_{チュートリアル_G.001a}: 正弦波グレーティングの、ニアフィールドと 効率解析

著者:	Hartwig Crailsheim(LightTrans GmbH)
キーワード:	Grating, Near field, diffraction efficiency analysis, sinusoidal
	range of the wavelength
必須ツールボックス:	Grating Toolbox
関連チュートリアル:	FS.003_Introduction_to_the_Parameter_Run
関連アプリケーション:	アプリケーション_246.01_Sinusoidal_Grating_with_Coating





VirtualLab (VL) では、ご所望のグレーティングの光学解析を、ユーザーガイド インターフェースを用いて誘導しながら可能とします

本書では、正弦波グレーティングによる、ニアフィールドと回折効率の解析法を解説するものです

2種のグレーティングを用いて解説します: 波長より大きなグレーティングと、小さなグレーティングです





回折次光毎の効率と ニアフィールドの厳密 シミュレーション



- 1. グレーティングの設定工程
- 2. ニアフィールドの解析
- 3. 伝播された回折次光の効率解析
- 4. 波長領域の構造を持つグレーティングに対し上記の工程を繰り返す

STEP 1

グレーティングの設定

Light Path Diagramのテンプレート

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List Grating Light Path Diagram
Grating Light Path Diagram
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Grating Toolboxの"Sinusoidal Grating Light Path Diagram"のテンプレートを メニューから選択します





		Default view
Edit General Grating 2 Geometry / Channels Position / Orientation Forentation Propagation	20 Solid Boundaries Base Block Base Block Medium Fusto Silica in Homogeneous ii Load Thickness Stacks ✓ Use Stack on First Interface Catalog Entry Stack ii Load ✓ Edit No rotation about z-Axis	Medium ✓ Edit ✓ Edit ✓ Use Stack on Second Interface Catalog Entry Stack ✓ Load ✓ Load ✓ Edit ✓ View ✓ Load ✓ View
Preview Wavelength	532 nm	OK Cancel Help

開かれたダイアログにて、 グレーティングの設定に必要な全ての 項目があります

・グレーティング構造の後ろの伝播 に興味があるので、ベースブロックの 厚みを"0"とします

Edit General Grating 2D		×
Geometry / Channels	Solid Boundaries Base Block Base Block Medium Fused Silica in Homogeneous Medium	✓ Edit Q View
Structure / Function	Thickness Stacks Stacks Use Stack on First Interface Catalog Entry Stack Catalog Entry Catalog Edit View No rotation about z-Axis	Use Stack on Second Interface Catalog Entry Stack Catalog Entry Stack Catalog Entry Stack
Tolerancing	Stack	Base Block
	Tools 🎢 🗸	Validity: 🗸
Preview Wavelength	532 nm	OK Cancel Help

- ・VirtualLabは"スタック"上の グレーティングを定義します
- "Edit"ボタンをクリックし、第一面の スタックの編集を行います。
 例:ベースブロックの左側に正弦波 グレーティングのモデリングを行い ます。

Edit Stack	
Base Block	
Index Distance Position Interface Subsequent Medium Cor 1 0 m 0 m Sinusoidal Grating Intes and and Air in Homog Enter your commer	Index Distance Position Interface Subsequent Medium Cor 1 0 m 0 Sinusoidal Griting L Standard Air in Homog Enter your commer
✓ III Validity: ✓ Period	< III
Stack Period is Dependent from the Period of Interface with Index 1 Stack Period 2 µm	
OK Cancel Help	

- 青で示した"Sinusoidal Grating...."のライン上にマウスを移動します
- 編集ボタン(鉛筆アイコン)を押します

dit Sinusoidal Grating Interface		×
Structure Discretization Scaling of	Elementary Interface Periodization	
Common Grating Values	t step	
Extension		
Grating Period	10 µm Modulation Depth	1µm
Position	3	
Lateral Shift	0 m Rotation Angle	0°
Inner Definition Area		
Shane @ Rectand	nular O Elliptic	
Sinape () Rectang		
Size	iu µm x +ini m	
Effect on Field Outside of Definition	Area	
Field Passes Plane Interface		
Field is Absorbed		·x·
- Position of Surrounding Interface	e Plane	
		Area
Specification Mode		¥
Boundary Minimum		
z-Position	-500 nm	
	0 z-Position	
Q II Tools Var	Area V Cancel	Help
Valie	dity: V	

