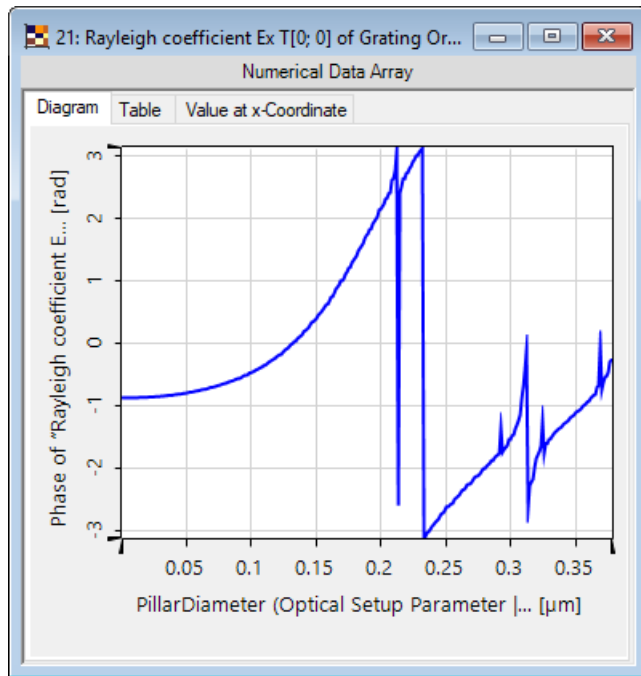


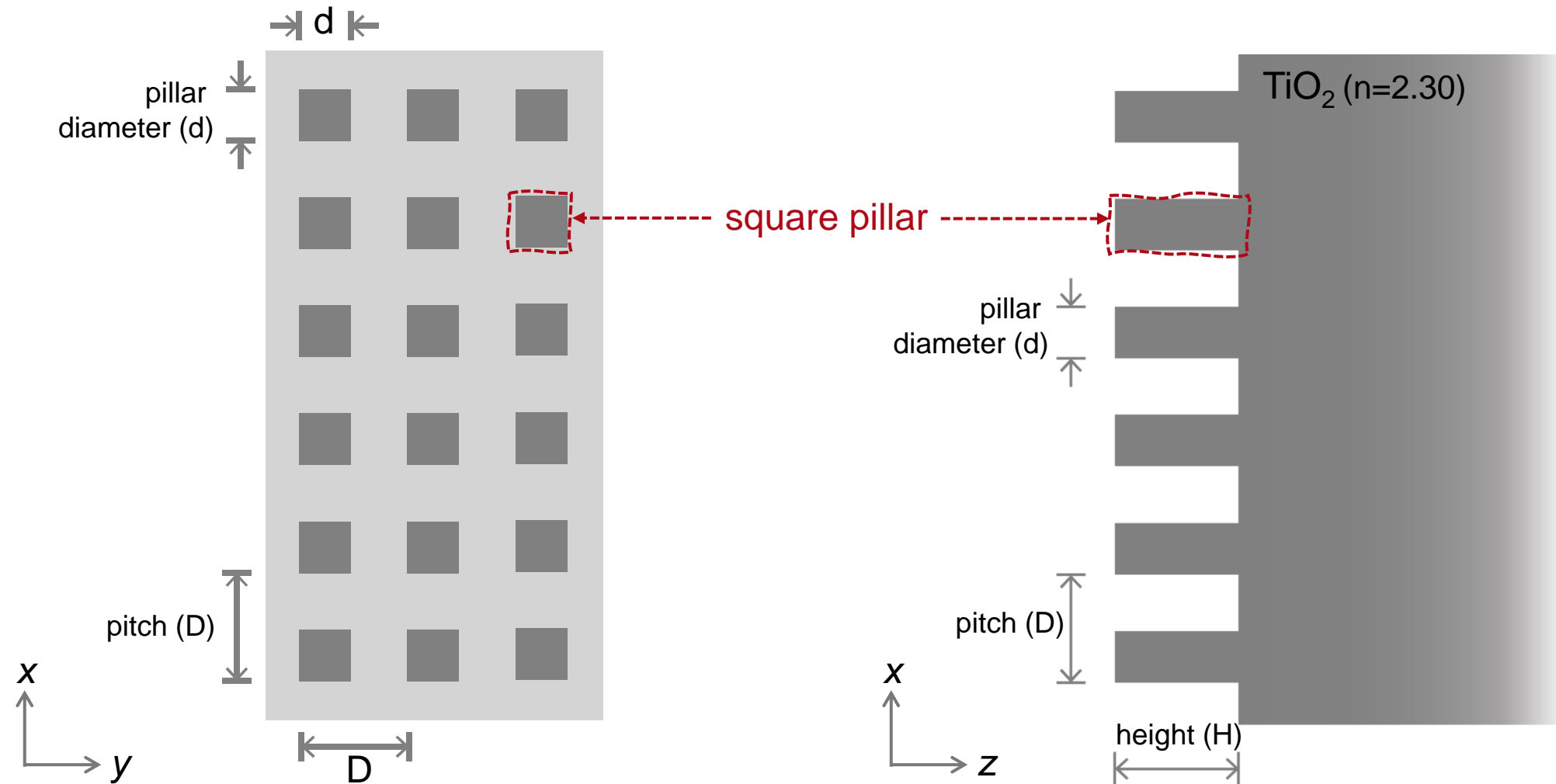
Modeling and Design of Blazed Meta-Gratings

Abstract

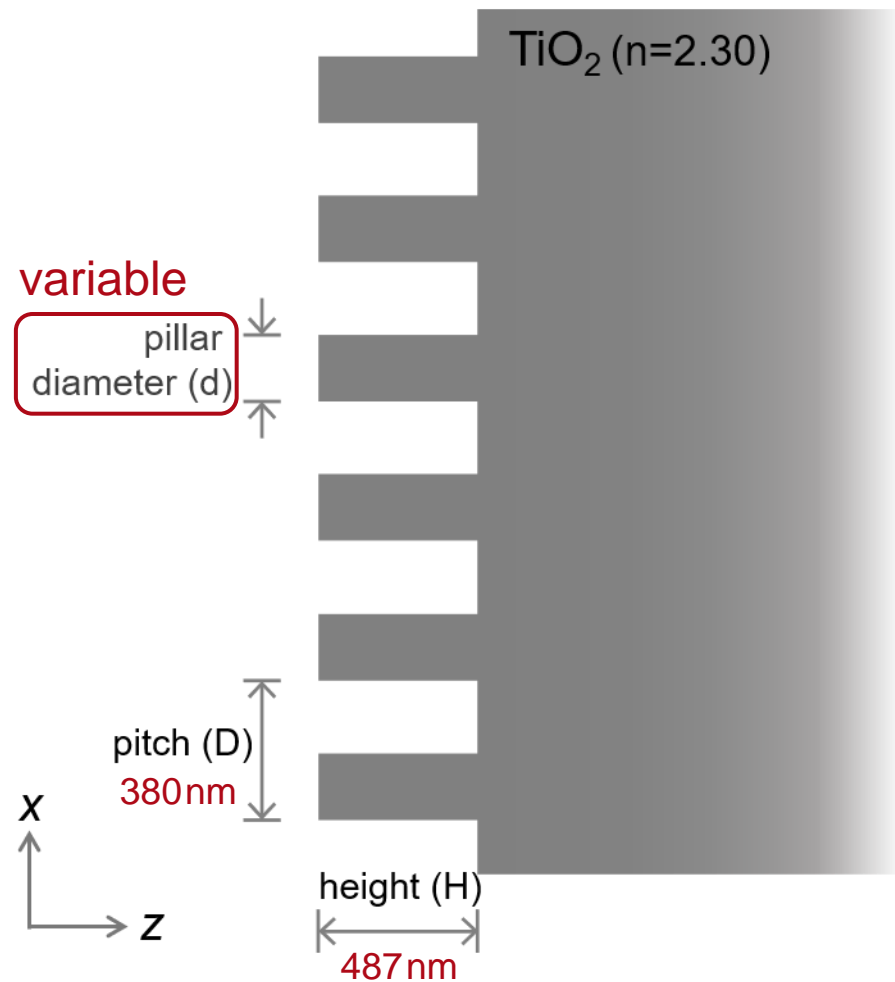


We show how to design a blazed meta-grating that is composed of nanopillars with spatially varying diameters. The (almost) polarization-independent behavior of such a meta-grating is analyzed. And, we also demonstrate further parametric optimization of the meta-gratings after its initial design.

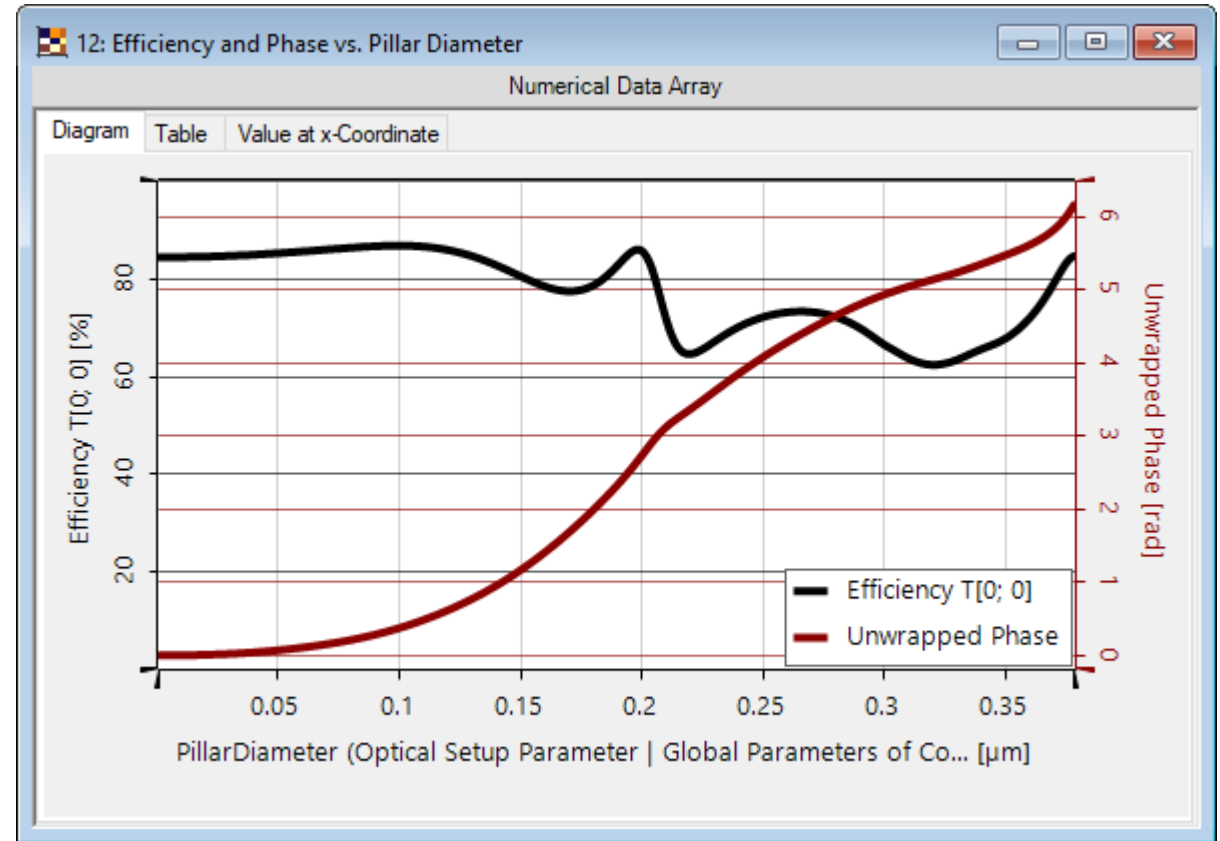
Building Block / Unit Cell Analysis (Index Matched)



