Fourieroptik

```
Needs["ErrorBarPlots`"]
```

```
λ = Quantity[635, "Nanometers"]
```

635 nm

```
f1 = Quantity[80, "Millimeters"]
```

80 mm

Aufgabe 1

Eichung

Die Eichwerte:

```
gauge = {{166.67, 2 * 0.25}, {326.84, 2 * 0.43}, {497.84, 2 * 0.63}, {655.84, 2 * 0.83}}
```

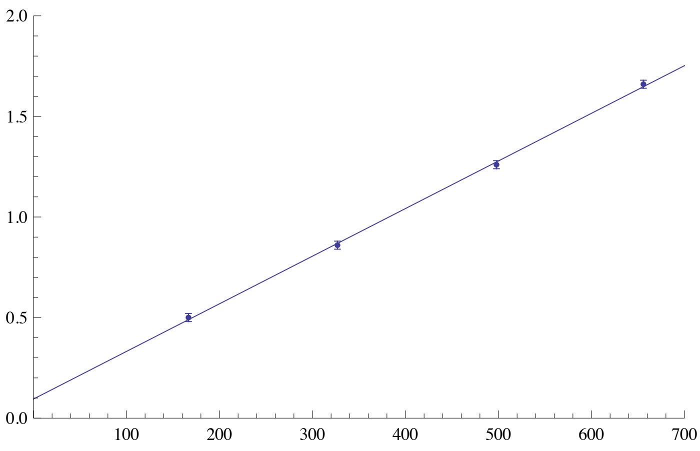
{{166.67, 0.5}, {326.84, 0.86}, {497.84, 1.26}, {655.84, 1.66}}

```
plotgauge = ErrorListPlot[Table[{gauge[[i]], ErrorBar[0.02]},
    {i, 1, Length[gauge]}], PlotRange → {{0, 700}, {0, 2}}];
```

```
fitgauge = LinearModelFit[gauge, x, x, VarianceEstimatorFunction → (1 &),
  Weights → Table[1 / 0.02^2, {i, 1, Length[gauge]}], IncludeConstantBasis → True]
```

FittedModel[0.0949966 + 0.00236768 x]

```
Show[plotgauge, Plot[fitgauge[x], {x, 0, 700}]]
```



Die Steigung dieser Geraden ist der Wert »Millimeter pro Pixel«. Wir können also eine Variable 1 Pixel = *x* Millimeter einführen.

```
{Pixel, ΔPixel} =
 Quantity[fit_gauge["ParameterTableEntries"][[2, 1 ;; 2]], "Millimeters"]
```

{0.00236768 mm, 0.0000545818 mm}

```
{Pixel // NumberForm[#, 3] &, ΔPixel // NumberForm[#, 1] &}
```

{0.00237 mm, 0.00005 mm}

Lage der Minima

Wir berechnen die Abstände gleich in geeichten Pixelwerten. Der Fehler ergibt sich als zwei mal der Fehler auf ein Pixel, quadratisch addiert.

```
dist_minima = {
   {1, 1091.40 Pixel - 924.73 Pixel},
   {2, 1173.65 Pixel - 844.64 Pixel},
   {3, 1255.90 Pixel - 758.06 Pixel},
   {4, 1338.15 Pixel - 677.98 Pixel},
   {5, 1418.24 Pixel - 595.73 Pixel},
   {6, 1496.16 Pixel - 511.31 Pixel}
 }
```

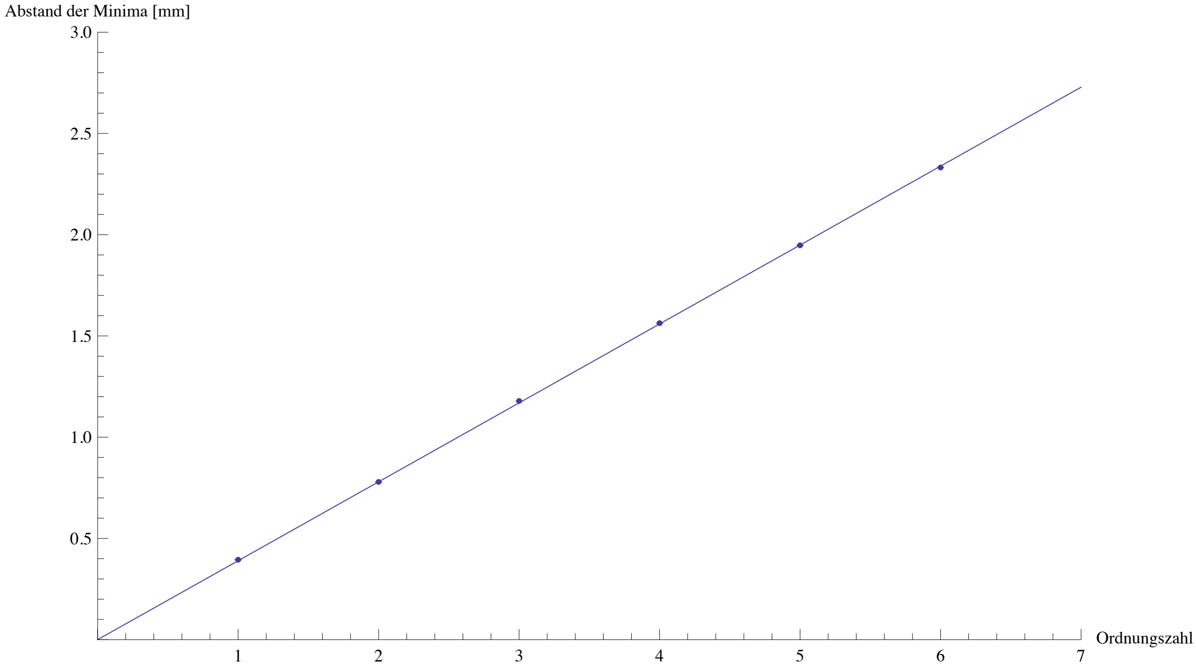
{{1, 0.394621 mm}, {2, 0.778989 mm}, {3, 1.17872 mm},
 {4, 1.56307 mm}, {5, 1.94744 mm}, {6, 2.33181 mm}}

```
plot_dist,minima = ErrorListPlot[Table[{QuantityMagnitude[dist_minima[[i]]],
      ErrorBar[√2 QuantityMagnitude[ΔPixel]]}, {i, 1, Length[dist_minima]}],
    AxesLabel → {"Ordnungszahl", "Abstand der Minima [mm]"},
    PlotRange → {{0, 7}, {0, 3}}];
```

```
fit_dist,minima =
 LinearModelFit[QuantityMagnitude[dist_minima], x, x, IncludeConstantBasis → False]
```

FittedModel[0.38977 x]

```
plotfit_{dist,minima} =
 Show[plot_{dist,minima}, Plot[fit_{dist,minima}[x], {x, 0, 7}], ImageSize → Full]
```




```
{m_1, Δm_1} =
 Quantity[fit_{dist,minima}["ParameterTableEntries"][[1, 1 ;; 2]], "Millimeters"]
```

