

Advanced modelling of gratings in VirtualLab software

Site Zhang, development engineer Lignt Trans

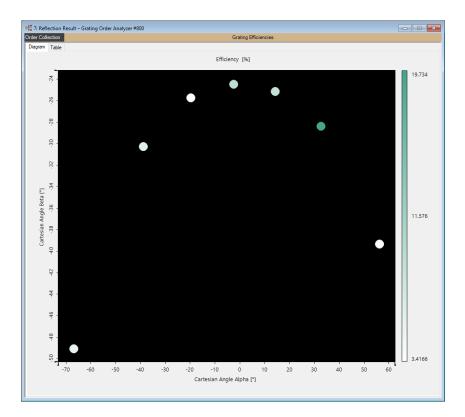


Content

1Grating Order Analyzer
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3Coupled Surfaces Analysis by Using Non-sequential Field Tracing
4Parametric Optimization and Tolerance Analysis of Slanted Gratings

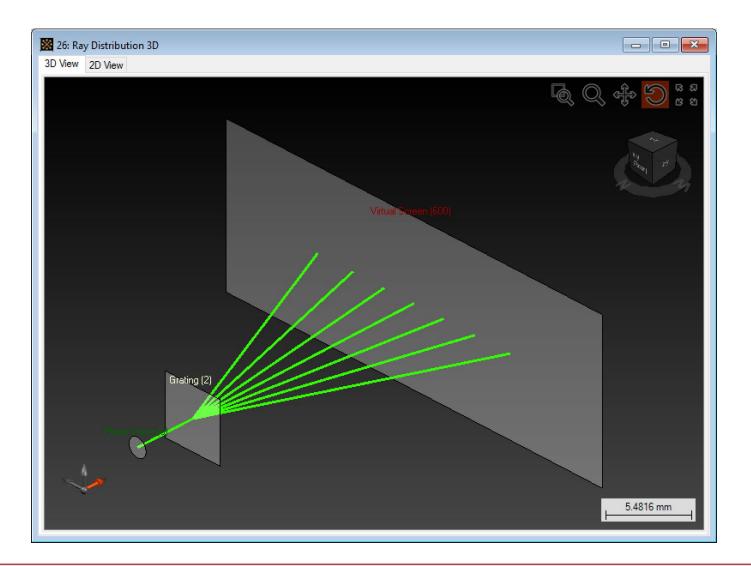


Abstract



The analysis of the diffraction efficiencies of gratings is the typical modeling task with gratings. The efficiencies follow from the Rayleigh coefficients. Both quantities are given for each of the diffraction orders of a grating. VirtualLab Fusion enables the calculation of efficiencies and Rayleigh coefficients by the fully vectorial Fourier modal method (FMM). This is done by the Grating Order Analyzer, which can display the efficiencies and Rayleigh coefficients of the distinct orders in various ways.

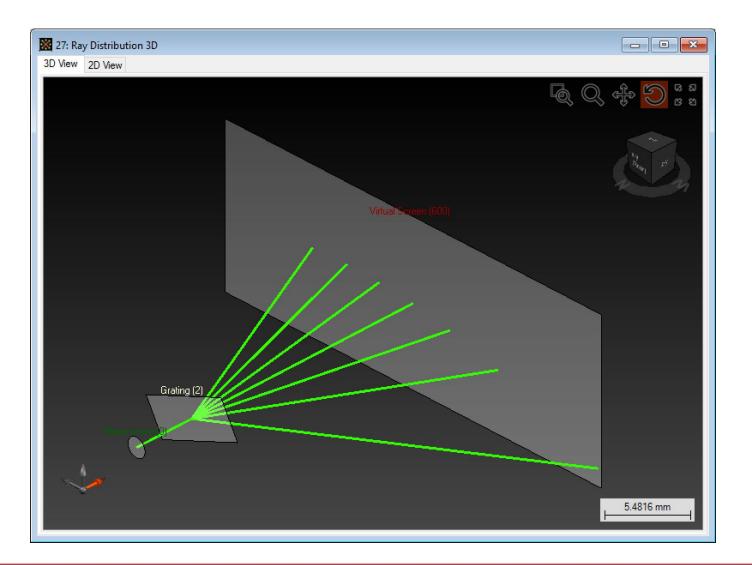
Discrete Orders Generated by a Grating



Grating Orders

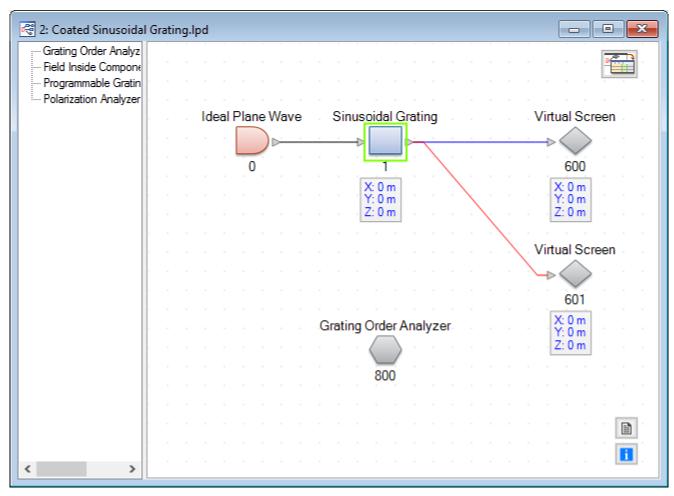
- When a grating is illuminated with a laser beam, it generates a set of discrete orders depending on the period.
- The deflection of the grating orders is defined by the twodimensional grating equation.
- The grating structure as well as the incident light determine the efficiencies of the orders.
- The efficiencies can be calculated by the Fourier modal method available in VirtualLab.
- If a linear grating is illuminated under an angle (conical incidence) the scattered orders of the grating are in general not distributed on a straight line.
- This is also included in the simulation of grating systems in VirtualLab.

Conical Incidence on a Grating



Applied VirtualLab Techniques and Tools

Sample File



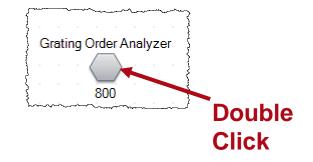
Filename: Coated Sinusoidal Grating.lpd

Grating Specification

Edit Stack					×
					J Base Block
Index	z-Distance	z-Position	Interface	Subsequent Medium	
) 1	0 m	0 m	Sinusoidal Grating I P 🕅	Silicon_Dioxide-SiO2-	Enter your com
2	107.31 nm	107.31 nm	Sinusoidal Grating Inte	Titanium_Dioxide-TiO	Enter your com
3	69.392 nm	176.7 nm	Sinusoidal Grating Inte	Silicon_Dioxide-SiO2-	Enter your com
4	107.31 nm	284.01 nm	Sinusoidal Grating Inte	Titanium_Dioxide-TiO	Enter your com
5	69.392 nm	353.4 nm	Sinusoidal Grating Inte	Silicon_Dioxide-SiO2-	Enter your com
6	107.31 nm	460.72 nm	Sinusoidal Grating Inte	Titanium_Dioxide-TiO	Enter your com
7	69.392 nm	530.11 nm	Sinusoidal Grating Inte	Silicon_Dioxide-SiO2-	Enter your com 🗸
<					>
Validity: Period	✓ Period is	Dependent	from the Period of Interfa	Add Insert	Delete
Stack			2 µm	OK Cancel	Help

- For the demonstration of the Grating Order Analyzer for 1D gratings we use a coated sinusoidal grating.
- The grating parameters can be specified within the stack that can be accessed in the edit dialog of the grating component.

- After the grating structure has been defined you can configure the grating order analyzer.
- Various output options can be specified.
- This is done through the edit dialog of the analyzer which is opened by double clicking on the light path element in the light path view.



 The options of the analyzer will be explained in the following slides.

Edit Grating Order Analyzer X
General Single Orders
Calculated Order Collections
Other Output
Summed Transmission, Absorption, and Reflection
✓ Polar Diagram in x-z-Plane
OK Cancel Help

- In the General tab page you can select whether transmission and/or reflection shall be analyzed.
- In addition you can specify whether you would like to evaluate the summed transmission, absorbtion and reflection values and whether you would like to show a polar diagram.

