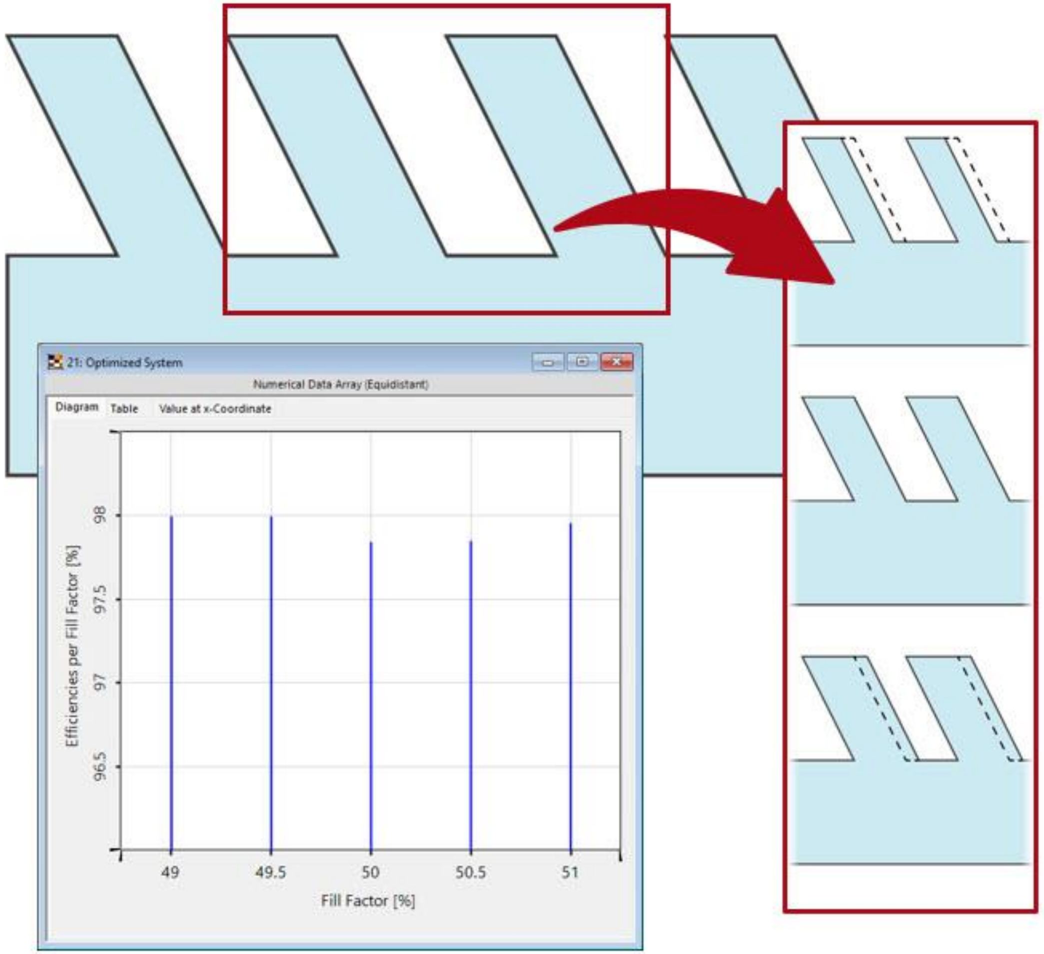
Robustness Optimization of a Slanted Grating

Abstract



Due to potential inaccuracies in the manufacturing process, it is essential for a good grating design to provide robust results in the face of slight variations in the grating parameters. VirtualLab Fusion offers the optical engineer various tools to incorporate this behavior directly in the optimization process, such as the Parameter Variation Analyzer. This tool combines multiple iterations of the same system, enabling the representation and automatic calculation of merit functions, like the mean efficiency, during optimization. In this use case we demonstrate this feature by optimizing a slanted grating with a slightly varying fill factor.

