

Scenario 101.01: Parametric optimization of a lens system for focusing of a laser beam

This application scenario demonstrates the parametric optimization of a doublet lens with spherical surfaces for focusing of a collimated laser beam.

Keywords: parametric optimization, lens system, focusing, beam parameter

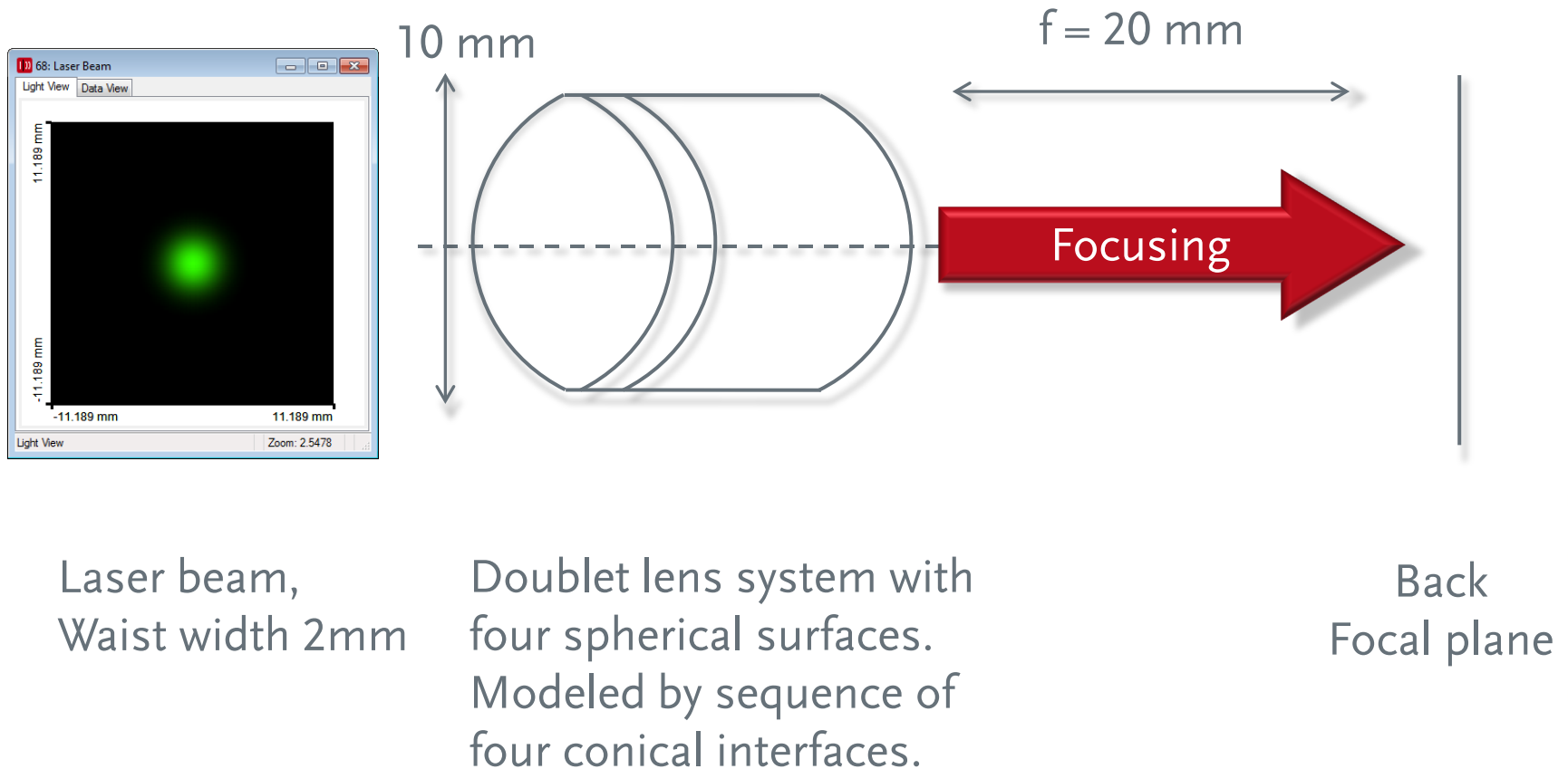
Required Toolboxes: Starter Toolbox Advanced