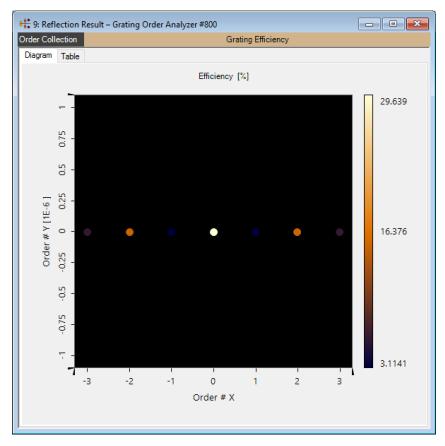
Edit Grating Order Analy	zer	×
General Single Orders		
Single Order Out	put	
Order Selection Strate	egy	
Selection Strategy	Order Range	\sim
	X Y	
Minimum Order	-1 🚖	0 ≑
Maximum Order	0 🜩	0 ≑
Coordinates		
Spherical Angles	Cartesian Angl	es
Wave Vector Cor	mponents Positions	
Efficiencies		
- Rayleigh Coefficients		
	Ey 🗌	Ez
TE	TM	
[OK Cancel	Help

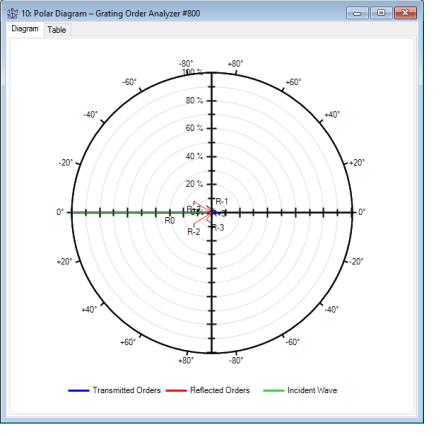
- In the Single Orders tab you can select whether information for single orders shall be logged.
- This option is very helpful if you would like to use the parameter run or the parametric optimization of VirtualLab to analyze and optimize specific orders of a grating.

Options for Single Order Output

Parameter	Description
Order Selection Strategy	The user can define which order shall be evaluated. The user can define whether to analyze All orders, analyze only those orders which have an efficiency Above a Given Threshold or calculate only orders in a manually defined Order Range . Depending on the selection strategy the user has to define additional parameters.
Coordinates	Logging of the coordinates of the orders is also supported. The user can specify whether to show the coordinates in Spherical Angles , Cartesian Angles , Wave Vector Components or Positions . For the Position calculation a z- distance between the grating and the screen has to be specified.
Efficiencies	The user can select whether efficiencies shall be logged.
Rayleigh Coefficients	In addition it is possible to log the Rayleigh coefficients. The user can select to show the coeffient E_x , E_y , E_z , TE or TM.

Grating Order Analyzer – Outputs





Grating Order Collection

Polar Diagram

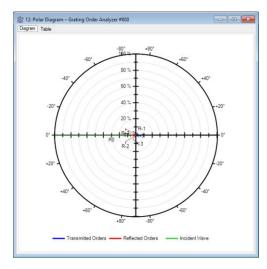
Grating Order Analyzer – Outputs

	Date/Time	Detector	Sub - Detector	Result
14			Spherical Angle Theta R[-1; 0]	15.422°
13			Spherical Angle Phi R[-1; 0]	0°
12			Efficiency R[-1; 0]	3.1141 %
11			Amplitude of Rayleigh coefficient Ex R[-1; 0]	173.26 mV/m
10	0000000000000000000	Grating Order Analyzer #800	Phase of Rayleigh coefficient Ex R[-1; 0]	3.0575 rad
9	02/02/2016 09:35:15	(Results for Individual Orders)	Spherical Angle Theta R[0; 0]	0°
8			Spherical Angle Phi R[0; 0]	0°
7			Efficiency R[0; 0]	29.639 %
6			Amplitude of Rayleigh coefficient Ex R[0; 0]	544.42 mV/m
5			Phase of Rayleigh coefficient Ex R[0; 0]	1.4436 rad
4		Grating Order Analyzer #800	Overall Reflection Efficiency	78.661 %
3	02/02/2016 09:35:15	(Results for Individual Orders) Grating Order Analyzer #800	Overall Transmission Efficiency	21.339 %
2	02/02/2016 05:35:15	Grating Order Anaryzer #000	Overall Reflection and Transmission Efficiency	100 %
1			Absorption	0 %

- If the Grating Order analyzer is processed within the Light Path Diagram, the single order output values are logged into the detector results tab.
- These values are also available in the parameter run and the parametric optimization.

Grating Order Output: Polar Diagram

Polar Diagram

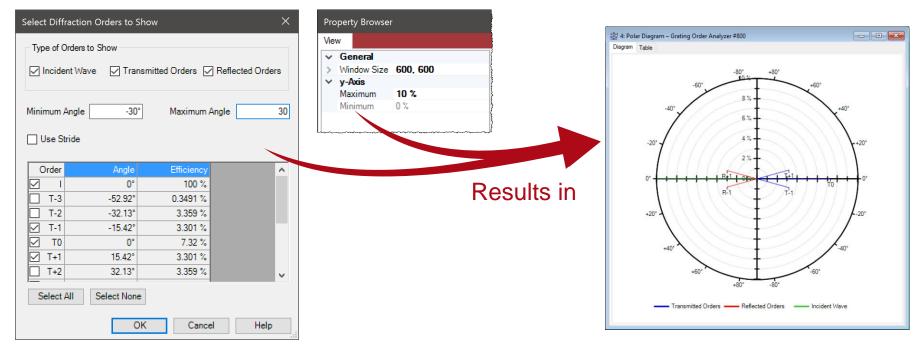


Order	Angle	Efficiency
l –	0°	100 %
T-3	-52.919°	0.34913 %
T-2	-32.131°	3.3594 %
T-1	-15.422°	3.3009 %
т0	0°	7.3204 %
T+1	15.422°	3.3009 %
T+2	32.131°	3.3594 %
T+3	52.919°	0.34913 %
R-3	52.919°	6.2033 %
R-2	32.131°	15.194 %
R-1	15.422°	3.1141 %
R0	0°	29.639 %
R+1	-15.422°	3.1141 %
R+2	-32.131°	15.194 %
R+3	-52.919°	6.2033 %

- The polar diagram output of the Grating Order Analyzer plots the efficiencies of both the reflected and the transmitted orders versus the angles in the x-zplane.
- It also provides a table of all angles and efficiencies of the displayed orders.

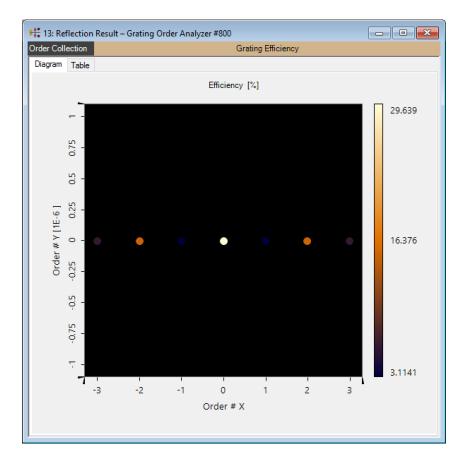
Configuring the Polar Diagram

- You can zoom into the polar diagram with the mouse wheel, the Property Browser and the ribbon.
- You can configure which orders are shown by rightclicking on the diagram.



Grating Order Output: Order Collection

Grating Order Collection



- The Grating Order Collection object is used to visualize the calculated grating efficiencies or the Rayleigh coefficients over different coordinates.
- The user can configure the data that shall be shown by setting diverse options via the property browser.

Setup of Data to Show

Data to Sho				
Sata to ono	View	Data Array	Selections	
✓ Gener				
	ate Type		Order Number	
Data to			fficiency	
 Order Strateg 	Selection		Verse Efficien	au. Thurselad
	/ cy Thresh		1E-08 %	ncy Threshold
Lindidi	oy 11110011	ora	2 00 10	
Coordinat	туре			
The type of		nates		

- You can specify via the property browser which data shall be shown over which coordinates.
- In addition the user can select the order to be shown in the diagram.
- These settings are done on the Data to Show tab page of the property browser.

