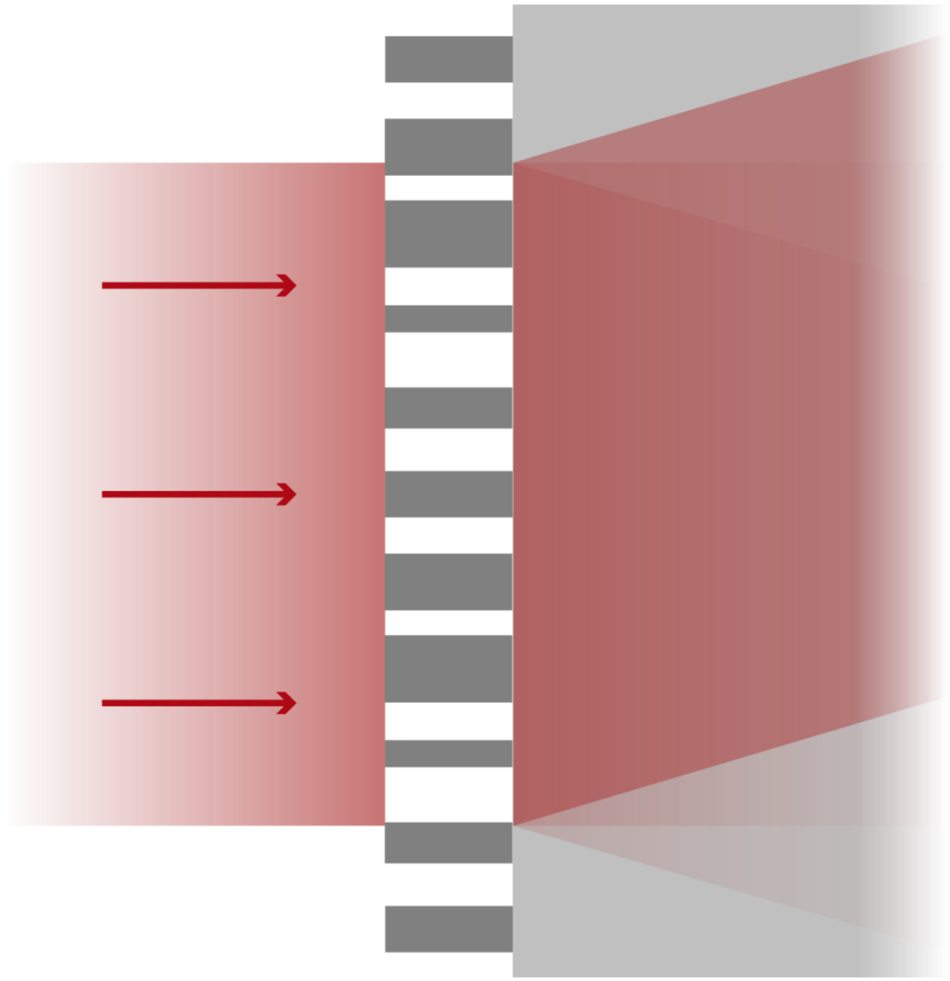
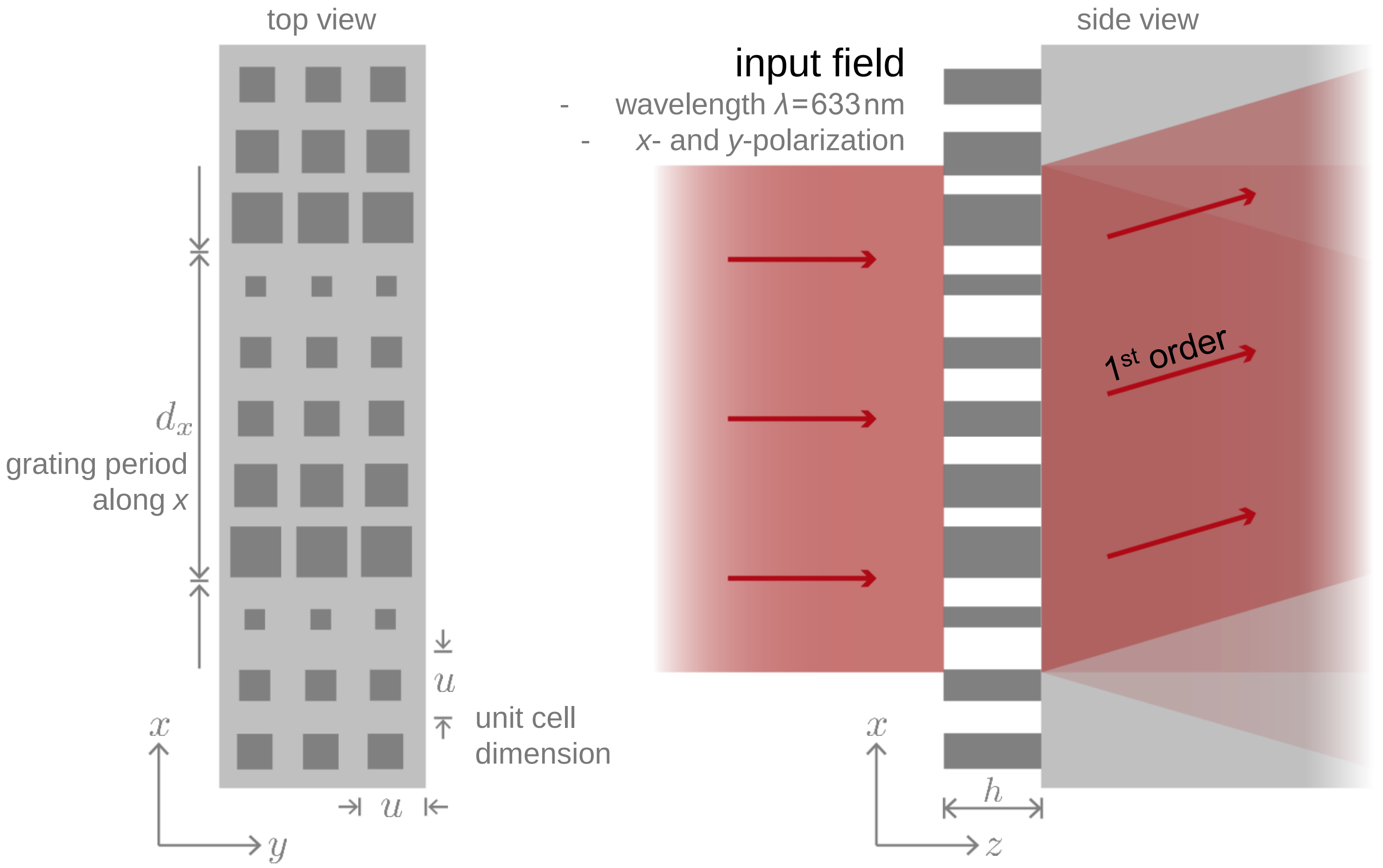
Modeling and Design of Blazed Metagratings

Abstract



Metagratings, which are usually composed of nano pillars, start to draw more and more attention for different applications. They are known for their high diffraction efficiency in non-paraxial cases and insensitivity to polarization. In this example, we construct a blazed metagrating using square nano pillars, following the work of P. Lalanne, *et al*., and demonstrate the optimization of metagratings in VirtualLab Fusion. Particularly, we evaluate the polarization-dependent efficiency in the simulation.

