# Scenario 307.01: Parametric optimization of refractive beam shaping element for shaping of circular Top Hat

This example demonstrates the setup of a beam shaper system by the refractive beam shaper session editor. The optical performance of the resulting system can be improved by the parametric optimization of VirtualLab™.

Keywords: parametric optimization, lens system, beam shaping, Top Hat, refractive beam shaping element

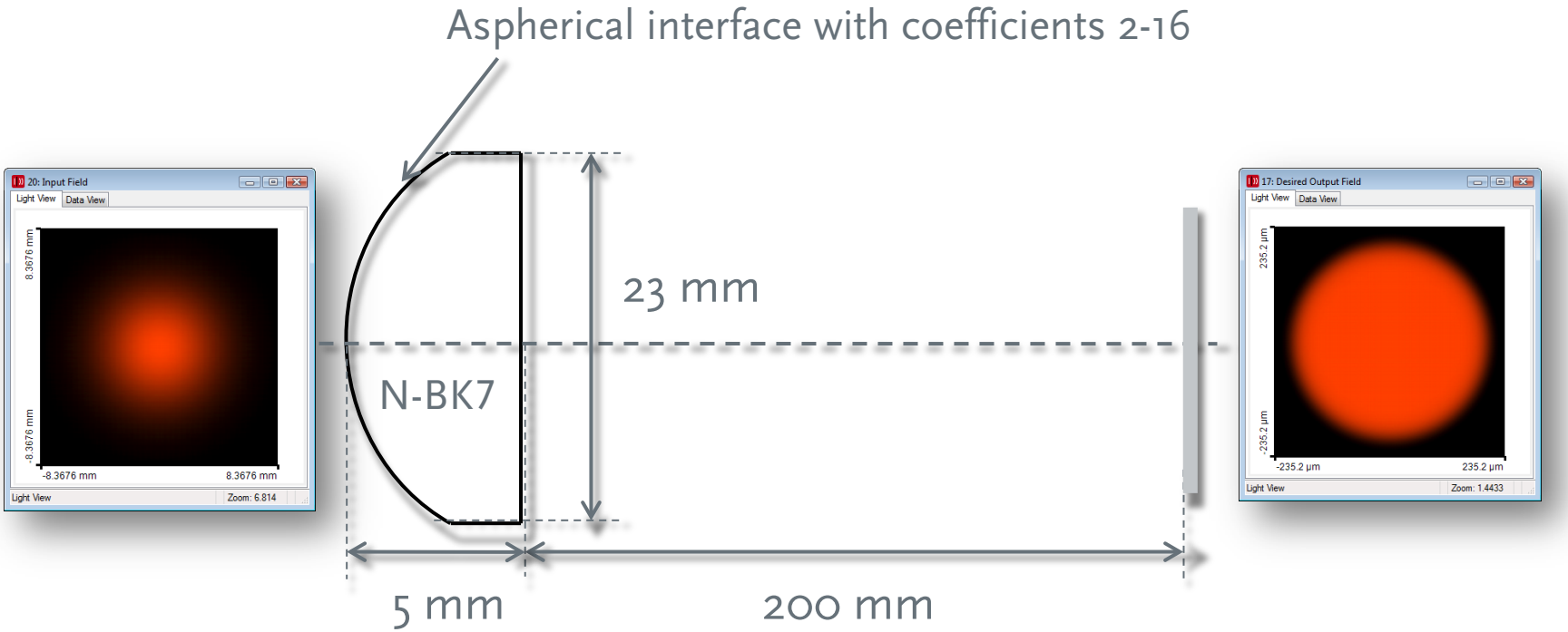
Required Toolboxes: Starter Toolbox Advanced

