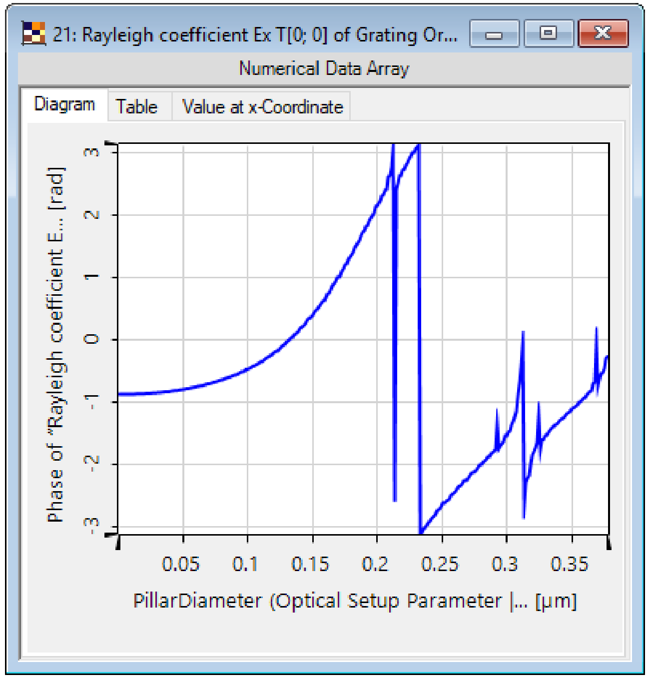
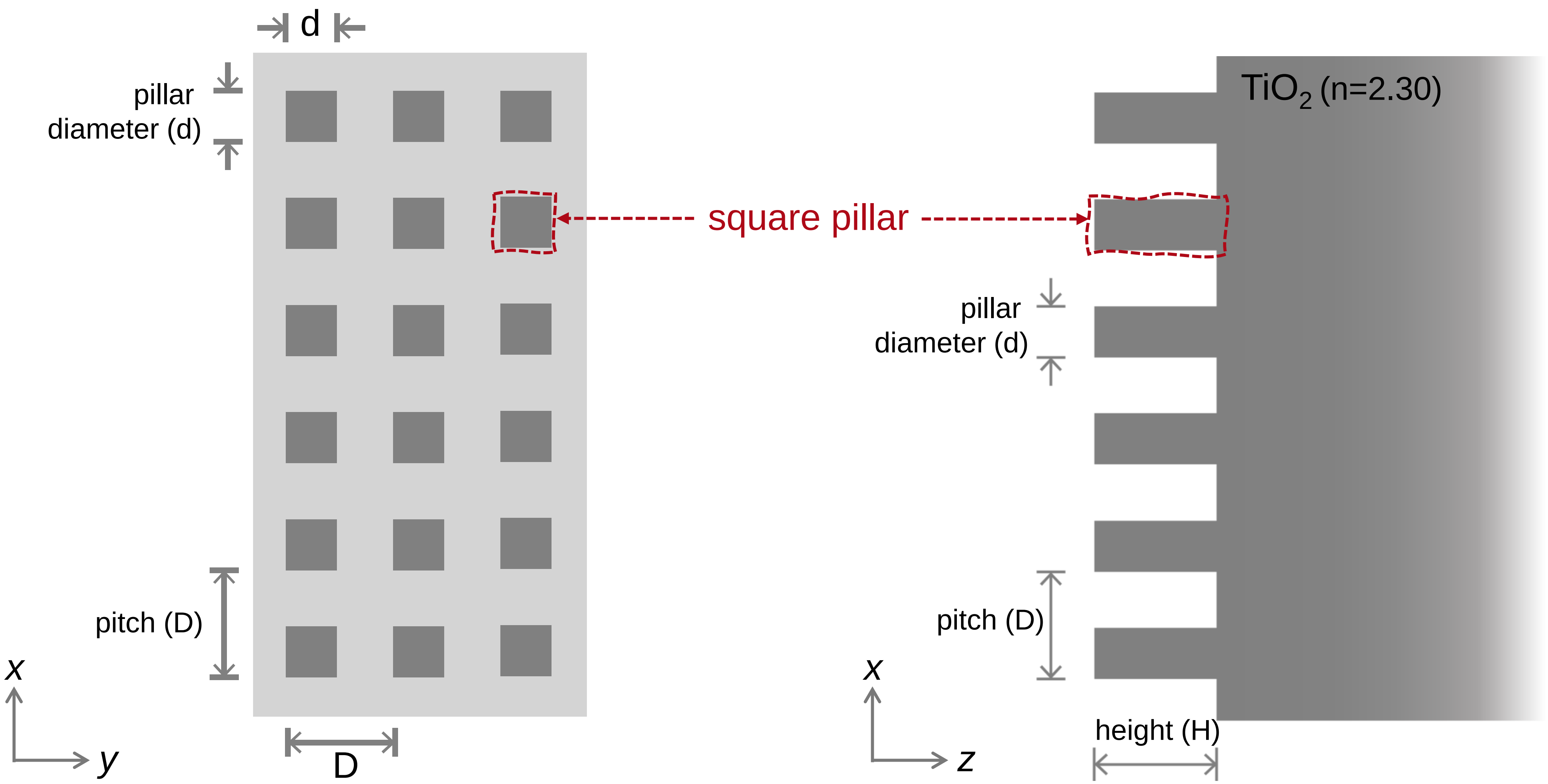
Modeling and Design of Blazed Meta-Gratings

Abstract

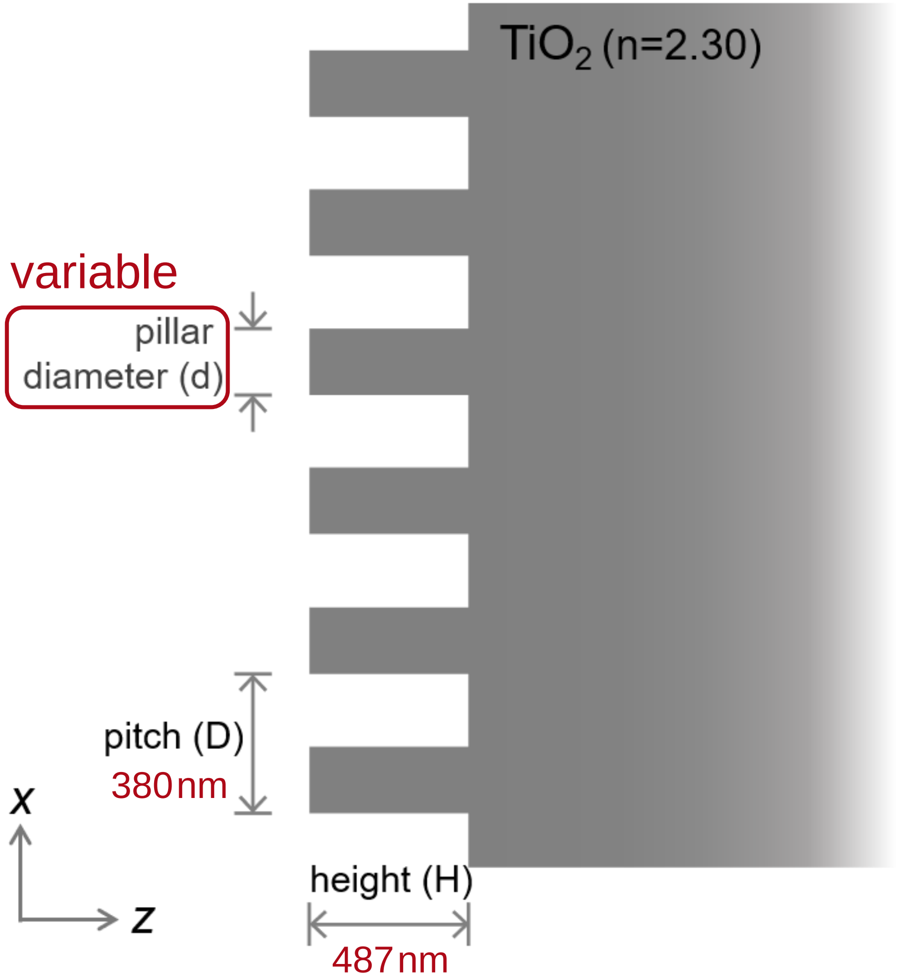


We show how to design a blazed meta-grating that is composed of nanopillars with spatially varying diameters. The (almost) polarization-independent behavior of such a meta-grating is analyzed. And, we also demonstrate further parametric optimization of the meta-gratings after its initial design.

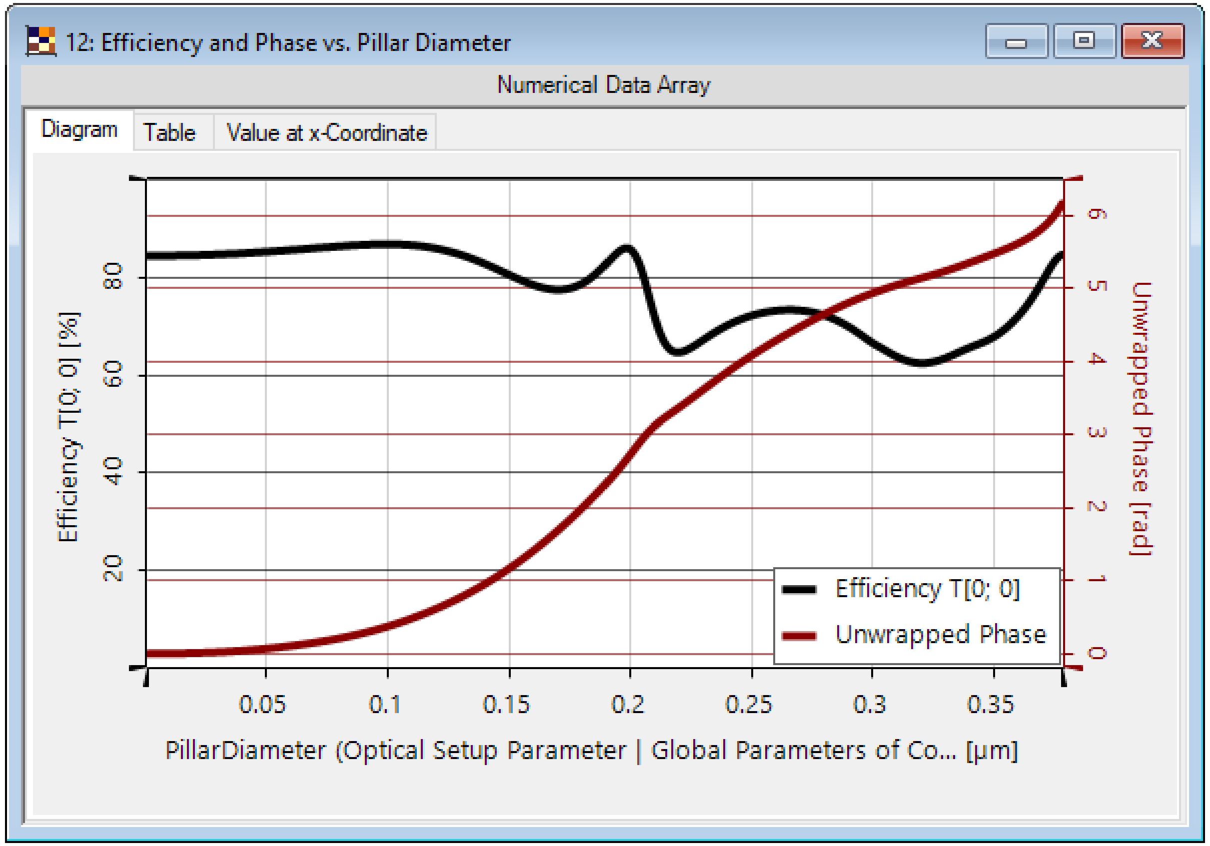
Building Block / Unit Cell Analysis (Index Matched)