{0.38977 mm, 0.00062334 mm}

Daraus können wir die Spaltbreite ermitteln (Herleitung siehe handgeschriebenes Dokument):

$$\{d_1, \Delta d_1\} = \frac{2\,\lambda\,f_1}{m_1}\left\{1, \frac{\Delta m_1}{m_1}\right\}$$

{0.260666 mm, 0.000416871 mm}

```
(d_1 // NumberForm[#, 4] &) ± (Δd_1 // NumberForm[#, 1] &)
```

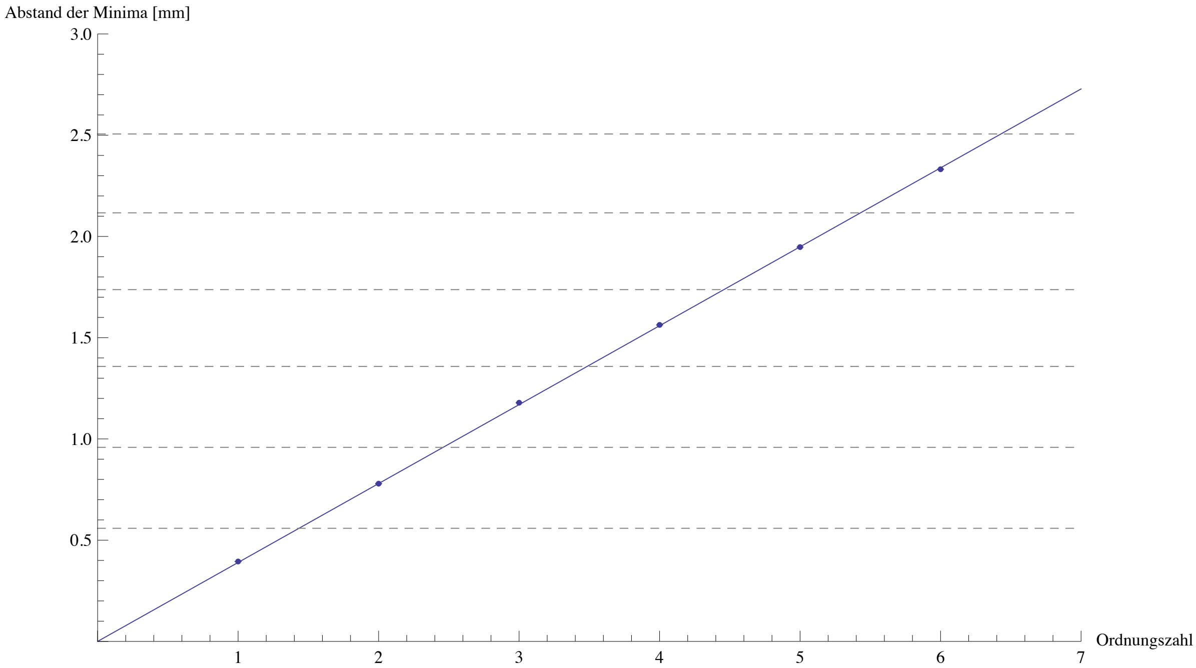
0.2607 mm ± 0.0004 mm

Lage der Maxima

```
dist_maxima = {
   1128.19 Pixel - 892.26 Pixel,
   1214.77 Pixel - 810.01 Pixel,
   1294.86 Pixel - 721.27 Pixel,
   1374.95 Pixel - 641.18 Pixel,
   1452.87 Pixel - 558.93 Pixel,
   1532.96 Pixel - 474.51 Pixel
  }
```

{0.558606 mm, 0.958341 mm, 1.35808 mm, 1.73733 mm, 2.11656 mm, 2.50607 mm}

```
Show[plotfit_{dist,minima}, Graphics[Join[{Gray, Dashed},
   Table[Line[Table[{x, QuantityMagnitude[dist_{maxima}[[i]]]}, {x, {0, 7}}]],
    {i, 1, Length[dist_{maxima}]}]]]]
```




```
ordmax =
 Flatten[Table[Solve[fit_{dist,minima}[x] == QuantityMagnitude[dist_{maxima}[[i]]], x],
    {i, 1, Length[dist_{maxima}]}]][[All, 2]]
```

{1.43317, 2.45873, 3.4843, 4.45732, 5.43028, 6.4296}

Der mittlere Fehler ist:

```
Mean[Abs[ordmax - Table[.5 + i, {i, 1, Length[ordmax]}]]]
```

0.0510987

Intensitätsverhältnisse

Für die Intensitätsverhältnisse ziehen wir allen Intensitätswerten das Mittel des Dunkelstromes ab.

```
dark_{1,unscaled} = Mean[{142.86, 139.19}]
```

141.025

```
intensities_{1,unscaled,raw} = {
   {0, 4880.34},
   {1, Mean[{395.60, 391.94}]},
   {2, Mean[{256.41, 223.44}]},
   {3, Mean[{216.12, 179.49}]},
   {4, Mean[{186.81, 158.73}]}
  };
```

```
intensities_{1,unscaled} = Table[i - {0, dark_{1,unscaled}}, {i, intensities_{1,unscaled,raw}}]
```

{{0, 4739.32}, {1, 252.745}, {2, 98.9}, {3, 56.78}, {4, 31.745}}

```
dark_{1,scaled} = Mean[{298.34, 260.64}]
```

279.49

```
intensities1,scaled,raw = {
    {1, Mean[{4634.08, 4849.86}]},
    {2, Mean[{2302.80, 2153.71}]},
    {3, Mean[{1200.57, 1098.05}]},
    {4, Mean[{680.78, 655.37}]},
    {5, Mean[{527.00, 494.24}]},
    {6, Mean[{461.31, 381.90}]}
  };
```

```
intensities1,scaled = Table[i - {0, dark1,scaled}, {i, intensities1,scaled,raw}]
```

{{1, 4462.48}, {2, 1948.77}, {3, 869.82}, {4, 388.585}, {5, 231.13}, {6, 142.115}}

```
intensity[n_, which_] := Select[intensities1,which, #[[1]] == n &][[1, 2]]
```

```
r11 = intensity[1, unscaled] / intensity[0, unscaled]
```

0.0533294

```
r12 = intensity[2, scaled] / intensity[1, scaled] *
  intensity[1, unscaled] / intensity[0, unscaled]
```

0.023289

```
r13 = intensity[3, scaled] / intensity[1, scaled] *
  intensity[1, unscaled] / intensity[0, unscaled]
```

0.0103949

```
r14 = intensity[4, scaled] / intensity[1, scaled] *
  intensity[1, unscaled] / intensity[0, unscaled]
```

0.00464383

```
r15 = intensity[5, scaled] / intensity[1, scaled] *
  intensity[1, unscaled] / intensity[0, unscaled]
```

0.00276215

```
r16 = intensity[6, scaled] / intensity[1, scaled] *
  intensity[1, unscaled] / intensity[0, unscaled]
```

0.00169836

Theoretisch sollten sich die Intensitäten mit $\frac{\sin^2\left(\frac{2n+1}{2}\pi\right)}{\left(\frac{2n+1}{2}\pi\right)^2}$ verhalten.

