

### **Metagrating Construction – Discussion at Examples**

#### Abstract



Metagratings, which are usually composed of nanopillars with spatially varying parameters, are shown to have superior performance in comparison to traditional gratings. Such gratings can be set up in VirtualLab Fusion with the help of the pillar medium and, in this example, we show how to properly configure the metagrating setups. That includes the configuration of media, materials, the pillar geometry, and the spatial distribution of the pillars. Additional hints on the setting of the number of spatial frequencies are also given.

## **Metagrating Construction and Modeling**

VirtualLab Fusion provides:

- Pillar Medium (General) for the construction of metagratings and other similar structures to arrange the distribution of circular/rectangular nanopillars;
- Fourier modal method (FMM) for the rigorous analysis of the performance of the metagratings thus configured, in terms of diffraction efficiency, polarization sensitivity, and so on.

Sources Functions Catalogs Windows Optical Setup Tools	
Diffractive Fiber Gratings Interferometry Microscopy Witual and More Calculate	s Diffractive Gratings Laser Light Light Quides Sharing Update Information
Focus Topics & Calculators	2D Gratings License
	General Grating Optical Setup
	Rectangular Grating Optical Setup
dit Pillar Medium (General)	Sawtooth Grating Optical Setup
Racio Parametero Contina Derindination	Sinusoidal Grating Optical Setup
Scaling renouzation	Triangular Grating Optical Setup
Embedding Material	Slanted Grating Optical Setup
Name Air	Volume Grating Optical Setup
Catalog Material 🗸 🖉	Programmable Grating Optical Setup
State of Matter Gas or Vacuum	Sampled Grating Optical Setup
	Transition Point List Grating Optical Setup
Pillar Material	3D Gratings
Name Fused_Silica	General Grating Optical Setup
Catalon Material	Metagrating Optical Setup
	Pillar Grating Optical Setup
State of Matter Solid V	LLGA Results
Pillar Geometry Pillar Distribution	K LLGA Results Generator
Height 500 pm	
Side Wall Slope Angle 88	
Shape O Squared O Circular	
Definition Mode of Diameters Half Height ~	
Round Edges Rounding via Diameter Percentage	

## **Media around Grating Component**

- The media in front of and behind the grating are set in the optical setup editor.
- These media have to be configured according to the actual situation under investigation.
- As a convention for grating efficiency analysis, the Fresnel loss between the substrate and the surrounding medium is usually neglected (meaning that the medium of the substrate of the structure and the medium behind it should be the same).



## **Materials inside Grating Stack**

- The metagrating stack is constructed with the *Pillar Medium (General)* and two plane interfaces that sandwich the medium from both sides.
- In the configuration dialog of the *Pillar Medium (General)*, there are two materials to configure: the material for the pillars, and the material that will fill the space between them.
- Both of these materials are configured independently from any other materials in the system. This means that achieving a correct description of the physical reality (where the embedding medium coincides with the medium filling the space between the pillars) is the responsibility of the user.



## **Single Pillar Geometry Configuration**

Edit Pillar I	Medium	ı (Genera	I)				>
Basic Para	ameters	Scaling	Periodization				
Embed	lding Ma	terial					
Name	Air						9
Catalo	og Materi	ial					~ 🥖 📔
	State of	of Matter	Gas or Va	acuum			~
- Pillar N	Naterial –						
Name	Non-[	Dispersive	e Material (n=2	2.3)			Q
Define	ed by Co	nstant Ref	fractive Index				~ 2.3
	State of	of Matter	Solid		al	l pillars	with the
Pillar G	ieometry	Pillar Dis	stribution			same h	eight.
Hei	ght			54	45 nm		
Sid	e Wall S	lope Angl	e		86°		
Sha	аре			O Squared		Oircular	
Def	inition M	lode of Di	ameters	Half Height	~		
	Round 8	Edges		Bottom Half Height		meter Percentag	e
Edg	ge Radiu	is (Bottom	)	10 nm Ed	ge Rad	dius (Top)	10 nm
l r	oun	a ed	ges tor	e.g.			
tole	eran	ce c	onside	rations			