Building Block / Unit Cell Analysis (Index Matched)



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



Building Block / Unit Cell Analysis (Index Matched)

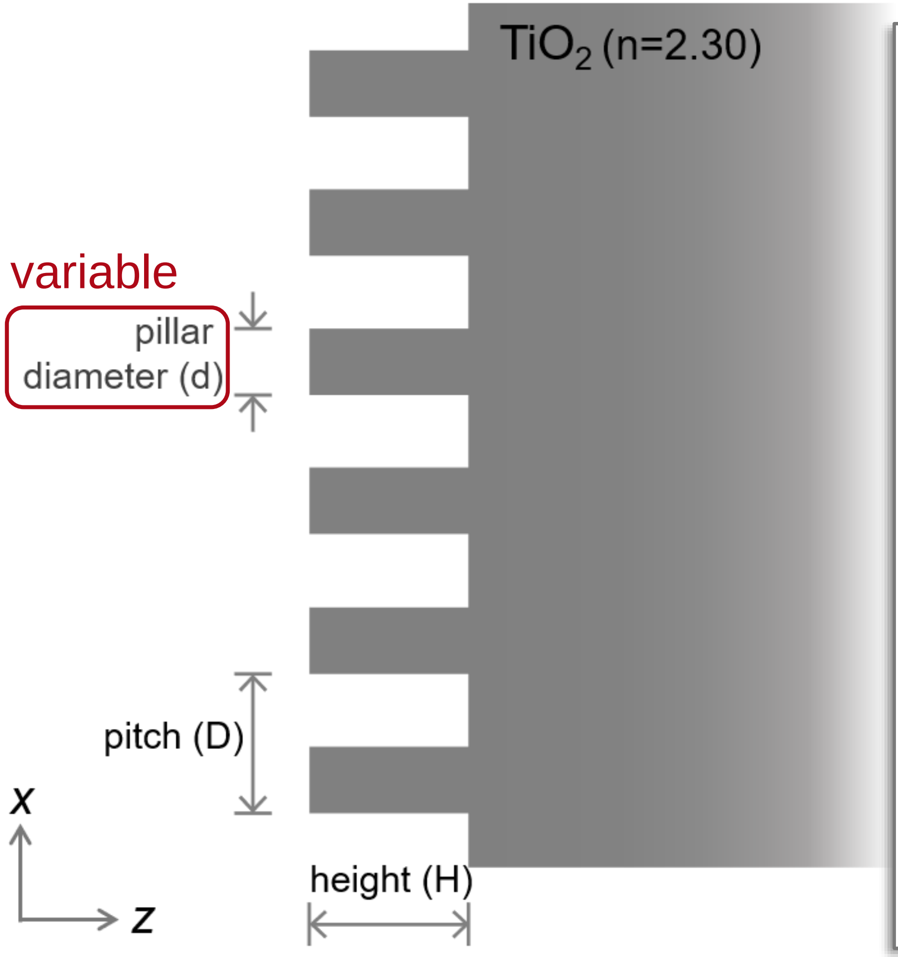


Figure 1 from P. Lalanne, *et al.*,
Opt. Lett. 23, 1081-1083 (1998)

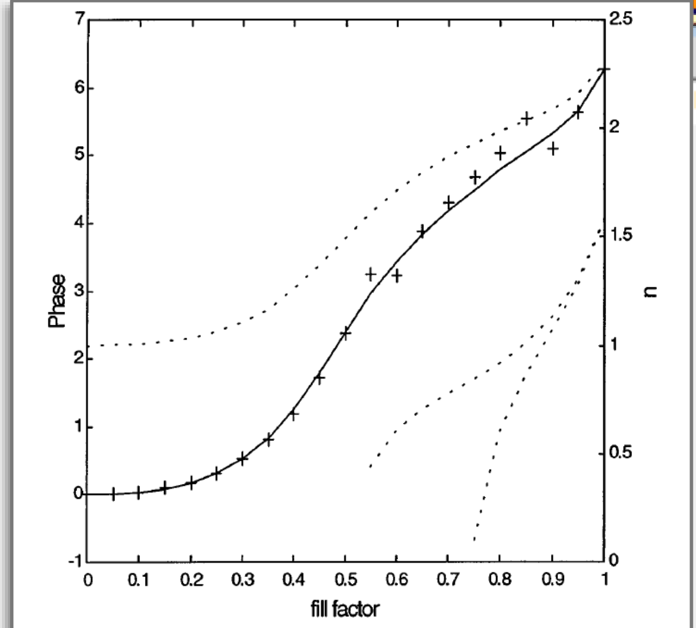
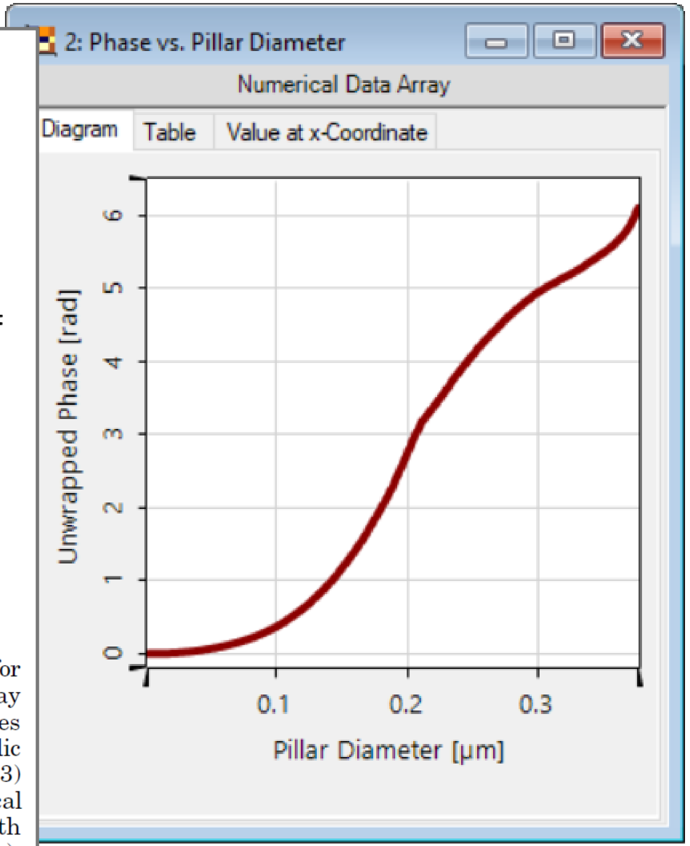
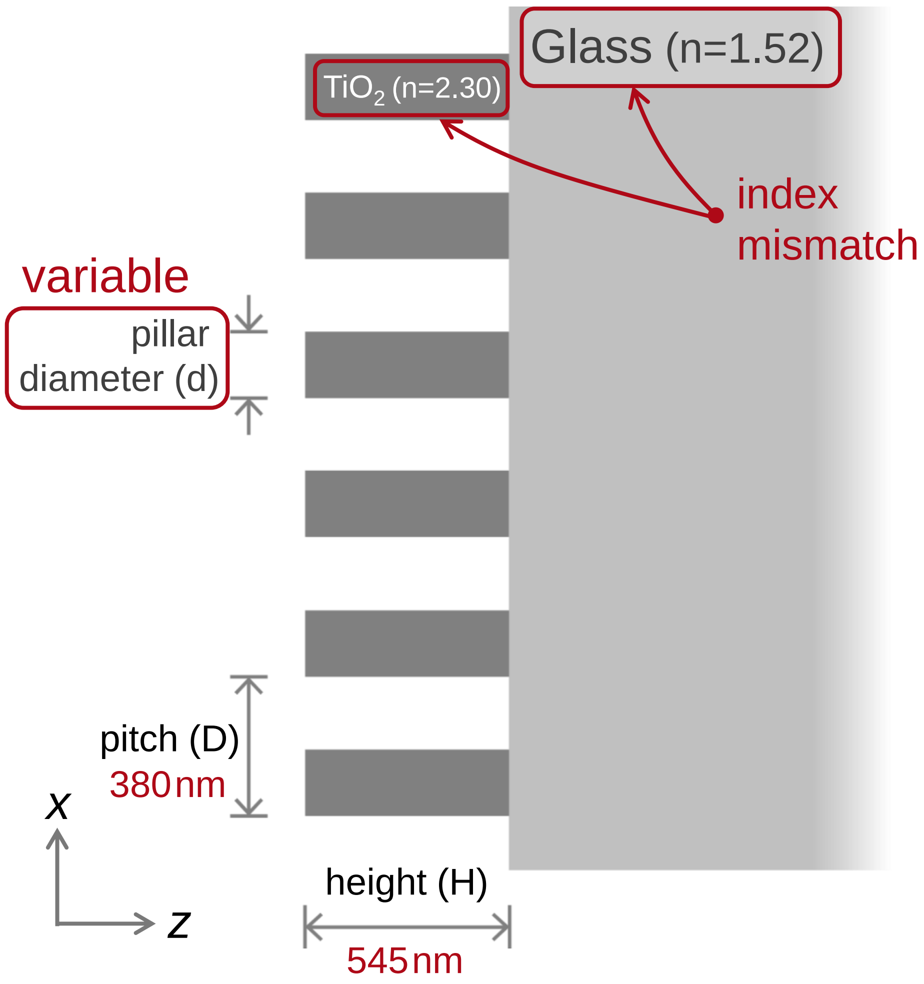


Fig. 1. Crosses, phases of the transmitted zeroth order for a 487-nm-thick grating composed of a 380-nm-period array of square pillars etched in TiO_2. Dotted curves, n values of all the propagating modes supported by the biperiodic structure. The uppermost curve (n varies from 1 to 2.3) corresponds 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.