$$r1_{1,theor} = \frac{1}{((1+0.5)\,\pi)^2}$$

0.0450316

$$r1_{2,theor} = \frac{1}{((2+0.5)\,\pi)^2}$$

0.0162114

$$r1_{3,theor} = \frac{1}{((3+0.5)\,\pi)^2}$$

0.00827112

$$r1_{4,theor} = \frac{1}{((4+0.5)\,\pi)^2}$$

0.00500352

$$r1_{5,theor} = \frac{1}{((5+0.5)\,\pi)^2}$$

0.00334946

$$r1_{6,theor} = \frac{1}{((6+0.5)\,\pi)^2}$$

0.00239813

Wir bilden wieder die quadratischen Fehler (gerundet auf eine Stelle):

```
Table[Abs[r1_i - r1_{i,theor}], {i, 1, 6}] // NumberForm[#, 1] &
```

{0.008, 0.007, 0.002, 0.0004, 0.0006, 0.0007}

Aufgabe 2

Berechnung des Spaltbildes mit den Werten aus Aufgabe 4:

```
PhysicalPixel = Quantity[14, "Micrometers"]
```

14 μm

Brennweite ist oben gesetzt.

Bildweite:

```
b = Quantity[730, "Millimeters"]
```

730 mm

```
B_width = Mean[{130.86 PhysicalPixel, 124.29 PhysicalPixel}]
```

1786.05 μm

```
B_distance = 338.20 PhysicalPixel
```

4734.8 μm

Aus der Abbildungsgleichung folgt $G = \frac{B f}{b - f}$.

$$d = \frac{B_{width}\, f_1}{b - f_1}$$

219.822 μm

$$g = \frac{B_{distance}\, f_1}{b - f_1}$$

582.745 μm

$$\frac{g}{d}$$

2.65099

In[273]:= **dm = QuantityMagnitude[UnitConvert[d]]**

Out[273]= 0.000219822

In[274]:= **gm = QuantityMagnitude[UnitConvert[g]]**

Out[274]= 0.000582745

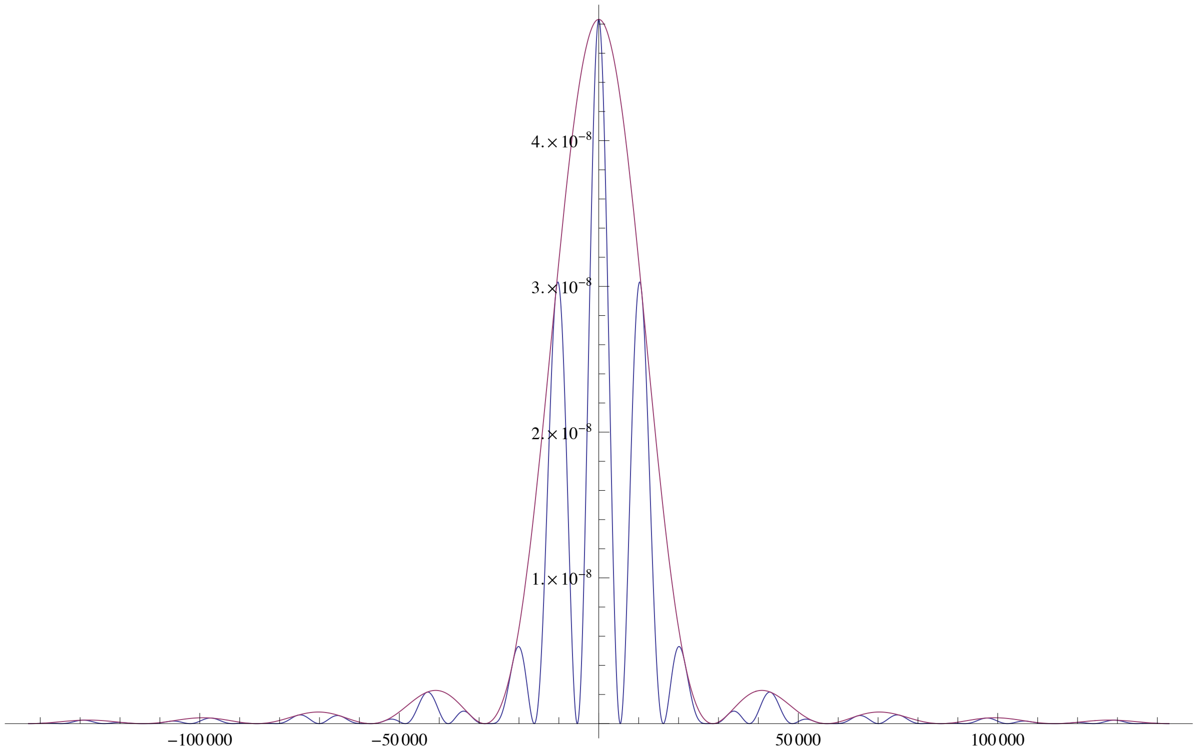
In[275]:= **functions =** $\left\{\mathrm{Cos}\left[k\,\frac{gm}{2}\right]^2, 1\right\} dm^2\,\frac{\mathrm{Sin}\left[k\,\frac{dm}{2}\right]^2}{\left(k\,\frac{dm}{2}\right)^2}$

Out[275]= $\left\{\frac{4.\,\mathrm{Cos}[0.000291372\,k]^2\,\mathrm{Sin}[0.000109911\,k]^2}{k^2}, \frac{4.\,\mathrm{Sin}[0.000109911\,k]^2}{k^2}\right\}$

In[281]:= $\mathbf{plot}_{\mathbf{doppelspalt,theor}}$ **=**

Plot$\left[\mathbf{functions}, \left\{k, -5\,\frac{2\,\pi}{dm}, 5\,\frac{2\,\pi}{dm}\right\}, \mathbf{PlotRange} \to \mathbf{Full}, \mathbf{ImageSize} \to \mathbf{Full}\right]$

Out[281]=



Intensitäten der Maxima

In[282]:=
```
intensities2,raw = {
   {0, 4611.31},
   {1, Mean[{2948.12, 2980.11}]},
   {2, Mean[{490.29, 461.80}]}
 }
```

Out[282]= {{0, 4611.31}, {1, 2964.12}, {2, 476.045}}

$\mathbf{dark}_2$ **= Mean[{173.14, 140.53}]**

156.835

In[283]:= $\mathbf{intensities}_2$ **= Table[i - {0,** $\mathbf{dark}_2$**}, {i,** $\mathbf{intensities}_{2,raw}$**}]**

Out[283]= {{0, 4454.48}, {1, 2807.28}, {2, 319.21}}

Verhältnisse der Maxima (0:1, 0:2)

```
r2₁ = intensities₂[[2, 2]] / intensities₂[[1, 2]]
```

0.630216

```
r2₂ = intensities₂[[3, 2]] / intensities₂[[1, 2]]
```

0.0716605

Theoretische Werte:

In[284]:= $r2_{1,theor} = \frac{\text{Sin}\left[\pi \frac{d}{g} 1\right]^2}{\left(\pi \frac{d}{g} 1\right)^2}$

Out[284]= 0.611264

In[285]:= $r2_{2,theor} = \frac{\text{Sin}\left[\pi \frac{d}{g} 2\right]^2}{\left(\pi \frac{d}{g} 2\right)^2}$

Out[285]= 0.0865274

Die Fehler:

In[204]:= $\text{Table}[\text{Abs}[r2_i - r2_{i,theor}], \{i, 1, 2\}] \text{ // NumberForm}[\#, 1] \&$

Out[204]//NumberForm=
{0.02, 0.01}

Aufgabe 3

In[263]:= $F_{einzelspalt}[ky\_] := dv \frac{\text{Sin}[ky\, dv / 2]}{(ky\, dv / 2)}$

In[293]:= $f_{einzelspalt,mod}[y\_, kn\_] := \text{Integrate}\left[\frac{1}{\pi} F_{einzelspalt}[ky] \text{Cos}[ky\, y], \{ky, 0, kn\}\right]$

In[294]:= $k_y[n\_, dv\_] := \frac{2 \pi n}{dv}$

In[295]:= $f_{einzelspalt,mod,1}[y\_] = \left(f_{einzelspalt,mod}\left[y, k_y[1, dm]\right] /. \{dv \to dm, gv \to gm\}\right);$

In[296]:= $f_{einzelspalt,mod,2}[y\_] = \left(f_{einzelspalt,mod}\left[y, k_y[2, dm]\right] /. \{dv \to dm, gv \to gm\}\right);$

In[312]:= $f_{einzelspalt,mod,3}[y\_] = \left(f_{einzelspalt,mod}\left[y, k_y[3, dm]\right] /. \{dv \to dm, gv \to gm\}\right);$

In[303]:= $norm = \text{FindMaximum}\left[f_{einzelspalt,mod,1}[y], \{y, 0\}\right] \text{ // First}$

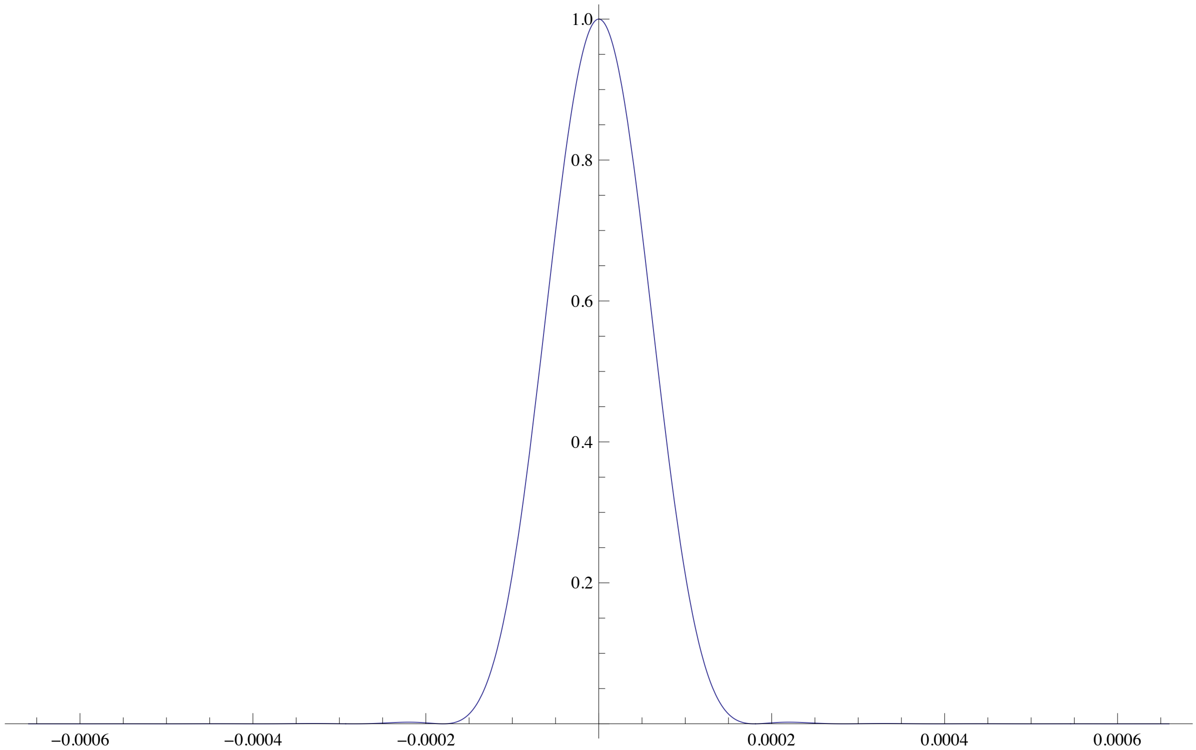
FindMaximum::lstol :
The line search decreased the step size to within the tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient increase in the function. You may need more than MachinePrecision digits of working precision to meet these tolerances. ≫

Out[303]= 1.17898

0. Beugungsordnung

In[401]:=
$$\text{Plot}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,1}}[y]\right)^2, \{y, -3*dm, 3*dm\}, \text{PlotRange} \to \text{Full}, \text{ImageSize} \to \text{Full}\right]$$

Out[401]=



Vergleich der theoretischen mit den gemessenen Werten:

In[317]:= $\text{maxima}_{\text{einzelspalt,1,theor}} = \{\{0, 1\}\}$

Out[317]= {{0, 1}}

In[323]:=
$$\text{minima}_{\text{einzelspalt,1,theor}} = \{\{\text{min}, 0\}, \{-\text{min}, 0\}\} \;/.\; \text{min} \to \text{FindMinimum}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,1}}[y]\right)^2, \{y, -\text{dm}, \text{dm}\}\right][[2, 1, 2]]$$

Out[323]= {{-0.000180088, 0}, {0.000180088, 0}}

Wir wählen die Mitte anhand der Lage des jeweils mittig gemessenen Extremums.

In[326]:= $\text{dark}_{\text{einzelspalt,1}} = 148.87$

Out[326]= 148.87

In[327]:= $\text{maxima}_{\text{einzelspalt,1}} = \{\{0, 4723.72 - \text{dark}_{\text{einzelspalt,1}}\}\}$

Out[327]= {{0, 4574.85}}

In[328]:=
$$\text{minima}_{\text{einzelspalt,1}} = \{\{-123.73, 159.01 - \text{dark}_{\text{einzelspalt,1}}\}, \{120.34, 160.01 - \text{dark}_{\text{einzelspalt,1}}\}\}$$

Out[328]= {{-123.73, 10.14}, {120.34, 11.14}}

Hier gibt es nicht viel zu vergleichen, da es nur wenige Referenzpunkte gibt. Da die Minima bei 0 liegen sollten, können wir keine Verhältnisse vergleichen, und über die Lagen der Minima können wir auch nicht mehr sagen, als daß sie symmetrisch sein sollten. Da die Höhen- und Breitenachsen unabhängig voneinander sind, läßt sich hier auch nichts sagen.

