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Introduction to Parametric Optimization

This tutorial provides an introduction to the usage of the parametric optimization in VirtualLab™ by means of an example for finding the real focus of a spherical lens.

Keywords: parametric optimization, introduction, laser system, lens system, focus, constraint, Starter Toolbox, VirtualLab™ Advanced

Required Toolbox: Starter Toolbox Advanced

Related Application Scenarios: 100.01, 101.01, 315.01

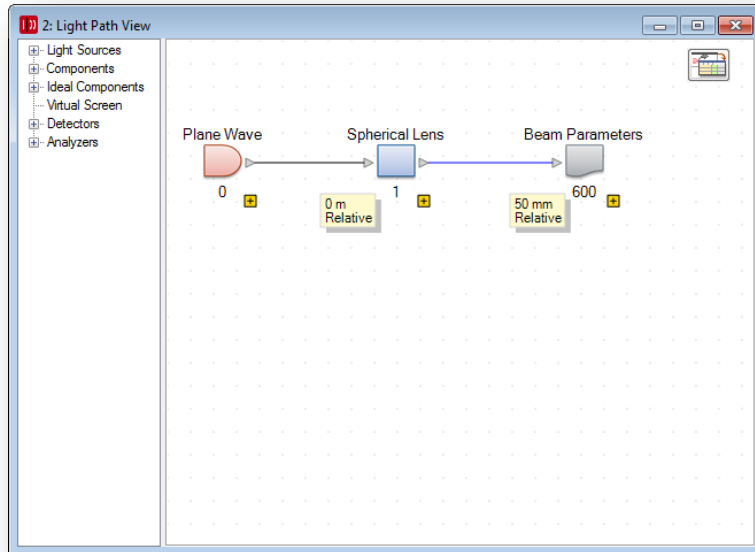
Related Tutorials and Technical Notes: TN.021



Parametric Optimization - Introduction

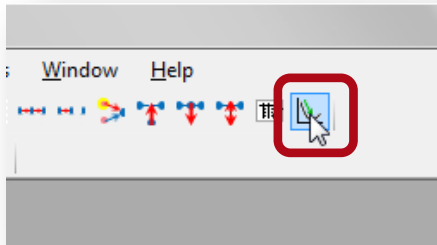
- Optical systems can be optimized with a wide range of applications including in particular laser systems.
- Optimization is done in VIRTUALLAB™ via the Parametric Optimization Document.
- In this tutorial, it is shown how the user can configure the optimization document.
- As an example we consider the following problem with one free parameter: the search of the back focal plane of a spherical lens. For that purpose the beam radius is to be minimized.
- Note, Parametric Optimization is available in VIRTUALLAB™ ADVANCED only.

1. Open Sample Light Path Diagram



- Open the sample light path diagram “Spherical_Lens_System.lpd”.
- We consider a plane wave that is propagated through a spherical lens.
- We measure the beam radius in some distance behind the lens. The initial distance is 50 mm.

2. Create Parametric Optimization Document

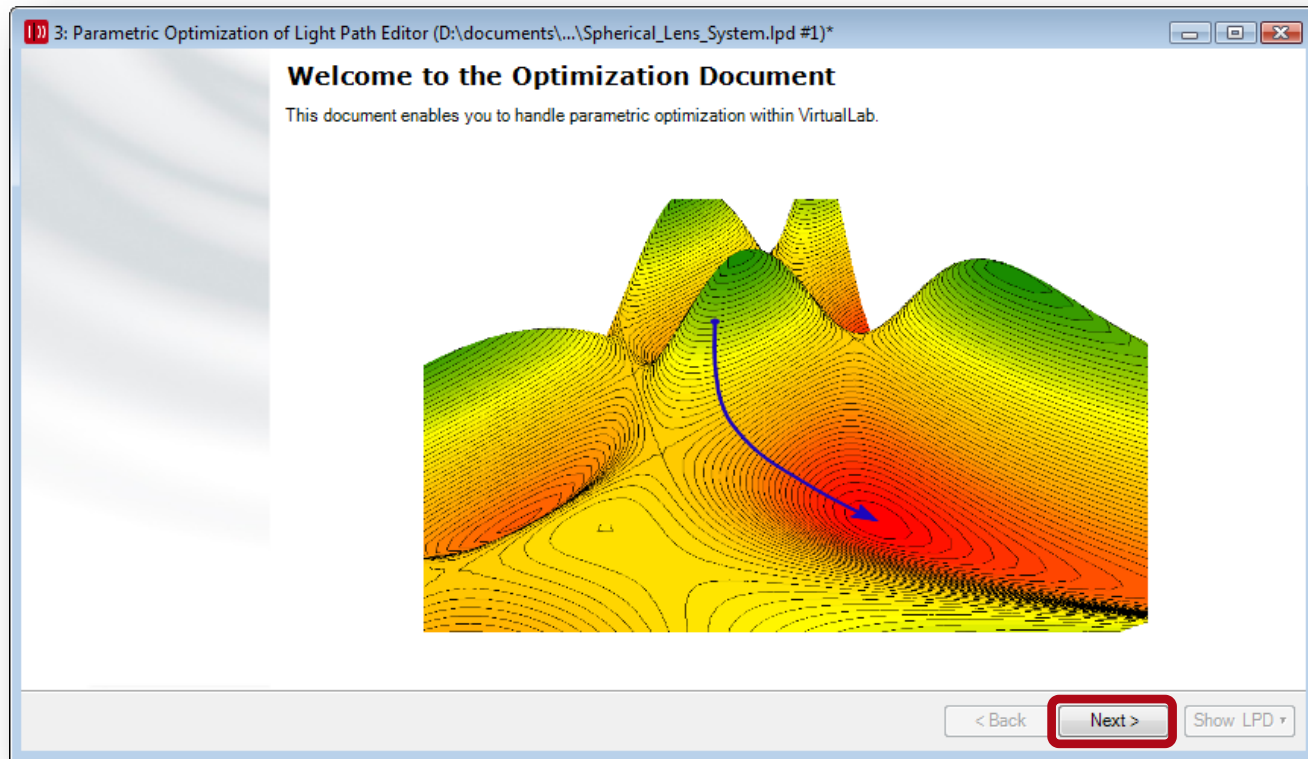


Click on the icon in the toolbar of VIRTUALLAB™ to open a new Parametric Optimization document.

Results in



2. Create Parametric Optimization Document

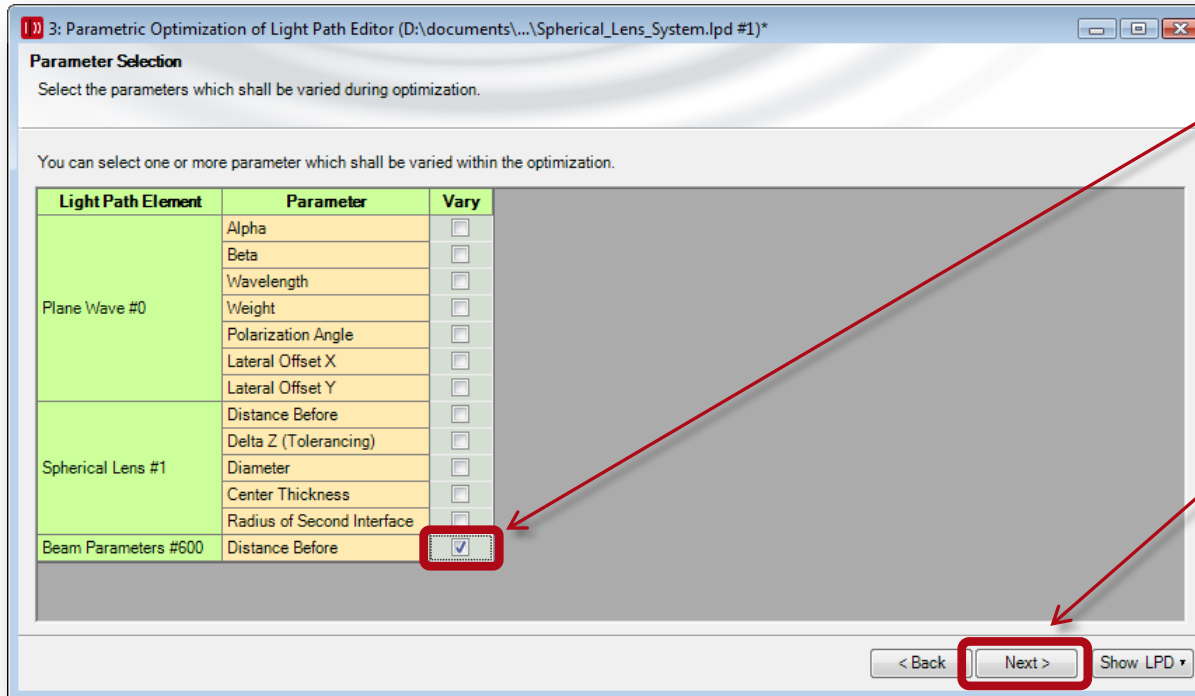


Click *Next*.

Results in



3. Select Variable Parameter(s)

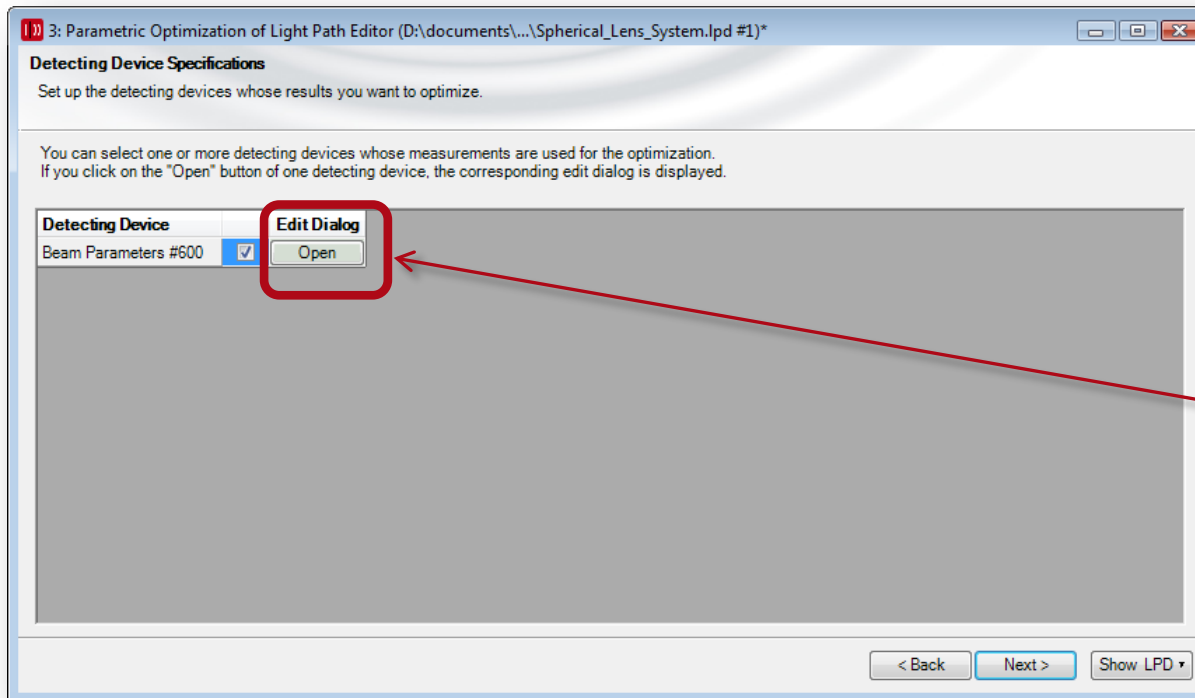


- Select *Distance Before Beam Parameters Detector* as free variable.
- Click *Next*.