Building Block / Unit Cell Analysis (Index Matched)



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



Building Block / Unit Cell Analysis (Index Matched)

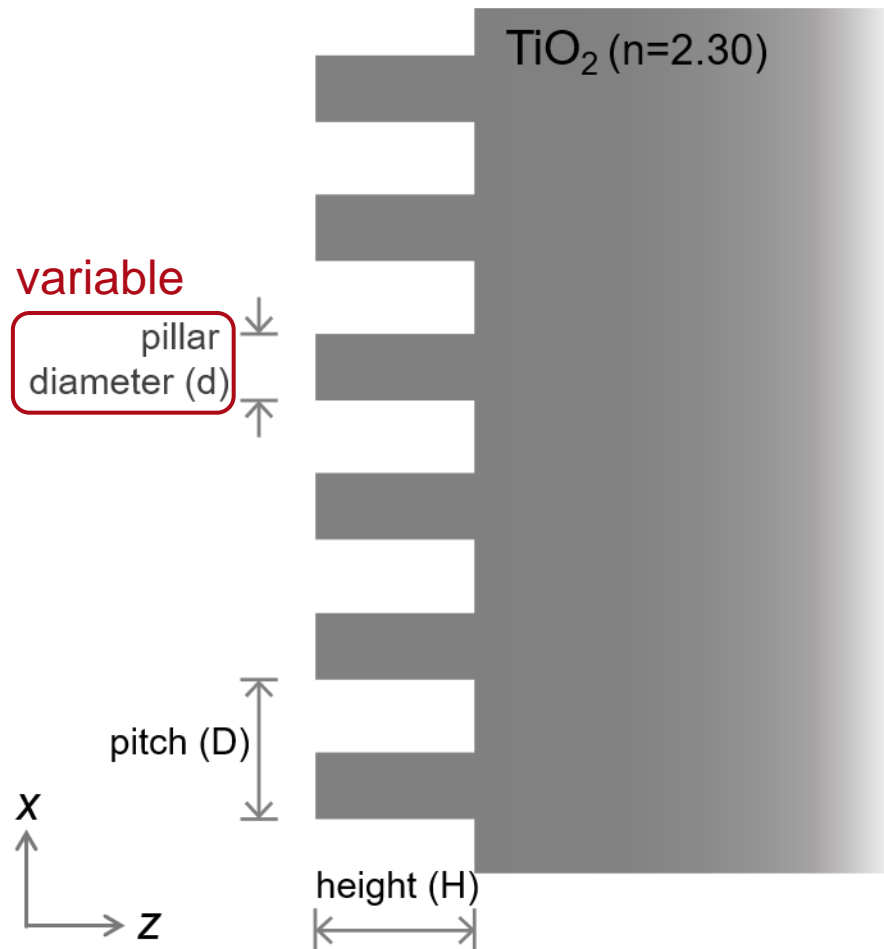


Figure 1 from P. Lalanne, *et al.*,
Opt. Lett. 23, 1081-1083 (1998)

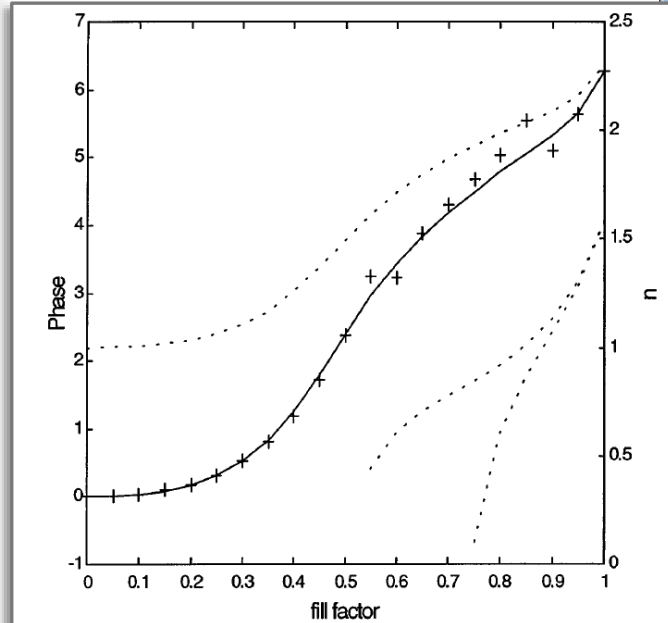
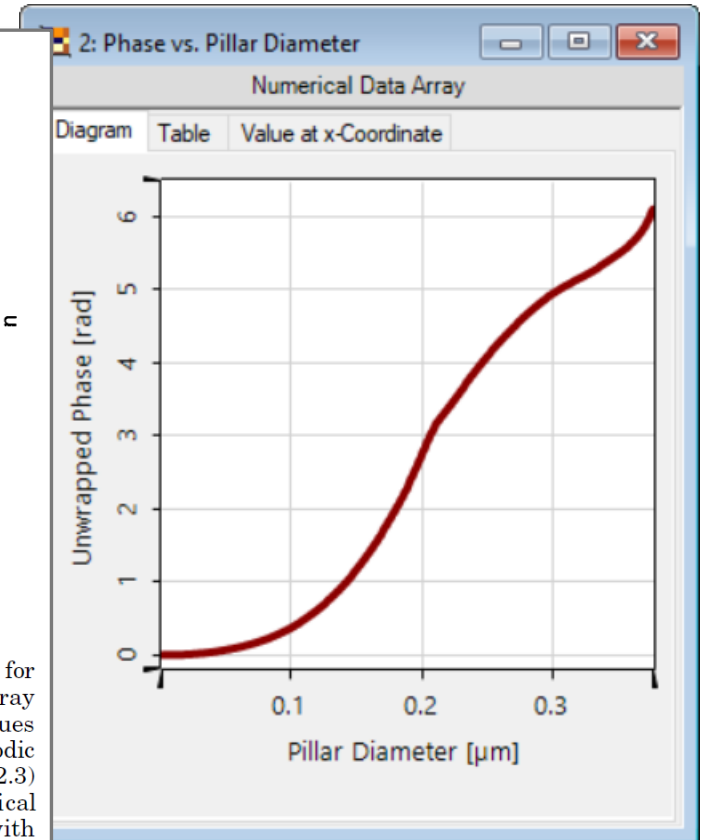
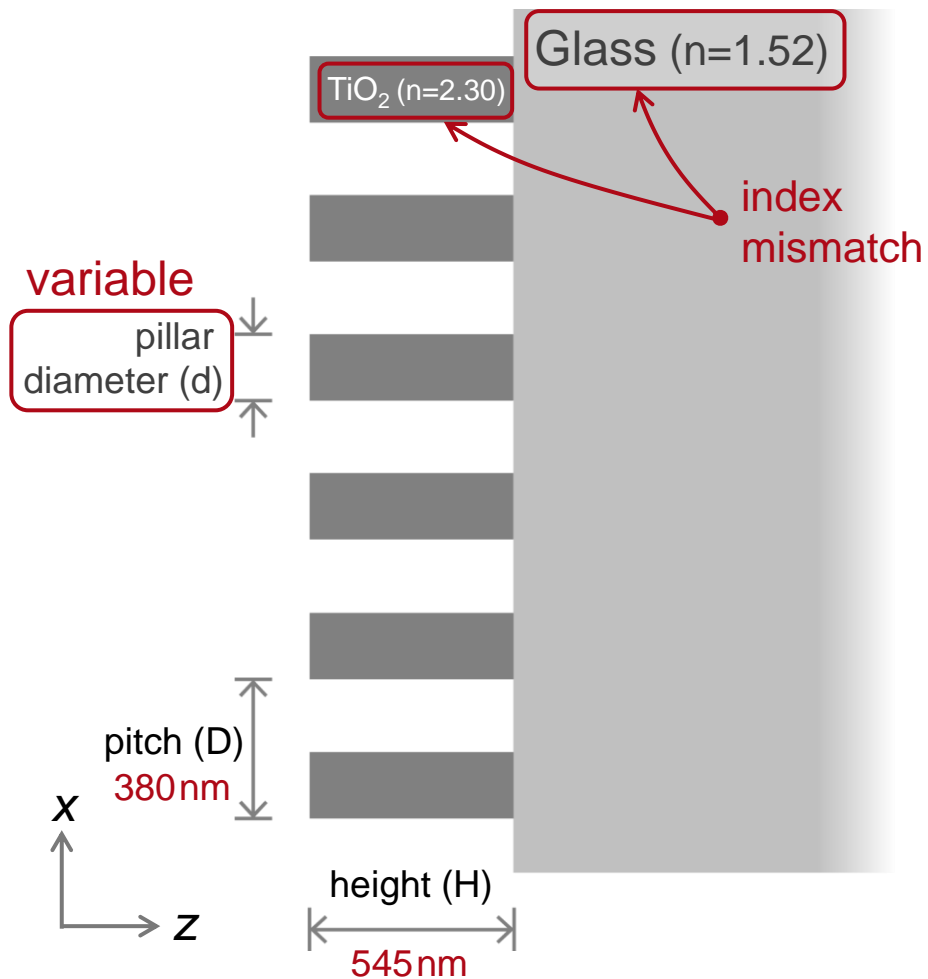


Fig. 1. Crosses, phases of the transmitted zeroth order for a 487-nm-thick grating composed of a 380-nm-period array of square pillars etched in TiO₂. Dotted curves, n values of all the propagating modes supported by the biperiodic structure. The uppermost curve (n varies from 1 to 2.3) corresponds to 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.

