

DO.001 Design of Diffractive Diffuser for Generation of Line Focus

Example for the design of a diffractive optical element for diffuse deflection of light along the x-axis.

Keywords: Diffractive Optics, Diffractive Optical Elements, Diffusers, Line Focus

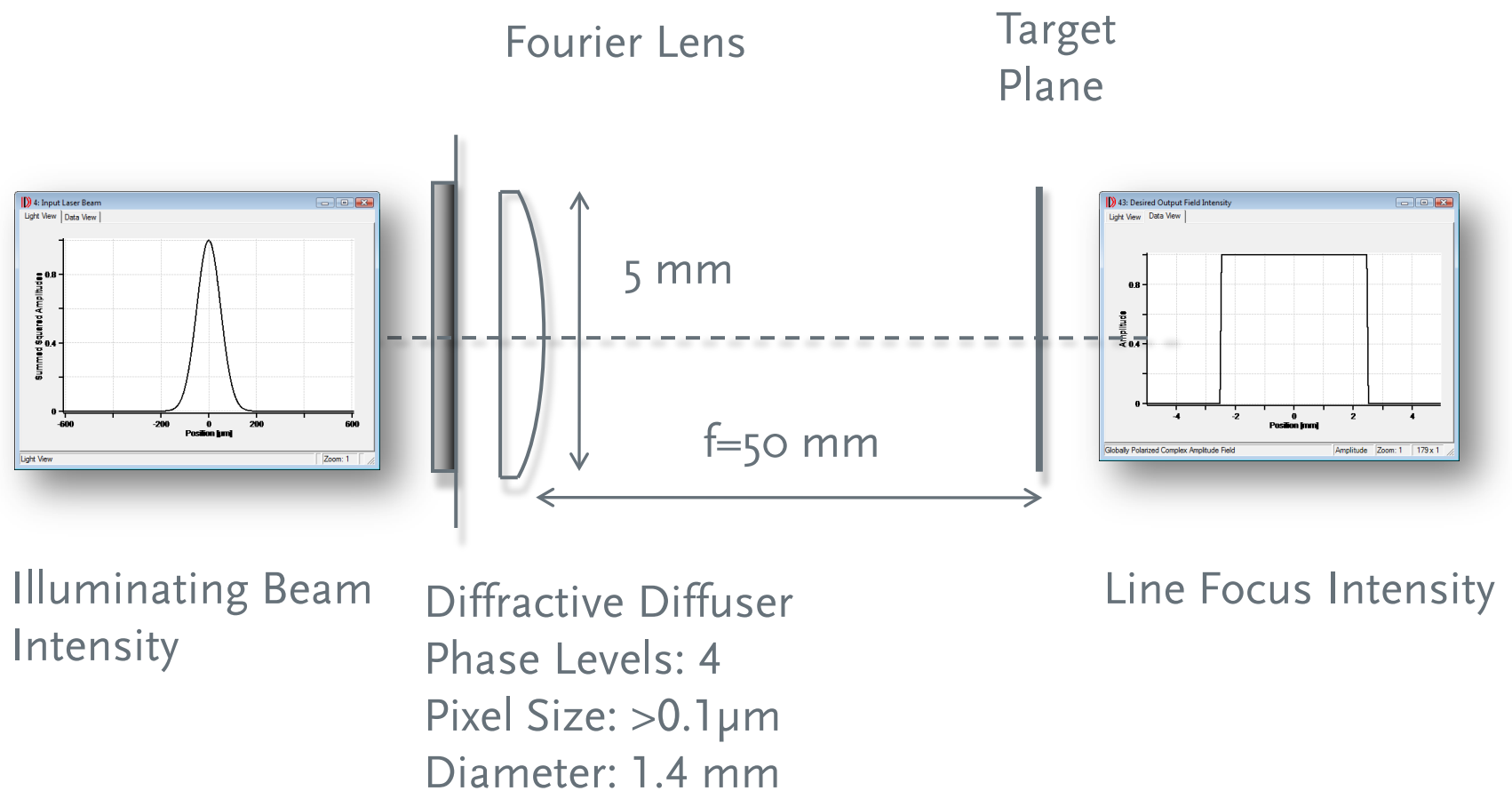
Required Toolboxes: Diffractive Optics Toolbox