Results in



4. Select Merit Functions

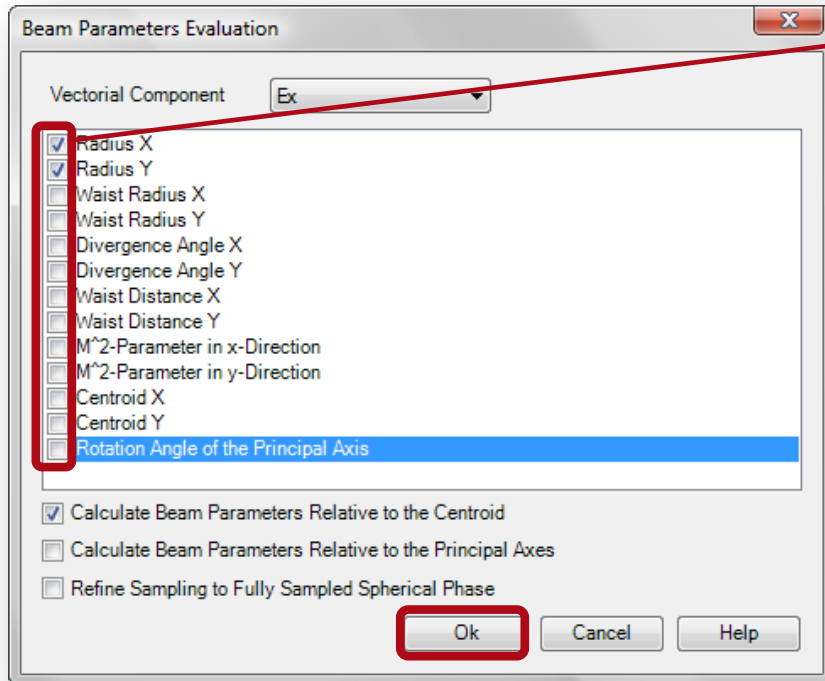


- On the Detectors page the merit functions that are to be optimized can be chosen.
- Click *Open* to open the edit dialog of the *Beam Parameters Detector*.

Results in



4. Select Merit Functions

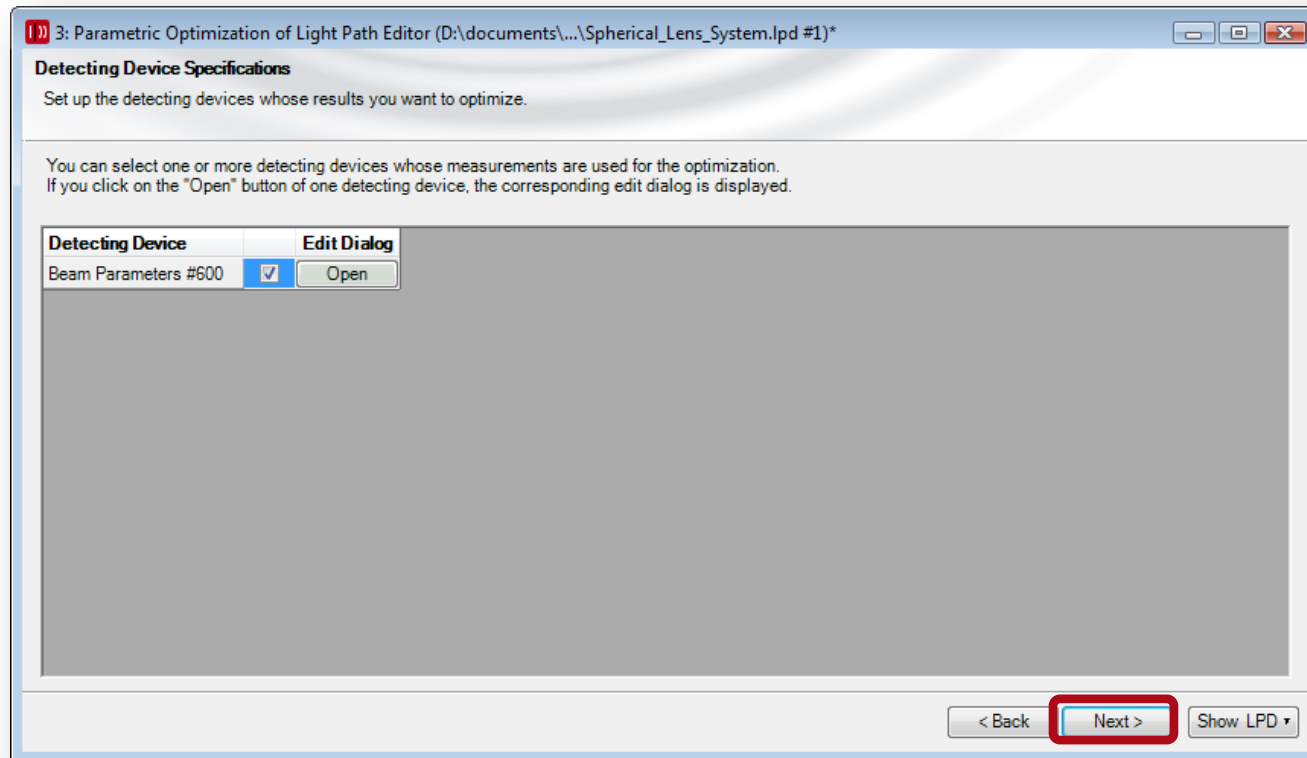


- Here, the settings from the light path diagram are preset and can be modified. All beam parameters except for *Radius X* and *Radius Y* are unchecked.
- Press *Ok*.

Results in



4. Select Merit Functions

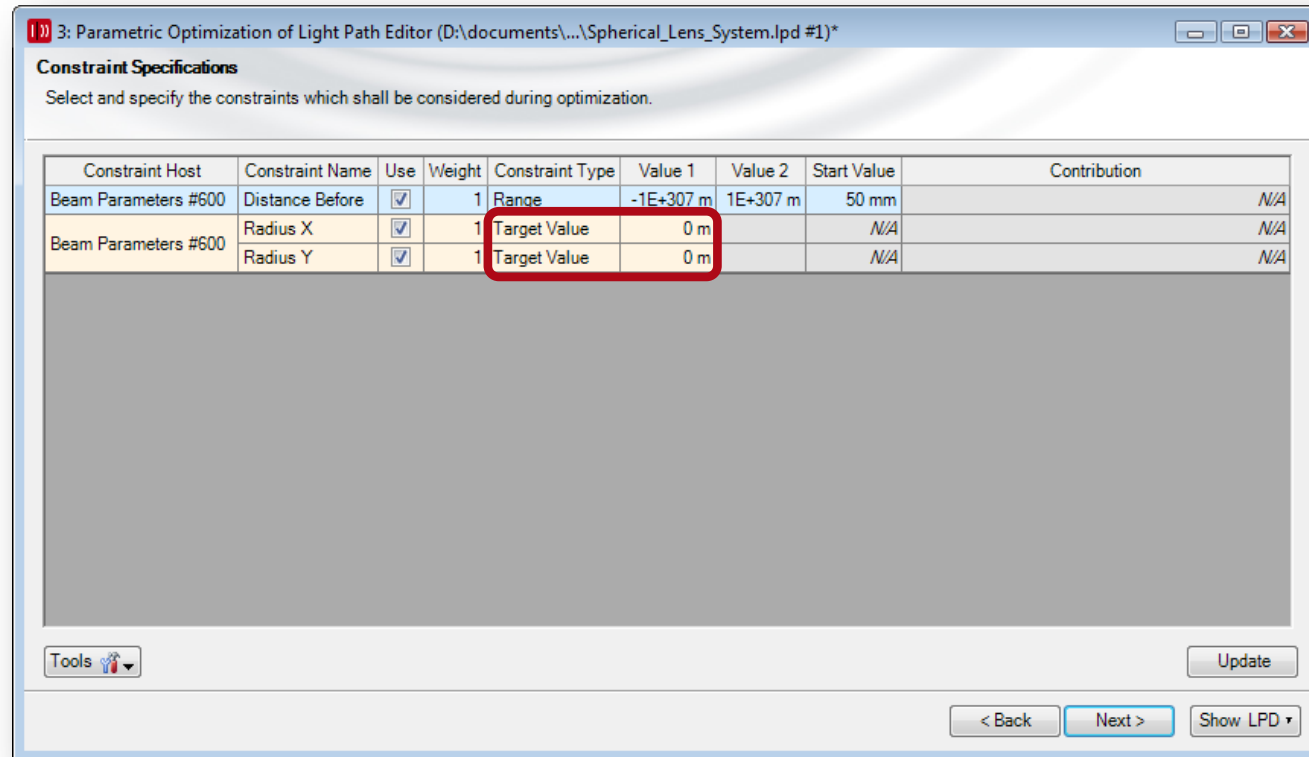


Click *Next*.

