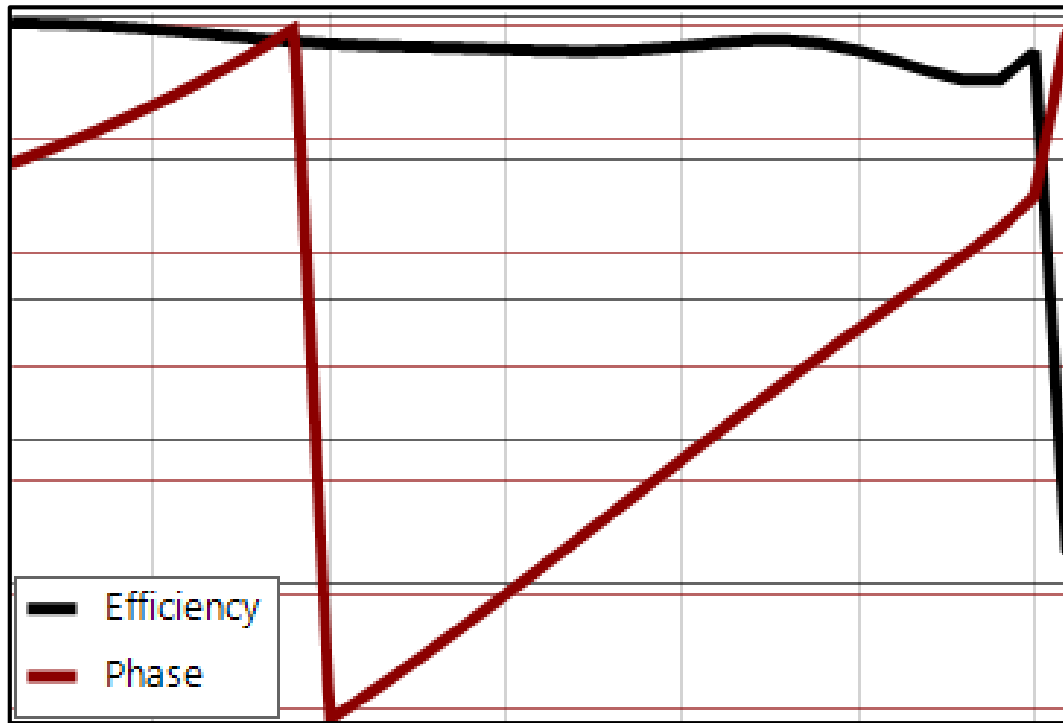


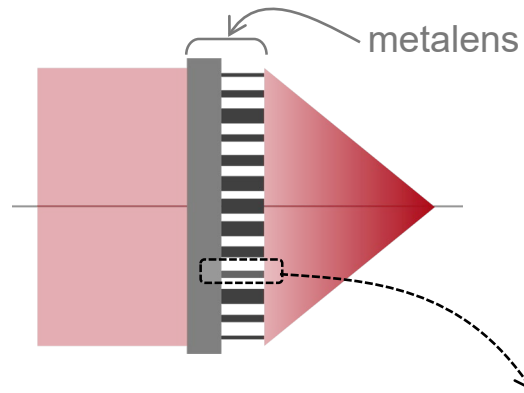
# **Rigorous Analysis of Nanopillar Metasurface Building Block**