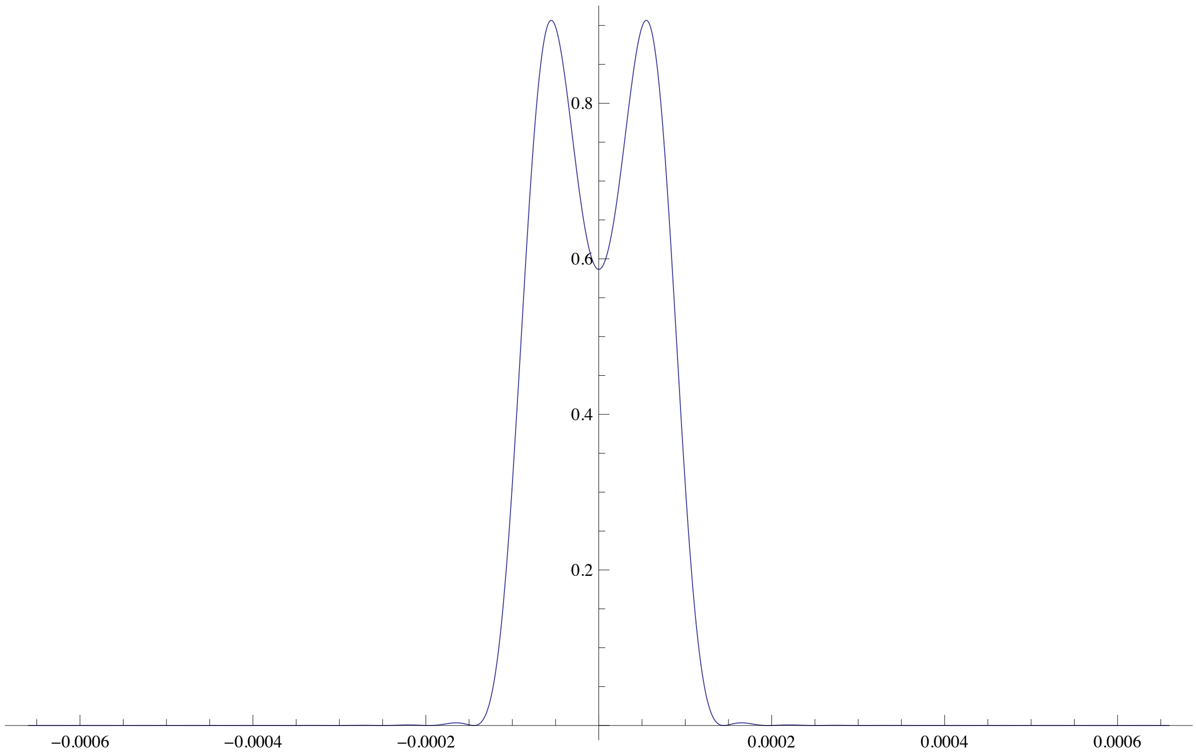
Die Abweichung von der Symmetrie läßt sich indes (in Pixeln) quantifizieren:

In[343]:=
```
StandardDeviation[Abs[minima_einzelspalt,1[[All, 1]]]]
```
Out[343]= 2.39709

0. und 1. Beugungsordnung

In[402]:=
$$\text{Plot}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,2}}[y]\right)^2,\ \{y, -3*dm, 3*dm\},\ \text{PlotRange} \to \text{Full},\ \text{ImageSize} \to \text{Full}\right]$$

Out[402]=



In[366]:=
$$\text{rawmax} = \text{FindMaximum}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,2}}[y]\right)^2,\ \{y, -dm/2, 0\}\right]$$

Out[366]= {0.906618, {y → -0.0000549554}}

In[337]:=
```
maxima_einzelspalt,2,theor = {{max, value}, {-max, value}} /.
   {value → (rawmax // First), max → rawmax[[2, 1, 2]]}
```
Out[337]= {{-0.0000549554, 0.906618}, {0.0000549554, 0.906618}}

In[372]:= $\text{minima}_{\text{einzelspalt,2,theor}} = \{\{0, \text{min}\}\} \text{ /. min -> FindMinimum}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,2}}[y]\right)^2, \{y, 0\}\right][[1]]$

FindMinimum::fmgz : Encountered a gradient that is effectively zero. The result returned may not be a minimum; it may be a maximum or a saddle point. ≫

Out[372]= {{0, 0.586399}}

Gemessene Werte:

In[339]:= $\text{dark}_{\text{einzelspalt,2}} = 153.19$

Out[339]= 153.19

In[340]:= $\text{maxima}_{\text{einzelspalt,2}} = \{\{-35.59, 4415.61 - \text{dark}_{\text{einzelspalt,2}}\}, \{37.29, 4442.13 - \text{dark}_{\text{einzelspalt,2}}\}\}$

Out[340]= {{-35.59, 4262.42}, {37.29, 4288.94}}

In[341]:= $\text{minima}_{\text{einzelspalt,2}} = \{\{0, 3168.46 - \text{dark}_{\text{einzelspalt,2}}\}\}$

Out[341]= {{0, 3015.27}}

Die Abweichung von der Symmetrie läßt sich auch hier in Pixeln quantifizieren:

In[344]:= $\text{StandardDeviation}[\text{Abs}[\text{maxima}_{\text{einzelspalt,2}}[[\text{All}, 1]]]]$

Out[344]= 1.20208

Die gemessenen Intensitäten von Maxima und Minima, normiert auf die Intensität des Maximums bei einer zugelassenen Beugungsordnung, lassen sich hier mit den theoretischen Werten vergleichen.

In[356]:= $I_{2,\text{max,links,theor}} = \text{maxima}_{\text{einzelspalt,2,theor}}[[1, 2]]$

Out[356]= 0.906618

In[357]:= $I_{2,\text{max,rechts,theor}} = \text{maxima}_{\text{einzelspalt,2,theor}}[[2, 2]]$

Out[357]= 0.906618

In[358]:= $I_{2,\text{min,theor}} = \text{minima}_{\text{einzelspalt,2,theor}}[[1, 2]]$

Out[358]= 0.586399

In[359]:= $I_{2,\text{max,links}} = \text{maxima}_{\text{einzelspalt,2}}[[1, 2]] / \text{maxima}_{\text{einzelspalt,1}}[[1, 2]]$

Out[359]= 0.931707

In[360]:= $I_{2,\text{max,rechts}} = \text{maxima}_{\text{einzelspalt,2}}[[2, 2]] / \text{maxima}_{\text{einzelspalt,1}}[[1, 2]]$

Out[360]= 0.937504

In[361]:= $I_{2,\text{min}} = \text{minima}_{\text{einzelspalt,2}}[[1, 2]] / \text{maxima}_{\text{einzelspalt,1}}[[1, 2]]$

