated by

$$a = N \cdot m \tag{11}$$

where N is the number of illuminated grid lines and m is the number of observed maxima.

2 Setup and Implementation

2.1 Setup

The setup in this experiment is using a HeNe-Laser so laser safety glasses must be used. In the first part of the experiment only the laser, a grid and a screen is used. To study the diffraction behavior of amplitude and phase grids the setup shown in fig. 1 is used, where in the second part of the experiment,where amplitude grids are measured,the ultrasonic chamber is not in the beam path. In the third part a calibration measurement is done so the grid and the chamber are in the beam path, but in the rest of the measurement only the ultrasonic chamber is used. For the measurement of the intensity distribution a trigger signal is used, which is provided by the split beam which is the focused on diode 2.

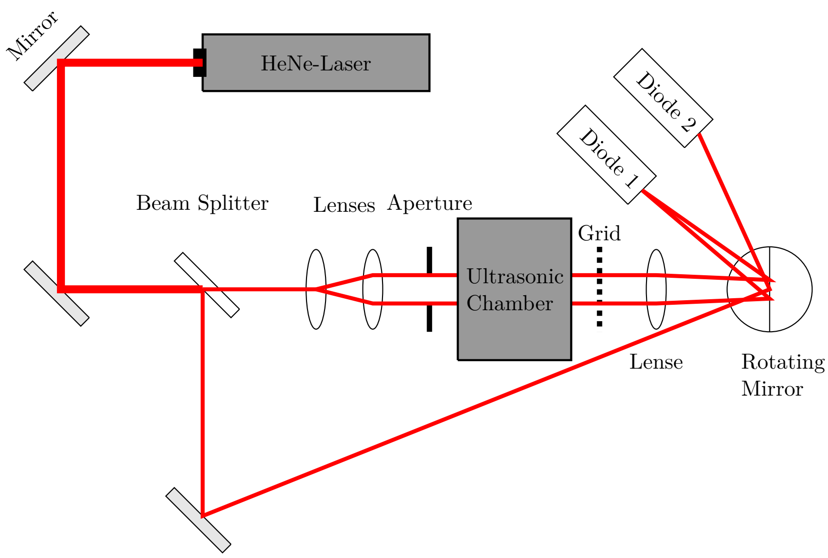


Figure 1: In this picture the schematic structure of the setup is displayed.

2.2 Implementation

2.3 Measurement of the Sine-Grid

In the first part of the experiment only the laser, a sine-grating and a screen are used. The screen has a millimeter scale so it is possible to determine the position of the diffraction maxima. Since the maxima where not on the same height of the scale both a x-position and a y-position where noted to later on calculate the distance between them properly.

2.4 Measurement of the Amplitude-Grids

Before starting with this measurement the optical path had to be adjusted. To do so the lenses where placed in a way that the laser beam is widened and collimated by the first two lenses. To ensure that the laser beam is collimated properly a piece of paper was used to see if the laser beam does not diverge or focus in the range of the optical path. After that the aperture was added to the setup to cut out scattered light. Finally the third lens was placed in a way that the light is focused on the diode. To ensure that the distance between diode and lens was measured and adjusted until it was one focal length. After the adjustment the beam width was measured behind the first two lenses using a screen with a millimeter scale on it. For the measurement of the amplitude-gratings five different gratings where given. So for every grating the intensity distribution was measured using the signal on the oscilloscope. Since the signal provided by the oscilloscope is dependent on time and not on the angle a reference grating with known grating constant was used, so the relation between the time axis on the oscilloscope to the measured angle can be calculated later on. For a later determination of the angular resolution the width of the widened laser beam was measured.

2.5 Measurement with the Ultrasonic Chamber

For the last part of the experiment another calibration is done, this time using the ultrasonic chamber with no voltage applied to it and the reference grating behind it. After that the grating is taken out of the optial path to start the main measurement. The frequency on the chamber was set to $\nu = (2096 \pm 1)\,\mathrm{kHz}$. Now for a voltage range from $0\,\mathrm{V}$ to $9.5\,\mathrm{V}$ a measurement was performed after every $0.5\,\mathrm{V}$-step. For a better determination of the peaks position often two measurements per step were done so one of the measurements where a zoomed in.

3 Analysis

3.1 Determining the Grating Constant of a Sine-Grating

In the first part of the experiment the interference of a laser proceeding a sine grating was measured. The maxima of zeroth and first oder were visible and the coordinates were measured. As the zeroth order maximum was not set in the origin on the screen also these coordinates were measured to $x_0 = 2.5\,\mathrm{mm}$ and $y_0 = -1\,\mathrm{mm}$. To determine the distance between the maxima

$$r = \sqrt{(x - x_0)^2 + (y - y_0)^2} \tag{12}$$

was used and the error was calculated with gaussian error propagation with

$$s_r = \frac{\sqrt{2} \cdot s_d}{r}. \tag{13}$$

The error on the measured distances $s_d = 1\,\mathrm{mm}$ was estimated during the measurements. The calculated values for the distances to the left and right maxima are:

$$\begin{aligned} x_{1,\mathrm{r}} &= 56\,\mathrm{mm} && \text{and} && y_{1,\mathrm{r}} = -8\,\mathrm{mm} && \Longrightarrow r_\mathrm{r} = (53.96 \pm 0.19)\,\mathrm{mm},\\ x_{1,\mathrm{l}} &= -50\,\mathrm{mm} && \text{and} && y_{1,\mathrm{l}} = 6\,\mathrm{mm} && \Longrightarrow r_\mathrm{l} = (52.96 \pm 0.19)\,\mathrm{mm}. \end{aligned}$$

For the later calculation of the grating constant the mean of the two distances is used as they are supposed to be equal:

$$\begin{aligned} r_\mathrm{m} &= \frac{1}{2}(r_r + r_l) = (5346 \pm 14)\,\mathrm{mm} \text{ with}\\ s_{r,\mathrm{m}} &= \frac{1}{2}\sqrt{s_{r,r}^2 + s_{r,l}^2}. \end{aligned} \tag{14}$$

With the distance between screen and grating $L = (65 \pm 2)\,\mathrm{mm}$ and the wavelength of the used laser $\lambda = 632.8\,\mathrm{nm}$ the grating constant g can be calculated with use of

$$\begin{aligned} g &= \frac{\lambda}{\sin\phi} = \lambda\frac{\sqrt{L^2 + r^2}}{r} = (996.2 \pm 1.8)\,\mathrm{nm} \text{ with}\\ s_g &= \lambda\sqrt{\left(\frac{L \cdot s_L}{r\sqrt{L^2 + r^2}}\right)^2 + \left(\frac{L^2 \cdot s_r}{r^2\sqrt{L^2 + r^2}}\right)^2}. \end{aligned} \tag{15}$$

3.2 Grating constants of Amplitude Gratings

3.2.1 Determine the Angle-Time Dependency

To later on determine the grating constants of five different gratings first of all the angle-time conversion had to be calculated. Thus a reference grating with a known grating constant $g_{\text{ref}} = 80\,\text{lines/cm}$, therefore $k_{\text{ref}} = 125\,\mu\text{m}$ was measured.

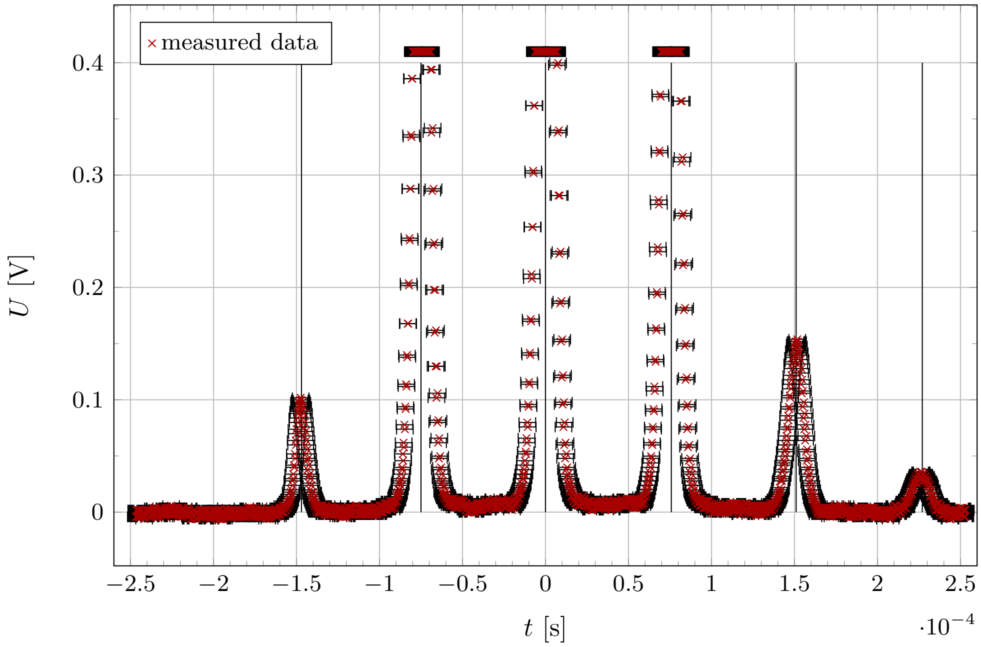


Figure 2: Measured interference using the reference grating. As the plot gets really confusing by plotting both, the zoomed and the overall data, just the zoomed data is show.

In fig. 2 the interference pattern of the reference grating is displayed. As it was not possible to measure the maxima of higher order without cutting the zeroth maximum, for each grating two datasets were taken and used for the analysis. It is also visible that the data has already been cleared by its offset. This was done by reading the position of the zeroth maximum out and setting the time to zero for that point. Therefore the error is given by

$$s_t = \sqrt{2} \cdot 0.1\,\text{s} \cdot \text{divisions}, \tag{16}$$

where the error on the measured time is determined out of the devisions that can be read out from the .bmp-pictures that has been taken during the experiment.

