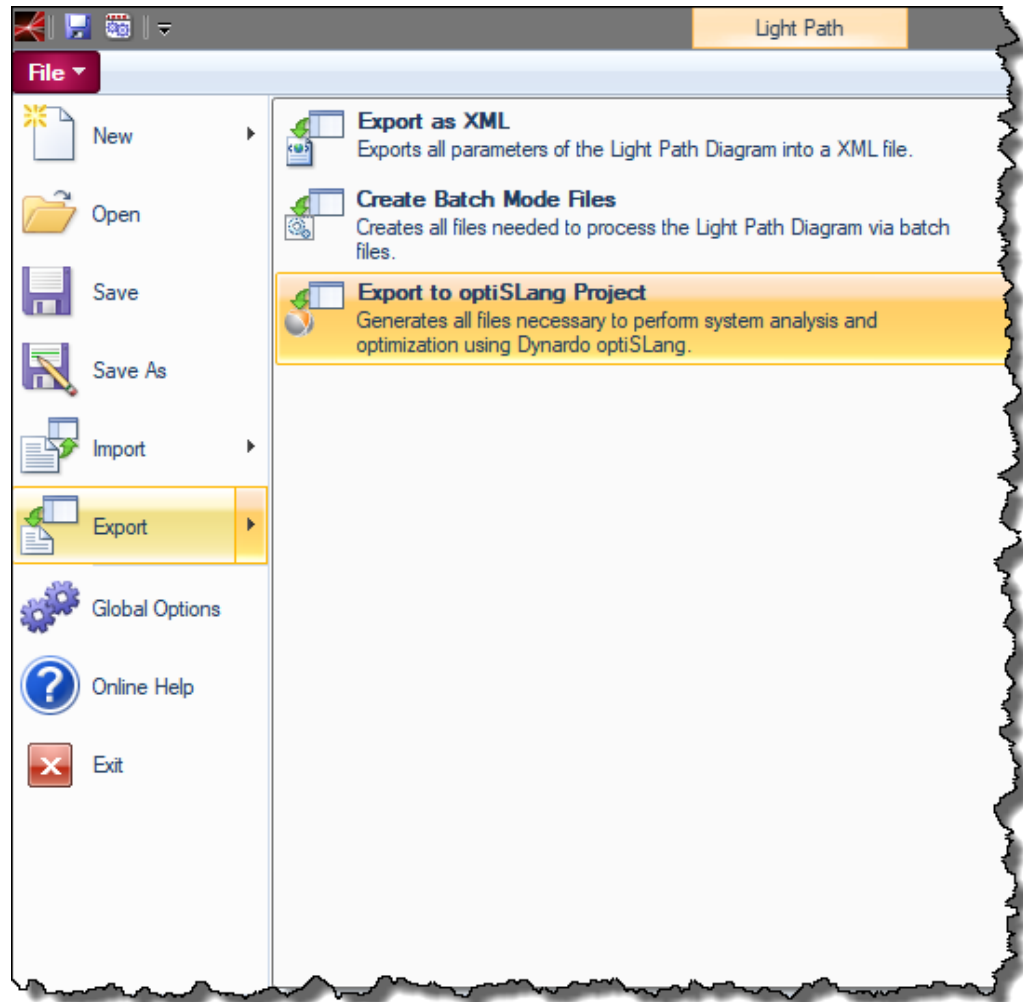


Grating Optimization in VirtualLab Fusion Using optiSLang

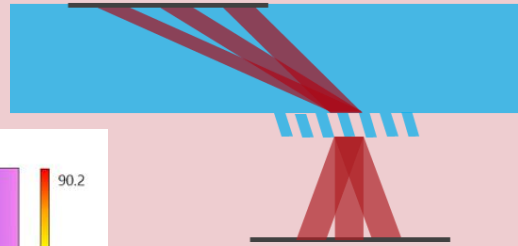
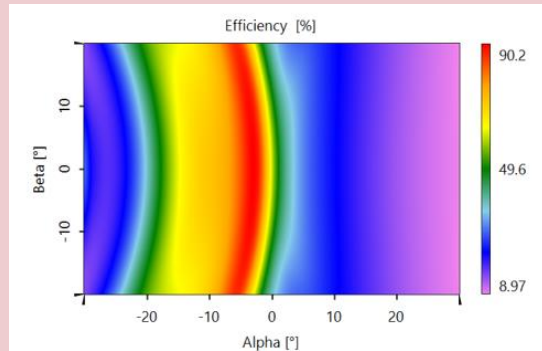
Abstract



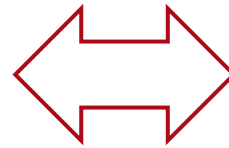
Optimization of a modern optical system often involves a large amount of parameters. As an example, for the optimization of gratings, not only the geometrical parameters of the grating shall be considered, but also the desired incidence directions. That leads to a challenging task with greatly increased number of parameters. For such cases, VirtualLab Fusion provides an interface to the software optiSLang from Dynardo, so that different advanced optimization algorithms can be applied.

Interface of VirtualLab Fusion and optiSLang

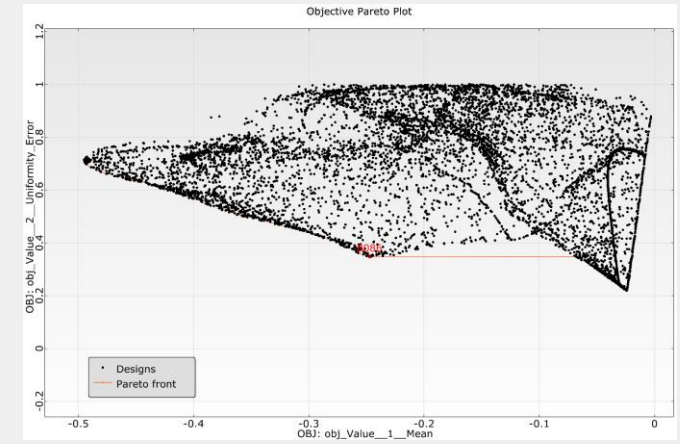
VirtualLab Fusion



VirtualLab Fusion is a flexible and customizable platform of modelling tools to simulate complex optical setups like e.g. coupling a set of plane waves into a lightguide.



optiSLang

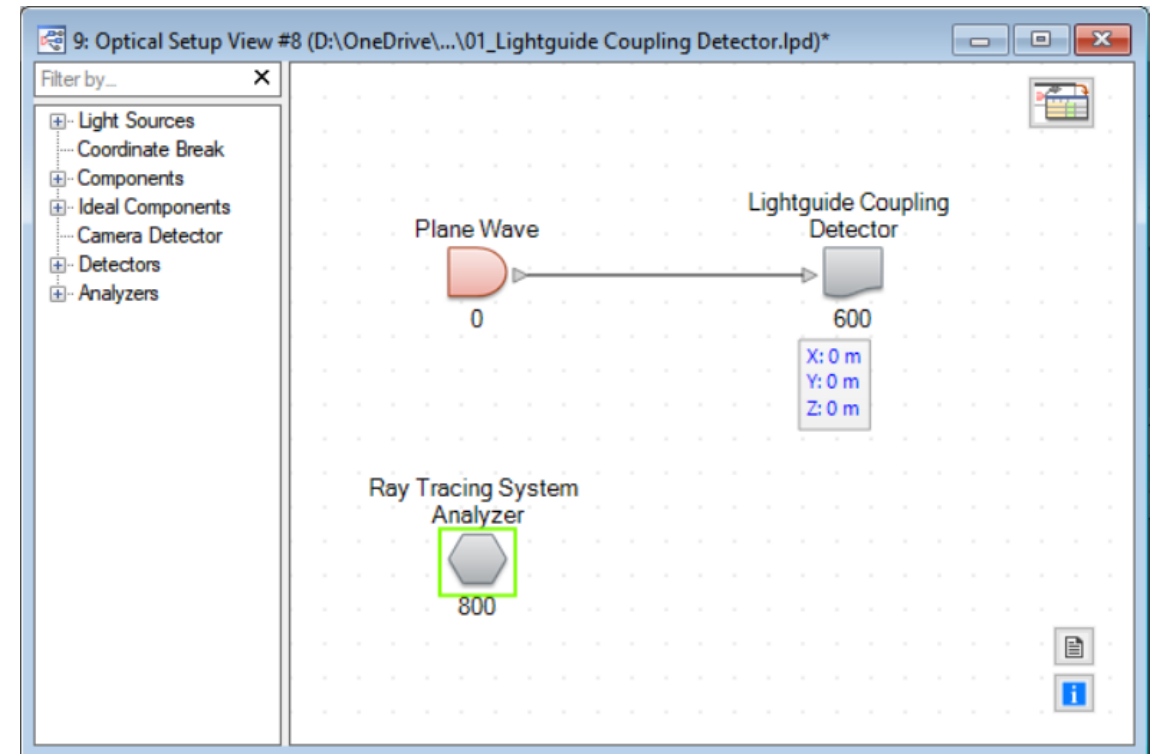


optiSLang is a software platform of advanced tools for sensitivity analysis, multiobjective and multidisciplinary optimization, robustness evaluation, reliability analysis and robust design optimization.

The combination of both software platforms enables advanced grating structure designs for e.g. smart lightguide coupling

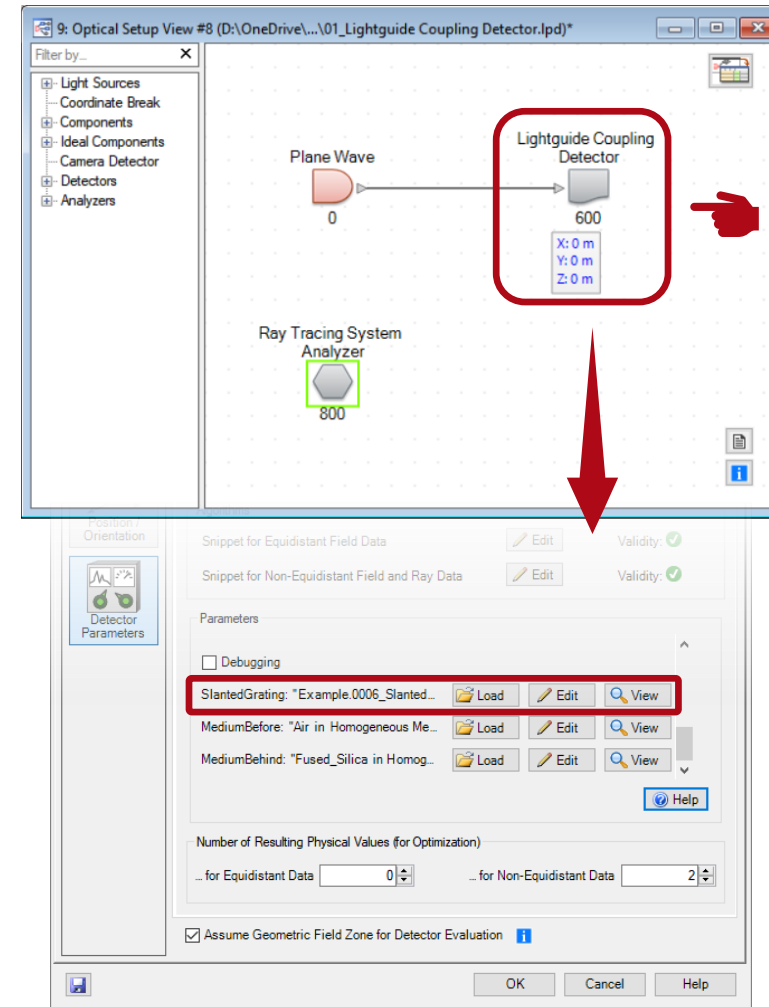
VirtualLab Fusion – Initialization of the Optical Setup

- Initial Setup
 - In general, each optical system defined in VirtualLab can be optimized using optiSLang.
 - For this example the optical system consists of a Plane Wave Source and the Lightguide Coupling Detector for periodic media.



VirtualLab Fusion – Lightguide Coupling Detector

- Lightguide Coupling Detection
 - The Lightguide Coupling Detector is a special tool to detect the efficiencies of a periodic structure regarding a specified angular incidence range.
 - The periodic structure can be defined or loaded from catalogs within the Edit Dialog of the detector.