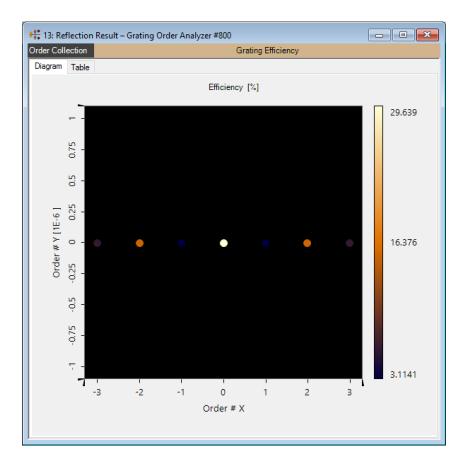
Option	Description
Coordinate Type	This property can be used to define the coordinates over which the data shall be visualized. Currently the order collection supports the visualization over Cartesian Angles , Spherical Angles , Wave Number Vectors and Positions .
Data to Show	It is possible to select the different data values that should be shown. The user can select to display the efficiency or the Rayleigh coefficient over the selected coordiante type. For Rayleigh coefficents E_x , E_y , E_z , TM and TE are supported.
Order Selection Strategy	The user can define which order shall be displayed. The user can define whether to show All , show only orders which have an efficiency Above a Given Threshold or show only orders for a manually defined Order Range . Depending on the selection strategy the user has to define additional parameters.

Setup of Additional View Settings

Property Browser	Ę
Data to Show View Data A	rray Selections
✓ General	
> Window Size	600, 600
✓ Aspect Ratio	
True To Scale	False
 Color Lookup Table Color Lookup Table 	Midnight Sun
Background Color	Black
- Data	Didek
Auto Scaling of Data	True
Format of color scale	Standard
✓ Labels	
Font Size	10
 Lines and Symbols 	
Dot Size	10
V X-Axis	[2 2 2 2]
 X-Axis Range Y-Axis 	[-3.3; 3.3]
 Y-Axis Range 	[-1.1E-06; 1.1E-06]
7 PAXIS Hange	
Dot Size	
The dot size for visualization	

- In the View tab page of the property browser the user can set up additional view parameters.
- Most important for the customization of the view are the color settings.
- The user can select the background color for the view as well as the color lookup table that shall be used to define the colors for the displayed data values.

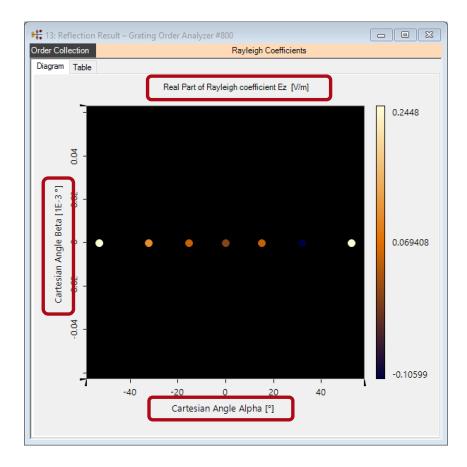
Example of View Customization



Visualization

Dat	a to Show	View	Data Array	Selections	
v	General				
	Coordinate	е Туре	(Order Number	
	Data to Sh	ow	1	Efficiency	
\mathbf{v}	Order Selection Strategy				
	Strategy		1	bove Efficiency Thr	eshold
	Efficiency	Thresh	bld	1E-08 %	
	r ategy fines how th	ne range	of shown or	ders is determined.	

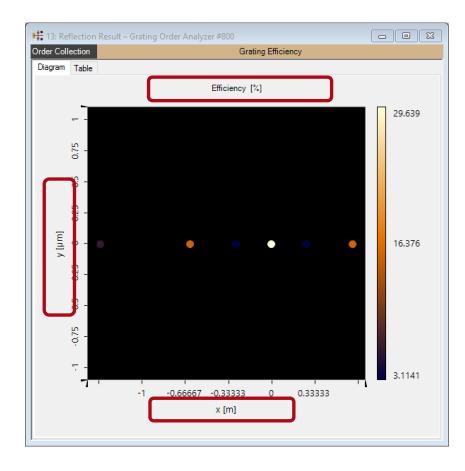
Example of View Customization



Visualization

Property Browser				
Data to Show Vie	ew Data Array	Selections		
✓ General				
Coordinate Ty	-	Cartesian A		
Data to Show		Rayleigh co	efficient Ez	
V Order Selec				
Strategy			ncy Threshold	
Efficiency Thr	resnold	1E-08 %		
Strategy				
Defines how the ra	ange of shown or	ders is deter	mined.	
Property Browser	r VirtualLab E	xplorer		

Example of View Customization



Visualization

Property Browser		
Data to Show View	Data Array Selections	
✓ General		
Coordinate Type	Position	
Distance	1 m	
Data to Show	Efficiency	
 Order Selection Strategy 	Order Range	
> Minimum Order	(-2; -3)	
> Maximum Order	(3; 3)	
	(=, =)	
Minimum Order The minimum shown o	order.	
Property Browser	VirtualLab Explorer	