Out[361]= 0.659097

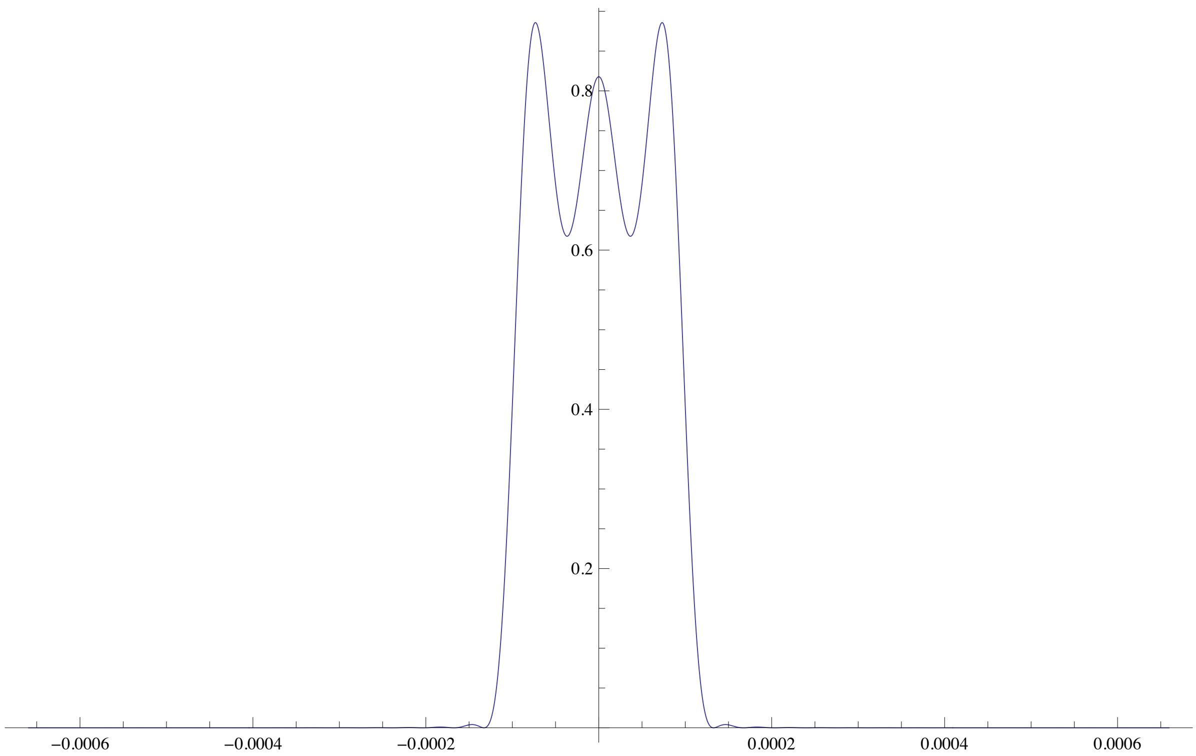
Die Fehler (links, rechts, mitte):

In[363]:=
```
Abs[{I2,max,links,theor - I2,max,links, I2,max,rechts,theor - I2,max,rechts, I2,min,theor - I2,min}] //
  NumberForm[#, 1] &
```
Out[363]//NumberForm=
```
{0.03, 0.03, 0.07}
```

0., 1. und 2. Beugungsordnung

In[403]:=
$$\text{Plot}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,3}}[y]\right)^2,\ \{y, -3*dm, 3*dm\},\ \text{PlotRange}\to\text{Full},\ \text{ImageSize}\to\text{Full}\right]$$

Out[403]=



In[365]:=
$$\text{rawmax2} = \text{FindMaximum}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,3}}[y]\right)^2,\ \{y, -dm/2, 0\}\right]$$

Out[365]= {0.885764, {y → -0.0000732739}}

In[368]:=
$$\text{maxima}_{\text{einzelspalt,3,theor}} = \{\{\text{max}, \text{value}\}, \{0, \text{val0}\}, \{-\text{max}, \text{value}\}\} \text{ /. } \Big\{\text{value}\to(\text{rawmax2 // First}),\ \text{max}\to\text{rawmax2}[[2,1,2]],\ \text{val0} \text{ -> } \text{FindMaximum}\left[\frac{1}{\text{norm}^2}\left(f_{\text{einzelspalt,mod,3}}[y]\right)^2,\ \{y, 0\}\right][[1]]\Big\}$$

FindMaximum::lstol :
The line search decreased the step size to within the tolerance specified by AccuracyGoal and PrecisionGoal but was unable to find a sufficient increase in the function. You may need more than MachinePrecision digits of working precision to meet these tolerances. ≫

Out[368]= {{-0.0000732739, 0.885764}, {0, 0.817812}, {0.0000732739, 0.885764}}

In[369]:=
```
rawmin = FindMinimum[1/norm^2 (f_{einzelspalt,mod,3}[y])^2, {y, -dm / 4, 0}]
```
Out[369]= {0.6174, {y → -0.0000366369}}

In[371]:=
```
minima_{einzelspalt,3,theor} =
  {{-min, value}, {min, value}} /. {min → rawmin[[2, 1, 2]], value → rawmin[[1]]}
```
Out[371]= {{0.0000366369, 0.6174}, {-0.0000366369, 0.6174}}

Gemessene Werte:

In[373]:=
```
dark_{einzelspalt,3} = 142.56
```
Out[373]= 142.56

In[374]:=
```
maxima_{einzelspalt,3} = {
   {-49.15, 4349.02 - dark_{einzelspalt,3}},
   {0, 4087.69 - dark_{einzelspalt,3}},
   {50.85, 4315.42 - dark_{einzelspalt,3}}
  }
```
Out[374]= {{-49.15, 4206.46}, {0, 3945.13}, {50.85, 4172.86}}

In[375]:=
```
minima_{einzelspalt,3} = {
   {-22.03, 3342.61 - dark_{einzelspalt,3}},
   {25.42, 3329.48 - dark_{einzelspalt,3}}
  }
```
Out[375]= {{-22.03, 3200.05}, {25.42, 3186.92}}

Die Abweichung von der Symmetrie:

In[382]:=
```
Mean[{StandardDeviation[Abs[minima_{einzelspalt,3}[[All, 1]]]],
    StandardDeviation[Abs[maxima_{einzelspalt,3}[[{1, -1}, 1]]]]}] // NumberForm[#, 3] &
```
Out[382]//NumberForm=
1.8

Nun können wir wieder die Intensitäten vergleichen:

Theoretisch:

In[394]:=
```
I_{3,max,1,theor} = maxima_{einzelspalt,3,theor}[[1, 2]]
```
Out[394]= 0.885764

In[384]:=
```
I_{3,max,2,theor} = maxima_{einzelspalt,3,theor}[[2, 2]]
```
Out[384]= 0.817812

In[385]:=
```
I_{3,max,3,theor} = maxima_{einzelspalt,3,theor}[[3, 2]]
```
Out[385]= 0.885764

In[386]:=
```
I_{3,min,1,theor} = minima_{einzelspalt,3,theor}[[1, 2]]
```
Out[386]= 0.6174

In[387]:=
```
I_{3,min,2,theor} = minima_{einzelspalt,3,theor}[[2, 2]]
```
Out[387]= 0.6174