Related Application Scenarios: 101.01, 100.01, 284.01

Related Tutorials and Technical Notes: Tutorial 101.01, TN.021

LIGHTTRANS

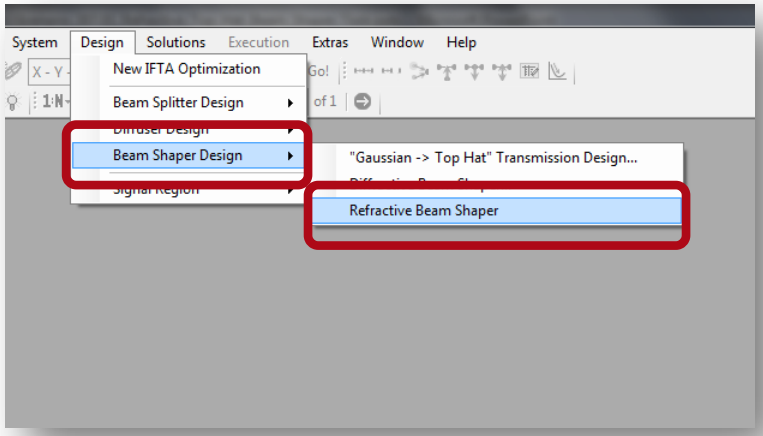
# Modeling Task

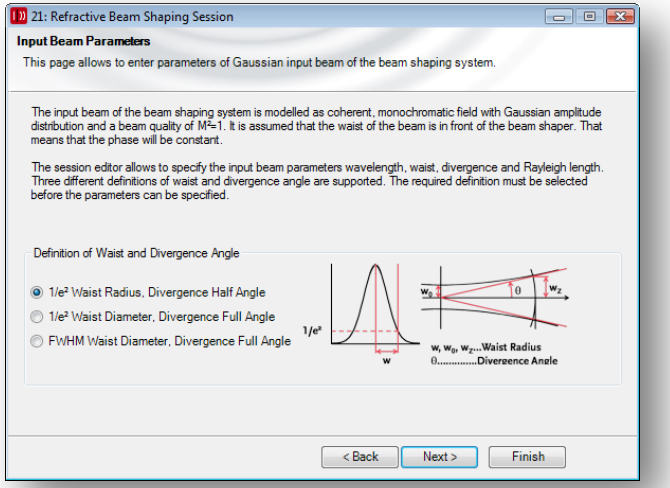



Incident beam:
Wavelength: 632.8 nm
Diameter ($1/e^2$): 8 mm

Desired output field:
Diameter ($1/e^2$): 400 µm
Edge width: 40 µm

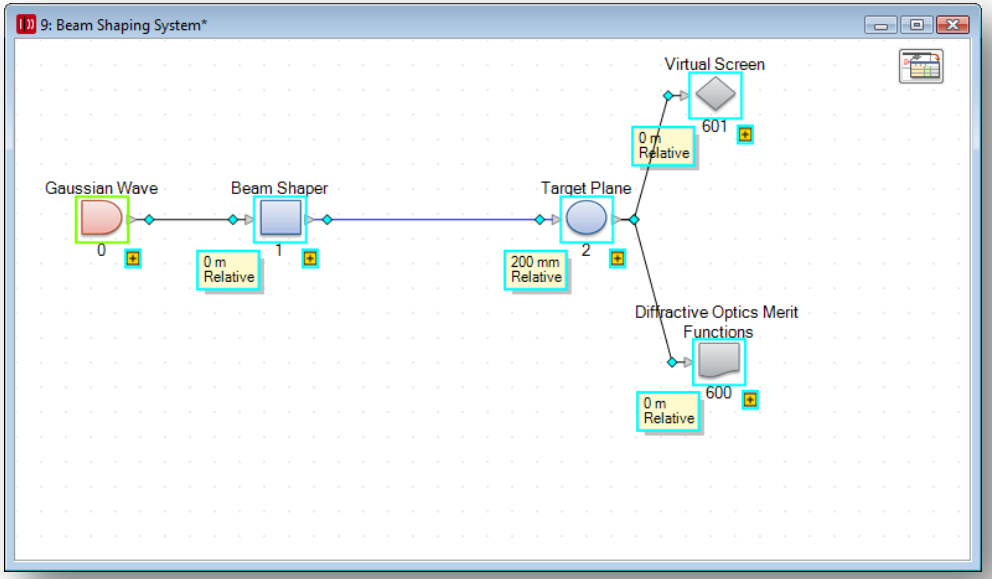
# Session Editor for System Setup



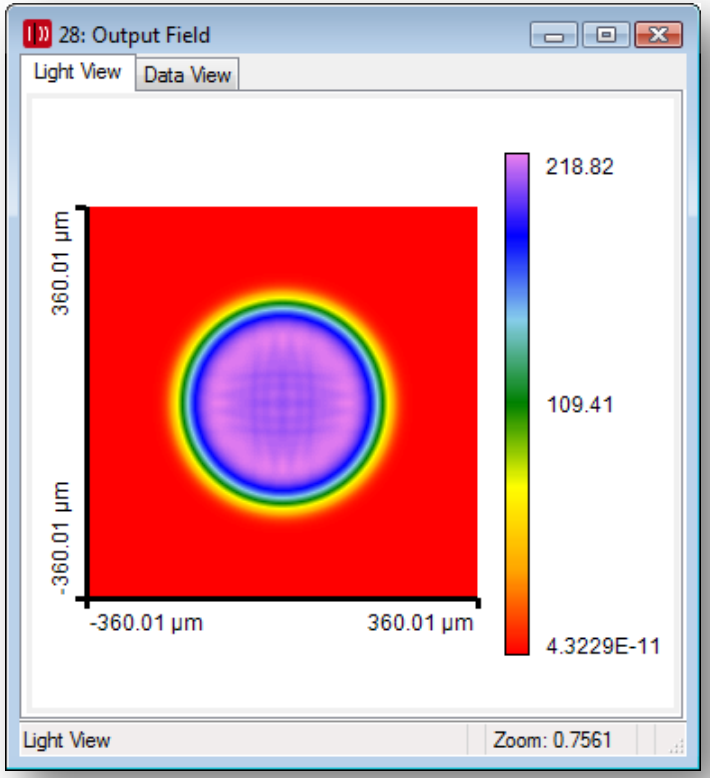

- The refractive beam shaper session editor assists during the setup of standard beam shaping systems.