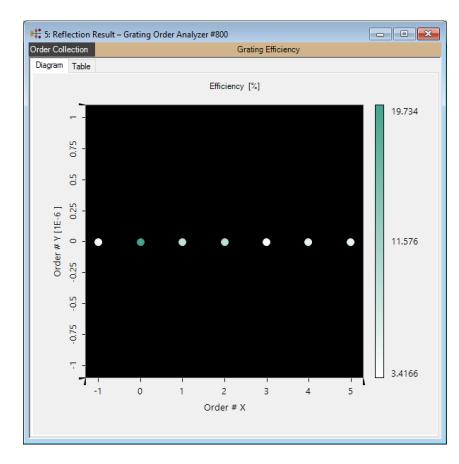
Visualization of Conical Incidence

Define Conical Incidence

Reference Output Channel Relative Distance on Axis Delta Z Un Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Spherical Angles Z-Axis Direction Definition	Reference Element 0: Ideal Plane Wave Reference Output Channel Relative Distance on Axis Delta Z Om Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Spherical Angles Y Theta (Spherical) ~ 40 Phi (Spherical) ~	Reference Element 0: Ideal Plane Wave Reference Output Channel Relative Distance on Axis Delta Z Om Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Spherical Angles Yalue Theta (Spherical) ~ Yalue Order Rotation About Z-Axis	Basal Position	ning Isolated Positioning Position	n Information (Absolute)	
Reference Output Channel Relative Distance on Axis Delta Z Om Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Spherical Angles Yalue Theta (Spherical) > 40° Phi (Spherical) >	Reference Output Channel Relative Distance on Axis Delta Z Om Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Synapt Theta (Spherical) × 40 Phi (Spherical) × 40 Phi (Spherical) × 40 Phi (Spherical) ×	Reference Output Channel Relative Distance on Axis Delta Z Om Lateral Shift Delta X Om Inclination / Rotation Orientation Definition Type Spherical Angles Y On Inclination / Rotation Orientation Definition Type Spherical Angles Y On Orientation Definition On On Orientation Definition Phi (Spherical) Value Phi (Spherical) App Rotation About Z-Axis				
Relative Distance on Axis Delta Z 0 m Lateral Shift Delta X 0 m Inclination / Rotation Orientation Definition Type Spherical Angles Y Content on Definition Y Content on Definition Y Content on Definition Y Y Swap Order ↓	Relative Distance on Axis Delta Z 0 m Lateral Shift Delta X 0 m Inclination / Rotation Orientation Definition Type Spherical Angles Z-Axis Direction Definition Year Inclination / Rotation Orientation Definition Year Image: Axis Value Theta (Spherical) × 40 Phi (Spherical) × 40 Phi (Spherical) × Attion About Z-Axis	Relative Distance on Axis Delta Z 0 m Lateral Shift Delta X 0 m Delta X 0 m Delta X 0 m Delta Y 0 m Delta Y 0 m Delta X 0 m Delta Y 0 m Delta X 0 m Delta X 0 m Delta Y 0 m Delta X 0 m Delta Y 0 m 2-Axis Direction Definition Image: Axis Value Theta (Spherical) ~ 40 Phi (Spherical) ~ 40 Phi (Spherical) ~ 40 Phi (Spherical) ~	Reference	e Element 0: Ideal Pl	ane Wave 🗸 🗸	
Delta Z 0 m Lateral Shift Delta X 0 m Delta Y 0 Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (##) Z-Axis Direction Definition Z-Axis Direction Definition Theta (Spherical) ✓ 40° Phi (Spherical) ✓ 40° Phi (Spherical) ✓ 40°	Delta Z 0 m Lateral Shift Delta X 0 m Delta Y 0 m Inclination / Rotation Orientation Definition Type Spherical Angles (;;;) Z-Axis Direction Definition Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) ~ 40 Phi (Spherical) ~ 40 Rotation About Z-Axis	Delta Z 0 m Lateral Shift Delta X 0 m Delta Y 0 m Inclination / Rotation Orientation Definition Z-Axis Direction Definition Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) ~ 40 Phi (Spherical) ~ 40 Phi (Spherical) ~ 40 Rotation About Z-Axis	Reference	e Output Channel -	\sim	
Lateral Shift Delta X 0 m Delta Y 0 Inclination / Rotation Orientation Definition Type Spherical Angles (##) Z-Axis Direction Definition Z-Axis Direction Definition Condent Swap Phi (Spherical) ~ 40 Phi (Spherical) ~	Lateral Shift Delta X 0 m Delta Y 0 n Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (iii) Z-Avis Direction Definition Z-Avis Direction Definition Angle / Axis Value Theta (Spherical) ✓ 40 Phi (Spherical) ✓ 40 Phi (Spherical) ✓ 40 Phi (Spherical) ✓ 40	Lateral Shift Delta X 0 m Delta Y 0 n Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (iii) Z-Avis Direction Definition Z-Avis Direction Definition Angle / Axis Value Theta (Spherical) ✓ 40 Phi (Spherical) ✓ 40 Phi (Spherical) ✓ 40 Phi (Spherical) ✓ 40	Relative D	Distance on Axis		
Delta X 0 m Delta Y 0 Inclination / Rotation Orientation Definition Type Spherical Angles (;;;) Z-Axis Direction Definition Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) ~ 40 Phi (Spherical) ~ 40	Delta X 0m Delta Y 0r Inclination / Rotation Orientation Definition Type Spherical Angles (##) Z-Axis Direction Definition Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) > 40 Phi (Spherical) > 40 Phi (Spherical) > 40 Rotation About Z-Axis	Delta X 0m Delta Y 0n Inclination / Rotation Vientation Definition Type Spherical Angles (##) Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) > 40 Phi (Spherical) > 40 Phi (Spherical) > 40 Rotation About Z-Axis	Delta Z		0 m	
Inclination / Rotation Orientation Definition Type Spherical Angles (iii) Z-Axis Direction Definition Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) Hi	Inclination / Rotation Orientation Definition Type Spherical Angles	Inclination / Rotation Orientation Definition Type Spherical Angles	Lateral Sh	ift		
Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (##)	Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (##) Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) ✓ 40° Phi (Spherical) ✓ 40° Rotation About Z-Axis	Inclination / Rotation Orientation Definition Type Spherical Angles ✓ (##) Z-Axis Direction Definition Angle / Axis Value Theta (Spherical) ✓ 40 Phi (Spherical) ✓ 40 Rotation About Z-Axis	Delta X	0 m	Delta Y	0 m
Orientation Definition Type Spherical Angles (##) Image: Construction Definition Z-Axis Direction Definition Image: Construction Definition Angle / Axis Value Image: Construction Definition Theta (Spherical) > 40° Swap Order Image: Construction Definition 40° 40°	Orientation Definition Type Spherical Angles (##) Image: Arge / Axis Value Image: Arge / Axis Value </td <td>Orientation Definition Type Spherical Angles (##) Image: Arge / Axis Value Image: Arge / Axis Value Image: Swap Order Phi (Spherical) 40° Phi (Spherical) 40° Phi (Spherical) 40° Rotation About Z-Axis 40°</td> <td>Inclination</td> <td>/ Rotation</td> <td></td> <td></td>	Orientation Definition Type Spherical Angles (##) Image: Arge / Axis Value Image: Arge / Axis Value Image: Swap Order Phi (Spherical) 40° Phi (Spherical) 40° Phi (Spherical) 40° Rotation About Z-Axis 40°	Inclination	/ Rotation		
Swap Order Phi (Spherical) 40*	Swap Order Rotation About Z-Axis	Swap Order Phi (Spherical) 4pr Rotation About Z-Axis	Orienta	tion Definition Type Spherical A	ngles v (iii)	
Swap Order 40	Swap Order Phi (Spherical) 4pt Rotation About Z-Axis	Swap Order Phi (Spherical) 4pt Rotation About Z-Axis		Z-Axis Direction Definition		
	Rotation About Z-Axis	Rotation About Z-Axis		Z-Axis Direction Definition	Value	
Z-Axis Rotation Angle 0°				Z-Axis Direction Definition Angle / Axis Theta (Spherical) V	Value 40°	
			n fi	Z-Axis Direction Definition Angle / Axis Theta (Spherical) ~ Phi (Spherical) ~ Rotation About Z-Axis	Value 40° 4p°	
			tion	Z-Axis Direction Definition Angle / Axis Theta (Spherical) ~ Phi (Spherical) ~ Rotation About Z-Axis	Value 40° 4p°	

- Within the positions and orientation definition of the grating the user can define an arbitrary orientation.
- This is done in the *Position / Orientation* tab within the edit dialog of the grating.
- For this use case we use
 Theta = 40° and Phi = 40°.

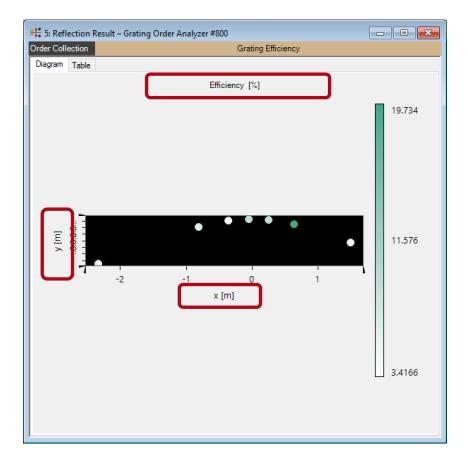
Result – Grating Efficiencies over Order Number



Visualization

Data to Show View Data Array Selections						
v	General					
	Coordinate Type Order Number Data to Show Efficiency					
\checkmark	Order Selection Strategy					
	Strategy		1	Above Efficiency Threshold		
	Efficiency	Thresh	old i	1E-08 %		
	rategy fines how th	ne range	of shown or	ders is determined.		

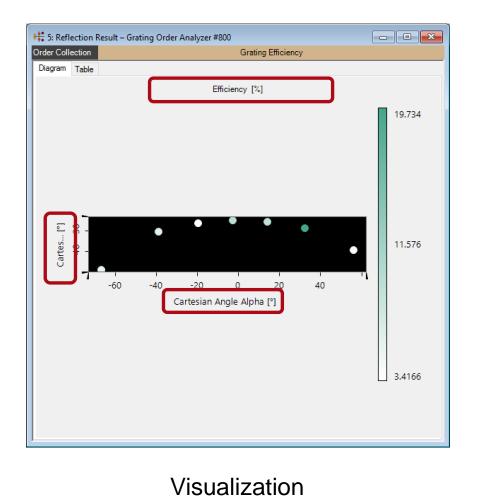
Result – Grating Efficiencies over Order Position



Visualization

Property Browser					
Data to Show View Data Array Selections					
✓ General					
	Coordinate Type Position				
	Distance 1 m				
Data to Show		ciency			
 Order Selection Strategy 		ove Efficiency Threshold			
Efficiency Thre		-08 %			
Coordinate Type					
The type of the coordinates.					
Property Browser VirtualLab Explorer					
Property Browser VirtualLab Explorer					