VirtualLab Fusion – Lightguide Coupling Detector

- Lightguide Coupling Detection
 - For this example a slanted grating is used.

The image displays three windows from the VirtualLab Fusion software interface, illustrating the setup of a Lightguide Coupling Detector.

Top Window: Optical Setup View #8
This window shows a ray tracing system. A "Plane Wave" (ID: 0) is directed towards a "Lightguide Coupling Detector" (ID: 600). The detector's position is defined as X: 0 m, Y: 0 m, Z: 0 m. A "Ray Tracing System Analyzer" (ID: 800) is also present. A red box highlights the detector, and a red arrow points to it.

Bottom-Left Window: Edit Slanted Grating Medium
This window shows the parameters for the slanted grating. The "Grating Material" is set to "Non-Dispersive Material (n=2.2)" with a refractive index of 2.2. The "Groove Material" is set to "Air". The "Fill Factor" is 50%, and the "z-Extension" is 400 nm. The "Slant Angle Left" and "Slant Angle Right" are both set to 40°. A red box highlights the "Fill Factor" and "Slant Angle" fields.

Bottom-Middle Window: Edit Stack
This window shows a stack of media. The "Base Block" is highlighted. The stack contains two layers:

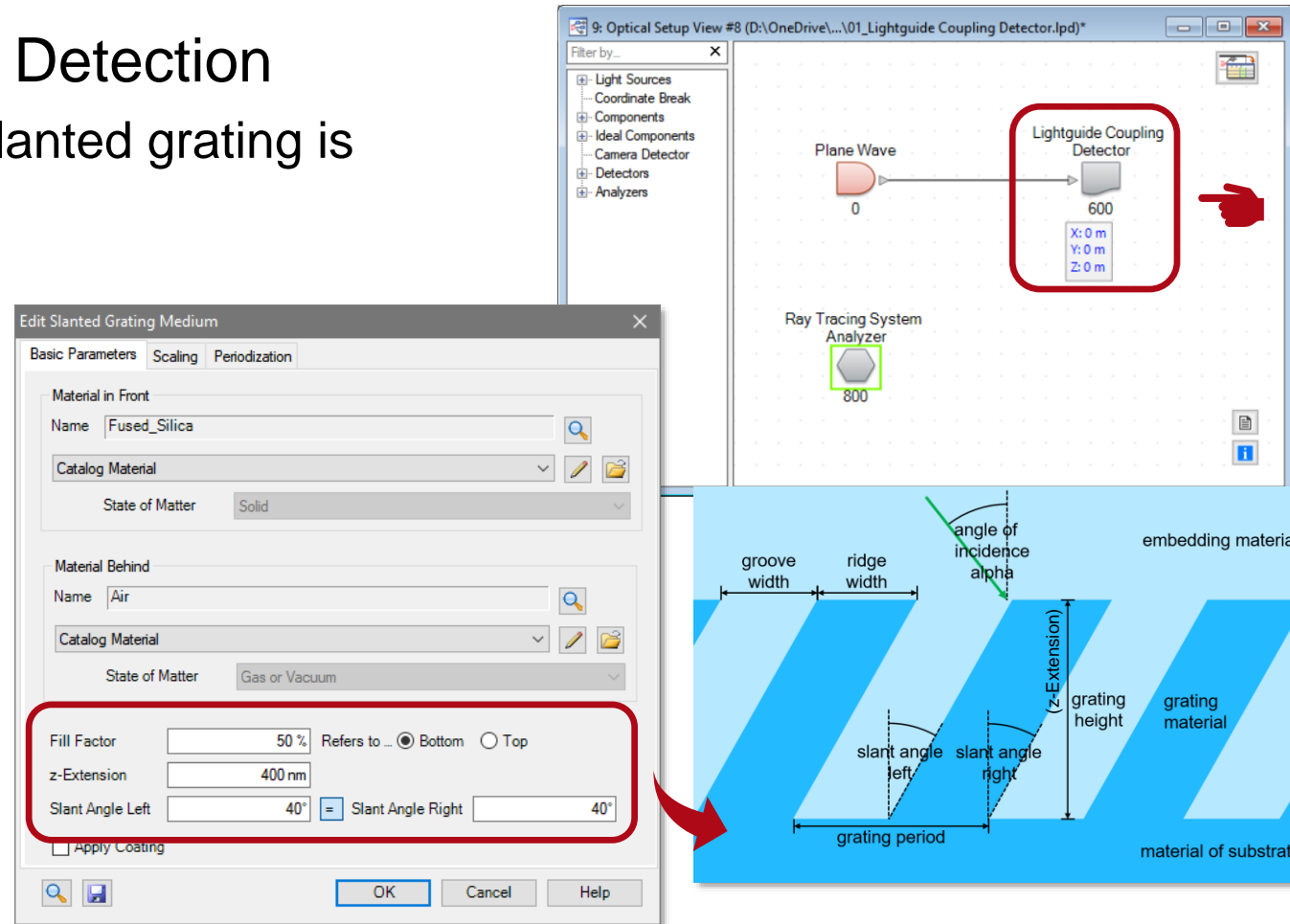
Index	z-Distance	z-Position	Interface	Subsequent Medium	Com
1	0 m	0 m	Plane Interface	Slanted Grating Med...	Enter your commen
2	400 nm	400 nm	Plane Interface	Air in Homogeneous M	Enter your commen

A red box highlights the "Slanted Grating Med..." layer, and a red arrow points to it.

Bottom-Right Window: Detector Parameters
This window shows the parameters for the detector. The "Grating_Stack" is set to "Incouple Grating". The "Number of Resulting Physical Values (for Optimization)" is set to 2 for Non-Equidistant Data. A red box highlights the "Grating_Stack" field.

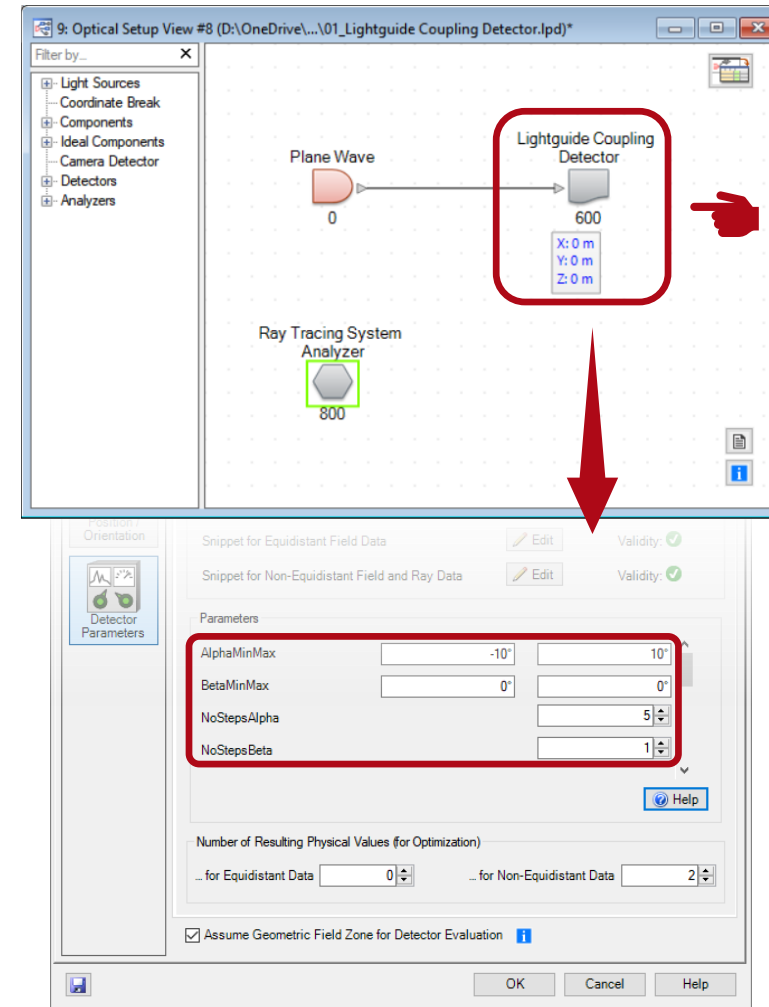
VirtualLab Fusion – Lightguide Coupling Detector

- Lightguide Coupling Detection
 - For this example a slanted grating is used.



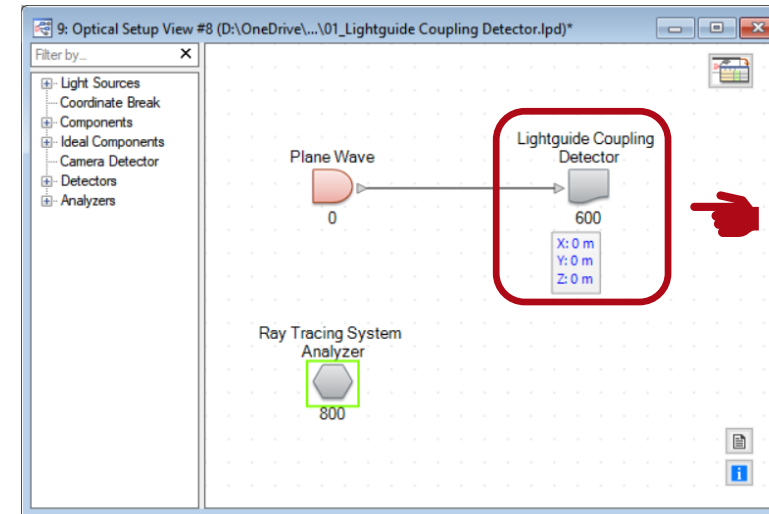
VirtualLab Fusion – Lightguide Coupling Detector

- Lightguide Coupling Detection
 - The angular range of the incidence directions of the input source is specified within the Edit Dialog of the detector.
 - These are defined by minimum and maximum cartesian angles alpha and beta and their number of sampling points.



VirtualLab Fusion – Lightguide Coupling

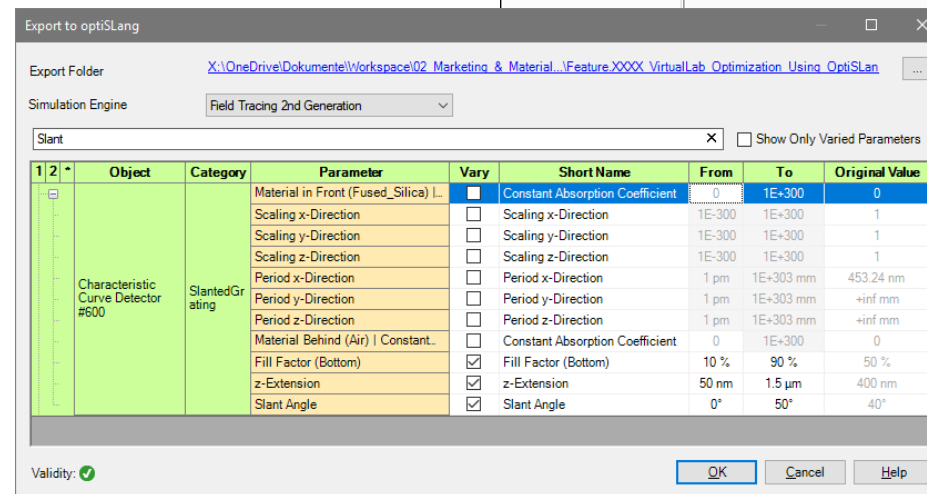
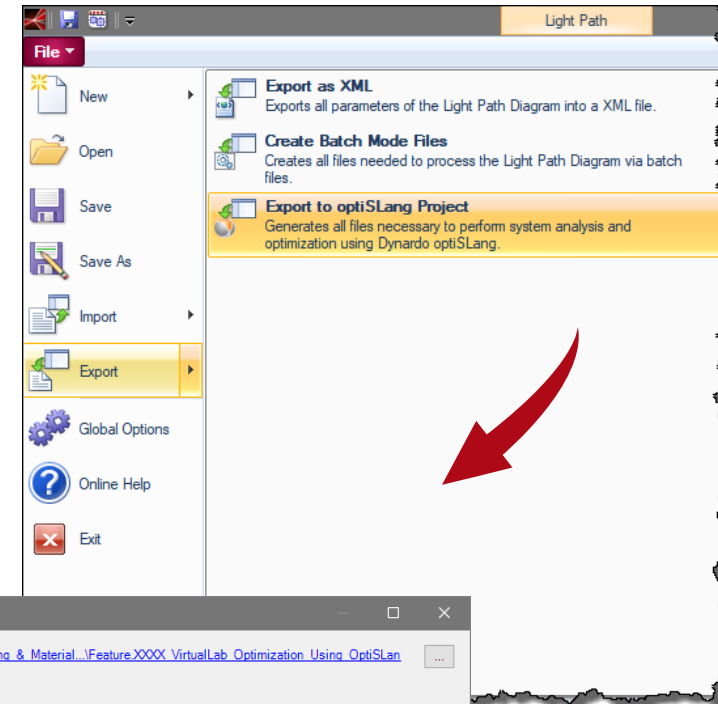
- Lightguide Coupling Detection
 - From the detected efficiencies, the mean value and the uniformity contrast is calculated and provided in the Detector Results tab.
 - As a result the detector enables the evaluation of a periodic structure within a specified angular space.