Results in

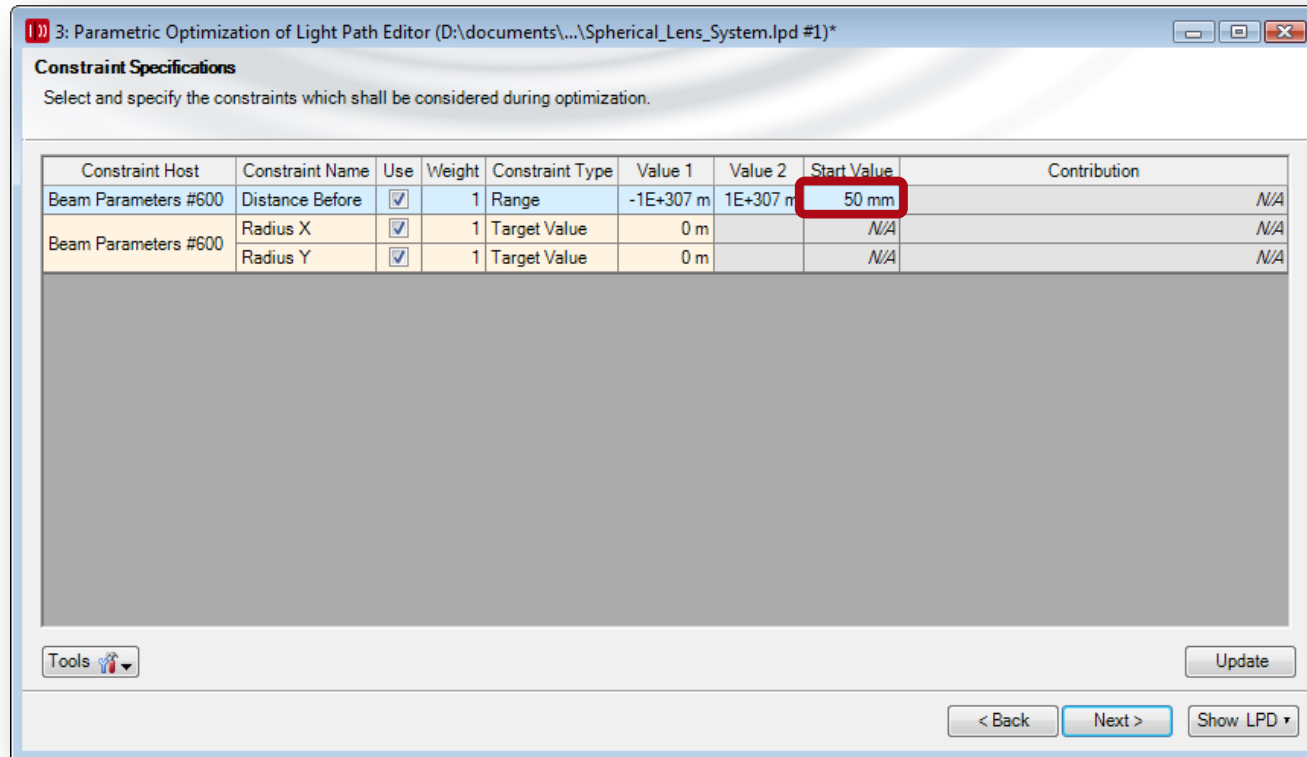


5. Specify the Constraints



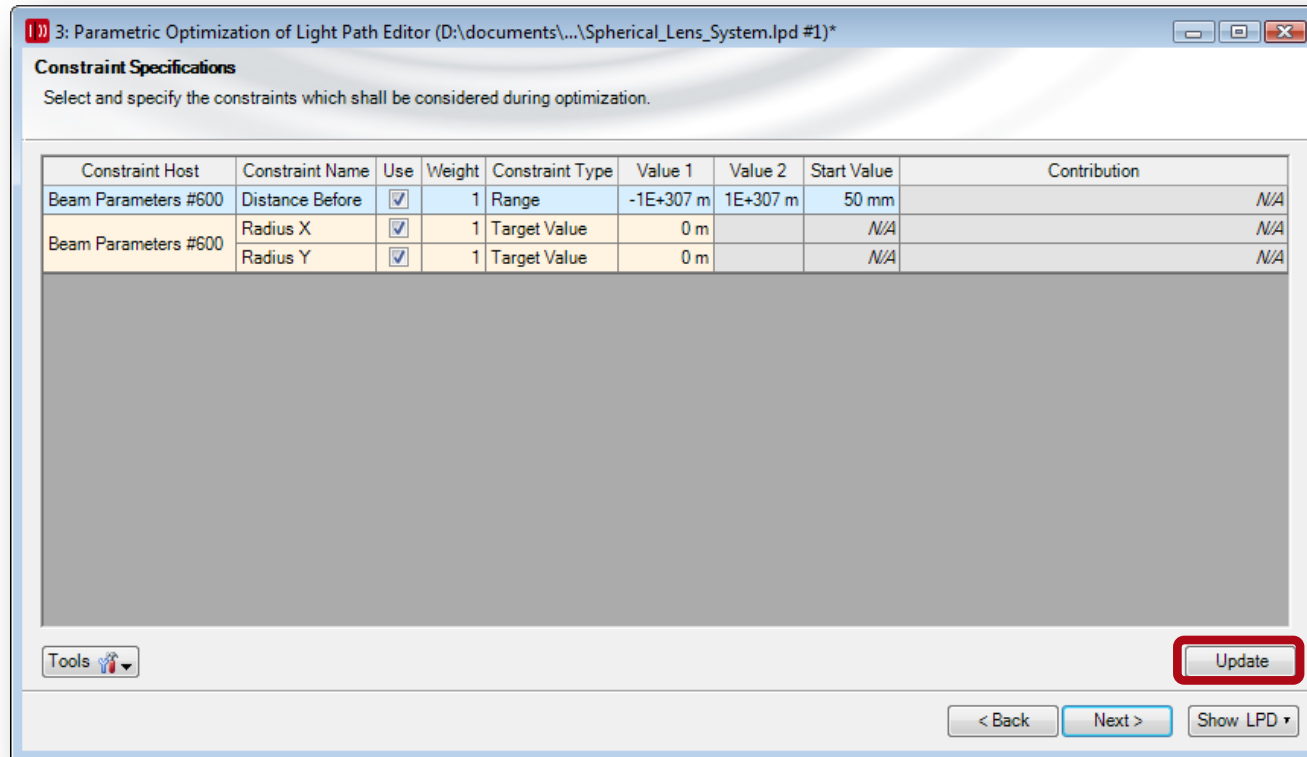
- Via the constraint specifications the target function to be minimized is defined. Keep the default settings – *Target Value* “0m” for *Radius X* and *Radius Y*.

5. Specify the Constraints – Start Values



- The *Start Value* for the free parameter(s), here *Distance Before*, can be set. The preset value is copied from the settings in the light path diagram, namely 50mm.

5. Specify the Constraints



- Press *Update* to compute the contributions of merit functions. This starts a simulation step of the light path diagram, if necessary.

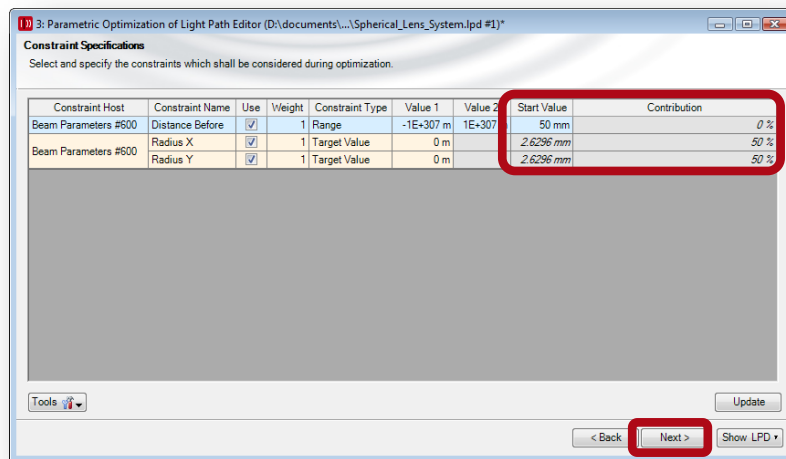
Results in



5. Specify the Constraints

Start Value	Contribution
50 mm	0 %
2.6296 mm	50 %
2.6296 mm	50 %

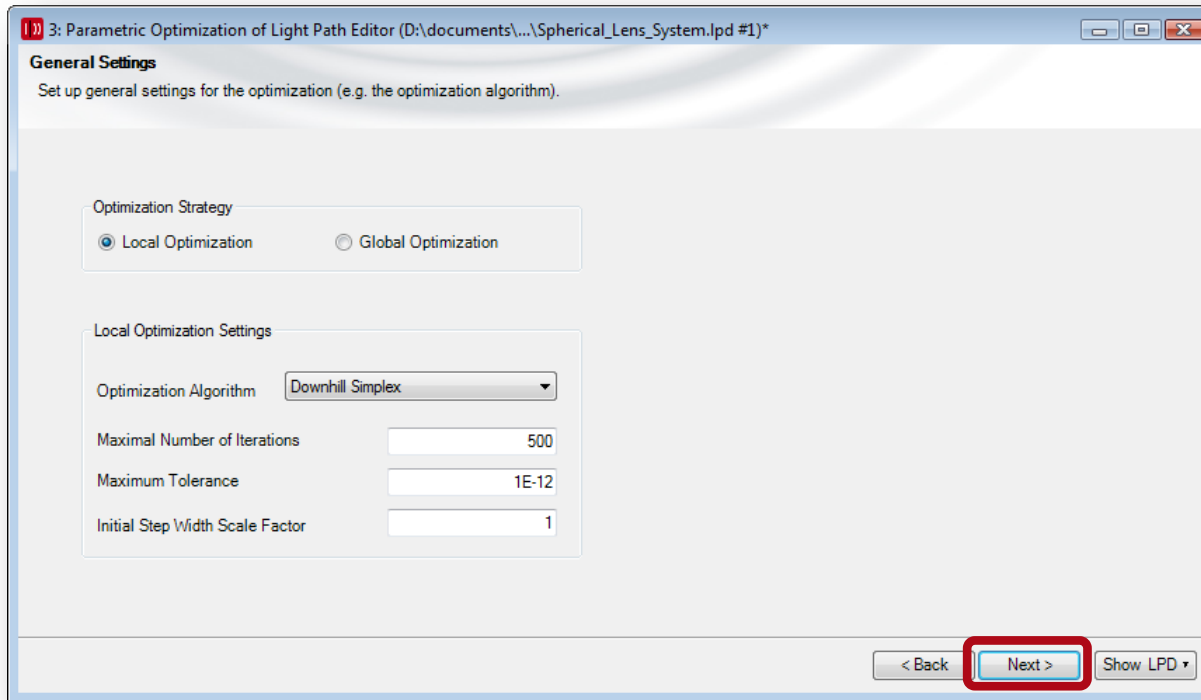
- All available merit functions (*Radius X* and *Radius Y* of *Beam Parameters* detector) are calculated for the given start values.
- Contributions to the target function of all available constraints in percent are updated.
- Click *Next*.



Results in



6. Specify General Settings

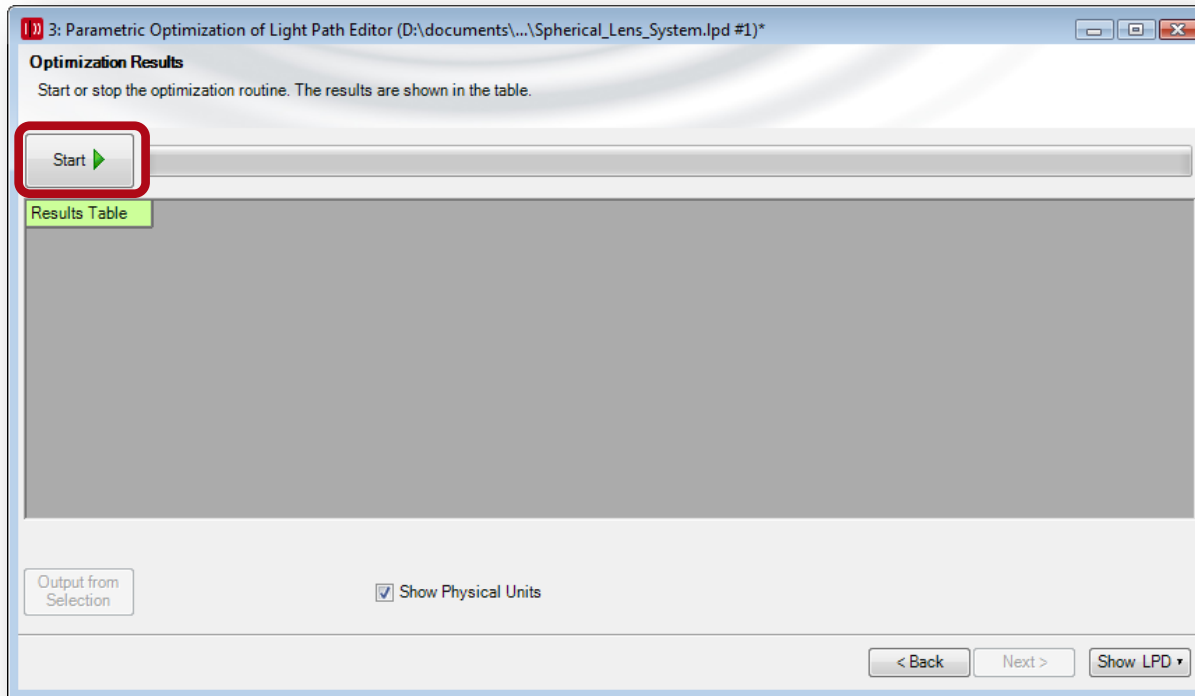


- Algorithmic parameters like *Global* or *Local Optimization*, the *Algorithm* and stop criteria can be adjusted on this page.
- Keep standard settings.
- Click *Next*.