Related Application Scenarios: DO.002;DO.003

Related Tutorials: 144.01

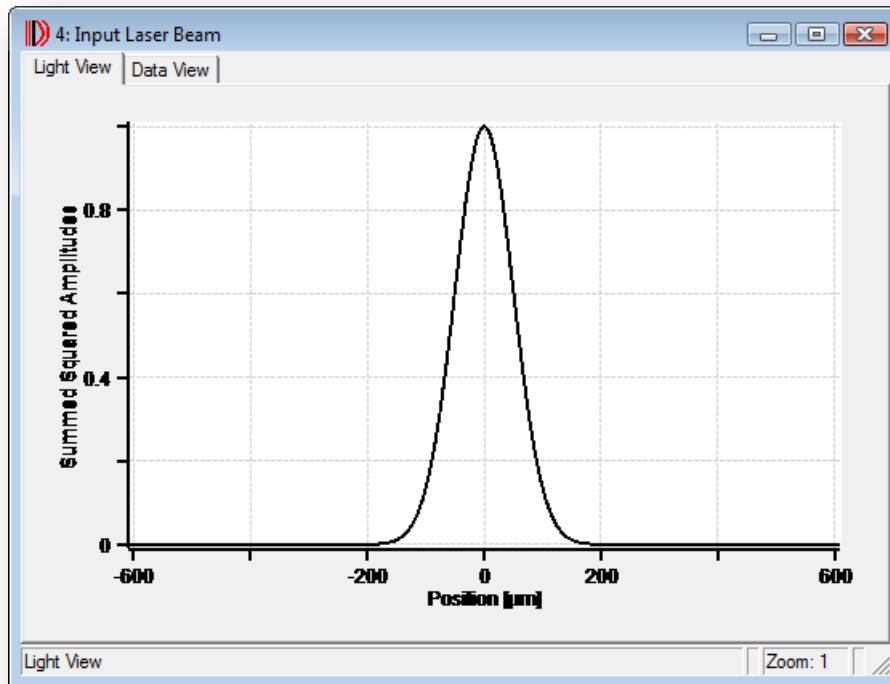


Modeling Task



Modeling Task

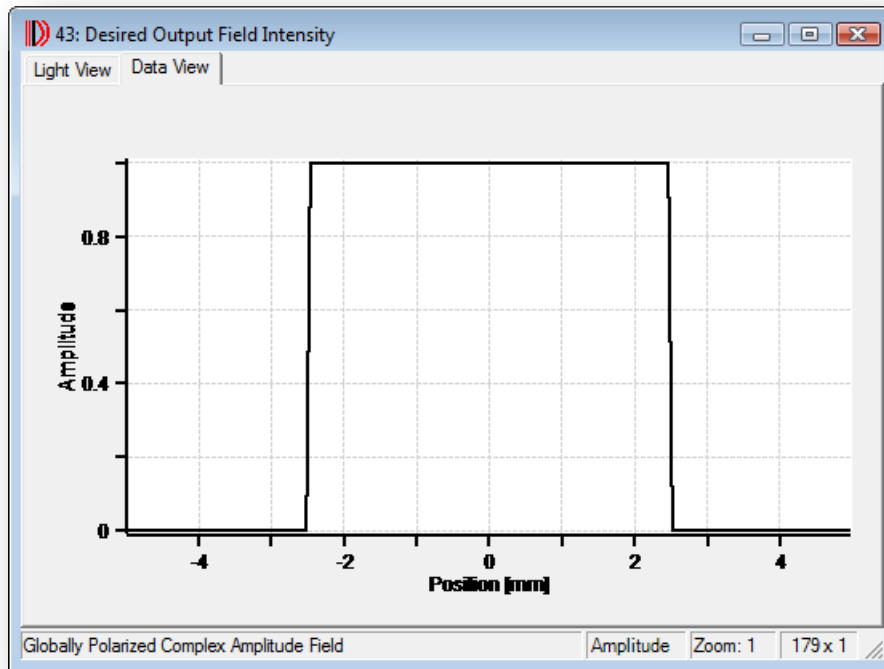
Illuminating Beam Parameters



Wavelength: 632.8 nm
Laser Beam
Diameter ($1/e^2$): 700 μm

Modeling Task

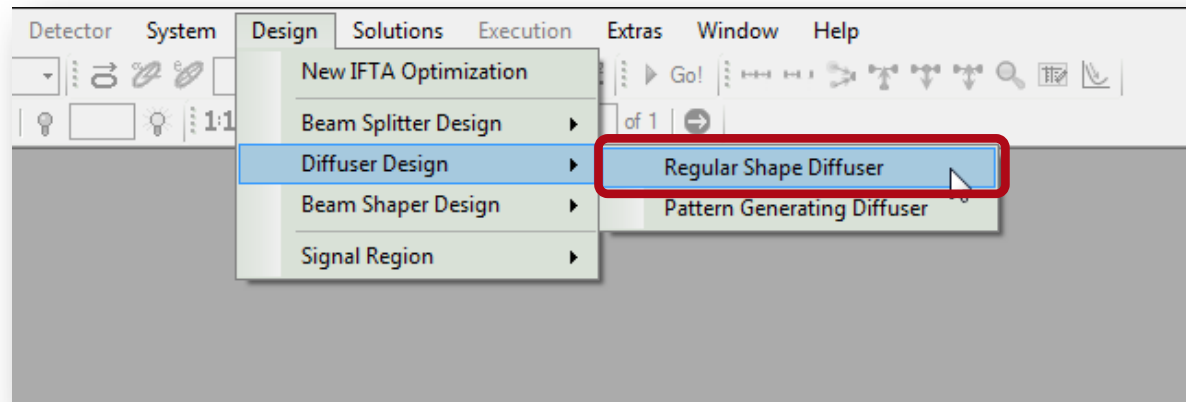
Desired Output Field Parameters



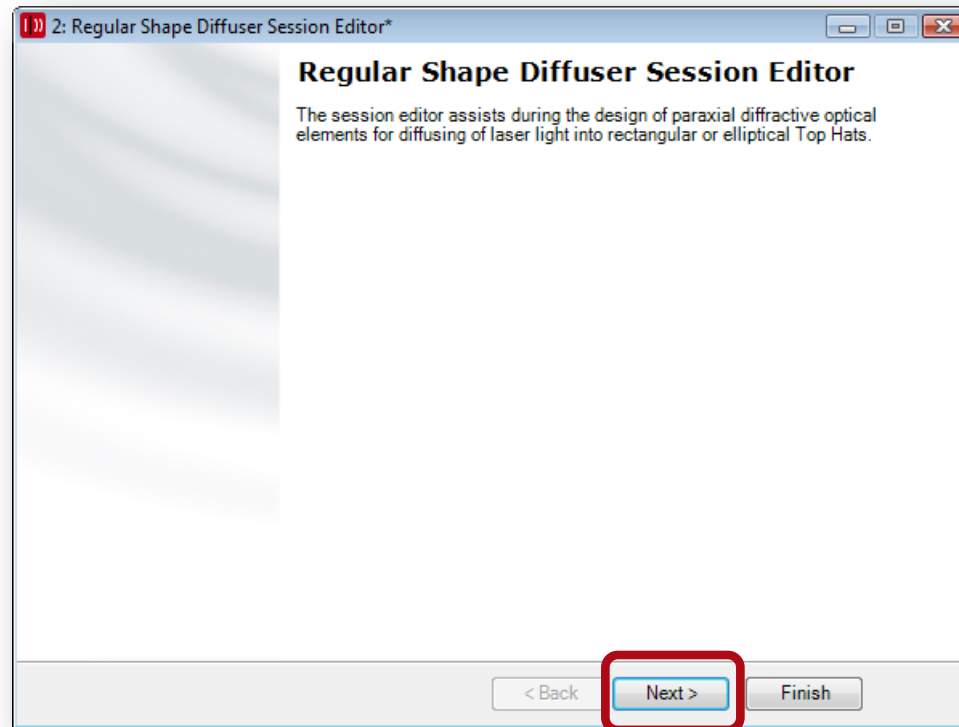
Diameter: 5 mm
Efficiency: >80 %
Noise limit: 5 %

The final light distribution will contain speckles because of coherent illumination!!!

