DO.002 Optimization of Diffractive Optical Element for diffuse illumination of rectangular area (Top Hat).

Example for the design of a diffractive diffuser for generation of a rectangular Top Hat.

Keywords: Diffractive Optics, Diffractive Optical Elements, Diffusers, Top Hat

Required Toolboxes: Diffractive Optics Toolbox

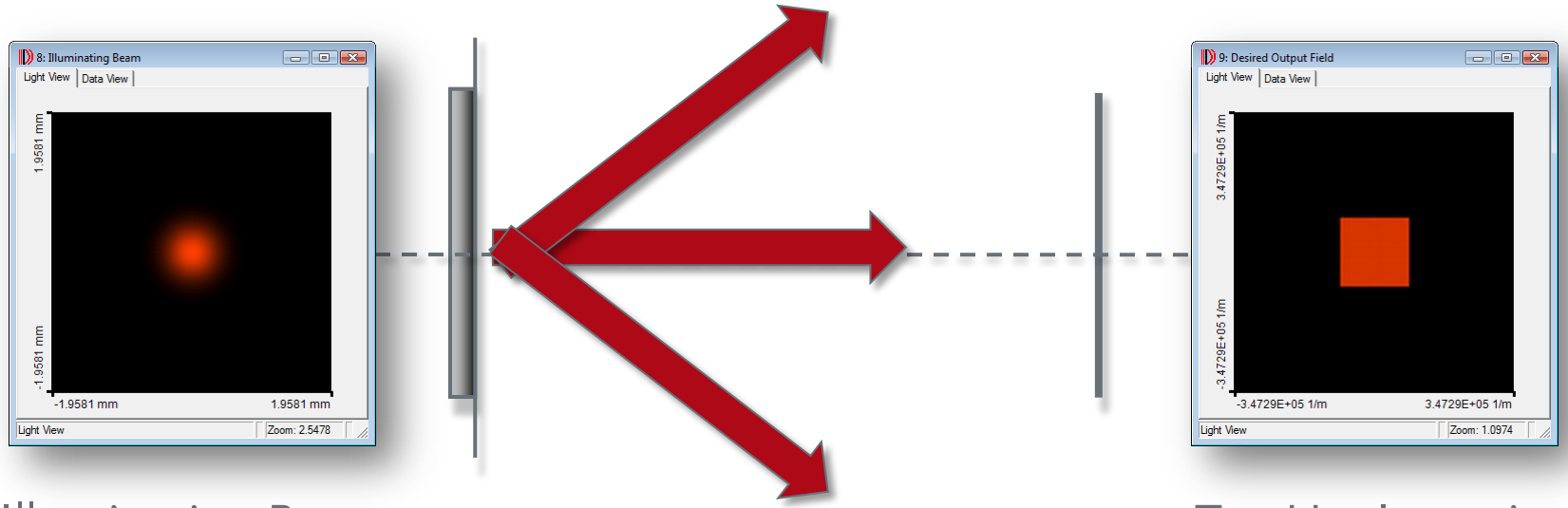
Related Application Scenarios: DO.001;DO.003
Related Tutorials: 144.01