- The parameters of the incident beam, of the optical setup and of the output field must be specified.
- The session editor with all parameters is stored in the file “Scenario_307.01_Refractive_Top_Hat_Beam_Shaper_1.seditor”

# System Generated by Session Editor



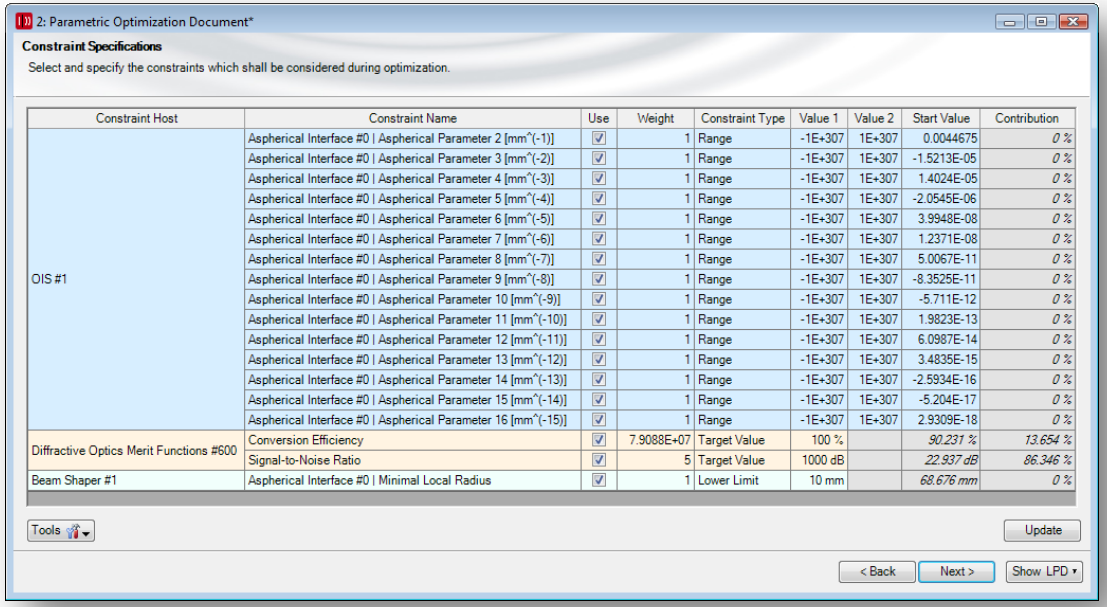

The session editor generates a light path diagram containing a Gaussian Wave source, an optical interface sequence components for modeling of the beam shaper and a diffractive optics merit function detector for the analysis of the quality of the generated Top Hat.