Grating Period (グレーティング周期) を"10 µm"にします

Periodizationタブに移行します



 ここでは"Outer Definition Area"のディフォルトサイズを示します。マウスを "i"アイコン上に置くと、表示されます

このダイアログの内容を"OK"にて承認します

Edit General Grating 2D							
21-	Propagation Methods Advanced	Settings					
Geometry / Channels	Component Propagation Fou	irier Modal Method	- Edit				
t	Interface	Stack	Medium				
	Plane Interface	Stack	Homogeneous Medium				
Pasition /	Fourier Modal Methor 🔻	Fourier Modal Methor 💌	Fourier Modal Methor 💌				
Orientation	2 Fourier Modal Methor	Stack	Homogeneous Medium				
Structure / Function Propagation							
Preview Wavelengt	h 532 nm	ОК	Cancel Help				

- "Edit General Grating 2D"
 ダイアログに戻り、"Propagation"
 を選択します
- "Propagation Methods"タブにて
 伝播法を選択する事が可能です
- ディフォルトとして"Fourier Modal Method"(FMM)が設定されており、 グレーティングの厳密解析を 可能としております

Edit General Grating 2D	
11-	Propagation Method Advanced Settings
	Layer Decomposition
Geometry /	Automatic
Channels	Accuracy Factor 1
	Manual
	Number of Layers (First Stack)
Position / Orientation	
	Overall Thickness 1000 nm
	Terration Paint Decomposition
Structure /	Automatic
Function	Accuracy Factor 1
	O Manual
	Number of Points
Propagation	Point Distance
-	Period 10 µm
Teleraneina	Information
	55 propagating orders (for perpendicular incident). 105 diffraction orders are used for calculation. Minimum layer thickness: 50 nm; Total number of layers: 20 Minimum transition point distance: 200 nm
	Remove Redundant Data
Preview Wavelength	532 nm OK Cancel Help
-	

 "Advanced Settings"タブを 選択し、"Decomposition Preview"をクリックします



 ここでは、グレーティング構造が レイヤーに分離され、FMMで唯一 解析可能な状態になります

- ・Y方向に不変であると想定されます
- "Close"をクリックし、"Edit General Grating 2D"ダイアログにて"OK"を 押します

設定についてのイラストレーション



・光源とグレーティング素子の距離
 グレーティング素子とVirtual Screen
 の距離はゼロに設定します。
 媒体も設定します。

この設定は、グレーティング構造直後の状況を解析すると言う意味となります

測定コンディションの設定

- ・ニアフィールドと効率の解析を行います
- ・ 両方を測定する上で、グレーティング素子の媒体は共通とします
- ・外郭媒体は空気、グレーティングの媒体は合成石英です
- ・ Light Path Editorの正弦波グレーティング(2行目)の"Medium" コラム内の 鉛筆アイコンをクリックします

I » 1:	🔋 1: Light Path Editor (Light Path Diagram #1)									
Path Path Detectors Analyzers										
	Start Element Target Element Linkage									
	Index		Туре	Channel	Medium	Index	Type	Propagation Method	On/Off	
	0 Ideal Plane Wave - Standard Air in Homogen		Standard Air in Homogen	1	Sinusoidal Grating	None	On			
	1 Sinusoidal Grating T Standard Air in Homogene									
					43)				
•									•	
٩	Tools				[Re-U Settir	se Automatic Simulation Type :	Field Tracing	Go!	

媒体のLoading 1

Edit Homogeneou:	s Mediun	n		23
Basic Parameters	Scaling	Periodization		
Material of Hom	nogeneous	s Medium		
Name Stand	ard Air			Q View
Catalog Materi	al		•	🚰 Load 📐
State of	of Matter		Gas or Vacu	
		ОК	Cancel	Help



つづく

 "Edit Homogeneous Medium" ダイアログにて "Load"をクリックします

2. "+"をクリックし、"Miscellaneous"を選択します

媒体のLoading 2



"Fused Silica"を選択し "OK"にて承認します

つづく

ŝ	Start Element								
{	Index	Туре	Channel	Medium	Inde				
7	0	Ideal Plane Wave	-	Standard Air in Homogen	~				
}	1	Sinusoidal Grating	Т	Fused Silica in Homogene					
				~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~					

#### ニアフィールド解析の選択

<b>I</b> ))	1: Light Path Editor (Light Path Diagram #1)*										
	Path Detectors Analyzers										
			Detector		Last Light Pat	h Element			Linkage		
	li	ndex	Туре	Index	Туре	Channel	Medium	Sum	Propagation Method	On/Off	Color
~		600	Virtual Screen	1	Sinusoidal Grating	Т	Fused Silica in	No	Near Field Propagation (behind	On	
<b>√</b>	ſ	601	Virtual Screen	1	Sinusoidal Grating	R	Standard Air in	No	Near Field Propagation (behind	On 👻	
( Q	Tools ☆     Tools ☆     Tools ☆     Settings     Simulation Type : Field Tracing     Go!										