LightTrans

Modeling Task

Diffractive Diffuser
Diameter: 1.4 x 1.4 mm
Phase Levels: 2
Pixel Size: >1µm

Target
Plane



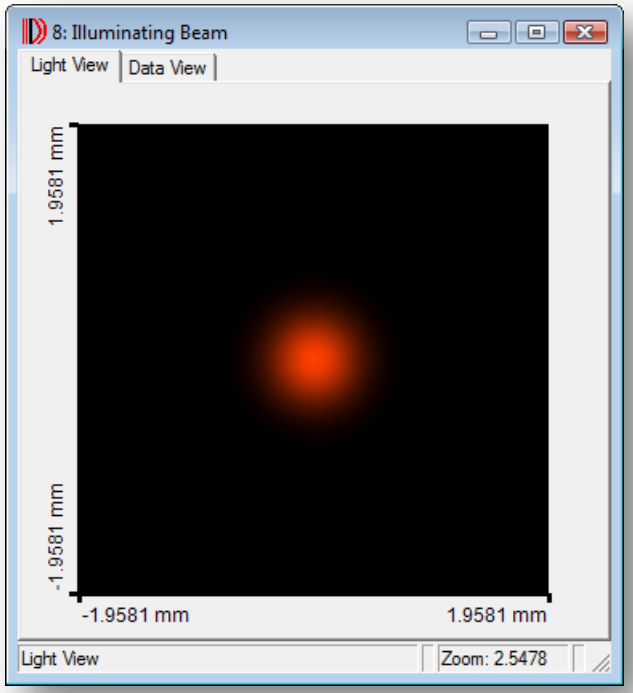
Illuminating Beam
Intensity

Top Hat Intensity

Angular Spectrum Setup

Modeling Task

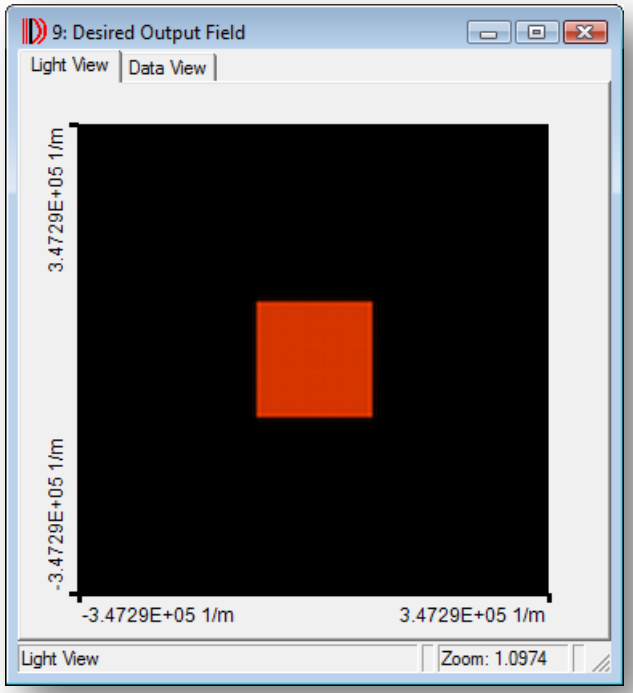
Illuminating Beam Parameters



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

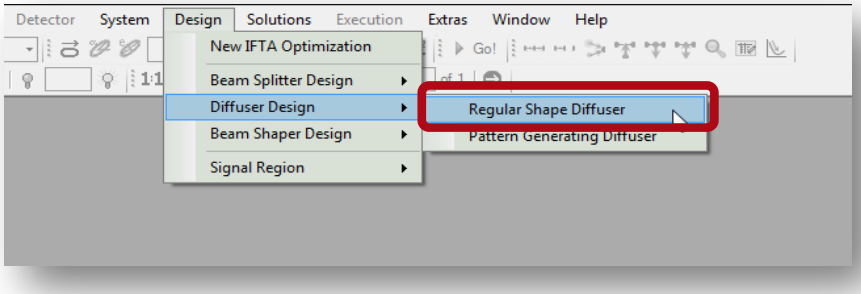
Modeling Task

Desired Output Field Parameters



Diameter: 1°
Resolution: ≤ 0.03°
Efficiency: >70 %
Stray light: <20 %

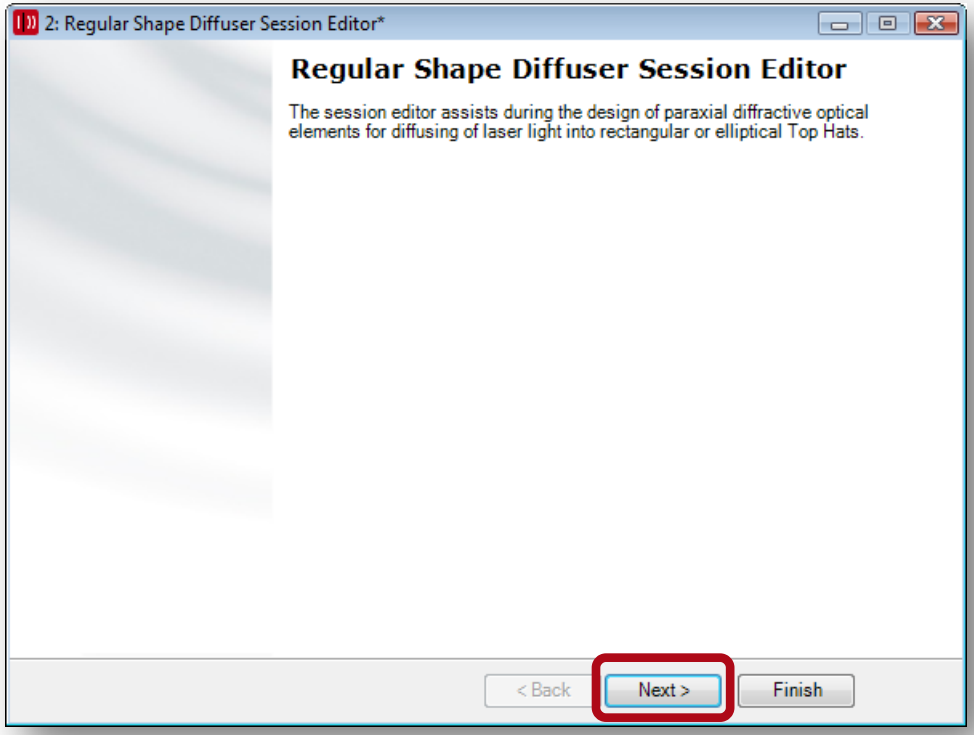
Creation of New Session Editor



- *Regular Shape Diffuser* session editor can be used for the generation of lines, circular and rectangular Top Hats.
- Click the *Regular Shape Diffuser* menu item in the main menu to create a new session editor.

Results in

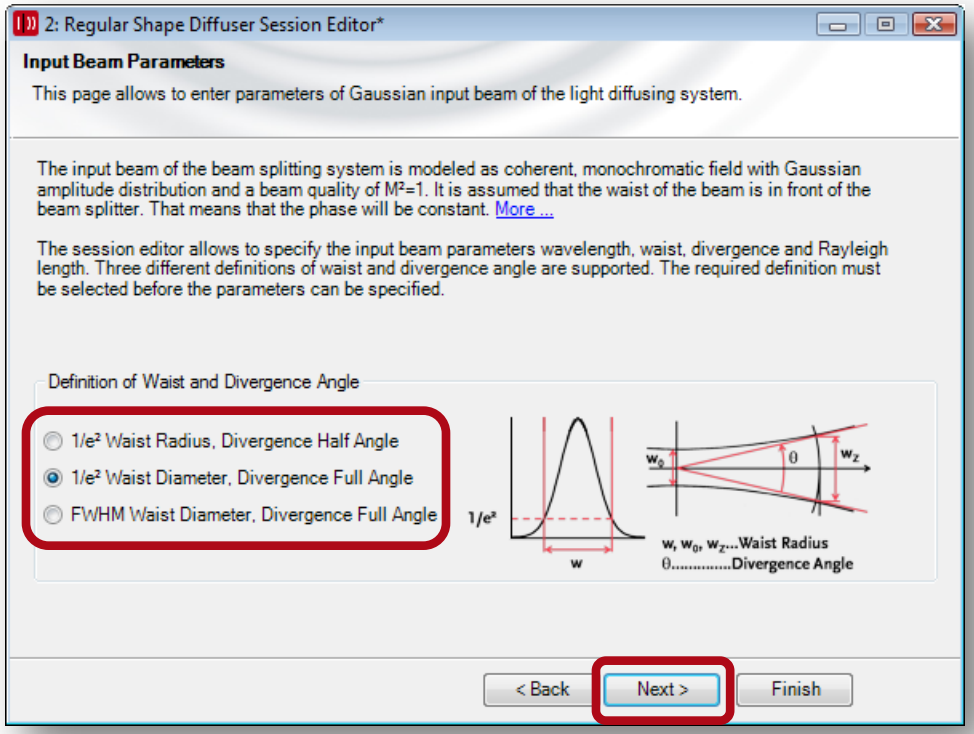
Specification of Illuminating Beam



- Click *Next* button to start specification of illuminating beam.

Results in

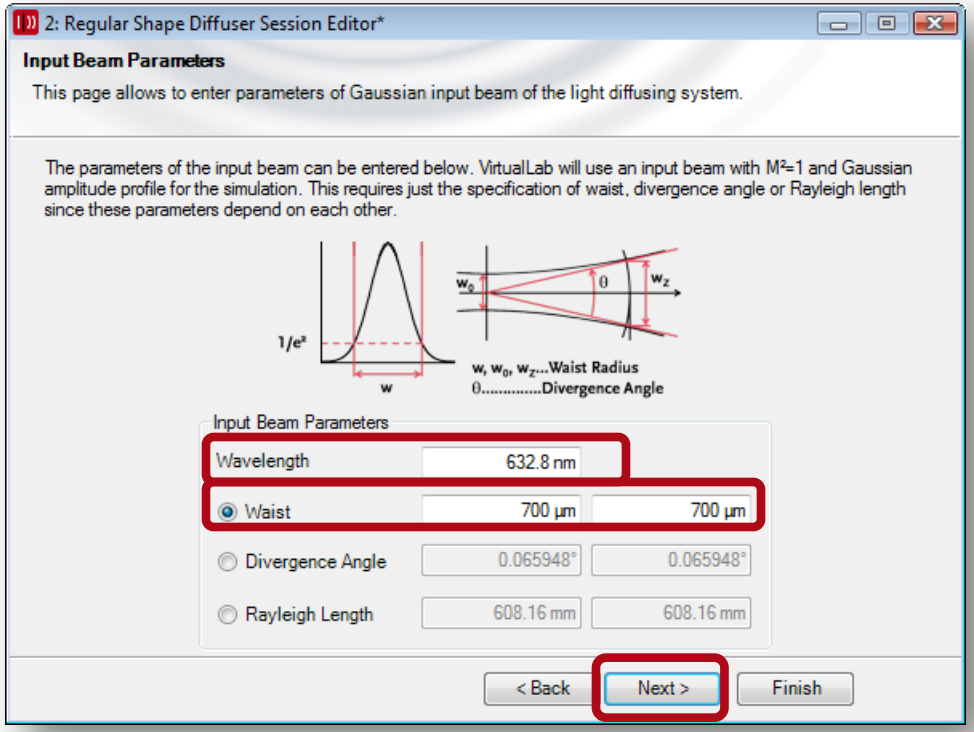
Specification of Illuminating Beam



- This page allows to modify the definition of illuminating beam diameter and divergence angle.
- Select *1/e² Waist Diameter, Divergence Full Angle*.
- Click *Next* button.

Results in

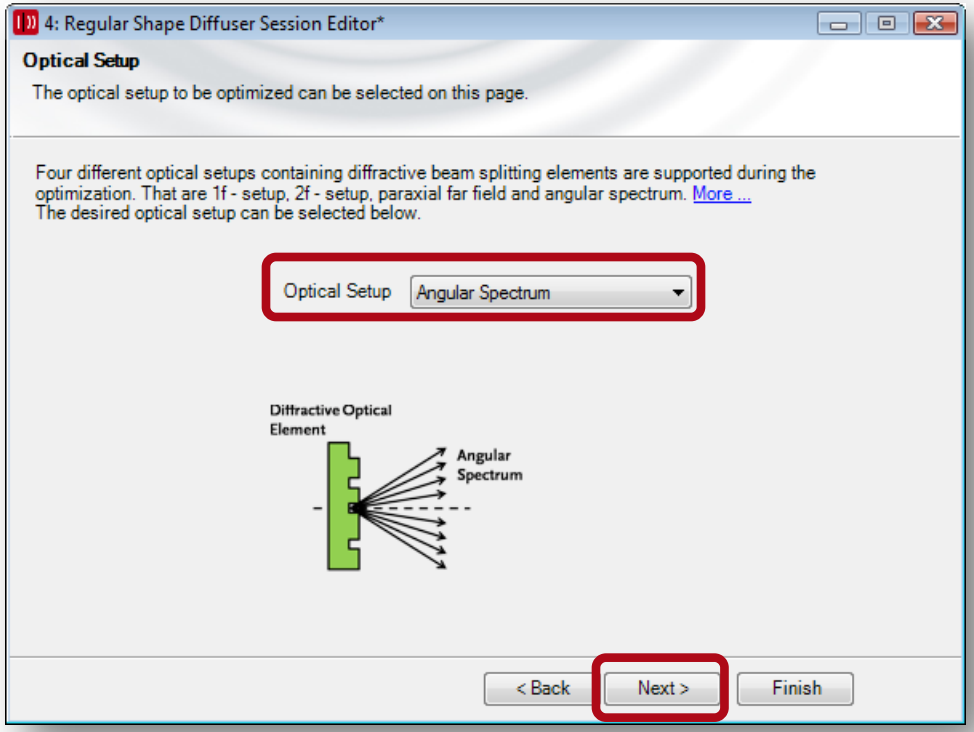
Specification of Illuminating Beam



- On this page the illuminating beam can be specified.
- VirtualLab™ assumes always a Gaussian beam.
- Enter the wavelength of 632.8 nm.
- Select waist specification and enter 700 µm x 700 µm.
- Click *Next* button.