Results in



7. Start Optimization



- On this page the optimization can be started or stopped and each simulation step is logged .
- Press *Start* and wait until optimization stops.

Results in



7. Start Optimization

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

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

Start ►

Simulation Step		26	27	28	29	30	31	32	33
Optimizer Logging	Target Function Value	10	5.2705E-10	5.3314E-10	5.2207E-10	5.2512E-10	5.2121E-10	5.2207E-10	5.2118E-10
	Distance Before	m	99.336 mm	99.414 mm	99.355 mm	99.395 mm	99.365 mm	99.355 mm	99.37 mm
Beam Parameters #600	Radius X	m	16.234 µm	16.327 µm	16.157 µm	16.204 µm	16.143 µm	16.157 µm	16.143 µm
	Radius Y	m	16.234 µm	16.327 µm	16.157 µm	16.204 µm	16.143 µm	16.157 µm	16.143 µm

Output from Selection ☒ Show Physical Units

< Back Next > Show LPD ▼

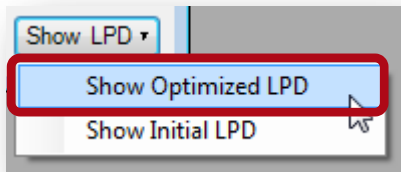
- Logging of all simulation steps.
- Algorithm stops either if one of the stop criteria were fulfilled or *Stop* (same button as *Start*) was clicked.
- Last column with optimized parameter(s) (distance from lens to detector).

Click *Show LPD*.

Results in



8. Show Optimized LPD

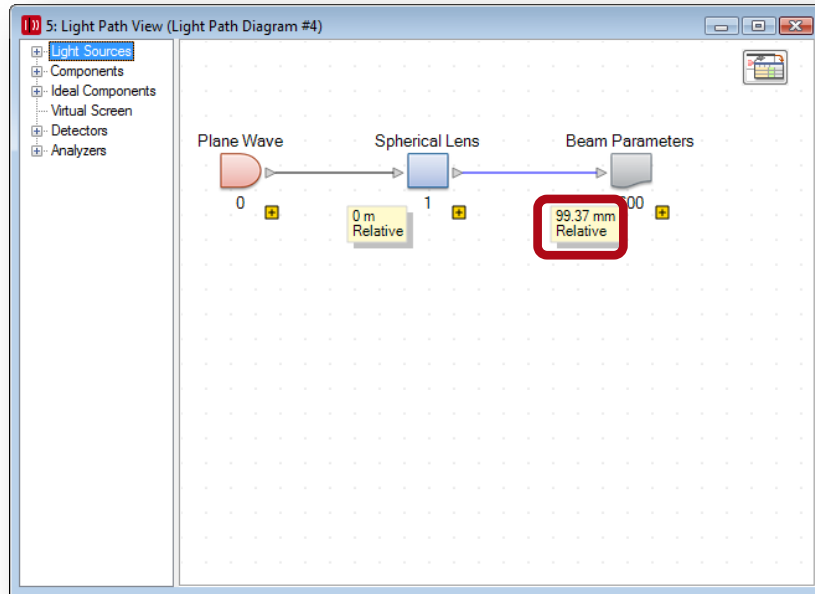


Click *Show Optimized LPD* on context menu to open a *Light Path Diagram* that contains the optimized parameter(s).

Results in

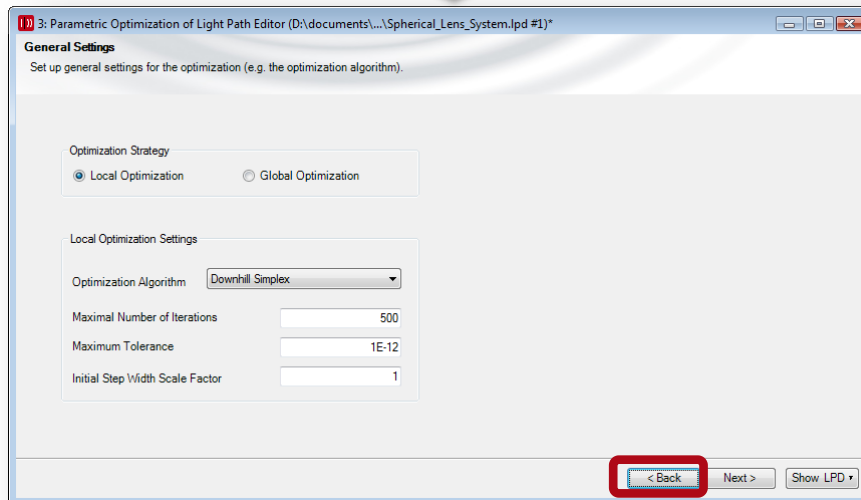
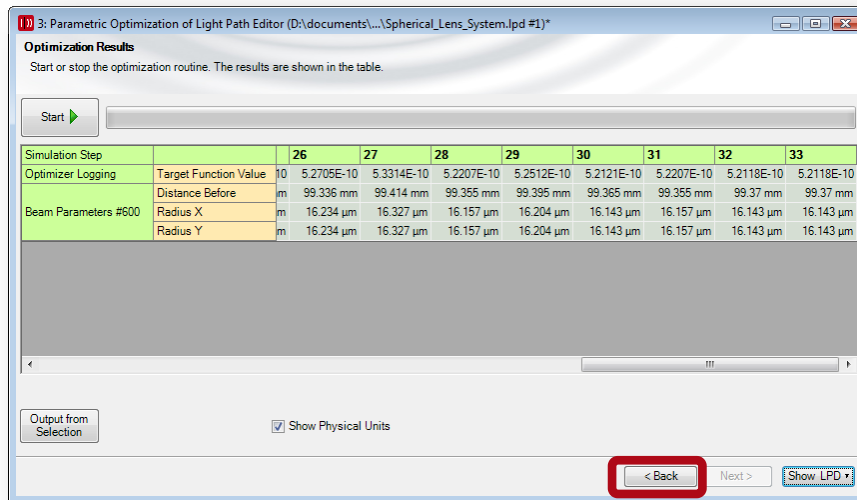


8. Show Optimized LPD



Resulting Light Path Diagram with optimized parameter(s).

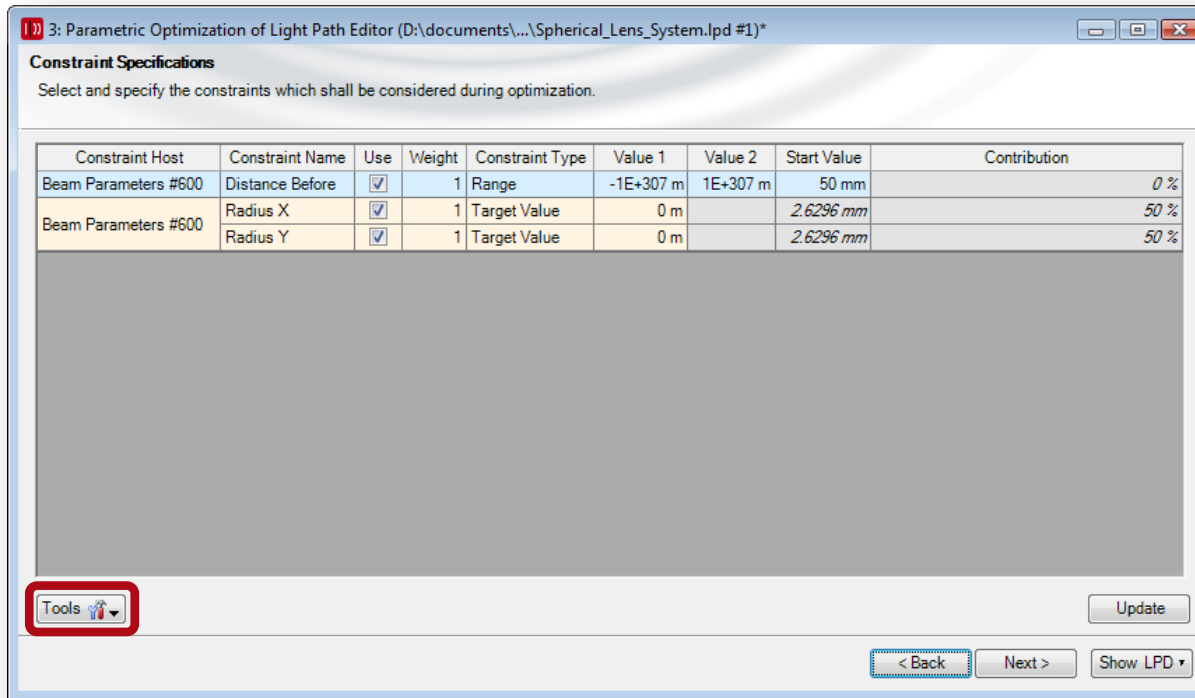
9. Modify Start Values via Optimization Tools



Go back to *Constraint Settings* page of document (click *Back* on *Optimization Results* page and *Back* on *General Settings* page).

9. Modify Start Values via Optimization Tools

Results in

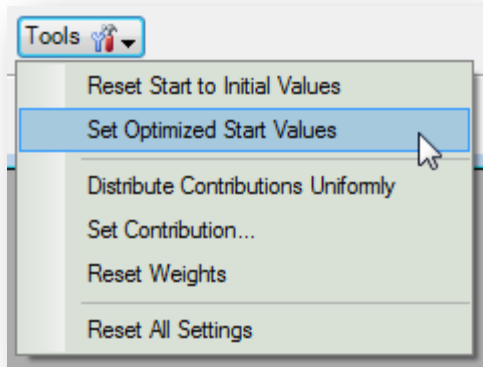


Press *Tools* button.