Related Tutorials and Technical Notes: Tutorial_101.01, TN.021

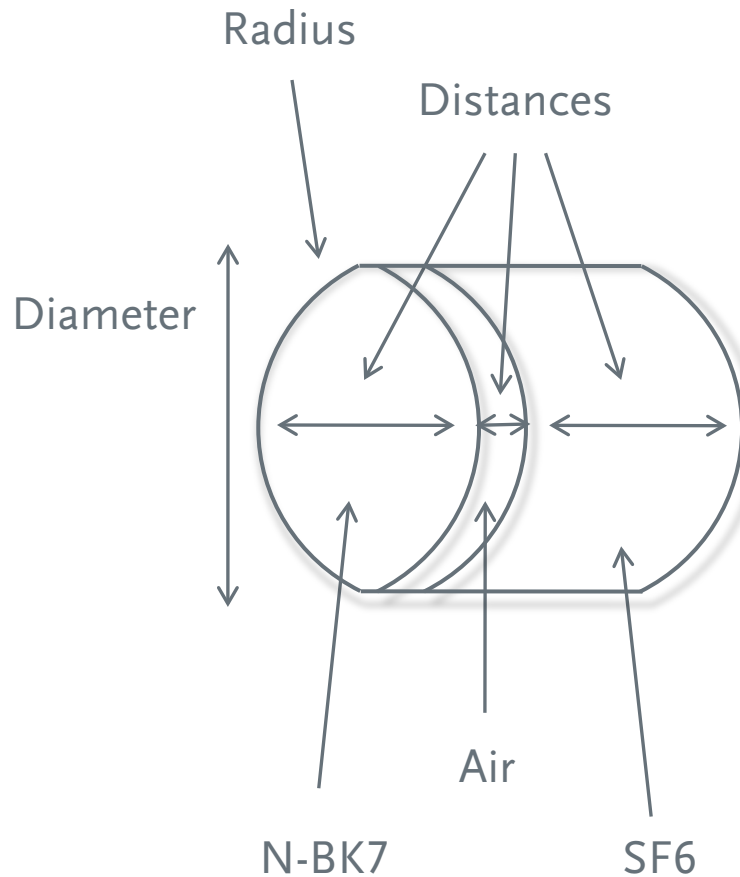
Related Application Scenarios: 100.01, 315.01



Modeling Task



Modeling Task

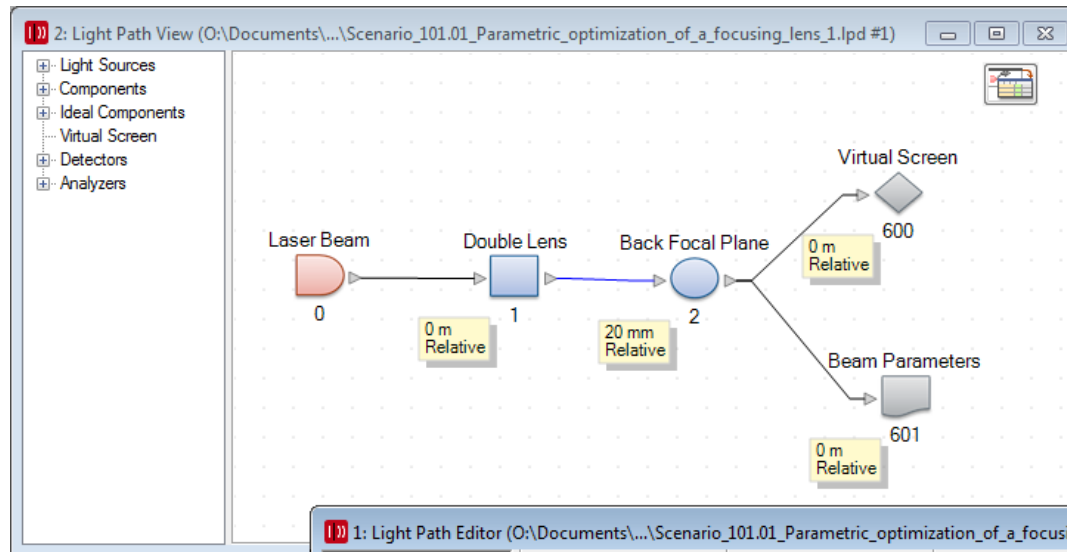


- 2 Lenses
- Diameter: 10 mm
- Distances (fixed): 3 mm, 0.5 mm, 3 mm
- Initial radius off all conical interfaces: ± 25 mm
- Glas: N-BK7 (first lens), SF6 (second lens)

Modeling Task

- Optimize the radii of the conical interfaces such that the focus for the given laser beam appears at the given back focal length.
- Free optimization parameters:
 - Radii of four conical interfaces.
- Target function to be optimized:
 - Minimize the beam radius in the back focal plane.