Modeling Task



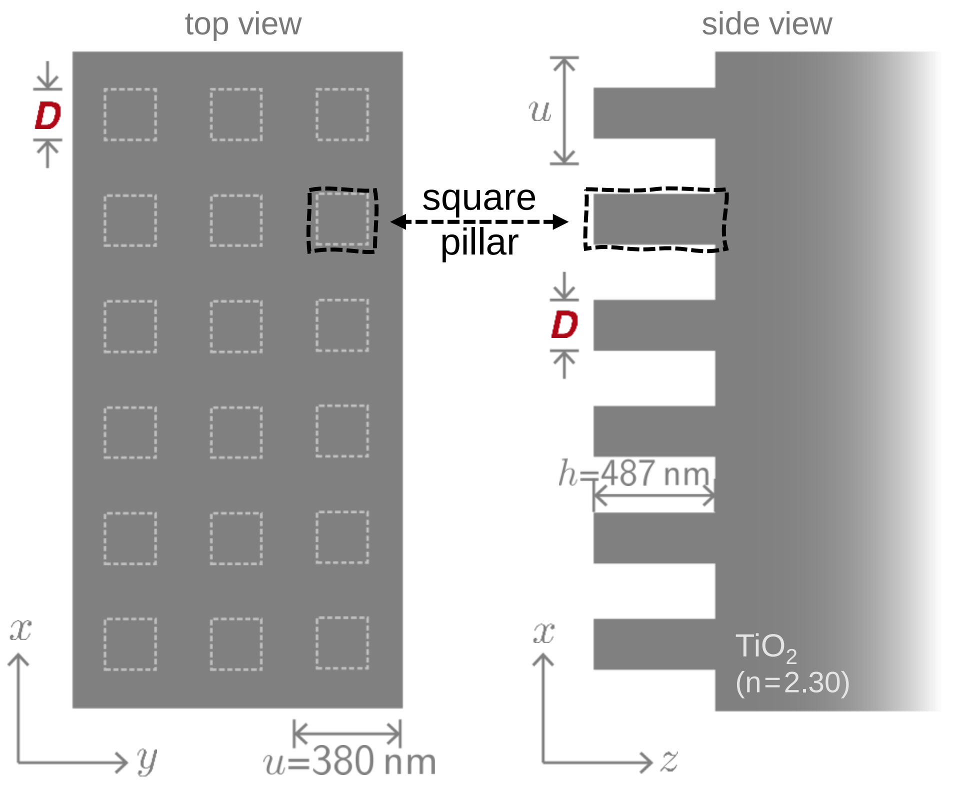
How to design a metagrating with optimized 1st order diffraction efficiency, by

- selecting the proper unit cells / building blocks, and
- arranging them and optimize their positions within one grating period?

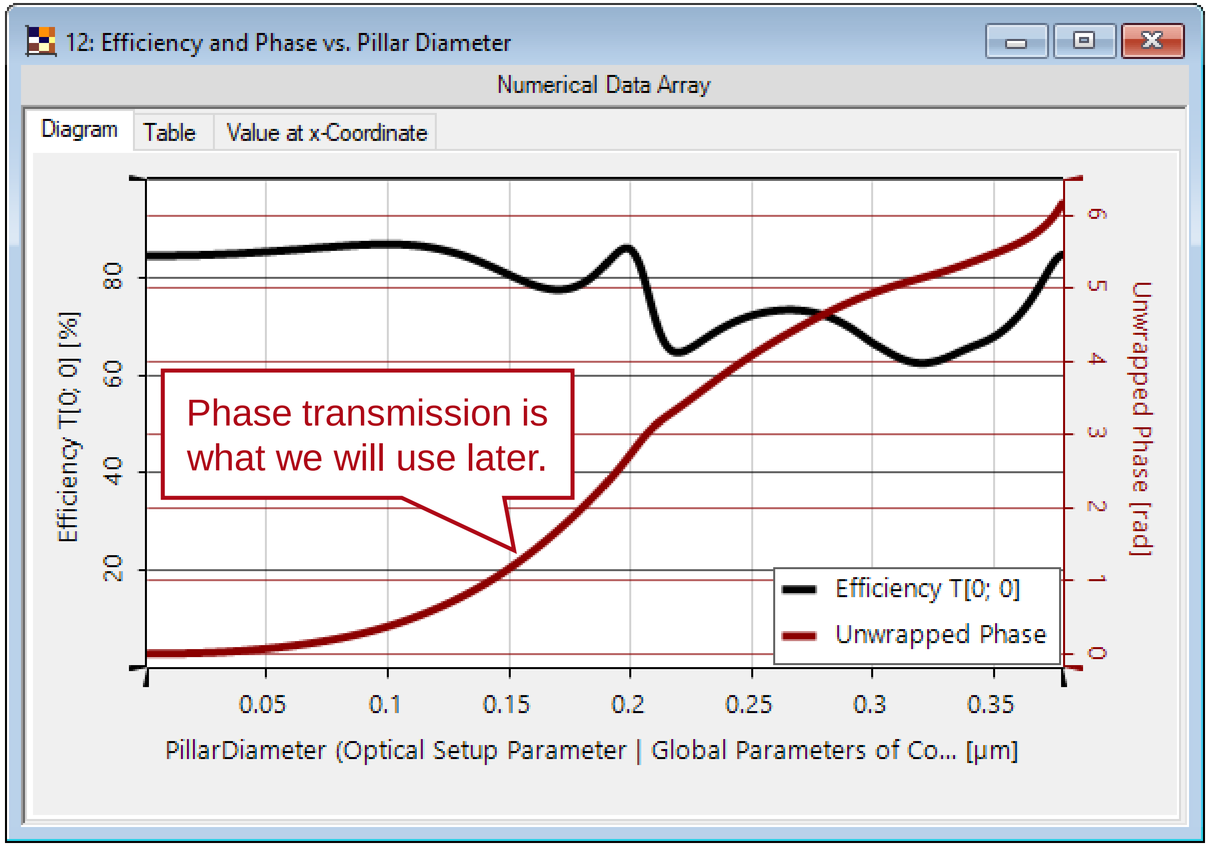
grating parameters and design method follows P. Lalanne, *et al*., Opt. Lett. 23, 1081-1083 (1998)

Unit Cell Analysis (Index Matched)

First, we assume a periodic replication of the same square pillars and vary the **pillar diameter (*D*)**.



transmission amplitude/phase vs. pillar diameter (@633nm)



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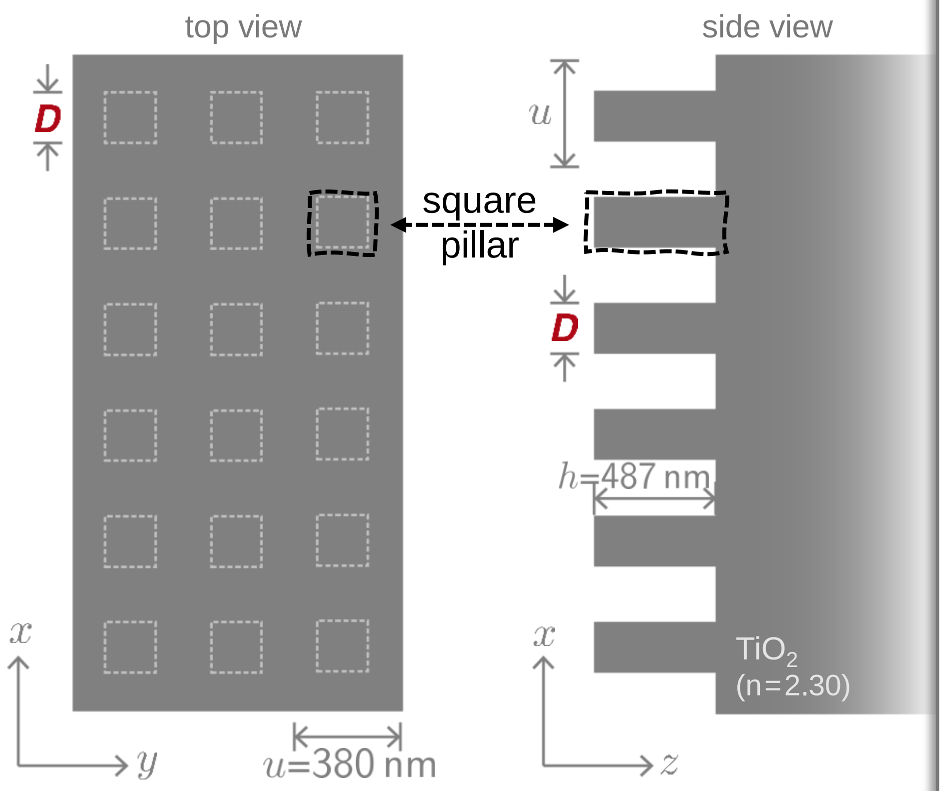


Fig. 1 from P. Lalanne, *et al.*, Opt. Lett. 23, 1081-1083 (1998)