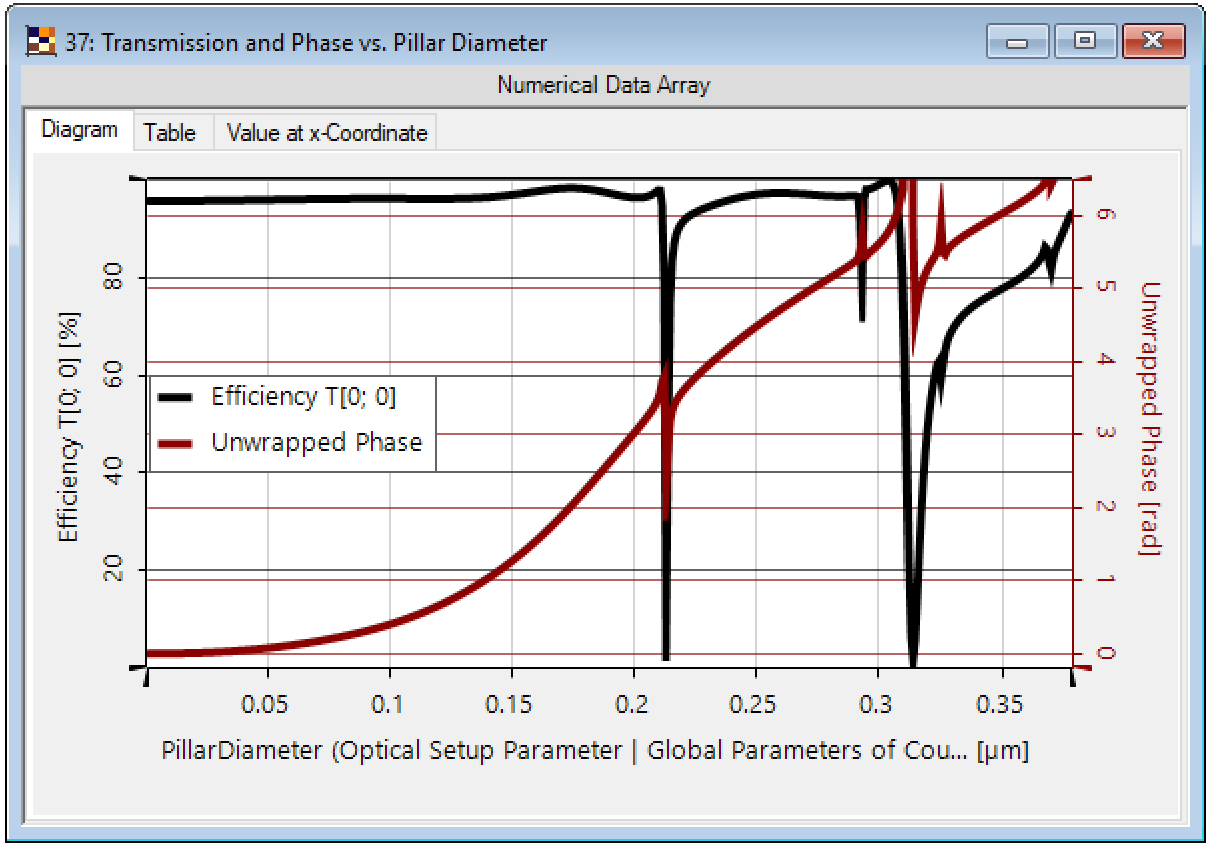


VirtualLab Fusion simulation

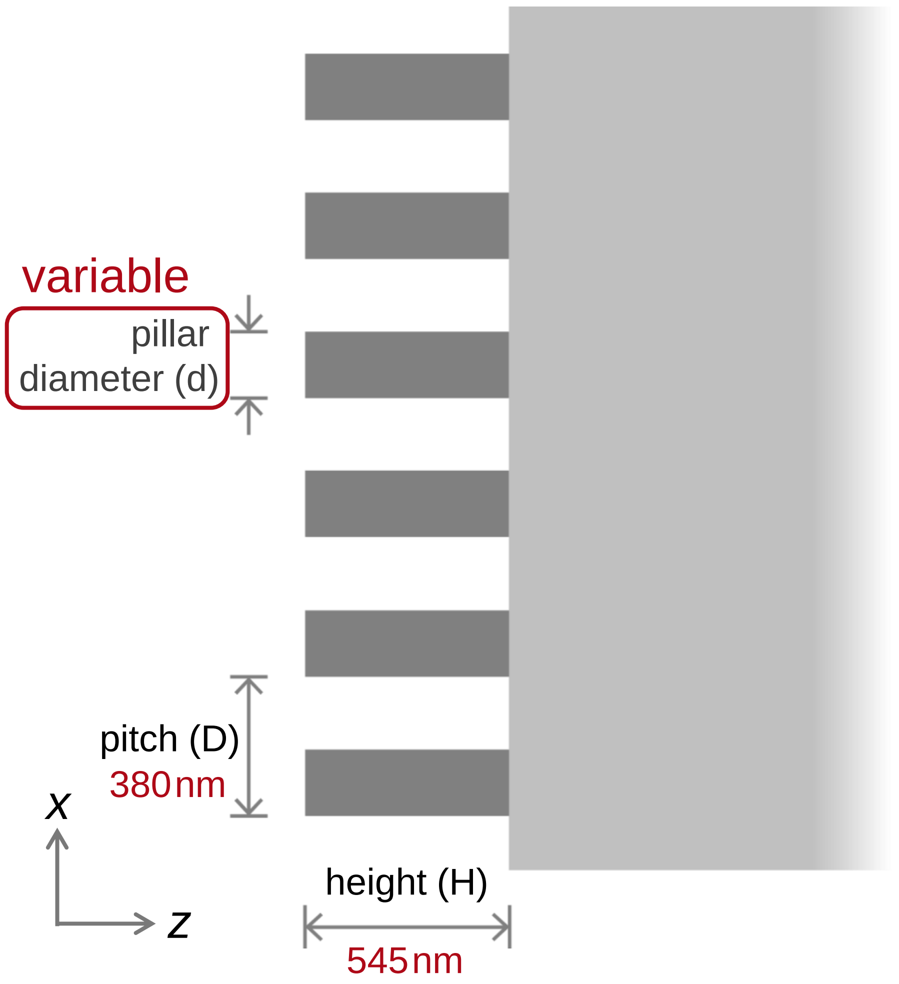
Building Block / Unit Cell Analysis (Glass Substrate)

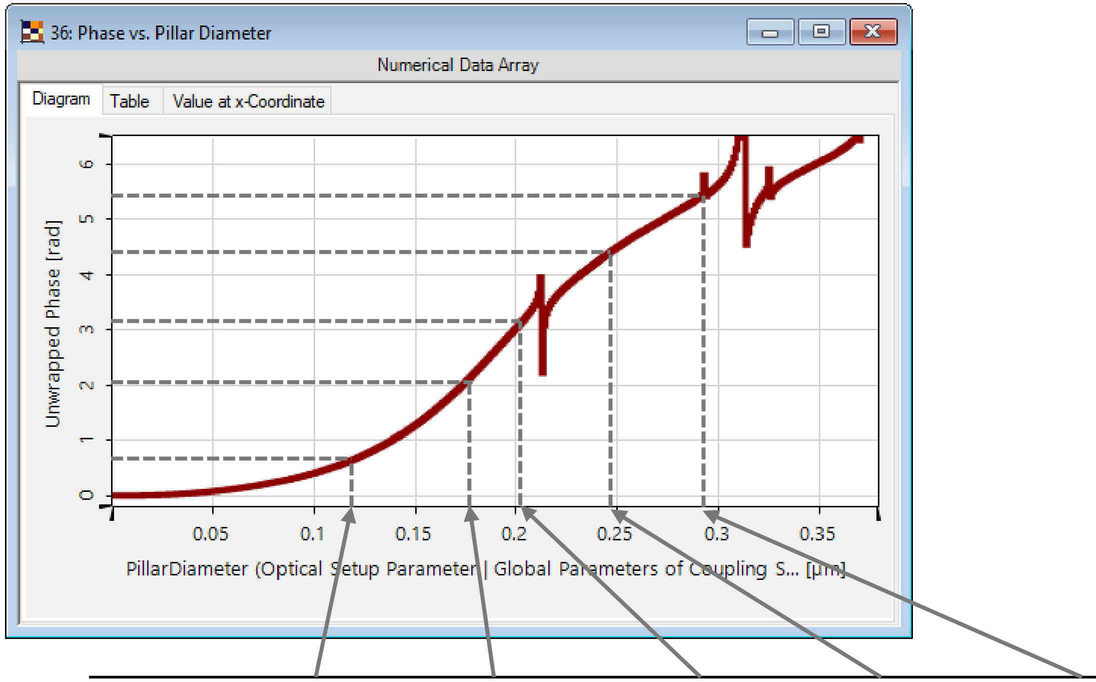


transmission amplitude/phase vs. pillar diameter (@633nm)



Selection of Unit Cells ➔ Linear Phase

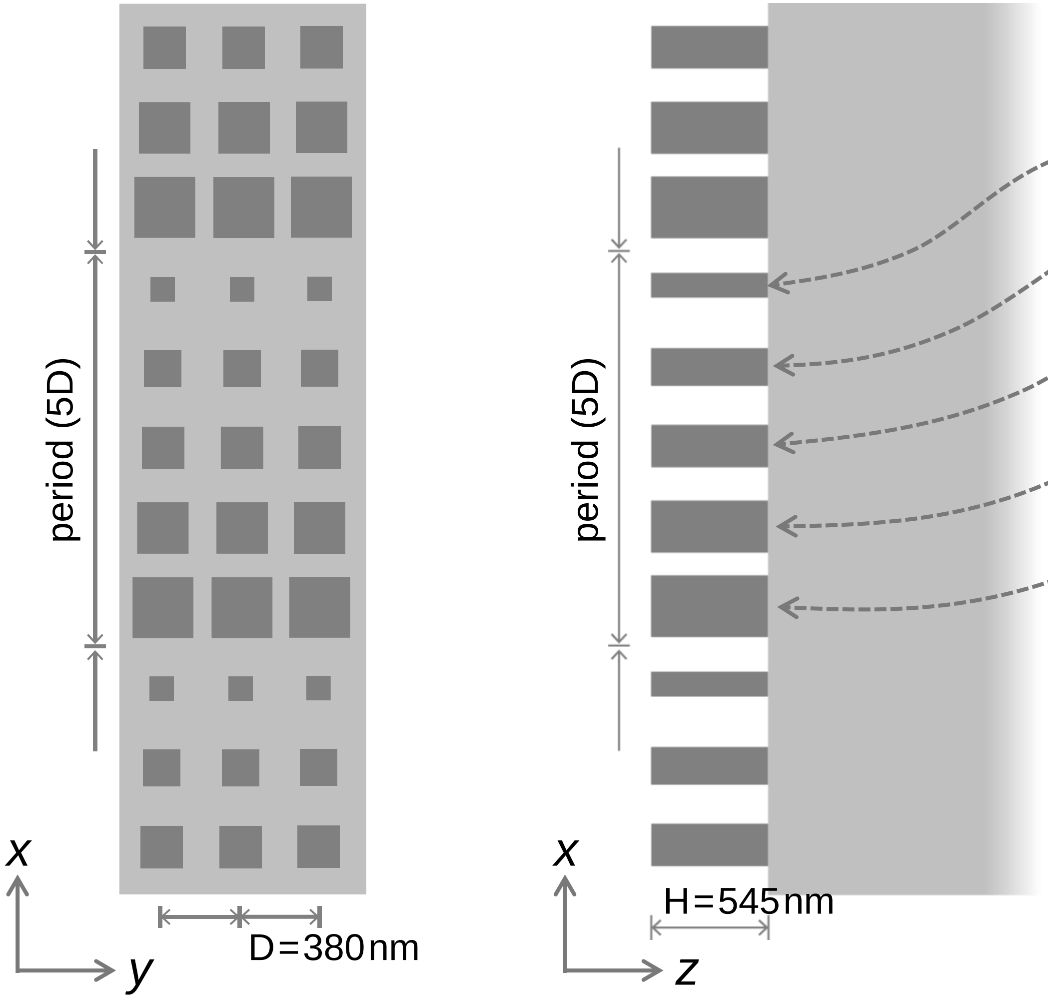




	#1	#2	#3	#4	#5
d	118nm	179nm	201nm	247nm	293nm
f=d/D	0.31	0.47	0.53	0.65	0.77
$\Delta\psi$	0.20π	0.69π	0.98π	1.40π	1.73π

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

Initial Composition of the Blazed Grating



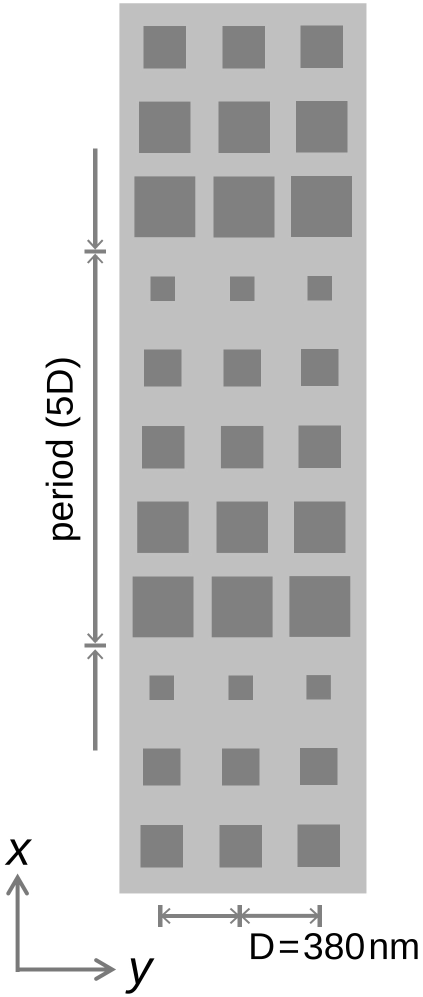
	#1	#2	#3	#4	#5
d	118nm	179nm	201nm	247nm	293nm
f=d/D	0.31	0.47	0.53	0.65	0.77
$\Delta\psi$	0.20π	0.69π	0.98π	1.40π	1.73π