To determine the angle-time dependency the position of the maxima is read out by eye. To do so the data records where the higher order maxima are visible and the second scaled dataset are plotted in on graph and the maxima are marked and the positions noted in a file. For the position of a maximum in a interference pattern of a grating we do know:

$$\phi = m\frac{\lambda}{k}, \tag{17}$$

where ϕ is the angle of the maximum,λ the wavelengths of the laser and k the grating constant. So by plotting $m\frac{\lambda}{k_{\text{ref}}}$ against the measured time the multiplier can be calculated with use of a linear fit. The linear fit of the form $f(x) = \alpha x + \beta$ that has been done with

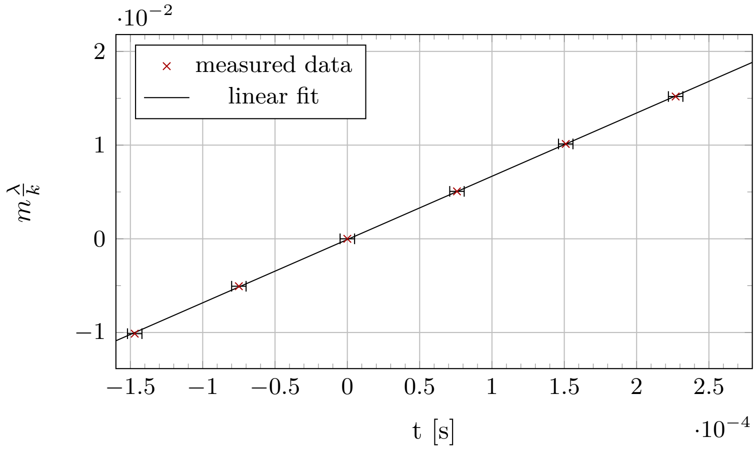


Figure 3: Linear fit for the reference grating. On the y-axis the order of the maximum times the laser-wavelengths is shown and on the x-axis the corresponding times are marked.

the function `scipy.optimize.curve_fit` in python delivers:

$$\begin{aligned} \alpha &= (67.5 \pm 0.3)\,\frac{1}{\text{s}} \\ \beta &= (-8 \pm 4) \cdot 10^{-5}. \end{aligned} \tag{18}$$

The determined α can now be used to recalculate the angles out of the measured times by multiplying.

3.2.2 Determining the Grating Constant

To determine the grating constant of five different gratings, the interference pattern has been measured. For the further analysis, the data has been cleared by its offset. As for all gratings the analysis follows the same principle it is only described for the first grating. All relevant plots for the other gratings and the read out maxima (marked with black lines in the plots) can be found in appendix A.

As seen in fig. 4 the interference maxima have been located. This was done by eye as Gauss-fitting each peak would cost a lot of time and most probably not yield better results. By using the factor determined with help of the reference grating, the time was converted to the corresponding angle. Therefore, with Gaussian error propagation the error on the angle is given by

$$s_\phi = \sqrt{\left(\sqrt{2} \cdot 0.1 \cdot \text{devisions} \cdot \alpha\right)^2 + (t \cdot s_\alpha)^2}. \tag{19}$$

Same as before the error on the time is determined out of the devisions and for the conversion-factor the error, given by the fit-function is used.

Next, the locations of the maxima were plotted against the corresponding order times the wavelengths of the laser. Same as for the reference grating we do know that the location of the maxima corresponds to the grating constant and a linear fit was made with use of `curve_fit`.

The fit yields

$$\alpha = (138.0 \pm 1.0) \cdot 10^{-6}\,\frac{\text{m}}{\text{rad}} \tag{20}$$

$$\beta = (1.4 \pm 0.9) \cdot 10^{-8}\,\text{m}. \tag{21}$$

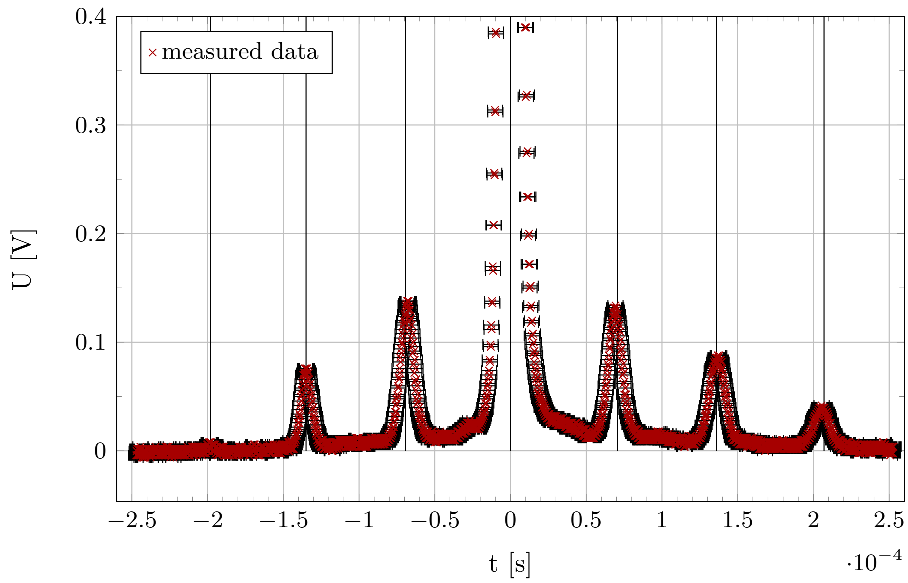


Figure 4: Measured interference after clearing the offset using grating number one. As the plot gets really confusing by plotting both, the zoomed and the overall data, just the zoomed data is show. The shown error on the time is calculated in the same way as for the reference grating. As the error on the voltage that is given by the manual of the oscilloscope is not used in the analysis it is not displayed in the plot.

So with use of eq. (17) the grating constant of grating 1 is given by the fit parameter α from the fit in fig. 5. This can be done as the used angles are rather small so the small-angle approximation should hold reasonable results. Also the error is given by the fit function so for the grating constant of grating 1

$$g_1 = \alpha \cdot 1\,\mathrm{rad} = (138.3 \pm 1.0)\,\mu\mathrm{m} \tag{22}$$

was measured.

Calculating the Resolution with the Measured Grating Constant To calculate the resolution eq. (11) is used. With the calculated grating constants and the measured width of the laser $w = (3.5 \pm 0.5)\,\mathrm{mm}$ the number of lighted lines can be calculated by

$$N = \frac{w}{g} \text{ with } s_N = \sqrt{\left(\frac{s_w}{g}\right)^2 + \left(\frac{s_g w}{g^2}\right)^2}. \tag{23}$$

The highest visible order was read out from the plots. Therefore for the resolution of grating 1

$$a_1 = 3 \cdot N = 76 \pm 10 \tag{24}$$

is determined.

The calculated values for the grating constants as well as for the resolution for other gratings are listed in table 1 and have been calculated completely analog.

3.2.3 Calculating the Aperture Function

For grating 1 the measured data was used to determine the aperture function (fig. 6). With use of eq. (6) this can be done by determining the measured voltage for the maxima

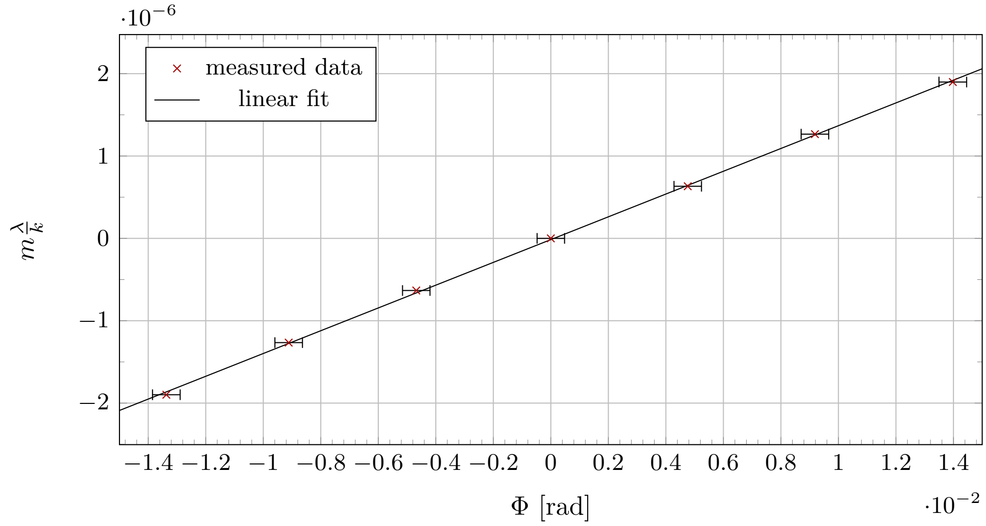


Figure 5: Linear fit for grating 1.

Table 1: Determined grating constants and resolution by measuring the interference pattern, converting the taken time to angles with use of the grating constant of the reference grating and performing a linear fit over the order of the maxima plotted against the corresponding angle.

Granting	Grating constant [µm]	Highest Order	Resolution
1	138.3 ± 1.0	3	76 ± 10
2	35.9 ± 0.4	3	290 ± 40
3	110.7 ± 0.9	2	62 ± 9
4	80.53 ± 0.10	2	87 ± 12
5	54.6 ± 0.3	2	128 ± 18

and calculating the sum to the highest measurable order. As voltages and not intensities have been measured the values for each maximum were normed with the value for the zeroth maximum. Also, as for each order apart from the zeroth one, two values are measured so the mean was taken. Furthermore, the aperture function was used to calculate the proportion p of slid-width b and grating constant g. As, if not approximated, the aperture function is supposed to be a rectangle function the Full-Width-Half-Maximum (FWHM) seems to be a good guess for the width of a slit. To calculate this the function `scipy.optimize.fsolve` has been use to solve

$$\frac{1}{2}(\min(g(x)) + \max(g(x))) - g(x) = 0 \tag{25}$$

numerically. This equation is solved by $x = \pm 2.36 \cdot 10^{-5}\,\mathrm{m}$ and the resulting FWHM is therefore e $\mathrm{FWHM} = 4.73 \cdot 10^{-5}\,\mathrm{m}$.

Using this approximated value the proportion p

$$p = \frac{b}{g_1} = 0.3419 \pm 0.0003 \text{ with } s_p = \frac{b \cdot d_{g_1}}{g_1^2} \tag{26}$$

can be calculated.

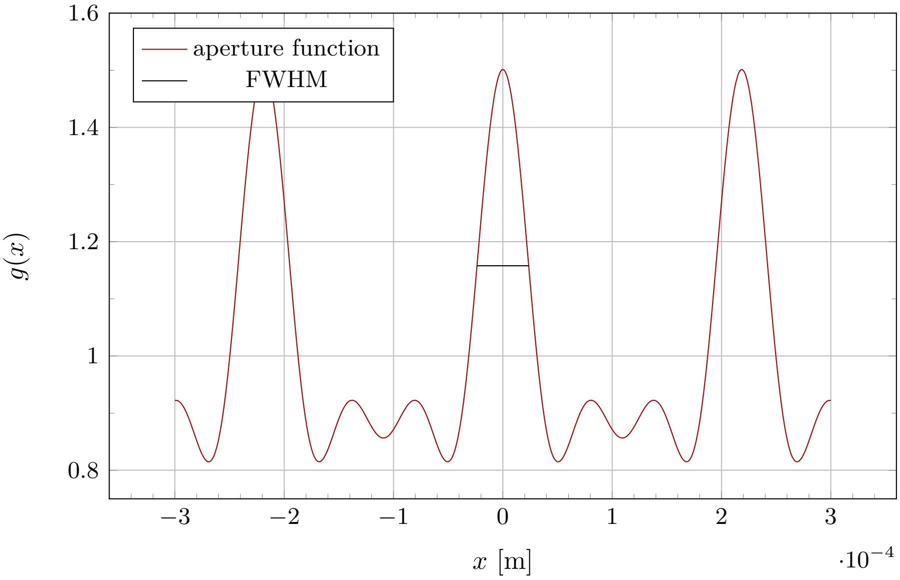


Figure 6: Plot of the approximately calculated aperture function

3.3 Analyzing a Phase Grating

In the second part of the experiment an ultrasound-cell was used to realize a phase grating. For different counter voltages the interference pattern was measured and analyzed. To give an overview a 3d-plot (fig. 7) was made.