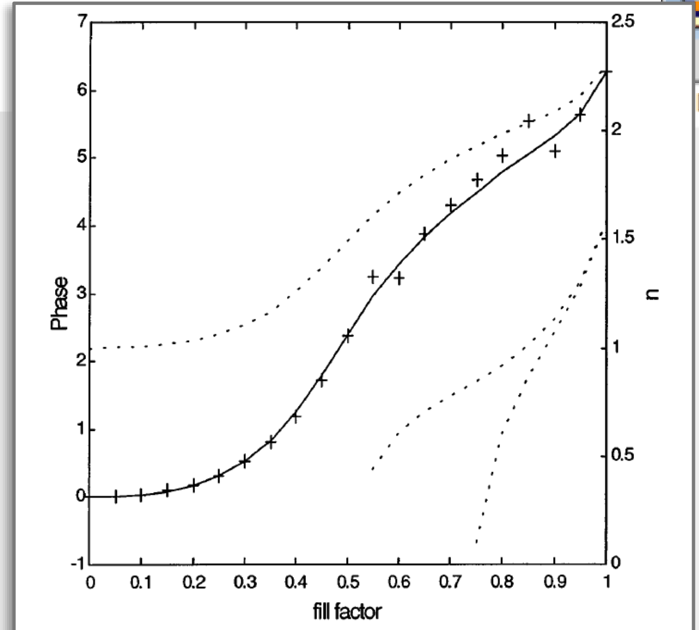
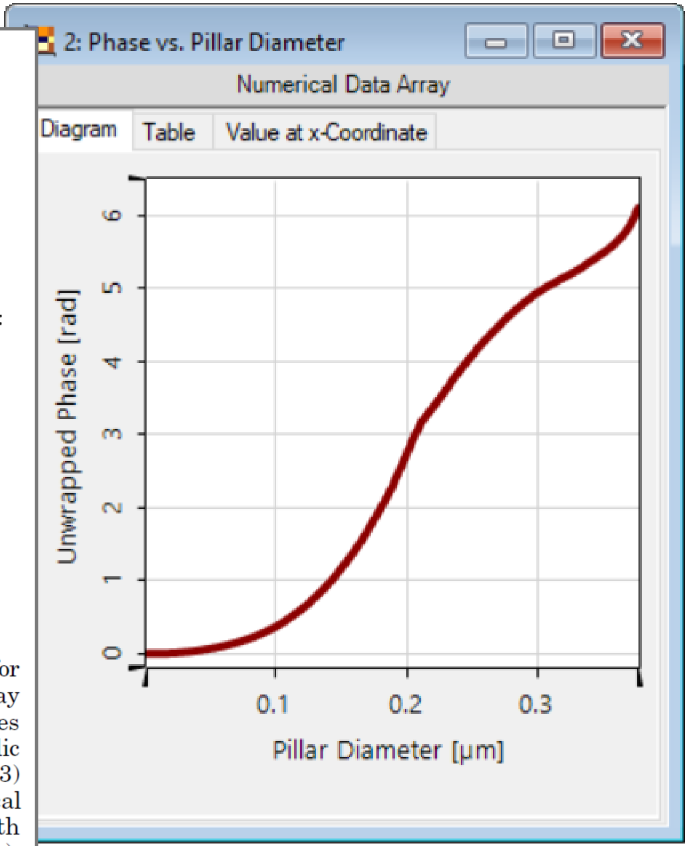


Fig. 1. Crosses, phases of the transmitted zeroth order for a 487-nm-thick grating composed of a 380-nm-period array of square pillars etched in TiO_2. Dotted curves, n values of all the propagating modes supported by the biperiodic structure. The uppermost curve (n varies from 1 to 2.3) corresponds to the grating effective index. Numerical results were obtained by the modal method of Ref. 10 with square truncation (17 orders are retained along each axis). Solid curve, phases of a plane wave transmitted through a 487-nm-thick homogeneous dielectric film whose refractive index is equal to the n value of the fundamental mode.

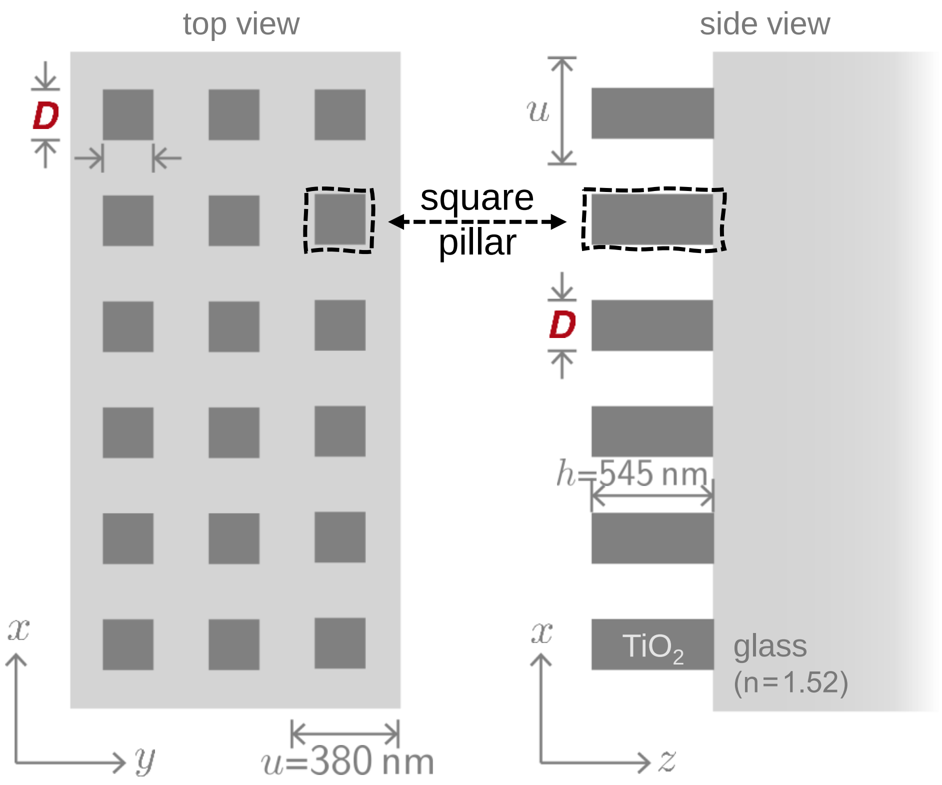
phase vs. pillar diameter (@633nm)



VirtualLab Fusion simulation

Choosing Unit Cell (TiO_2-Glass Interface)

In practice, the substrate is in a different material as the pillars. Here, we consider glass substrate.