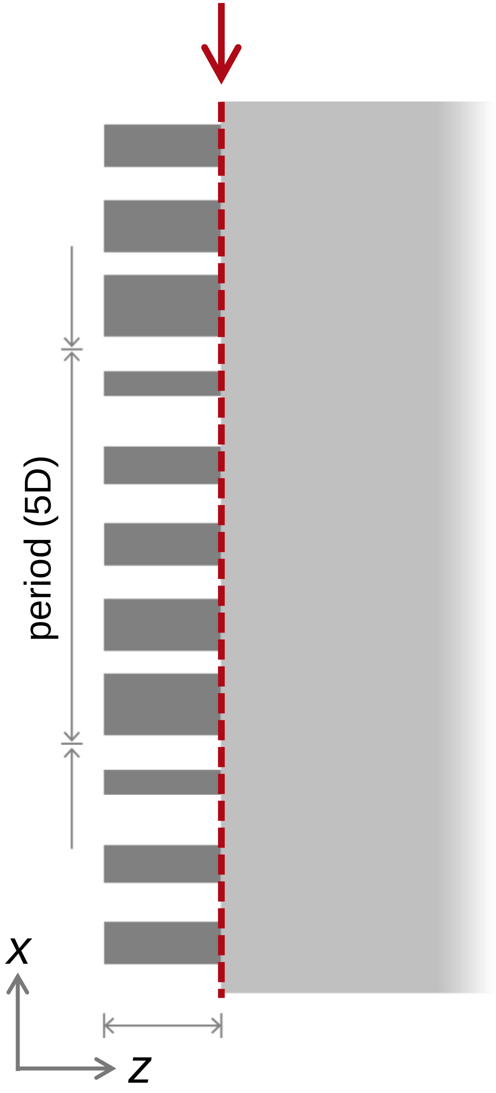
grating performance evaluation

	Efficiency
TE-polarization	79.6%
TM-polarization	74.5%
Average	**77.1%**

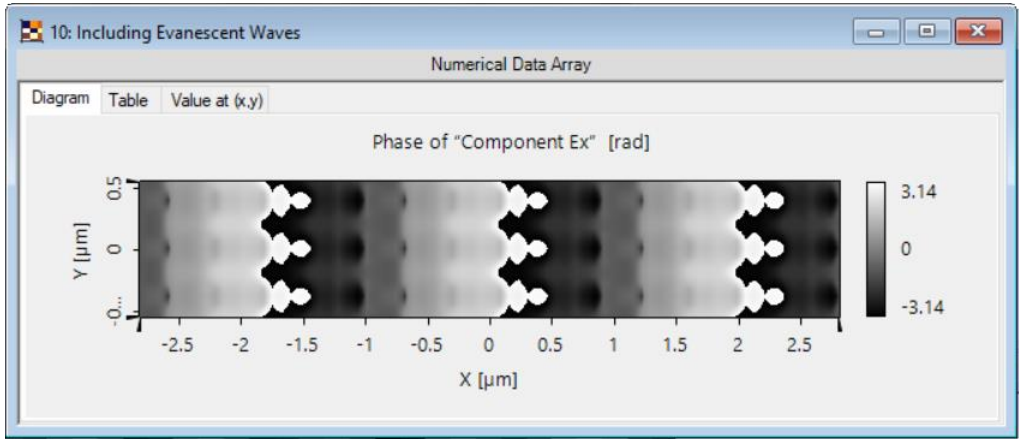
Same average efficiency value reported in
P. Lalanne, *et al.*, Opt. Lett. 23, 1081-1083 (1998)

Phase Distribution behind Blazed Meta-Grating

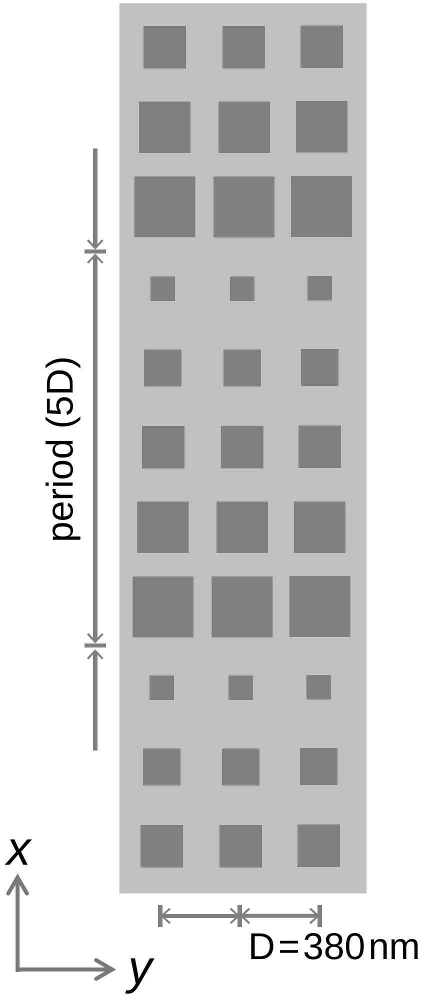


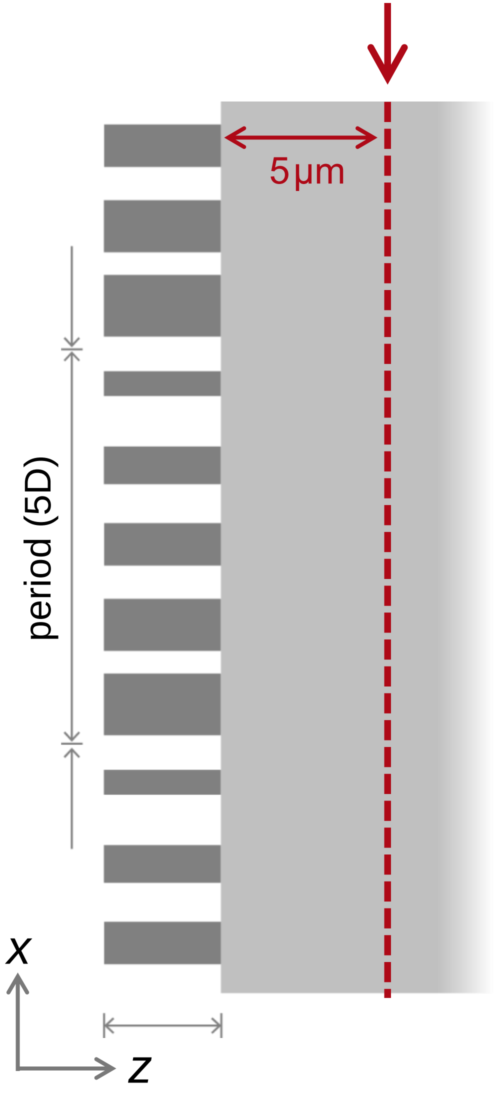


directly behind the grating



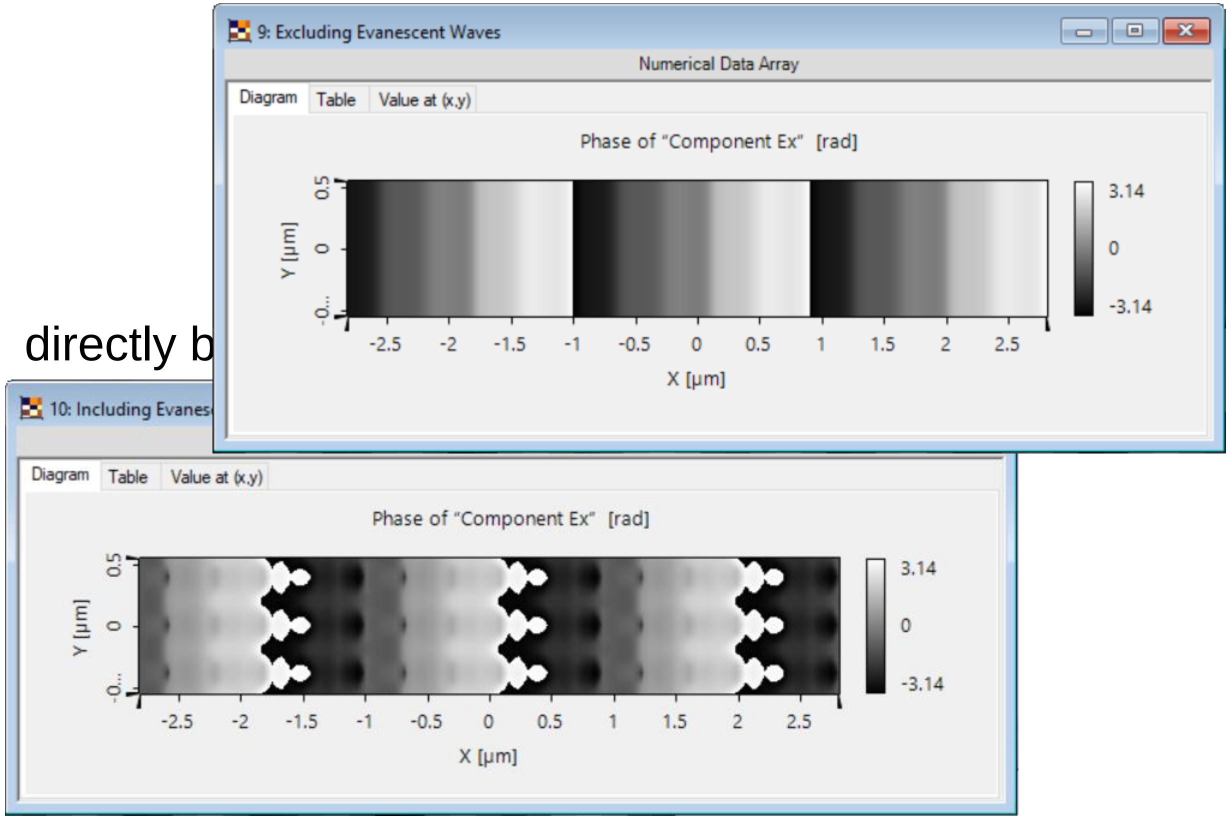
Phase Distribution behind Blazed Meta-Grating