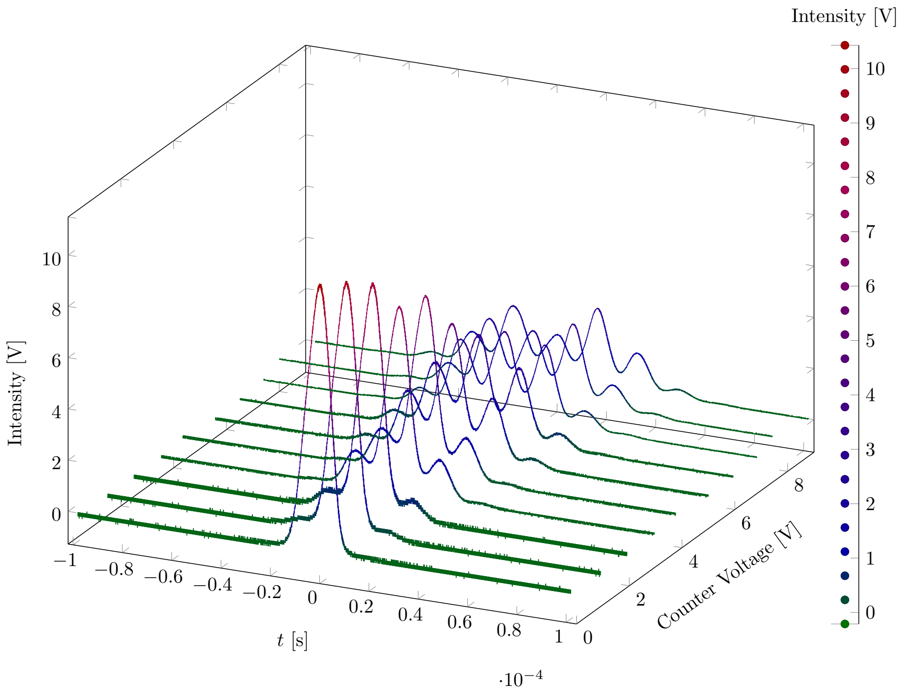


Figure 7: In the plot the measured intensity is plotted against the corresponding time that has been cleared by its offset before. This dependency is displayed for different counter voltages on the ultrasound cell. As the plots gets confusing by using all measured counter voltages only every second is displayed. In the following analysis the single 2d-versions of this plot are going to be used to determine the maxima.

3.3.1 Dependence of the Intensity of the Applied Counter Voltage

By analyzing the different interference pattern for different applied counter voltages the Raman-Nath-Theory is considered.

As seen in fig. 8 the interference pattern has alredy been cleared by its offset by reading out the offset-time and substracting it. Therefore the error on the time is given by

$$s_t = \sqrt{2} \cdot 0.1 \cdot \text{devisions} \tag{27}$$

same as for the first part of the experiment. For the further analysis the position of the maxima and the corresponding voltage had to be determined. Same as for the amplitude grating it did not seem to make sense to fit each peak so it was decided to locate the peaks by eye (as an example see fig. 8) and then determine the corresponding voltage analytically.

For each measured interference pattern the maxima were determined and the corresponding voltage was calculated.

To review the Raman-Nath-Theory, for each interference-order the intensities were plottet against the belonging counter-voltage. To do so all measured voltages were normed with the voltage of the zeroth maximum for zero counter voltage. Following the Raman-Nath-Theory the resulting plot should have the form of a squared Bessel-function of the same

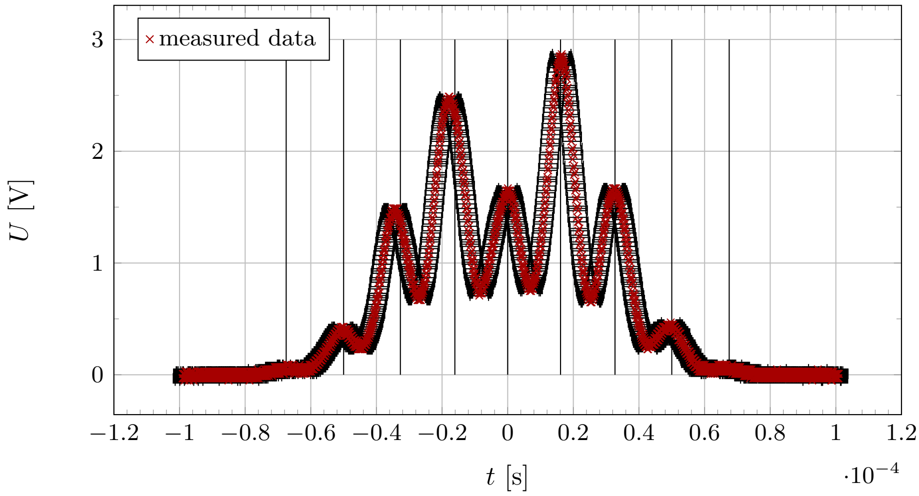


Figure 8: The plot shows the interference pattern for the highest counter voltage (9.5 V). The determined maxima are marked with lines. The error on the time is calculated in the same way as for the amplitude grating. As the angle is not needed in this part of the analysis the times were not converted.

order as the chosen maxima. Furthermore the theory sais that the argument of the function is supposed to be proportional to the counter-voltage and have the same proportional-factor for all orders. Therefore, for each interference-order a Bessel-fit of the form

$$U_m = J_m^2(\alpha U_\mathrm{C}) \tag{28}$$

was made using the `scpipy.optimize.curve_fit` and `scipy.special.jv`. The errors that are displayed in fig. 9 have been calculated with help of two estimations:

Firstly, for each intensity 3 % of the value is taken as an error, as this should give an rough estimation for the error that appears because of reading out the location of the maxima by eye. It was chosen to take a percantage error, as for higher values the maximum voltage changes much more for a small change in the maximum-location than for smaller values. Secondly a fixed error of 0.02 V was chosen as this describes the uncertainty for the determined voltage due to fluctuation and flat and noisy maxima. These two errors were taken and added with Gaussian error propagation and they were also given to the fit-function.

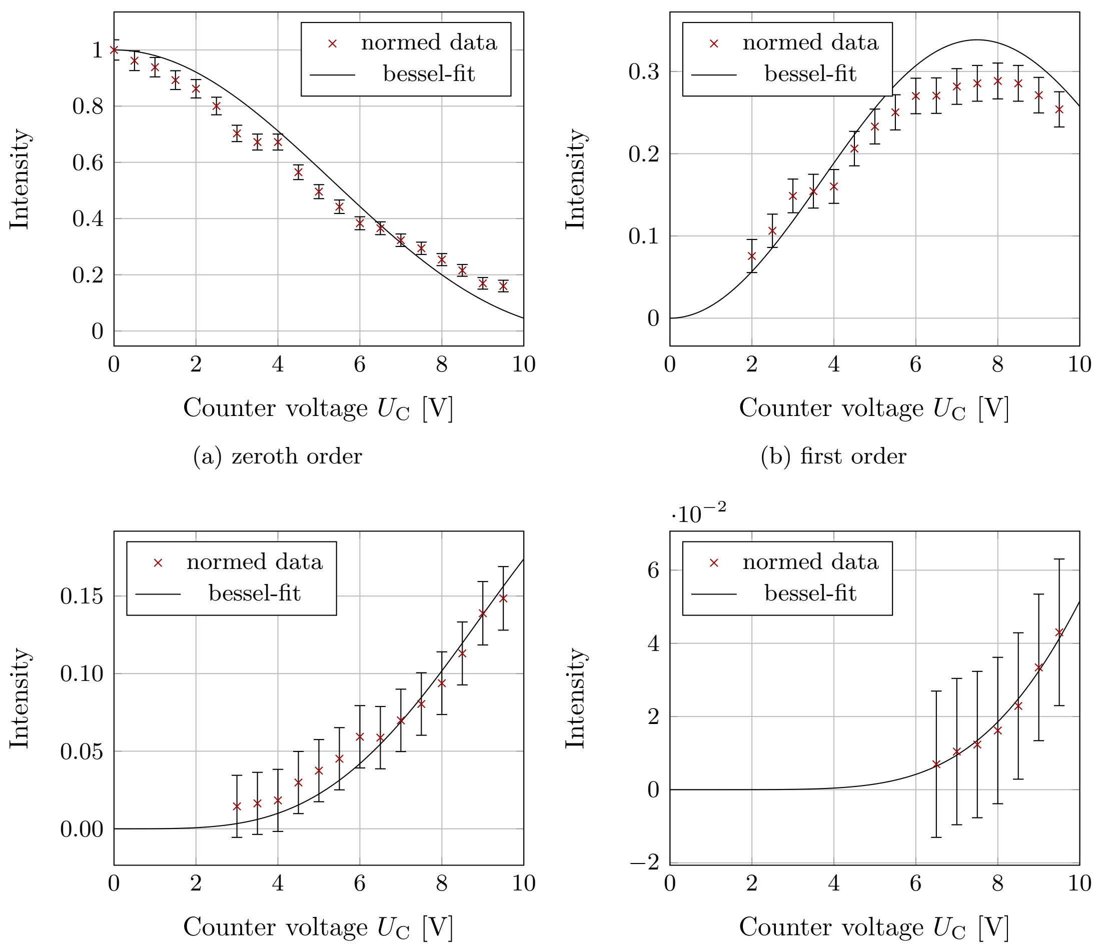
Following this procedure yields four values for the fit parameter α that are shown in table 2.

Table 2: Calculated fit parameters that are used to take a look at the Raman-Nath-theory, the error is given by the fit-function.

Order m	α [V]
0	0.202 ± 0.005
1	0.246 ± 0.009
2	0.232 ± 0.003
3	0.2556 ± 0.0014

3.3.2 Calculating the Wavelengths in Isooctane

Calculating the wavelengths in isooctan follows more or less the same principle as determining the grating constants for the amplitude gratings.



(a) zeroth order

(b) first order

(c) second order

(d) third order

Figure 9: Measured and normed intensities of the different orders with Bessel fits of same order.