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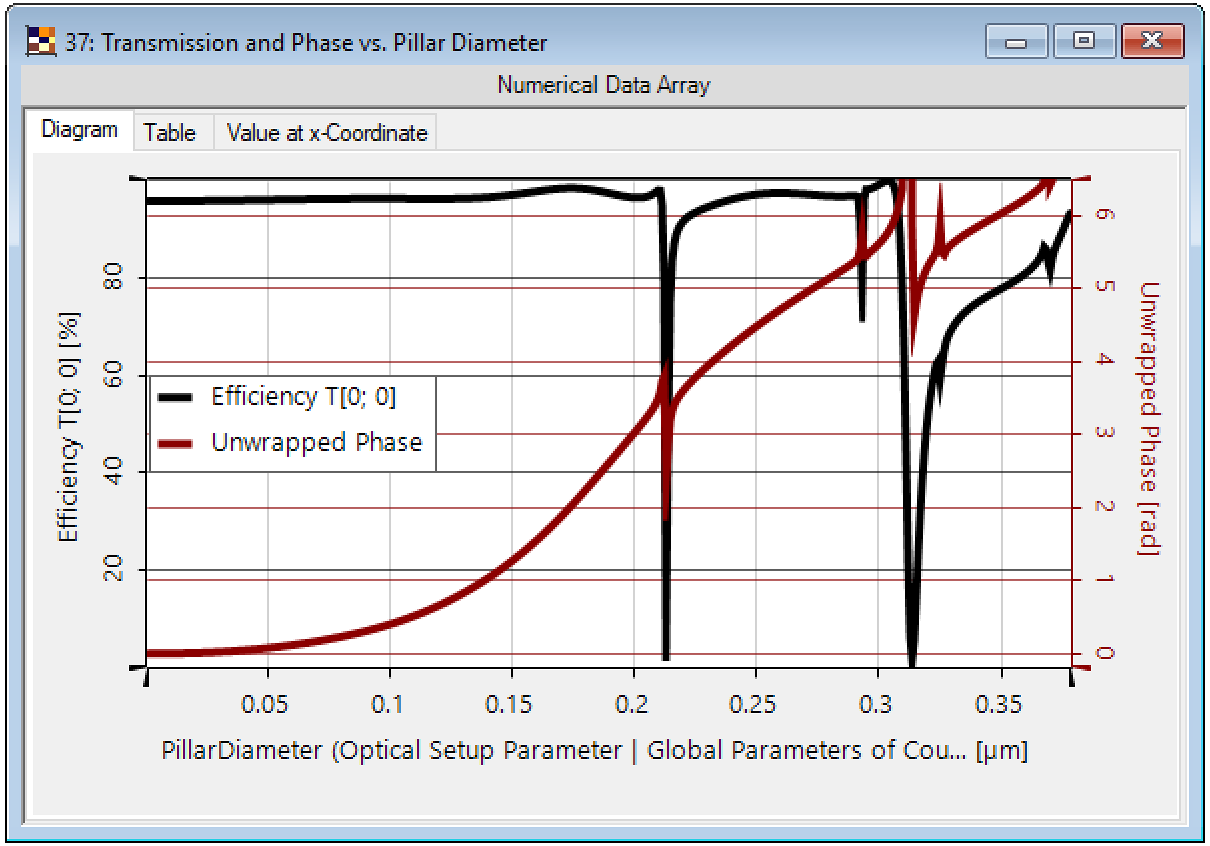
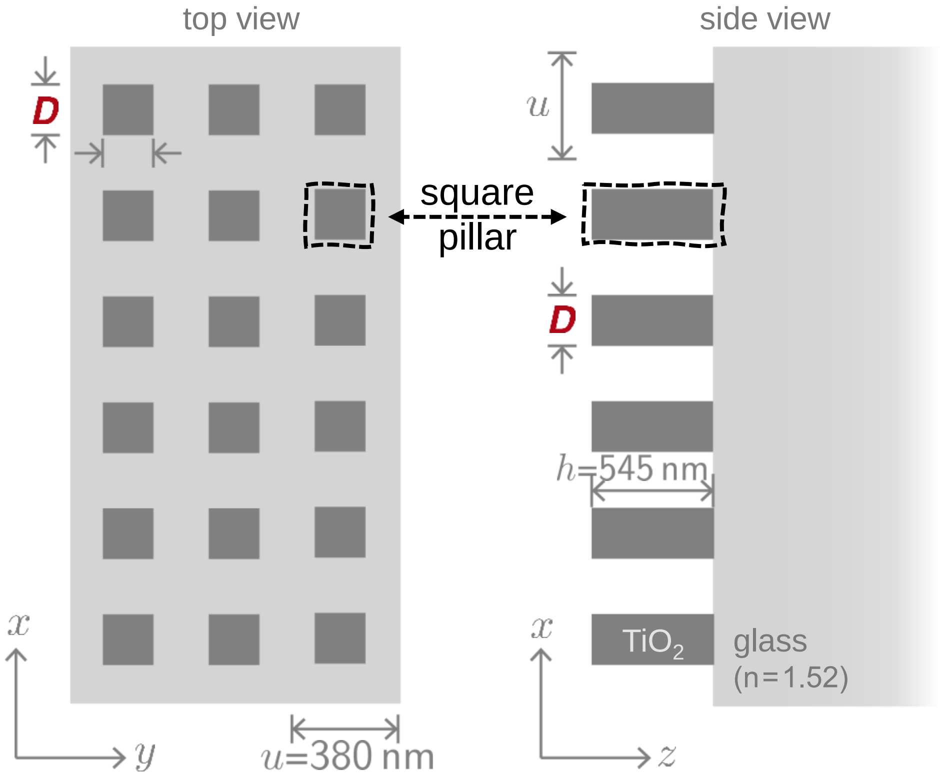
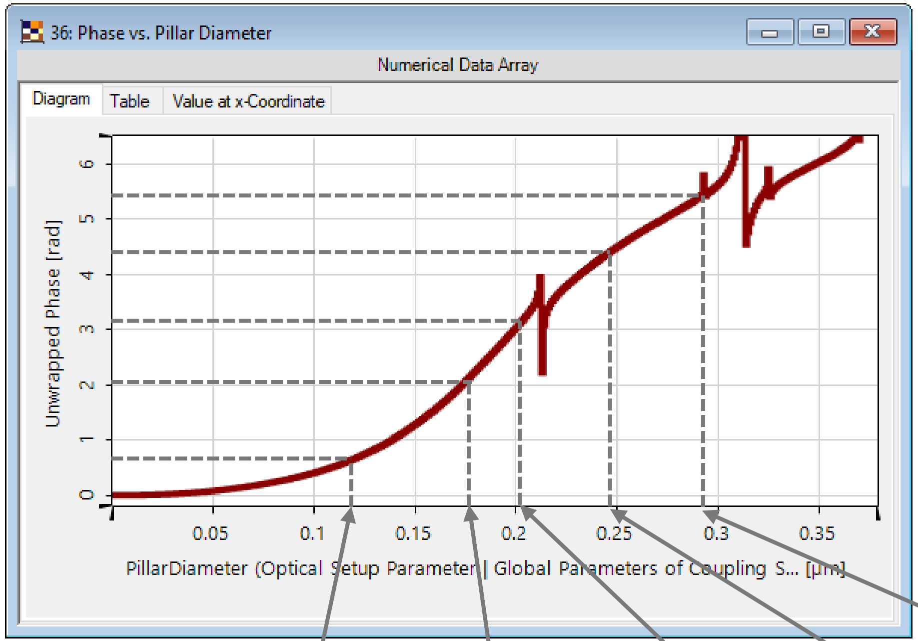


Selection of Pillar Diameters

In practice, the substrate is in a different material as the pillars. Here, we consider glass substrate.

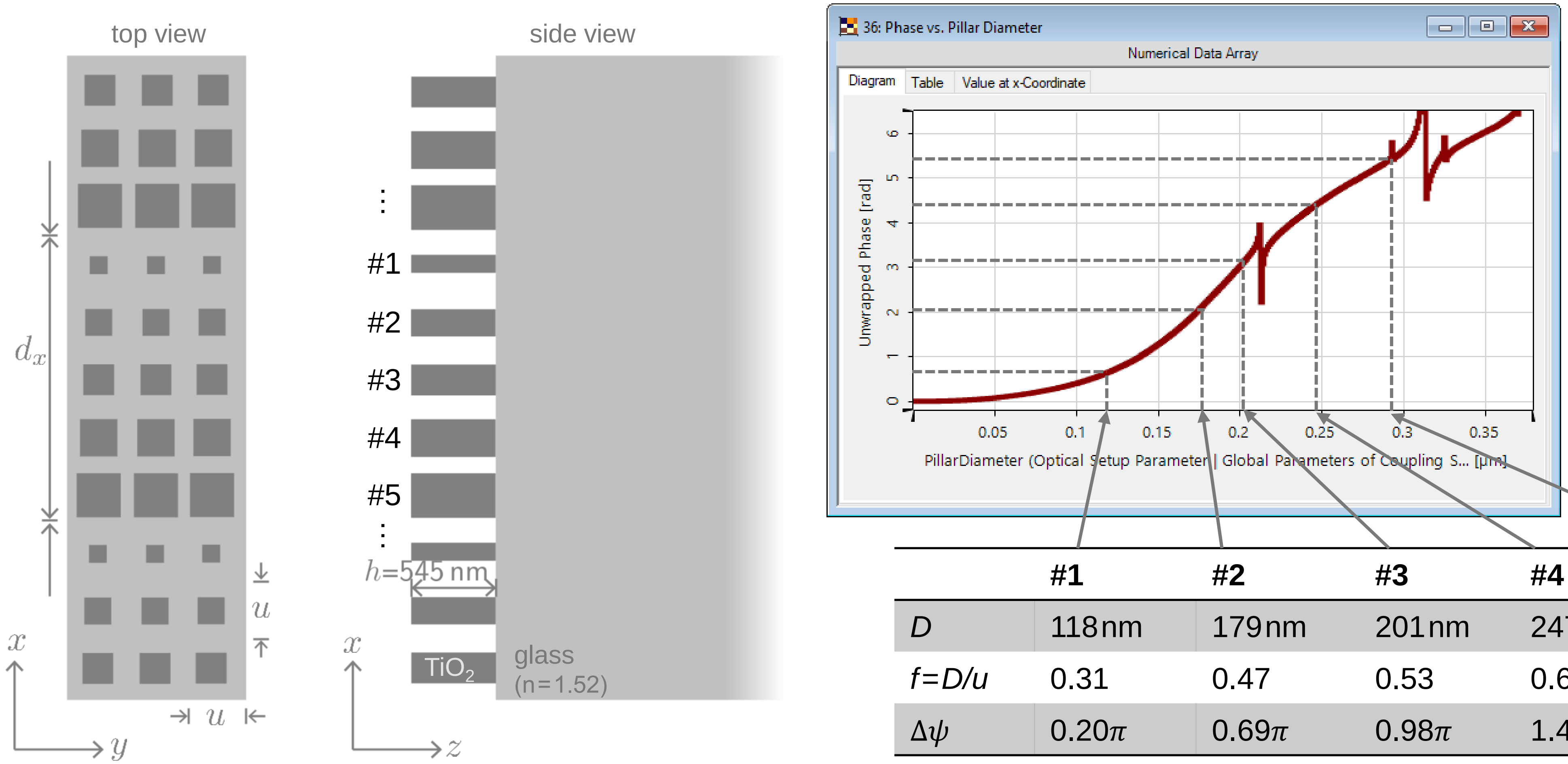




	#1	#2	#3	#4	#5
D	118nm	179nm	201nm	247nm	293nm
$f=D/u$	0.31	0.47	0.53	0.65	0.77
$\Delta\psi$	0.20π	0.69π	0.98π	1.40π	1.73π