Parameter	Value & Unit
Mean value	45.47%
Uniformity contrast	84.48%

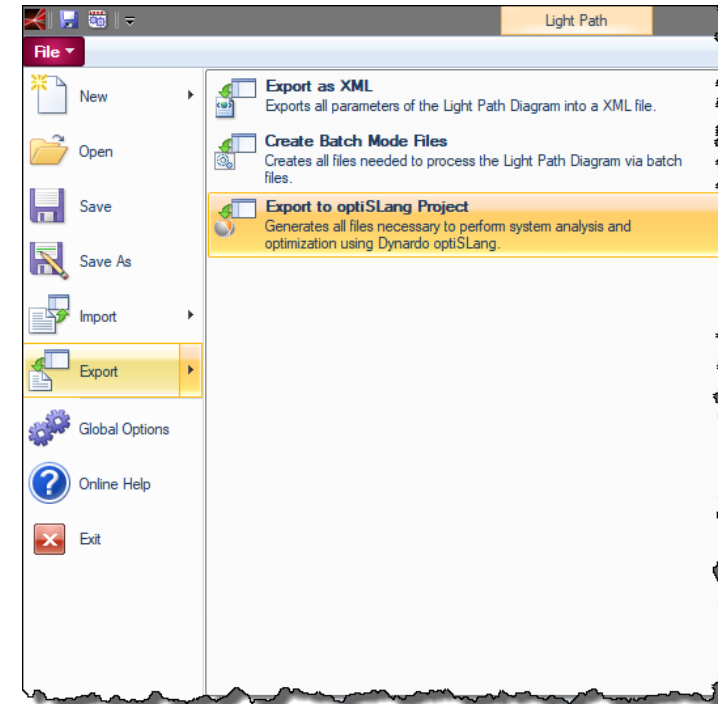
VirtualLab Fusion – Export LPD to OptiSLang





- Export LPD to optiSLang
 - File → Export → Export to optiSLang Project



VirtualLab Fusion – Export LPD to optiSLang

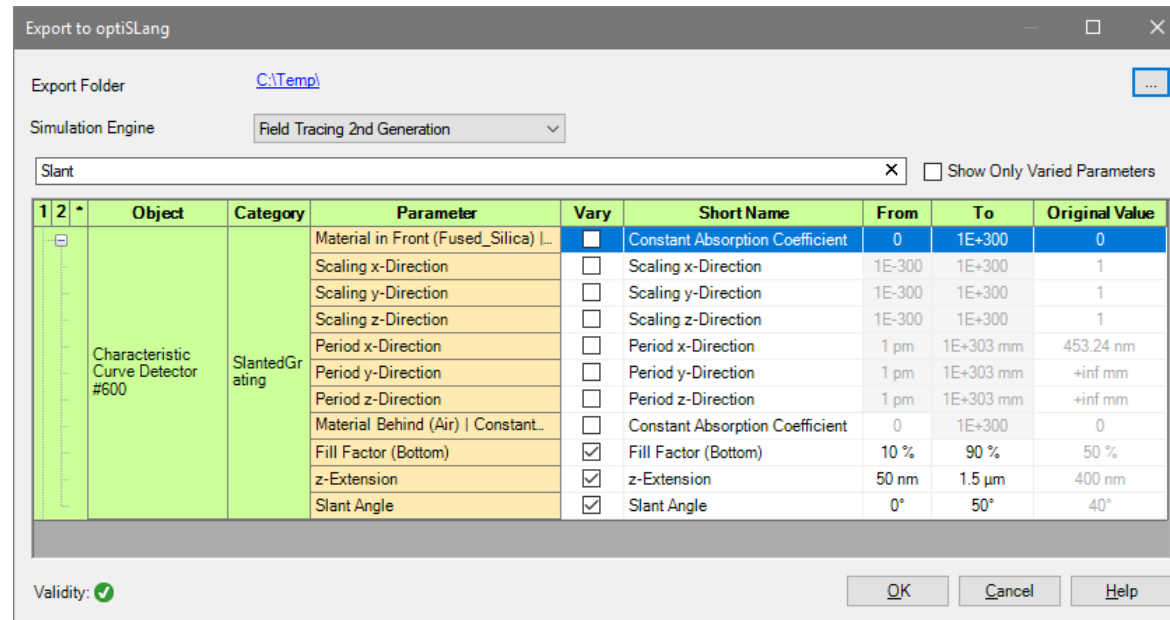
- Export LPD to optiSLang
 - File → Export → Export to optiSLang Project
 - The LPD is exported by generating all files necessary for importing the optical setup to optiSLang.



 parameters.xml	19.01.2018 09:42	XML-Datei	19 KB
 results.xml	19.01.2018 09:42	XML-Datei	1 KB
 run_VirtualLab.bat	19.01.2018 09:42	Windows-Batchda...	1 KB
 system.lpd	19.01.2018 09:42	Light Path Diagram	117 KB

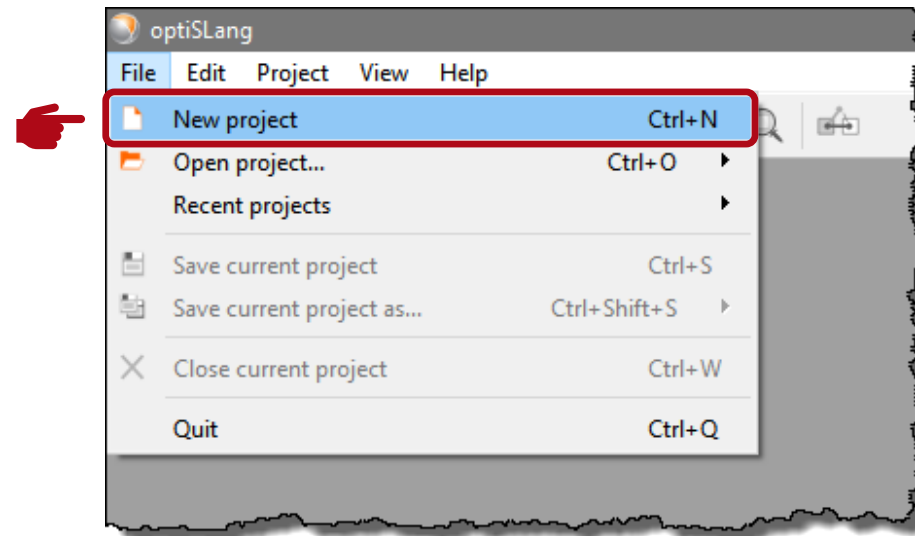
VirtualLab Fusion – Export LPD to optiSLang

- Export LPD to optiSLang
 - In the export dialog window
 - the parameter space can be defined including the variation range of the parameters
 - the export folder is chosen, where the files are saved
 - the simulation engine is specified, which is used for the analysis



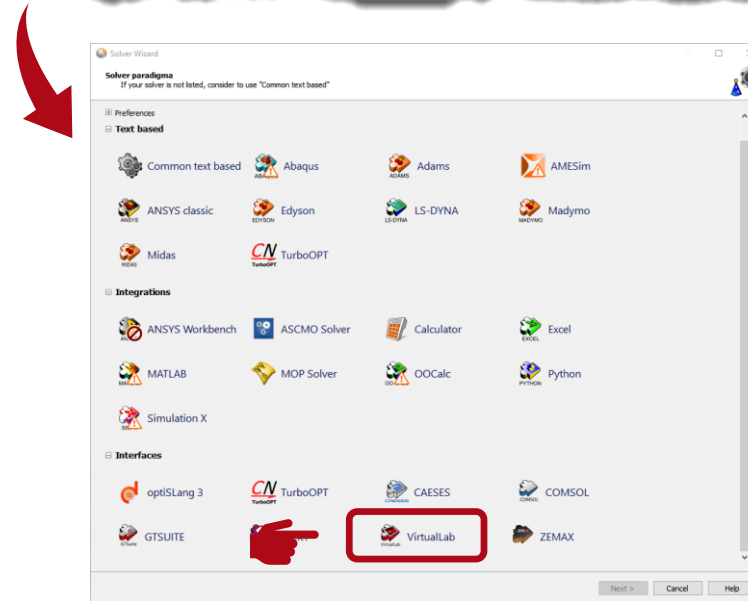
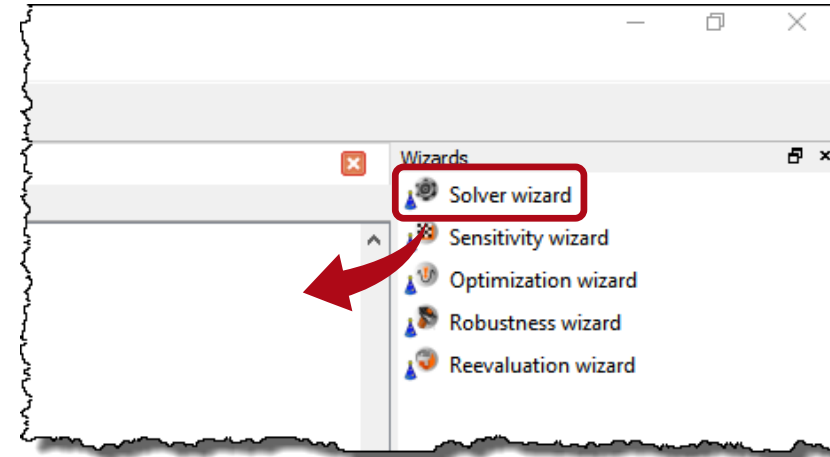
optiSLang – Initializing the Optimization

- Setting up the solver system
 - File → New project ...



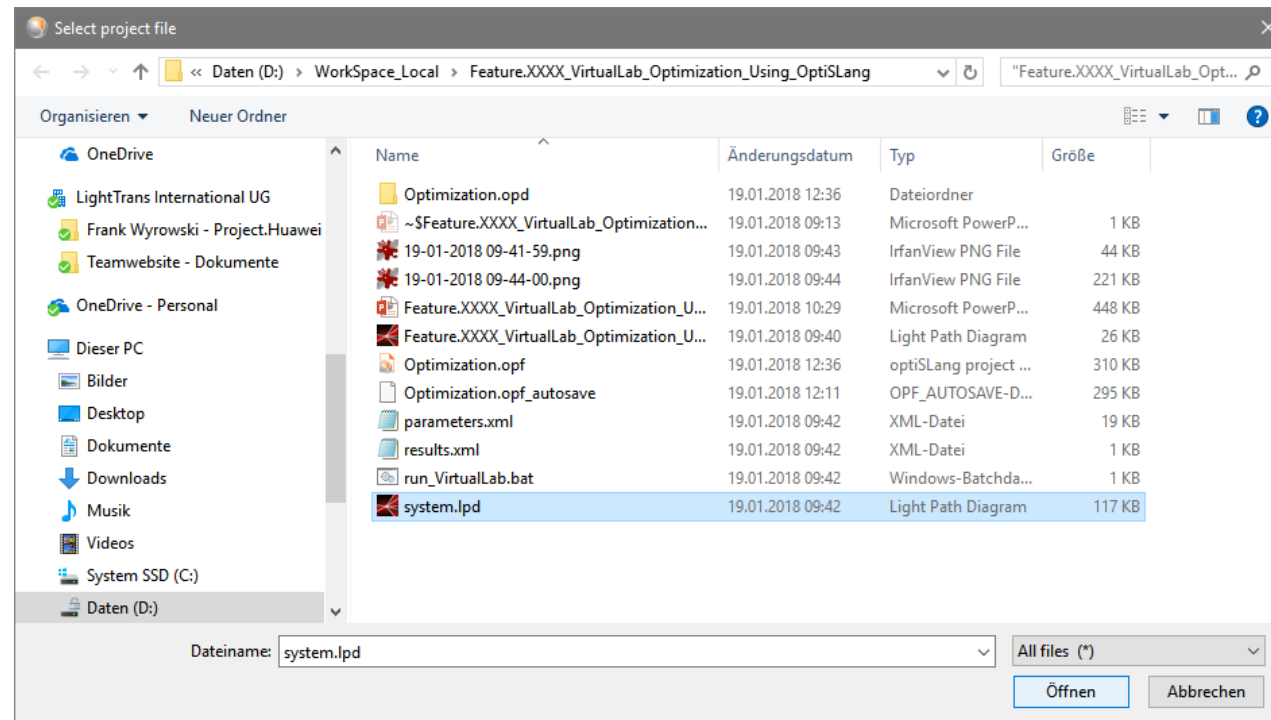
optiSLang – Initializing the Optimization

- Setting up the solver system
 - Next, drag the Solver wizard to the Scenery window.
 - A dialog opens, where several Solver paradigm are listed.
 - The Solver paradigm VirtualLab has to be selected.