Results in

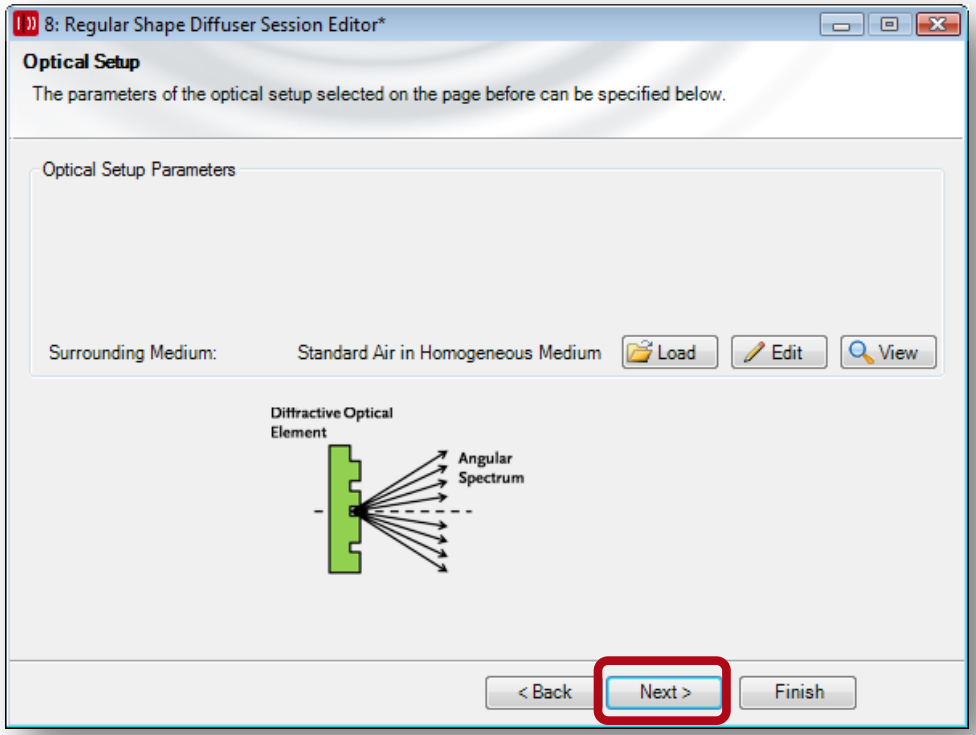
Specification of Optical System Setup



Results in

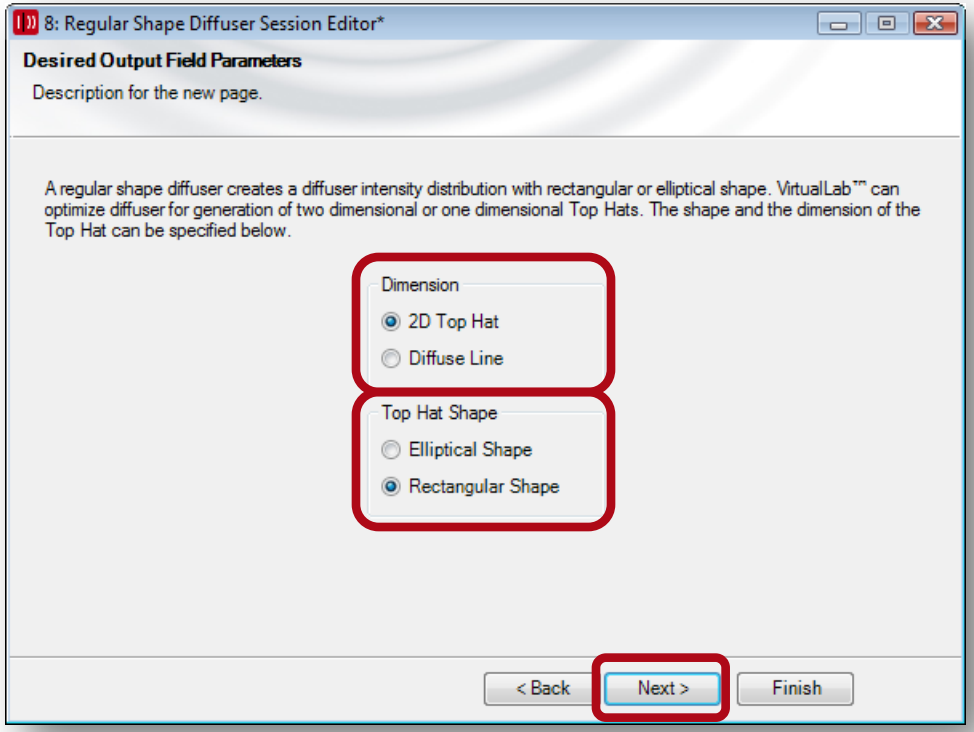
- On this page the fundamental optical setup can be selected.
- The session editor supports 1f/2f-setups, paraxial far field and angular spectrum.
- In case of 1f/2f-setup or paraxial far field further parameters must be specified on the following page.
- Select angular spectrum setup and click *Next*.

Specification of Optical System Setup



- Leave Standard Air as *Surrounding Medium.*
- Click *Next* button.

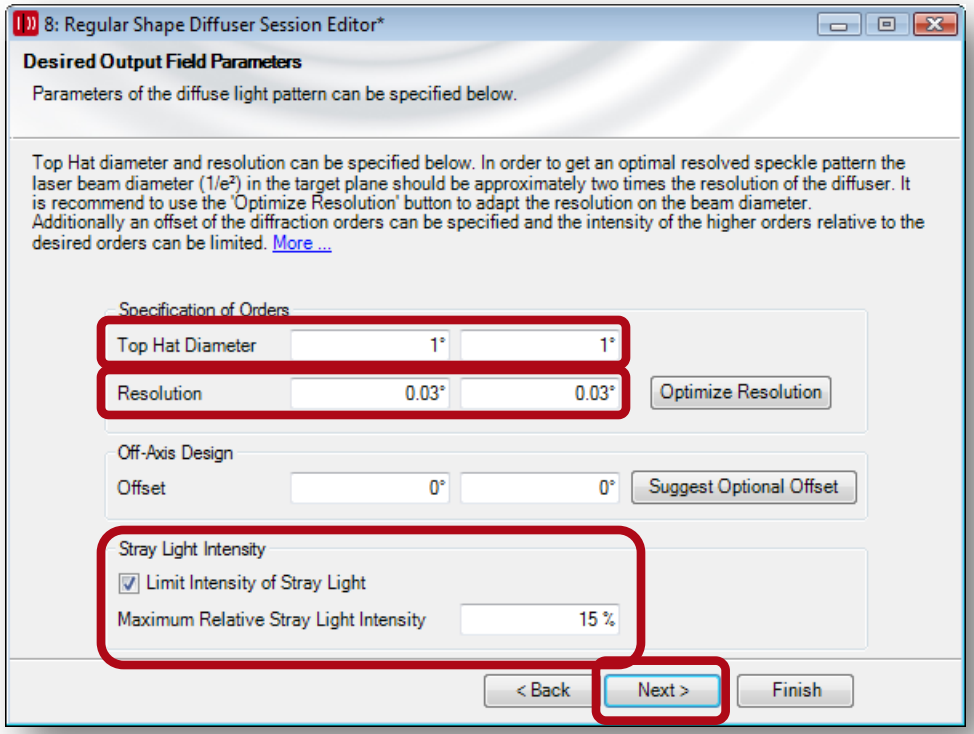
Specification of Desired Output Field



- The session editor allows the design of diffusers for generation of Top Hats and lines.
- Select *2D Top Hat*.
- Select *Rectangular Shape*.
- Click *Next* button.