Result – Grating Efficiencies over Cartesian Angles



Property Browser				
Data to Show View	Data Am	ay Selection:	s	
✓ General				
	Coordinate Type Cartesian Angle			
	Data to Show Efficiency			
V Urder Selection		Laura FØCatana		
Strategy Efficiency Thres		bove Efficienc E-08 %	y Inreshold	
Eniciency miesi		E-00 %		
Coordinate Type				
The type of the coordinates.				
Property Browser	VirtualLa	b Explorer		
View Settings				

Result – Grating Efficiencies over Spherical Angles

Property Browser

✓ General

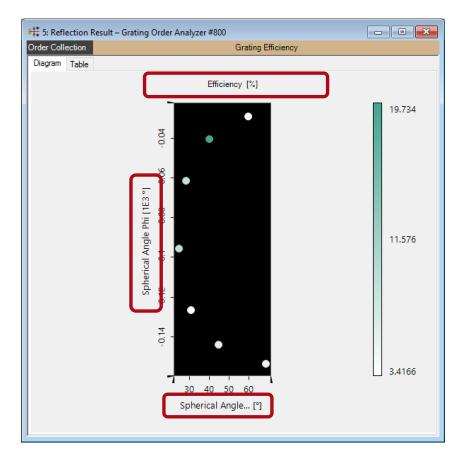
Data to Show View

Coordinate Type

V Order Selection Strategy

Data to Show

Strategy



Visualization

Efficiency Threshold 1E-08 %

Data Array Selections

Efficiency

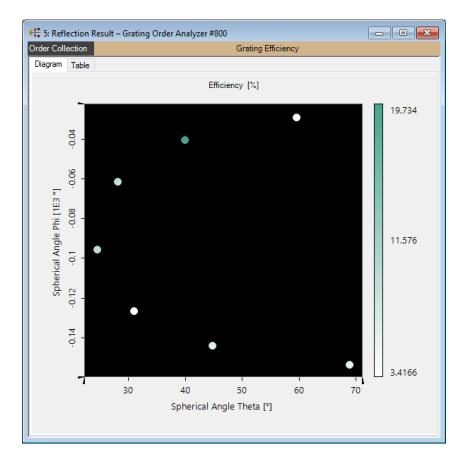
Spherical Angle

Above Efficiency Threshold

View Settings

31

Tips & Tricks: Aspect Ratio



Free Aspect Ratio

- Depending on the coordinate range which is displayed it could be helpful to change the aspect ratio of the data.
- The aspect ratio can be adapted via the property browser or via the corresponding ribbon entry:



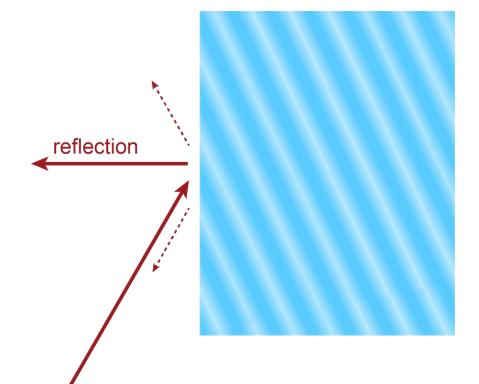
Document Information

title	Grating Order Analyzer
version	1.0
VL version used for simulations	7.0.3.4
category	Feature Use Case



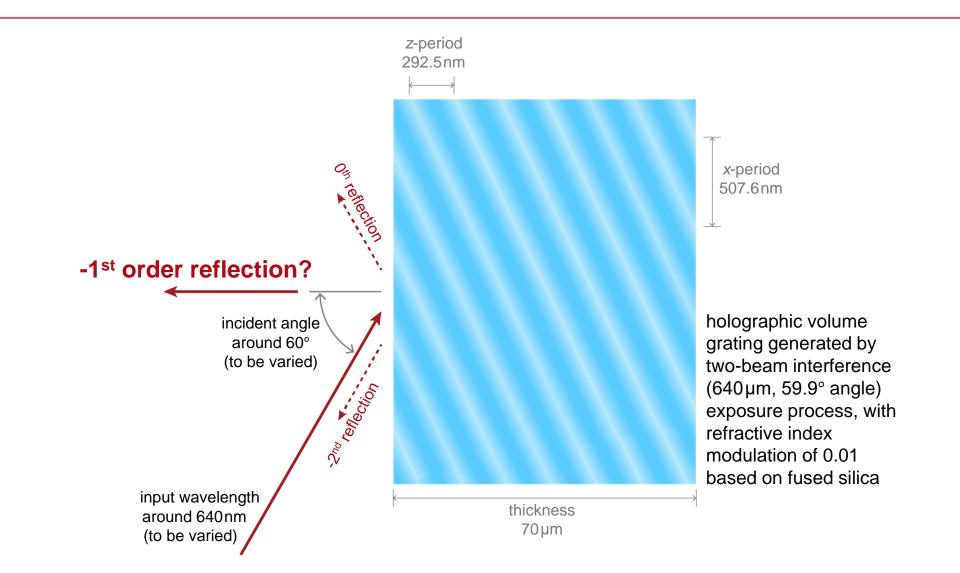
Rigorous Simulation of Holographic Generated Volume Grating

Abstract

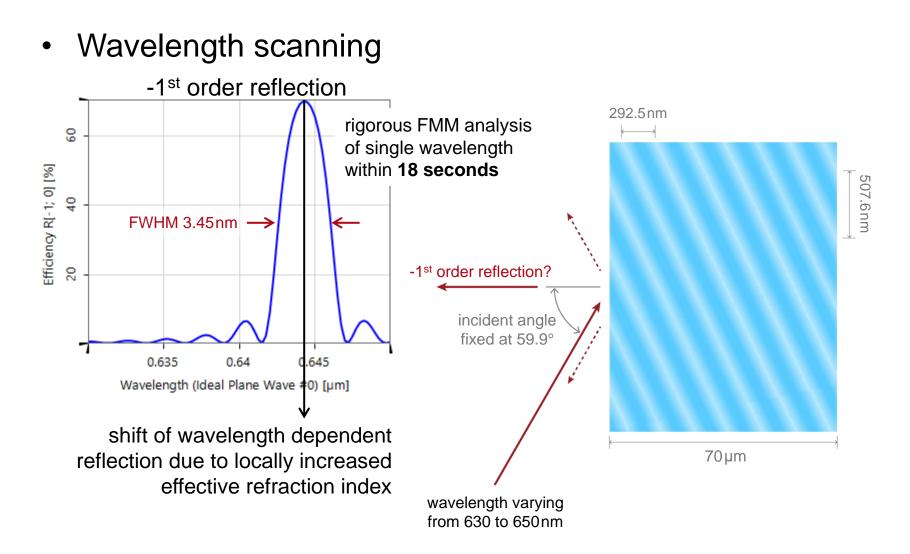


Holographic generated volume gratings, with a thickness much larger than the wavelength, often shows a narrow bandwidth around particular wavelength and angle. Following the two-beam interference exposure process, a volume grating inside fused silica is generated and simulated with the rigorous Fourier modal method (FMM) in VirtualLab. Both the spectral and angular dependent reflection property of the grating are analyzed.

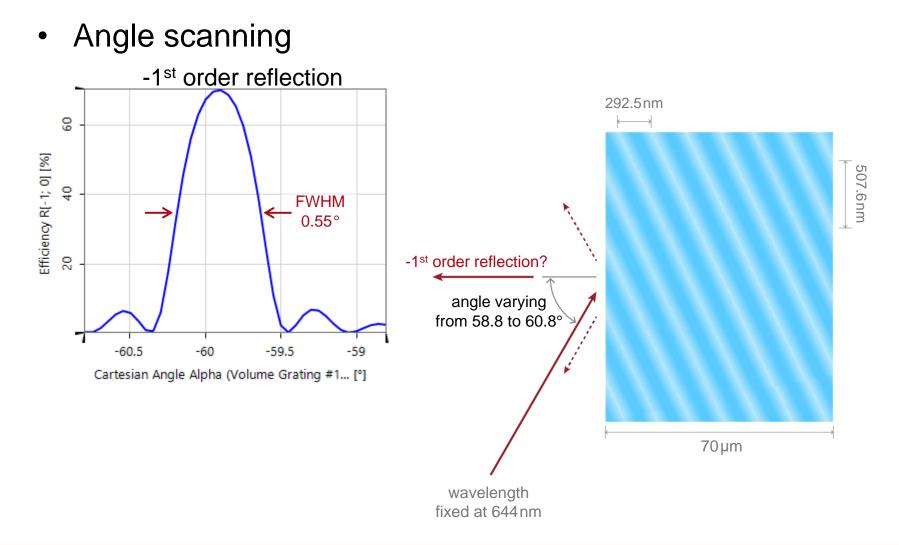
Modeling Task



Results



Results



Document Information

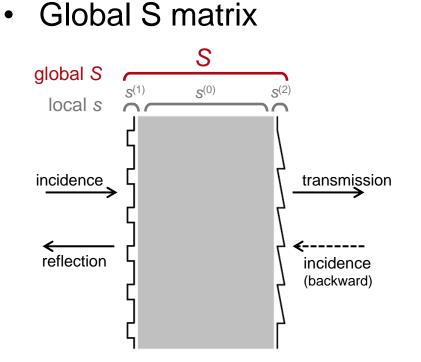
title	Rigorous Simulation of Holographic Generated Volume Grating
version	1.0
VL version used for simulations	7.0.3.4
category	Technology Use Case