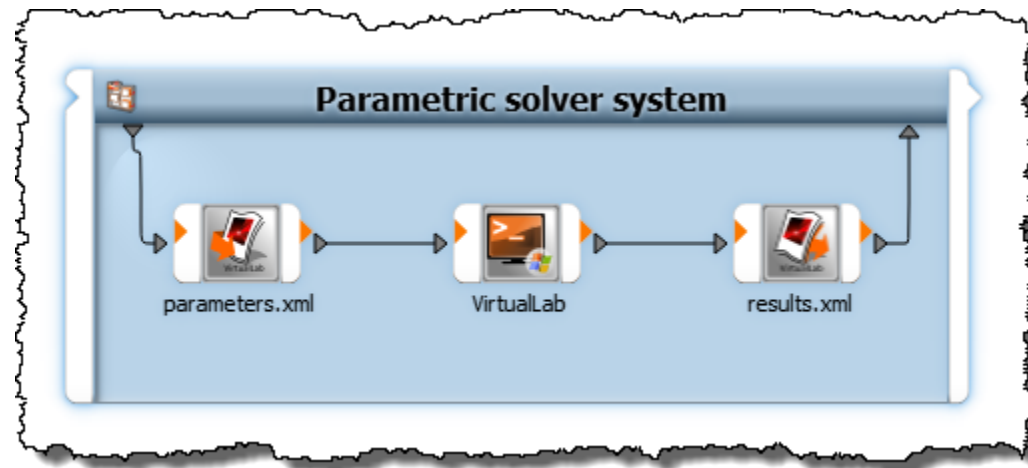
optiSLang – Initializing the Optimization

- Setting up the solver system
 - Then a file dialog opens, where the system.lpd generated by the VirtualLab export has to be opened.



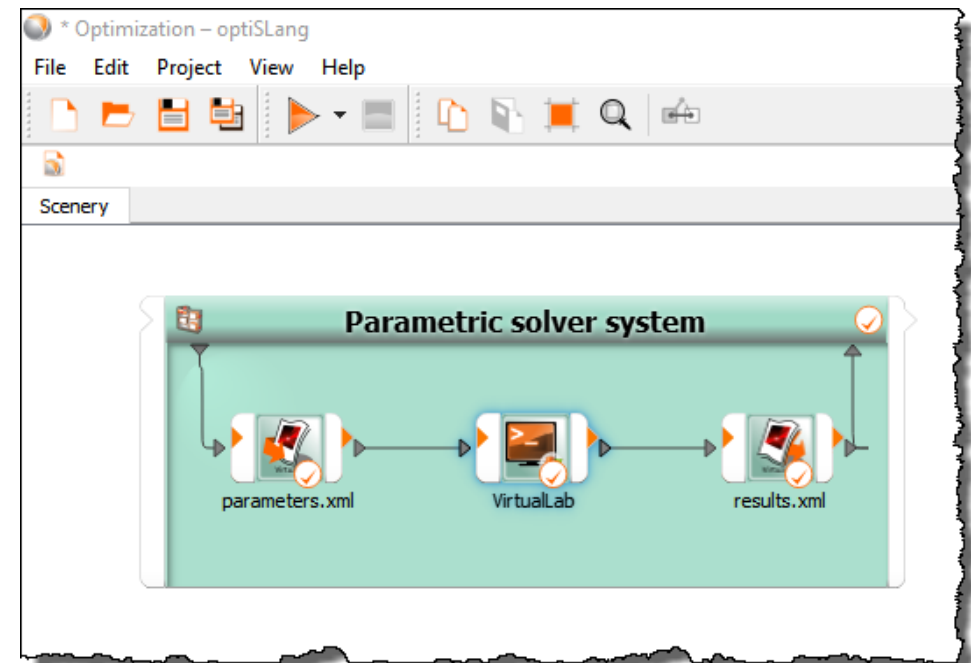
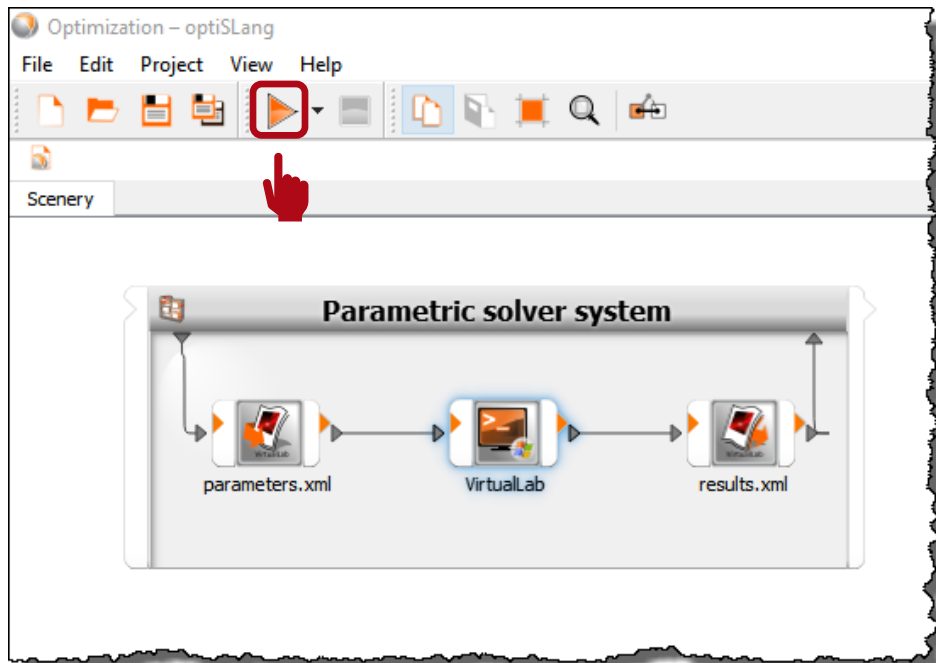
optiSLang – Initializing the Optimization

- Parametric solver system
 - The parametric solver system consists of the corresponding VirtualLab file and two XML files containing the parameters and results to define the merit function.
 - Please save the project.



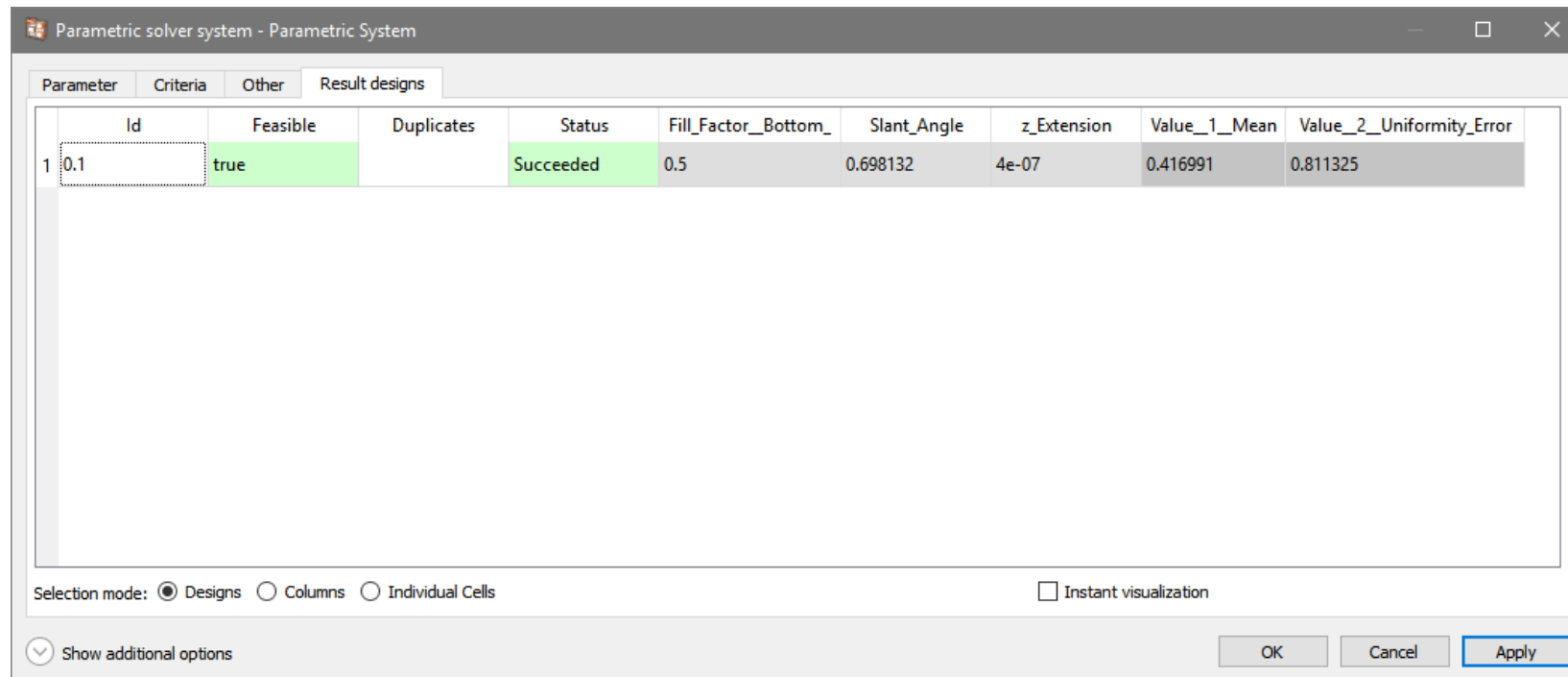
optiSLang – Initializing the Optimization

- Parametric solver system
 - Run the solver system to check it is working correctly and provides the expected results.



optiSLang – Initializing the Optimization

- Parametric solver system
 - Run the solver system to check it is working correctly and provides the expected results.
 - The parameters and the results can be checked by double-clicking on the Parametric solver system window in the Result designs tab.