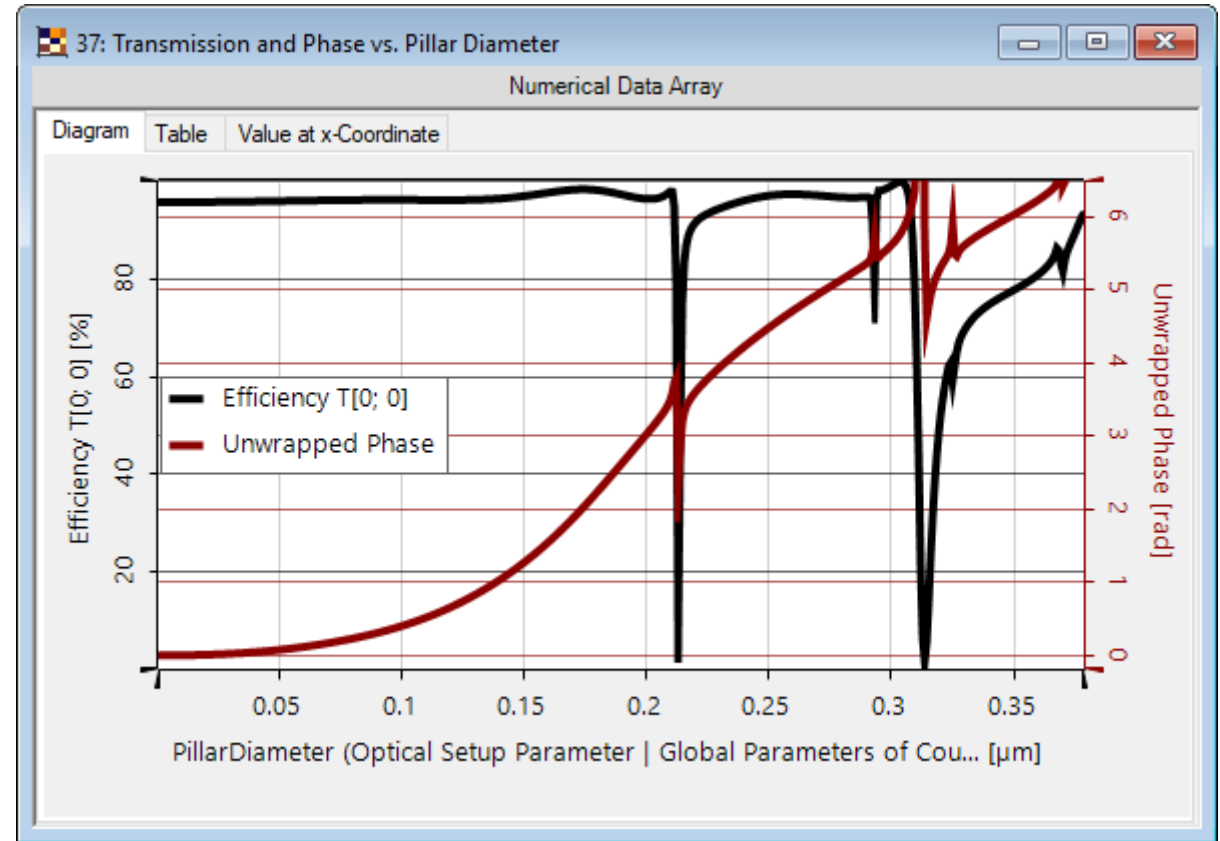


VirtualLab Fusion simulation

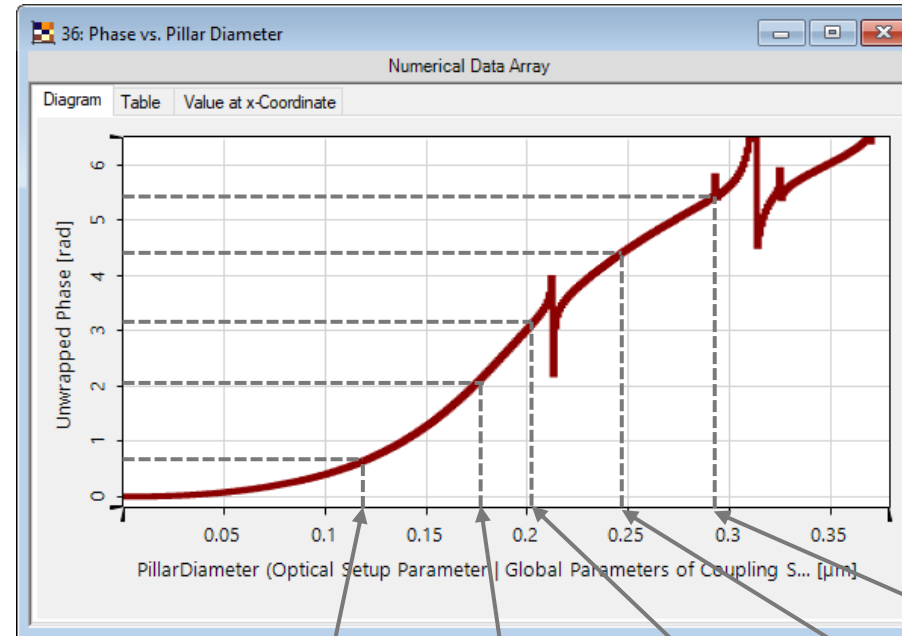
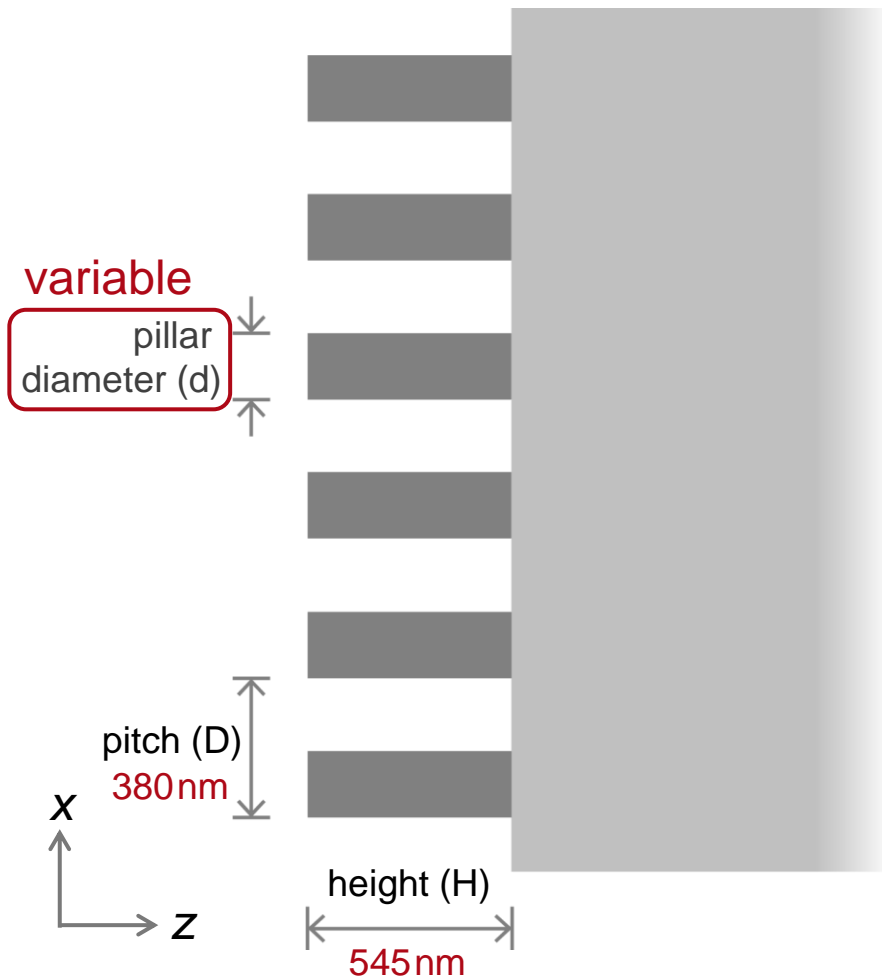
Building Block / Unit Cell Analysis (Glass Substrate)