Simulation Task

plane wave

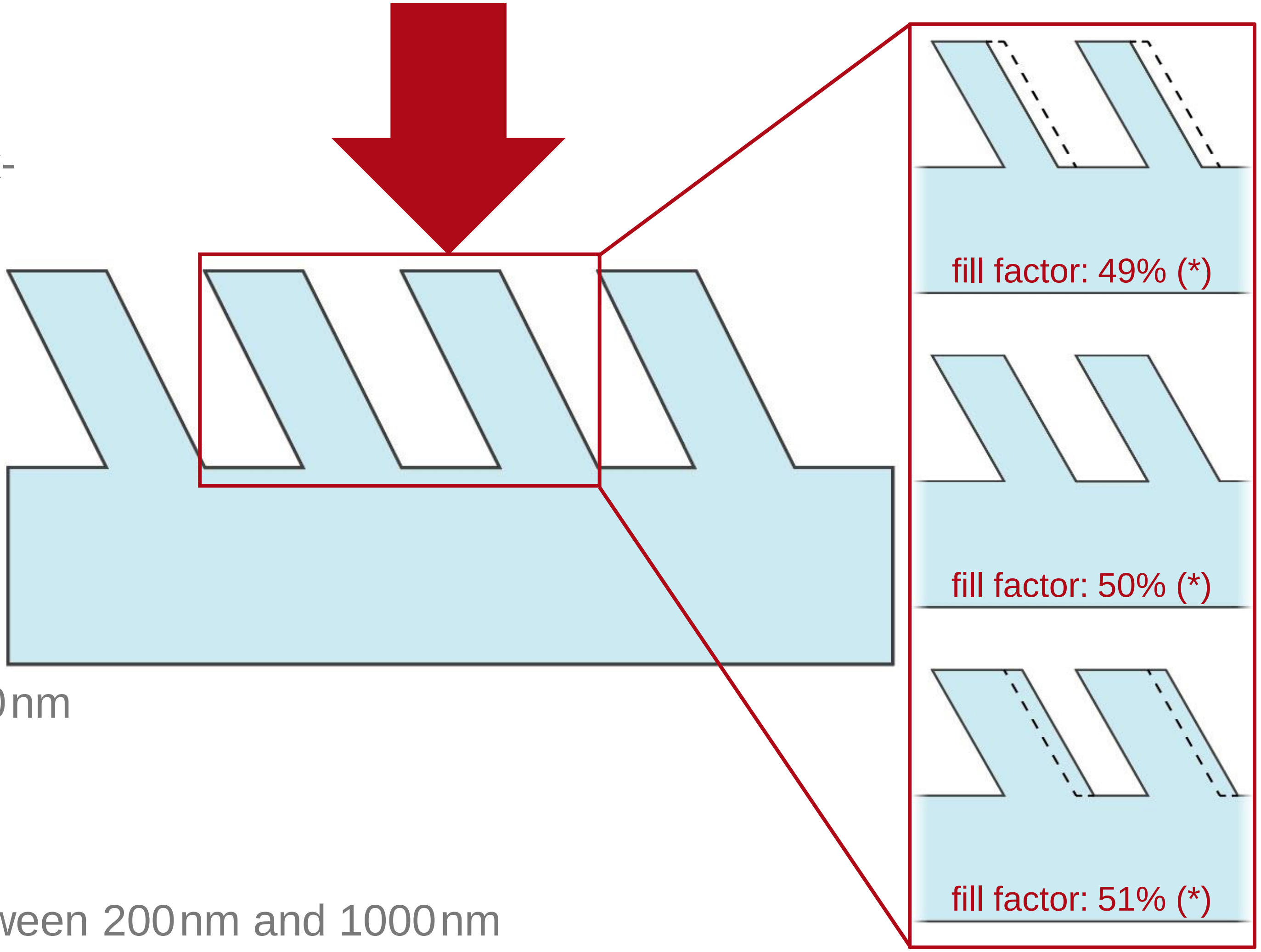
- wavelength: 532 nm
- linearly polarized along x-axis

slanted grating

- operation order: +1st (transmission)
- fill factor: 50% ± 1%
- medium in front: air
- medium behind: n=1.6
- period: 500 nm
- grating height (initial): 250 nm
- slant angle (initial): 40°

optimization parameters

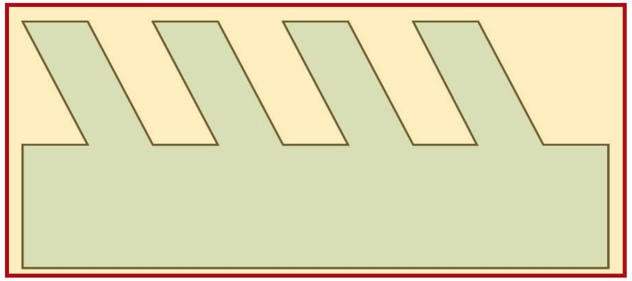
- grating height: varied between 200 nm and 1000 nm
- slant angle: varied between 0° and 60°



To perform a robustness analysis, efficiencies of 5 different fill factors between 49% and 51% will be combined in two merit functions: contrast (of the diffraction efficiencies) & mean efficiency.