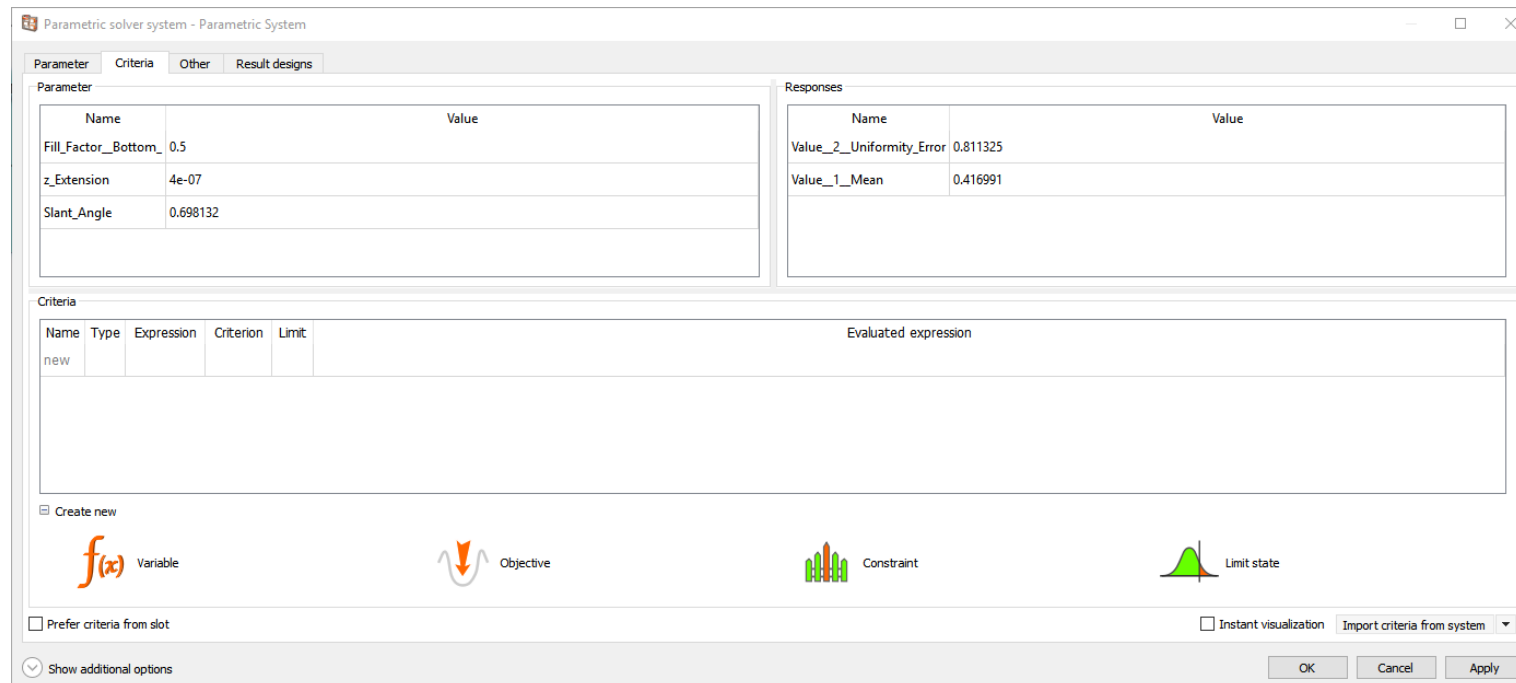
The screenshot shows a window titled "Parametric solver system - Parametric System" with a tab labeled "Result designs". The window contains a table with the following data:

Id	Feasible	Duplicates	Status	Fill_Factor_Bottom_	Slant_Angle	z_Extension	Value_1_Mean	Value_2_Uniformity_Error
1	true		Succeeded	0.5	0.698132	4e-07	0.416991	0.811325

At the bottom of the window, there are options for "Selection mode" (Designs, Columns, Individual Cells) and "Instant visualization". There are also buttons for "OK", "Cancel", and "Apply".

optiSLang – Setting Up the Optimization

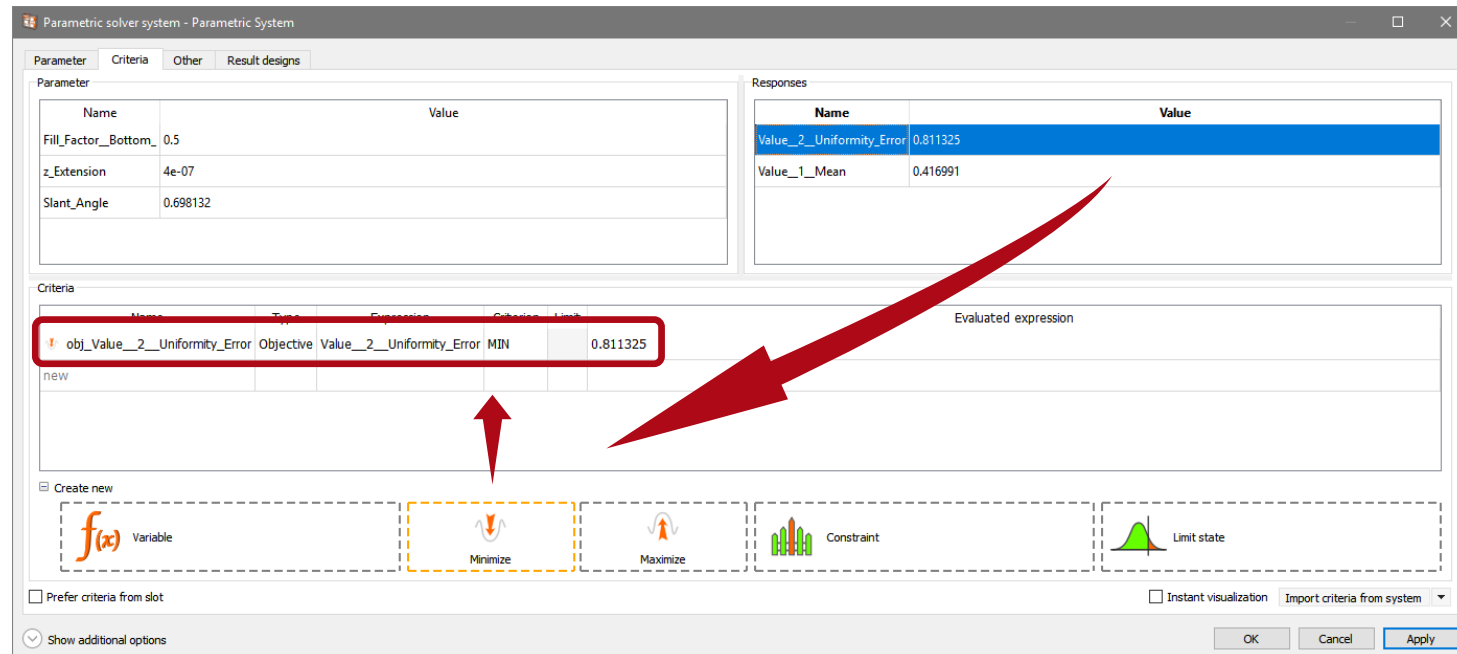
- Parametric solver system
 - optiSLang enables the possibility to optimize the optical system using multiple target functions.
 - This can be defined in the Criteria tab of the Parametric solver system configuration.



optiSLang – Setting Up the Optimization

- Parametric solver system

- The first target function is defined by drag the Uniformity Contrast to the Objective Minimize criteria.
- As a consequence the optimization algorithm tries to minimize the uniformity contrast as best as possible.



optiSLang – Setting Up the Optimization

- Parametric solver system

- The second target function is defined by drag the Mean to the Objective Maximize criteria.
- As a consequence the optimization algorithm tries to maximize the mean efficiency as best as possible.
- This specification is called a multiple target optimization.

Parametric solver system - Parametric System

Parameter Criteria Other Result designs

Parameter

Name	Value
Fill_Factor_Bottom_	0.5
z_Extension	4e-07
Slant_Angle	0.698132

Responses

Name	Value
Value_2__Uniformity_Error	0.811325
Value_1__Mean	0.416991

Criteria

Name	Type	Expression	Criterion	Limit
obj_Value__2__Uniformity_Error	Objective	Value_2__Uniformity_Error	MIN	0.811325
obj_Value__1__Mean	Objective	Value_1__Mean	MAX	-0.416991

Create new

Variable Minimize Maximize Constraint Limit state

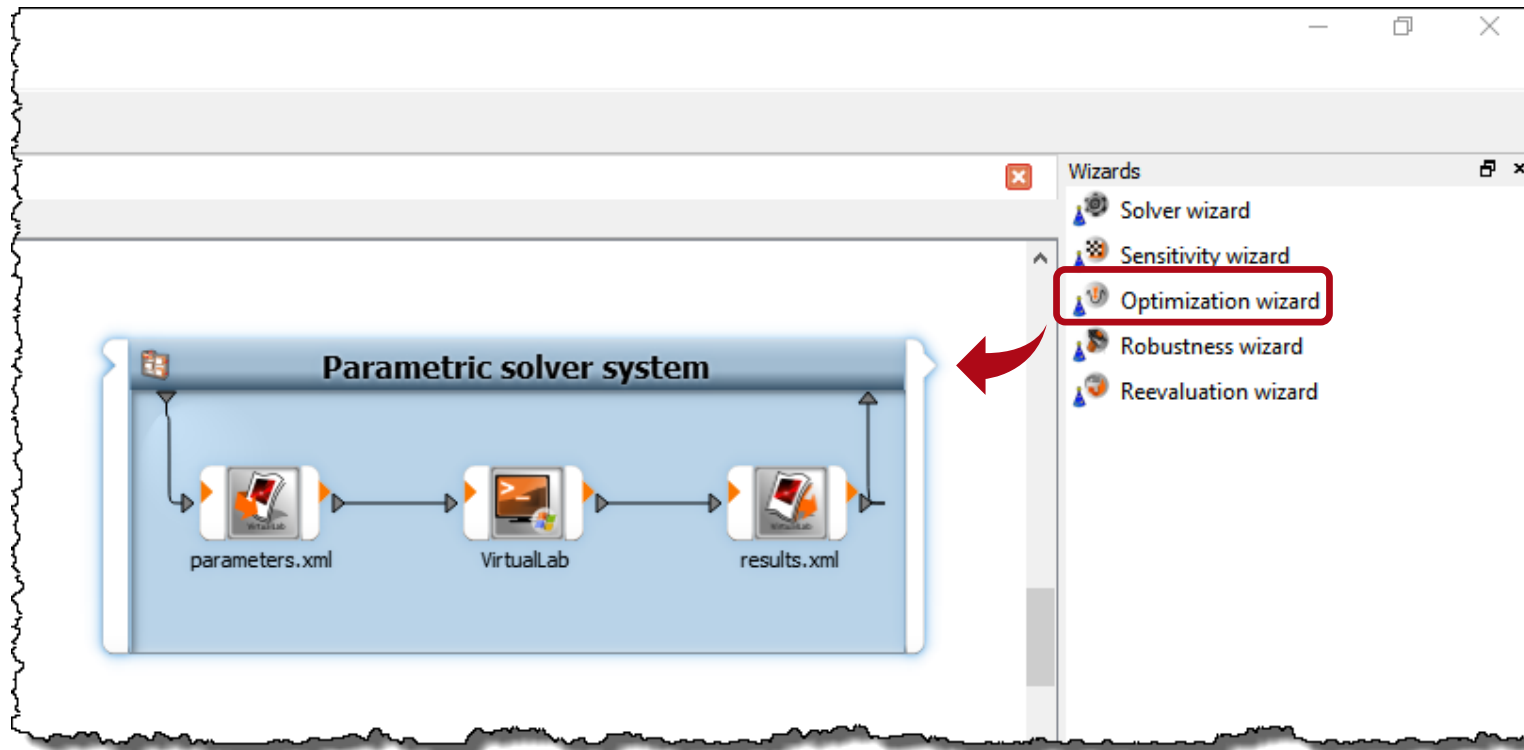
Prefer criteria from slot Instant visualization Import criteria from system

Show additional options

OK Cancel Apply

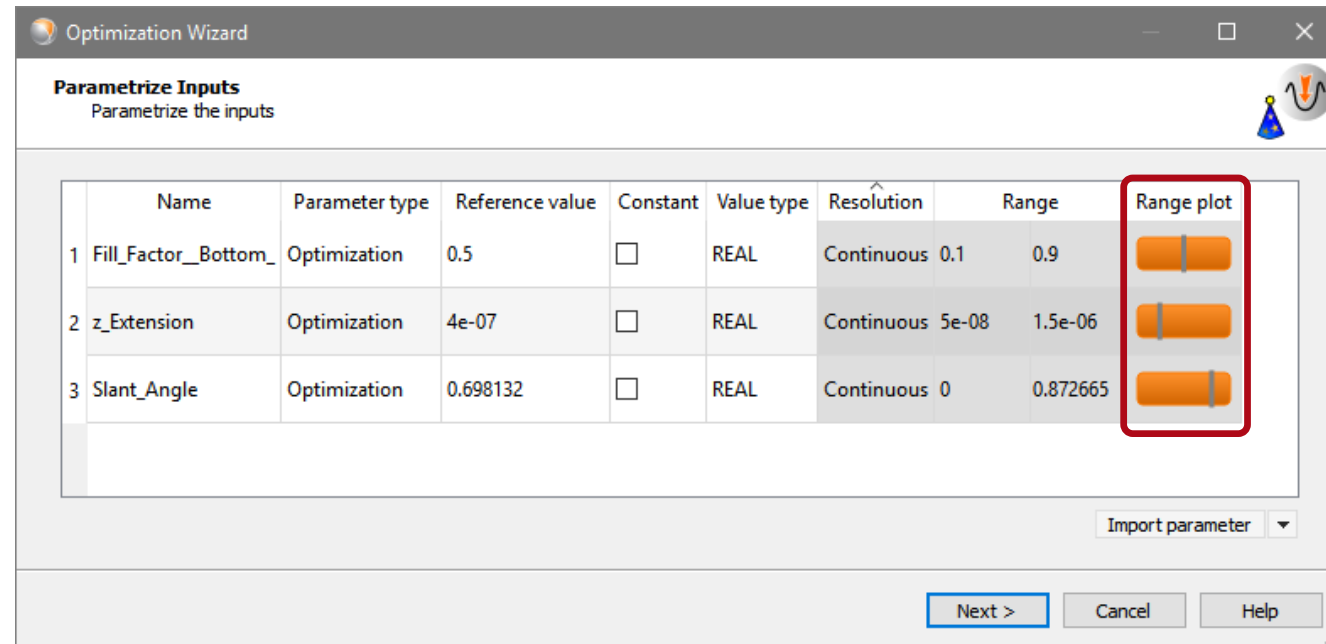
optiSLang – Setting Up the Optimization

- Optimization wizard
 - As next step the Optimization wizard is applied to the solver system by Drag & Drop.