# Abstract



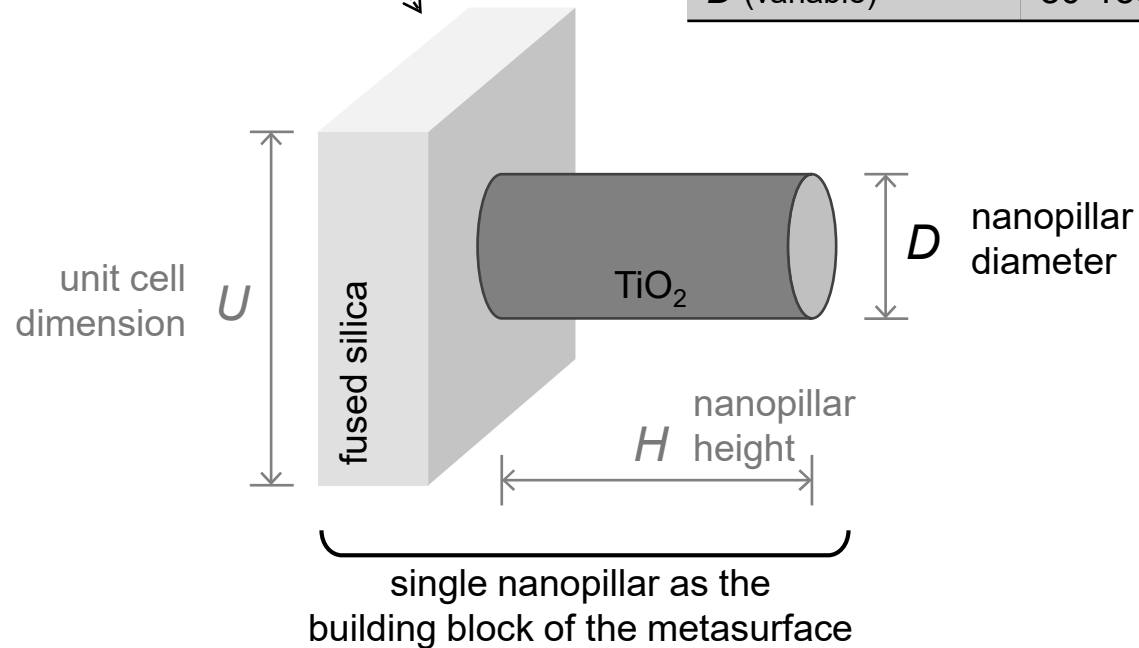
With advanced fabrication techniques, people have demonstrated metalenses for visible wavelengths with high numerical apertures. A metalens is usually constructed with spatially varying nanostructures as its building blocks. In this example, we analyze the nanopillar structure which is used to compose polarization-insensitive metalenses. With the Fourier modal method (FMM, also known as RCWA), the amplitude and phase transmission of such nanopillars are calculated rigorously.

# Modeling Task



parameters from M. Khorasaninejad,  
*Nano Lett.* 2016, 16, 7229-7234

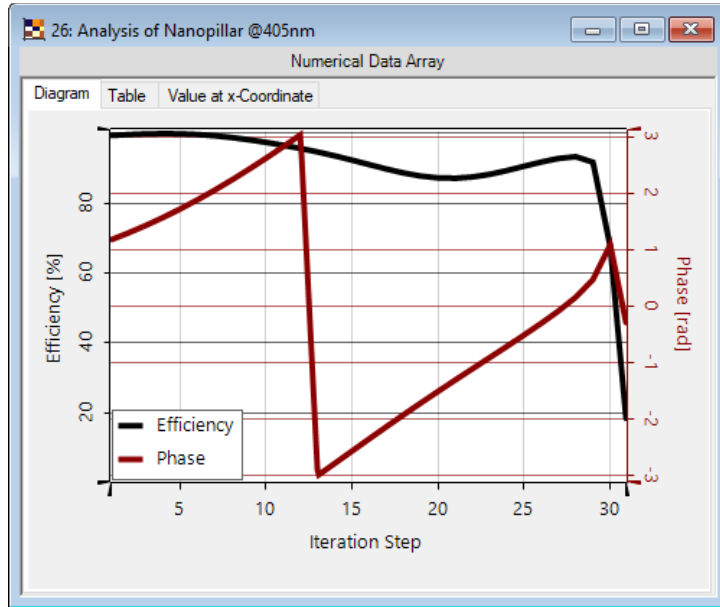
Nanopillars No.	#1 (405nm)	#2 (532nm)	#3 (660nm)
$U$	180nm	250nm	350nm
$H$	400nm	600nm	600nm
$D$ (variable)	80-155nm	100-220nm	100-320nm