Results in



9. Modify Start Values via Optimization Tools

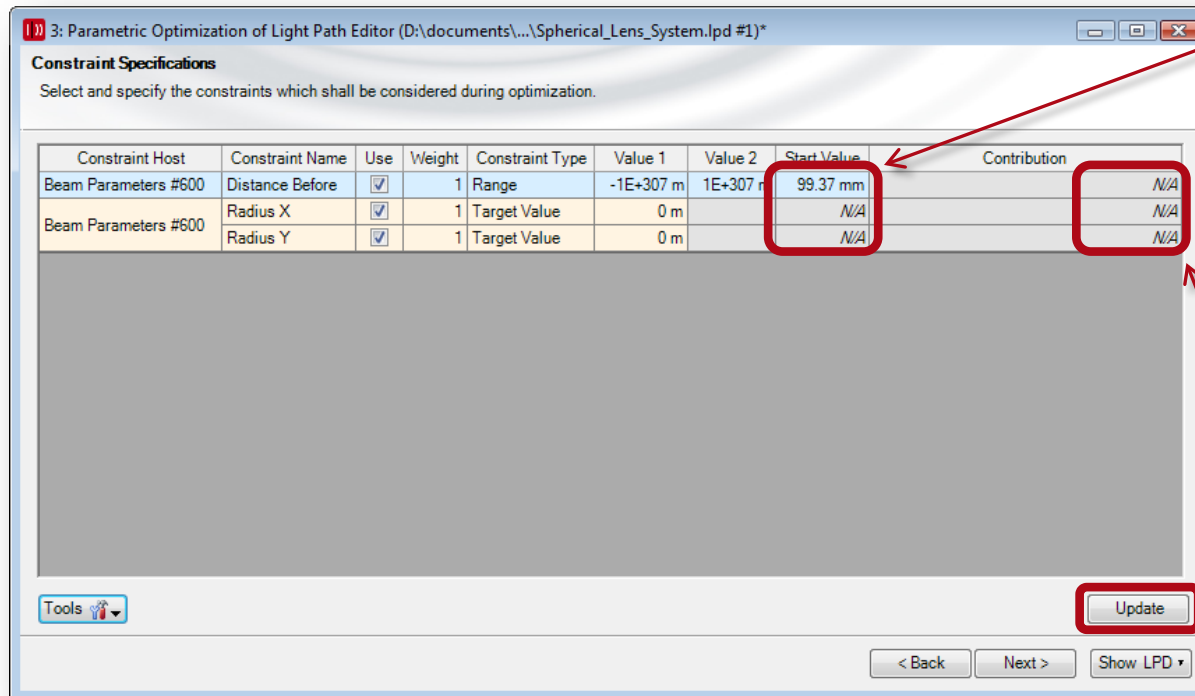


Click on *Set Optimized Start Values* to set optimized *Distance Before* as new start parameter.

Results in



9. Modify Start Values via Optimization Tools



- Start value of variable parameter (*Distance Before*) changed to optimized value (99.37mm).

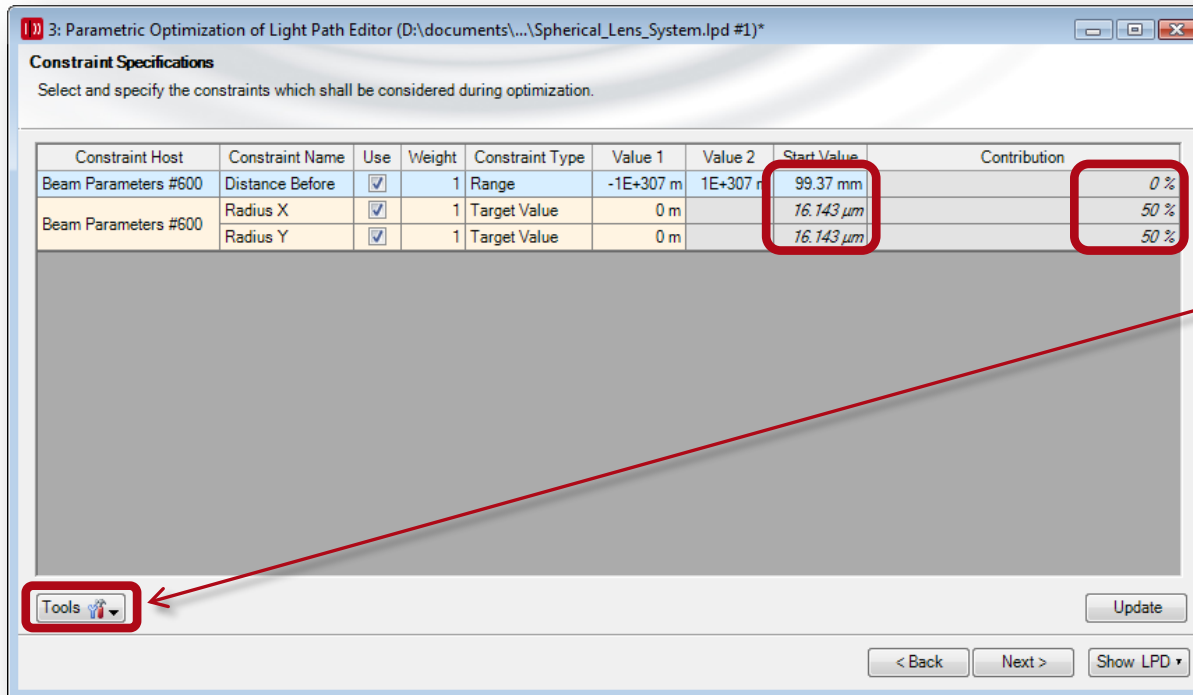
- Merit function values (*Radius X*, *Radius Y*) and contributions need to be updated (N/A).

- Click *Update*.

Results in



9. Modify Start Values via Optimization Tools

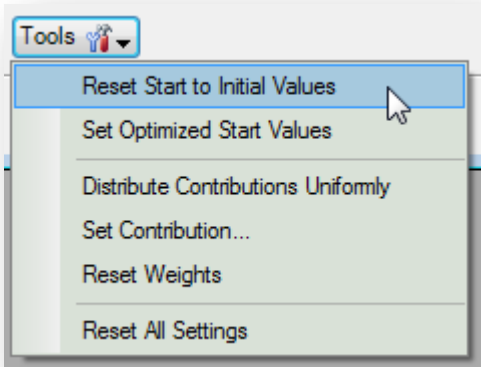


- *Start Values* and *Contributions* have been recalculated.
- Press *Tools* button again.

Results in



9. Modify Start Values via Optimization Tools

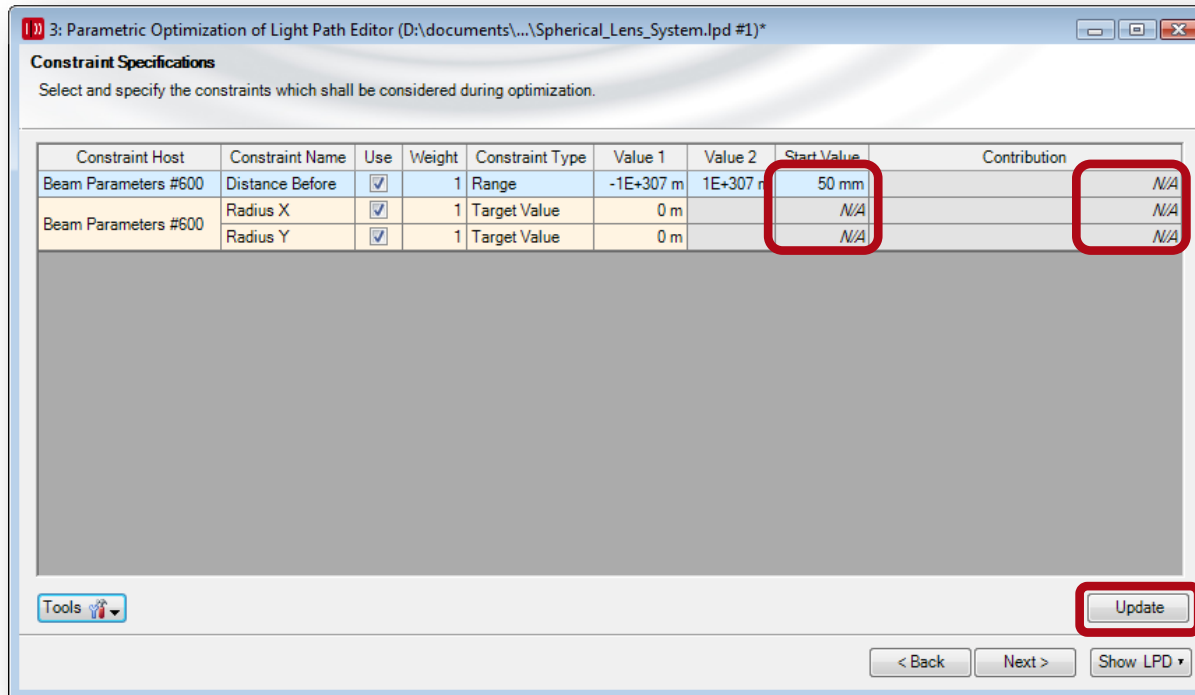


Click on *Reset Start to Initial Values* to copy the *Distance Before Beam Parameters Detector* from the initial LPD into constraint table.

Results in



9. Modify Start Values via Optimization Tools

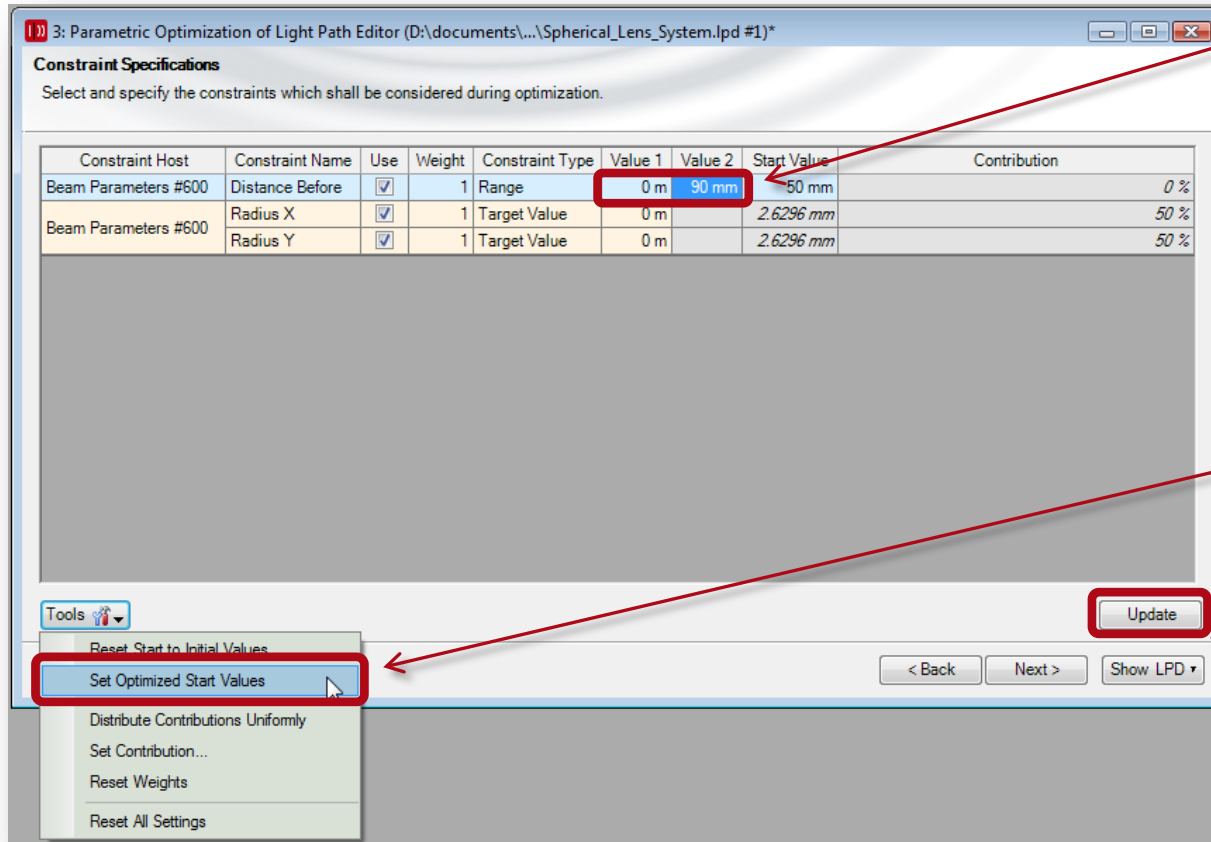


Start value of variable parameter (*Distance Before*) changed to initial value (50mm).