First of all the time-angle convertion had to be done and therefore the reference grating was measured again, this time in combination with the ultrasound-cell. As the setup was not changed in between the results for the reference grating did not change a lot. The data and the linear fit that are displayed in fig. 10 yields

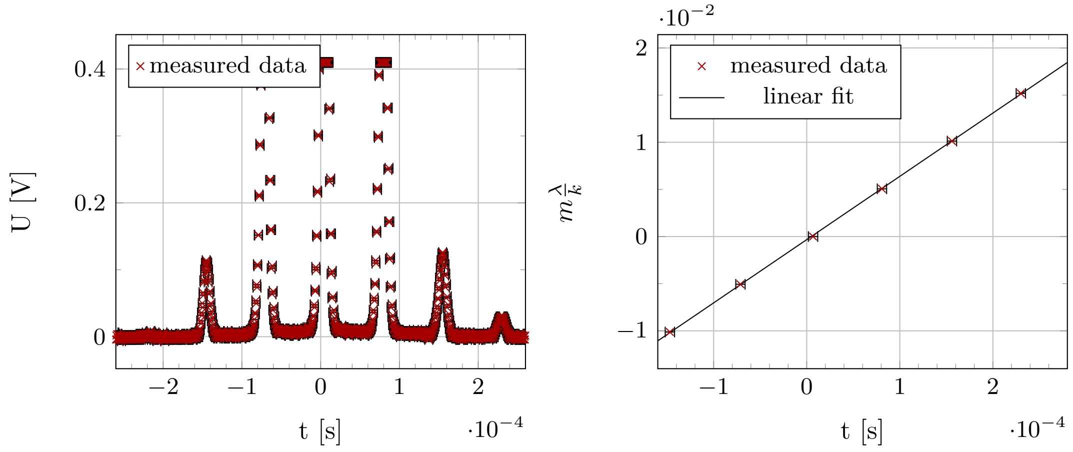
$$\alpha = (67.09 \pm 0.27)\,\frac{1}{\mathrm{s}} \tag{29}$$

$$\beta = (3.2 \pm 0.4) \cdot 10^{-4} \tag{30}$$

The fit parameter α now is used to convert the times of the interference pattern wit 9.5 V counter voltage to angles. This interference pattern was chosen for the further analysis as it showed the maxima of highest order and therefore should deliver the best result. For the analysis the same maxima as already shown in fig. 8 have been used. Plotting these maxima against their corresponding order delivers fig. 11. Same as in the analysis of the amplitude grating a linear fit of the form

$$m\lambda = \gamma\phi_m + \delta \tag{31}$$

can be made as the loaction of the maxima still follows eq. (1), the grating constant g just



(a) interference pattern (b) linear fit

Figure 10: Determining the conversion factor for time and angle.

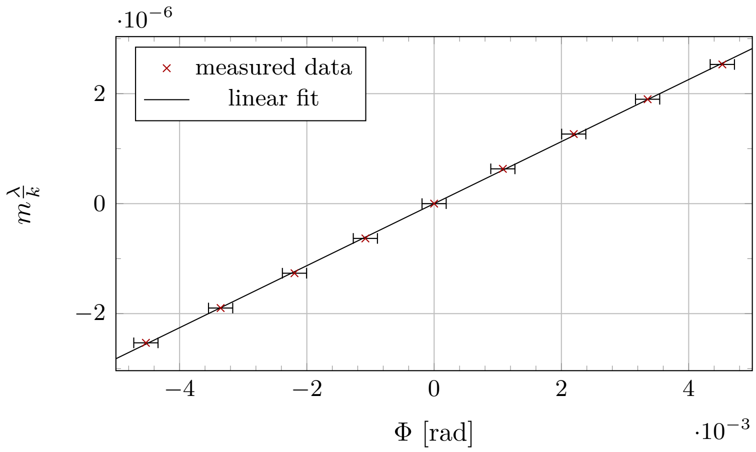


Figure 11: Linear fit to determine the wavelengths in isooctane out of the data measured with a counter voltage of 9.5 V.

needs to be replaced with the wavelenghts Λ in isooctane. The fitted parameters are

$$\gamma = (56 \pm 3) \cdot 10^{-5}\,\frac{\mathrm{m}}{\mathrm{rad}} \tag{32}$$

$$\delta = (0.0 \pm 2.3) \cdot 10^{-8}\,\mathrm{m}. \tag{33}$$

Using the fitted parameters the wavelengths in isooctane can be easily calculated as the angles are really small and allow an approximation. Therefore the wavelength is

$$\Lambda = \gamma \cdot 1\,\mathrm{rad} = (560 \pm 3)\,\mathrm{\mu m}. \tag{34}$$

The theoretical value for the wavelengths in isooctane can be calculated with the used frequency $\nu = (2096 \pm 1)\,\mathrm{kHz}$ and the speed of sound $c = 1111\,\frac{\mathrm{m}}{\mathrm{s}}$ by using the dispersion relation

$$\Lambda_{\mathrm{theo}} = \frac{c}{\nu} = (530.1 \pm 0.3)\,\mathrm{\mu m}. \tag{35}$$

4 Discussion

4.1 The Sine-Grating

Using the data provided by this experiments measurement we calculated the grating-constant of the sine-grating to a value of

$$g = (996.2 \pm 1.8)\,\mathrm{nm}.$$

Since there is no further information given about this grating there is no possibility to check whether the computed value is sensible or not. What is striking, however, is that the grating-constant is way smaller for the sine-grating then for the other amplitude grating. But never the less it is a sensible result for a grating constant. And since the relative error of that result is 0.18% assuming there are no unrecognized systematical errors on that measurement the value should be reasonable.

4.2 Amplitude Gratings

For the amplitude gratings the values for the grating constant and the resolution were computed. These values are displayed in table 3. Owing to the circumstance that no

Table 3: Determined grating constants and resolutions.

Granting	Grating constant [µm]	Highest Order	Resolution
1	138.3 ± 1.0	3	76 ± 10
2	35.9 ± 0.4	3	290 ± 40
3	110.7 ± 0.9	2	62 ± 9
4	80.53 ± 0.10	2	87 ± 12
5	54.6 ± 0.3	2	128 ± 18

reference values were given it is not possible to compare the computed values to test their goodness. Considering the low relative errors of the grating constants and taking into account that the values are in a sensible range it can be assumed that the measurement yielded good results.

Furthermore the aperture function for grating 1 was computed. As it is determined by an approximation observing more interference orders would definitely yield better results. Nevertheless the pattern has a sensitive look and it seems that it would become the expected rectangle plot for more orders. Using the FWHM of the peaks in the aperture function the proportion p was calculated. We determined a value of

$$p = \frac{b}{g_1} = 0.3419 \pm 0.0003, \tag{36}$$

which seems quite reasonable. But it is questionable that the Fourier series provides a good approximation in this case, because a transmitivity of more than 1 is not a sensible value in a aperture function.

4.3 Phase-Grating

Another goal of the experiment was to test the Raman-Nath-Theory. To do so the measured intensity peaks of the different orders are plotted against the voltage applied on the ultrasound generator. The so combined data was Bessel fitted to determine the value for

Table 4: Calculated fit parameters that are used to take a look at the Raman-Nath-theory, the error is given by the fit-function.

Order m	α [V]
0	0.202 ± 0.005
1	0.246 ± 0.009
2	0.232 ± 0.003
3	0.2556 ± 0.0014

α in the Bessel function. The Raman-Nath-Theory predicts that the value of α should remain constant for different orders of the maxima. The values calculated are displayed in table 4. One can see that the values of α are within a reasonable range. Considering the probably not ideal setting of the experiment the error on the values might be estimated too low. Also the fits for at least the first two orders seem to be not that good since the fit does not even hit half of the error bars. For the zeroth order this can be explained with the fact that only one maximum is visible. For the higher orders most of the time the left and the right maximum were combined so a probable offset would be canceled out. Nevertheless the different values do not completely fit each other but it seems promising to try a slightly modified setup with a better optical path to prove the Raman-Nath-Theory with help of this experiment.

Using the data of this measurement also the wavelength of the ultrasound in isooctane was computed. We calculated a value of

$$\Lambda = (560 \pm 3)\,\mu\text{m}.$$

Since we also know the frequency of the ultrasound from a display on the generator we can calculate a theoretical value for the frequency too.

$$\Lambda_{\text{theo}} = (530.1 \pm 0.3)\,\mu\text{m} \tag{37}$$

Comparing these values one can see that the measured value lies in a 21σ-range of the theoretical value. Since the error calculation seems reasonable there might also be a systematical error which was not considered. Never the less the determined values for the parameter α and the wavelengths Λ of the ultrasound are probably not significant enough to either discard or accept the Raman-Nath-Theory.