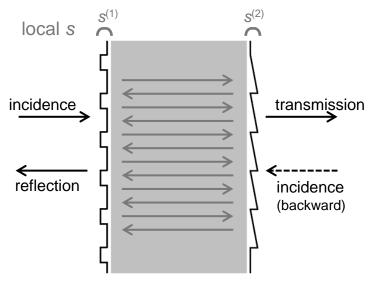
Non-sequential Field Tracing

Coupled Surfaces Analysis by Using Non-sequential Field Tracing

Theory Background



 Recursion with respect to number of regions / layers Non-sequential field tracing

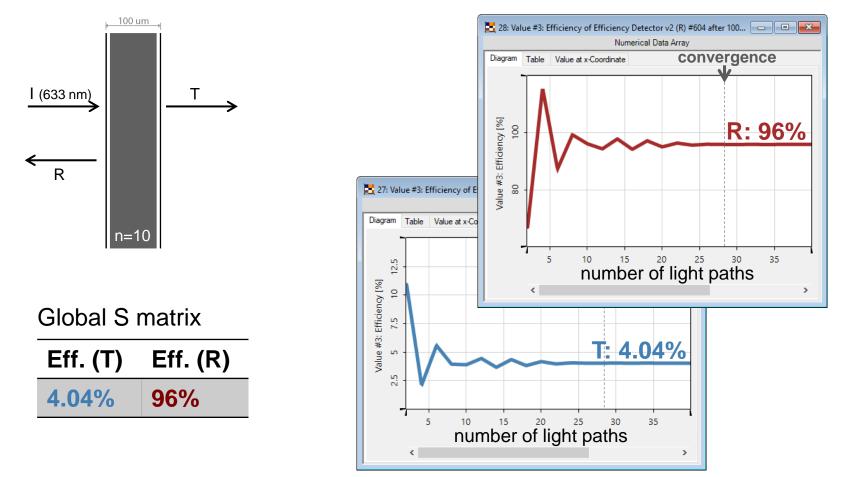


 Recursion with respect to number of light paths

Planar Surface + Planar Surface

• Structure

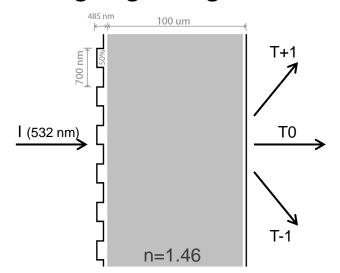
Non-sequential field tracing



www.LightTrans.com

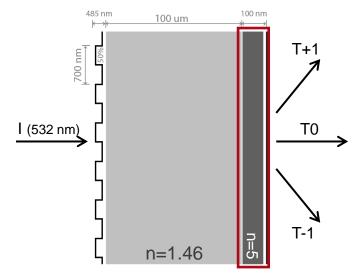
Rectangular Grating + Backside Coating

• Single grating



Global S matrix (TM)			
Т	Eff.	R	Eff.
<u>+</u> 1	31.9%	<u>+</u> 1	1.26%
0	30.6%	0	3.03%

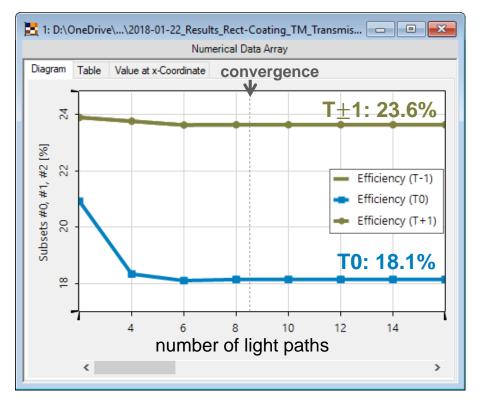
with backside coating



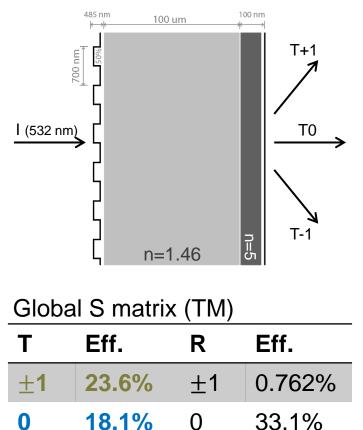
Global S matrix (TM)			
Т	Eff.	R	Eff.
<u>+</u> 1	23.6%	<u>+</u> 1	0.762%
0	18.1%	0	33.1%

Rectangular Grating + Backside Coating

Non-sequential field
 tracing

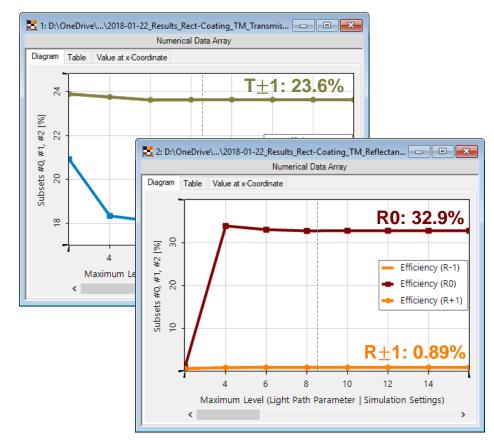


... with backside coating

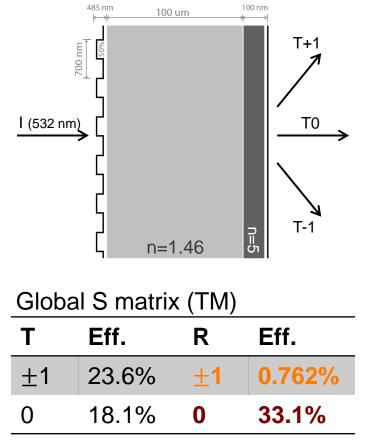


Rectangular Grating + Backside Coating

Non-sequential field
 tracing

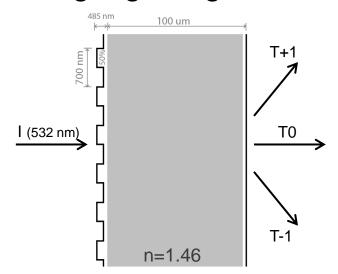


... with backside coating



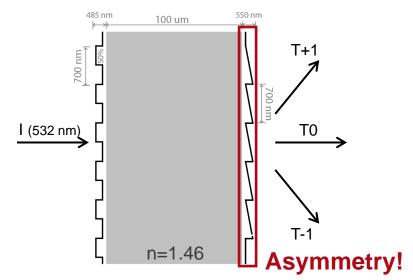
Rectangular + Sawtooth Grating (parallel)

• Single grating



Global S matrix (TM)			
Т	Eff.	R	Eff.
<u>+</u> 1	31.9%	<u>+</u> 1	1.26%
0	30.6%	0	3.03%