Results in

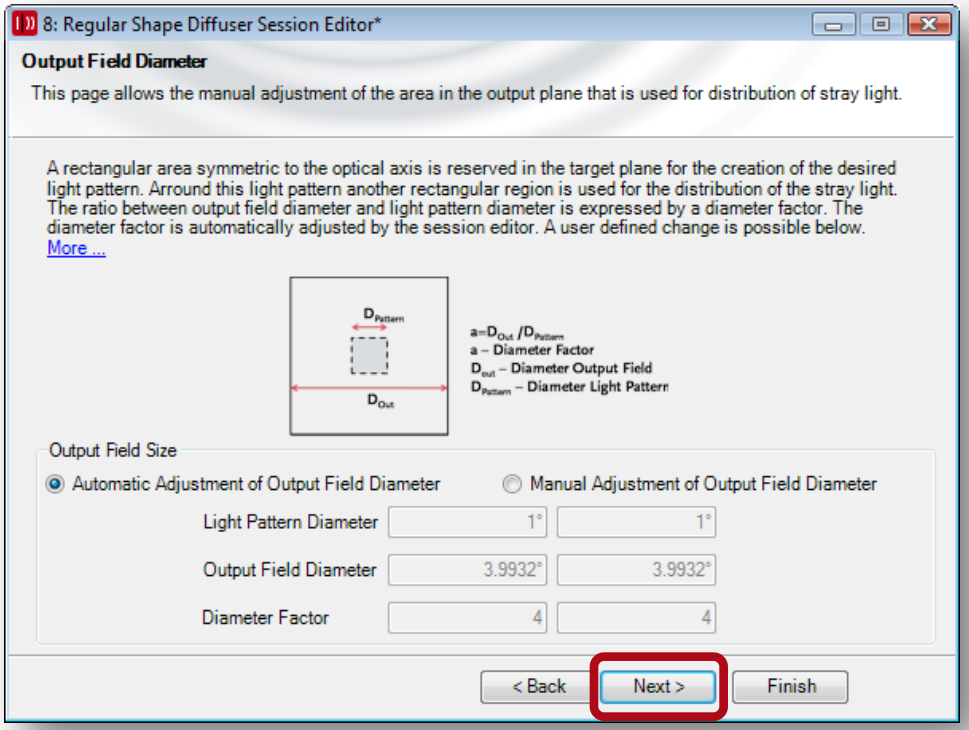
Specification of Desired Output Field



- Specify a *Top Hat Diameter* of 1° x 1°.
- The Top Hat *Resolution* should be set to 0.03° x 0.03°.
- Since the maximum stray light should be smaller than 20% *Limit Intensity of Stray Light* must be activated. Set the *Maximum Relative Stray Intensity* to 15%.

Results in

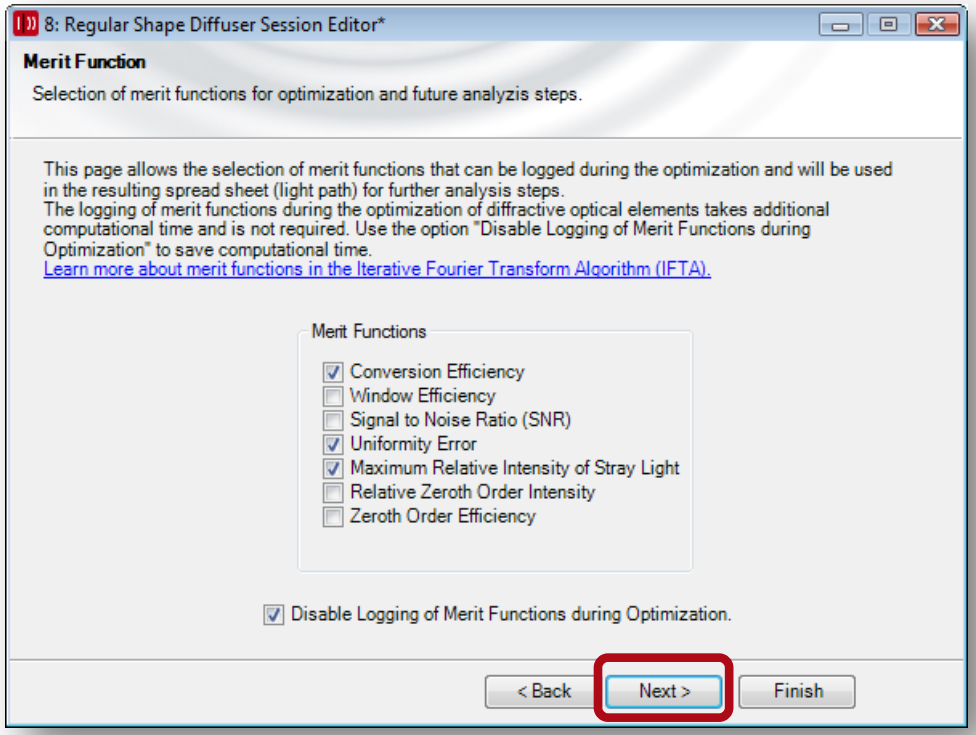
Specification of Output Field Diameter



Results in

- Diffractive diffusers typically will not diffract all light in the desired pattern.
- Stray light will be diffracted to larger diffraction angles.
- Additional space is required in the target plane for stray light.
- The total diameter of the output field in the target plane can be seen her. In manual mode user defined adjustment is possible.

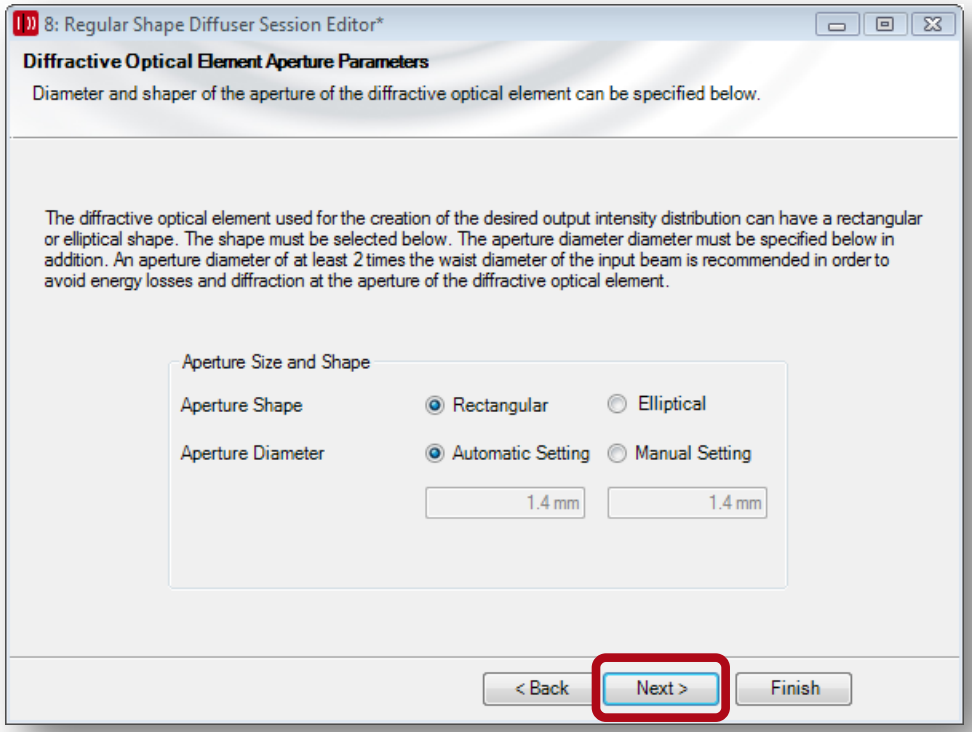
Selection of Merit Functions



- This page allows the selection of merit functions.
- The logging of merit functions during optimization can be disabled to speed up the optimization.