A Analizing Amplitude Gratings

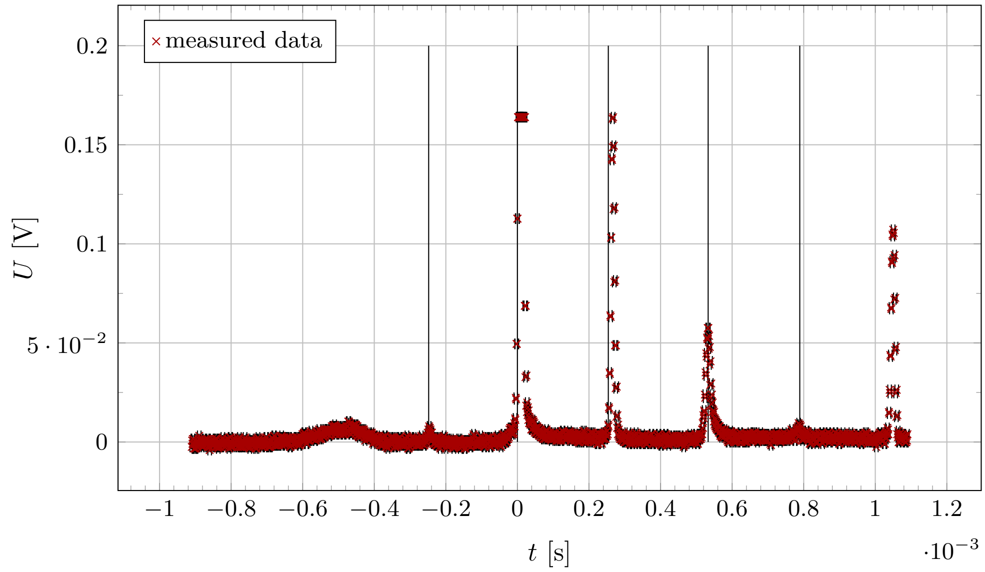


Figure 12: Interference pattern for grating 2

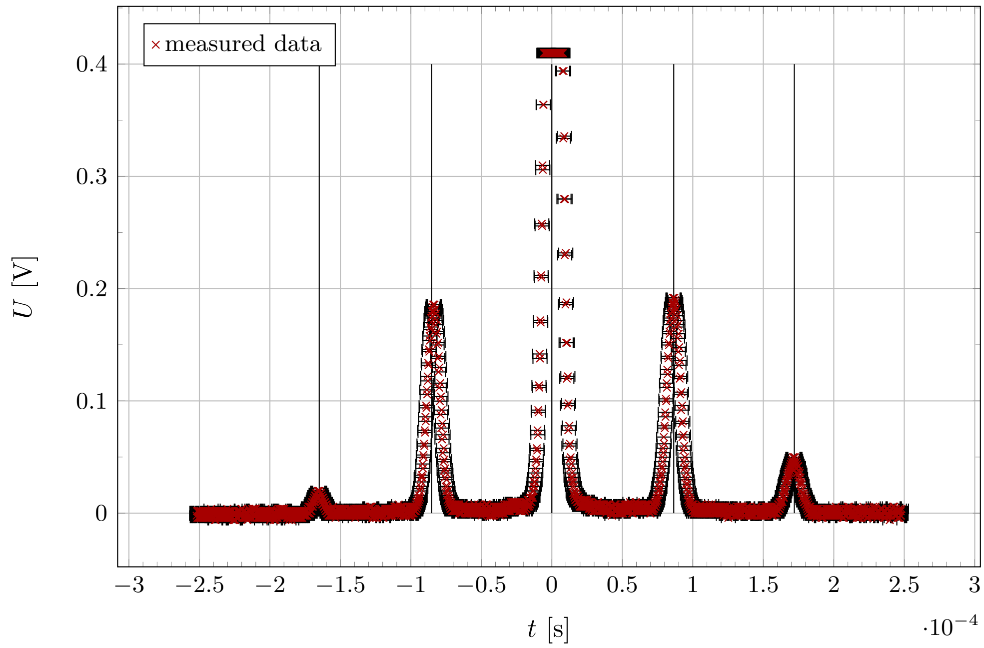


Figure 13: Interference pattern for grating 3

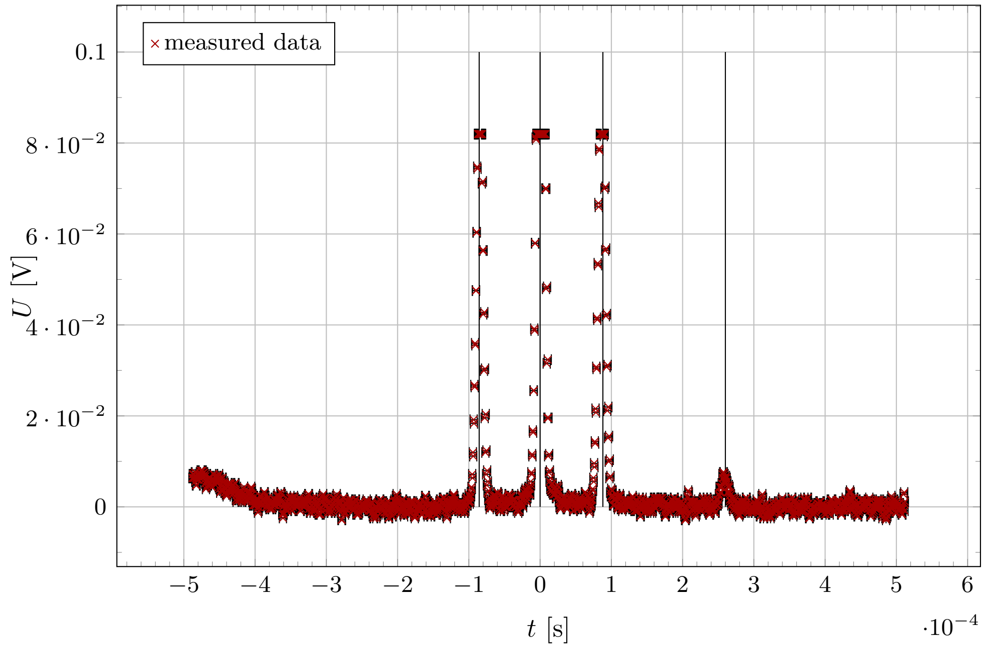


Figure 14: Interference pattern for grating 4

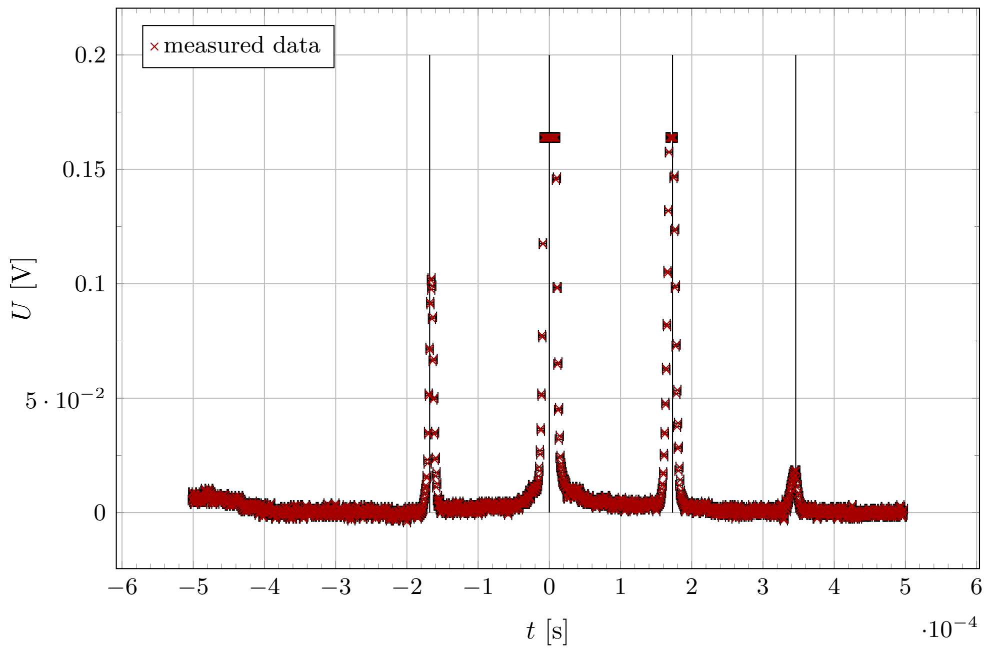


Figure 15: Interference pattern for grating 5

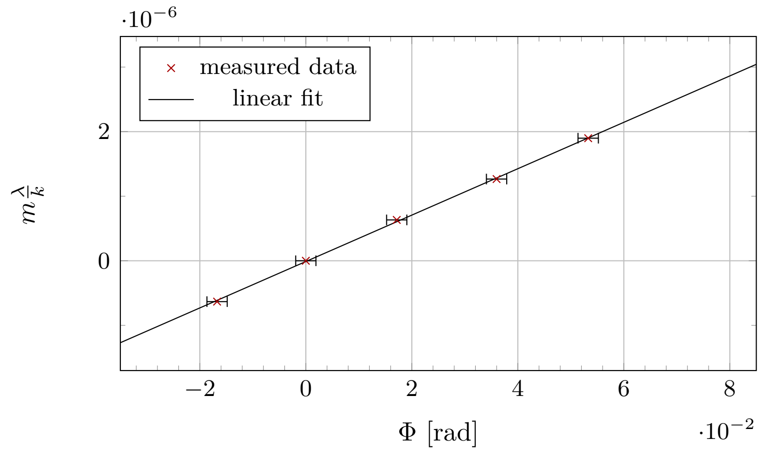


Figure 16: Linear fit for grid 2.

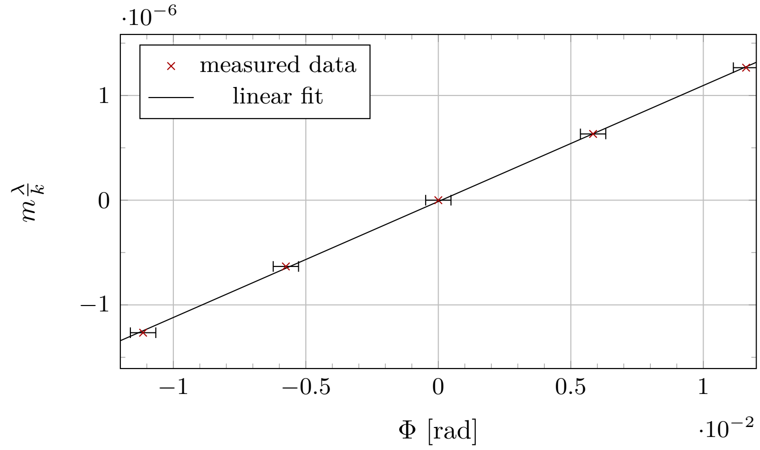


Figure 17: Linear fit for grid 3.

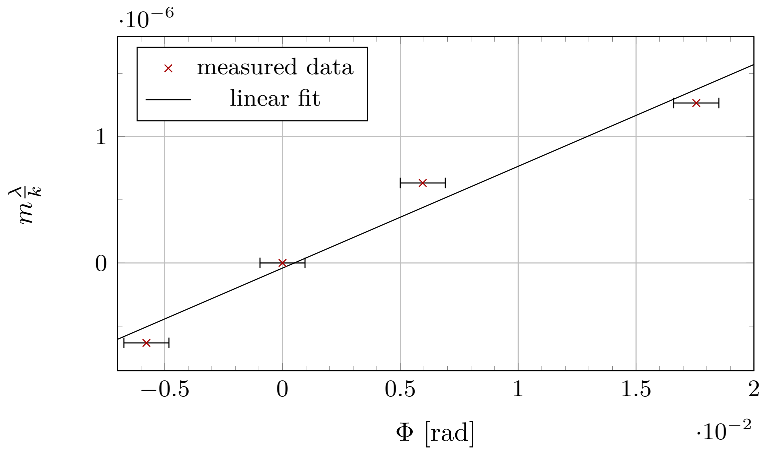


Figure 18: Linear fit for grid 4.