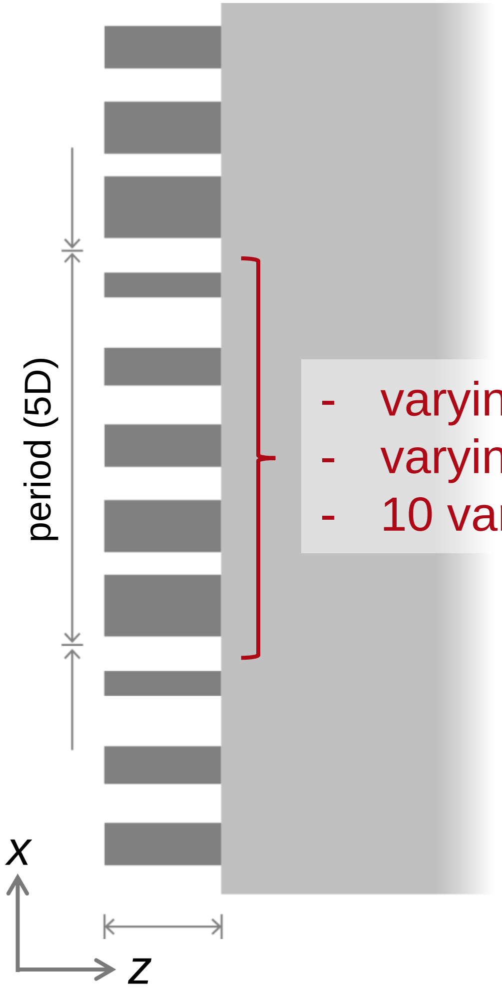


5µm behind the grating (evanescent waves damped)

directly b

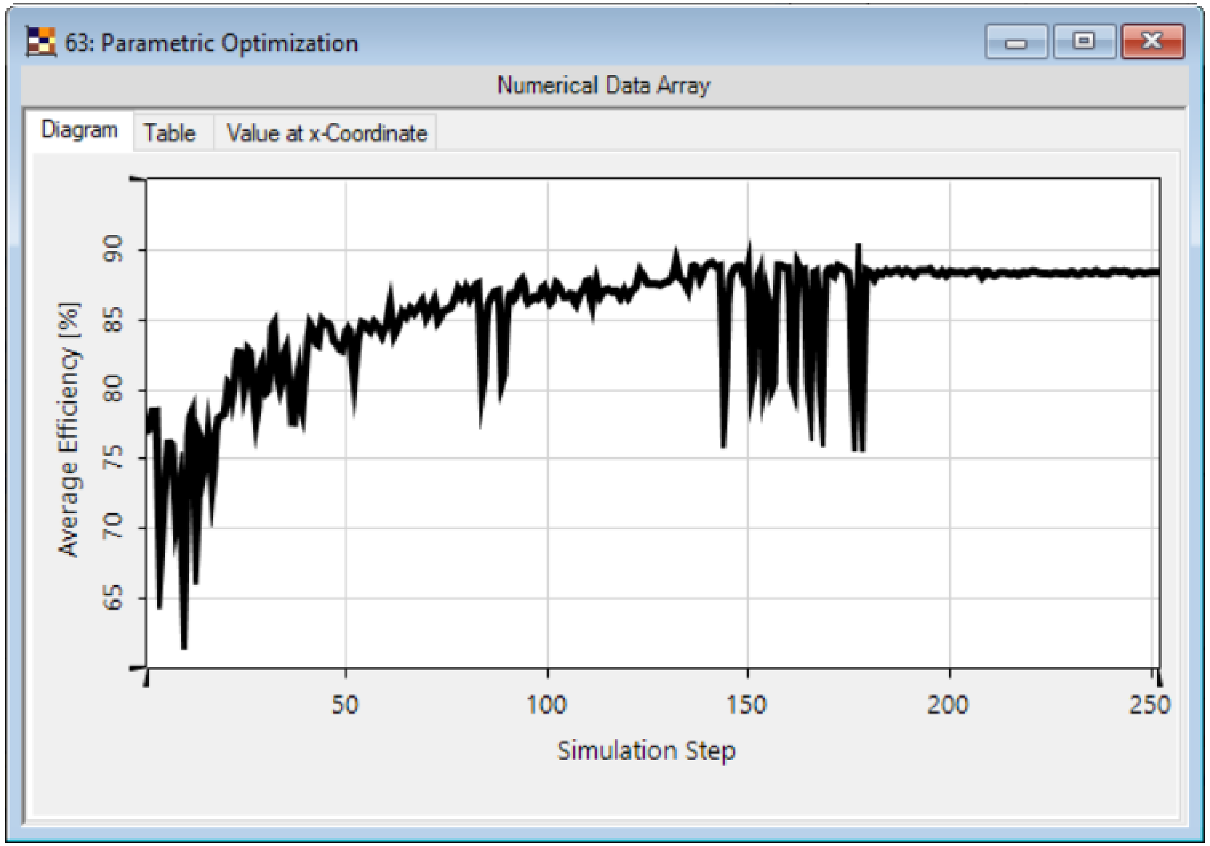


Further Optimization of Grating Structure

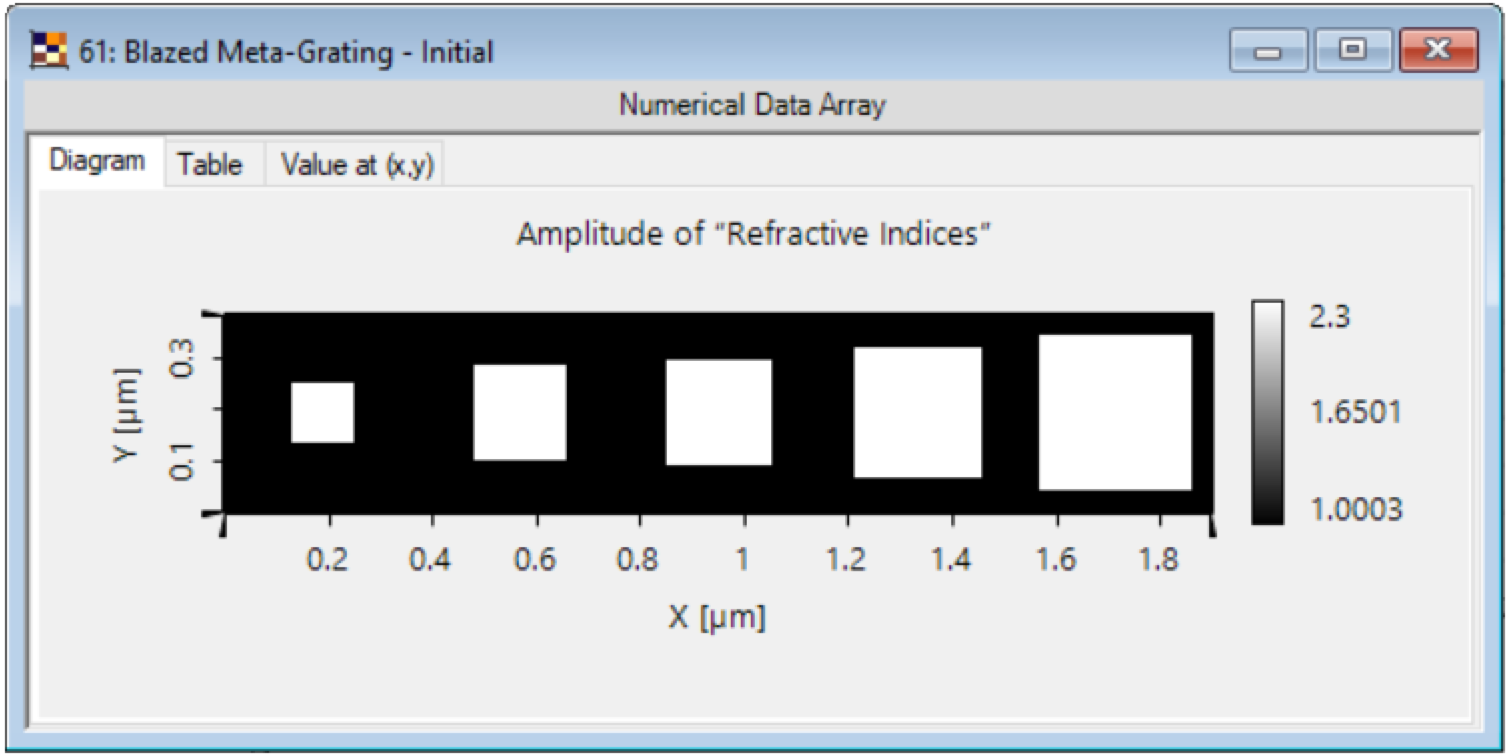


- varying pillar positions
- varying pillar diameters
- 10 variables in total

downhill simplex optimization with FMM/RCWA for grating analysis



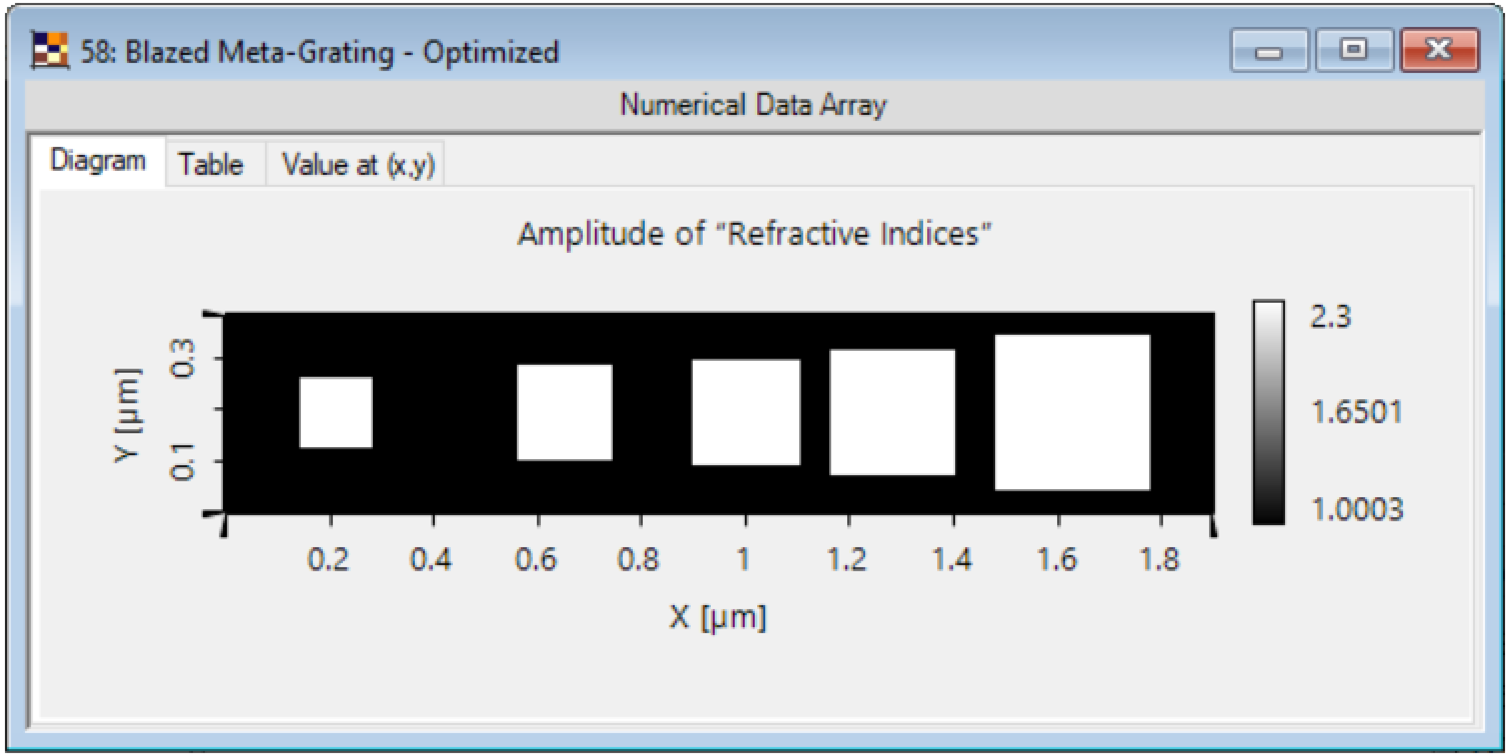
Blazed Meta-Grating Design – Initial Structure