Results in

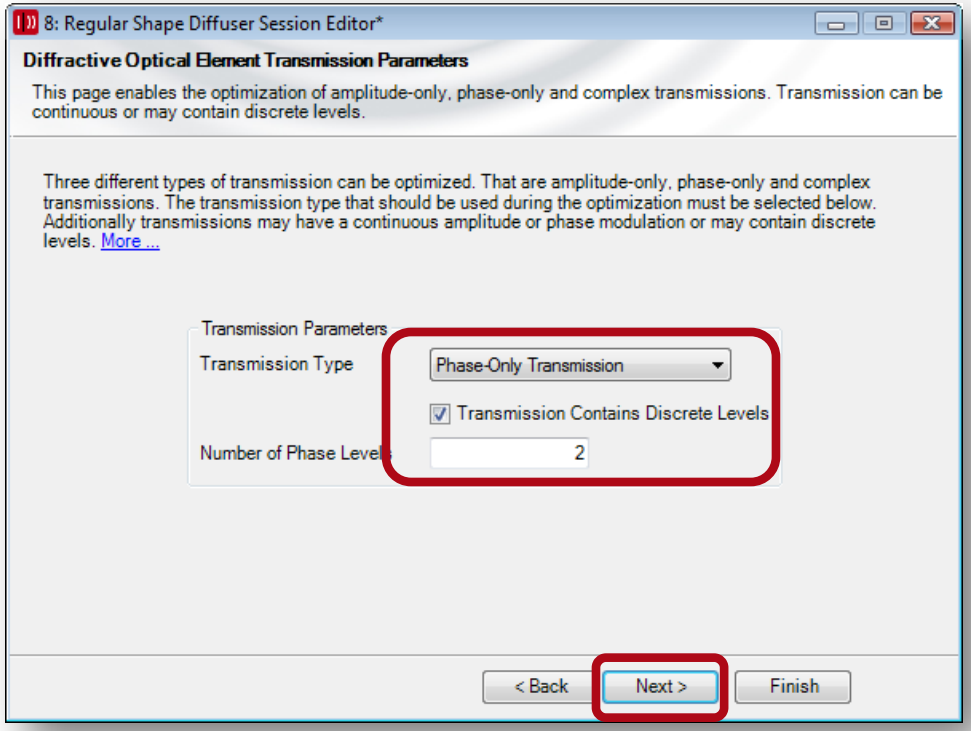
Specification of Diffuser Aperture



- Keep the diffuser *Aperture Shape* at *Rectangular* and the *Aperture Diameter* at *Automatic.*
- The Aperture diameter should be approximately 2-3 times larger than the $1/e^2$ diameter of the illuminating beam.

Results in

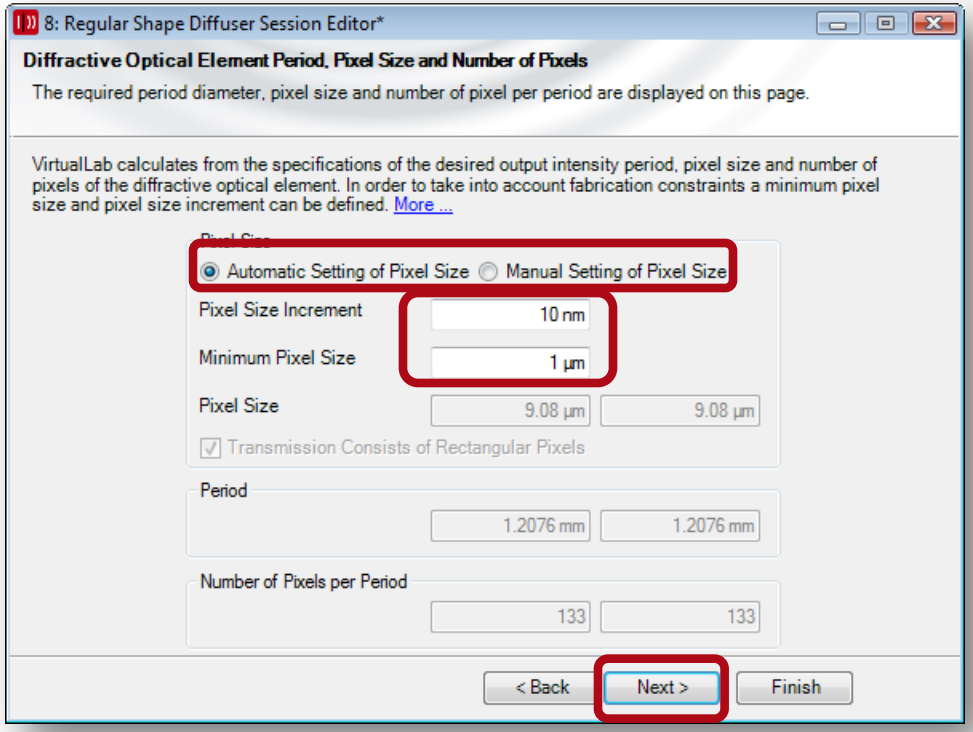
Specification of DOE Transmission Parameters



- VirtualLab™ will optimize a diffuser transmission.
- In a second step a height profile can be calculated. See tutorial DO.8 for more details.
- Select *Phase-Only Transmission*.
- Activate *Transmission Contains Discrete Levels*.
- Set *Number of Phase Levels* to 2.

Results in

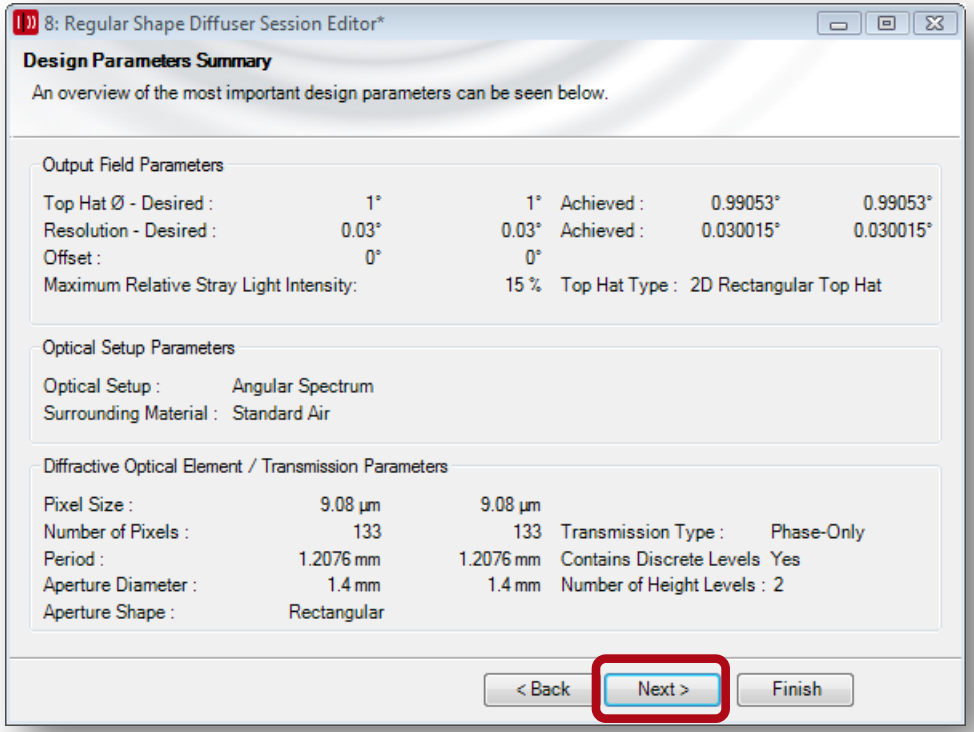
Specification of DOE Transmission Parameters



Results in

- Pixel size and period of the diffuser transmission are calculated automatically.
- Set the *Pixel Size Increment* to 10 nm and the *Minimum Pixel Size* to 1 µm.
- The *Pixel Size Increment* indicates the step size in that the pixel size can be changed by the machine used for fabrication of the diffuser.
- Expert user may set a user defined pixel size.