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



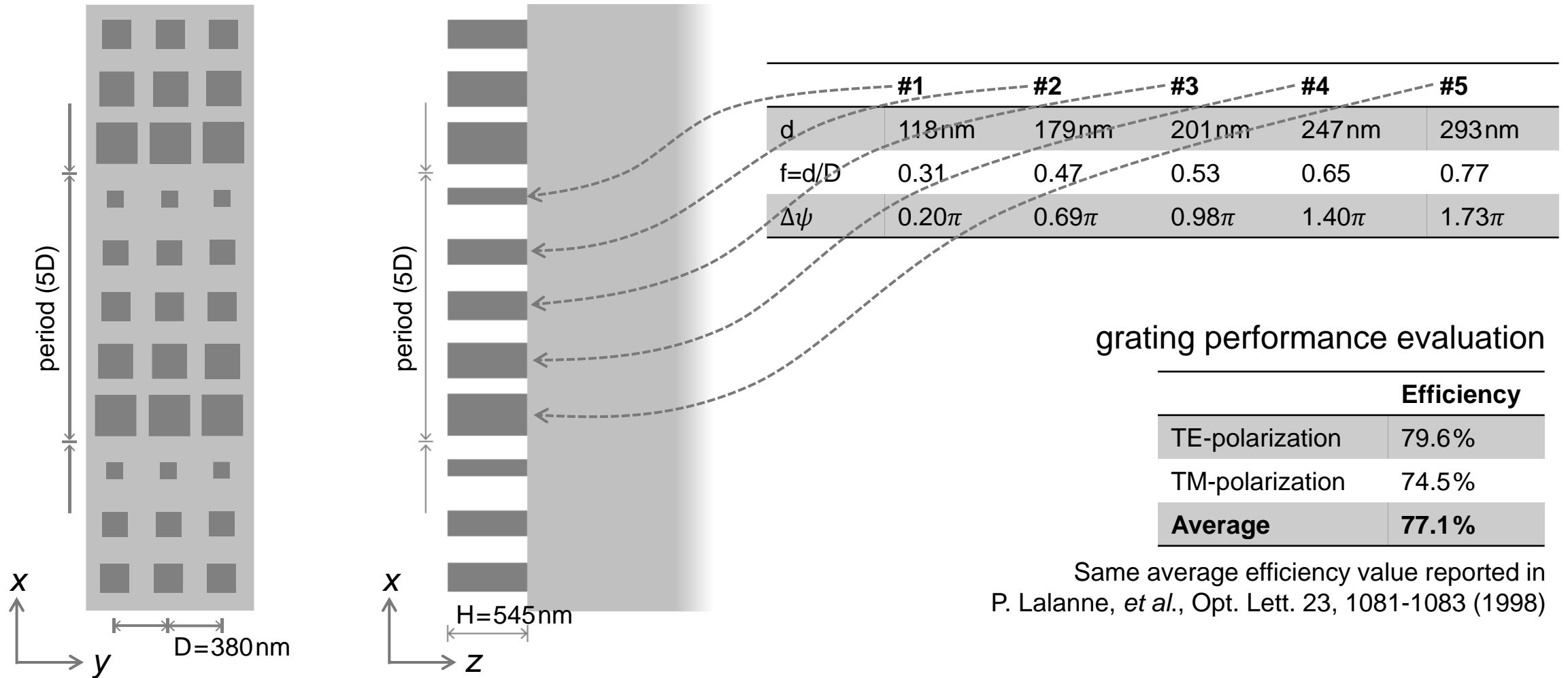
Selection of Unit Cells → Linear Phase



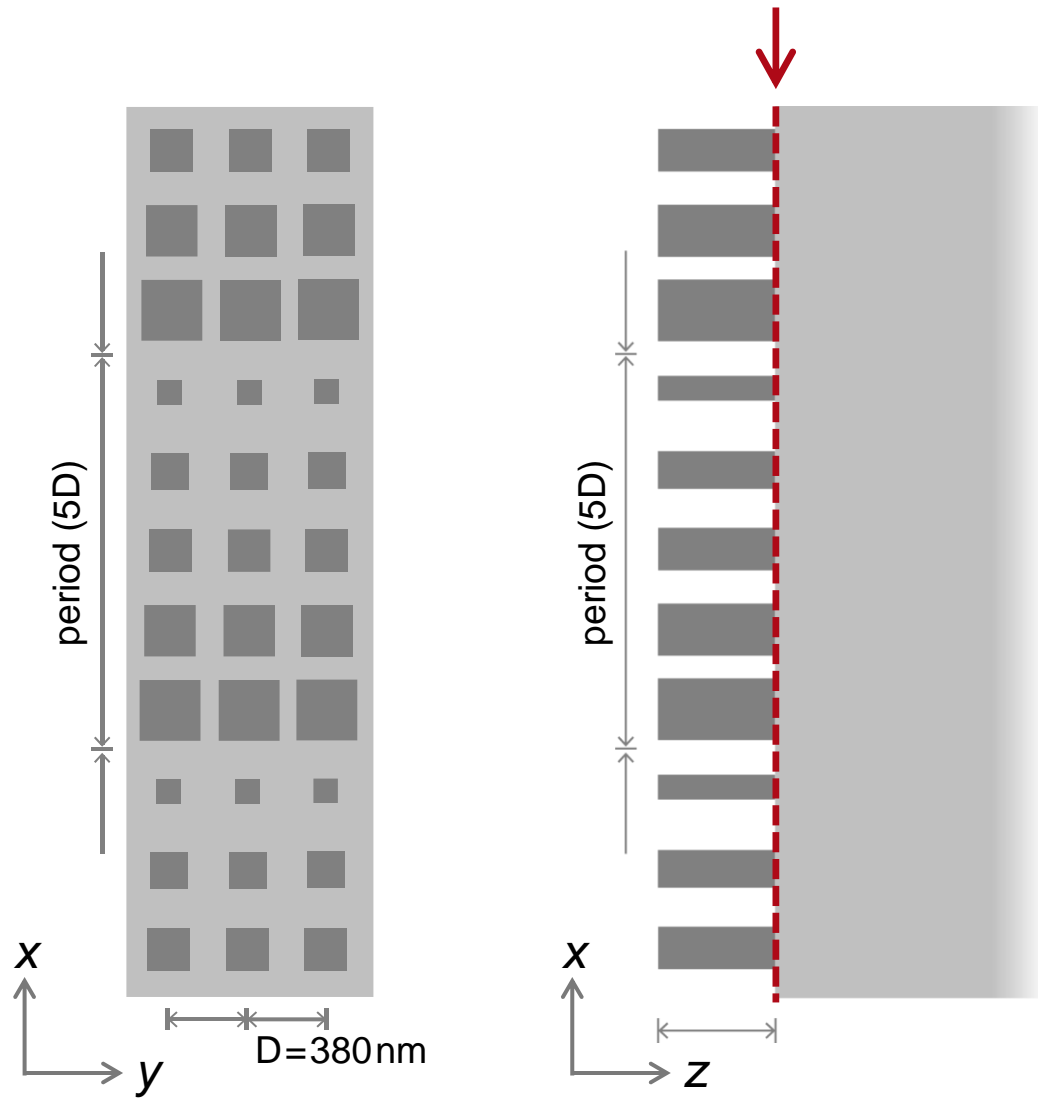
	#1	#2	#3	#4	#5
d	118nm	179nm	201nm	247nm	293nm
f=d/D	0.31	0.47	0.53	0.65	0.77
$\Delta\psi$	0.20π	0.69π	0.98π	1.40π	1.73π

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

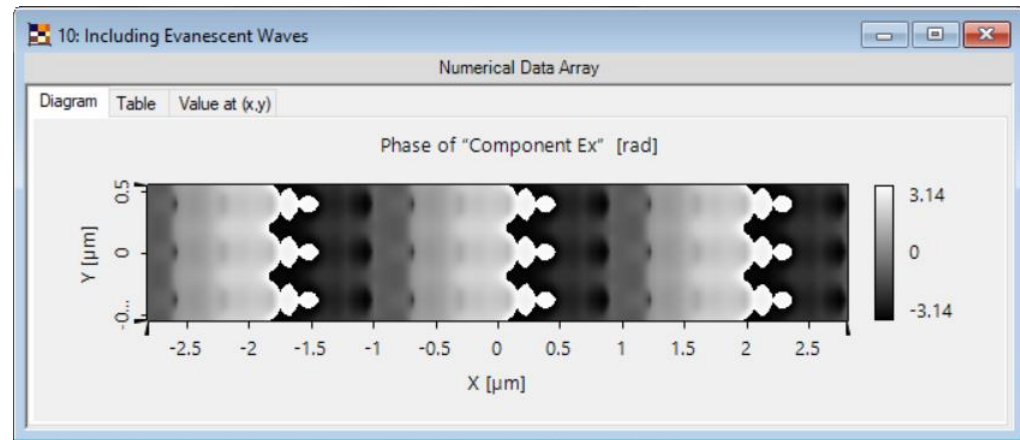
Initial Composition of the Blazed Grating



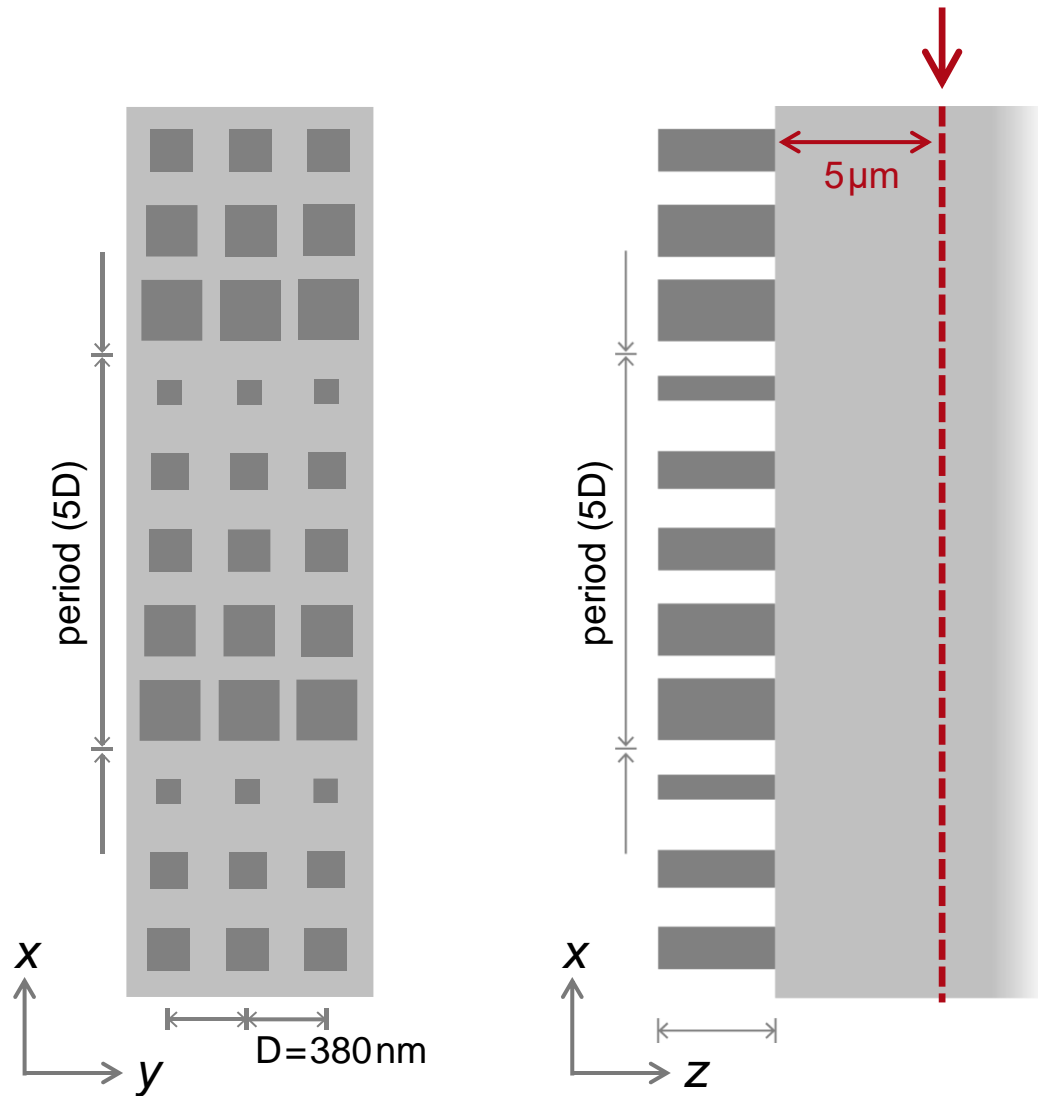
Phase Distribution behind Blazed Meta-Grating