- ・フィールドの解析は、トランスミッションに着目します
- 反射のVirtual Screenを解除します(これにより、Light Path Diagramの赤線が 波線表示になります)

## STEP 2 ニアフィールドの解析

#### **First Near Field Simulation**

• Because the near field behind the grating is of interest an accordant propagation method is preset in the Light Path Editor.

1)) 1	: Light Path	Editor (Light Path Diag ath	ram #1)) etecto	* ors 📑 • Analyzer	5					
		Detector		Last Light Path	h Element			Linkage		
	Index	Туре	Index	Туре	Channel	Medium	Sum	Propagation Method	On/Off	Color
	600	Virtual Screen	1	Sinusoidal Grating	Т	Fused Silica in	No	Near Field Propagation (behind	On	
	601	Virtual Screen	1	Sinusoidal Grating	R	Standard Air in	No	Near Field Propagation (behind	On	
•					III					4
٩	Tools 🎢	•				Re-Use Automati Settings	^c Si	imulation Type : Field Tracing	•	Go!

• In order to calculate the near field click "Go!".



- 3 periods of the near field's sinusoidal phase distribution with a 2Pi modulus step due to a constant phase offset.
- Now change the displayed physical quantity from "phase" to "amplitude" by clicking the according symbol.





- The amplitude of the field is also varying a bit.
- To increase the resolution go to the 1st line in the "Detector" tab in the Light Path Diagram and double click in the column "Propagation Method".

	Index	Туре	Index	Туре	Channel	Medium	Sur	Propagation Method	Dn/Off	Color
$\checkmark$	600	Virtual Screen	1	Sinusoidal Grating	Т	Standard Air in	No	Near Field Propagation (behind	On	
	oov viitual Screen							45		
	C01	Vietual Casesa	1	Sinusoidal Grating	R	Standard Air in	No	Near Field Propagation (behind	Off	
	001	virtual Screen								

dit Propagation Method	
Propagation Method	
Near Field Propagation (behind Gratings)	Settings for Near Field Propagation (behind Gratings)
Ok Cancel	Return One-Dimensional Field
	Return Two-Dimensional Field
	Output Size and Sampling
	Number of Periods 3
Results in	Output Field Oversampling Factor 3
	Ok Cancel Help

- Click "Edit".
- Change the resolution by a factor of 3.
- Confirm both dialogs with "Ok".
- Then repeat the simulation with "Go!".



- You see again 3 periods of the phase behind the grating structure.
- Switch again to the amplitude view as shown before and expand the window.



#### **STEP 3**

# Analysis of the Efficiencies of the Propagating Orders

#### **Configuration for Efficiency Analysis 1**

- Now let's consider efficiencies.
- With the Grating Efficiency Analyzer you can investigate the efficiencies for every order.
- Double click the "Grating Efficiency Analyzer (2D)" in the Light Path Diagram.



#### **Configuration for Efficiency Analysis 2**

Edit Grating Efficiency Analyzer	
Order	
Calculate Efficiency of all Orders of the Field	
Minimum Order -3	
Maximum Order 3	
Channels to be Analyzed	
Transmission Reflection	
Output	
Polar Diagram and Table	
Intensity Distribution at Distance of 1 m	
Rayleigh Coefficients (Amplitude and Phase)	
Ex-Direction TM-Direction	
Ey-Direction TE-Direction	
Summed Transmission, Absorption, and Reflection	
Ok Cancel Help	

- By default the Grating Efficiency Analyzer calculates all orders of the field and the transmission as well as the reflection will be calculated and displayed in a polar diagram.
- For some further results in table form check "Summed Transmission, Absorption, and Reflection.

• Then click "Ok".

#### **First Efficiency Simulation**



- In the Light Path Editor change the Simulation Type from "Field Tracing" to "Grating Efficiency Analyzer (2D)".
- Then click "Go!".

#### **First Efficiency Results 1**



You get a polar diagram showing the directions of the incident wave and the directions as well as the efficiencies of the reflected and transmitted orders.

- Move the mouse into the diagram and zoom in via the scroll wheel.
- At first you'll see only the strongest orders.