(*) figures slightly exaggerated for illustration purposes

Connected Modeling Techniques: Slanted Grating

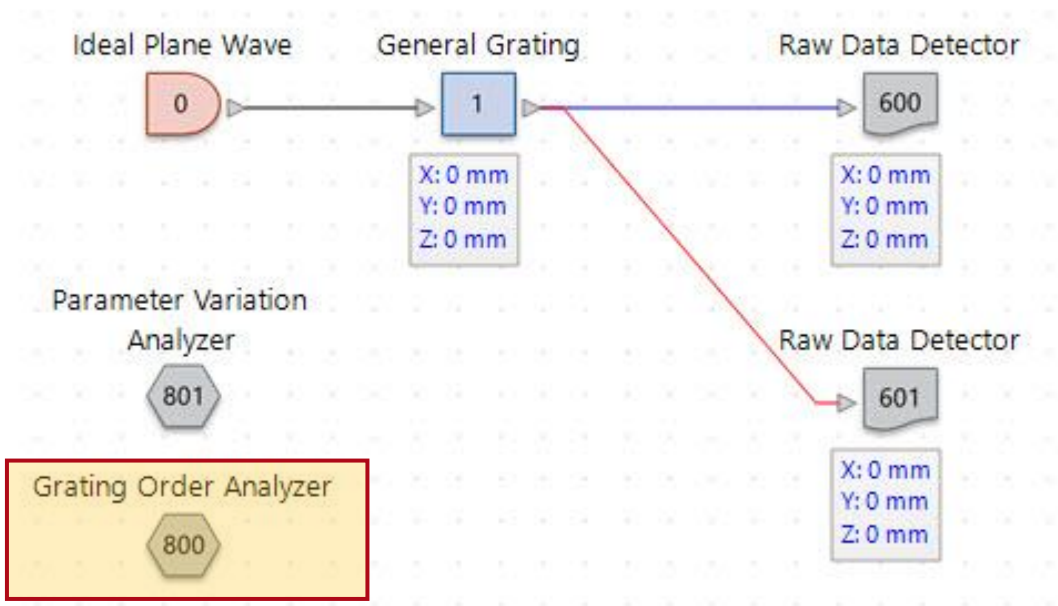


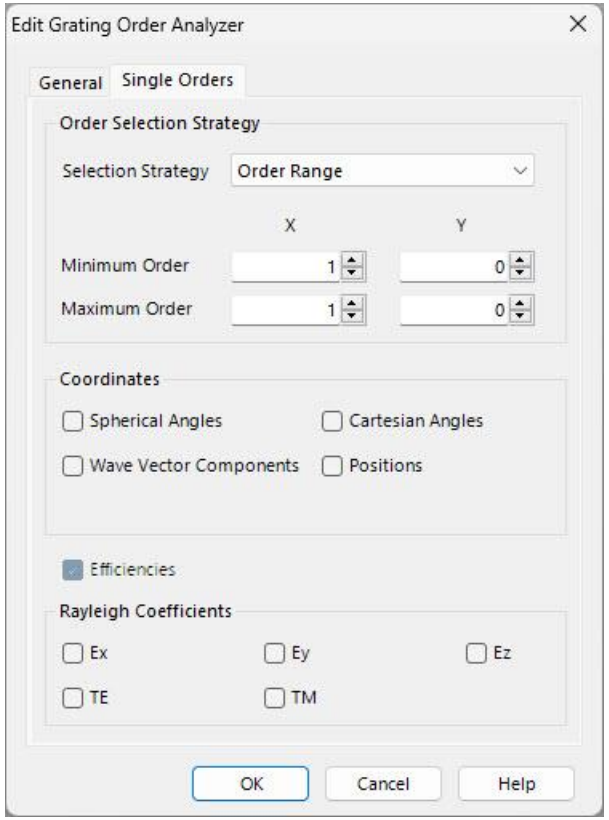
Available modeling techniques for microstructures:

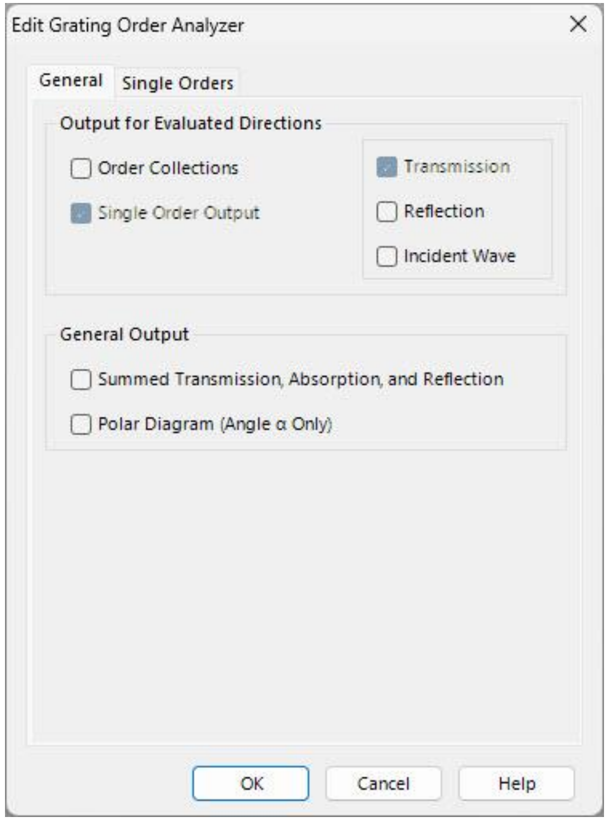
Methods	Preconditions	Accuracy	Speed	Comments
Functional Approach	-	low	very high	diffraction angles acc. to grating equation; manual efficiencies
Thin Element Approximation (TEA)	smallest features > $\sim 10\lambda$	high	very high	inaccurate for larger NA and thick elements; x-domain
	smallest features < $\sim 2\lambda$	low	very high	
Fourier Modal Method (FMM)	period < ~ $(5\lambda \times 5\lambda)$	very high	high	rigorous solution; fast for structures and periods similar to the wavelength; more demanding for larger periods; k-domain
	period > ~ $(15\lambda \times 15\lambda)$	very high	slow	