Selection of pillar diameters follows from P. Lalanne, *et al.*, Opt. Lett. 23, 1081-1083 (1998)

Blazed Metagrating Construction



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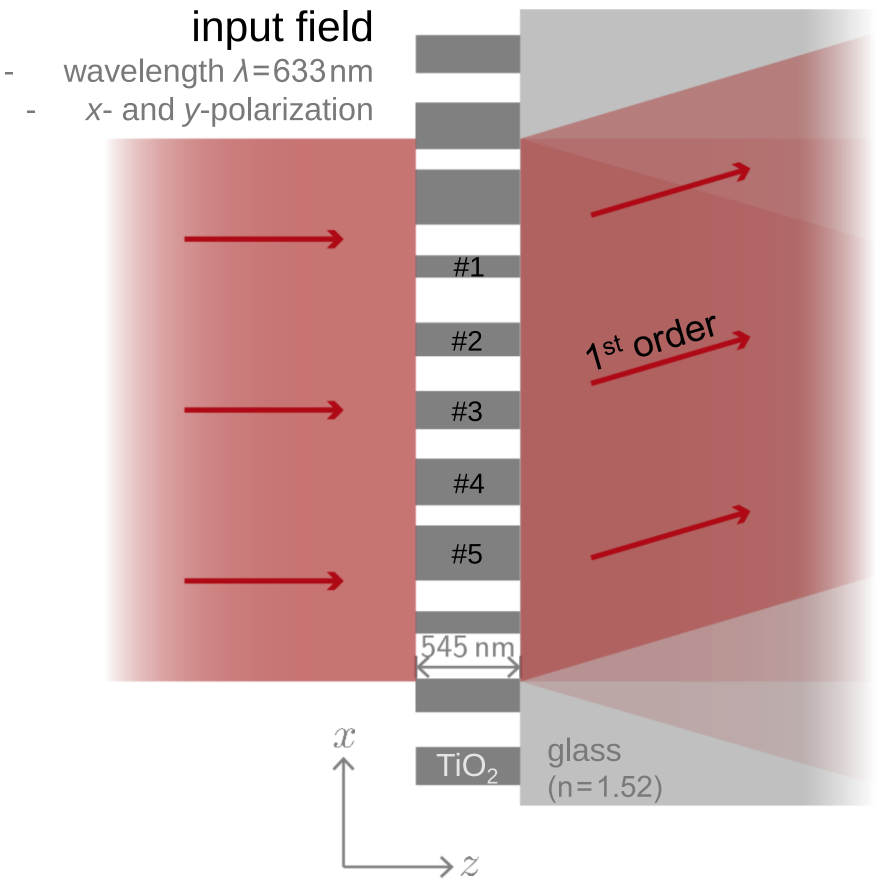
Performance Analysis of Initial Design



grating performance evaluation

	Efficiency
y-polarization (TE)	80.2%
x-polarization (TM)	74.2%
average	**77.2%**

The same average efficiency value is reported in P. Lalanne, *et al.*, Opt. Lett. 23, 1081-1083 (1998)

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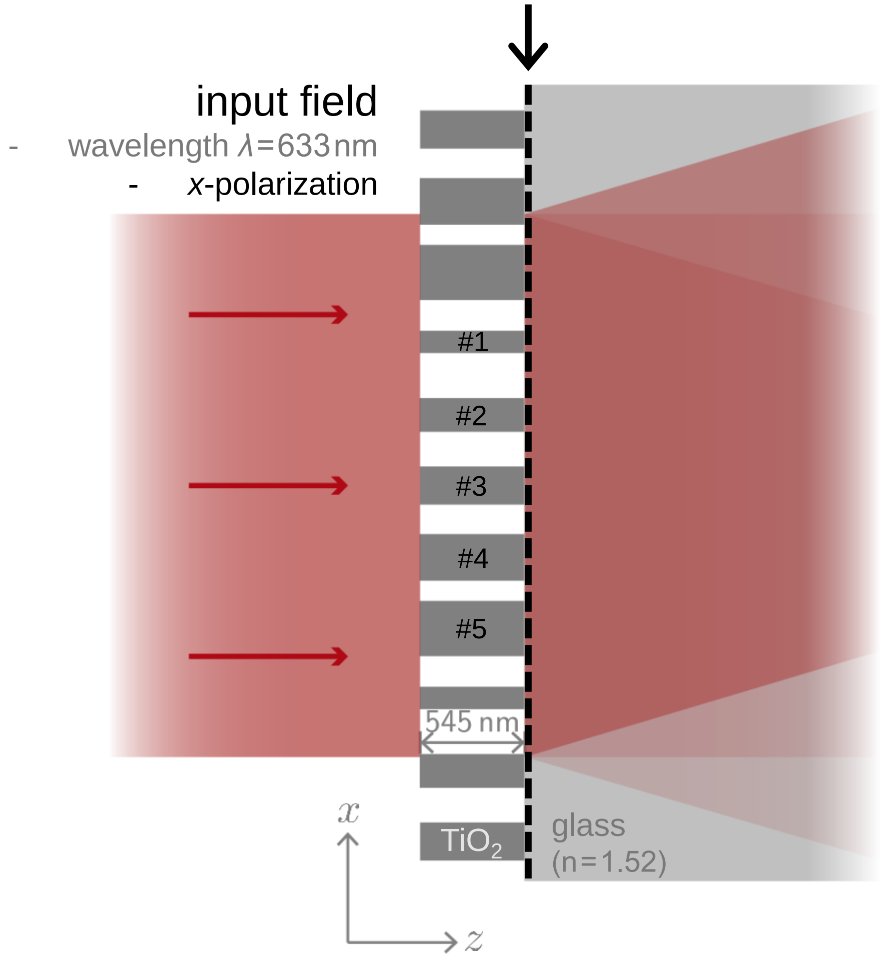
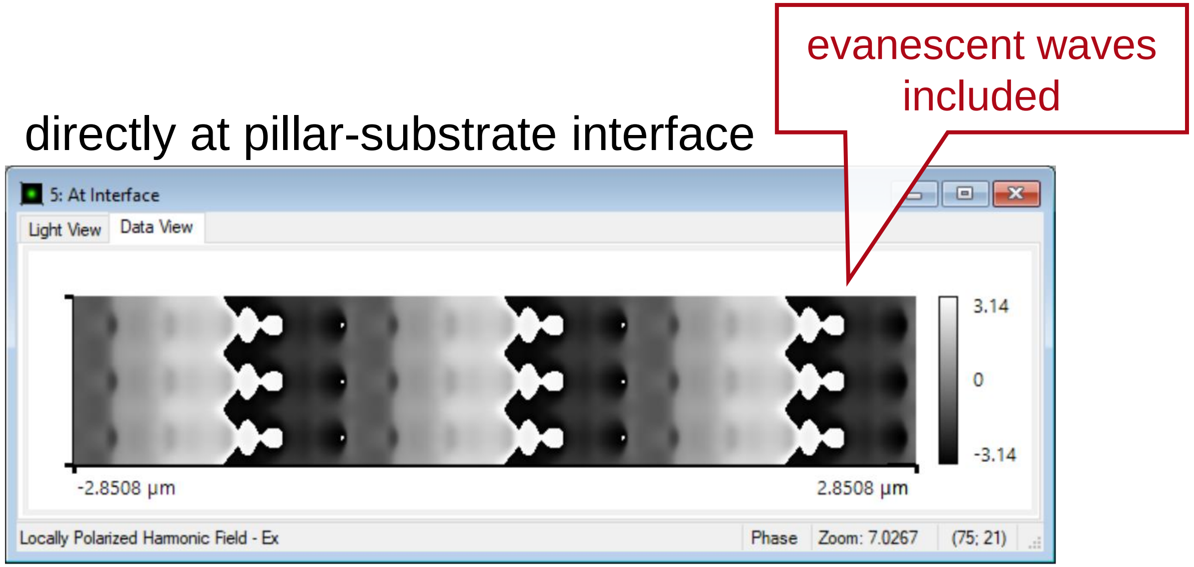
Visualization of Transmitted Field