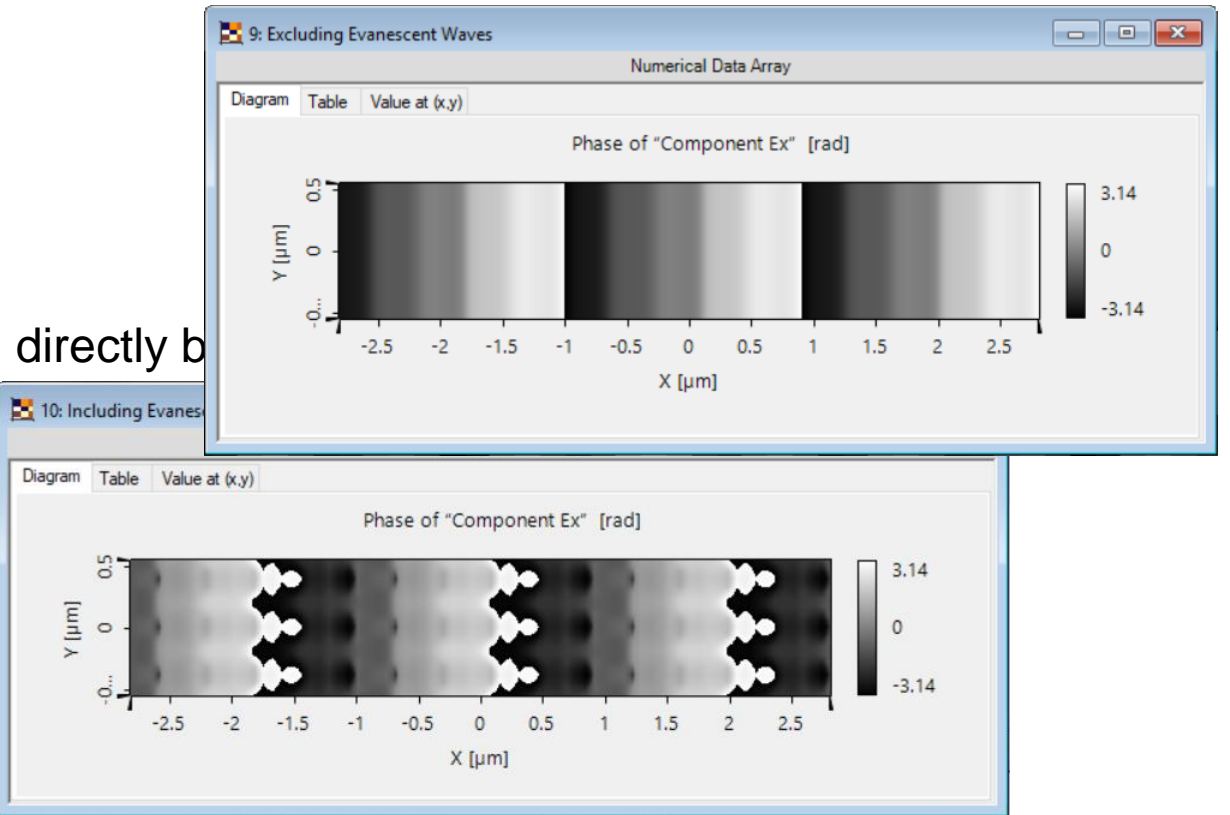
directly behind the grating



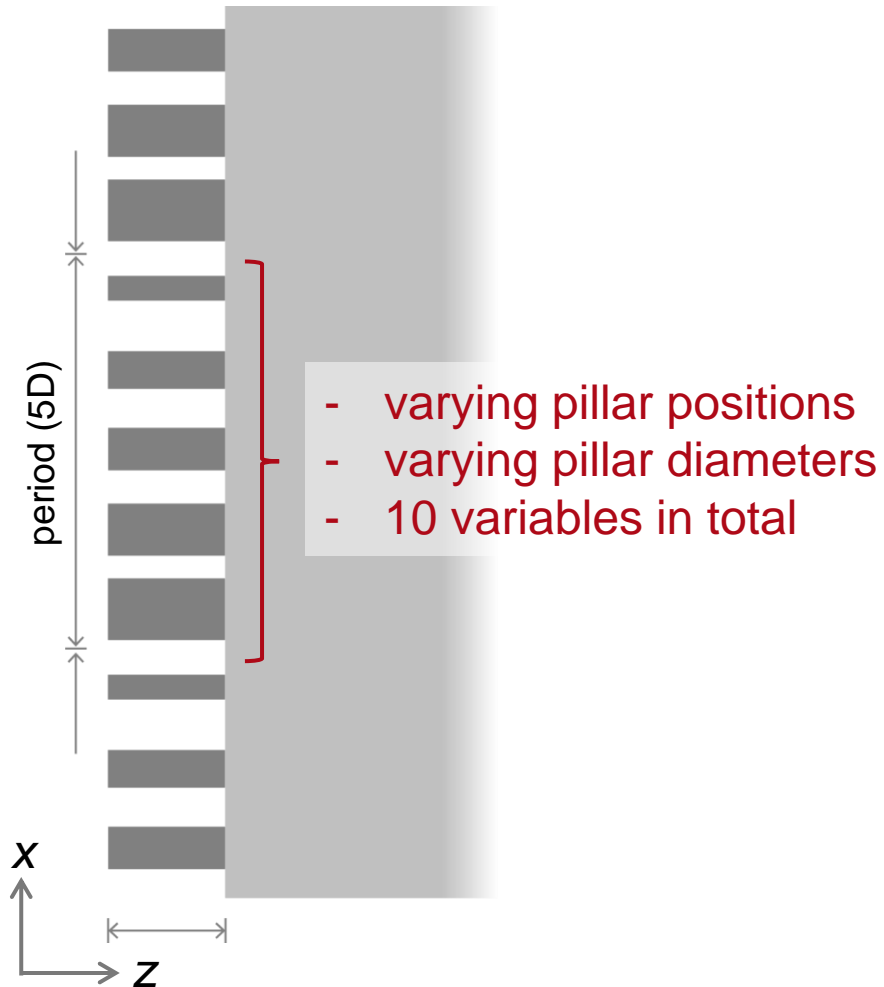
Phase Distribution behind Blazed Meta-Grating



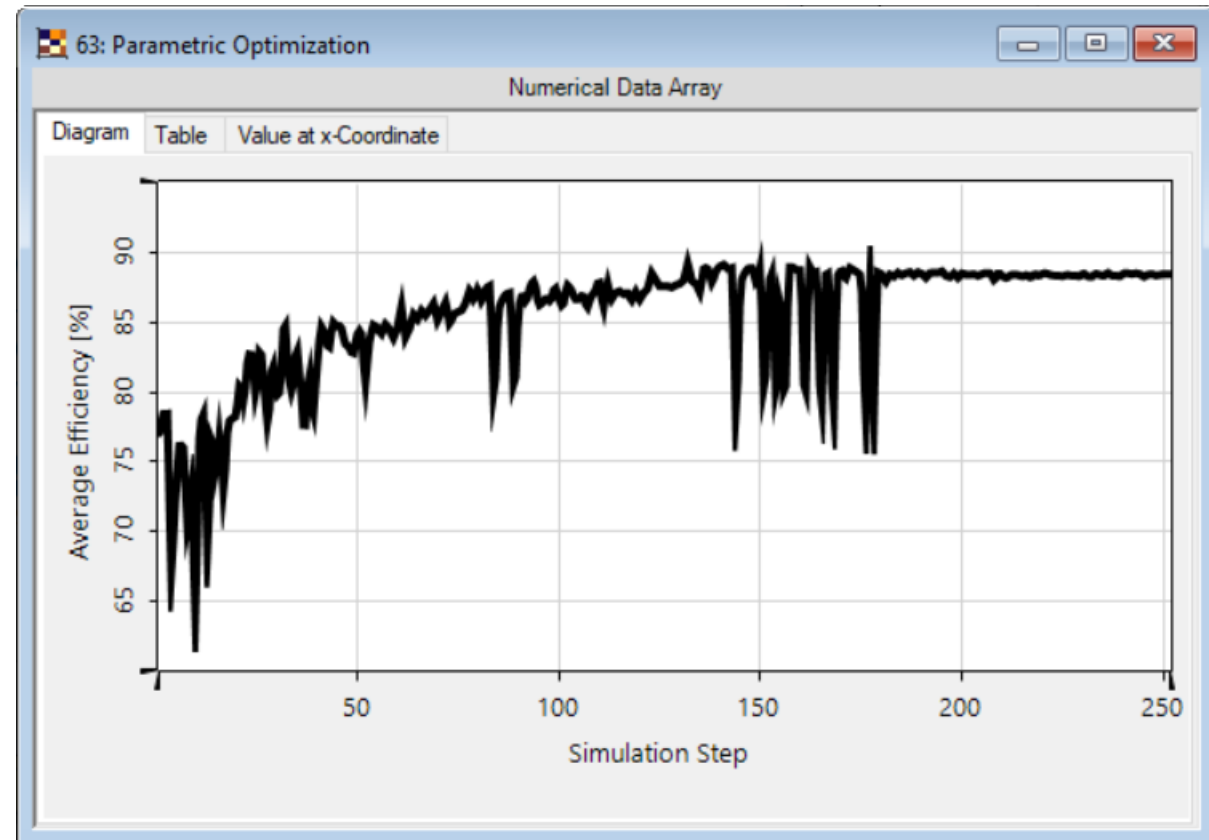
5 μm behind the grating (evanescent waves damped)



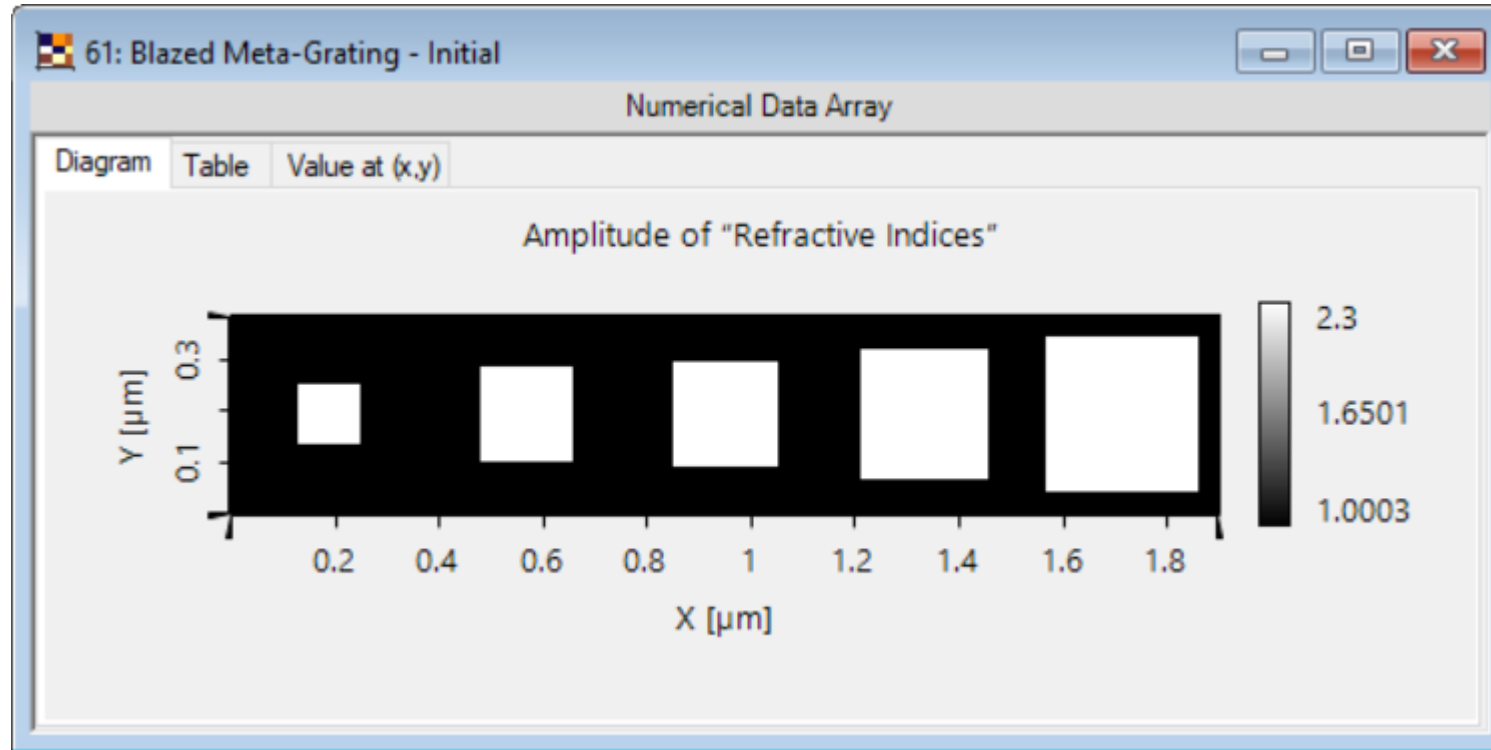
Further Optimization of Grating Structure