# System Generated by Session Editor




- The session editor calculates the beam shaper surface by an analytical geometrical optics approach.
- Merit functions:
  - SNR: 22 dB
  - Efficiency: 90 %
- The SNR is comparable low since the edge width of the Top Hat is too small.

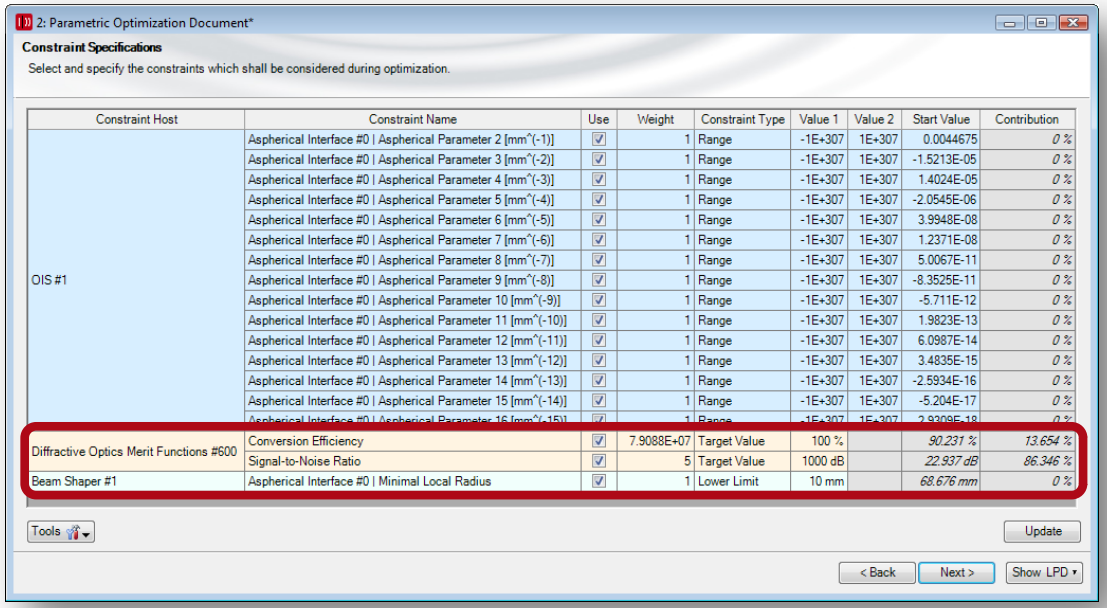
# Parametric Optimization




| Constraint Host | Constraint Name | Use | Weight | Constraint Type | Value 1 | Value 2 | Start Value | Contribution |
|---|---|---|---|---|---|---|---|---|
| OIS #1 | Aspherical Interface #0 \| Aspherical Parameter 2 [mm^(-1)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 0.0044675 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 3 [mm^(-2)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -1.5213E-05 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 4 [mm^(-3)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 1.4024E-05 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 5 [mm^(-4)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -2.0545E-06 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 6 [mm^(-5)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 3.9948E-08 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 7 [mm^(-6)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 1.2371E-08 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 8 [mm^(-7)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 5.0067E-11 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 9 [mm^(-8)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -8.3525E-11 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 10 [mm^(-9)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -5.711E-12 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 11 [mm^(-10)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 1.9823E-13 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 12 [mm^(-11)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 6.0987E-14 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 13 [mm^(-12)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 3.4835E-15 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 14 [mm^(-13)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -2.5934E-16 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 15 [mm^(-14)] | ☑ | 1 | Range | -1E+307 | 1E+307 | -5.204E-17 | 0 % |
| | Aspherical Interface #0 \| Aspherical Parameter 16 [mm^(-15)] | ☑ | 1 | Range | -1E+307 | 1E+307 | 2.9309E-18 | 0 % |
| Diffractive Optics Merit Functions #600 | Conversion Efficiency | ☑ | 7.9088E+07 | Target Value | 100 % | | 90.231 % | 13.654 % |
| | Signal-to-Noise Ratio | ☑ | 5 | Target Value | 1000 dB | | 22.937 dB | 86.346 % |
| Beam Shaper #1 | Aspherical Interface #0 \| Minimal Local Radius | ☑ | 1 | Lower Limit | 10 mm | | 68.676 mm | 0 % |

- The parametric optimization can improve the Top Hat SNR. It is especially possible to reduce the edge width of the Top Hat since the field tracing simulation of the system allows taking into account diffraction, interference and aberrations.
- The optimization document is stored in the file “Scenario_307.01_Refractive_Top_Hat_Beam_Shaper_2.opt”.