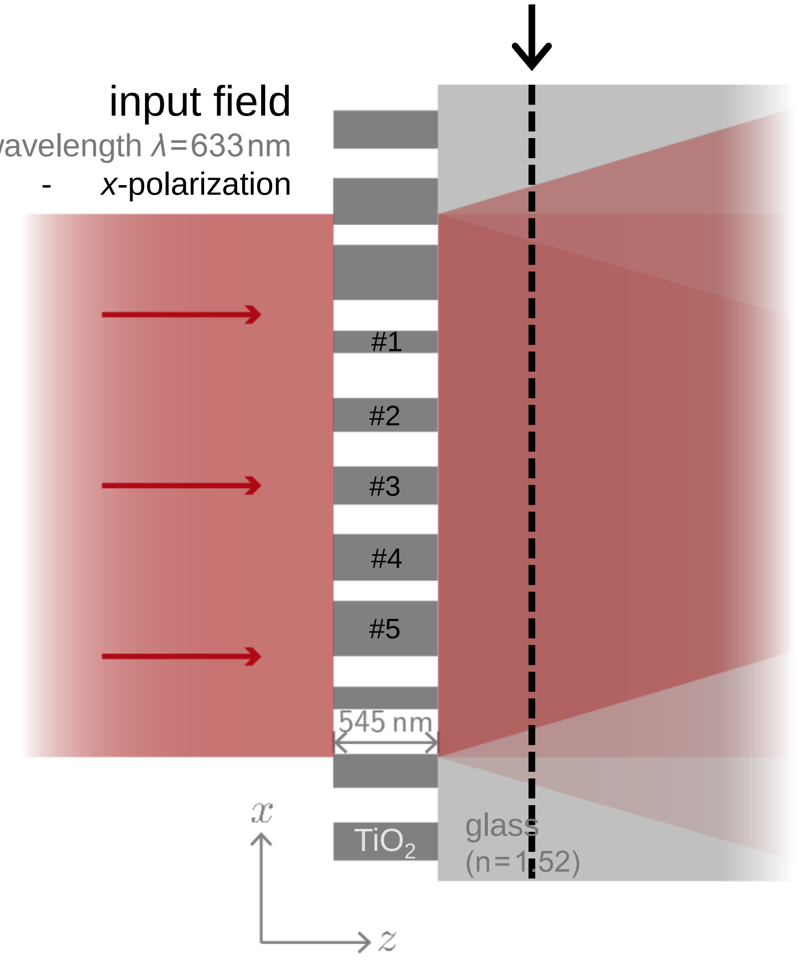


directly at pillar-substrate interface

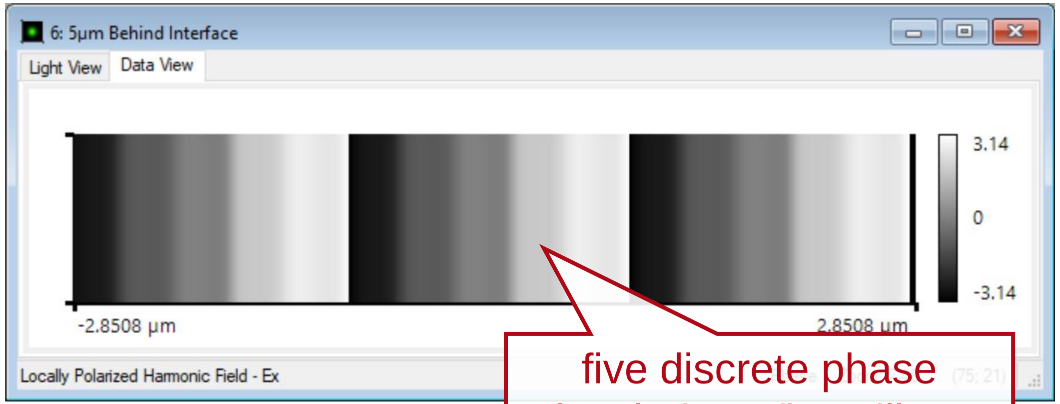


Visualization of Transmitted Field

input field
- wavelength λ=633 nm
- x-polarization



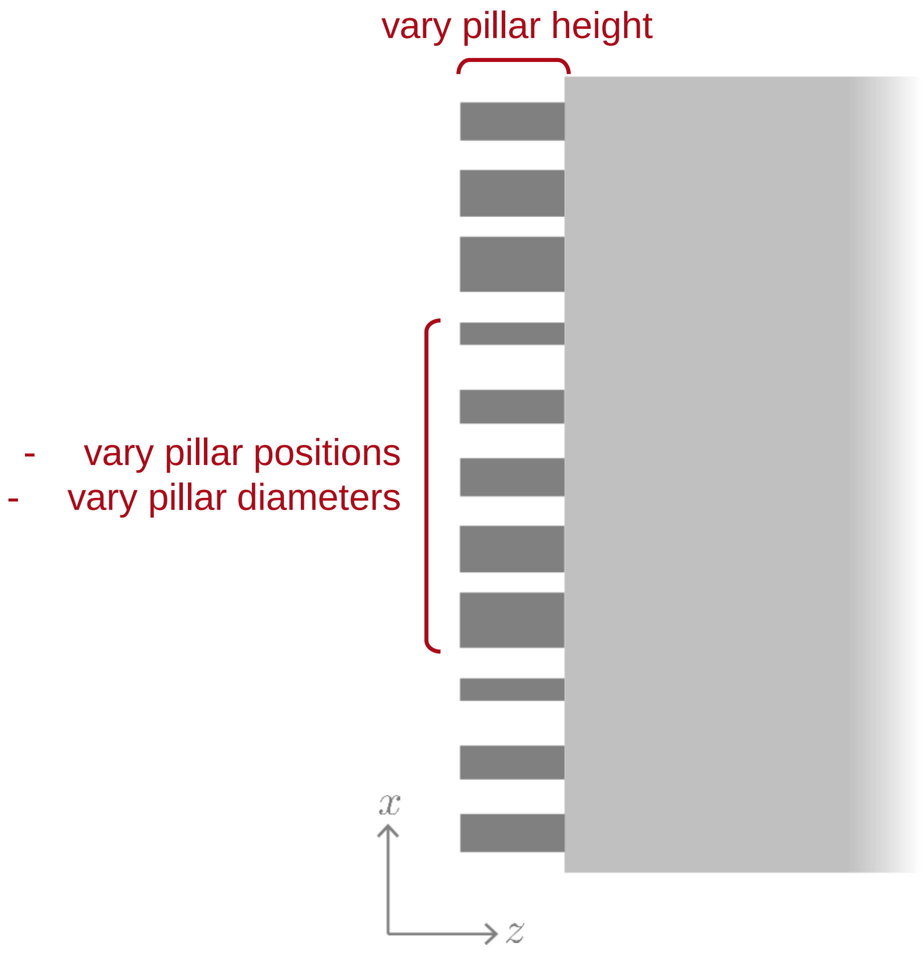
5µm behind interface (evanescent waves damped)