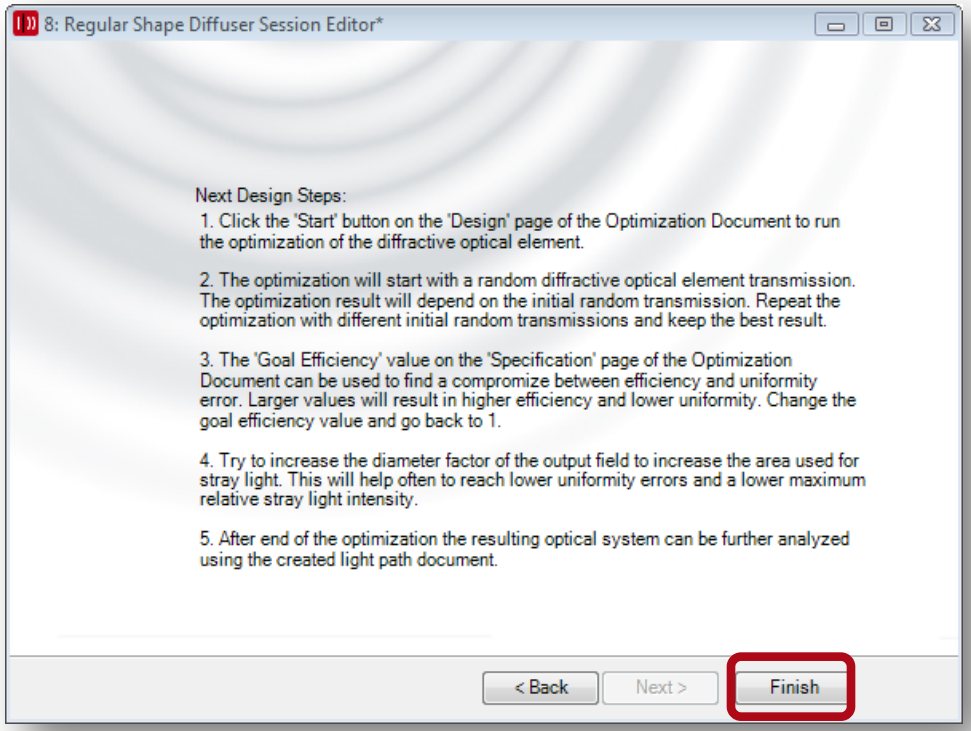
Summary of Parameters



Results in

- This page shows a summary of the most important user defined and automatically calculated parameters.
- Most important are the desired and achieved Top Hat diameter and resolution.
- Because of specified pixel size increment and minimum pixel size probably the desired values can't exactly achieved.

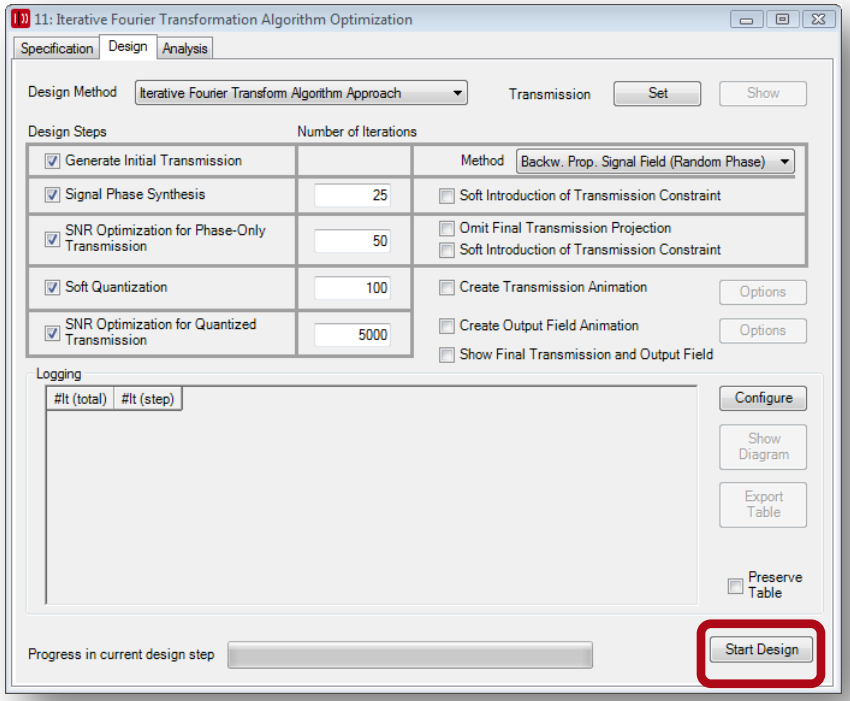
Next Design Steps



Results in

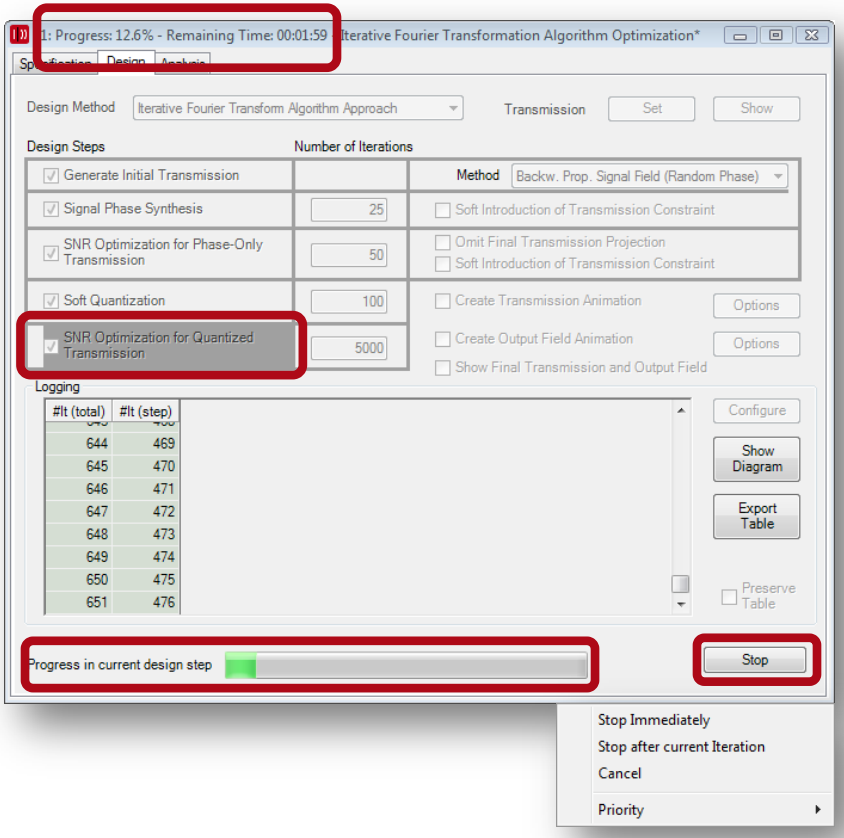
- The last page of the session editor suggests next steps for the design of the diffuser.
- Click the *Finish* button to create the *Optimization Document* used to optimized the diffuser and the *Light Path Diagram* used to simulate the complete optical system containing the diffuser.

Diffuser Optimization



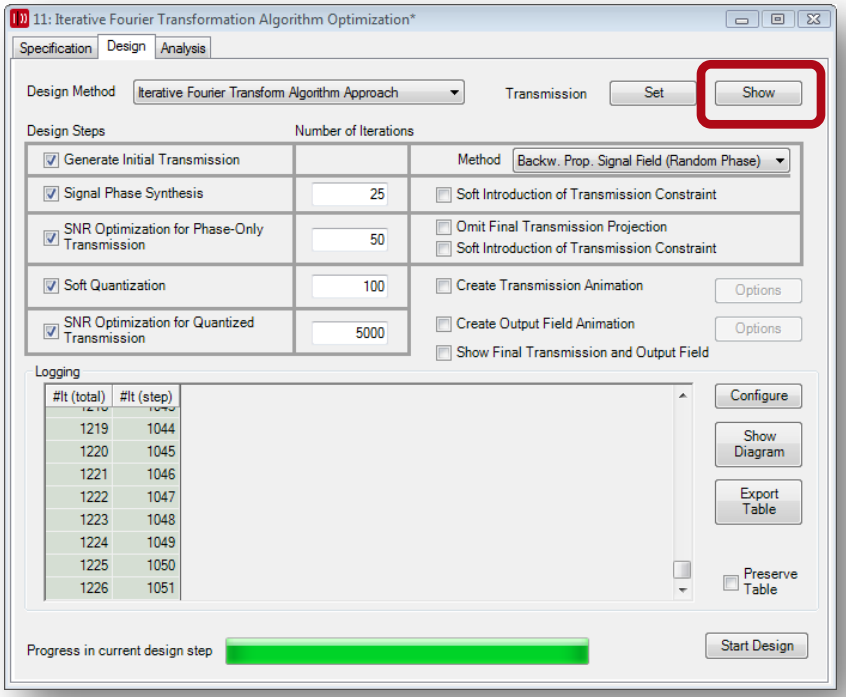
- Switch to the *Iterative Fourier Transformation Algorithm Document*
- The *Design* page allows the specification of the number of iterations per optimization steps.
- Click the *Start Design* button to start the optimization.
- The step *SNR Optimization for Quantized Transmission* will stop automatically if no improvement is achievable. Probably, the specified maximal number of iterations won't be performed.