The considerable modulation height and small period make the **Thin Element Approximation (TEA)** solver inaccurate in the given case. Hence, the **Fourier Modal Method (FMM)** is used to provide a rigorous solution.

Grating Order Analyzer



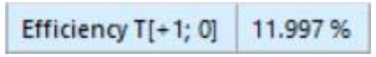




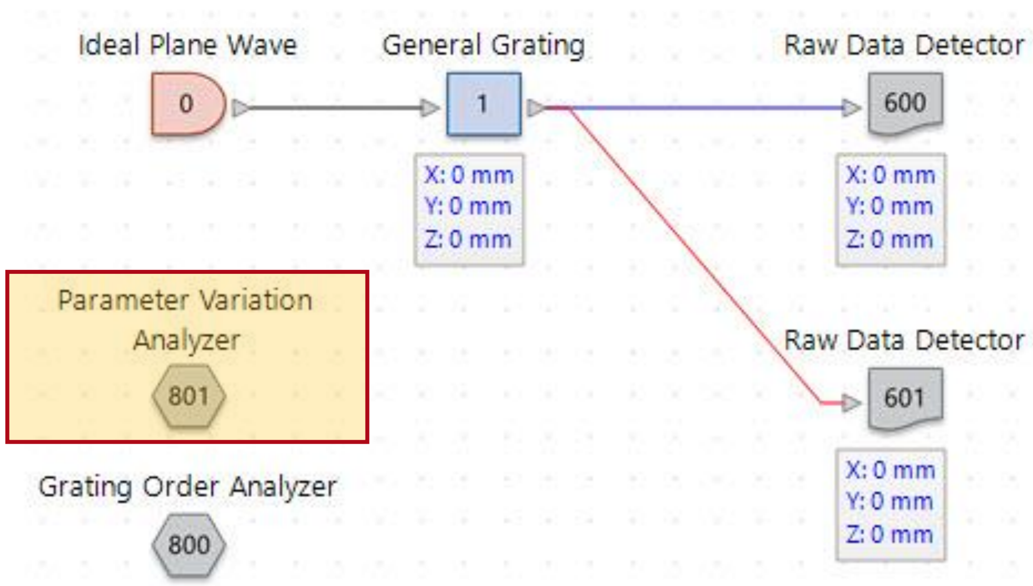
The *Grating Order Analyzer* can be used to investigate the efficiency of the diffraction orders of a given grating. Find more information under:

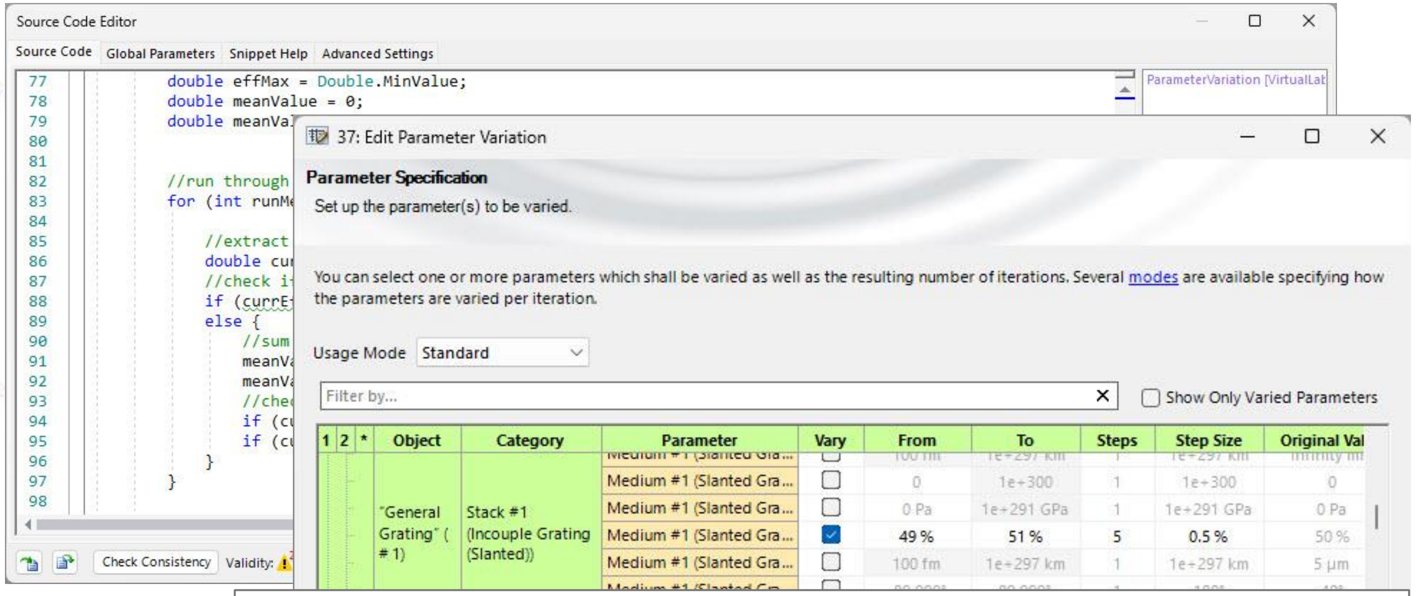
Grating Order Analyzer

resulting efficiency in the *Detector Results* tab:



Parameter Variation Analyzer





Since results generated with different grating configurations must be considered, the *Parameter Variation Analyzer* is used to calculate the overall merit function. This tool enables the computation of efficiencies for gratings with different fill factor values, automatically determining the resulting mean efficiency and contrast. For more information, see:

[Parameter Variation Analyzer]

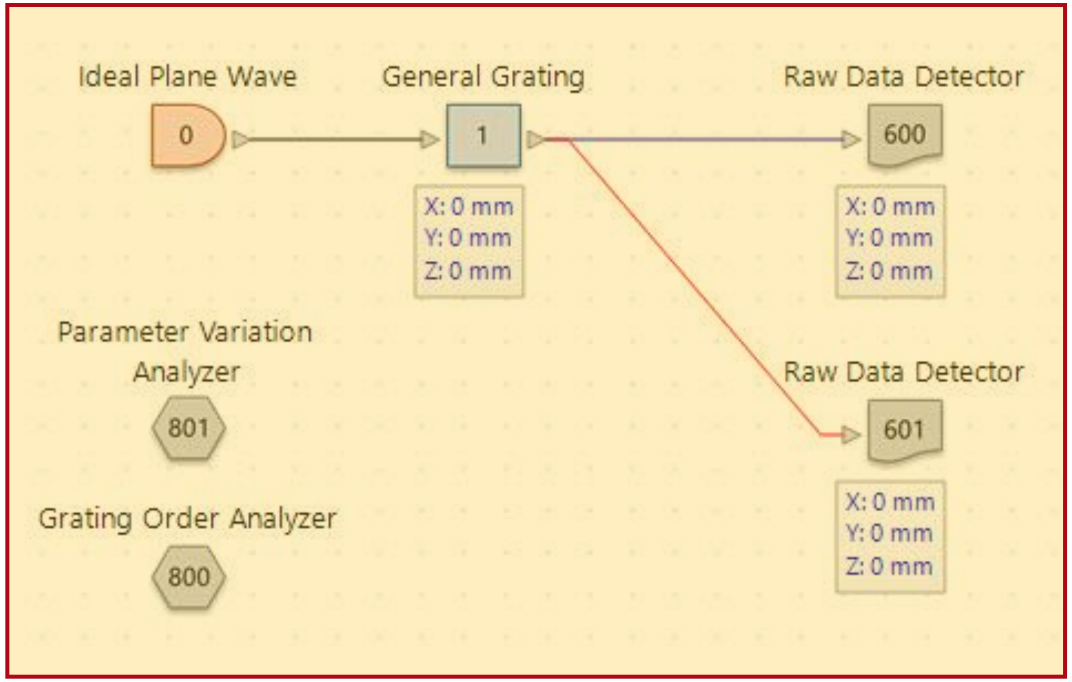
merit functions:

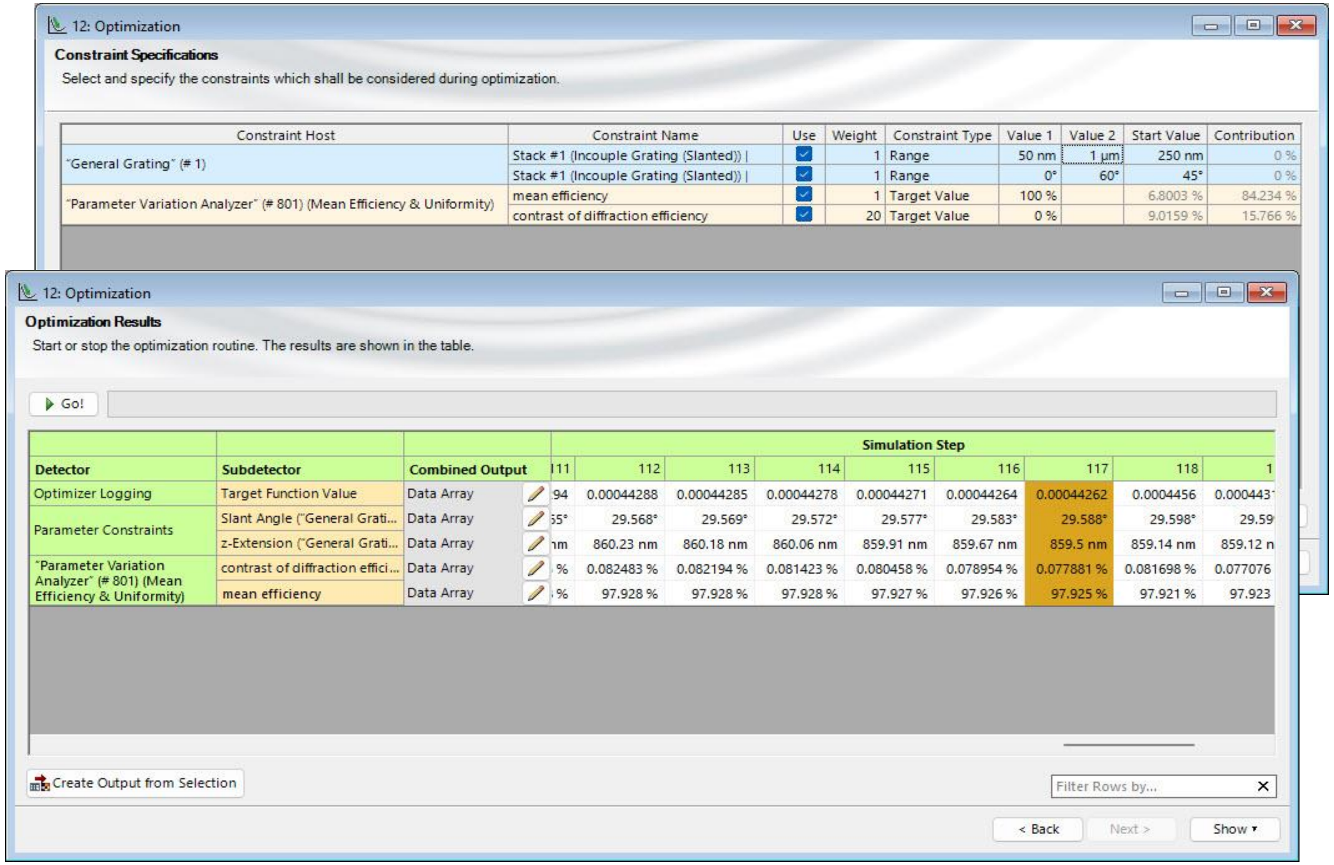
mean efficiency – to be maximized: $\eta_{\text{mean}} = \frac{\Sigma_i^n \eta_i}{n}$

contrast (of diffraction efficiency) – to be minimized: $u = \frac{\eta_{\max} - \eta_{\min}}{\eta_{\max} + \eta_{\min}}$

With η_i the 1st order transmission efficiency for the ith value of the fill factor.

Parametric Optimization





Now, the grating can be optimized using the inbuilt *Parametric Optimization*. A mean efficiency of 100% (to maximize this value) und uniformity contrast of 0% (to minimize this value) are used as target values for the merit function.

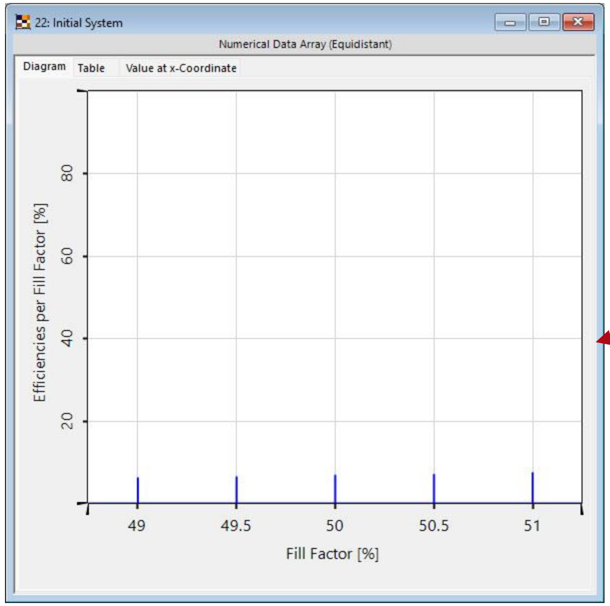
More information under:
Introduction to the Parametric Optimization Document