downhill simplex optimization with FMM/RCWA for grating analysis



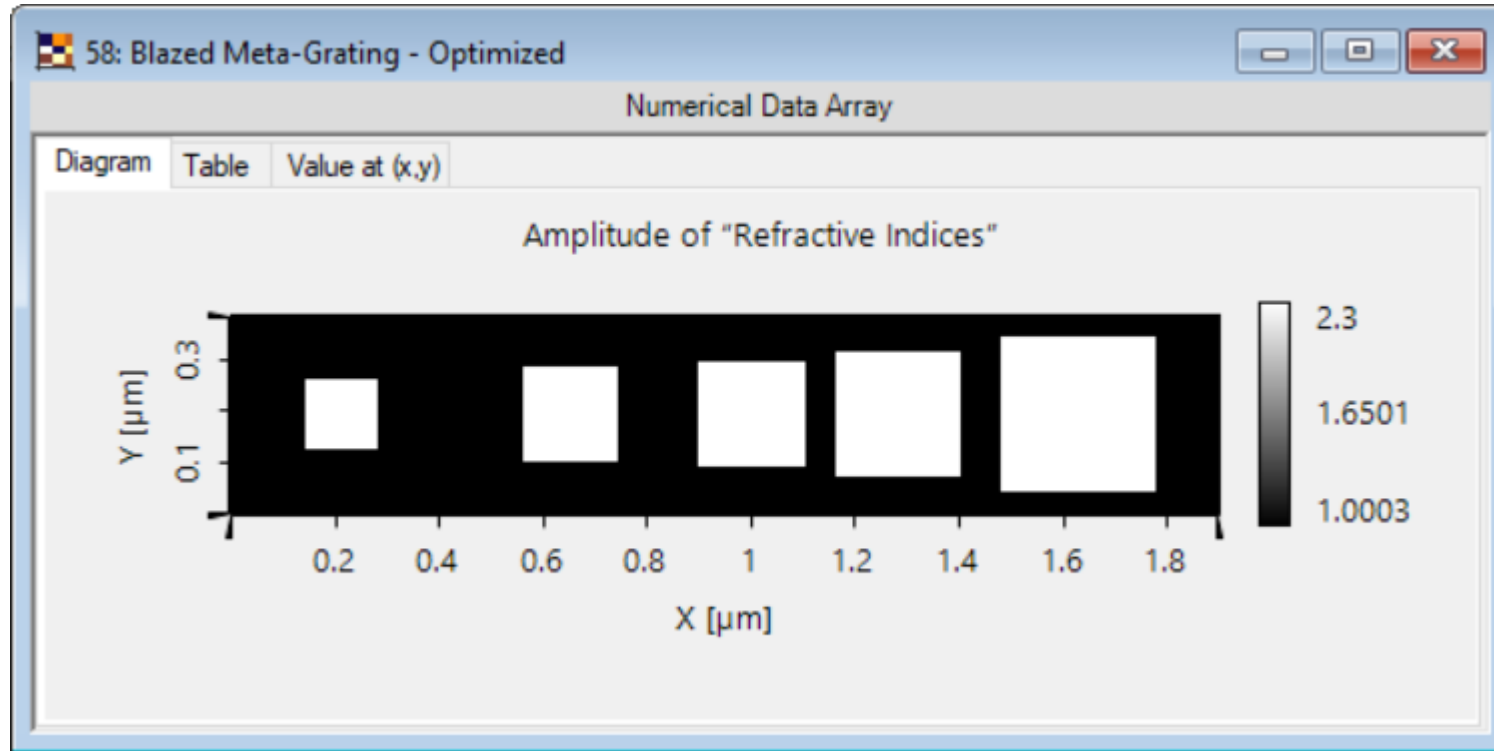
Blazed Meta-Grating Design – Initial Structure



grating performance evaluation

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

Blazed Meta-Grating Design – After Optimization

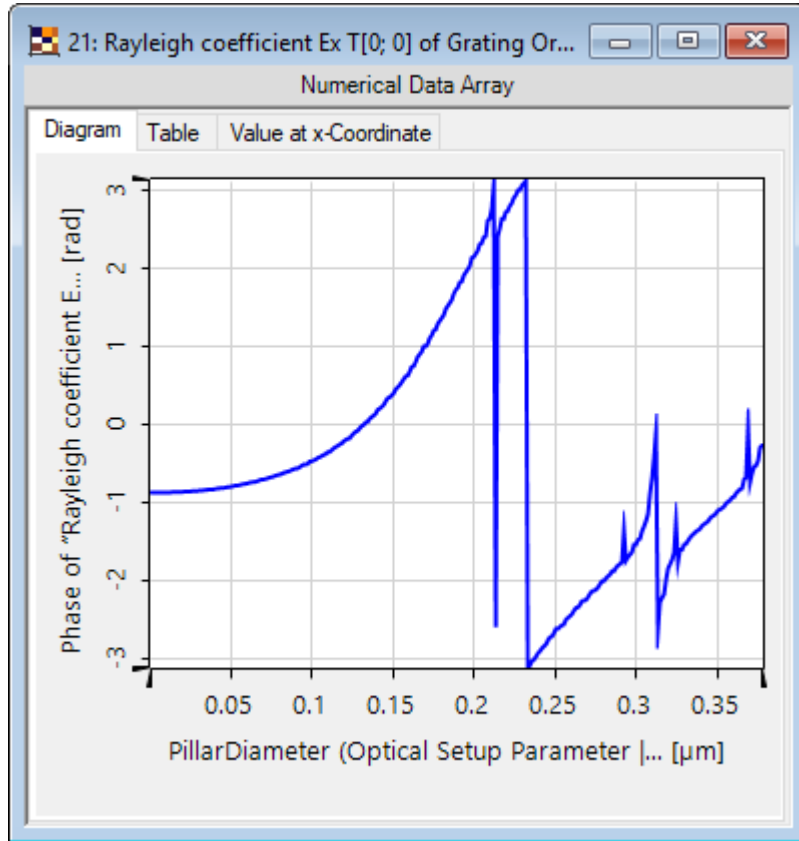


grating performance evaluation

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

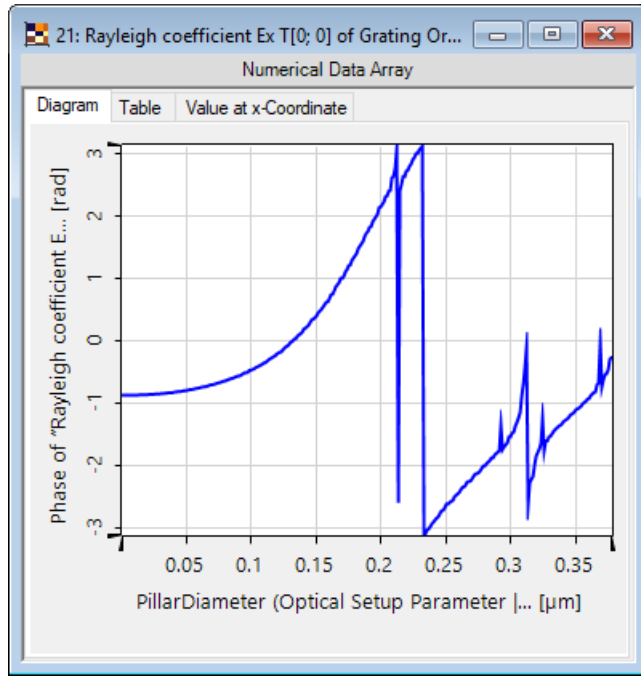
Brief Instruction on Workflows in VirtualLab Fusion

Step 1: Unit Cell Analysis

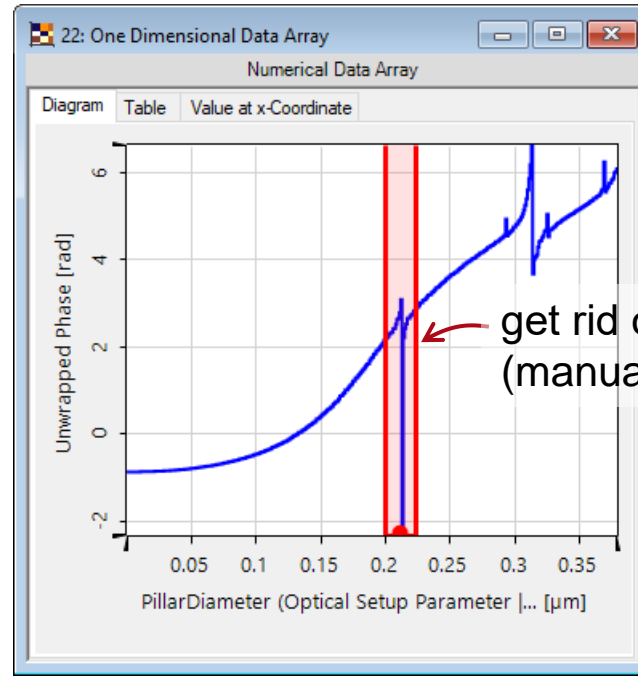


- Vary the pillar diameter and obtain the phase-diameter characteristic curve.
- Note that the phase value is wrapped within $[-\pi, +\pi]$, and it may contain certain dips.
- In the next steps, we will first regularize the phase-diameter relation, and then define its inverse, which will be used to define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