grating performance evaluation

	Efficiency
TE-polarization	79.6%
TM-polarization	74.5%
Average	**77.1%**

Blazed Meta-Grating Design – After Optimization

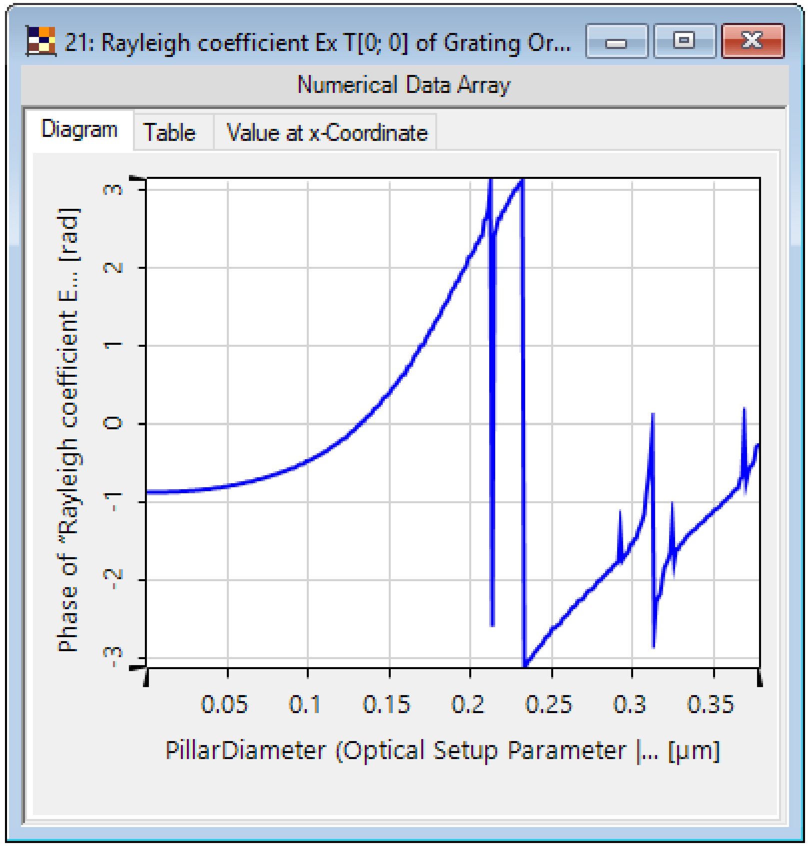


grating performance evaluation

	Efficiency
TE-polarization	88.7%
TM-polarization	88.2%
Average	**88.5%**

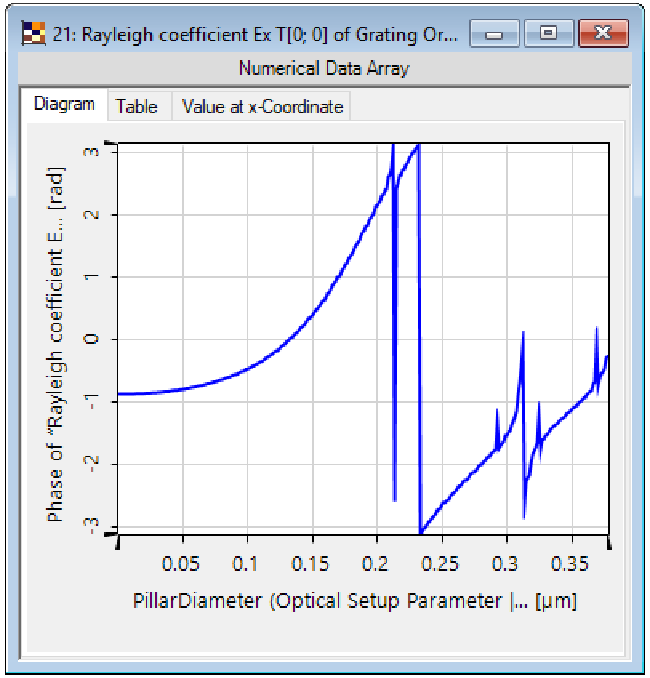
Brief Instruction on Workflows in VirtualLab Fusion

Step 1: Unit Cell Analysis

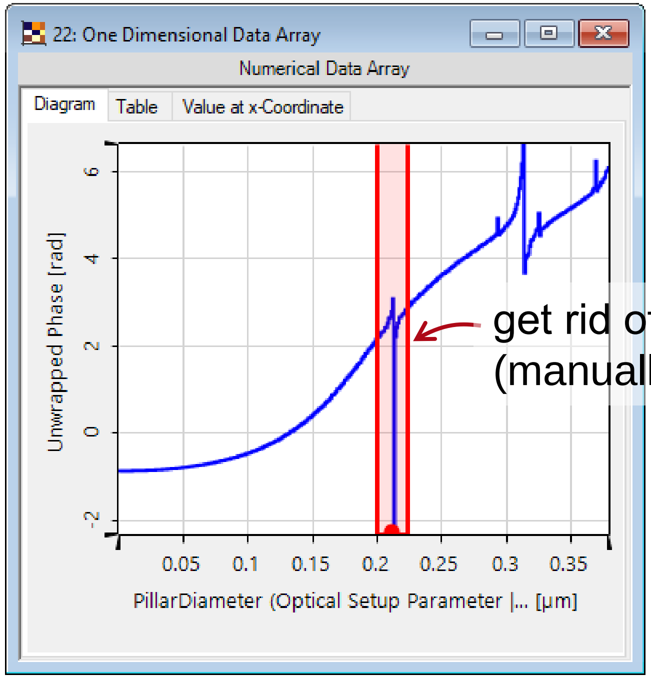


- Vary the pillar diameter and obtain the phase-diameter characteristic curve.
- Note that the phase value is wrapped within [-pi, +pi], and it may contain certain dips.
- In the next steps, we will first regularize the phase-diameter relation, and then define its inverse, which will be used to define the meta-grating structure later.

Step 2: Regularize Phase-Diameter Curve



unwrap phase

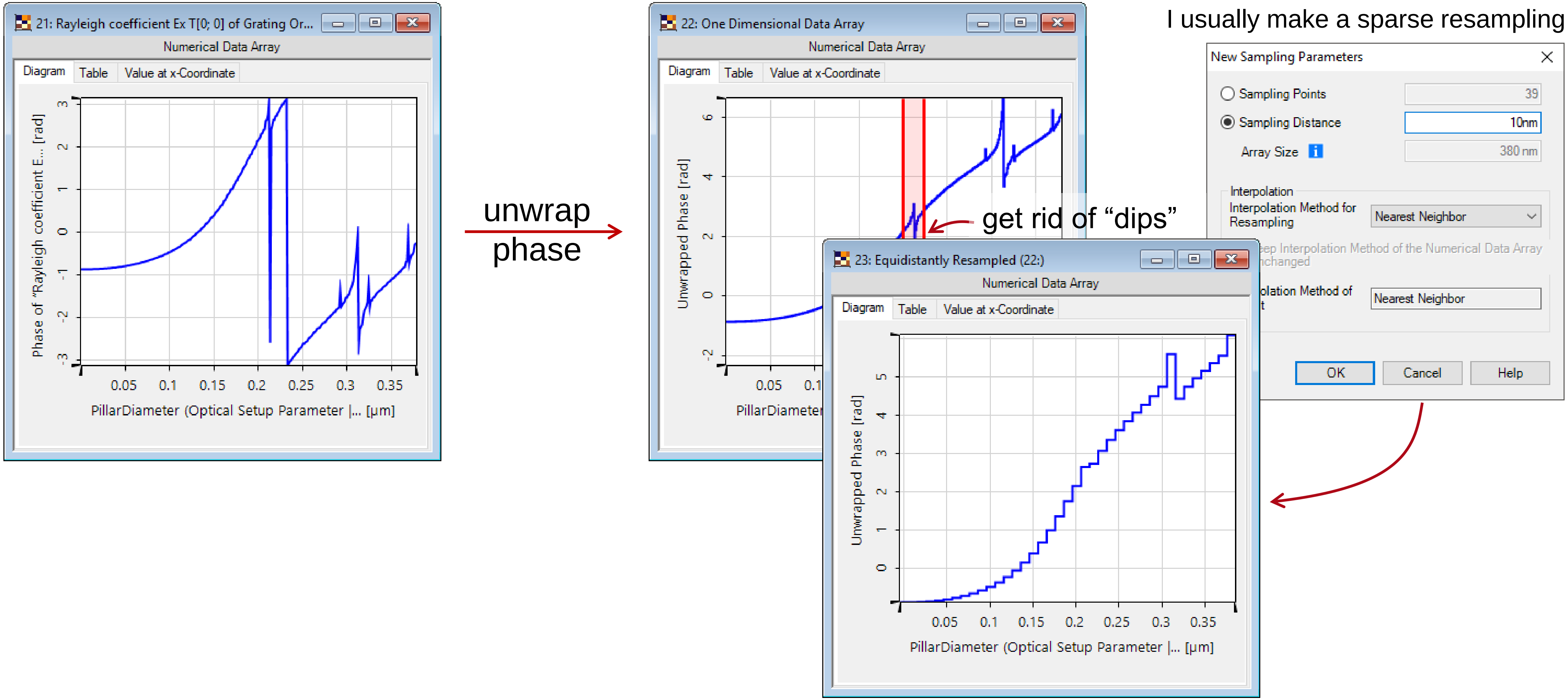


get rid of "dips" (manually)

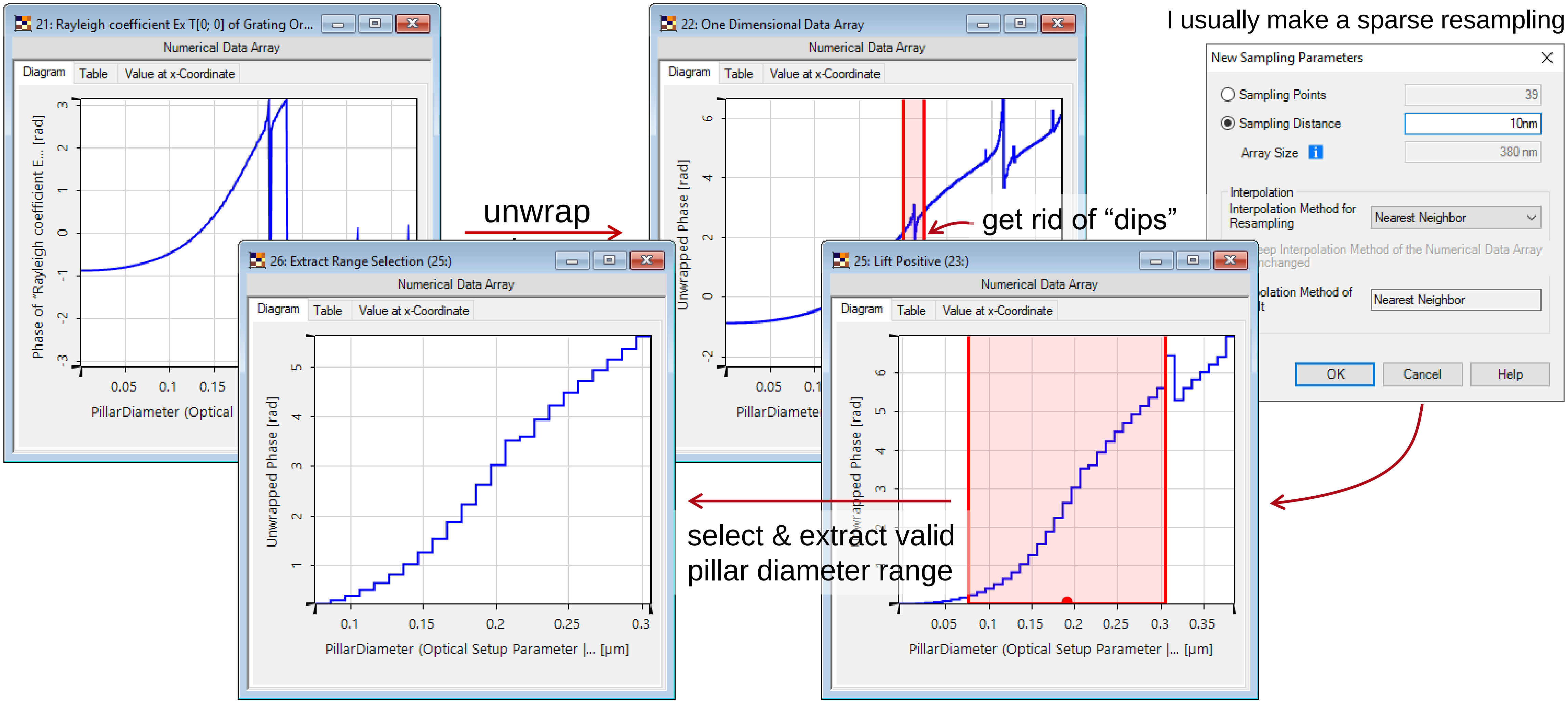
You may skip this step if your unit cell is properly chosen without any „dips".