Light Path Diagram



The automatic propagation operator is used between lens and back focal plane.

1: Light Path Editor (O:\Documents\...\Scenario_101.01_Parametric_optimization_of_a_focusing_lens_1.lpd #1)

Path Detectors Analyzers

Start Element				Target Element		Linkage	
Index	Type	Channel	Medium	Index	Type	Propagation Method	On/Off
0	Laser Beam	-	Standard Air in Homogen...	1	Double Lens	Combined SPW/Fresnel Operator	On
1	Double Lens	T	Standard Air in Homogen...	2	Back Focal Plane	Automatic Propagation Operator	On
2	Back Focal Plane	0	Standard Air in Homogen...				

Tools

☐ Re-Use Automatic Settings

Simulation Type: Field Tracing

Go!


Optimization Document

1: Parametric Optimization Document*

Constraint Specifications

Select and specify the constraints which shall be considered during optimization.

Constraint Host	Constraint Name	Use	Weight	Constraint Type	Value 1	Value 2	Start Value	Contribution
OIS #1	Conical Interface #0 Radius of Curvature	<input checked="" type="checkbox"/>	1	Range	10 nm	10 km	25 mm	N/A
	Conical Interface #1 Radius of Curvature	<input checked="" type="checkbox"/>	1	Range	-10 km	10 km	-25 mm	N/A
	Conical Interface #2 Radius of Curvature	<input checked="" type="checkbox"/>	1	Range	-10 km	10 km	-25 mm	N/A
	Conical Interface #3 Radius of Curvature	<input checked="" type="checkbox"/>	1	Range	-10 km	10 km	-25 mm	N/A
Beam Parameters #601	Radius X	<input checked="" type="checkbox"/>	1	Target Value	0 m		N/A	N/A
	Radius Y	<input checked="" type="checkbox"/>	1	Target Value	0 m		N/A	N/A

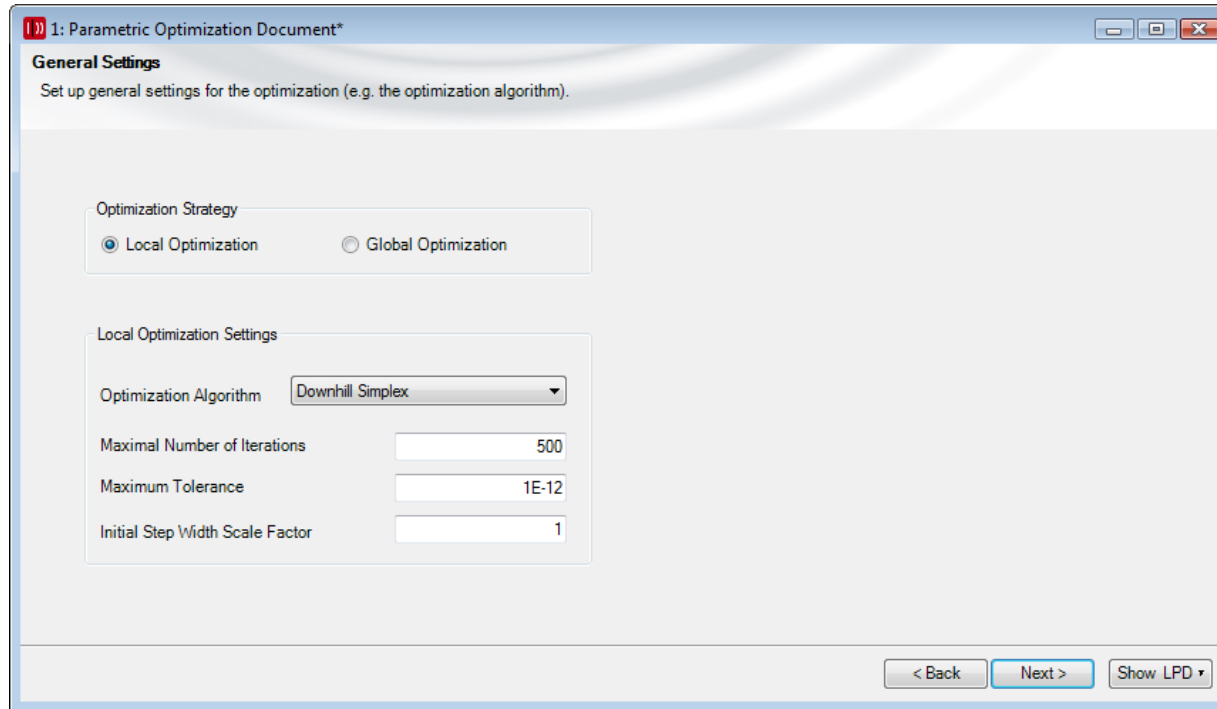
Tools 

Update

< Back Next > Show LPD ▾

- Constraint specification for the free parameters and the target function.