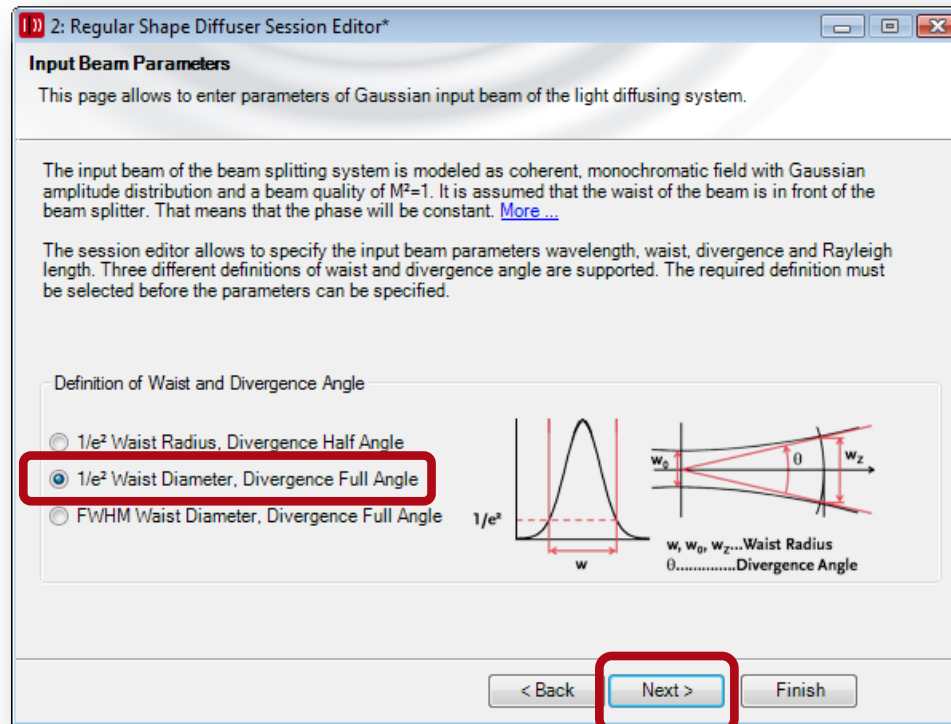
Setup of Design Parameters



1. Illuminating Beam Specification



1. Illuminating Beam Specification



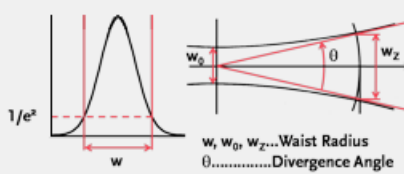
1. Illuminating Beam Specification

2: Regular Shape Diffuser Session Editor*

Input Beam Parameters

This page allows to enter parameters of Gaussian input beam of the light diffusing system.

The parameters of the input beam can be entered below. VirtualLab will use an input beam with $M^2=1$ and Gaussian amplitude profile for the simulation. This requires just the specification of waist, divergence angle or Rayleigh length since these parameters depend on each other.



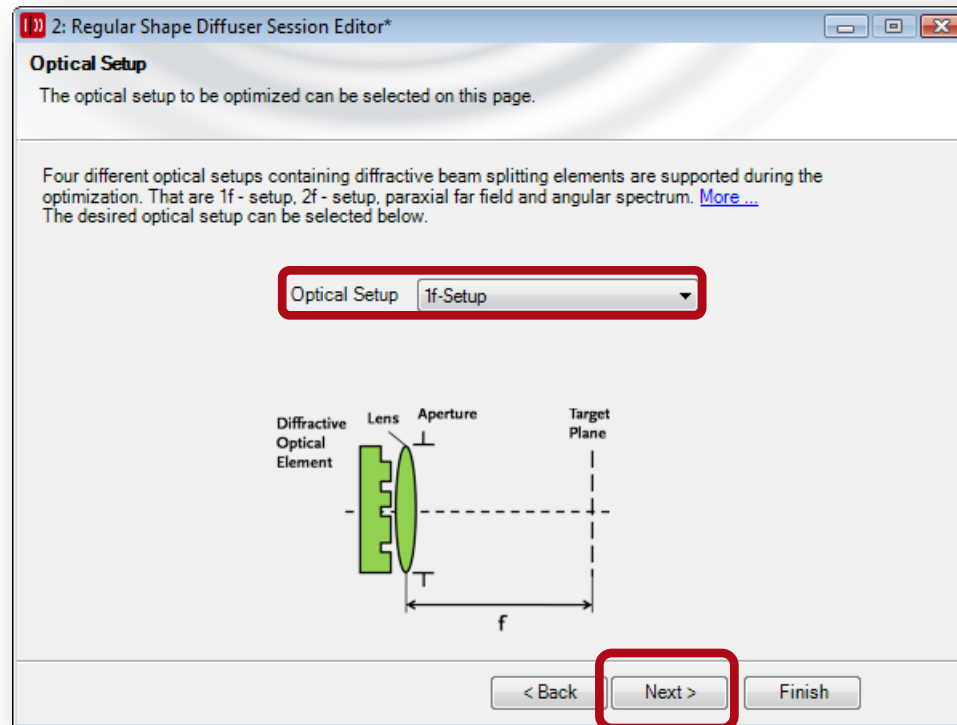
$w, w_0, w_z \dots$ Waist Radius
 $\theta \dots \dots \dots$ Divergence Angle

Input Beam Parameters

Wavelength	632.8 nm	
<input checked="" type="radio"/> Waist	700 μm	700 μm
<input type="radio"/> Divergence Angle	0.065948°	0.065948°
<input type="radio"/> Rayleigh Length	608.16 mm	608.16 mm

< Back **Next >** Finish

2. Optical Setup



2. Optical Setup

2: Regular Shape Diffuser Session Editor*

Optical Setup

The parameters of the optical setup selected on the page before can be specified below.