Results in



10. Edit Parameter Constraint



Edit constraint of *Distance Before* to range

[0, 90mm] via *Value 1* and *Value 2*

Click *Optimization Tools > Set Optimized Start Values*

Press *Update*

Results in




10. Edit Parameter Constraint

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

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
Beam Parameters #600	Distance Before	<input checked="" type="checkbox"/>	1	Range	0 m	90 mm	99.37 mm	99.999 %
Beam Parameters #600	Radius X	<input checked="" type="checkbox"/>	1	Target Value	0 m		16.143 μm	0.0002968 %
Beam Parameters #600	Radius Y	<input checked="" type="checkbox"/>	1	Target Value	0 m		16.143 μm	0.0002968 %

Tools  Update

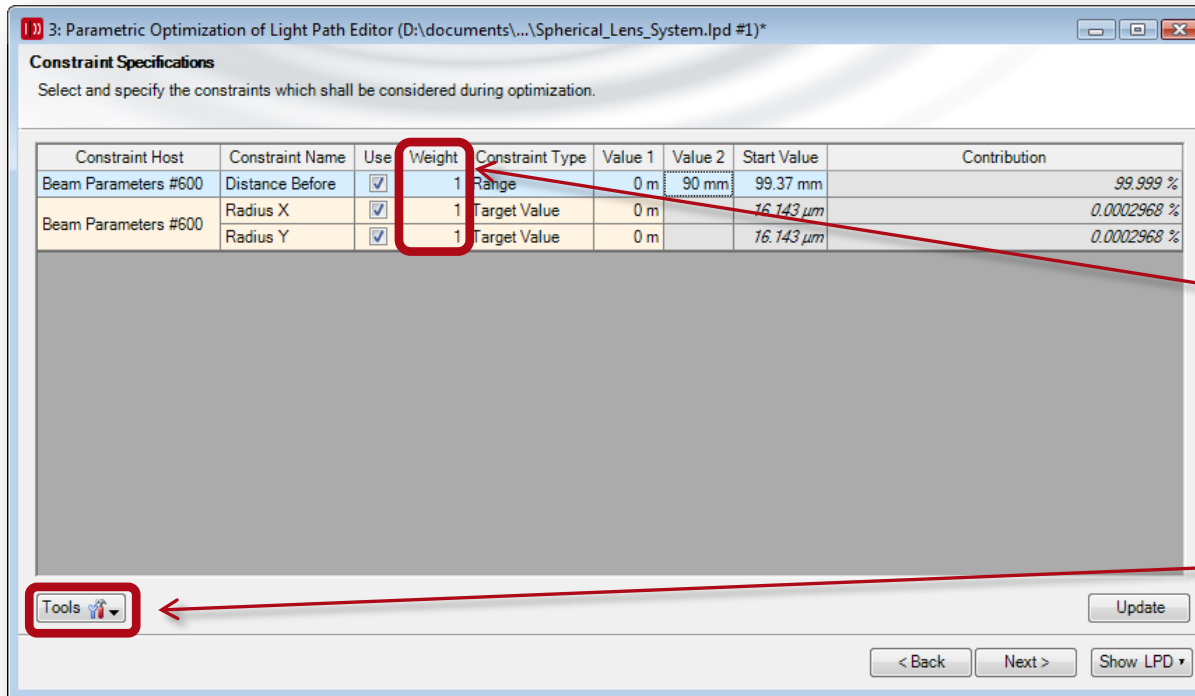
< Back Next > Show LPD ▾

- Parameter constraint is violated at start value now.
- Due to definition of the target function in SI derived units (namely m here) the contribution of the parameter constraint is very high (99.999%).

Results in



11. Modify Constraint Weights

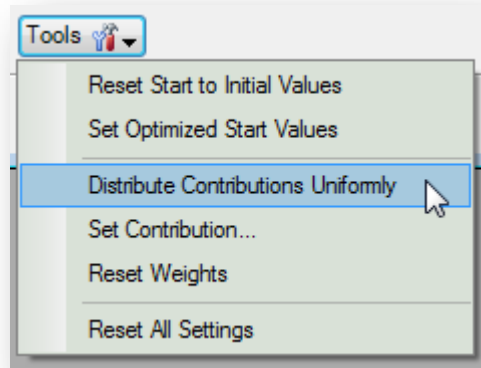


- Contributions of constraints can be modified by their weights
- *Weights* can be entered directly or via Optimization *Tools*
- Click *Tools* button

Results in



12. Set Equal Contributions

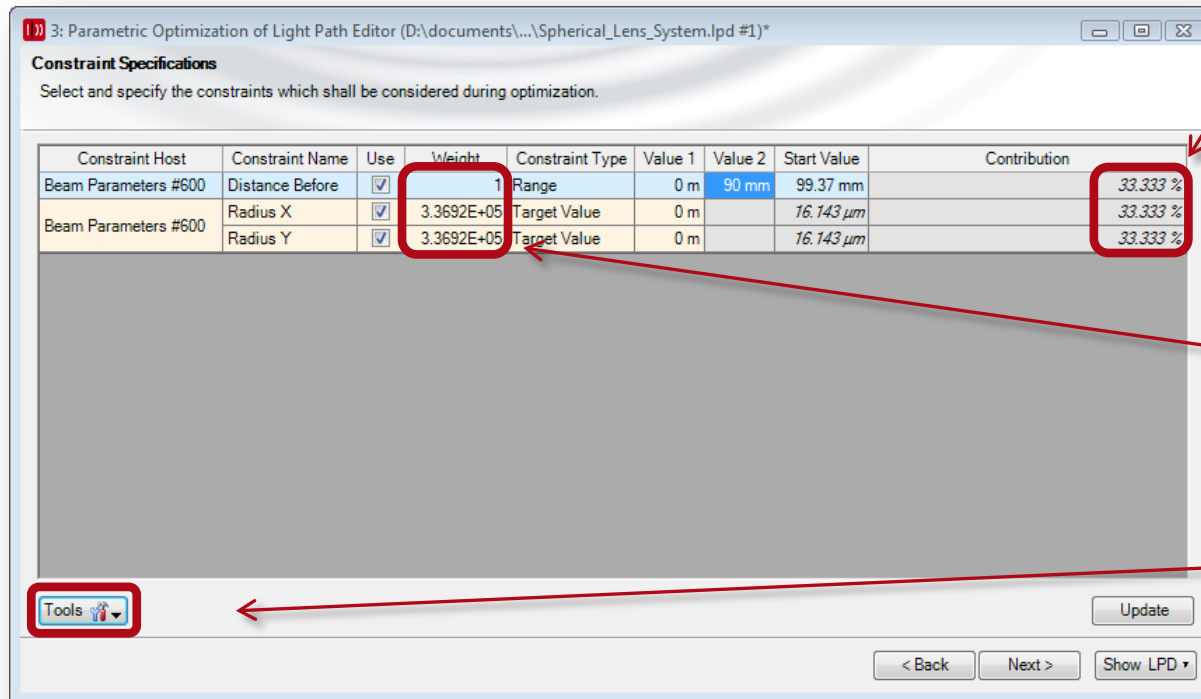


Click on *Distribute Contributions Uniformly* to calculate weights for equal contributions of violated constraints.

Results in



12. Set Equal Contributions



- Contributions of all violated constraints are equal now (namely 33.333%).

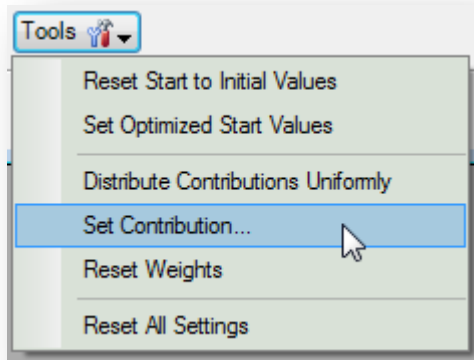
- This has been achieved by proper weights.

- Press *Tools* button.

Results in



13. Set Target Contribution



Click on *Set Contribution* to specify an arbitrary target contribution between 0 and 100% for any violated constraint (contribution > 0).

Results in



13. Set Target Contribution

Set Target Contribution for Single Constraint

Choose Constraint from List:

Constraint Host	Constraint Name	Select
Beam Parameters #600	Distance Before	<input checked="" type="checkbox"/>
	Radius X	<input type="checkbox"/>
	Radius Y	<input type="checkbox"/>

Enter Target Contribution:

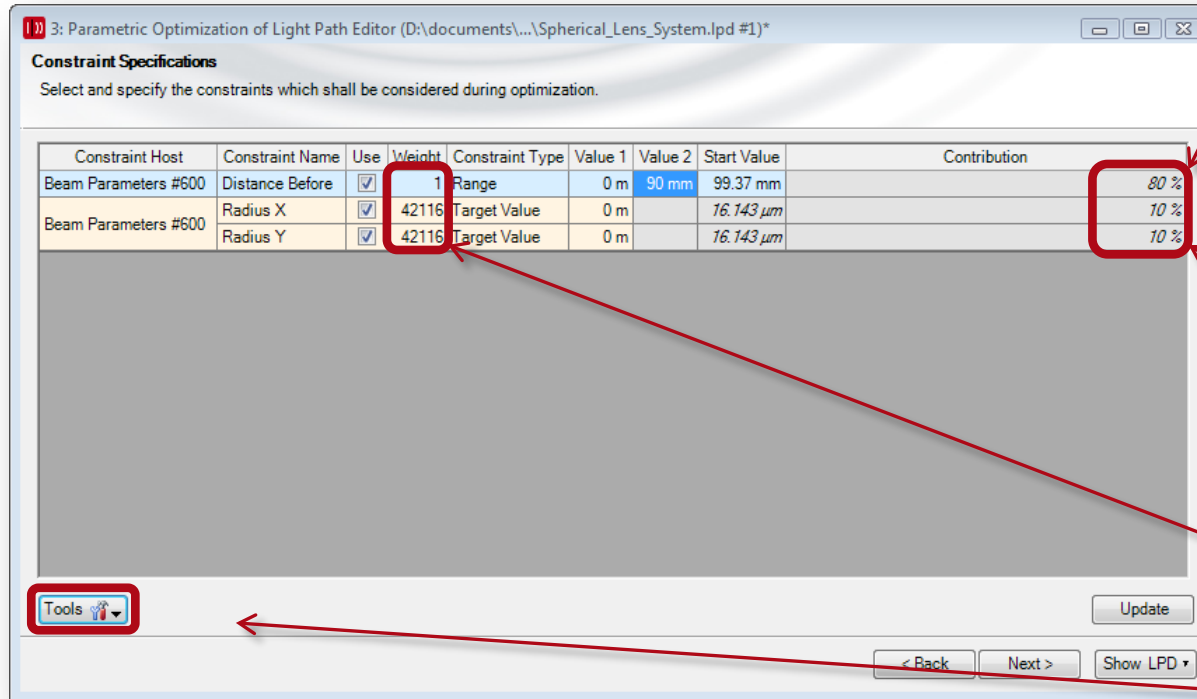
Ok Apply Cancel Help

- Enter 80 % as *Target Contribution* for parameter constraint (*Distance Before* has to be selected).
- Click *Ok*.