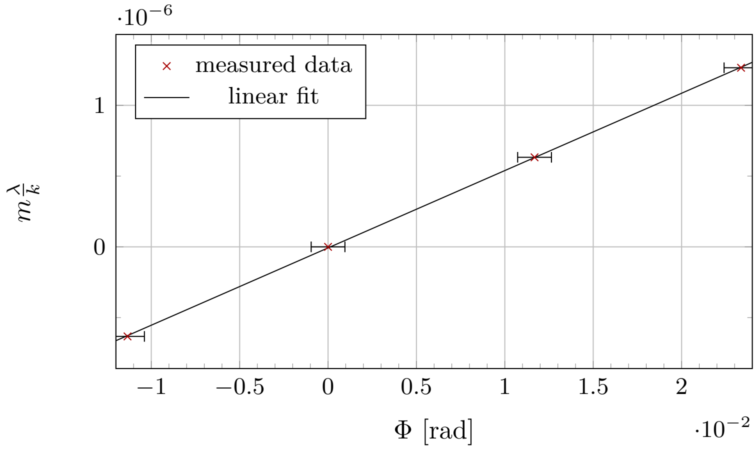


Figure 19: Linear fit for grid 5.

B Analizing a Phase Grating

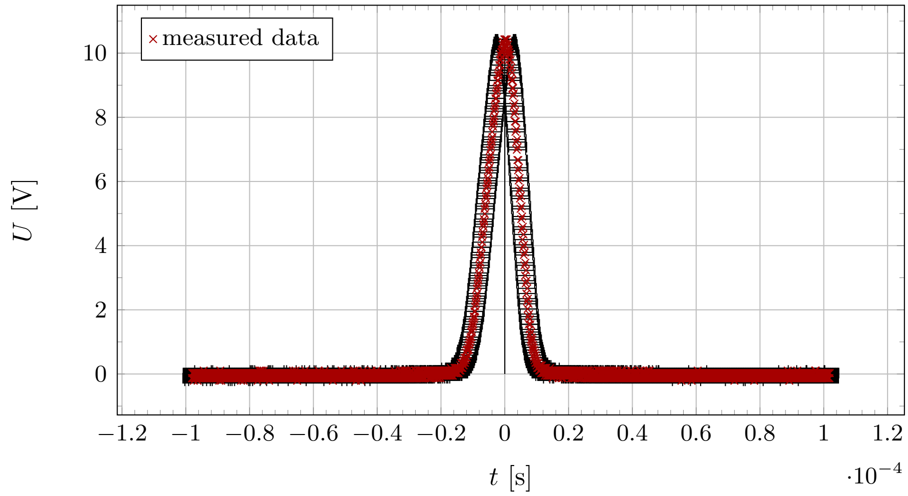


Figure 20: Interference pattern for a counter voltage of 0 V.

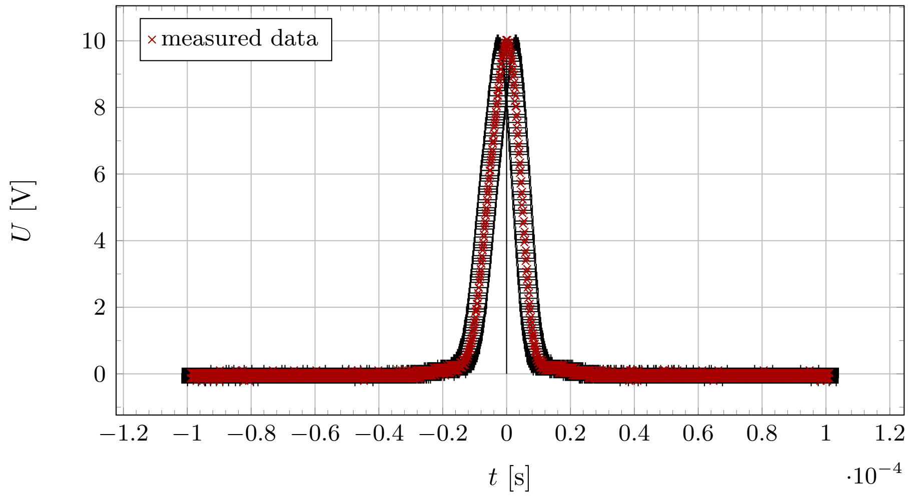


Figure 21: Interference pattern for a counter voltage of 0.5 V.

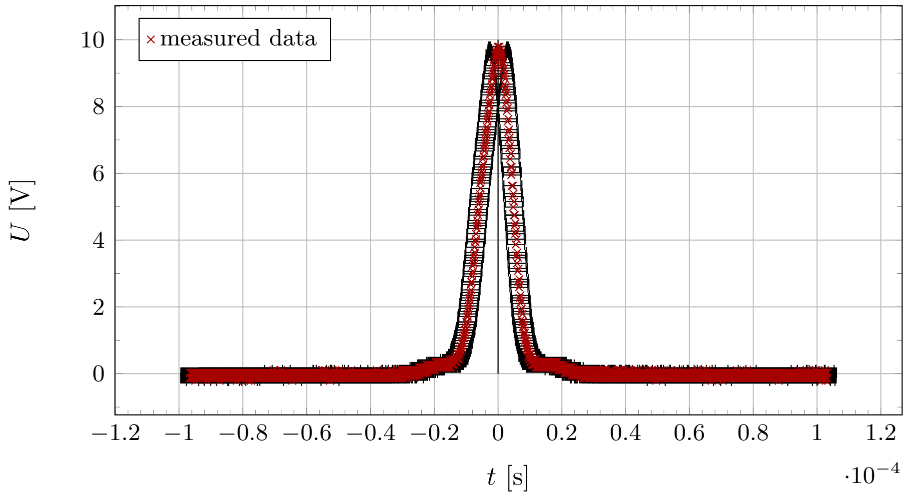


Figure 22: Interference pattern for a counter voltage of 1 V.

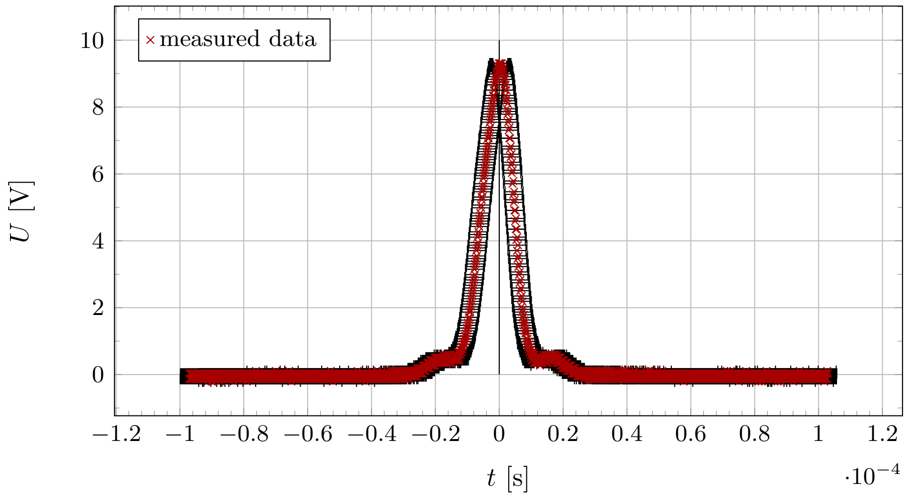


Figure 23: Interference pattern for a counter voltage of 1.5 V.

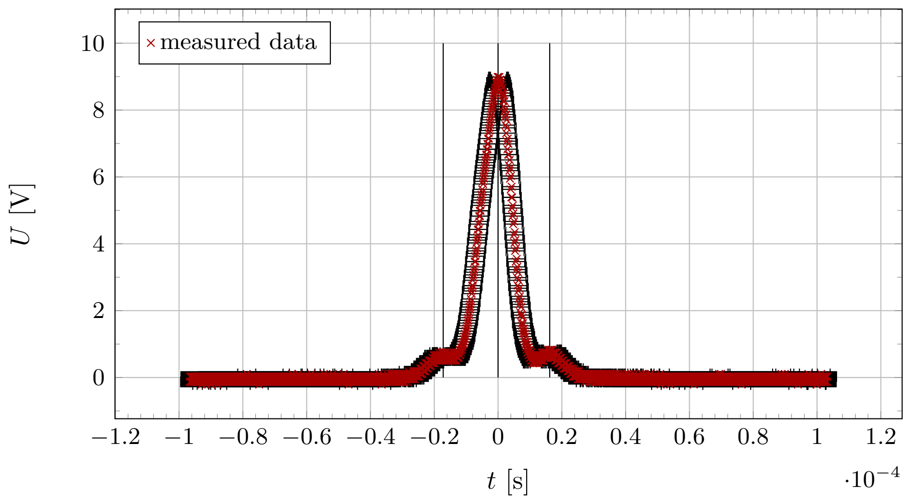


Figure 24: Interference pattern for a counter voltage of 2 V.

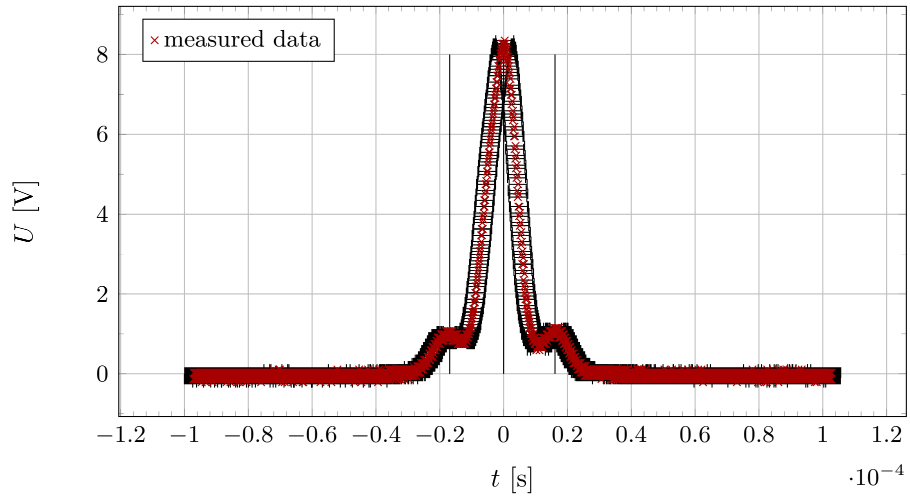


Figure 25: Interference pattern for a counter voltage of 2.5 V.

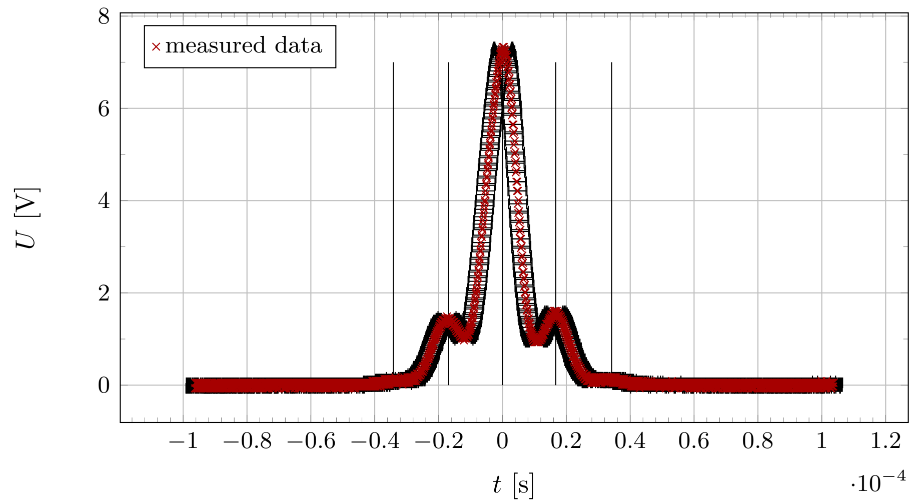


Figure 26: Interference pattern for a counter voltage of 3 V.