VirtualLab Module: Step_02_Extract and Unwrap 1D Phase Function.cs

Step 2: Regularize Phase-Diameter Curve

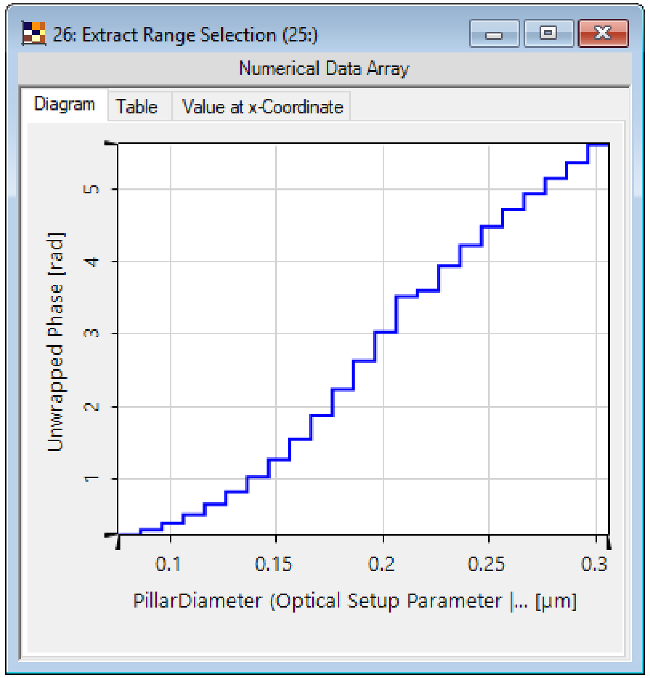


Step 2: Regularize Phase-Diameter Curve



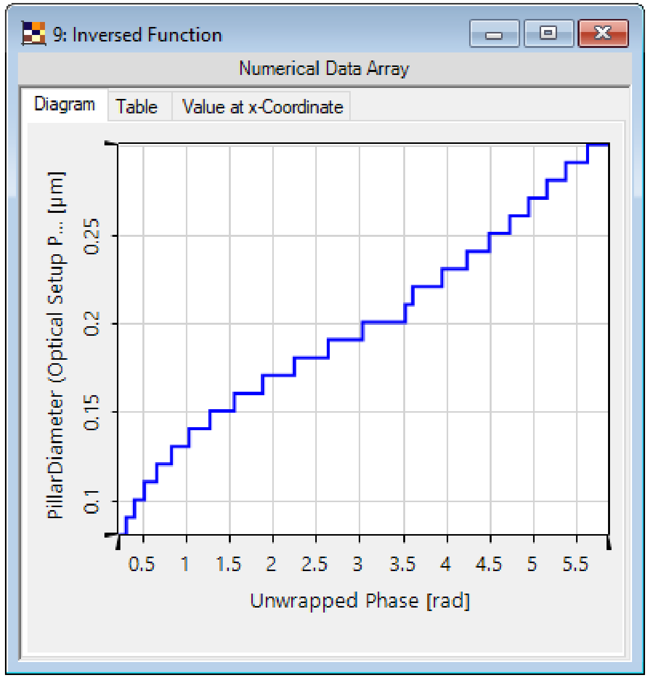
Step 3: Define Diameter – Phase Mapping Relation

The result from last step is the phase-diameter relation, as shown below.



inverse

By inversing, we get the diameter-phase relation, which will be used later.

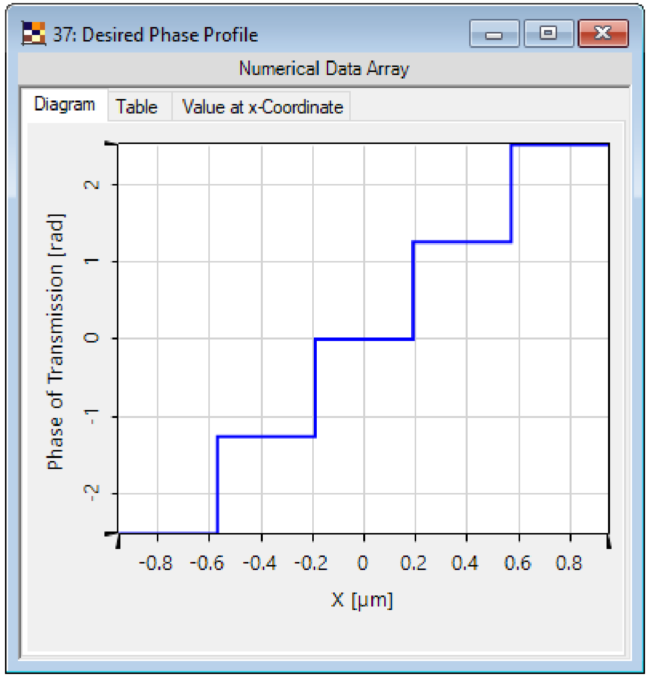


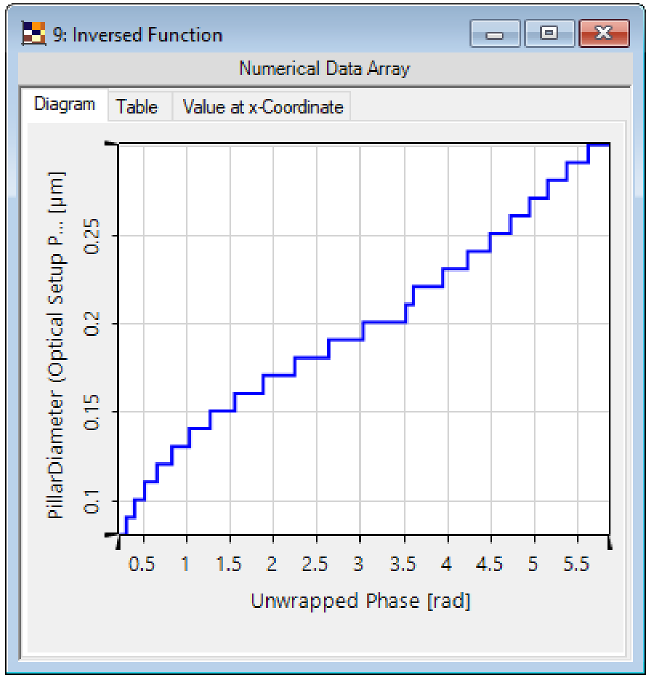
VirtualLab Module: Step_03_Calculate Inverse of 1D Function.cs