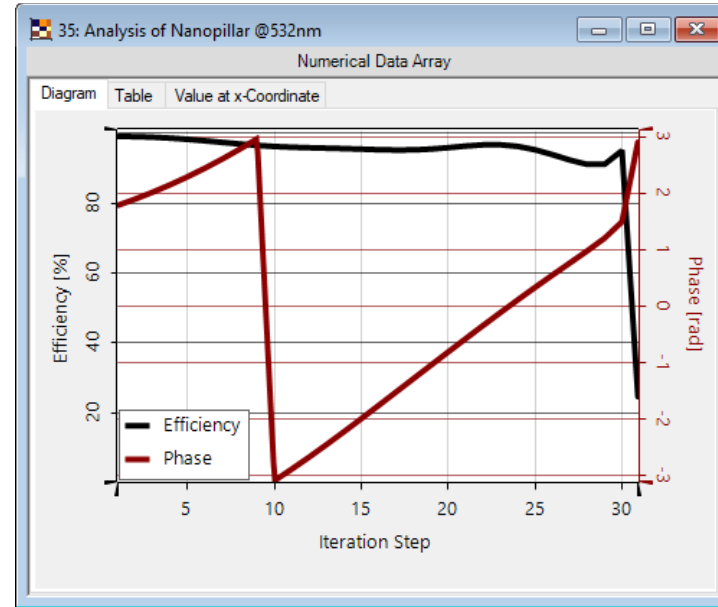
By varying the nanopillar diameter, the metasurface building block is supposed to have phase modulation covering  $2\pi$ . How to evaluate such nanopillar structure rigorously?

# Nanopillar Analysis vs. Pillar Diameter

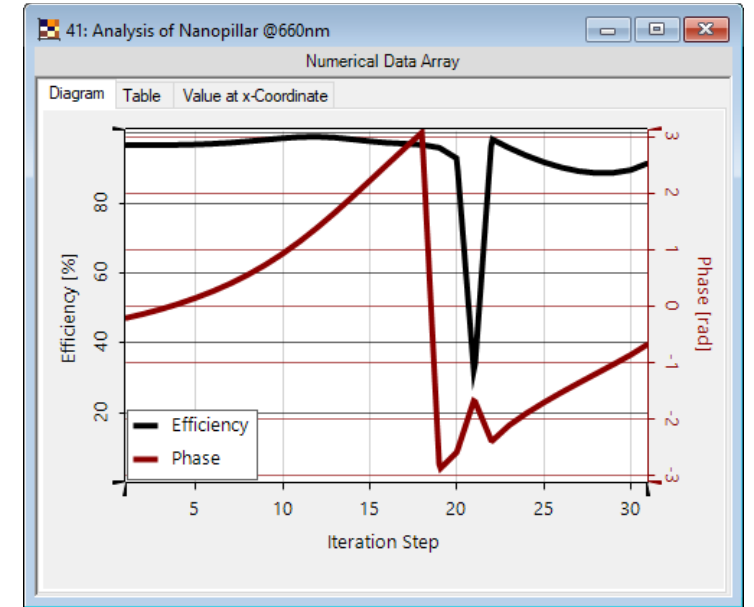
nanopillar #1



nanopillar #2



nanopillar #3



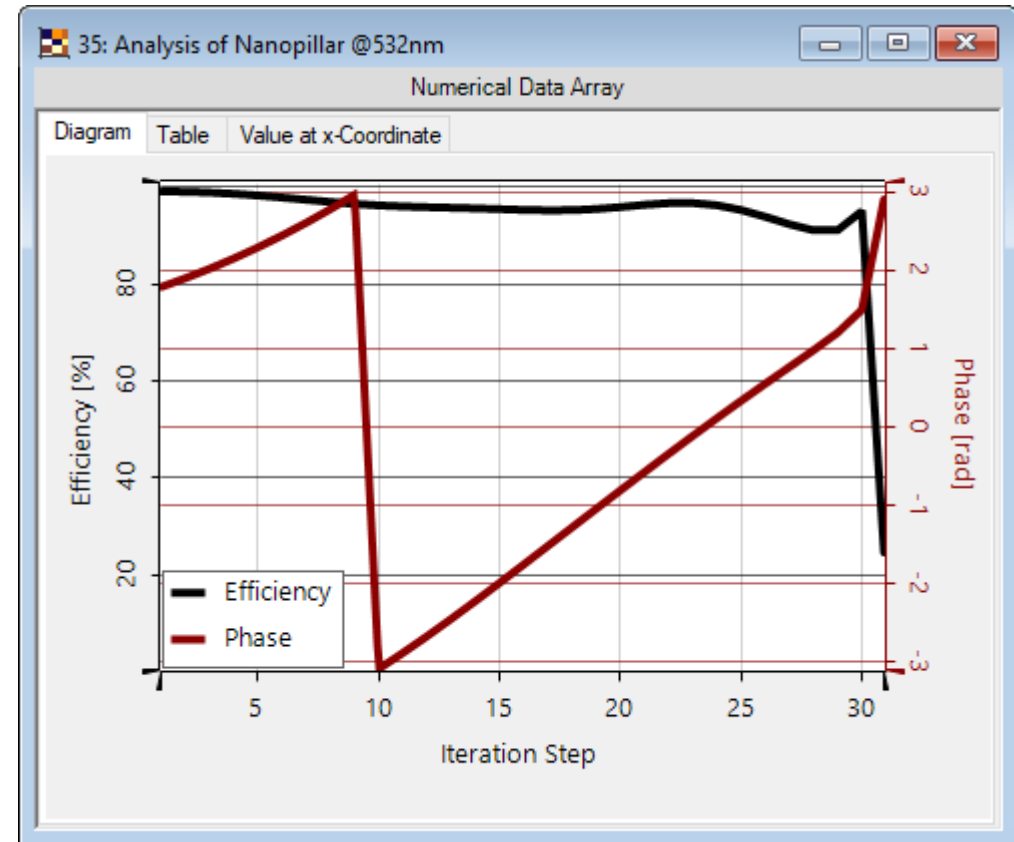
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# Nanopillar Analysis vs. Pillar Diameter