Step 2: Regularize Phase-Diameter Curve



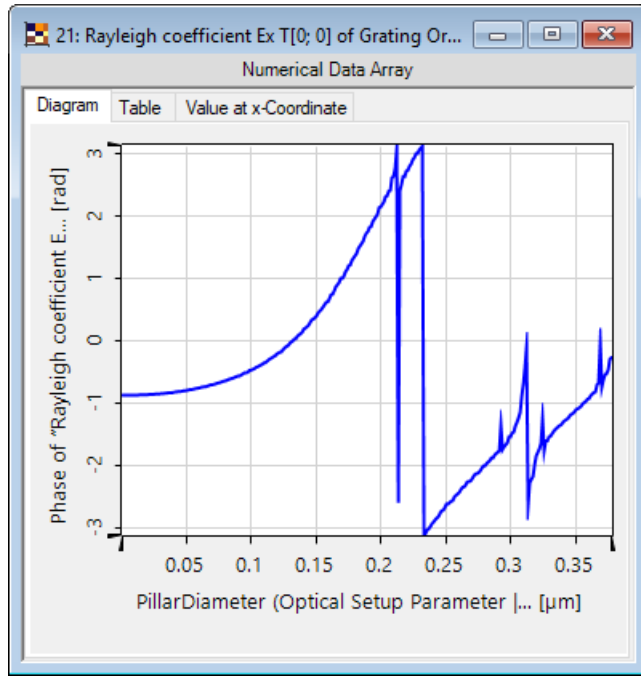
unwrap
phase →



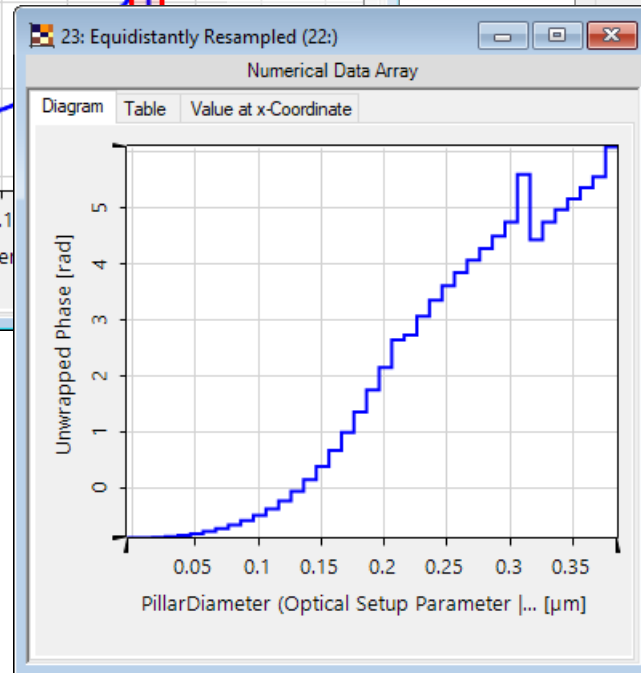
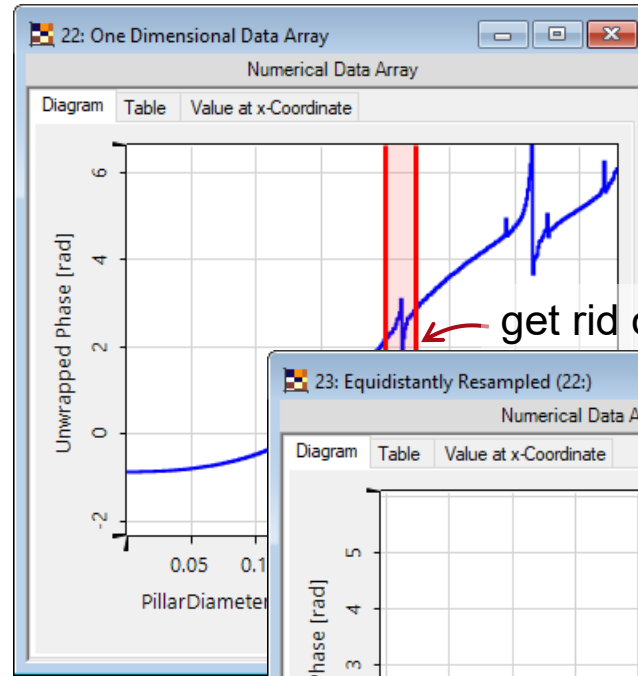
You may skip this step if your unit cell is properly chosen without any „dips“.

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

Step 2: Regularize Phase-Diameter Curve

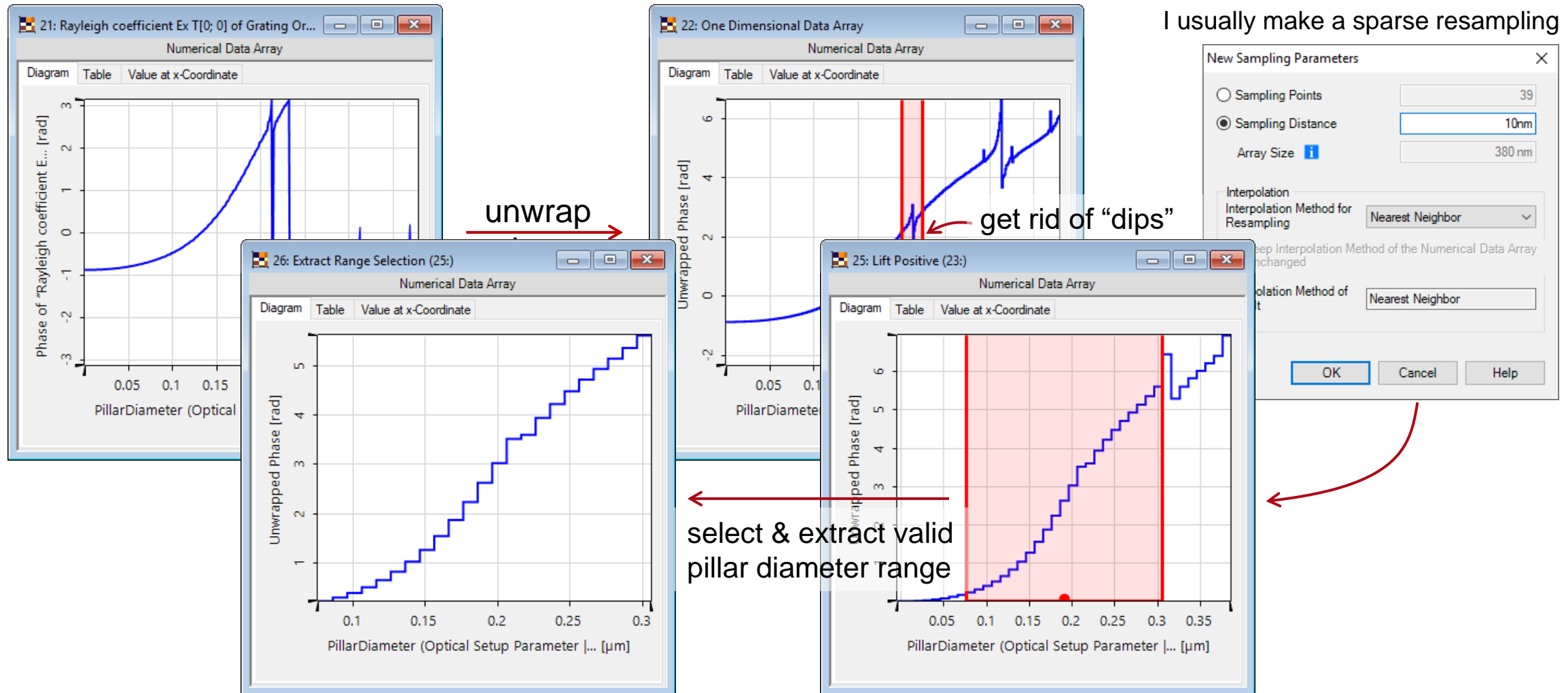


unwrap
phase →



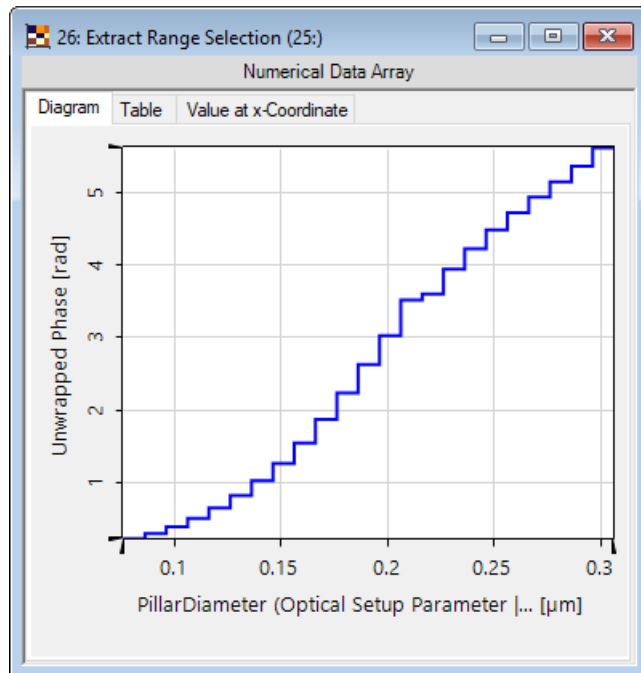
I usually make a sparse resampling

Step 2: Regularize Phase-Diameter Curve

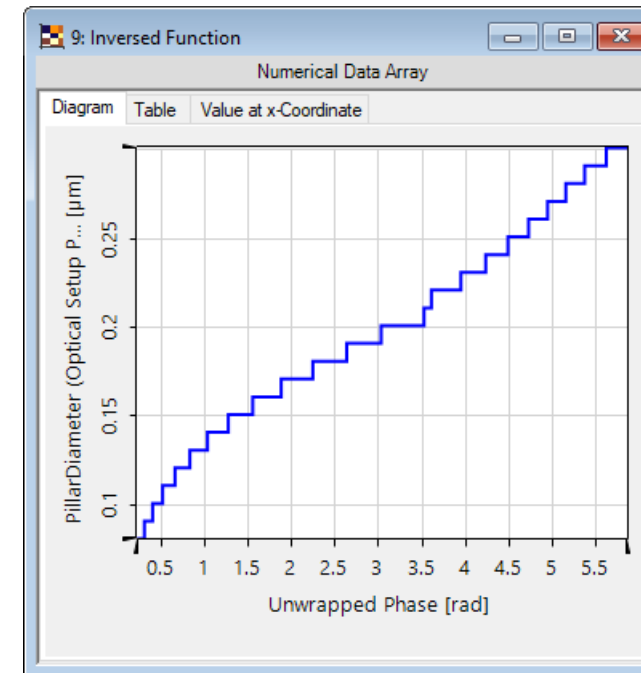
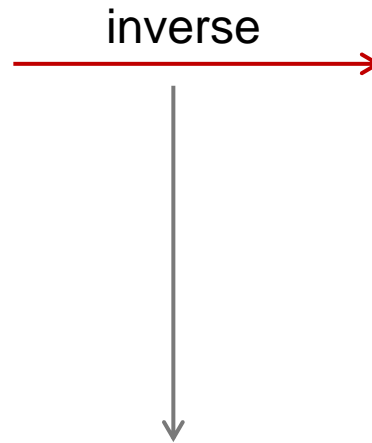


Step 3: Define Diameter – Phase Mapping Relation

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



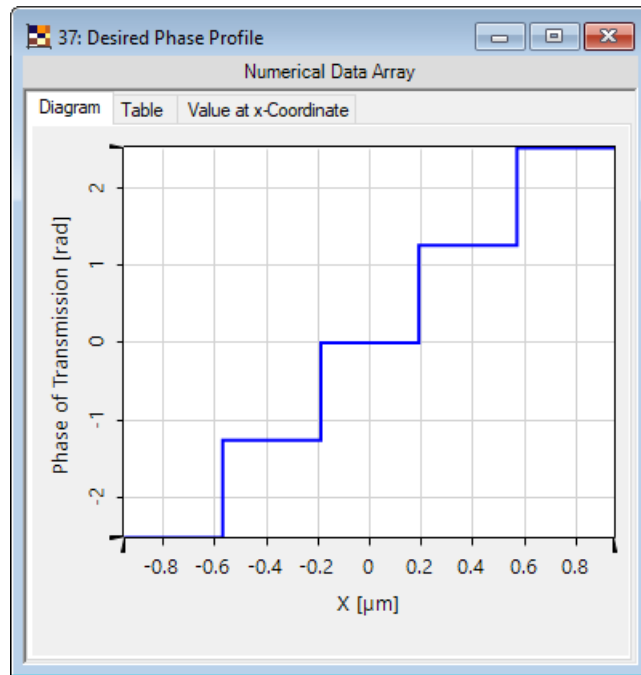
By inverting, we get the diameter-phase relation, which will be used later.