#### First Efficiency Results 2



- The more you zoom in the more orders you see.
- For more details switch to the "Table" tab.



### First Efficiency Results 3

🔰 4: Efficiency Diagram 📃 📼 💌							
Diagram Tabl	e						
	Reflected		Transmit	ted	-		
Label	x-Value	y-Value	Label	x-V			
R-18	-73.204°	0.0010254 %	T-27	-79.449°			
R-17	-64.709°	5.9167E-05 %	T-26	-71.206°	-		
R-16	-58.317°	0.0018156 %	T-25	-65.543°			
R-15	-52.919°	0.0026568 %	T-24	-60.91°	Ē		
R-14	-48.124°	0.0014505 %	T-23	-56.872°			
R-13	-43.742°	0.0080819 %	T-22	-53.229°			
R-12	-39.66°	0.015903 %	T-21	-49.874°			
R-11	-35.806°	0.10674 %	T-20	-46.737°			
R-10	-32.131°	0.25302 %	T-19	-43.773°			
R-9	-28.599°	0.27119 %	T-18	-40.95°			
R-8	-25.181°	0.11524 %	T-17	-38.242°			
R-7	-21.857°	0.0095196 %	T-16	-35.632°			
R-6	-18.609°	0.20912 %	T-15	-33.104°			
R-5	-15.422°	0.070362 %	T-14	-30.647°			
R-4	-12.283°	0.070056 %	T-13	-28.251°	-		
•				Þ			

	Reflected			Transmitted		
Label	x-Value	y-Value	Label	x-Value	y-Value	
R+9	28.599°	0.27119 %	то	0°	2.2496 %	
R+10	32.131°	0.25302 %	T+1	2.0866°	18.273 %	
		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			Martin Martin	~

- Here you see the angle and the efficiency for each reflected and transmitted order.
- E.g. scroll down to the zeroth transmission order (T0).
- Table with efficiencies can be copied into clipboard or converted into a complex field of VirtualLab via the context menu (right mouse button).

STEP 4

Same Investigations of a Grating with a Period in the Range of the Wavelength

Change of the Grating Setup

- The scenario till now showed good paraxial behavior. So the results are quite suitably in accordance with the scalar grating theory.
- Now let's change the grating period from "10µm" to "1µm". The modulation depth remains "1µm".
- Thus follow some previous demonstrated steps...

1 st step	Sinusoidal Grating	2 nd step	Stacks Stacks Image: Catalog Entry Stack Image: Catalog Entry Image: Catalog Entry Stack Image: Catalog Entry Image: Catalog En	Use Stack on Second Interface Catalog Entry Stack Catalog Entry Stack Catalog Entry Stack No rotation about z-Axis
3 rd step	Sinusoidal Grating L. Edit	4 th step	Structure Discretization Scaling of Elementary Common Grating Values Extension Grating Period	Interface Periodization

Explanations

- Scenarios like this with a wavelength of 532nm and a grating period of 1µm, i.e. a structure in the range of the wavelength, typically ask for a rigorous analysis which the Fourier Modal Method offers.
- So VirtualLab is predestined for such investigations.
- This constellation results in only 3 reflecting and 5 transmitting orders. Thus the analysis is quite fast.

Second Efficiency Results



	Reflected			Transmitted			Incident Wave		
Label	x-Value	y-Value	Label	x-Value	y-Value	Label	x-Value	y-Value	
R-1	-32.131°	0.029906 %	T-2	-46.737°	6.1858 %	Point 1	0°	100 %	
RO	8.5924E-31°	0.0052498 %	T-1	-21.353°	38.602 %				
R+1	32.131°	0.029906 %	то	0°	10.358 %				
			T+1	21.353°	38.602 %				
			T+2	46.737°	6.1858 %				

Second Near Field Simulation

- For the near field change the simulation type back to "Field Tracing".
- Then run the simulation by clicking "Go!".



Second Near Field Results 1



- Again 3 periods are displayed.
- With these small grating structures there is no longer a sinusoidal phase distribution because of the occurring resonance effects.
- Switch to the amplitude view and the cubic interpolation.





Second Near Field Results 2



- The amplitude is also dramatically changed.
- Now it varies from 0.2 to almost 1.
- This is a typical phenomenon for gratings with a period close to the wavelength.

CONCLUSION

Conclusion

- VirtualLab allows the rigorous simulation of surface gratings.
- The Grating Toolbox allows the simulation of near field and diffraction efficiency of gratings.