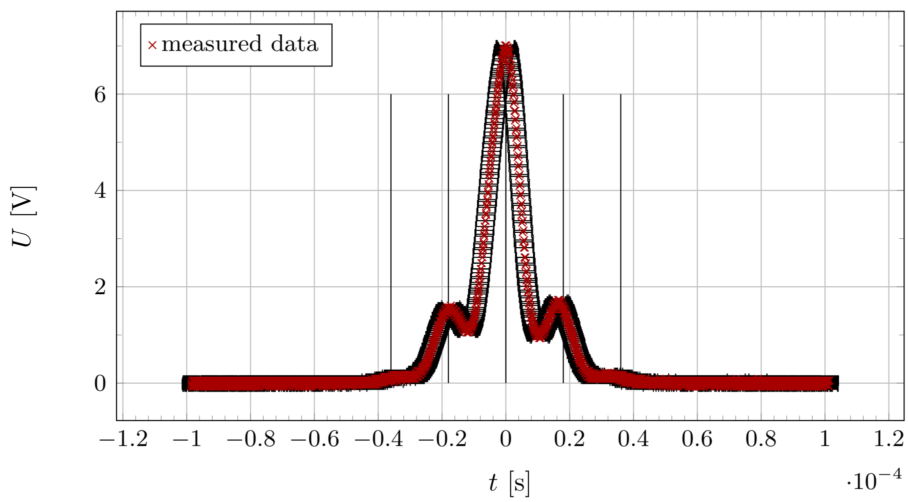


Figure 27: Interference pattern for a counter voltage of 3.5 V.

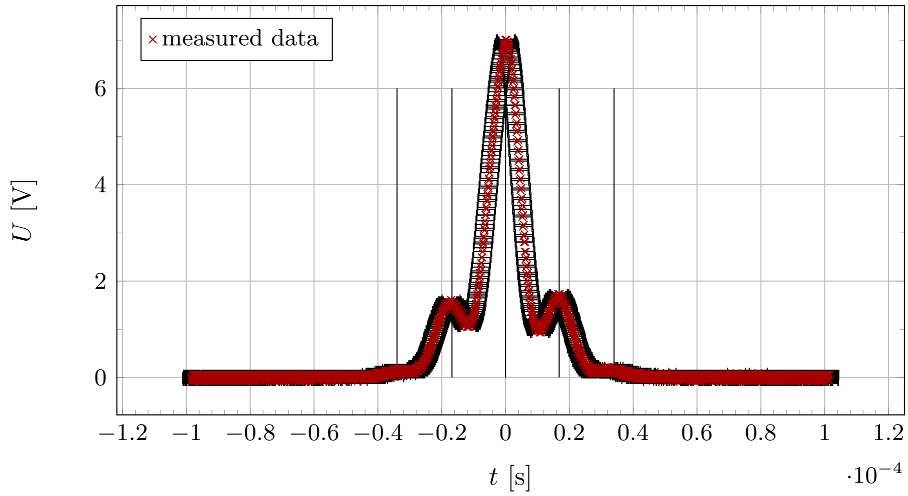


Figure 28: Interference pattern for a counter voltage of 4 V.

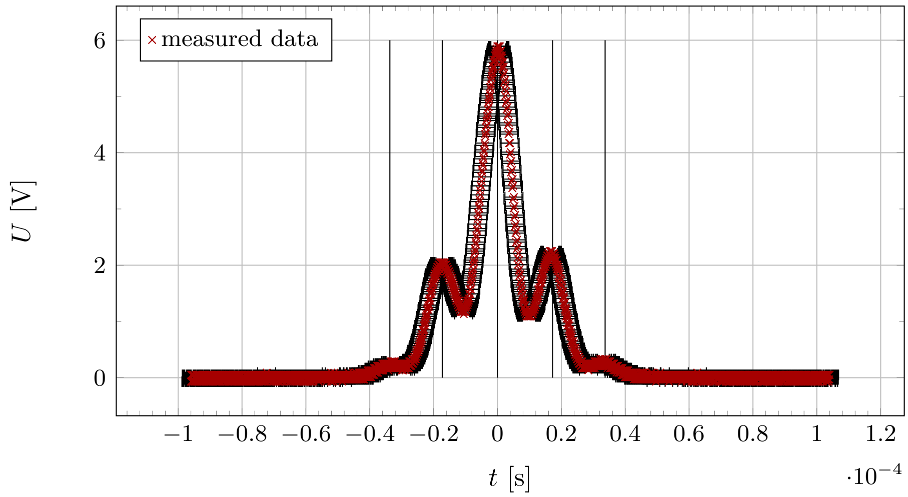


Figure 29: Interference pattern for a counter voltage of 4.5 V.

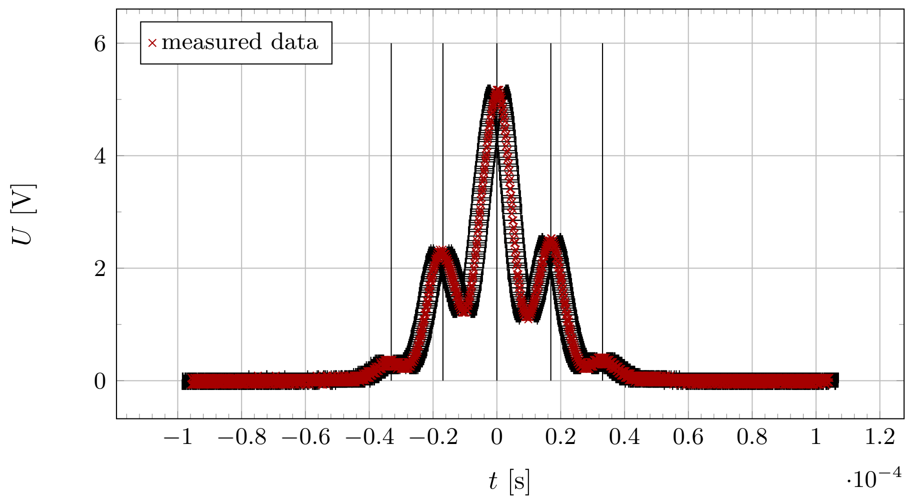


Figure 30: Interference pattern for a counter voltage of 5 V.

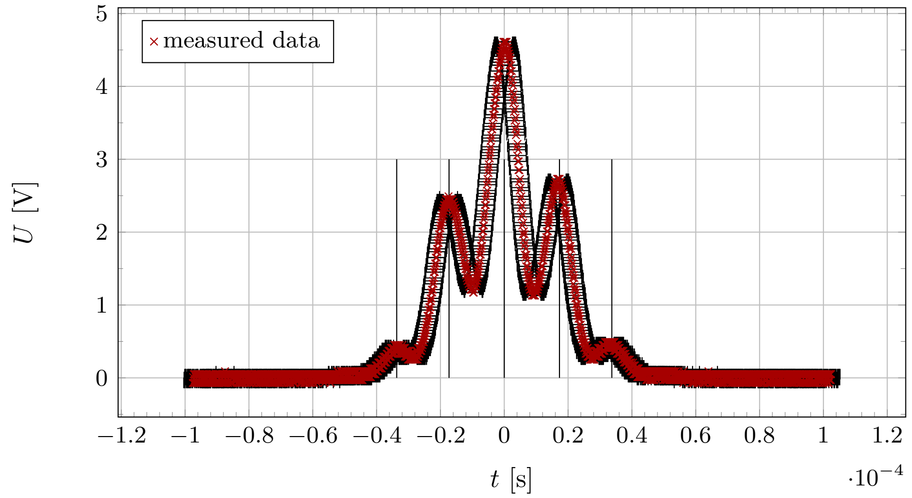


Figure 31: Interference pattern for counter voltage of 5.5 V.

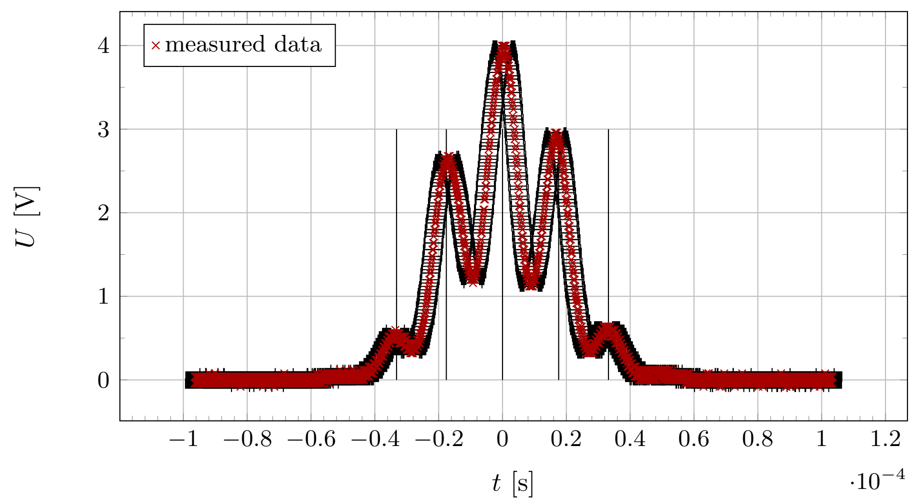


Figure 32: Interference pattern for counter voltage of 6 V.

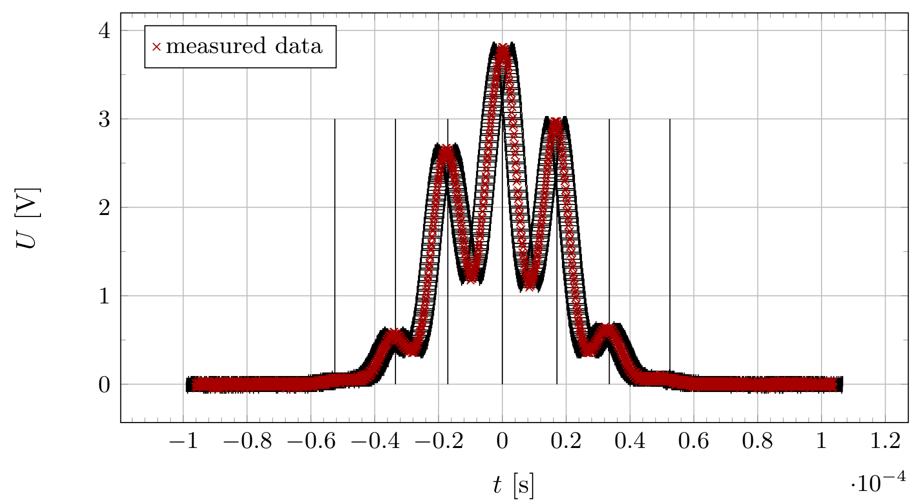


Figure 33: Interference pattern for counter voltage of 6.5 V.