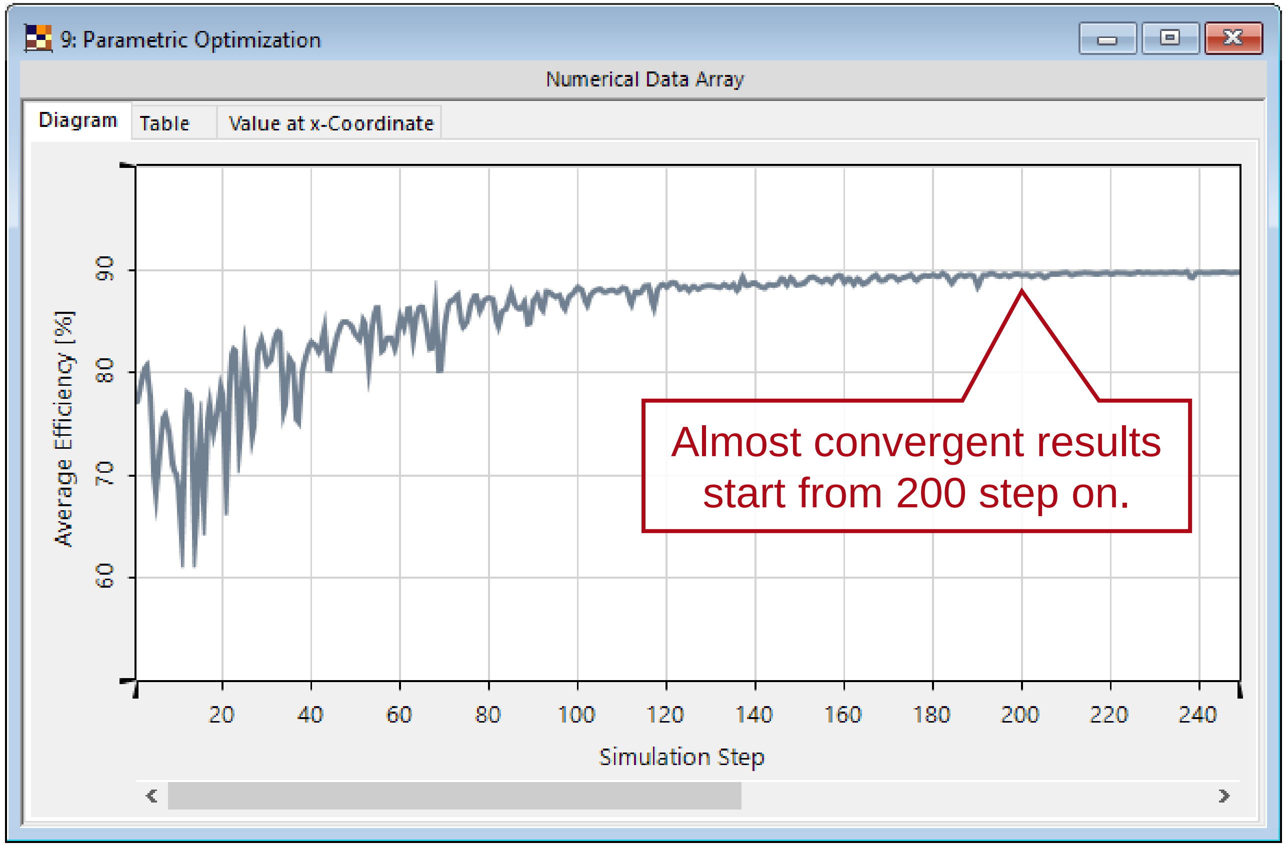
five discrete phase levels from five pillars with different diameters

directly at pillar-substrate interface

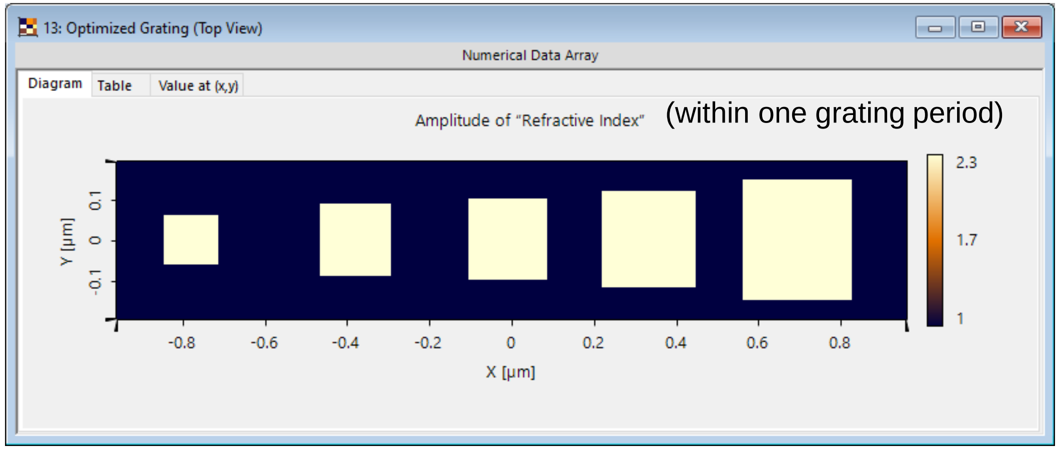
Further Optimization of Metagrating

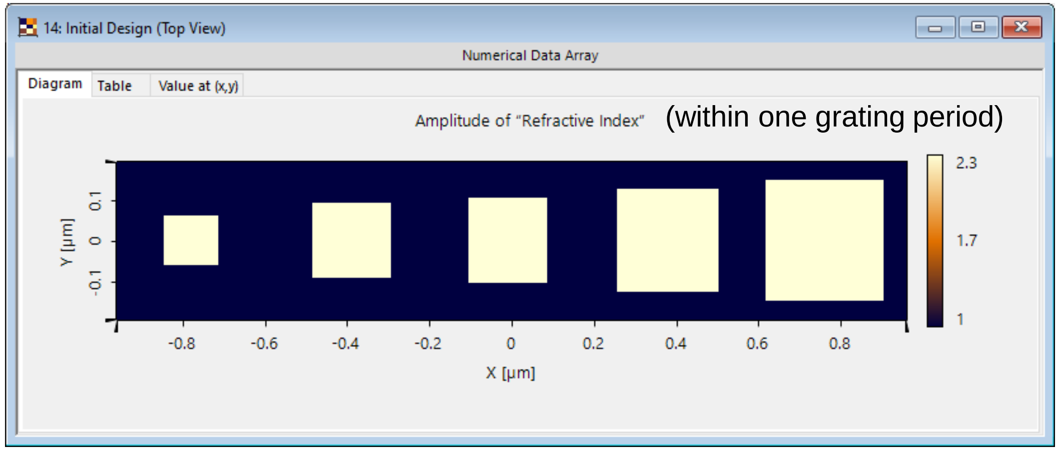


downhill simplex optimization with FMM/RCWA for grating analysis



Performance Analysis of Optimized Design





optimized grating

	Efficiency
y-polarization (TE)	90.0%
x-polarization (TM)	89.6%
average	**89.8%**

After optimization, the resulting grating shows over 10 percentage points increase in the 1st order diffraction efficiency.