- The phase modulation covers  $2\pi$  range, and it changes almost linearly with pillar diameter, which enables convenient phase control.
- The transmission efficiency remains above 90% for varying pillar diameter over the design range.

Nanopillars No.	#1 (405nm)	#2 (532nm)	#3 (660nm)
<i>U</i>	180nm	250nm	350nm
<i>H</i>	400nm	600nm	600nm
<i>D</i> (variable)	80-155nm	100-220nm	100-320nm

nanopillar #2



# Appendix: Refractive Index of TiO<sub>2</sub>

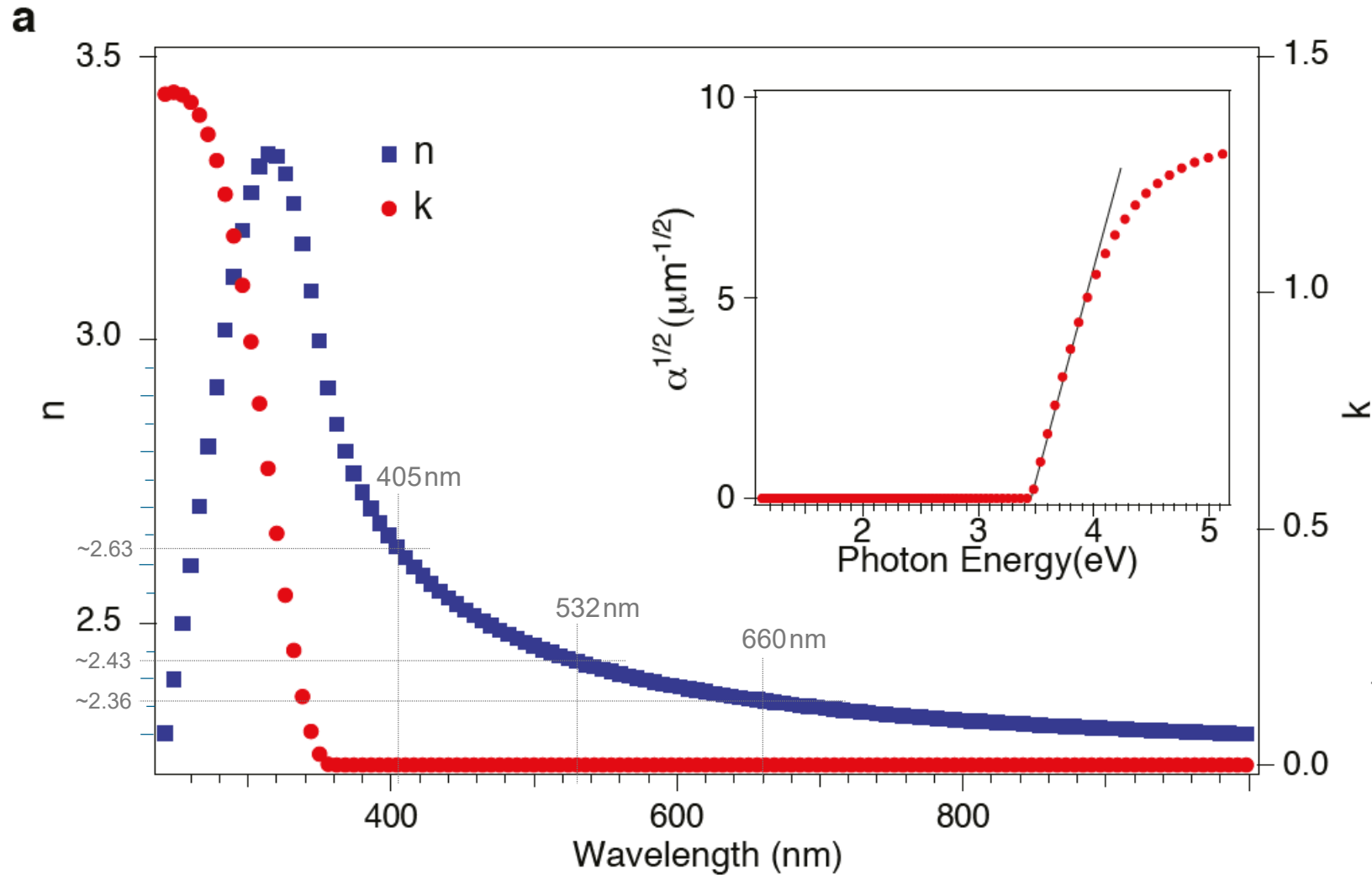


figure from R. C. Devlin, M. Khorasaninejad, W.-T. Chen, J. Oh, F. Capasso, arXiv:1603.02735 (2016)

# Peek into VirtualLab Fusion

flexible pillar structure definition

The screenshot displays two windows from the VirtualLab Fusion interface. The top window, titled "Edit Stack", shows a 3D stack of layers. A green rectangular layer is highlighted, with a vertical label "Base Block" and a small 3D coordinate system (x, y, z) next to it. Below the stack is a table with columns: Index, z-Distance, z-Position, Interface, Subsequent Medium, and Comments. The table contains two rows of data.

Index	z-Distance	z-Position	Interface	Subsequent Medium	Comments
1	0 mm	0 mm	Plane Interface	Non-Dispersive Materi	Enter your comment