Diffuser Optimization



- The optimization of a diffuser may take a while depending on the number of iterations and pixels.
- A running optimization can be stopped by clicking the *Stop* button.
- The total progress of the optimization is shown in the window caption.
- The current optimizations step is marked by grey color.
- The progress in current step is shown by the progress bar.

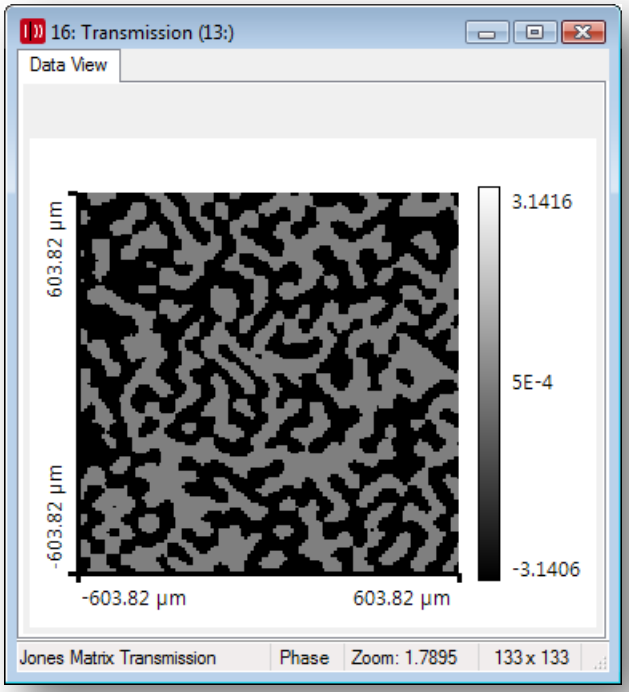
Diffuser Optimization



- Click the *Show* button after the end of the optimization to display the optimized diffuser transmission.
- The *Set* button allows to set any other user defined transmission. It can be used as a start point for an optimization or for further analysis.

Results in

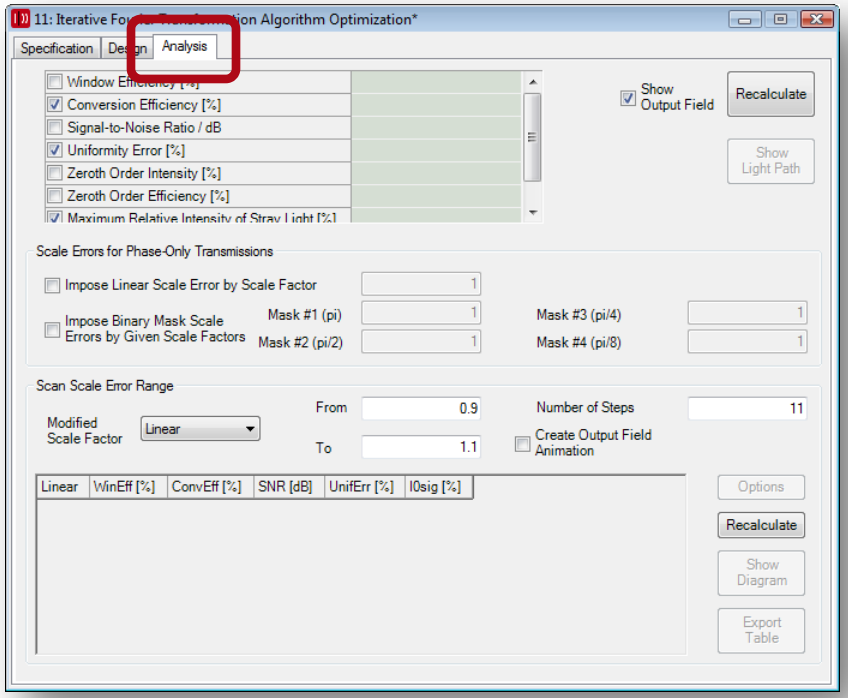
Optimized Transmission



- Data View with typical phase distribution (click φ on toolbar) of optimized transmission.
- Since the optimization of diffractive diffusers starts with random phases the resulting transmission phase differs between different optimizations.

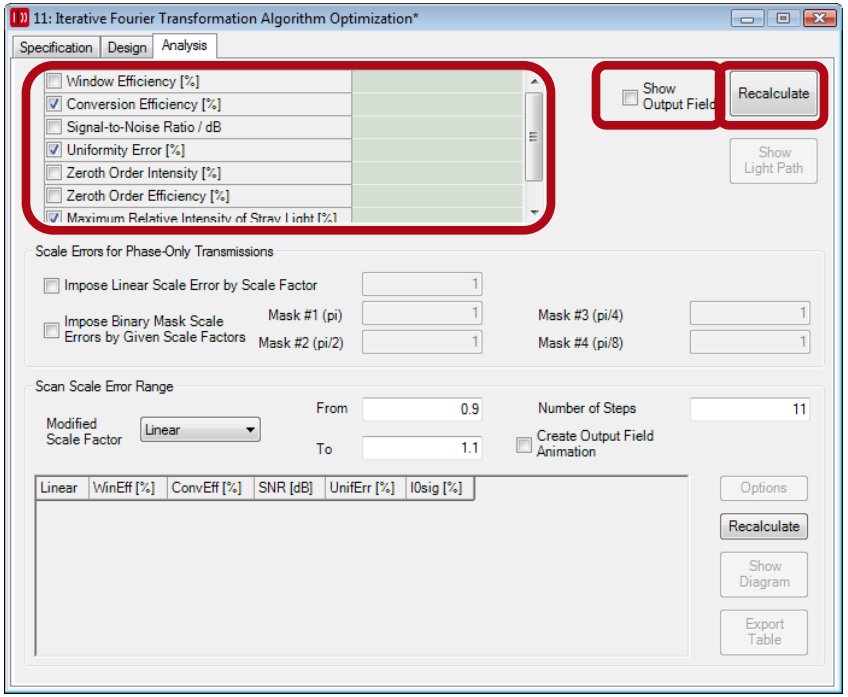
Diffuser System Analysis

- Switch to Analysis page after the end of the optimization to calculate merit functions.