# Parametric Optimization

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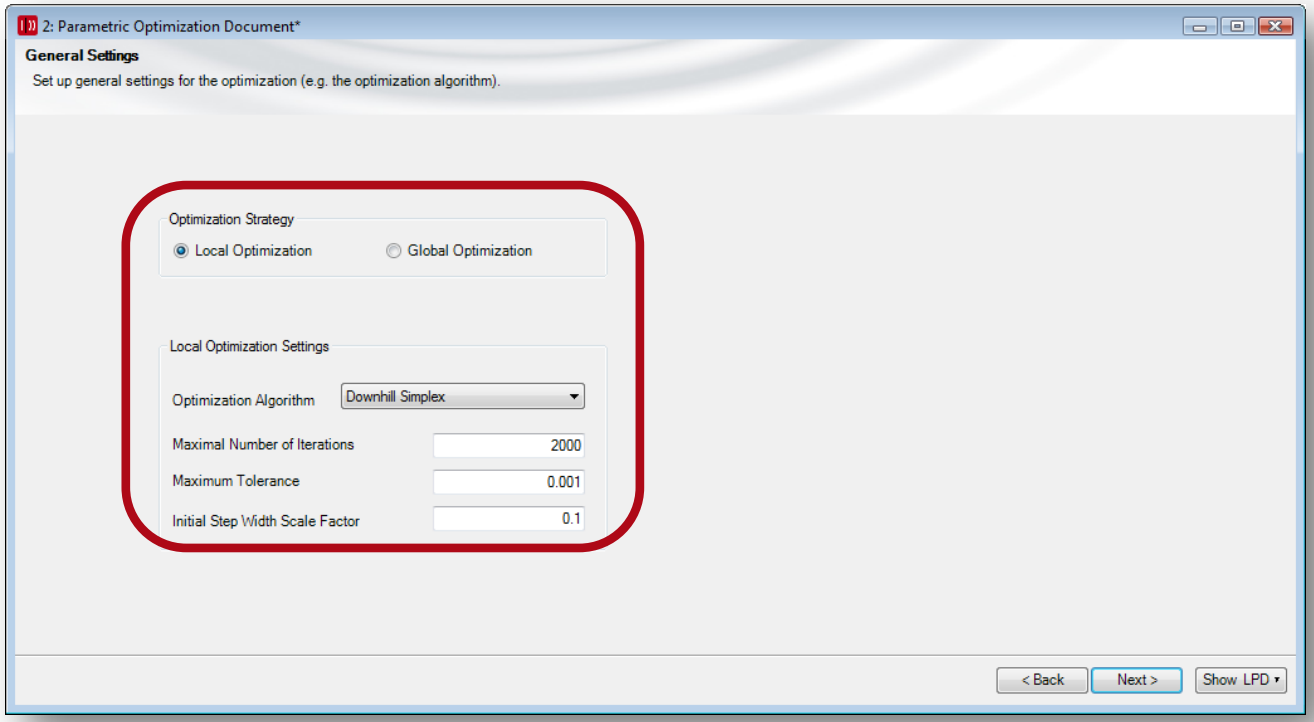
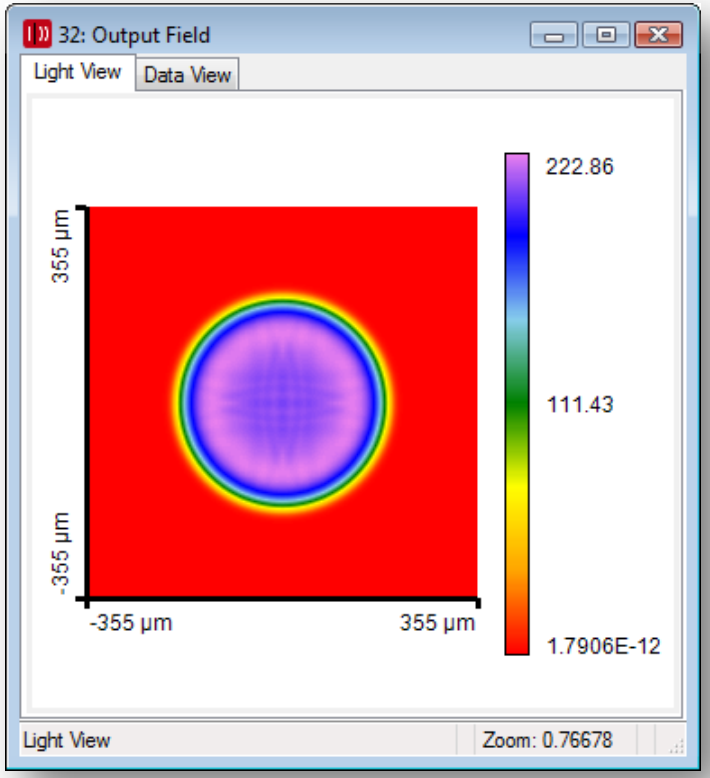
- Conversion efficiency and SNR are optimized by the parametric optimization.
- Since the efficiency is already quite good the impact of the SNR on the common merit function is increased.