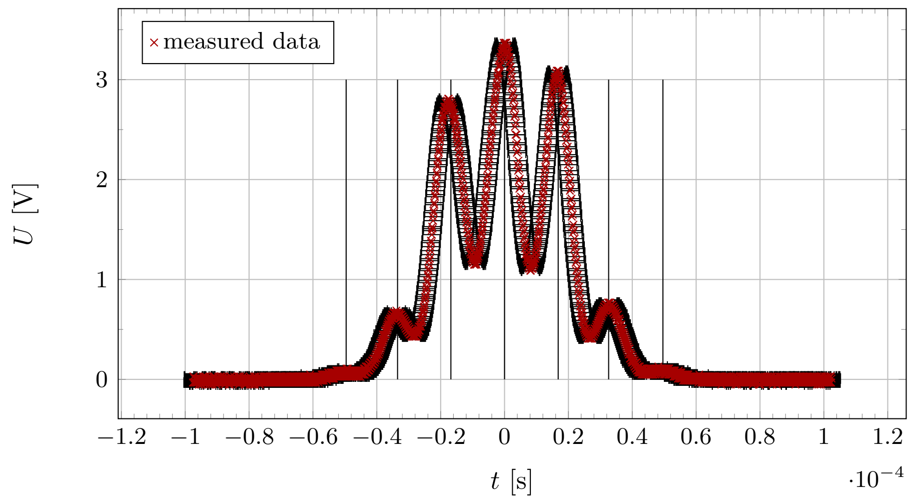


Figure 34: Interference pattern for counter voltage of 7 V.

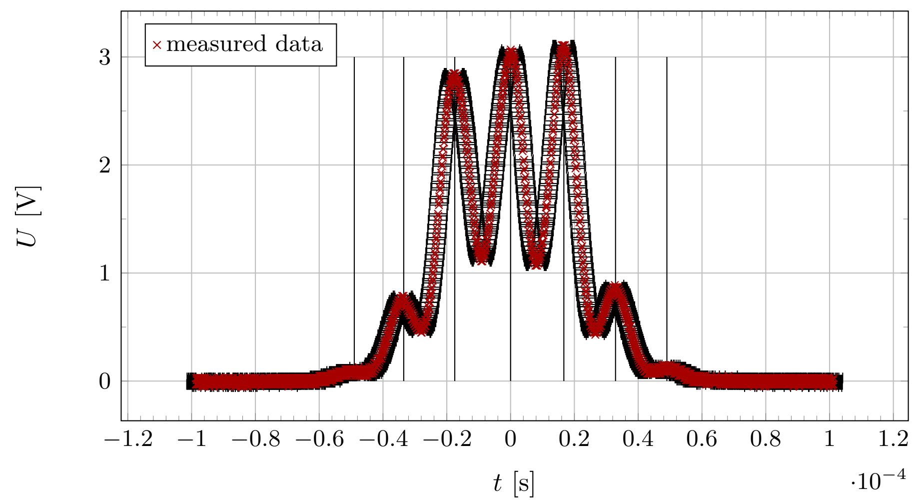


Figure 35: Interference pattern for counter voltage of 7.5 V.

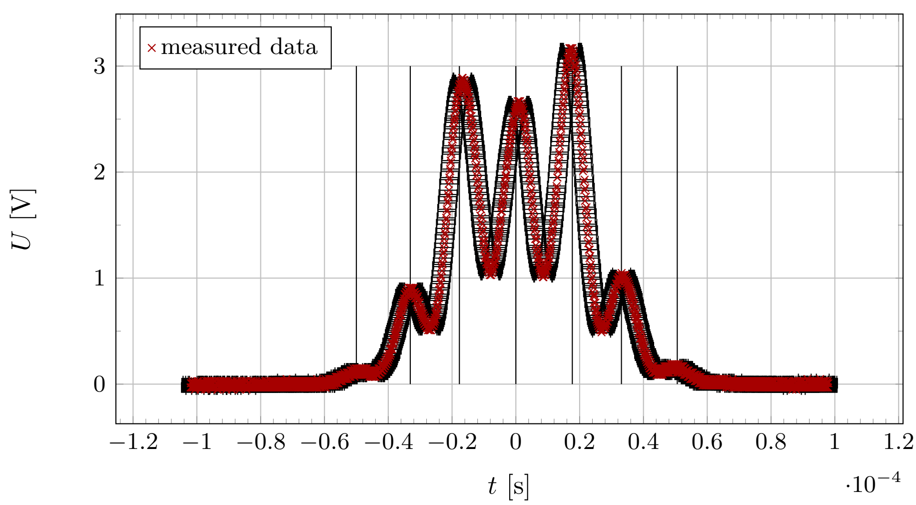


Figure 36: Interference pattern for counter voltage of 8 V.

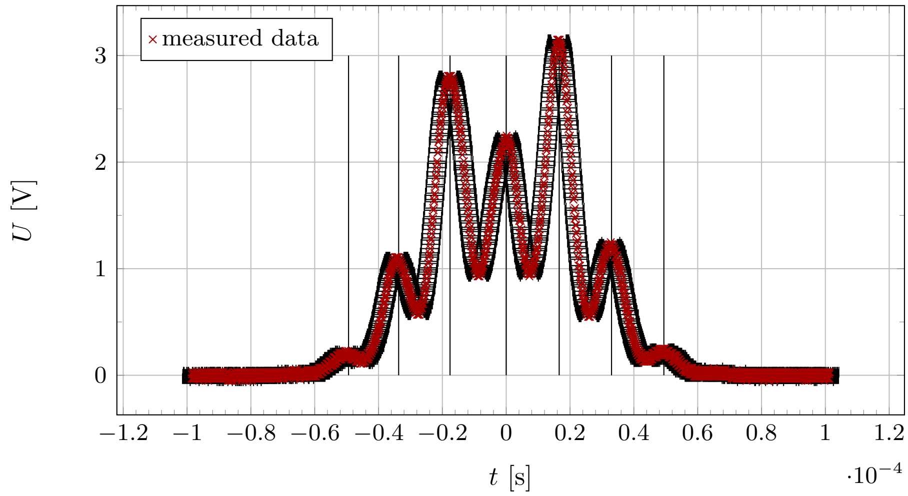


Figure 37: Interference pattern for counter voltage of 8.5 V.

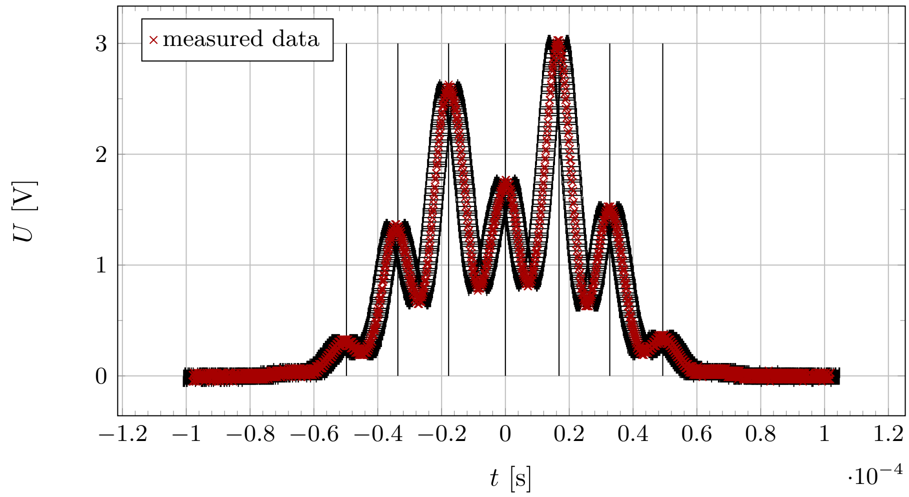


Figure 38: Interference pattern for counter voltage of 9 V.

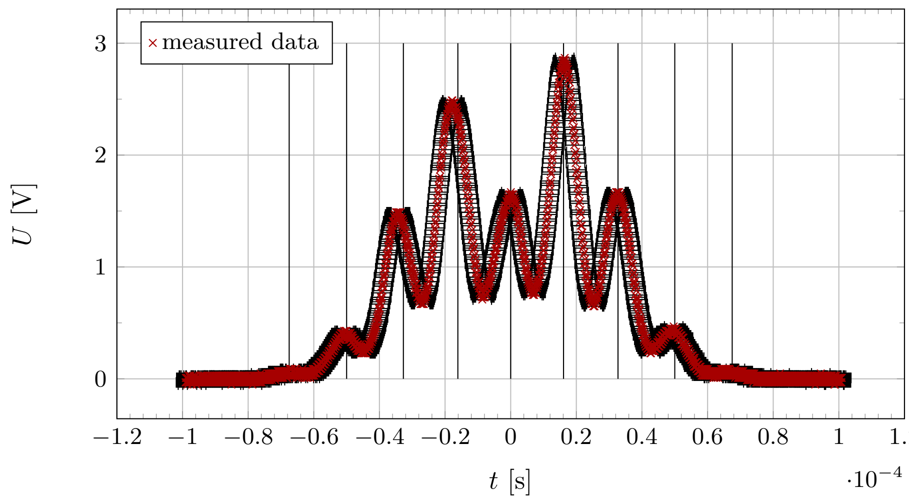


Figure 39: Interference pattern for counter voltage of 9.5 V.

C Index and References

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References

[Source 1] *"Versuchsanleitung Fortgeschrittenenpraktikum Teil 1, Ultraschall, M. Köhli Stand 04/2011."*

ultrasound

part I : d gnd - screen = 6,~~8~~5 cm ± 0,2 cm
mitte ...

Fehler ± 1mm
- 0te : x = 2,5 mm   y = -1 mm
- 1te R : x = 56 mm   y = -8 mm
- -1te L : x = -50 mm   y = 6 mm

part III : Frequenz f = 2096 kHz ± 1

Einheit : ~~ref 2~~ , ~~ref 2 kein~~
ref 130 raus , kein

Spannung $\delta V = \pm 10\,mV$

durchmesser Laser : 3,5mm ± 0,5mm

Simona Cozzolo