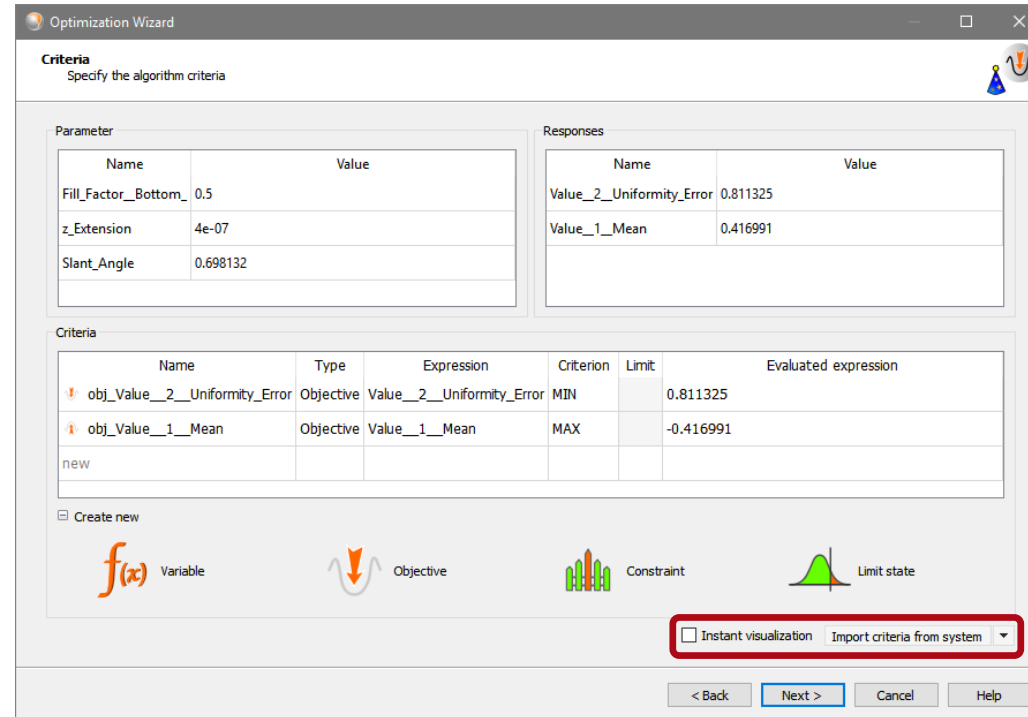
optiSLang – Setting Up the Optimization

- Optimization wizard
 - First, the varied system parameters are presented including their specified value range.
 - Furthermore, optiSLang provides a visualization of the value range including a mark for the initial value.
 - Then click on Next.



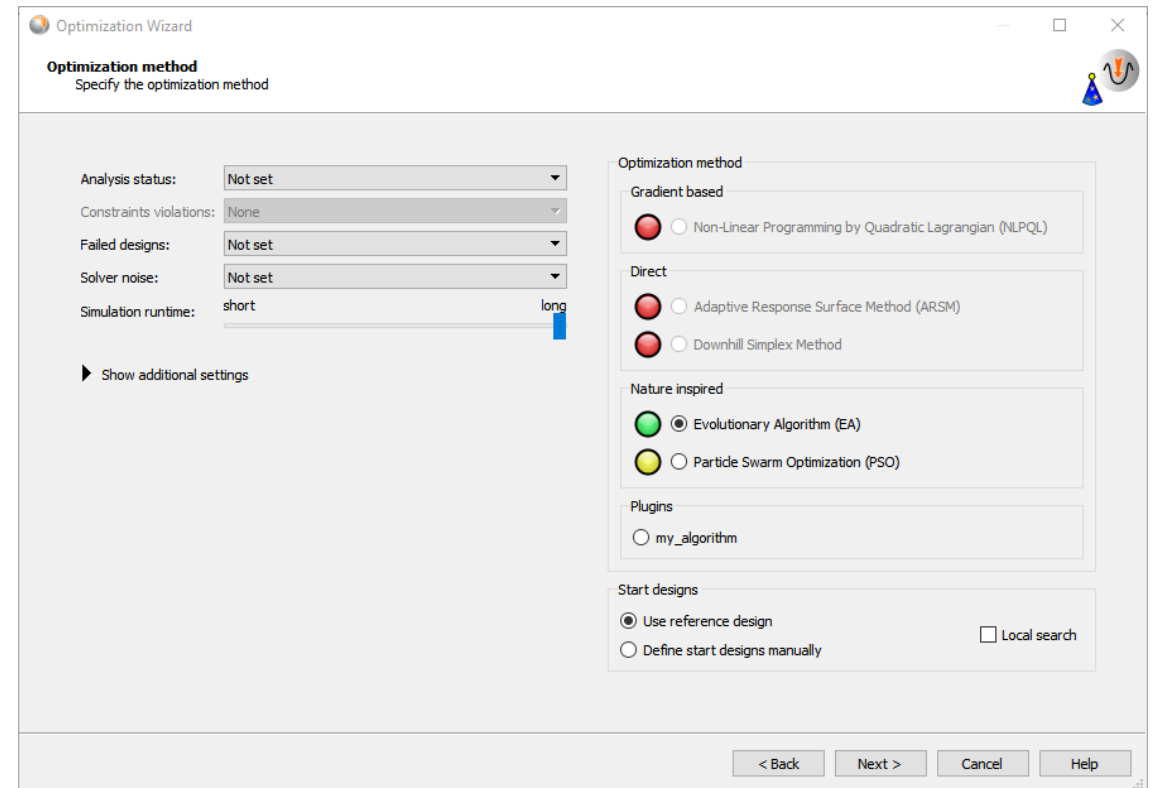
optiSLang – Setting Up the Optimization

- Optimization wizard
 - Second, the criteria for the optimization can be specified, if not already done in the Parametric solver system.
 - There is also the possibility to import the criteria from other documents.
 - Then, click on Next.



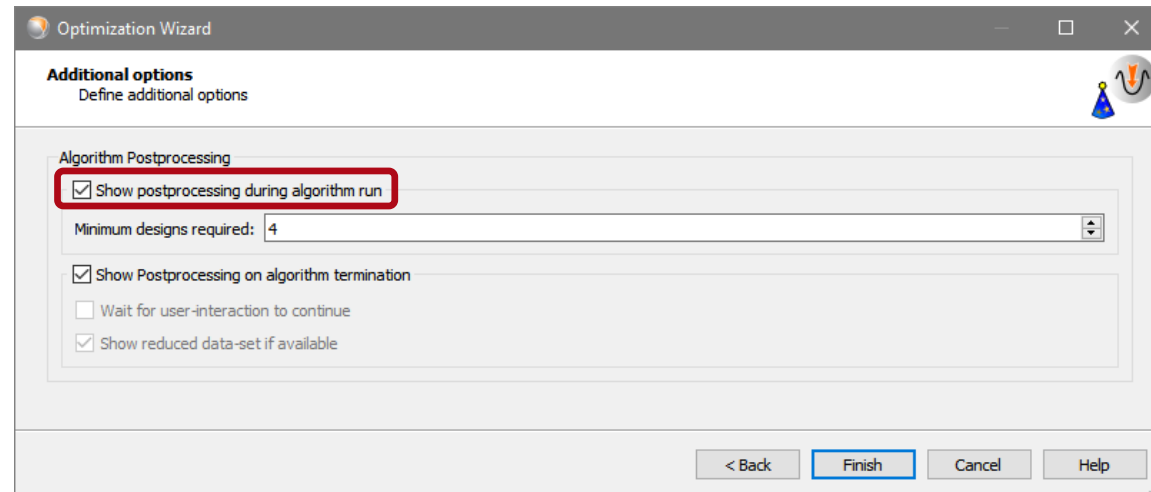
optiSLang – Setting Up the Optimization

- Optimization wizard
 - Third, the Optimization method has to be selected.
 - optiSLang provides a suggestion for suitable methods by an analogy to a traffic light system
 - Red: unsuitable
 - Yellow: suitable
 - Green: recommended
 - In this example an Evolutionary Algorithm is recommended and used.
 - Then, click on Next.



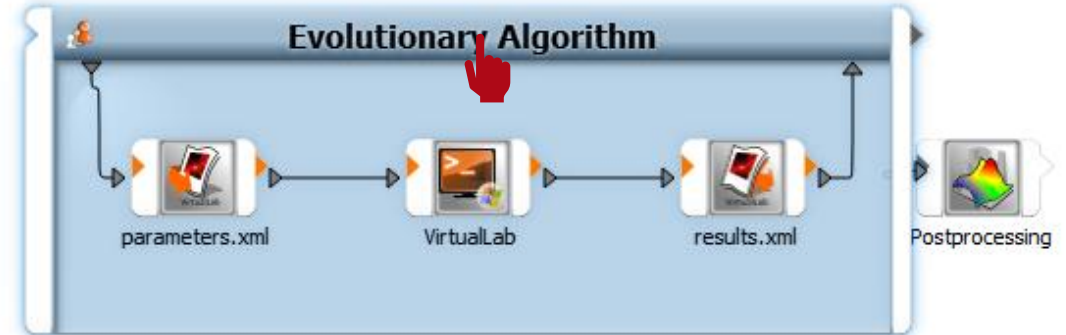
optiSLang – Setting Up the Optimization

- Optimization wizard
 - Next, some additional options might be specified.
 - The option Show postprocessing during algorithm run is recommended to get access to the result data during the optimization run.
 - Then, click on Finish.



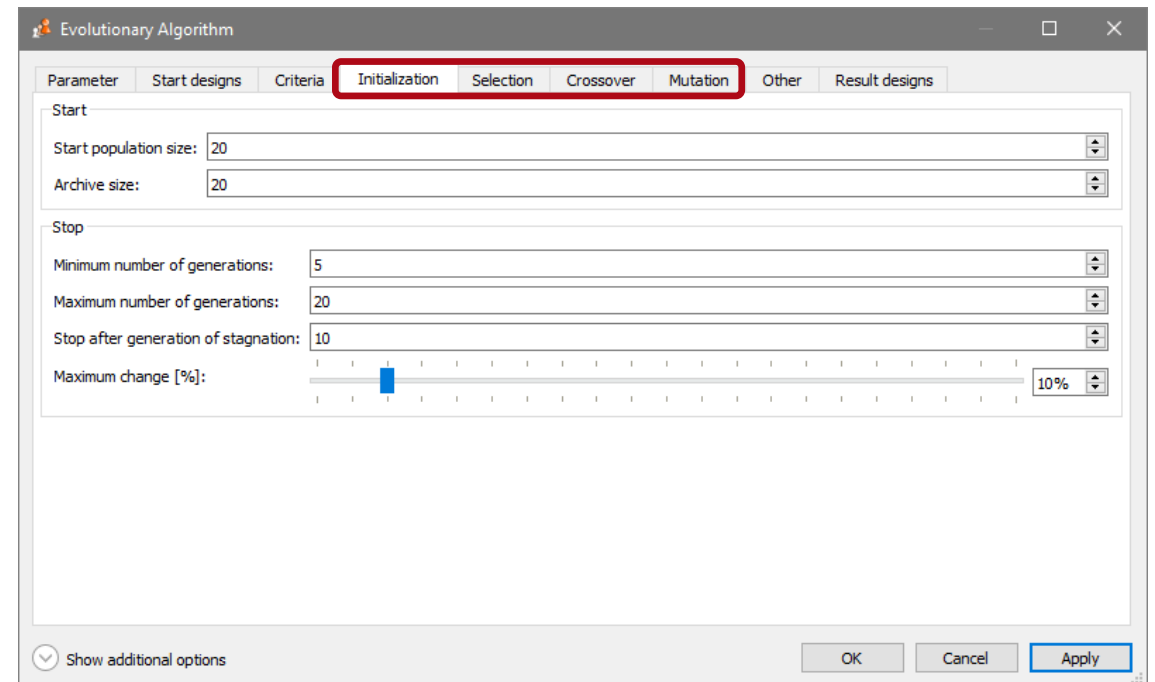
Advanced Settings of the Evolutionary Algorithm

- Advanced Settings
 - By double-clicking the created optimization, the detailed parameters of the optimization algorithm can be adapted.