# Parametric Optimization



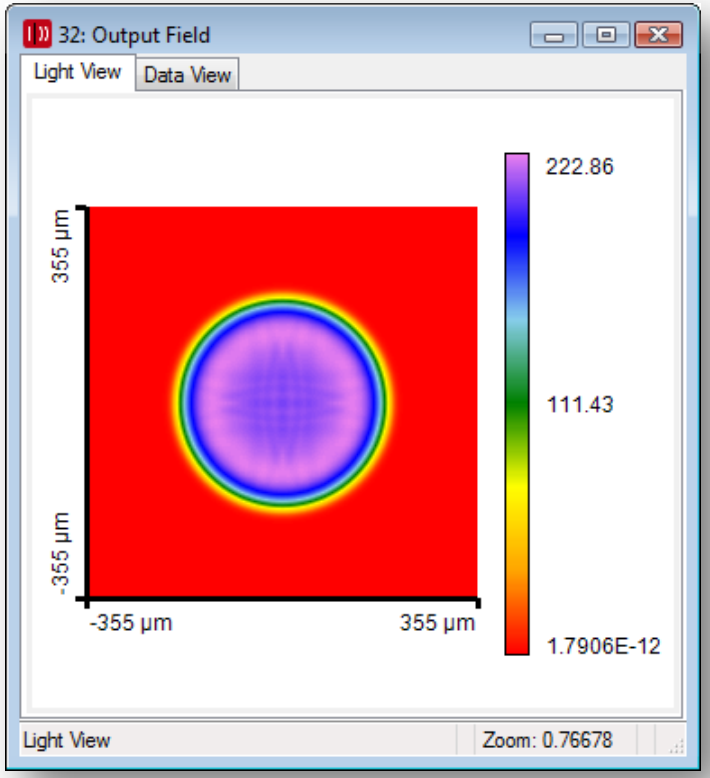

Downhill-Simplex-algorithm used for local optimization.

# Optimization Result




- Top Hat quality after optimization:
  - SNR: 39 dB
  - Efficiency: 91 %
- SNR was significantly increased.

# Optimization Result




- Optimized light path diagram stored in "Scenario_307.01_Refractive_Top_Hat_Beam_Shaper_3.lpd".
- Top Hat contains still small uniformity errors close to the optical axis since the overall Top Hat shape was optimized. A second diffraction optics merit function detector for the calculation of the uniformity error in the central Top Hat region could be used for further improvement of the quality and for finding compromises between sharpness of the edges and uniformity close to the optical axis.

# Conclusions

- VirtualLab™ allows the parametric optimization of refractive beam shaping systems.
- Simulation and optimization take into account diffraction, interference and aberration effects.
- Signal to Noise Ratio and conversion efficiency merit functions can be used for the evaluation of the system quality.