Gemessen:

In[388]:= $I_{3,max,1}$ = $maxima_{einzelspalt,3}$[[1, 2]] / $maxima_{einzelspalt,1}$[[1, 2]]

Out[388]= 0.919475

In[389]:= $I_{3,max,2}$ = $maxima_{einzelspalt,3}$[[2, 2]] / $maxima_{einzelspalt,1}$[[1, 2]]

Out[389]= 0.862352

In[390]:= $I_{3,max,3}$ = $maxima_{einzelspalt,3}$[[3, 2]] / $maxima_{einzelspalt,1}$[[1, 2]]

Out[390]= 0.91213

In[391]:= $I_{3,min,1}$ = $minima_{einzelspalt,3}$[[1, 2]] / $maxima_{einzelspalt,1}$[[1, 2]]

Out[391]= 0.699487

In[392]:= $I_{3,min,2}$ = $minima_{einzelspalt,3}$[[2, 2]] / $maxima_{einzelspalt,1}$[[1, 2]]

Out[392]= 0.696617

Mittlerer Fehler der Maxima:

In[398]:= Mean[Table[Abs[$I_{3,max,i}$ - $I_{3,max,i,theor}$], {i, 1, 3}]] // NumberForm[#, 1] &

Out[398]//NumberForm=
0.03

Mittlerer Fehler der Minima:

In[399]:= Mean[Table[Abs[$I_{3,min,i}$ - $I_{3,min,i,theor}$], {i, 1, 2}]] // NumberForm[#, 1] &

Out[399]//NumberForm=
0.08

Aufgabe 4

In[465]:= dml = QuantityMagnitude[d]

Out[465]= 219.822

In[466]:= gml = QuantityMagnitude[g]

Out[466]= 582.745

In[431]:= $F_{doppelspalt}$[ky_] := 2 dv Cos[ky gv / 2] $\frac{\text{Sin[ky dv / 2]}}{\text{(ky dv / 2)}}$

Wir führen Fouriersynthese durch:

In[458]:= $f_{doppelspalt,mod}$[y_, kn_] := Integrate[$\frac{1}{\pi}$ $F_{doppelspalt}$[ky] Cos[ky y], {ky, 0, kn}]

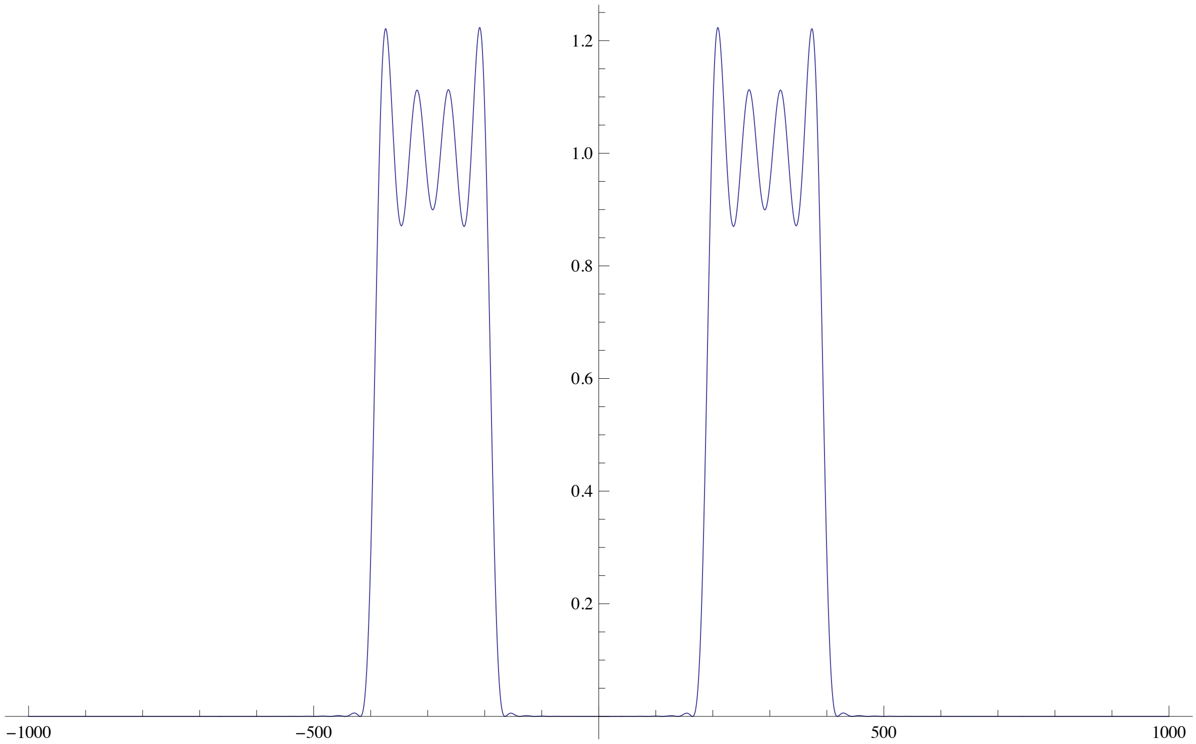
In[459]:= k_y[n_, dv_] := $\frac{2\,\pi\,n}{dv}$

Und vollziehen die experimentell erhaltenen Bilder nach:

In[467]:= $f_{doppelspalt,mod,4}$[y_] = $f_{doppelspalt,mod}$[y, k_y[4, dv]] /. {dv → dml, gv → gml}

Out[467]=
$$\frac{1}{\pi}\left(\text{SinIntegral}[0.0571662\,(-362.923-2\,y)]+\text{SinIntegral}[0.0571662\,(802.566-2\,y)]+\text{SinIntegral}[0.0571662\,(-362.923+2\,y)]+\text{SinIntegral}[0.0571662\,(802.566+2\,y)]\right)$$

In[469]:= Plot[($f_{doppelspalt,mod,4}$[y])^2, {y, -1000, 1000}, PlotRange → All, ImageSize → Full]