Results in



13. Set Target Contribution



Contribution of parameter constraint is 80% now.

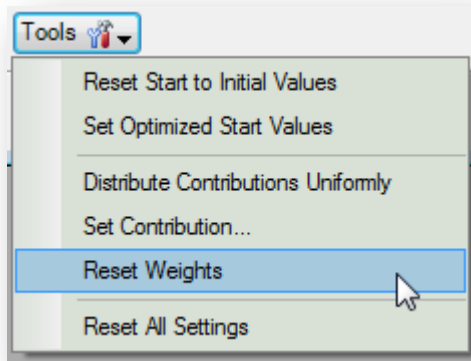
Sum of other contributions in percent yields 20%.

Weights are adapted accordingly.

Press

Optimization Tools button.

14. Reset Weights

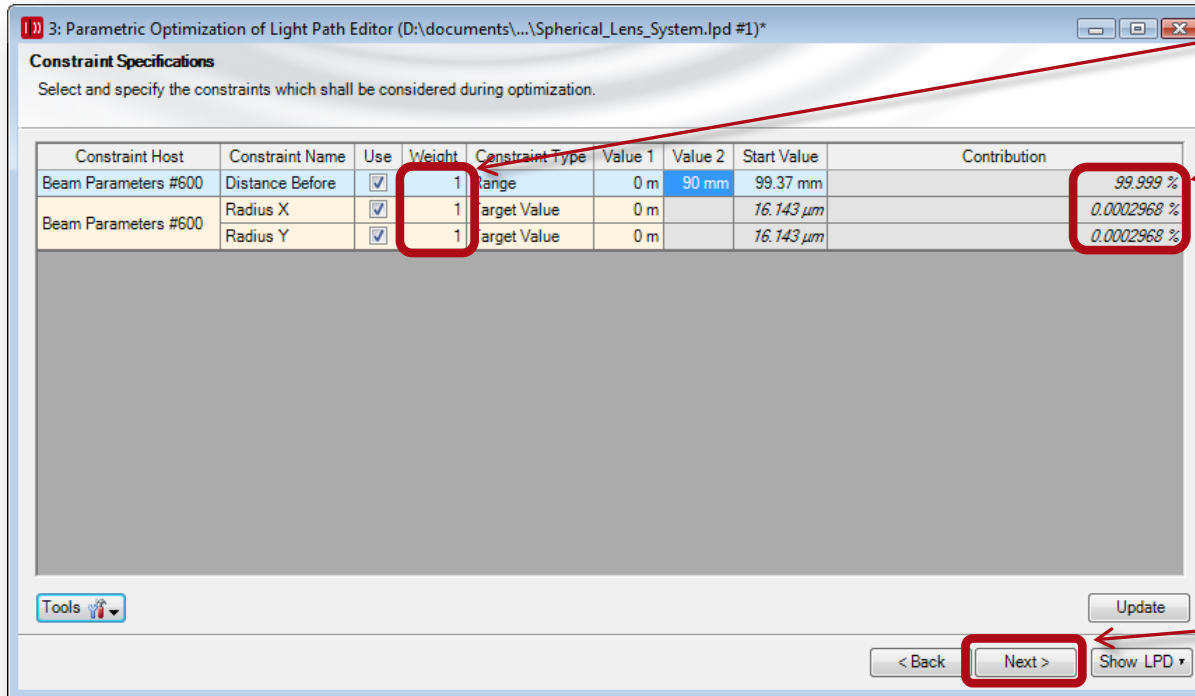


Click on *Reset Weights* to reset all weights to 1.

Results in



15. Reset Weights



- Weight have been reset to 1.

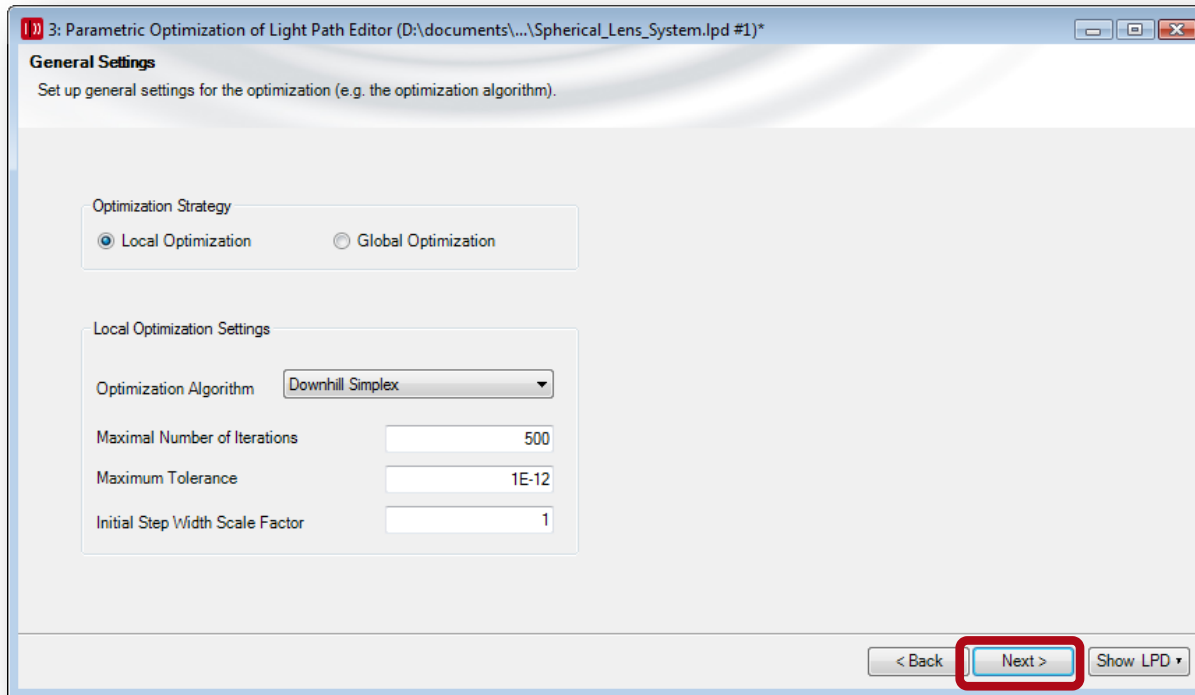
- Contributions have been updated – contribution of parameter constraint is very high (99.999%).

- Press *Next*.

Results in



16. Start Optimization #2



Press *Next*.

Results in



16. Start Optimization #2

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

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

Start ►

Simulation Step		26	27	28	29	30	31	32	33
Optimizer Logging	Target Function Value	10 5.2705E-10	5.3314E-10	5.2207E-10	5.2512E-10	5.2121E-10	5.2207E-10	5.2118E-10	5.2118E-10
	Distance Before	m 99.336 mm	99.414 mm	99.355 mm	99.395 mm	99.365 mm	99.355 mm	99.37 mm	99.37 mm
Beam Parameters #600	Radius X	m 16.234 μm	16.327 μm	16.157 μm	16.204 μm	16.143 μm	16.157 μm	16.143 μm	16.143 μm
	Radius Y	m 16.234 μm	16.327 μm	16.157 μm	16.204 μm	16.143 μm	16.157 μm	16.143 μm	16.143 μm

Output from Selection ☒ Show Physical Units

< Back Next > Show LPD ▾

Press *Start* to start a new optimization and wait until optimization stops.

Results in



17. Optimization Result #2

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

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

Start ►

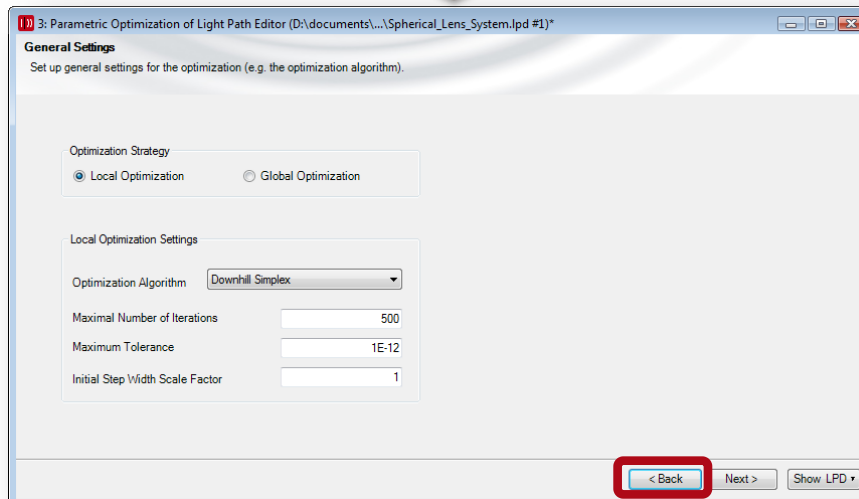
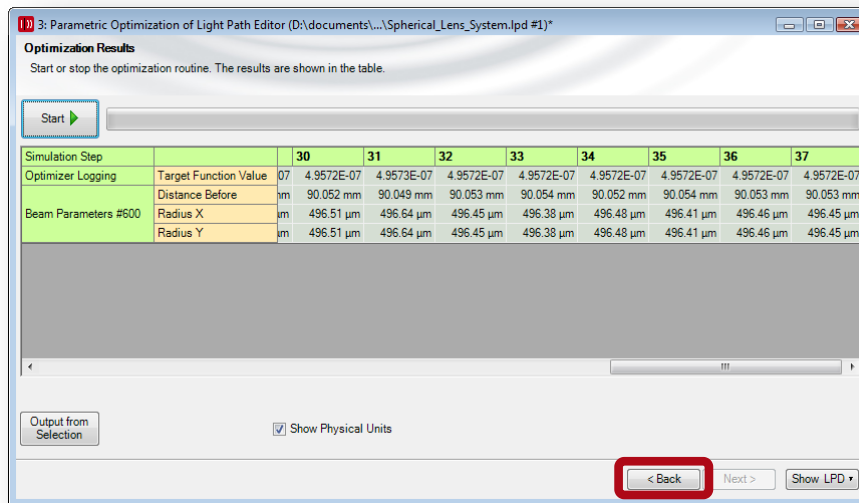
Simulation Step		30	31	32	33	34	35	36	37
Optimizer Logging	Target Function Value	07	4.9572E-07	4.9573E-07	4.9572E-07	4.9572E-07	4.9572E-07	4.9572E-07	4.9572E-07
	Distance Before	mm	90.052 mm	90.049 mm	90.053 mm	90.054 mm	90.052 mm	90.054 mm	90.053 mm
Beam Parameters #600	Radius X	μm	496.51 μm	496.64 μm	496.45 μm	496.38 μm	496.48 μm	496.41 μm	496.46 μm
	Radius Y	μm	496.51 μm	496.64 μm	496.45 μm	496.38 μm	496.48 μm	496.41 μm	496.46 μm

Output from Selection ☒ Show Physical Units

< Back Next > Show LPD ▼

Optimization result of *Distance Before* gets very close to upper limit of 90mm now – due to the high contribution of its constraint.