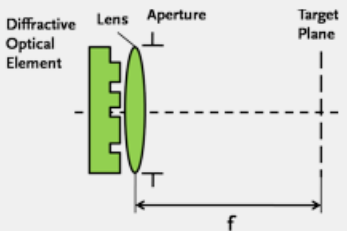
Optical Setup Parameters

Effective Focal Length of Lens

Lens Aperture Shape ☐ Rectangular ☒ Elliptical

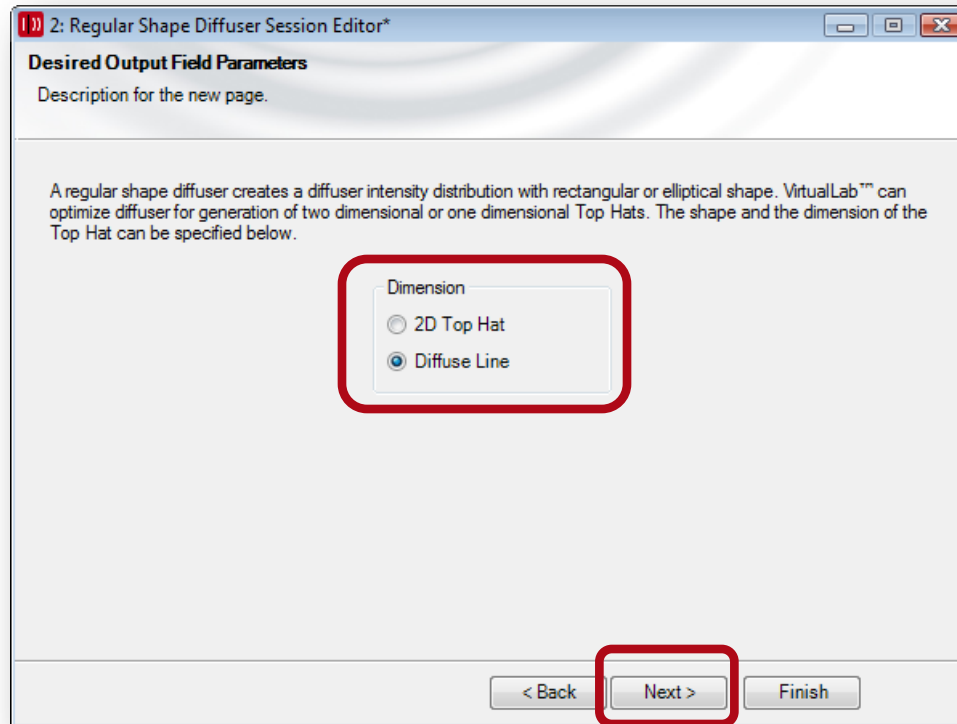
Lens Aperture Diameter

Surrounding Medium: Standard Air in Homogeneous Medium



< Back **Next >** Finish

3. Desired Output Field Specification



3. Desired Output Field Specification

2: Regular Shape Diffuser Session Editor*

Desired Output Field Parameters

Parameters of the diffuse light pattern can be specified below.

Top Hat diameter and resolution can be specified below. In order to get an optimal resolved speckle pattern the laser beam diameter ($1/e^2$) in the target plane should be approximately two times the resolution of the diffuser. It is recommended to use the 'Optimize Resolution' button to adapt the resolution on the beam diameter. Additionally an offset of the diffraction orders can be specified and the intensity of the higher orders relative to the desired orders can be limited. [More...](#)

Specification of Orders

Top Hat Diameter: 5 mm

Resolution: 30 μm Optimize Resolution

Off-Axis Design

Offset: 0 m Suggest Optional Offset

Stray Light Intensity

☒ Limit Intensity of Stray Light

Maximum Relative Stray Light Intensity: 1 %

< Back Next > Finish

Automatically calculated but can be modified by user.

The stray light limit can be smaller.

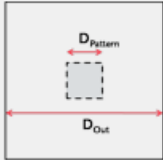
3. Desired Output Field Specification

2: Regular Shape Diffuser Session Editor*

Output Field Diameter

This page allows the manual adjustment of the area in the output plane that is used for distribution of stray light.

A rectangular area symmetric to the optical axis is reserved in the target plane for the creation of the desired light pattern. Around this light pattern another rectangular region is used for the distribution of the stray light. The ratio between output field diameter and light pattern diameter is expressed by a diameter factor. The diameter factor is automatically adjusted by the session editor. A user defined change is possible below.
[More...](#)



$a = D_{Out} / D_{Pattern}$
 a – Diameter Factor
 D_{out} – Diameter Output Field
 $D_{Pattern}$ – Diameter Light Pattern

Output Field Size

☒ Automatic Adjustment of Output Field Diameter ☐ Manual Adjustment of Output Field Diameter

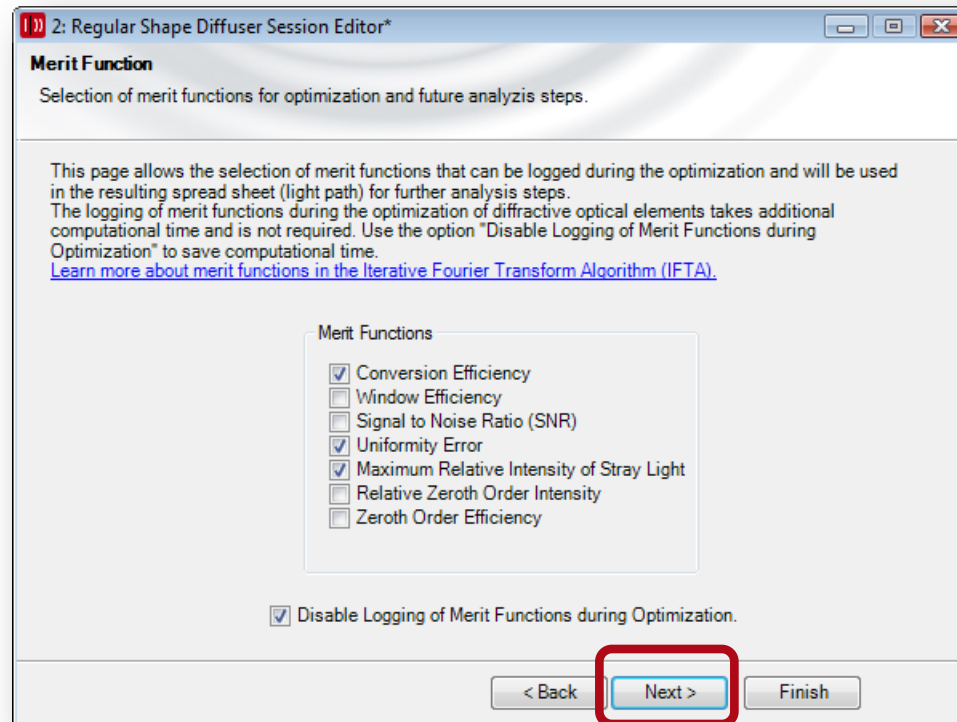
Light Pattern Diameter

Output Field Diameter

Diameter Factor

< Back **Next >** Finish

4. Merit Functions Selection



5. Diffuser Parameter

2: Regular Shape Diffuser Session Editor*

Diffraction Optical Element Aperture Parameters

Diameter and shaper of the aperture of the diffractive optical element can be specified below.