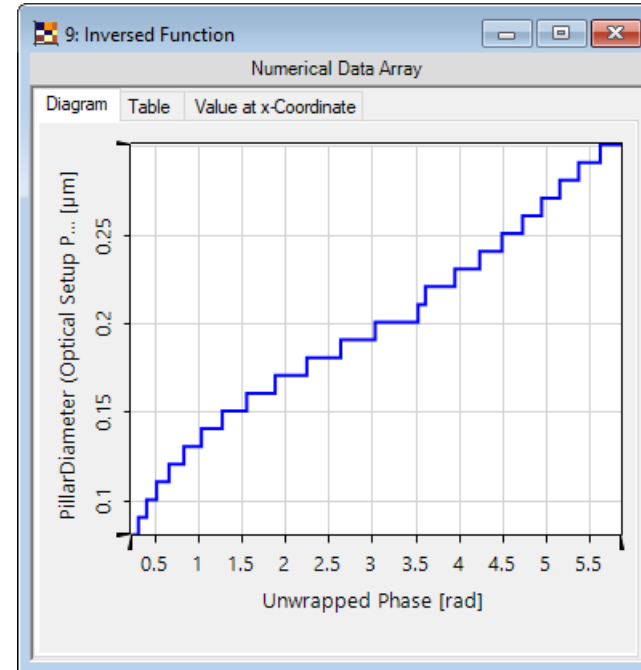
VirtualLab Module: Step_03_Calculate Inverse of 1D Function.cs

Step 4: From Phase Profile to Structure

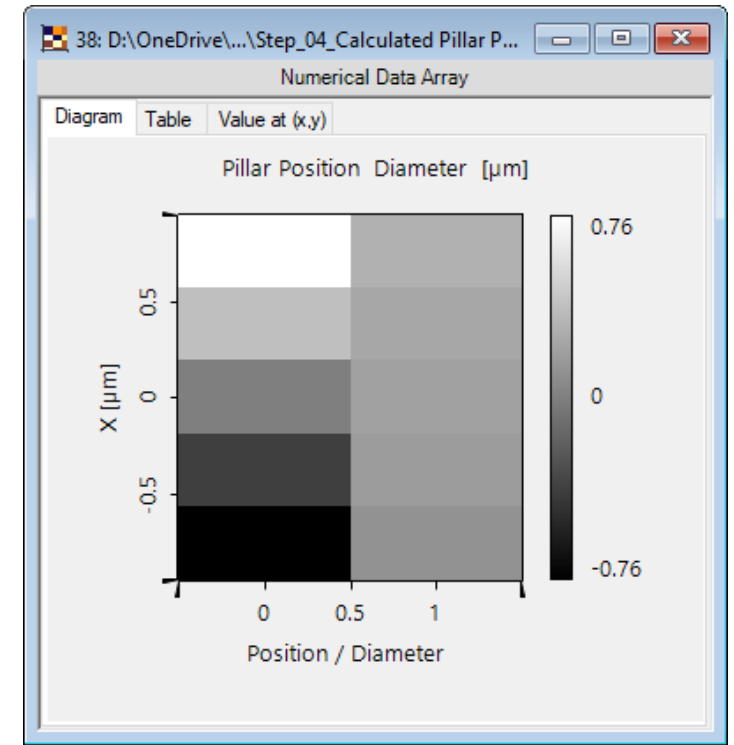
desired linear phase profile



diameter-phase relation from last step



generate meta-grating structure



Step_04_Calculate Pillar Diameters from Phase Profile_1D Unstructured Array.cs

Step 5: Load Meta-Grating Structure in FMM Simulation

The 'Edit Stack' window displays a stack of layers. The 'Base Block' is highlighted in red. The table below shows the stack configuration:

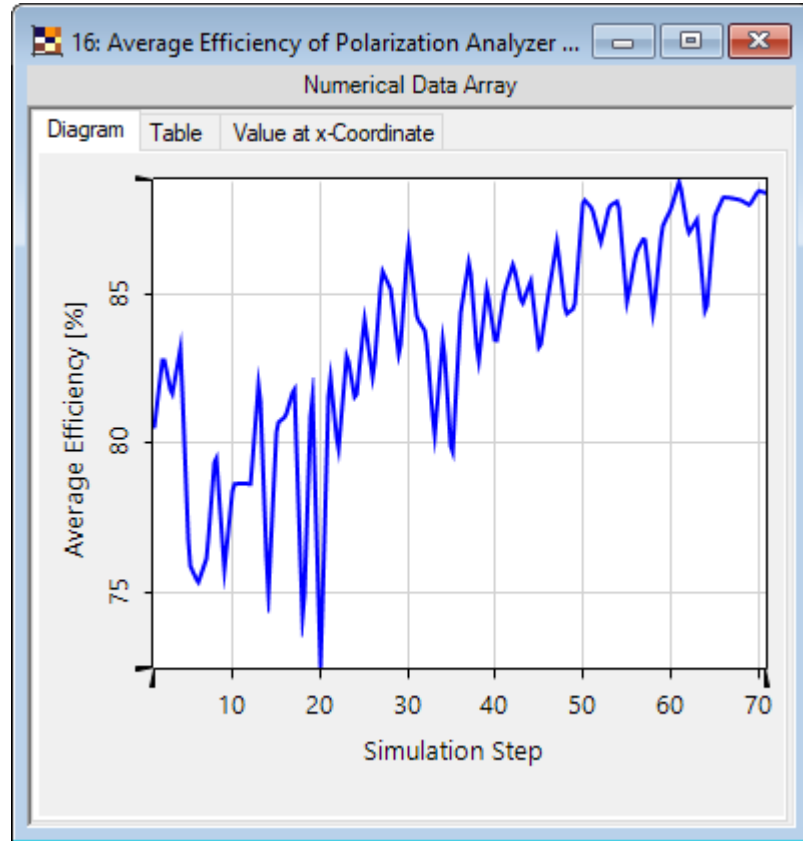
Index	z-Distance	z-Position	Interface	Subsequent Medium	Comments
1	0 mm	0 mm	Plane Interface	Cylinder Pillars [1D...	Enter your comment
2	545 nm	545 nm	Plane Interface	Air in Ho... us M	Enter your comment

The 'Cylinder Pillars' dialog box shows the following parameters:

- Validity:
- Parameters:
 - PillarHeight: 545 nm
 - PillarPositionsAndDiameters:
 - DiameterDefinitionMode: 0
 - SideWallSlopeAngle: 90°
 - RoundedEdgeRadiusTop: 0 mm
 - RoundedEdgeRadiusBottom: 0 mm
 - PillarMaterial: "ConstantIndexMaterial" (Load, Edit, View buttons)

Load the pillar position and diameter information here

Step 6: Optimize Pillar Position and Diameter



10: Parametric Optimization from "5: D:\OneDrive\...\Step_05_Meta-Grating Rigorous Analysis_Initial Setup.os"

Optimization Results

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

Stop

		Simulation Step						
Detector	Subdetector	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 %	

Create Output from Selection

< Back Next > Show

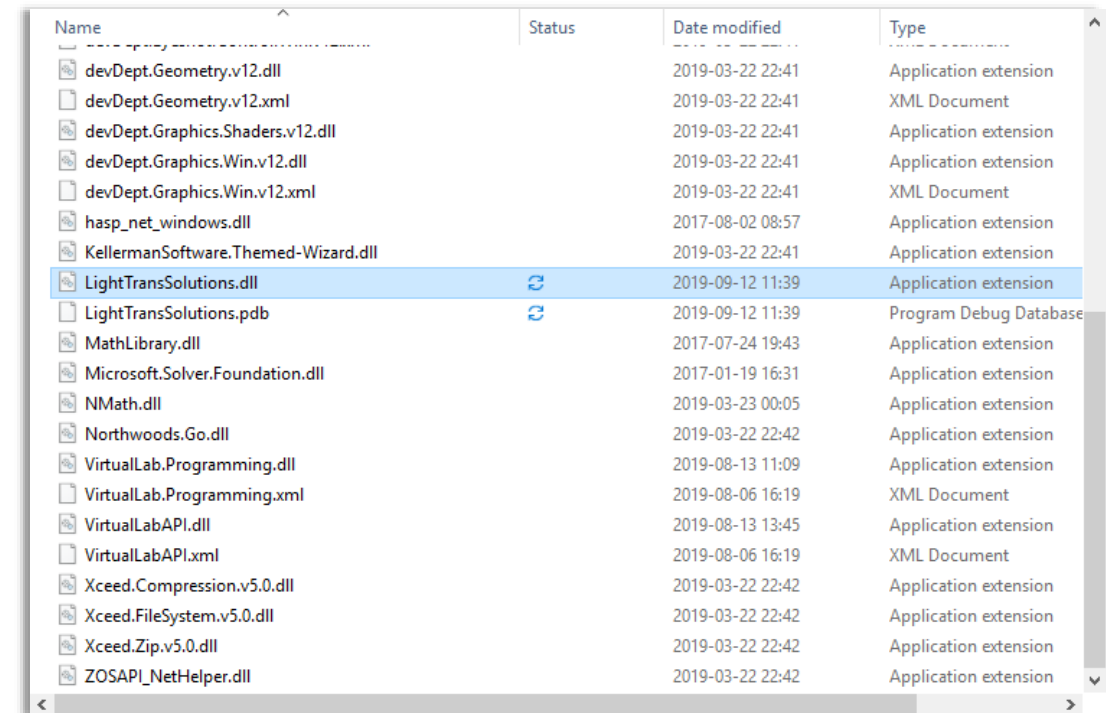
Appendix: How to Use LightTransSolutions.dll?

- 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)*



Name	Status	Date modified	Type
devDept.Geometry.v12.dll		2019-03-22 22:41	Application extension
devDept.Geometry.v12.xml		2019-03-22 22:41	XML Document
devDept.Graphics.Shaders.v12.dll		2019-03-22 22:41	Application extension
devDept.Graphics.Win.v12.dll		2019-03-22 22:41	Application extension
devDept.Graphics.Win.v12.xml		2019-03-22 22:41	XML Document
hasp_net_windows.dll		2017-08-02 08:57	Application extension
KellermanSoftware.Themed-Wizard.dll		2019-03-22 22:41	Application extension
LightTransSolutions.dll	☞	2019-09-12 11:39	Application extension
LightTransSolutions.pdb	☞	2019-09-12 11:39	Program Debug Database
MathLibrary.dll		2017-07-24 19:43	Application extension
Microsoft.Solver.Foundation.dll		2017-01-19 16:31	Application extension
NMath.dll		2019-03-23 00:05	Application extension
Northwoods.Go.dll		2019-03-22 22:42	Application extension
VirtualLab.Programming.dll		2019-08-13 11:09	Application extension
VirtualLab.Programming.xml		2019-08-06 16:19	XML Document
VirtualLabAPI.dll		2019-08-13 13:45	Application extension
VirtualLabAPI.xml		2019-08-06 16:19	XML Document
Xceed.Compression.v5.0.dll		2019-03-22 22:42	Application extension
Xceed.FileSystem.v5.0.dll		2019-03-22 22:42	Application extension
Xceed.Zip.v5.0.dll		2019-03-22 22:42	Application extension
ZOSAPI_NetHelper.dll		2019-03-22 22:42	Application extension

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	