2	600 nm	600 nm	Programmable Interfac	Air in Homogeneous M	Enter your comment

The bottom window is the "Source Code Editor", showing a C# code snippet for defining a pillar structure. The code includes comments and logic for calculating the radial distance and setting the height of the pillar based on its diameter.

```
1 double height = 0.0;
2
3 // convert to radial distance
4 double rho = Math.Sqrt(x * x + y * y);
5 if(rho <= 0.5 * Diameter)
6 {
7     height = Height;
8 }
9
10 return height;
```

Parameter list on the right side of the code editor:

- ApertureDiameterX [double]
- ApertureDiameterY [double]
- x [double]
- y [double]
- Diameter [double]
- Height [double]

customized structure  
via programming

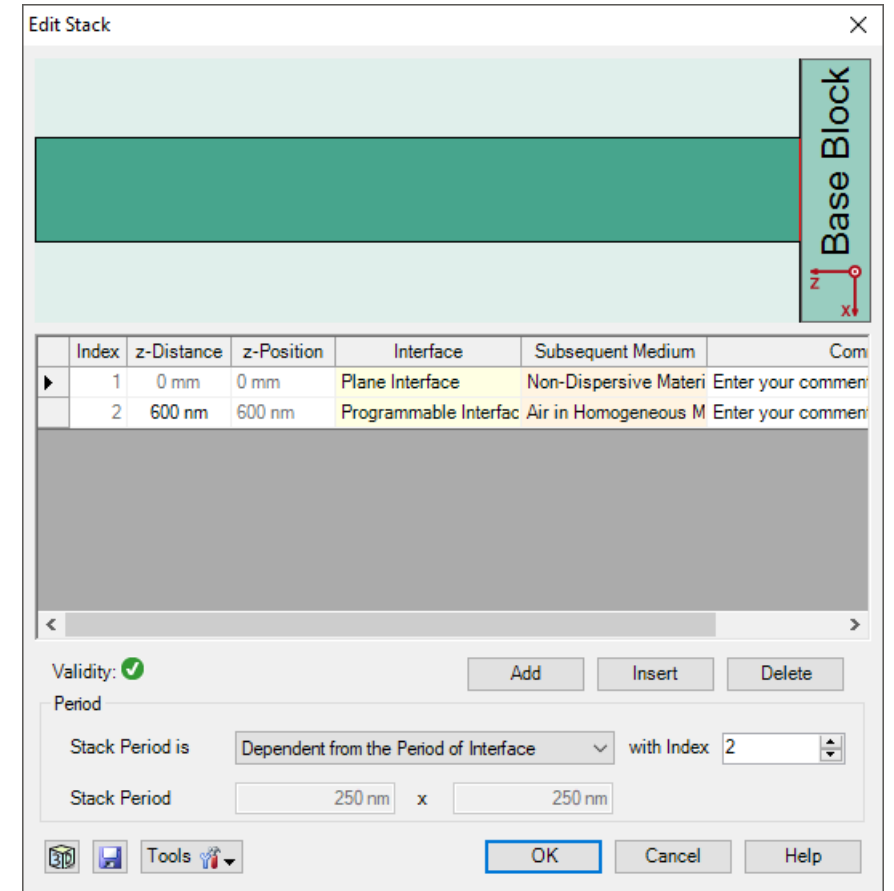
The screenshot displays two windows from the VirtualLab Fusion interface. The left window is the "Edit Grating Order Analyzer" dialog box, showing settings for the "Single Orders" tab. The "Order Selection Strategy" is set to "Order Range", with "Minimum Order" and "Maximum Order" both set to 0. The "Coordinates" section has "Spherical Angles" and "Cartesian Angles" unchecked. The "Efficiencies" section has "Ex" and "Ey" checked, and "Ez" unchecked. The "Rayleigh Coefficients" section has "TE" and "TM" unchecked.