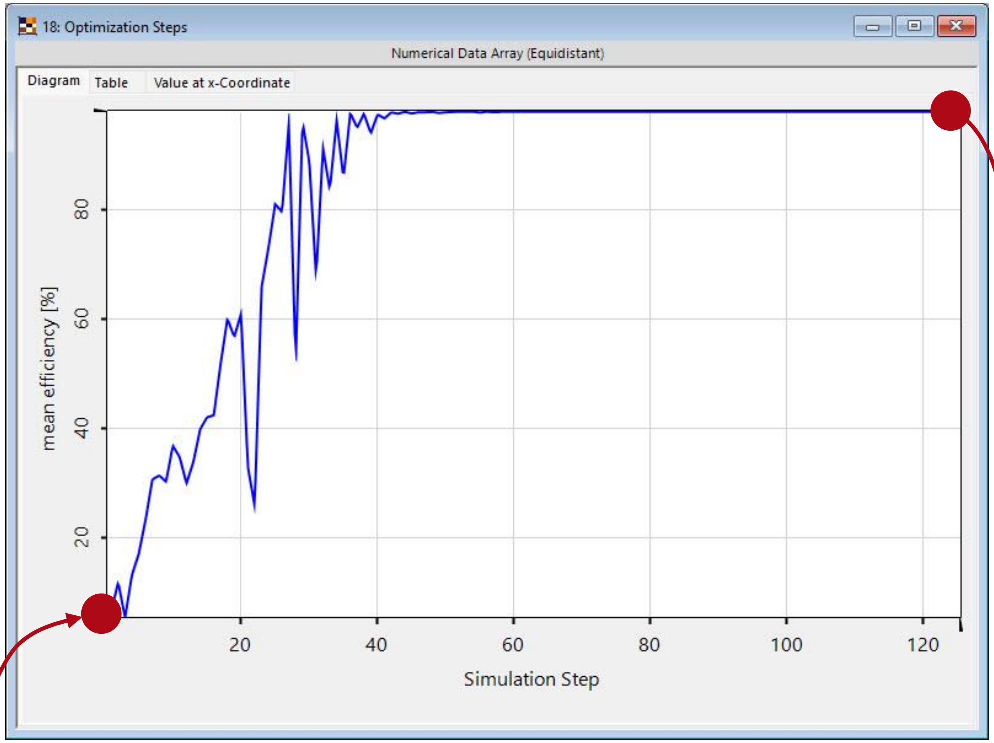
Optimization Result – Mean Efficiency

initial design:

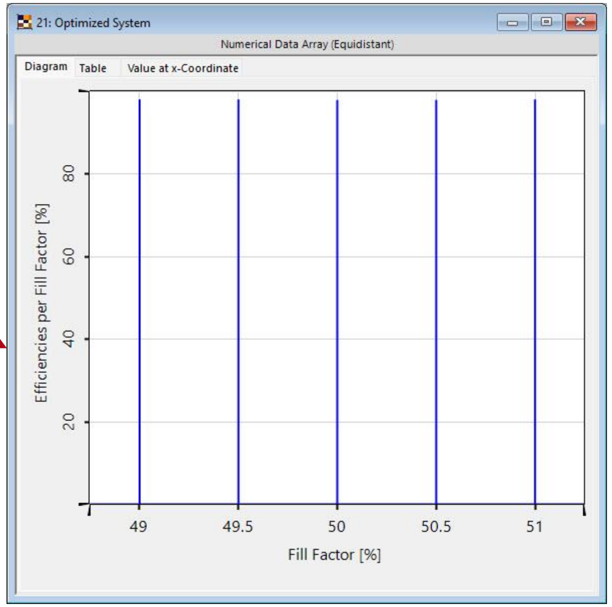
- height: 250 nm
- slant angle: 45°

- mean efficiency: 6.8%
- contrast: 9.0%





The optimization led to a drastic improvement of the mean efficiency, increasing from ~7% to almost 100%.



optimized design:

- height: 859.5 nm
- slant angle: 29.6°

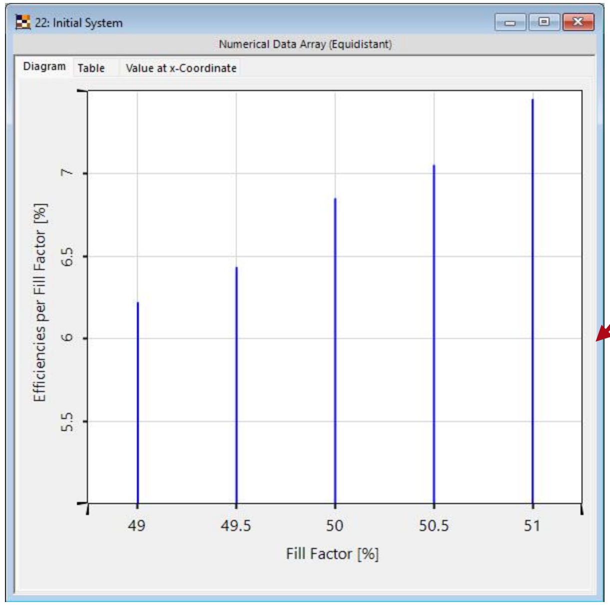
- mean efficiency: 97.9%
- contrast: 0.1%