... with sawtooth coating

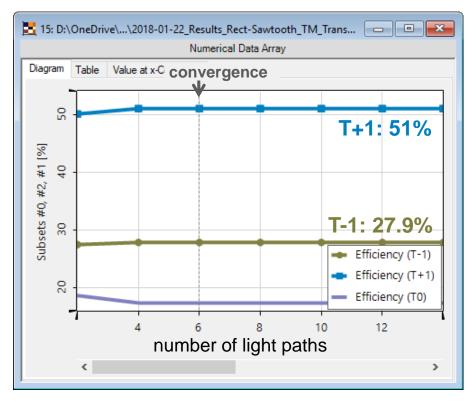


Global S matrix (TM)

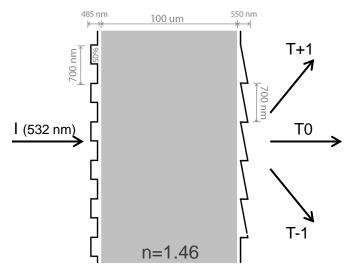
Т	Eff.	R	Eff.
-1	28.1%	-1	0.65%
0	18.2%	0	0.923%
+1	51.4%	+1	0.74%

Rectangular + Sawtooth Grating (parallel)

Non-sequential field
 tracing



... with sawtooth coating



Global S matrix (TM)

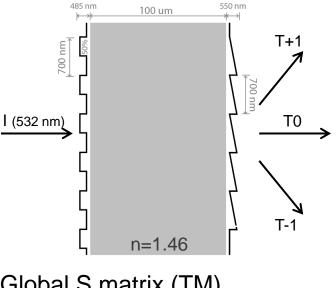
Т	Eff.	R	Eff.
-1	28.1%	-1	0.65%
0	18.2%	0	0.923%
+1	51.4%	+1	0.74%

Rectangular + Sawtooth Grating (parallel)

 Non-sequential field tracing



... with sawtooth coating

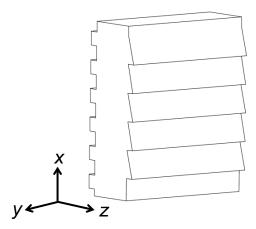


Global S matrix (TM)

Т	Eff.	R	Eff.
-1	28.1%	-1	0.65%
0	18.2%	0	0.923%
+1	51.4%	+1	0.74%

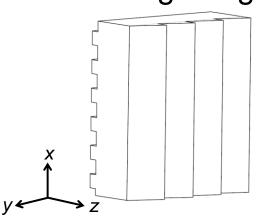
Computational Effort

• Parallel gratings



Global S matrix	Non-sequential field tracing
$\sim N^3$ (scaling with number of layers)	$\sim N^3$ (scaling with number of light paths)
with <i>N</i> as the number of diffracti used in calculation	on (evanescent included) orders

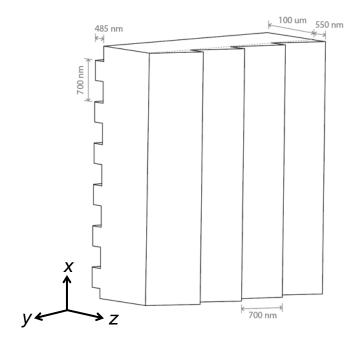
Crossed gratings

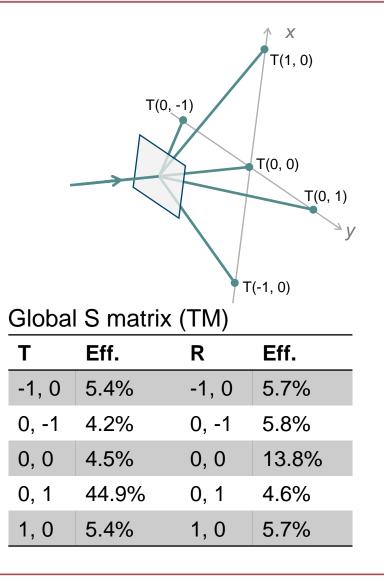


Global S matrix	Non-sequential field tracing
$\sim (N_{\chi} \times N_{\gamma})^{3}$ (scaling with number of layers)	$\sim (N_x^3 + N_y^3)$ (scaling with number of light paths)
with N_x and N_y as the number of included) orders in both direction	

Rectangular + Sawtooth Grating (crossed)

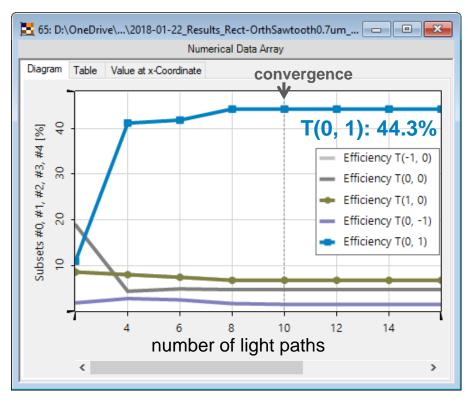
- Structure
 - Front: rectangular grating (along *x* direction)
 - Back: sawtooth grating (along *y* direction)

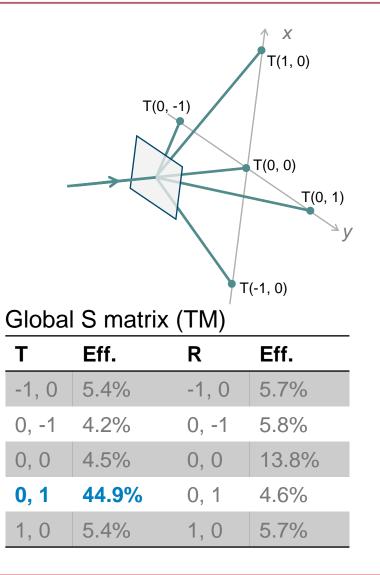




Rectangular + Sawtooth Grating (crossed)

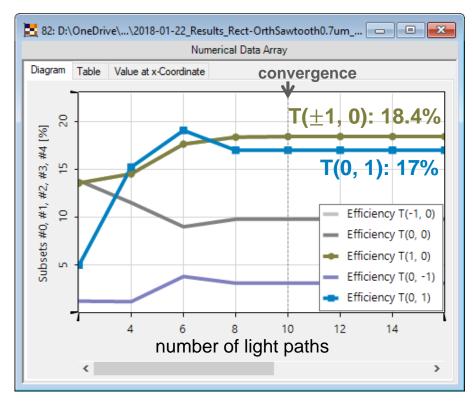
• Non-sequential field tracing (TM)

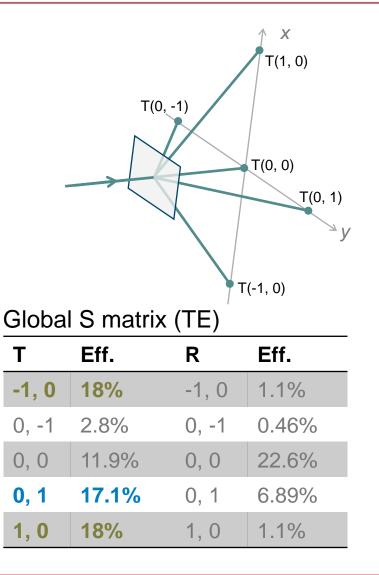




Rectangular + Sawtooth Grating (crossed)

 Non-sequential field tracing (TE) Polarization included!

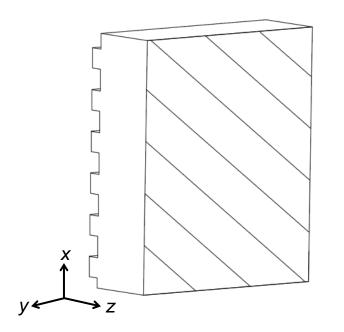


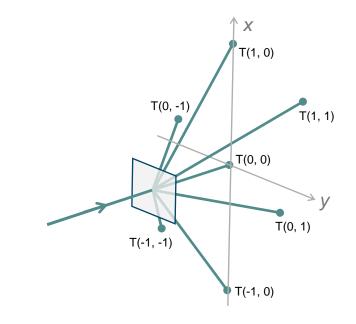


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Rectangular + Sawtooth Grating (45° rotated)

- Structure
 - Front: rectangular grating (along *x* direction)
 - Back: sawtooth grating (along *x-y* diagonal direction)





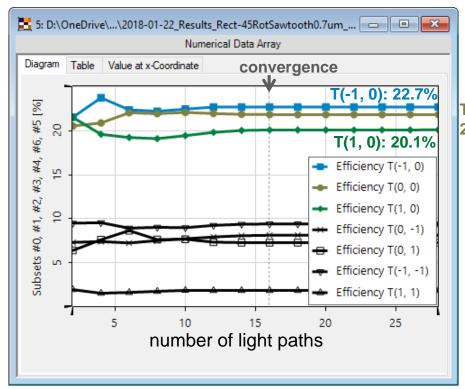
Global S matrix (TM)

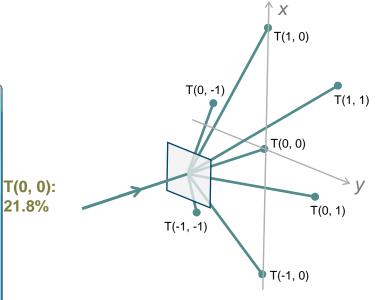
➔ No common period!