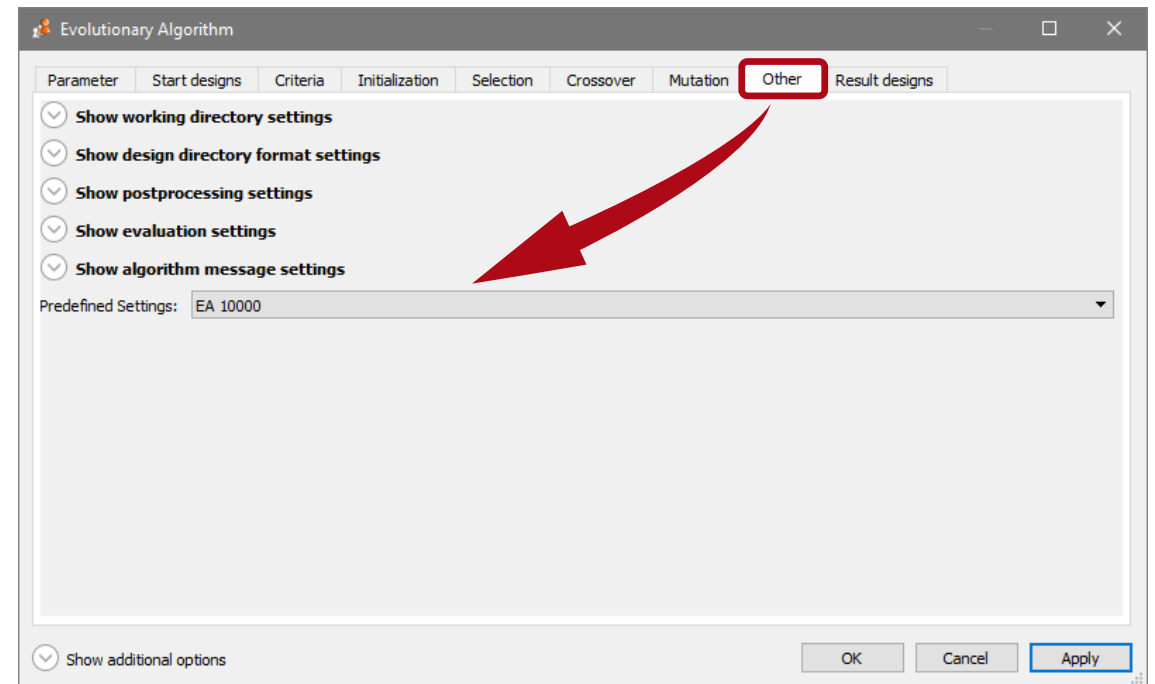
Advanced Settings of the Evolutionary Algorithm

- Advanced Settings
 - By double-clicking the created optimization, the detailed parameters of the optimization algorithm can be adapted.
 - In the tabs “Initialization”, “Selection”, “Crossover” and “Mutation” grant access to numerous parameters of the algorithm.



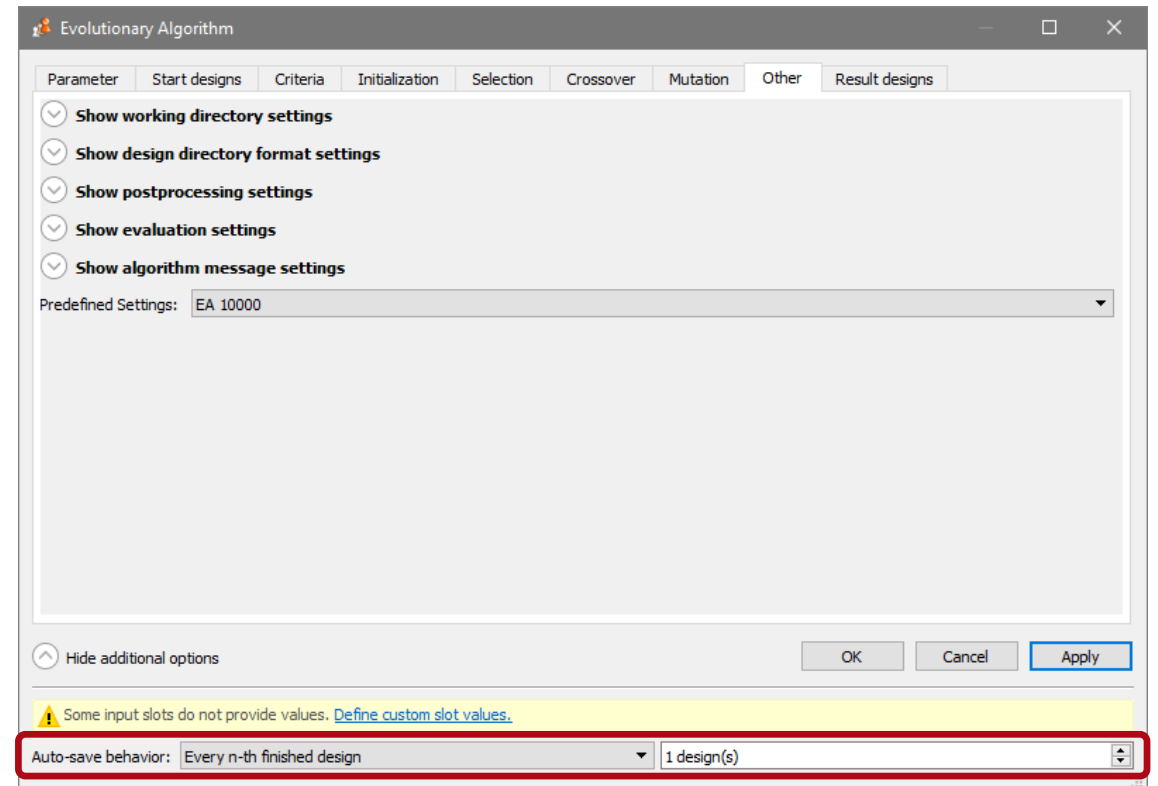
Advanced Settings of the Evolutionary Algorithm

- Advanced Settings
 - By double-clicking the created optimization, the detailed parameters of the optimization algorithm can be adapted.
 - In the tabs “Initialization”, “Selection”, “Crossover” and “Mutation” grant access to numerous parameters of the algorithm.
 - In the tab “Others”, some predefined parameter sets are provided, which are appropriate for most optimizations (e.g. “EA 10000”)



Advanced Settings of the Evolutionary Algorithm

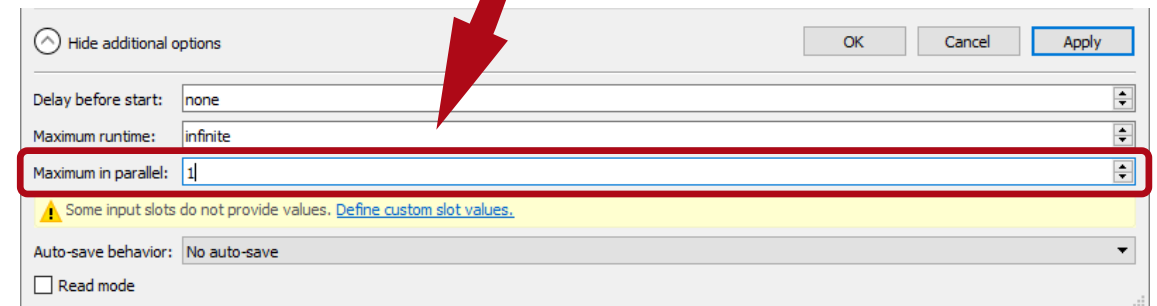
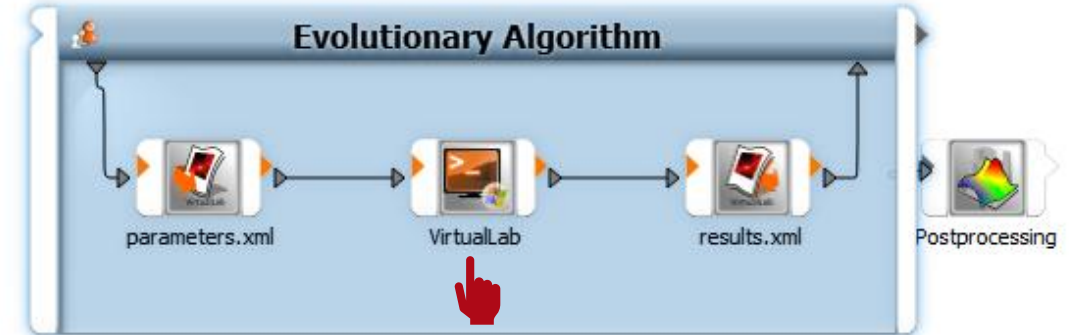
- Advanced Settings
 - Further, as an additional option the auto-save behavior of optiSLang can be adjusted.
 - By default, the project is automatically saved after the calculation of each design iteration.
 - Especially for designs with short calculation times, this can generate a lot of overhead and slows down the optimization.
 - Thus, it is recommended to set the auto-save option to only every 50 or 100 finished designs.



Parallelization of Design Calculation

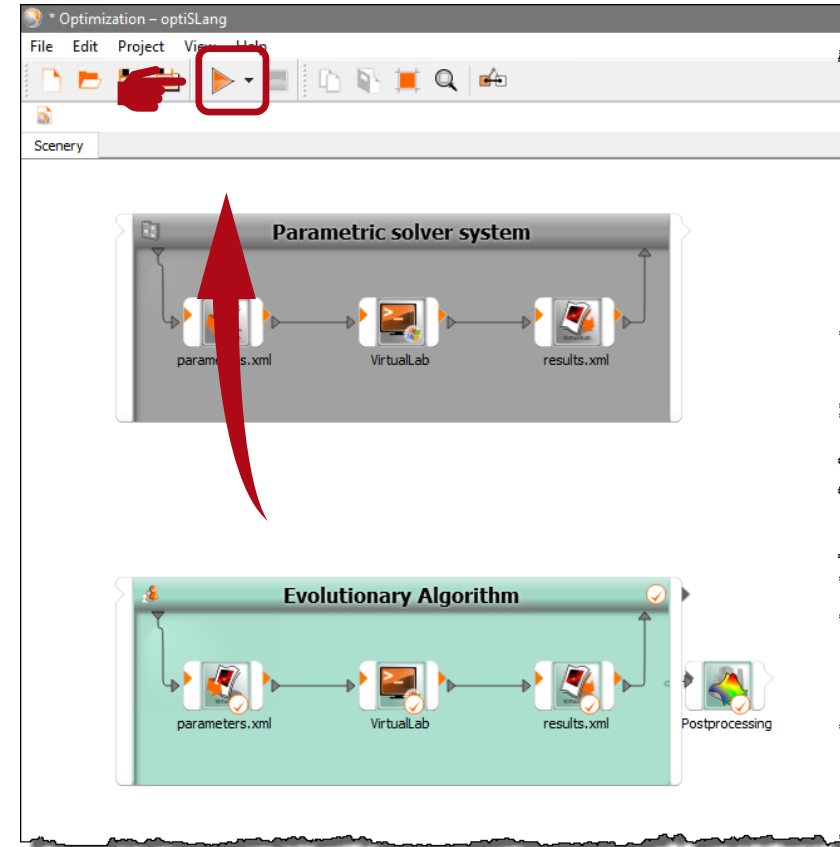
- Parallelization Settings

- Some optimization algorithms allow a parallel computation of designs.
- For instance in case evolutionary algorithm, the parameters of all member designs of one generation are known and thus can be calculated at the same time in order to reduce the computational time.
- In order to allow parallel calculation, the execution of more than one solver has to be enabled.
- By double-clicking the VirtualLab solver, this additional option can be found.
- The recommendation is, to use between the half number up to all of the real cores of the CPU, depending on the parallelization of the calculation of each individual design.