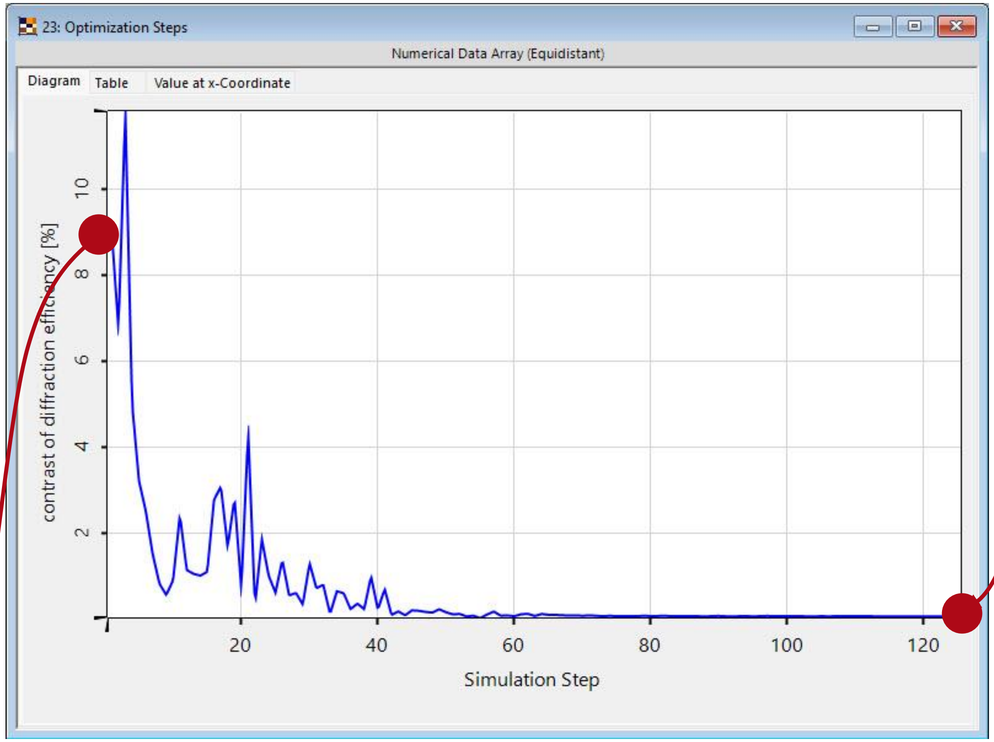
Optimization Result – Contrast

initial design:

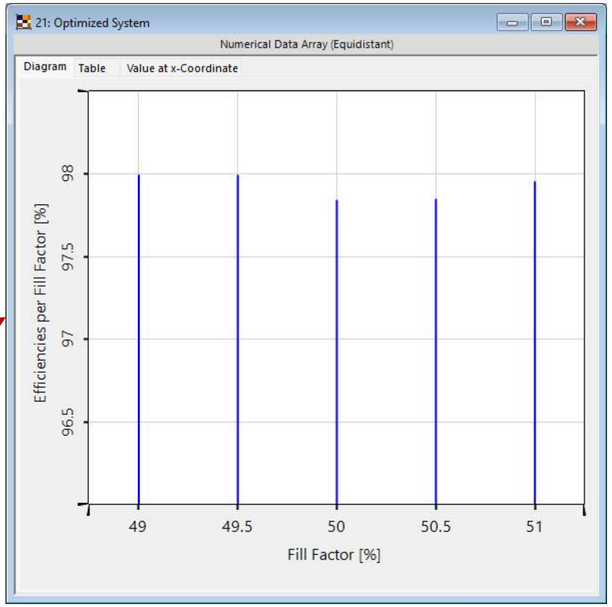
- height: 250 nm
- slant angle: 45°

- mean efficiency: 6.8%
- contrast: 9.0%





At the same time, the contrast also improved. While in the initial system a linear behavior between efficiency and fill factor was observed, the optimized result is much more even.



optimized design:

- height: 859.5 nm
- slant angle: 29.6°

- mean efficiency: 97.9%
- contrast: 0.1%

Document Information

title	Robustness Optimization of a Slanted Grating
document code	GRT.0034
document version	1.0
required packages	• Grating Package
software version	2023.2 (Build 1.242)
category	Application Use Case
further reading	• Grating Order Analyzer • Parameter Variation Analyzer • Introduction to the Parametric Optimization Document