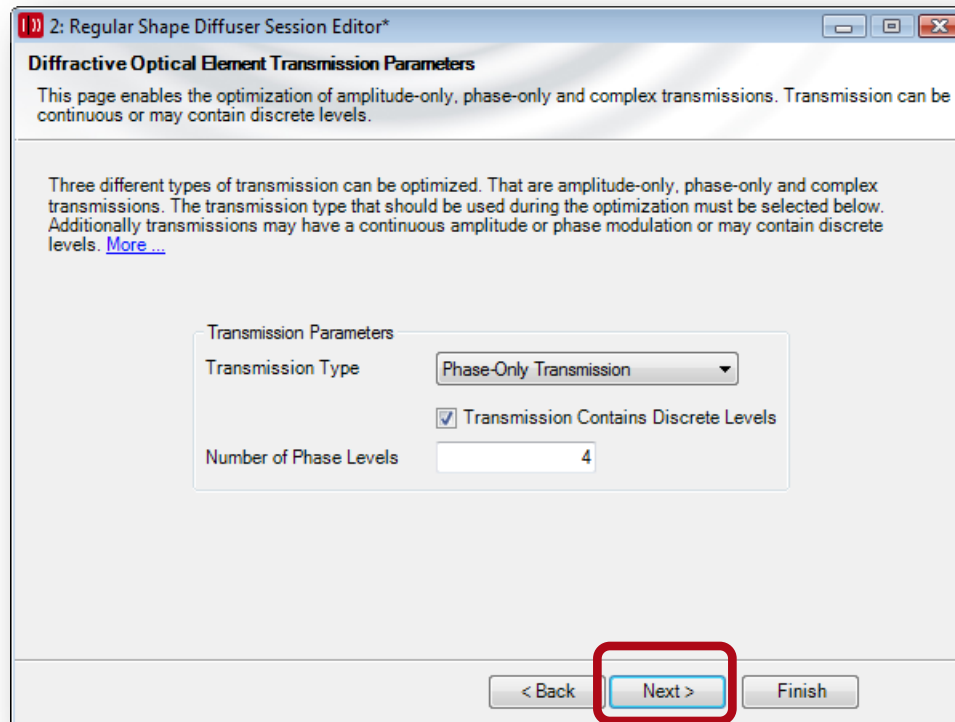
The diffractive optical element used for the creation of the desired output intensity distribution can have a rectangular or elliptical shape. The shape must be selected below. The aperture diameter diameter must be specified below in addition. An aperture diameter of at least 2 times the waist diameter of the input beam is recommended in order to avoid energy losses and diffraction at the aperture of the diffractive optical element.

Aperture Size and Shape

Aperture Shape	<input checked="" type="radio"/> Rectangular	<input type="radio"/> Elliptical
Aperture Diameter	<input checked="" type="radio"/> Automatic Setting	<input type="radio"/> Manual Setting
	<input type="text" value="1.4 mm"/>	<input type="text" value="1.4 mm"/>

< Back **Next >** Finish

5. Diffuser Parameter



5. Diffuser Parameter

2: Regular Shape Diffuser Session Editor*

Diffractive Optical Element Period, Pixel Size and Number of Pixels

The required period diameter, pixel size and number of pixel per period are displayed on this page.

VirtualLab calculates from the specifications of the desired output intensity period, pixel size and number of pixels of the diffractive optical element. In order to take into account fabrication constraints a minimum pixel size and pixel size increment can be defined. [More ...](#)

Pixel Size

☒ Automatic Setting of Pixel Size ☐ Manual Setting of Pixel Size

Pixel Size Increment

Minimum Pixel Size

Pixel Size

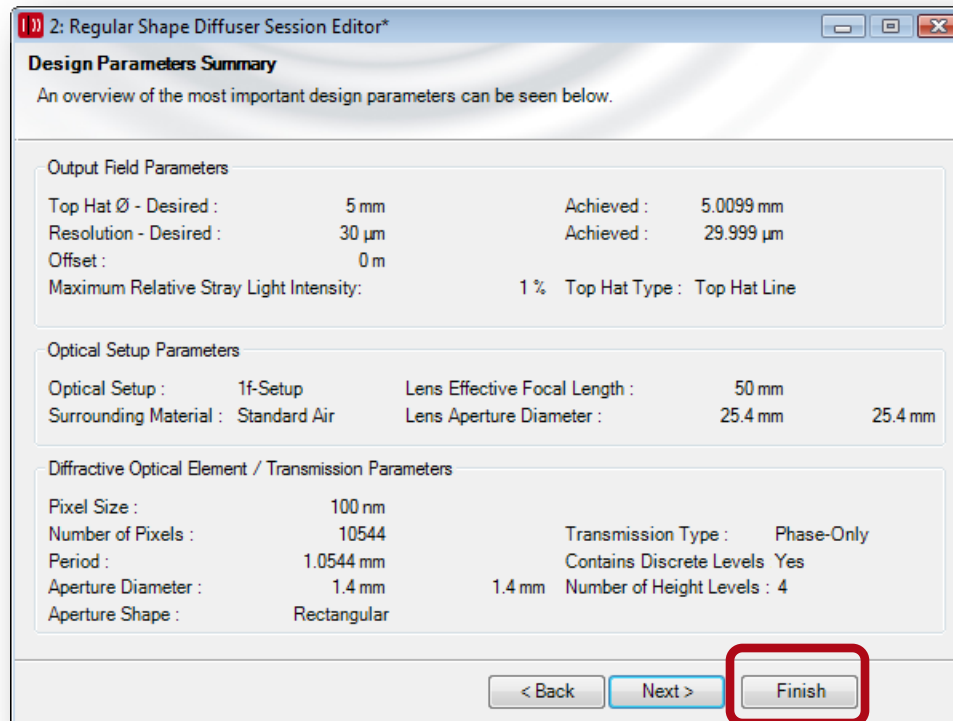
☒ Transmission Consists of Rectangular Pixels