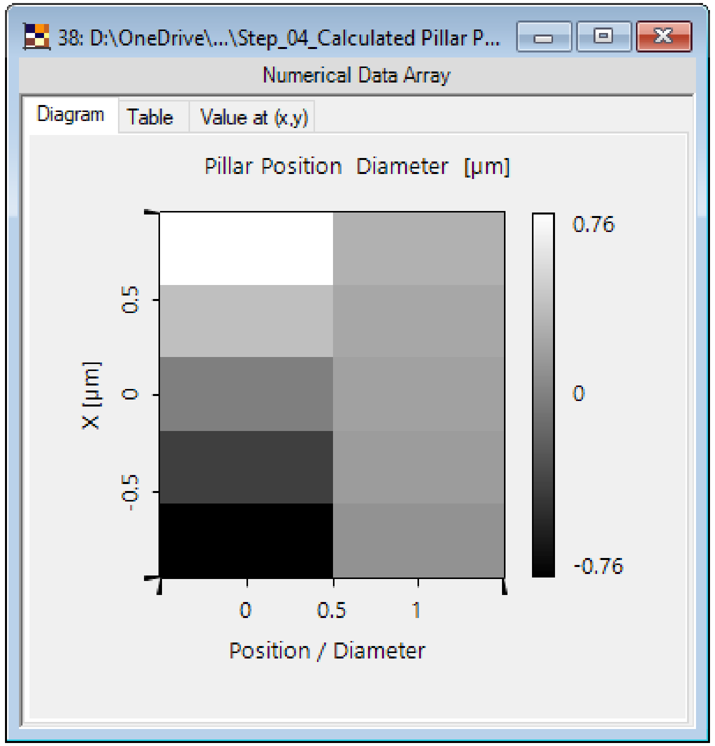
Step 4: From Phase Profile to Structure

diameter-phase relation from last step

desired linear phase profile



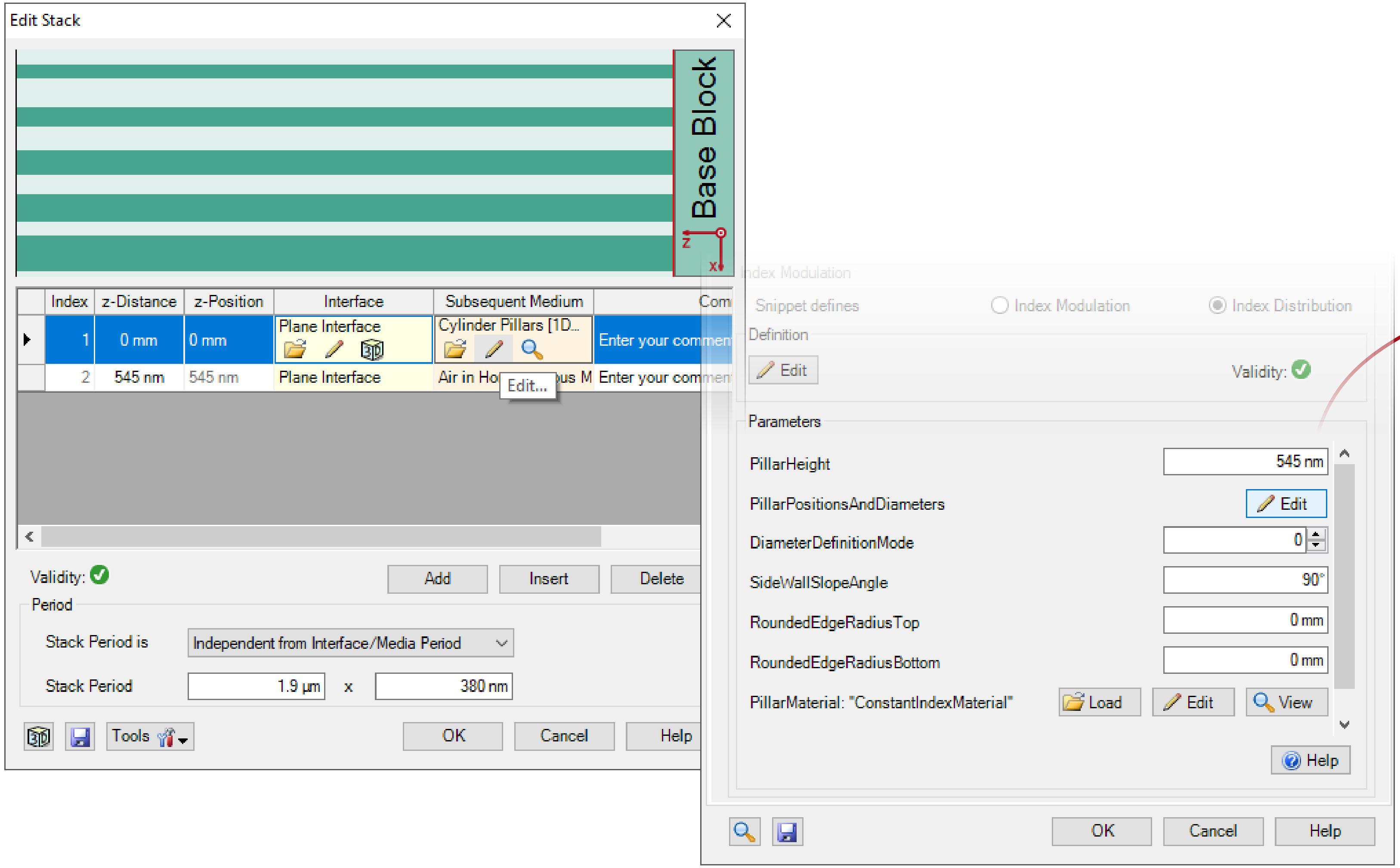




generate meta-grating structure

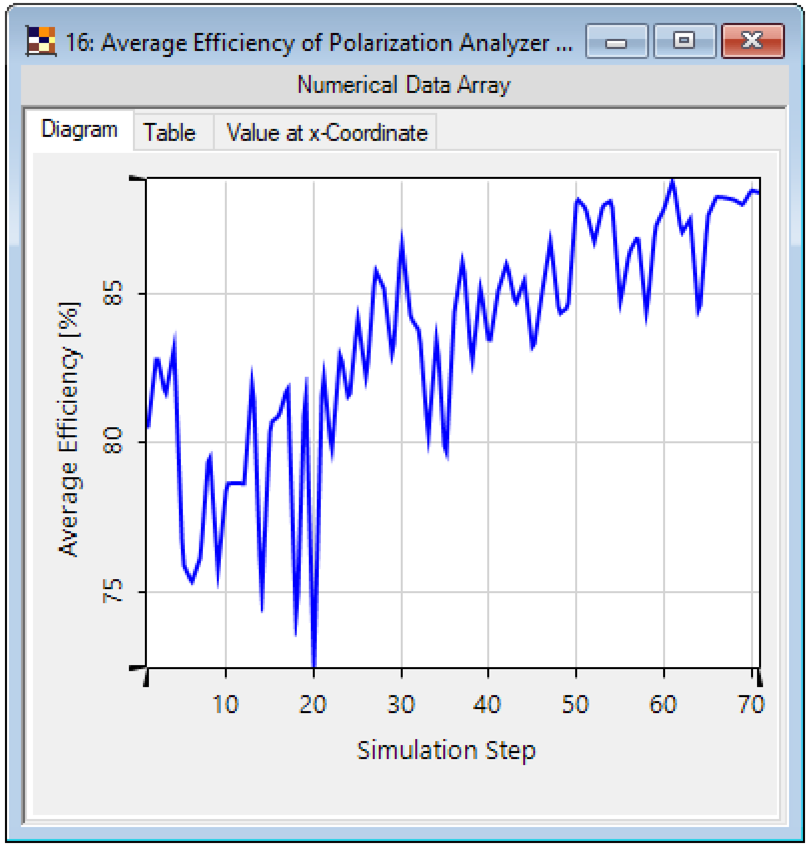
Step_04_Calculate Pillar Diameters from Phase Profile_1D Unstructured Array.cs

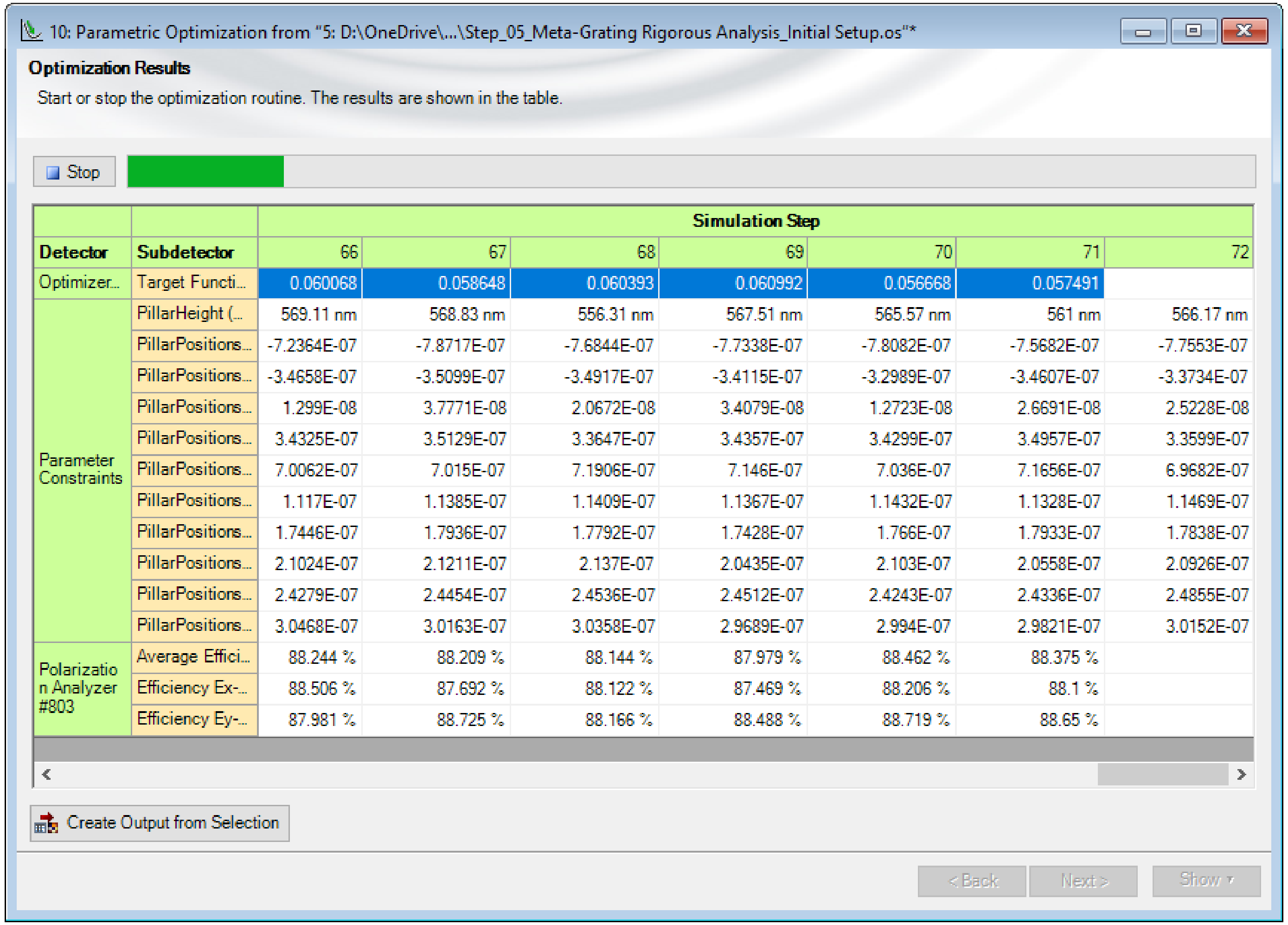
Step 5: Load Meta-Grating Structre in FMM Simulation



Load the pillar position and diameter information here

Step 6: Optimize Pillar Postion and Diameter





Detector	Subdetector	Simulation Step 66	67	68	69	70	71	72
Optimizer...	Target Functi...	0.060068	0.058648	0.060393	0.060992	0.056668	0.057491	
Parameter Constraints	PillarHeight (...	569.11 nm	568.83 nm	556.31 nm	567.51 nm	565.57 nm	561 nm	566.17 nm
	PillarPositions...	-7.2364E-07	-7.8717E-07	-7.6844E-07	-7.7338E-07	-7.8082E-07	-7.5682E-07	-7.7553E-07
	PillarPositions...	-3.4658E-07	-3.5099E-07	-3.4917E-07	-3.4115E-07	-3.2989E-07	-3.4607E-07	-3.3734E-07
	PillarPositions...	1.299E-08	3.7771E-08	2.0672E-08	3.4079E-08	1.2723E-08	2.6691E-08	2.5228E-08
	PillarPositions...	3.4325E-07	3.5129E-07	3.3647E-07	3.4357E-07	3.4299E-07	3.4957E-07	3.3599E-07
	PillarPositions...	7.0062E-07	7.015E-07	7.1906E-07	7.146E-07	7.036E-07	7.1656E-07	6.9682E-07
	PillarPositions...	1.117E-07	1.1385E-07	1.1409E-07	1.1367E-07	1.1432E-07	1.1328E-07	1.1469E-07
	PillarPositions...	1.7446E-07	1.7936E-07	1.7792E-07	1.7428E-07	1.766E-07	1.7933E-07	1.7838E-07
	PillarPositions...	2.1024E-07	2.1211E-07	2.137E-07	2.0435E-07	2.103E-07	2.0558E-07	2.0926E-07
	PillarPositions...	2.4279E-07	2.4454E-07	2.4536E-07	2.4512E-07	2.4243E-07	2.4336E-07	2.4855E-07
	PillarPositions...	3.0468E-07	3.0163E-07	3.0358E-07	2.9689E-07	2.994E-07	2.9821E-07	3.0152E-07
Polarization Analyzer #803	Average Effici...	88.244 %	88.209 %	88.144 %	87.979 %	88.462 %	88.375 %	
	Efficiency Ex-...	88.506 %	87.692 %	88.122 %	87.469 %	88.206 %	88.1 %	
	Efficiency Ey-...	87.981 %	88.725 %	88.166 %	88.488 %	88.719 %	88.65 %	

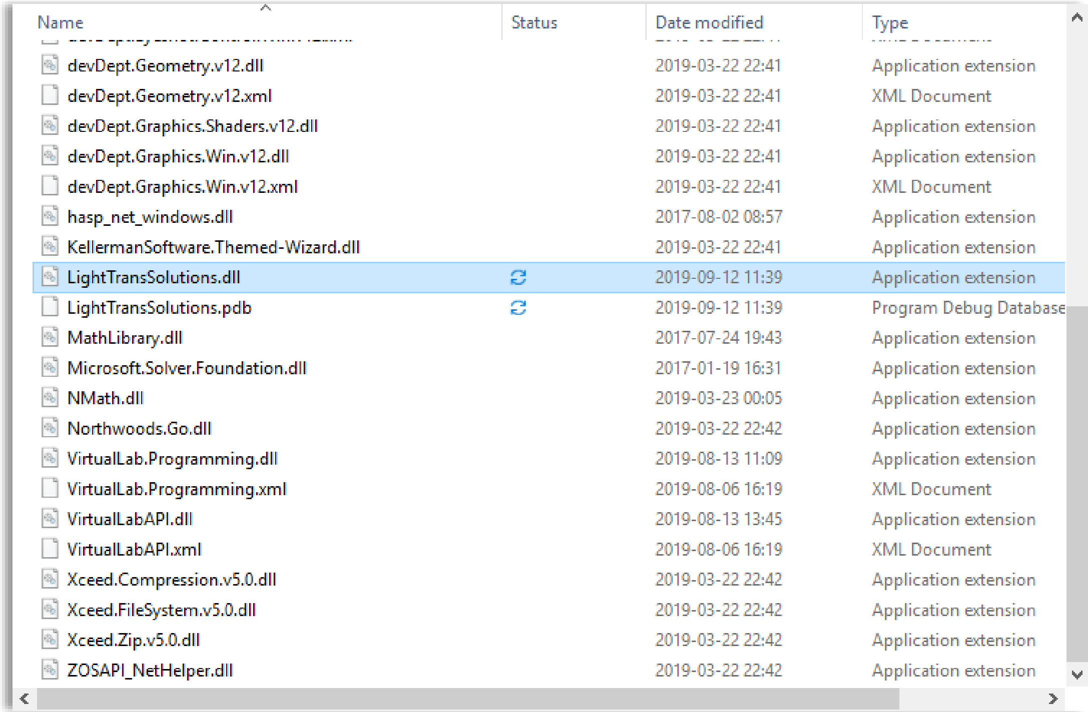
Appendix: How to Use LightTransSolutions.dll?

- Make a copy of

  LightTransSolutions.dll

- Paste it into the installation location of VirtualLab Fusion, e.g.,

  C:\Program Files\Wyrowski Photonics\VirtualLab Fusion (7.5.0)



Document Information

title	Modeling and Design of Blazed Meta-Gratings
document code	Demo.14
version	1.0
VL version used for simulations	VirtualLab Fusion Summer Release 2019 (7.6.1.18)
category	Demo
further reading	