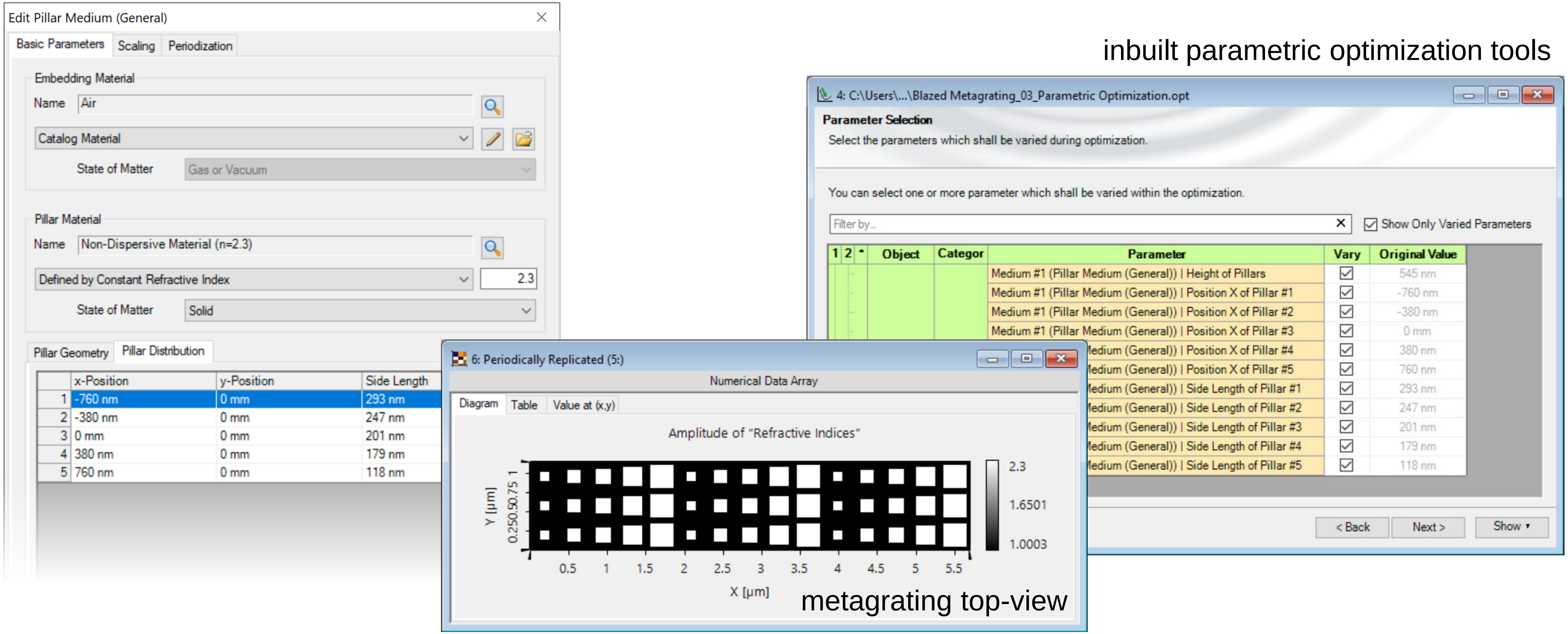
initial grating design

	Efficiency
y-polarization (TE)	80.2%
x-polarization (TM)	74.2%
average	**77.2%**

Peek into VirtualLab Fusion

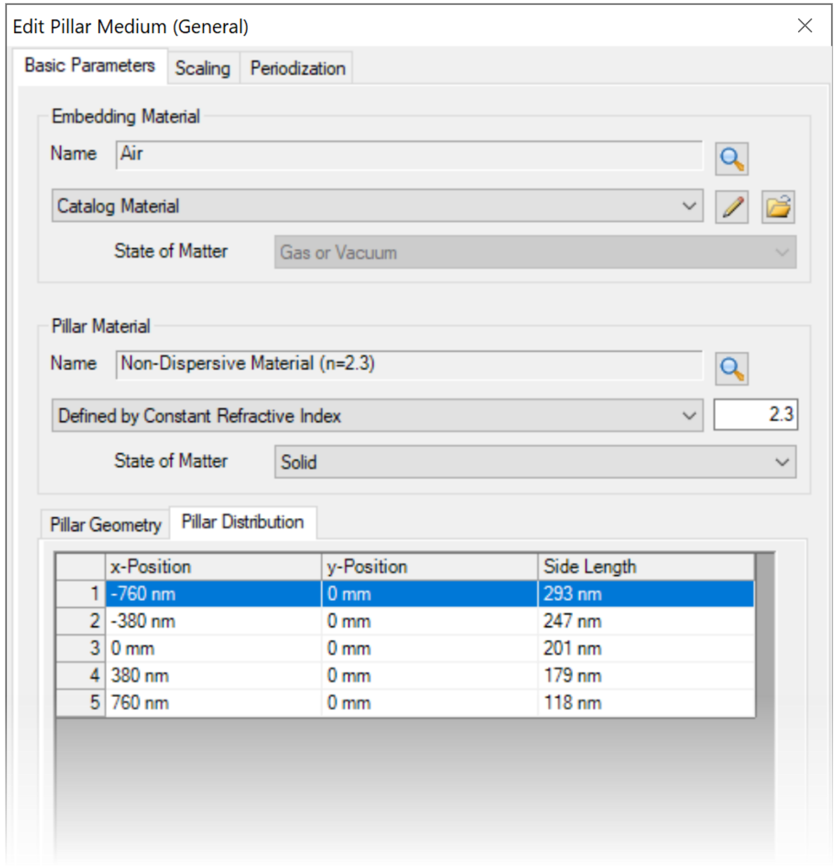
flexible distribution of unit cells / pillars

inbuilt parametric optimization tools

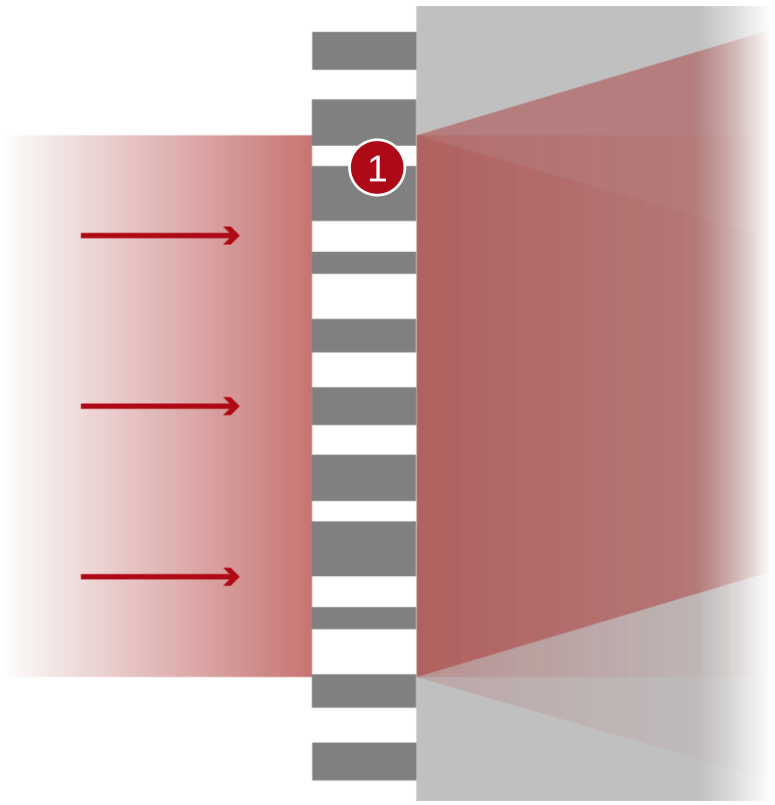


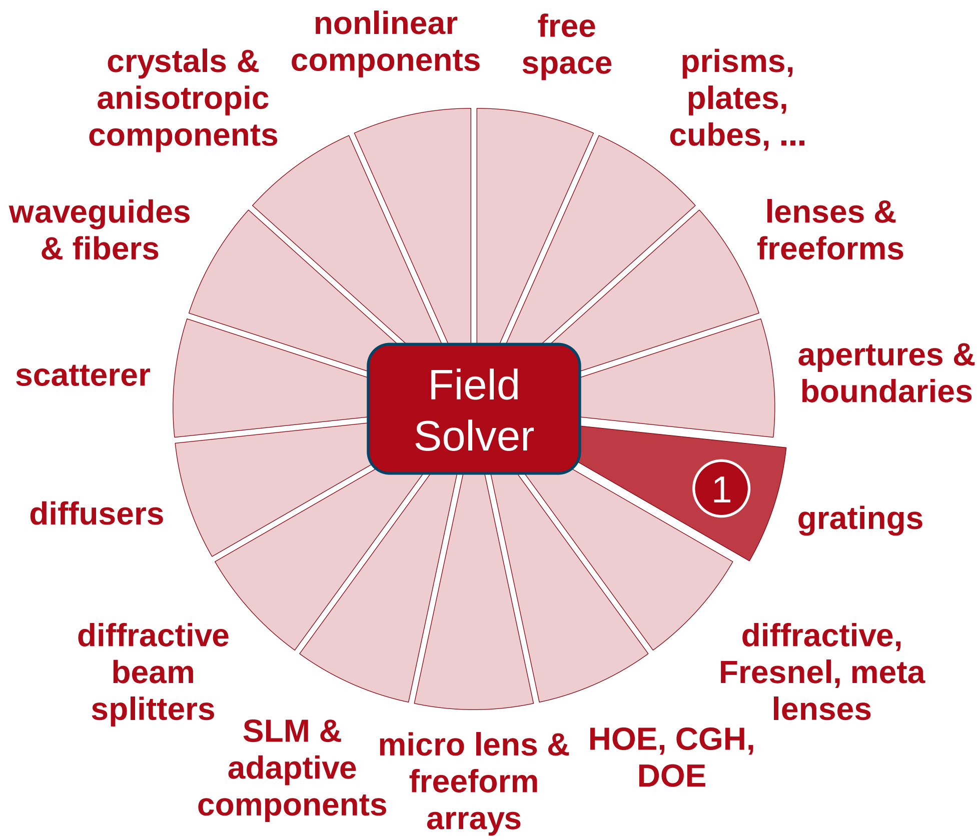
Workflow in VirtualLab Fusion

- Analyze metasurface unit cell
  - Rigorous Analysis of Nanopillar Metasurface Building Block [Use Case]
- Construct metagratings
  - Metagrating Construction - Discussion at Examples [Use Case]
- Analyze grating diffraction efficiency
  - Grating Order Analyzer [Use Case]
- Parametric optimization of grating structure
  - Parametric Optimization [Tutorial Video]



VirtualLab Fusion Technologies





Document Information

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software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	- Rigorous Analysis of Nanopillar Metasurface Building Block - Design of 2D Non-Paraxial Beam-Splitting Metagrating - Analysis and Design of Highly Efficient Polarization Independent Transmission Gratings