Period

Number of Pixels per Period

< Back **Next >** Finish

6. Summary



Results in



7. Diffuser Optimization

5: Iterative Fourier Transformation Algorithm Optimization

Specification Design Analysis

Design Method: Iterative Fourier Transform Algorithm Approach Transmission Set Show

Design Steps	Number of Iterations	Method
<input checked="" type="checkbox"/> Generate Initial Transmission		Backw. Prop. Signal Field (Random Phase)
<input checked="" type="checkbox"/> Signal Phase Synthesis	25	<input type="checkbox"/> Soft Introduction of Transmission Constraint
<input checked="" type="checkbox"/> SNR Optimization for Phase-Only Transmission	50	<input type="checkbox"/> Omit Final Transmission Projection
<input checked="" type="checkbox"/> Soft Quantization	100	<input type="checkbox"/> Soft Introduction of Transmission Constraint
<input checked="" type="checkbox"/> SNR Optimization for Quantized Transmission	5000	<input type="checkbox"/> Create Transmission Animation Options
		<input type="checkbox"/> Create Output Field Animation Options
		<input type="checkbox"/> Show Final Transmission and Output Field

Logging

#It (total)	#It (step)
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Configure

Show Diagram

Export Table

☐ Preserve Table

Progress in current design step

Start Design

7. Diffuser Optimization

The screenshot shows the 'Analysis' tab of the '5: Iterative Fourier Transformation Algorithm Optimization*' window. The 'Analysis' tab is highlighted with a red box. Below it, a table lists merit functions with their values. The first four rows are highlighted with red boxes: 'Conversion Efficiency [%]' (76.6165815800436), 'Uniformity Error [%]' (25.656915656992467), and 'Maximum Relative Intensity of Stray Light [%]' (5.8115876312739569). To the right of the table are buttons for 'Show Output Field', 'Recalculate', and 'Show Light Path'. Below the table is a section for 'Scale Errors for Phase-Only Transmissions' with checkboxes for 'Impose Linear Scale Error by Scale Factor' and 'Impose Binary Mask Scale Errors by Given Scale Factors'. The 'Impose Binary Mask Scale Errors by Given Scale Factors' section has input fields for Mask #1 (pi), Mask #2 (pi/2), Mask #3 (pi/4), and Mask #4 (pi/8), all set to 1. Below this is the 'Scan Scale Error Range' section with a 'Modified Scale Factor' dropdown set to 'Linear', 'From' and 'To' input fields set to 0.9 and 1.1, and a 'Number of Steps' input field set to 11. There is also a 'Create Output Field Animation' checkbox. At the bottom, there is a table with columns 'Linear', 'ConvEff [%]', 'UnifErr [%]', and 'StrayLight [%]'. To the right of the table are buttons for 'Options', 'Recalculate', 'Show Diagram', and 'Export Table'.

Merit Function	Value
Window Efficiency [%]	
Conversion Efficiency [%]	76.6165815800436
Signal-to-Noise Ratio / dB	
Uniformity Error [%]	25.656915656992467
Zeroth Order Intensity [%]	
Zeroth Order Efficiency [%]	
Maximum Relative Intensity of Stray Light [%]	5.8115876312739569

Scale Errors for Phase-Only Transmissions

☐ Impose Linear Scale Error by Scale Factor

☐ Impose Binary Mask Scale Errors by Given Scale Factors

Mask #1 (pi) 1 Mask #2 (pi/2) 1 Mask #3 (pi/4) 1 Mask #4 (pi/8) 1

Scan Scale Error Range

Modified Scale Factor: Linear

From: 0.9 To: 1.1

Number of Steps: 11

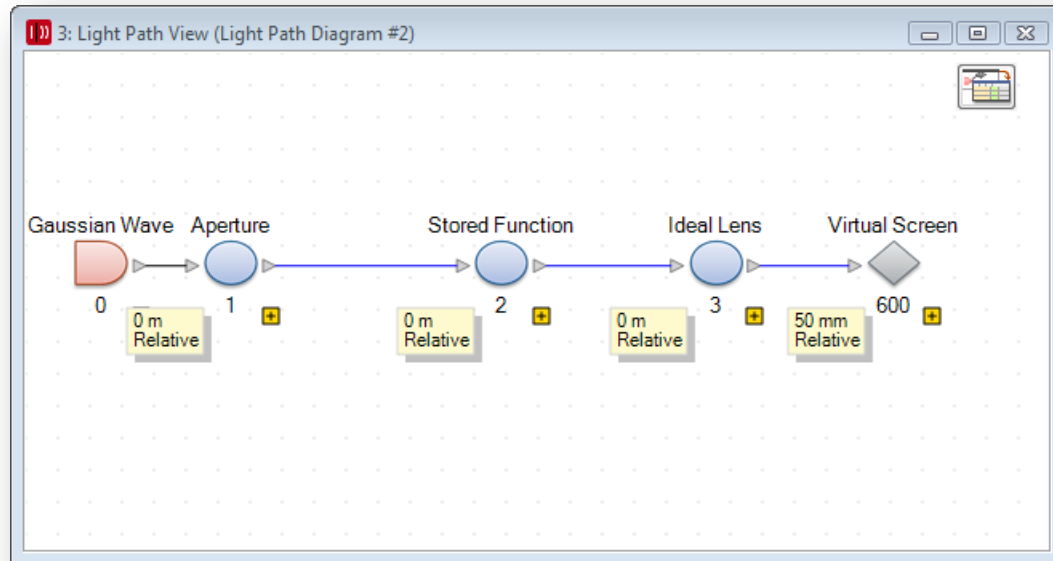
☐ Create Output Field Animation

Linear	ConvEff [%]	UnifErr [%]	StrayLight [%]

Options Recalculate Show Diagram Export Table

The *Analysis* tab allows to calculate the merit functions results of the output field generated by the diffuser. Repeat optimization and keep best diffuser transmission.