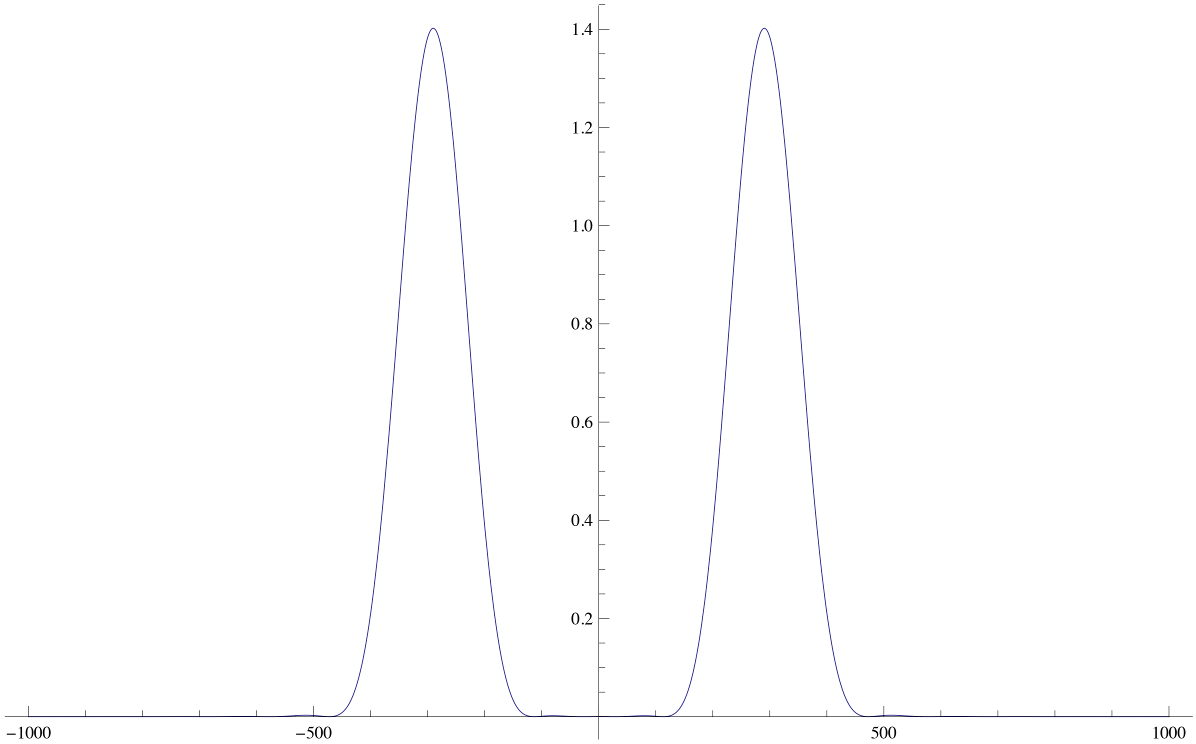
Out[469]=


In[473]:= $f_{doppelspalt,mod,1}$[y_] = $f_{doppelspalt,mod}$[y, k_y[1, dv]] /. {dv → dml, gv → gml}

Out[473]=
$$\frac{1}{\pi}\left(\text{SinIntegral}[0.0142916\,(-362.923-2\,y)]+\text{SinIntegral}[0.0142916\,(802.566-2\,y)]+\text{SinIntegral}[0.0142916\,(-362.923+2\,y)]+\text{SinIntegral}[0.0142916\,(802.566+2\,y)]\right)$$

In[471]:= **Plot[$(f_{doppelspalt,mod,1}[y])^2$, {y, -1000, 1000}, PlotRange → All, ImageSize → Full]**

Out[471]=

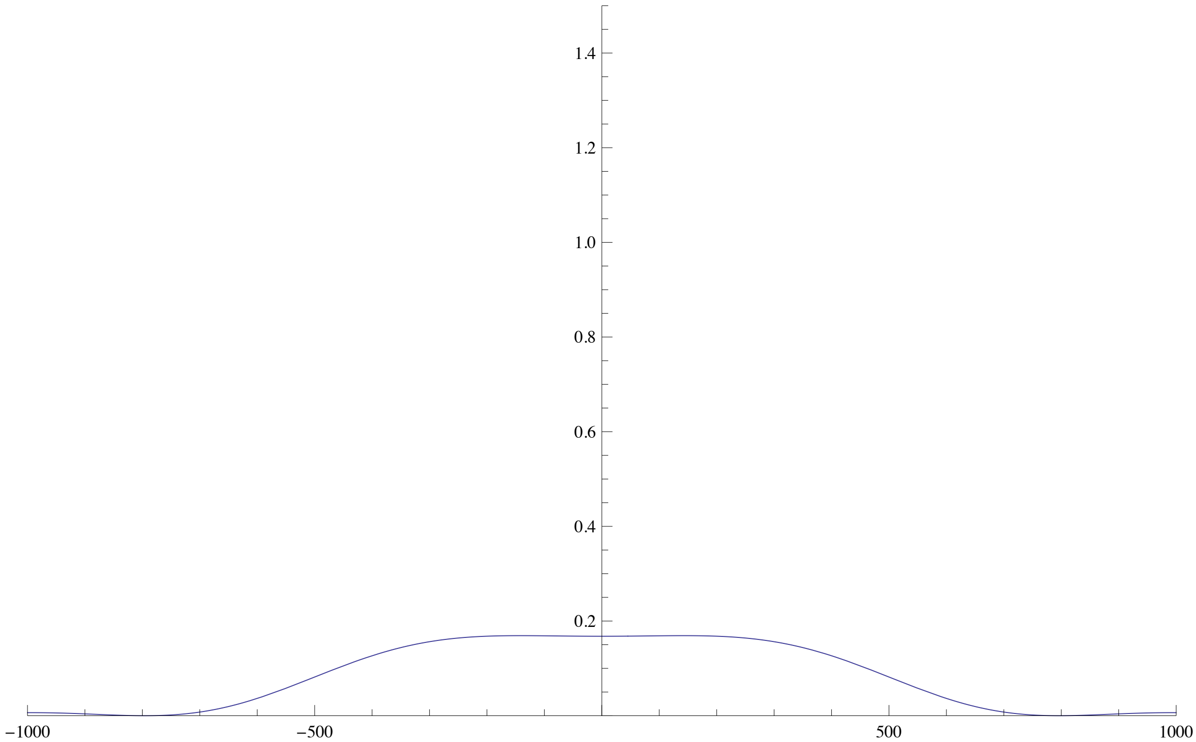


In[474]:= **$f_{doppelspalt,mod,n}$[y_] = $f_{doppelspalt,mod}$[y, k_y[n, dv]] /. {dv → dml, gv → gml}**

Out[474]= $\frac{1}{\pi}$ (SinIntegral[0.0142916 n (-362.923 - 2 y)] +
SinIntegral[0.0142916 n (802.566 - 2 y)] + SinIntegral[
0.0142916 n (-362.923 + 2 y)] + SinIntegral[0.0142916 n (802.566 + 2 y)])

In[485]:=
```
Plot[(f_{doppelspalt,mod,n}[y] /. {n → 0.255})^2, {y, -1000, 1000},
  PlotRange → {{-1000, 1000}, {0, 1.5}}, ImageSize → Full]
```

Out[485]=



Der Grenzwert für k_y ist beim letzten Bild:

In[511]:=
```
k_y[.255, dm]
```

Out[511]= 7288.7

Den experimentellen Wert für k_y errechnen wir so:

In[516]:=
```
{Δ, ΔΔ} = UnitConvert[1/2 Quantity[{.125, .01}, "Millimeters"]]
```

Out[516]= $\{0.0000625\,\text{m}, 5.\times 10^{-6}\,\text{m}\}$

In[517]:=
```
{k_{y,exp}, Δk_{y,exp}} = UnitConvert[(2 π)/(λ f_1) {Δ, ΔΔ}]
```

Out[517]= {7730.3 per meter, 618.424 per meter}

Sieht nach σ-Übereinstimmung aus.