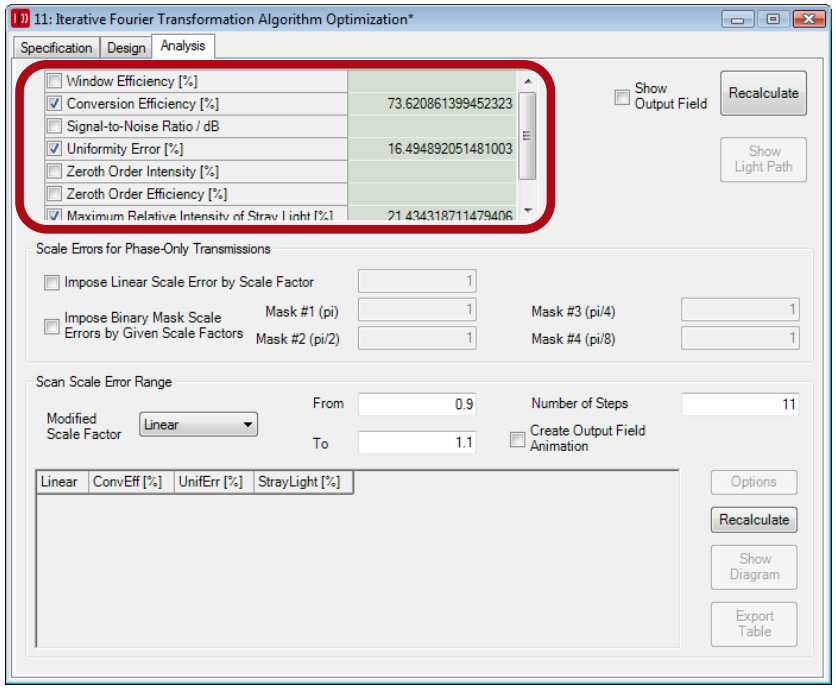
Results in

Diffuser System Analysis



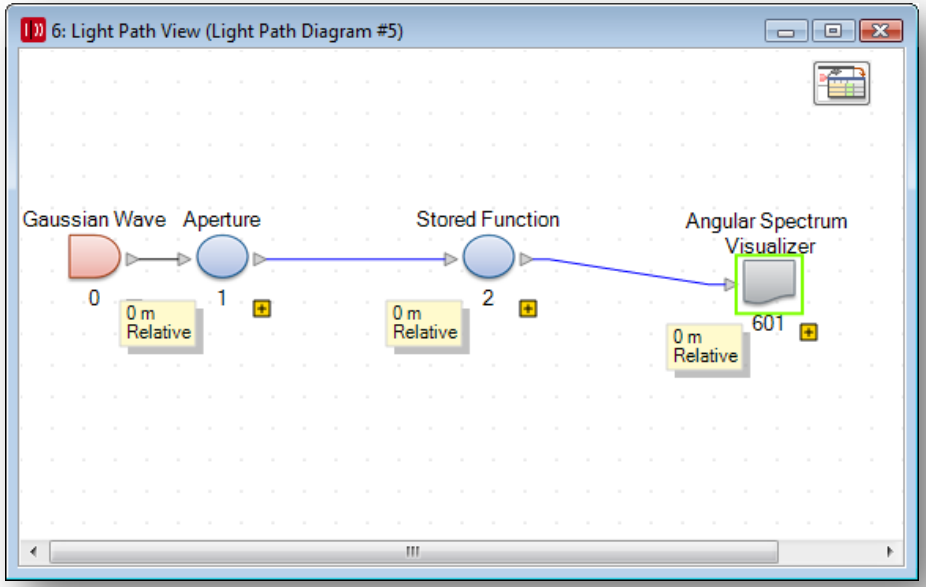
- Select the merit functions desired for the evaluation of the output field.
- Deactivate the option *Show Output Field*. We will simulate the output field later using the *Light Path Diagram*.
- Click the *Recalculate* button to evaluate the merit functions values.

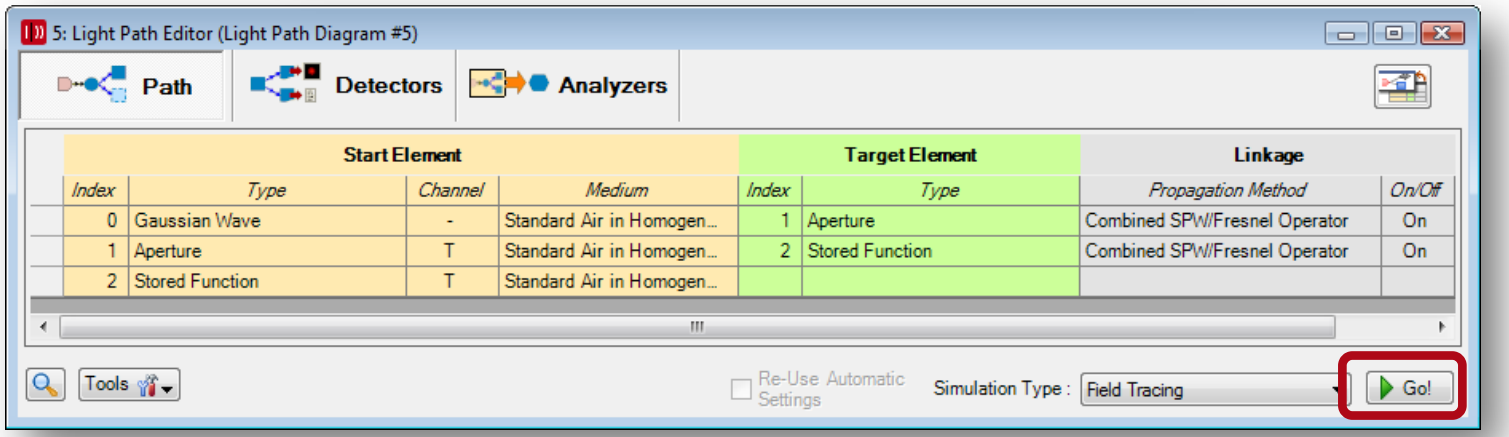
Diffuser System Analysis



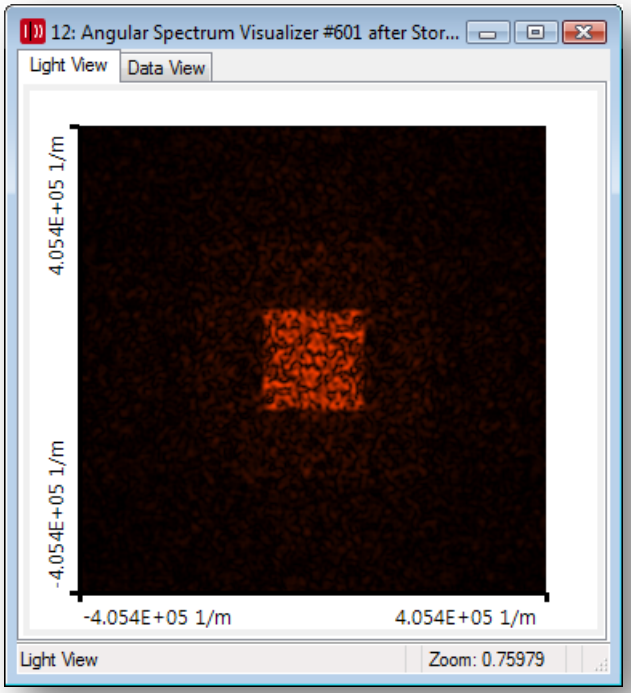
- The merit functions values will be displayed in the marked table.
- Since the optimization starts with random transmission phase the merit functions values may differ between different optimizations.
- The optimization should be repeated several times and the transmission with the best merit functions values should be kept.

Light Path

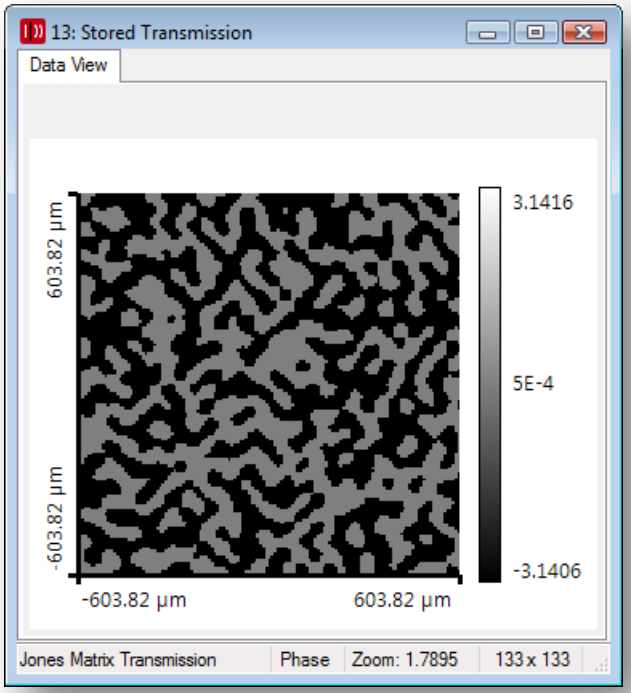

6: Light Path View (Light Path Diagram #5)
Gaussian Wave
Aperture
Stored Function
Angular Spectrum Visualizer
0
1
2
601
0 m Relative
0 m Relative
0 m Relative


5: Light Path Editor (Light Path Diagram #5)
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...
Tools
Re-Use Automatic Settings
Simulation Type :
Field Tracing
Go!

Simulation Results



Intensity Top Hat



Diffuser Transmission Phase

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.