8. Light Path



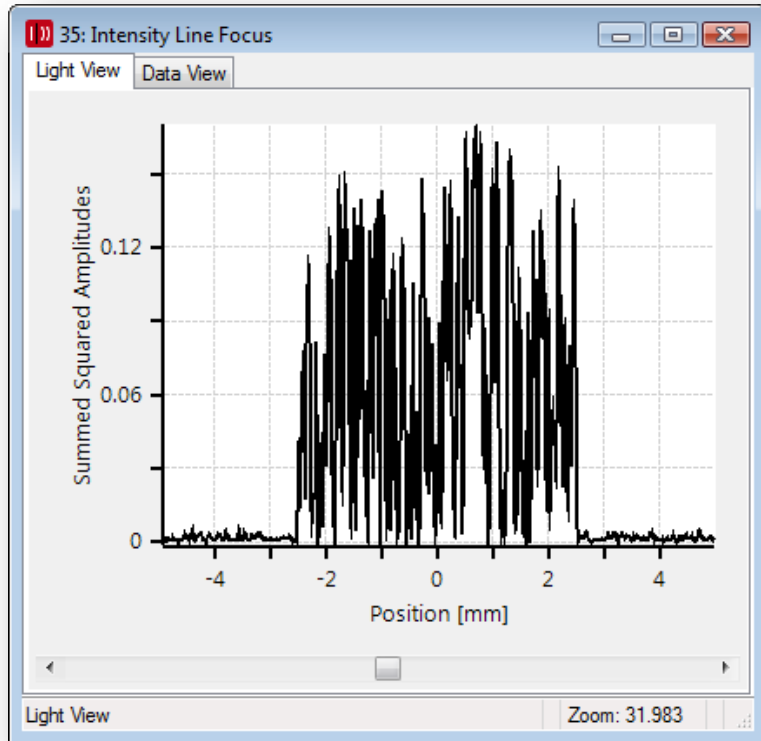
2: Light Path Editor (Light Path Diagram #2)

Path Detectors Analyzers

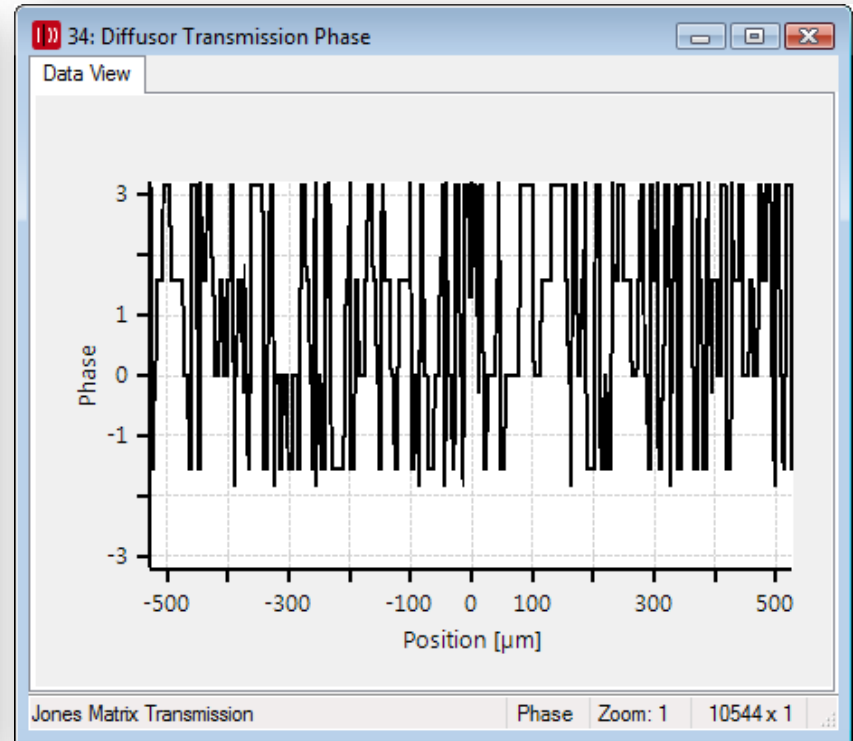
Start Element				Target Element		Linkage	
Index	Type	Channel	Medium	Index	Type	Propagation Method	On/Off
0	Gaussian Wave	-	Standard Air in Homogen...	1	Aperture	Combined SPW/Fresnel Operator	On
1	Aperture	T	Standard Air in Homogen...	2	Stored Function	Combined SPW/Fresnel Operator	On
2	Stored Function	T	Standard Air in Homogen...	3	Ideal Lens	Combined SPW/Fresnel Operator	On
3	Ideal Lens	T	Standard Air in Homogen...				

Tools ☐ Re-Use Automatic Settings Simulation Type: Field Tracing **Go!**

8. Simulation Results

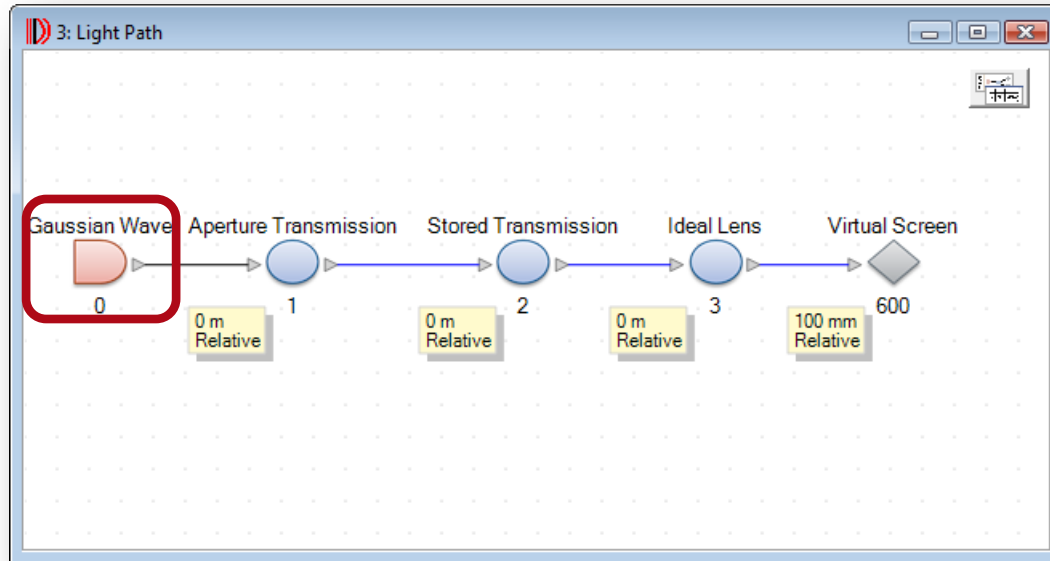


Intensity Line Focus



Diffuser Transmission Phase
(Click φ on toolbar)