Optimization Algorithm



The screenshot shows a software window titled "1: Parametric Optimization Document*". Inside, the "General Settings" section is active, with the instruction "Set up general settings for the optimization (e.g. the optimization algorithm)".

Optimization Strategy

☒ Local Optimization ☐ Global Optimization

Local Optimization Settings

Optimization Algorithm: Downhill Simplex

Maximal Number of Iterations: 500

Maximum Tolerance: 1E-12

Initial Step Width Scale Factor: 1

At the bottom right, there are three buttons: "< Back", "Next >", and "Show LPD ▾".

- The downhill simplex algorithm is used for the optimization.

Optimization Results

1: Parametric Optimization Document*

Optimization Results
Start or stop the optimization routine. The results are shown in the table.

Start ►

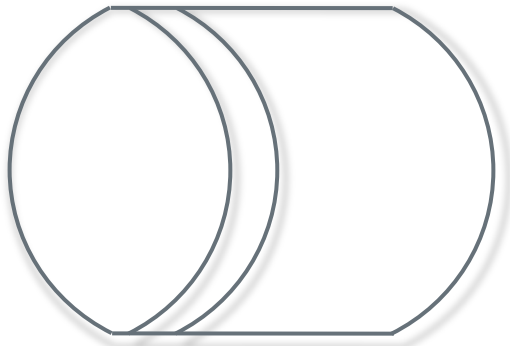
Iteration		217	218	219	220	221	222
Optimizer Logging	Target Function Value	9.737E-12	8.4685E-12	8.6193E-12	8.4708E-12	8.7129E-12	8.457E-12
OIS #1	Conical Interface #0 Radius of Curvature	2.921 mm	12.772 mm	12.83 mm	12.823 mm	12.778 mm	12.826 mm
	Conical Interface #1 Radius of Curvature	9.644 mm	-29.781 mm	-29.732 mm	-29.737 mm	-29.782 mm	-29.731 mm
	Conical Interface #2 Radius of Curvature	3.778 mm	-15.635 mm	-15.69 mm	-15.683 mm	-15.641 mm	-15.686 mm
	Conical Interface #3 Radius of Curvature	2.296 mm	-21.299 mm	-21.299 mm	-21.299 mm	-21.306 mm	-21.297 mm
Beam Parameters #601	Radius X	2.116 μm	2.0558 μm	2.0737 μm	2.0559 μm	2.0855 μm	2.0537 μm
	Radius Y	1.1205 μm	2.0596 μm	2.0783 μm	2.0602 μm	2.0889 μm	2.0589 μm

Output from Selection ☒ Show Physical Units

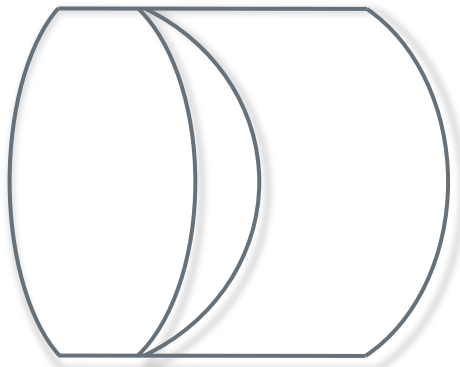
< Back Next > Show LPD ▾

- The optimization results are:
 - Radii of conical interfaces are 12.826 mm, -29.731 mm, -15.686 mm, -21.297 mm.
 - Beam radius in the back focal plane: 2.05 μm .

Optimization Results



- Initial System:
 - Radii -25mm, 25 mm, 25 mm, 25 mm
 - Beam radius in back focal plane: 226 μm



- Optimized System:
 - Radii 12.8 mm, -29.7 mm, -15.6 mm, -21.2 mm
 - Beam radius in back focal plane: 2.05 μm

Conclusions

- VIRTUALLAB™ allows the parametric optimization of laser systems.
- Simulation and optimization take into account diffraction, interference and aberration effects if necessary and allow wave-optical quality measurements.
- Further free parameters, e.g. distances between the interfaces, could be used for optimization.