## **Distribution of Pillars**

Define	d by Constant Refrac	tive Index		~ 3.8
	State of Matter	Solid		$\checkmark$
Pillar G	eometry Pillar Distrib	oution		
	x-Position	y-Position	Diameter	<u>^</u>
1	-800 nm	-800 nm	211 nm	
2	-800 nm	-400 nm	238 nm	
3	-800 nm	0 mm	240 nm	
4	-800 nm	400 nm	210 nm	
5	-800 nm	800 nm	202 nm	
6	-400 nm	-800 nm	207 nm	
7	-400 nm	-400 nm	251 nm	
8	-400 nm	0 mm	143 nm	
9	-400 nm	400 nm	187 nm	
10	-400 nm	800 nm	196 nm	
11	0 mm	-800 nm	205 nm	~
< 1	2	100	105	>
Table	Tools 🎢 🚽	mport Diameter Data	;	add pillars by imported
F	Add Pillar	odd o	oingle piller men	u ollu
	Demous Connet Dill		i single pillar man	lually
~	Remove Current Pill	ar Dei		
3	Reset		OK Cancel	Help
	Add Equidistant Pilla	irs_ <b>&lt;</b>	<ul> <li>add pillars on a</li> </ul>	an equidistant grid
	a character and a second state of the second	-		

- The lateral position (x, y) and diameter of each pillar in the distribution (in the period of the metastructure) can be freely configured.
- There are several ways to do this:
  - pillar by pillar, manually;
  - on an equidistant grid all at once;
  - using an imported array containing the data that defines the lateral position and diameter of each pillar.
- Pillar positions can be arbitrarily varied either directly, or as deviations from their original positions.

## **Numerical Parameter Setting**

- To obtain a convergent result from the FMM/RCWA simulation, a high enough number of spatial frequencies must be used.
- For metagratings (which are usually composed of an array, 1D or 2D, of pillars) we recommend performing a convergence test to ensure numerical convergence of the algorithm.
- For 1D metagratings (e.g. blazed metagrating), the required number of spatial frequencies should be checked separately for the x and y directions.



### **Example #1: One-Dimensional Blazed Metagrating**

## **Configuration of Materials and Media**



see the full Application Use Case

	St	art Element				Target El
Index	Element Name	Ref. Type	Me	dium	Index	Eleme
0	Ideal Plane Wave	-	Air in Homog	eneous Medi	1	Blazed Ma
1	Blazed Metagrating	Т	Non-Dispersi	ve Material (		

The medium behind grating is set the same as the glass substrate, with n=1.52.



The pillar material is set with n=2.3 for  $TiO_2$  at the given wavelength.

## **Pillar Geometry and Distribution**



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

## **Number of Spatial Frequencies**



Edit General Grating	g 3D Component			×
21 -	Propagation Methods Advanced S	ettings		
Coordinate Systems	Component Propagation Fourie	r Modal Method	✓ 📝 Edit	
	Interface	Stack	Medium	
1	Plane Interface	Stack	Non-Dispersive Material (	
	Fourier Modal Metho $\smallsetminus$	Fourier Modal Metho ${\scriptstyle \lor}$	Fourier Modal Metho $\smallsetminus$	
Position / Orientation	2 Plane Interface Fourier Modal Metho ~	Stack	Non-Dispersive Material (	
Structure		Fourier M	lodal Method	×
Tiopagauon		Parame Num Num Num	ters to Specify nber of Diffraction Orders nber of Evanescent Orders	(ere)
In the	FMM calculation,	more	isidening Air Propagating Ord	lers)
spatia along t grating p	al frequencies are he x direction sinc eriod along x is 5 t	used Number e the Number imes Of	of Diffraction Orders X of Diffraction Orders Y Cancel	25 ÷
	that along v dire	ction.		

# Example #2: Two-Dimensional Beam-Splitting Metagrating

## **Configuration of Materials and Media**



The medium in front of the grating is set equal to the substrate, with n=1.5, and, in this way, the incident light is assumed to come from inside the substrate.

## **Pillar Geometry and Distribution**



title	Metagrating Construction – Discussion at Examples
document code	GRT.0022
version	1.1
edition	VirtualLab Fusion Advanced
software version	2023.1 (Build 1.556)
category	Feature Use Case
further reading	<ul> <li><u>Configuration of Grating Structures by Using Interfaces</u></li> <li><u>Configuration of Grating Structures by Using Special Media</u></li> <li><u>VirtualLab Fusion Technology – FMM / RCWA [S-Matrix]</u></li> </ul>