The right window is a "Numerical Data Array" plot titled "8: Analysis of Nanopillar @532nm". The plot shows "Amplitude [V/m]" on the left y-axis (ranging from 0.2 to 0.8) and "Phase [rad]" on the right y-axis (ranging from -3 to 3). The x-axis is "Diameter (Nanopillar @532nm #1 | Stack #1 (Progr... [μm])" (ranging from 0.12 to 0.2). A black line represents the Amplitude, which is relatively flat around 0.8 V/m. A red line represents the Phase, which increases linearly from approximately -2.5 rad at 0.12 μm to 2.5 rad at 0.2 μm.

access to full vectorial  
and complex-valued  
information

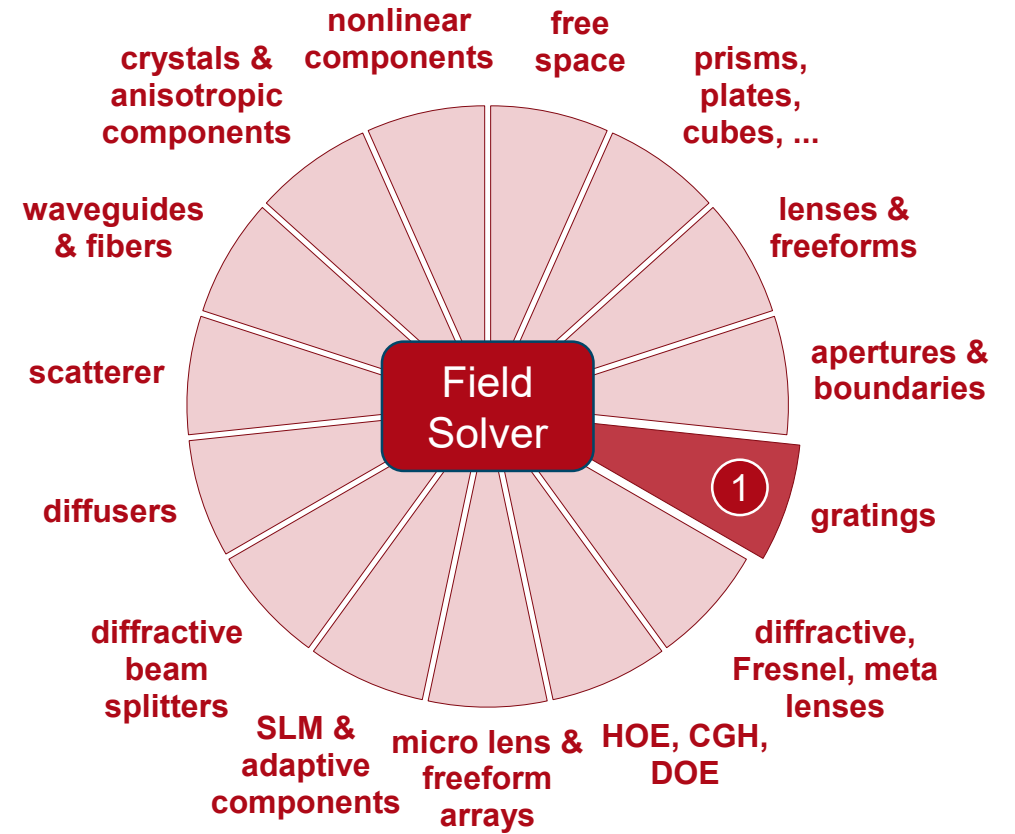
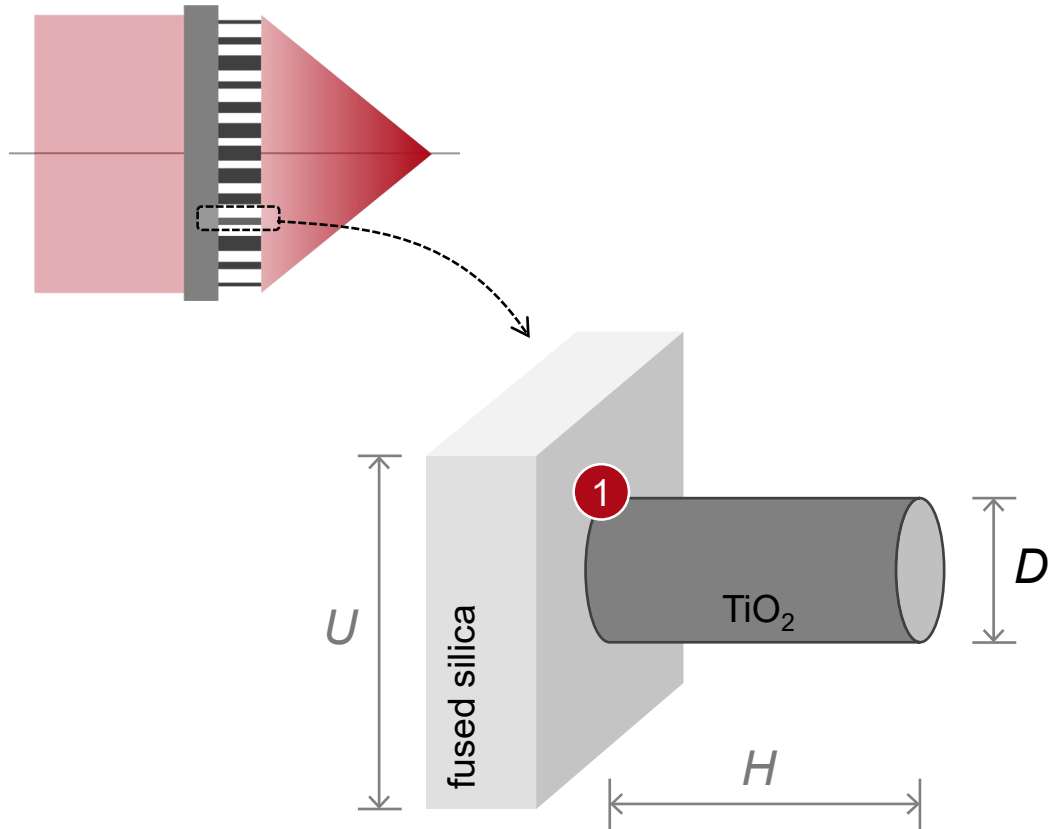
# Workflow in VirtualLab Fusion

- Construct grating structure
  - [Configuration of Grating Structures by Using Interfaces](#) [Use Case]
  - [Configuration of Grating Structures by Using Special Media](#) [Use Case]
- Analyze grating diffraction efficiency
  - [Grating Order Analyzer](#) [Use Case]
- Check influence from specific parameters with Parameter Run
  - [Usage of the Parameter Run Document](#) [Use Case]





# VirtualLab Fusion Technologies



# Document Information

title	Rigorous Analysis of Nanopillar Metasurface Building Block
document code	GRT.0012
version	1.0
toolbox(es)	Grating Toolbox
VL version used for simulations	7.4.0.49
category	Application Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#">Ultra-Sparse Dielectric Nano-Wire Grid Polarizers</a></li><li>- <a href="#">Investigation of Polarization State of Diffraction Orders</a></li><li>- <a href="#">Rigorous Analysis and Design of Anti-Reflective Moth-Eye Structures</a></li></ul>