→ Huge computational effort even with approximated common period

Rectangular + Sawtooth Grating (45° rotated)

• Non-sequential field tracing (TM)





Global S matrix *NOT* possible!
→ No common period
→ Huge computational effort even with approximated common period

Document & Technical Info

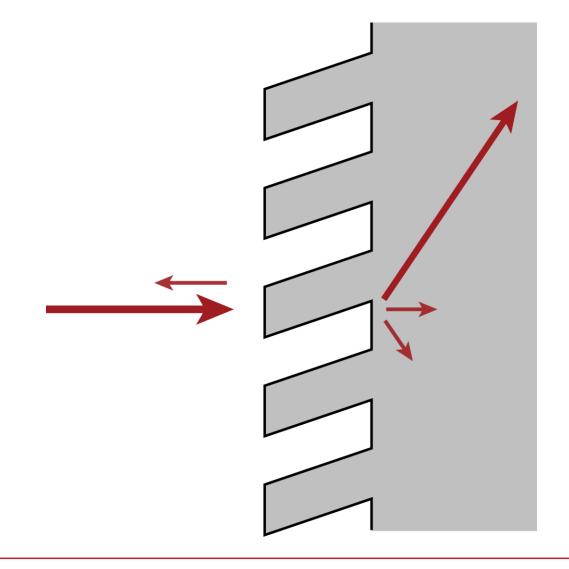
code	
version of document	1.0
title	Coupled Surfaces Analysis by Using Non-sequential Field Tracing
category	Non-sequential Field Tracing
author	Site Zhang (LightTrans)
used VL version	7.2.0.2

Specifications of PC Used for Simulation	
Processor	i7-4910MQ (4 CPU cores)
RAM	32GB
Operating System	Windows 10



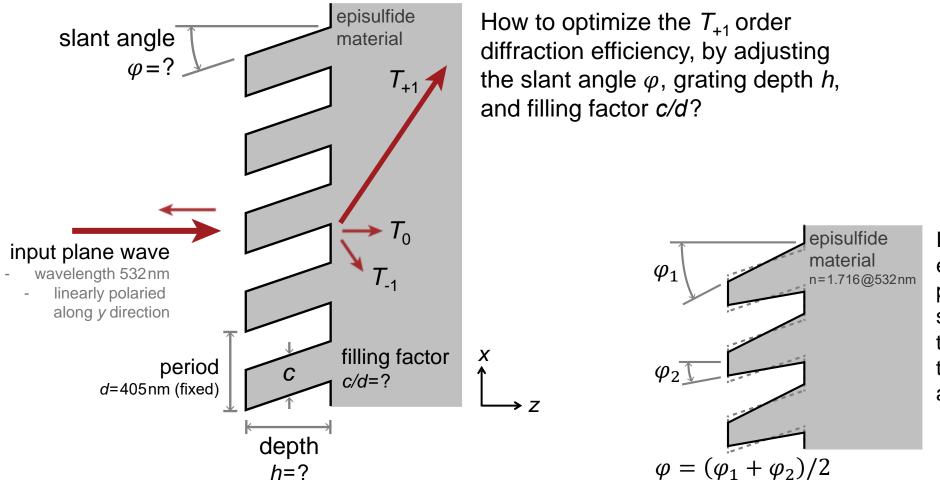
Parametric Optimization and Tolerance Analysis of Slanted Gratings

Abstract



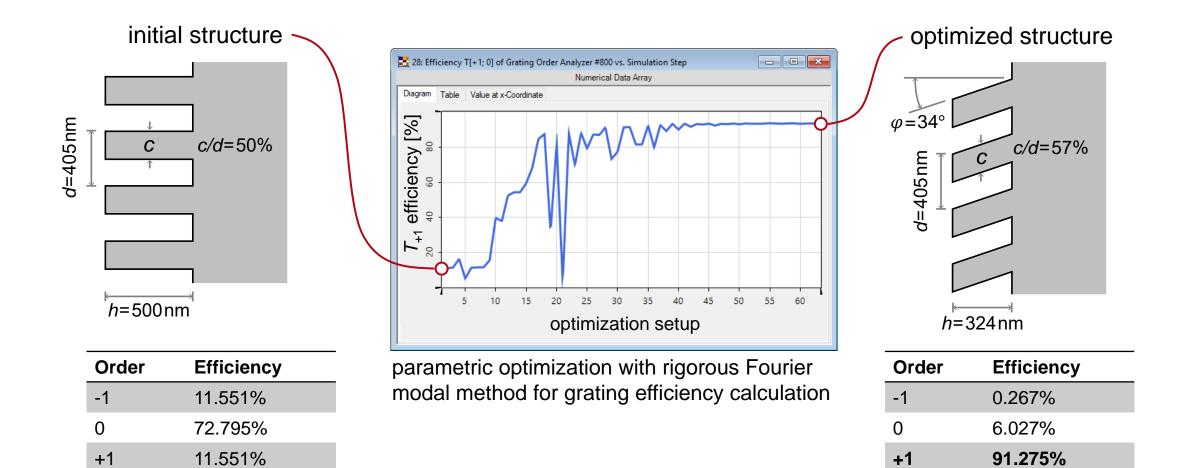
Coupling of light into guiding structures with high efficiency is an important issue for many applications, like backlight, optical interconnector, and near-to-eye displays. For such applications, slanted gratings are well known for being capable to couple monochromatic light with high efficiency. In this example, the optimization of a slanted grating with the rigorous Fourier modal method is presented. The optimized grating shows a diffraction efficiency of over 90% for a predefined direction order. In addition, the influence from the slope deviation of the grating is investigated.

Modeling Task

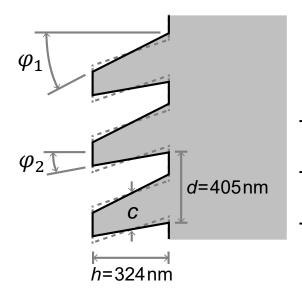


In addition, how to evaluate the grating performance with the slope deviation due to the fabrication technique taken into account?

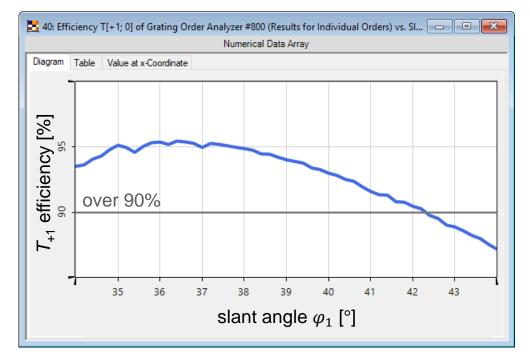
Results – Parametric Optimization



The fabricated slanted gratings often shows a deviation from the perfect parallel grating lines. Such slope deviations should be taken into account for the tolerance analysis.



- fixed average slant angle
- $\varphi = (\varphi_1 + \varphi_2)/2 = 34^\circ$
- fixed filling factor c/d=57%
- varying φ_1 from 34 to 44°



Rigorous simulation with Fourier modal method, for tolerance analysis over 50 steps, takes 30 seconds.

title	Parametric Optimization and Tolerance Analysis of Slanted Gratings
version	1.0
VL version used for simulations	7.3.0.48
category	Application Use Case