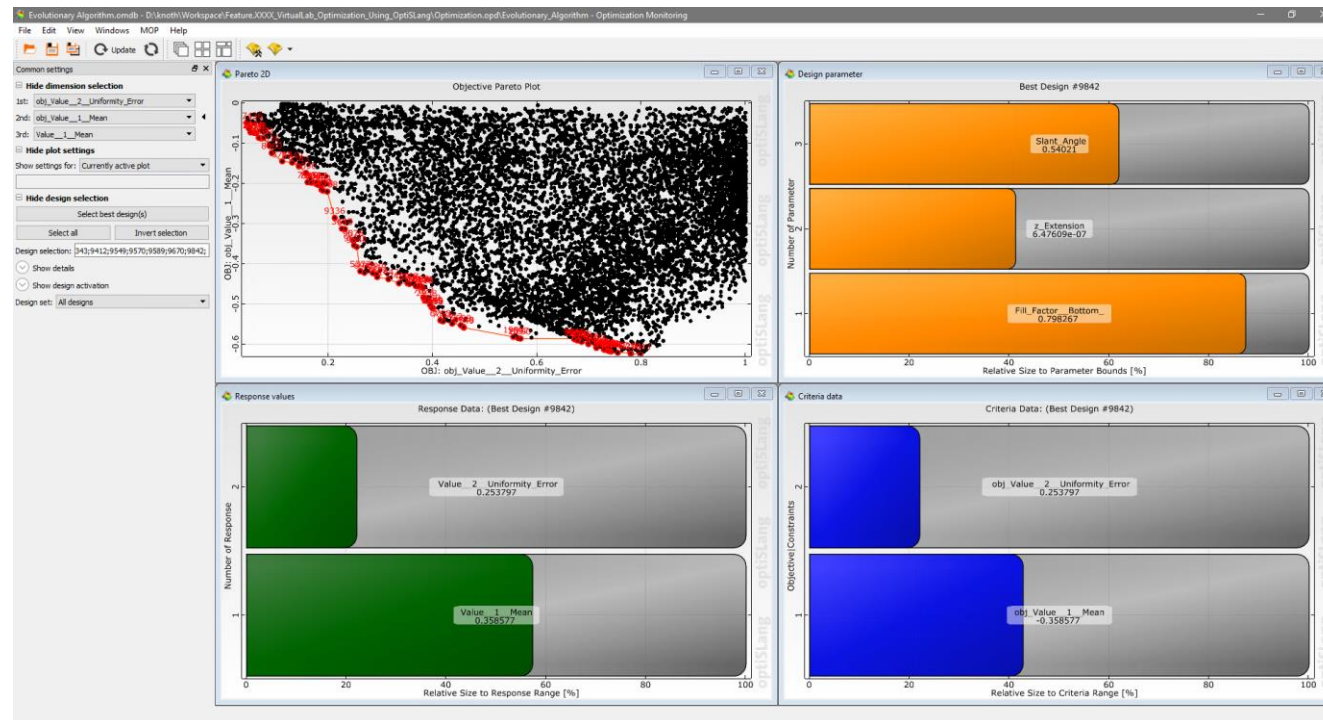
optiSLang – Starting the Optimization

- Run the optimization
 - Activate the Evolutionary Algorithm window within the Scenery by clicking on it.
 - Start the optimization by pushing the Run button.



optiSLang – Optimization Results

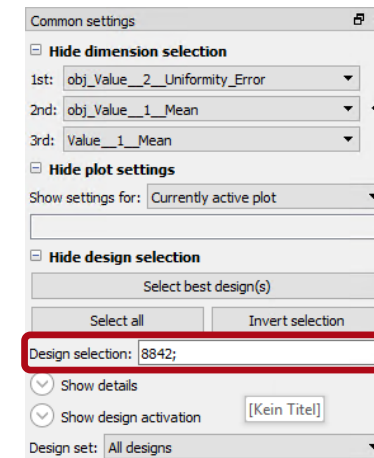
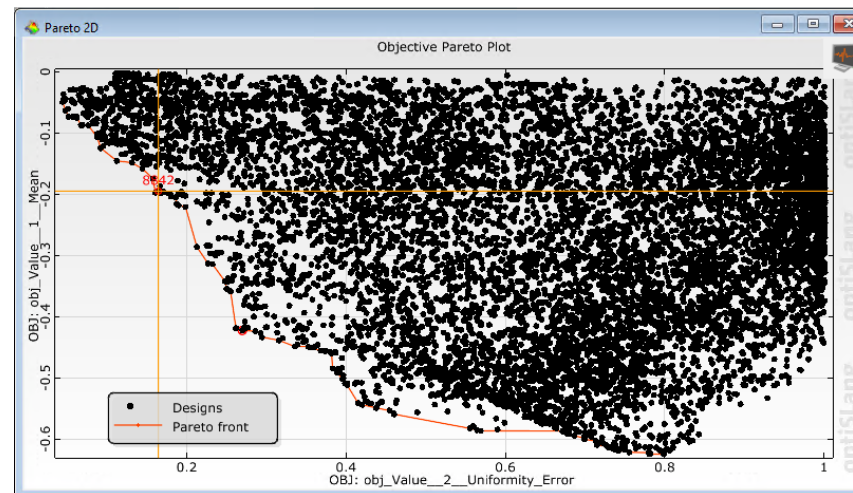
- Optimization Results
 - After the optimization is finished the results are obtained within an additional window.



optiSLang – Optimization Results

- Optimization Results

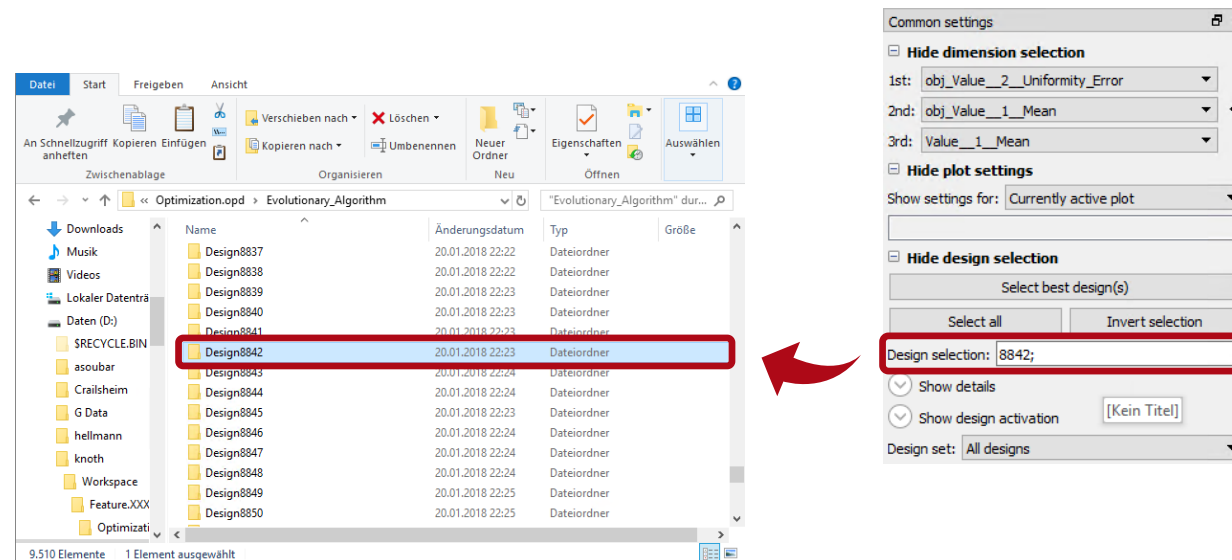
- The Pareto 2D diagram visualizes both target values, Uniformity contrast and Mean Efficiency, as a point cloud.
- There the user is able to select the most appropriate design for his application.
- In this example the design no. 8842 was selected with ~16% uniformity contrast and ~20% mean efficiency.



optiSLang – Optimization Results

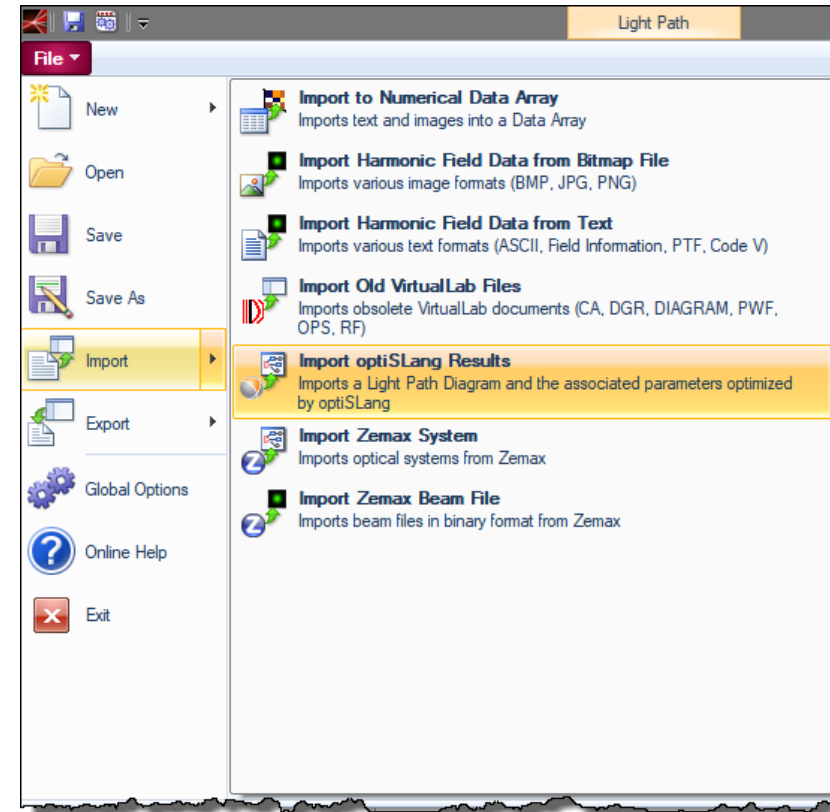
- Optimization Results

- Each design is stored within the optiSLang project directory in the subfolder ~\Optimization.opd\Evolutionary_Algorithm.
- Each folder within this directory, named by the design number, contains all the files necessary to import the design again to VirtualLab.



VirtualLab Fusion – Import Optimization Result

- Import design result
 - To import the design of interest the Import optiSLang Results feature is used, where the corresponding design folder is chosen.
 - Finally, the imported LPD can be analyzed further in VirtualLab.



Summary

- As a summary the table below shows a comparison of the grating parameter and the performance criteria for the initial and the optimized design setup.

Parameter	Value & Unit Initial Setup	Value & Unit Designed Setup
Slanted Grating: Fill Factor	50.00%	80.08%
Slanted Grating: z-Extension	400.00nm	411.96nm
Slanted Grating: Slanted Angle	40.00°	30.08°
Mean value	45.47%	19.49%
Uniformity Error	84.48%	16.32%

Document Information

title	Grating Optimization in VirtualLab Using optiSLang
document code	LGC.0004
version	1.0
toolbox(es)	Starter Toolbox, Grating Toolbox
VL version used for simulations	7.4.0.49
category	Application Use Case
further reading	<ul style="list-style-type: none">– <u>Analysis of Slanted Gratings for Lightguide Coupling</u>– <u>Optimization of Lightguide Coupling Grating for Single Incidence Direction</u>– <u>RDO-Journal Article: “Innovation in Optics and Photonics – VirtualLab and OptiSLang”</u>