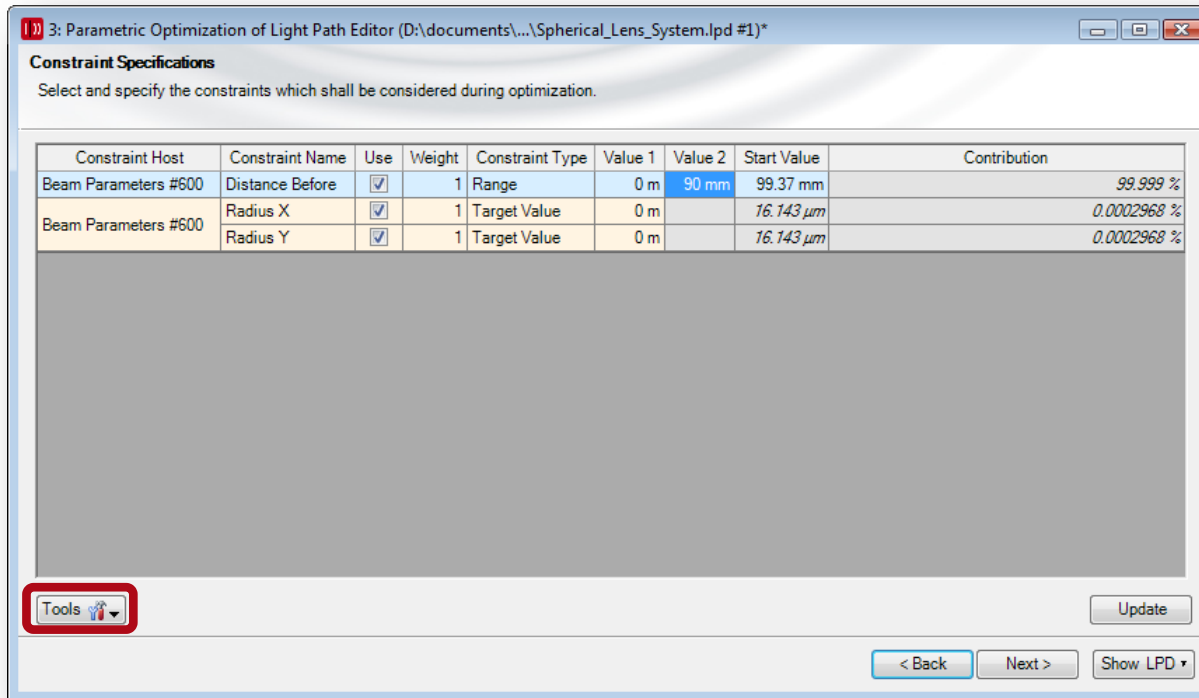
18. Option: Reset All Settings



- All settings can be reset to the initial values.
- Go back to *Constraint Settings* page of document (click **Back** on *Optimization Results* page and **Back** on *General Settings* page).

18. Reset All Constraint Settings

Results in

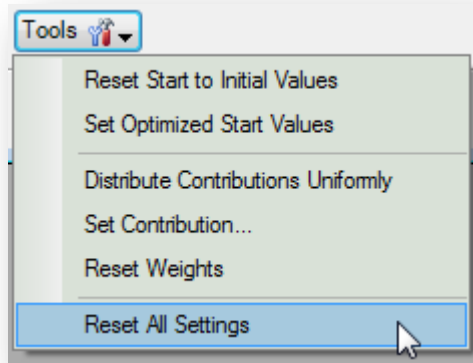


Press *Tools* button.

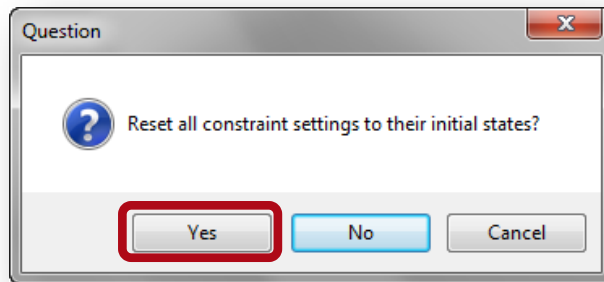
Results in



18. Reset All Constraint Settings



Click on *Reset All Settings* to reset all constraint settings and start values.

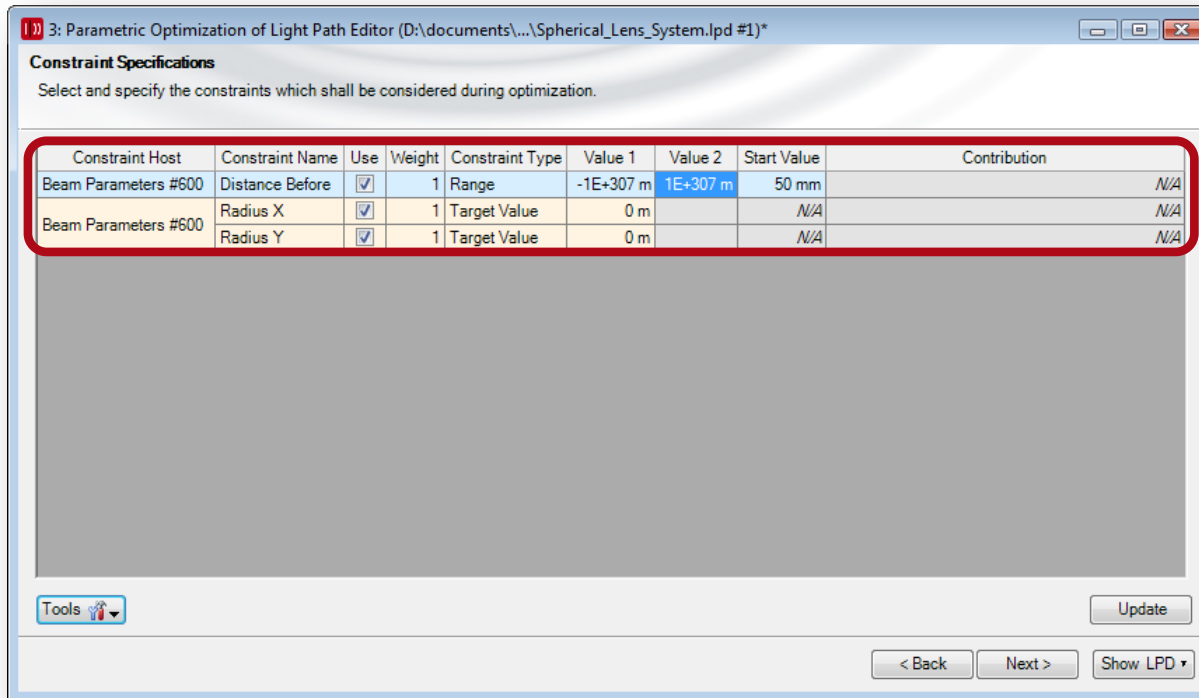


Confirm action by *Yes*.

Results in



18. Reset All Constraint Settings




All constraint settings and start values have been reset to their initial states.

19. Start Optimization #3

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

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
Beam Parameters #600	Distance Before	<input checked="" type="checkbox"/>	1	Range	-1E+307 m	1E+307 m	50 mm	N/A
Beam Parameters #600	Radius X	<input checked="" type="checkbox"/>	1	Target Value	0 m		N/A	N/A
Beam Parameters #600	Radius Y	<input checked="" type="checkbox"/>	1	Target Value	0 m		N/A	N/A

Tools  Update

< Back **Next >** Show LPD ▾



3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

General Settings
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

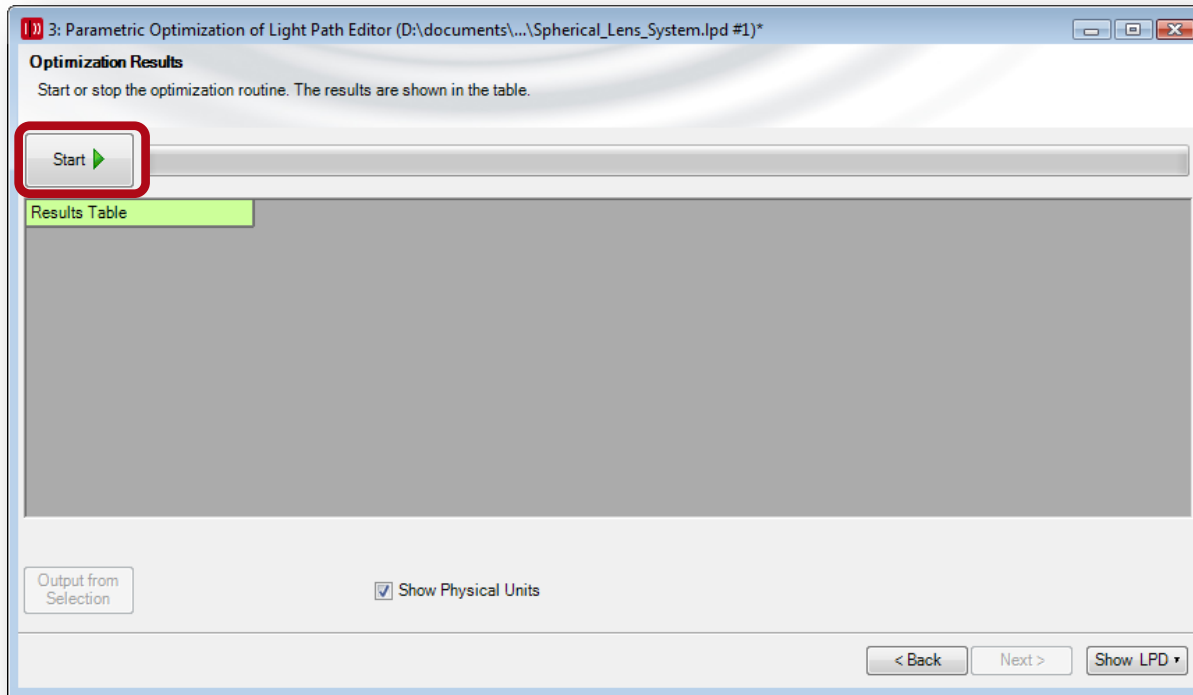
Maximum Tolerance: 1E-12

Initial Step Width Scale Factor: 1

< Back **Next >** Show LPD ▾

Go forward to *Optimization Results* page of document (click **Next** on *Constraint Specification* page and **Next** on *General Settings* page).

19. Start Optimization #3



Press *Start* and wait until optimization stops.

Results in



19. Start Optimization #3

3: Parametric Optimization of Light Path Editor (D:\documents\...\Spherical_Lens_System.lpd #1)*

Optimization Results

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

Start

Simulation Step		26	27	28	29	30	31	32	33	
Optimizer Logging	Target Function Value	-10	5.2705E-10	5.3314E-10	5.2207E-10	5.2512E-10	5.2121E-10	5.2207E-10	5.2118E-10	5.2118E-10
	Distance Before	mm	99.336 mm	99.414 mm	99.355 mm	99.395 mm	99.365 mm	99.355 mm	99.37 mm	99.37 mm
Beam Parameters #600	Radius X	μm	16.234 μm	16.327 μm	16.157 μm	16.204 μm	16.143 μm	16.157 μm	16.143 μm	16.143 μm
	Radius Y	μm	16.234 μm	16.327 μm	16.157 μm	16.204 μm	16.143 μm	16.157 μm	16.143 μm	16.143 μm

Output from Selection

☒ Show Physical Units

< Back

Next >

Show LPD ▾

Now the optimization result is the correct position of lens focus again (namely 99.37mm).