9. Light Path



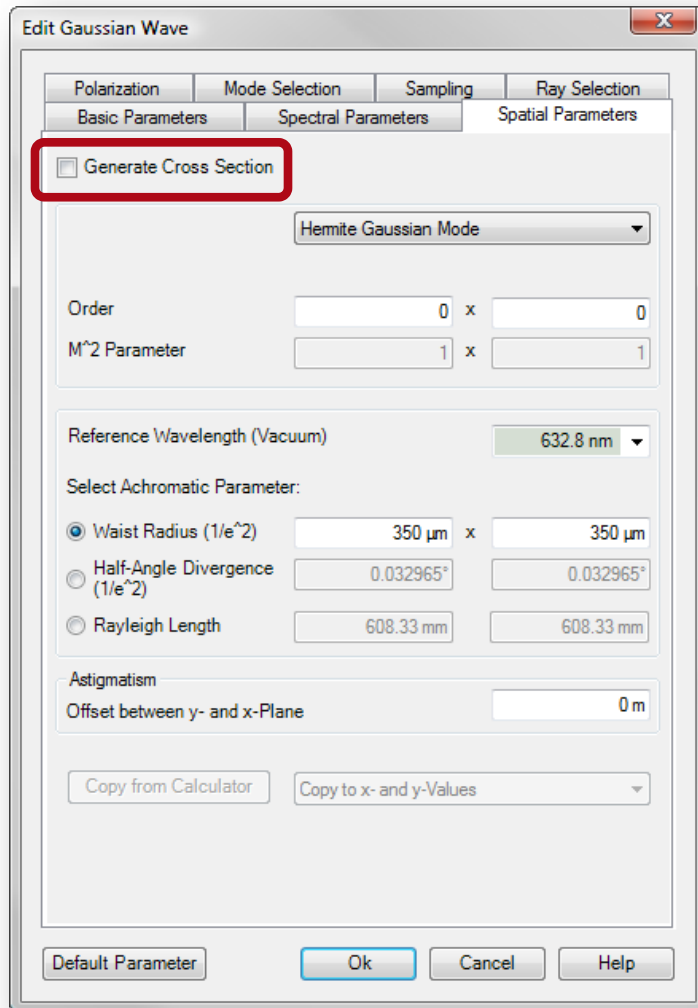
Double click
Gaussian Wave
light source.

The screenshot shows the '2: Light Path' window with a detailed table of the light path elements. The table is organized into three main sections: Start Element, Target Element, and Linkage. The Start Element section lists the elements from index 0 to 3. The Target Element section lists the elements from index 1 to 3. The Linkage section details the propagation method, on/off status, and color for each linkage.

Start Element				Target Element		Linkage		
Index	Type	Channel	Medium	Index	Type	Propagation Method	On/Off	Color
0	Gaussian Wave	-	Standard Air	1	Aperture Transmission	Combined SPW/Fresnel Operator	On	Black
1	Aperture Transmission	T	Standard Air	2	Stored Transmission	Combined SPW/Fresnel Operator	On	Blue
2	Stored Transmission	T	Standard Air	3	Ideal Lens	Combined SPW/Fresnel Operator	On	Blue
3	Ideal Lens	T	Standard Air					

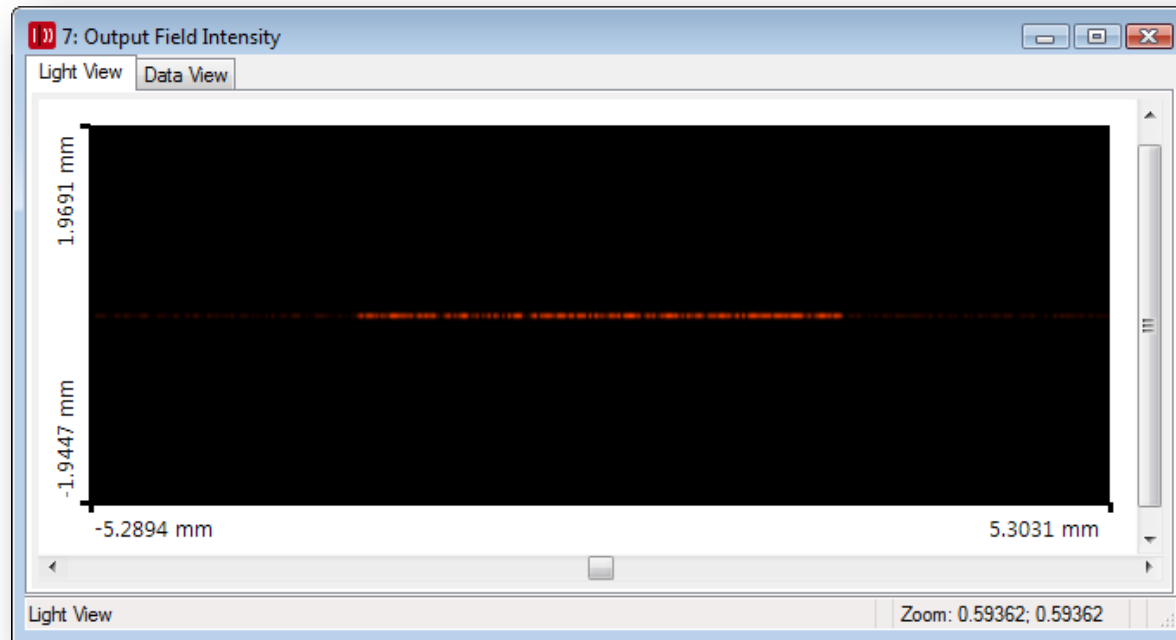
At the bottom of the window, there is a 'Light Path Tools' button, a checkbox for 'Re-Use Automatic Settings', a 'Simulation Type' dropdown menu set to 'Light Path Diagram', and a 'Go!' button.

9. Gaussian Wave Light Source



- Switch off Generate Cross Section.
- Click Ok button.
- Press *Go!* on the Light Path Table

10. Simulation Results



2D Intensity distribution in target plane

Conclusion

- VIRTUALLAB™ assists customer during design of diffractive optical elements for generation of diffuse lines or Top Hats.
- Assisted design steps enable also optical engineers inexperienced in diffractive optics to benefit from current developments.