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

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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

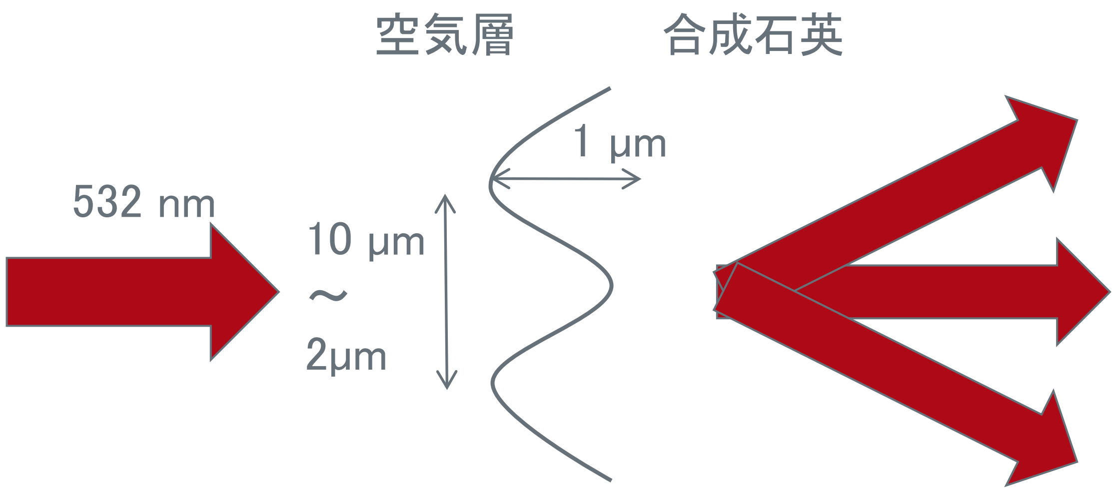
はじめに

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

モデリング概要



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

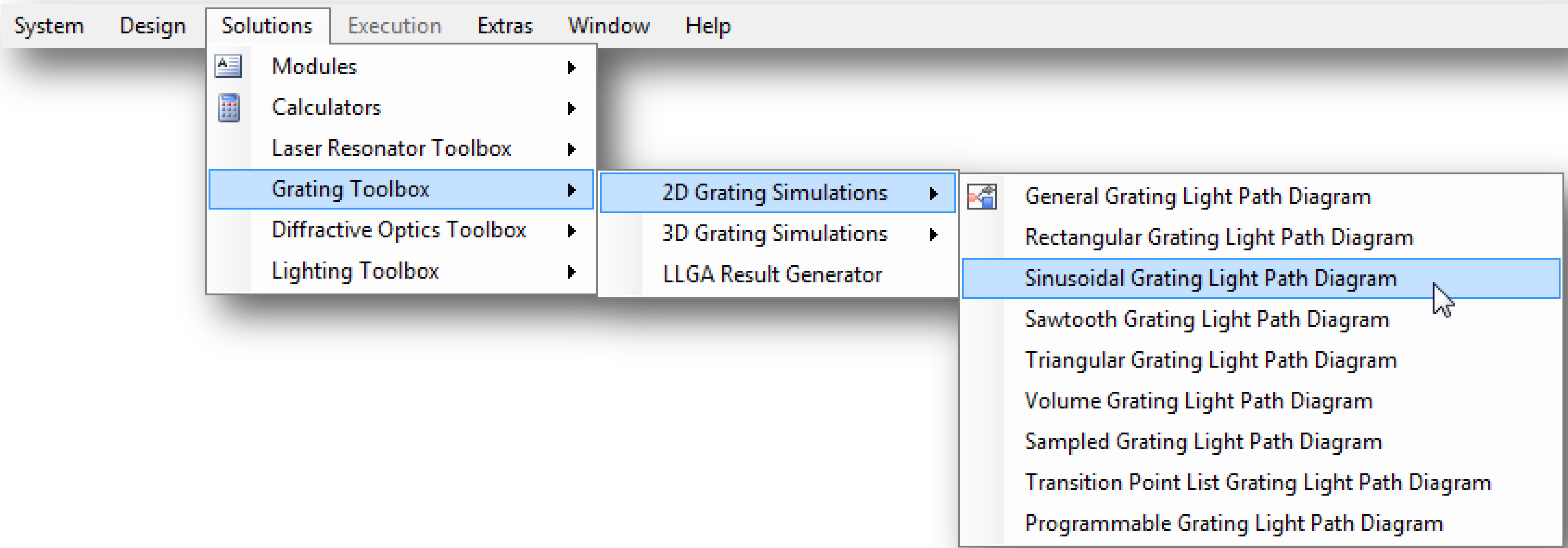
デモンストレートの工程

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

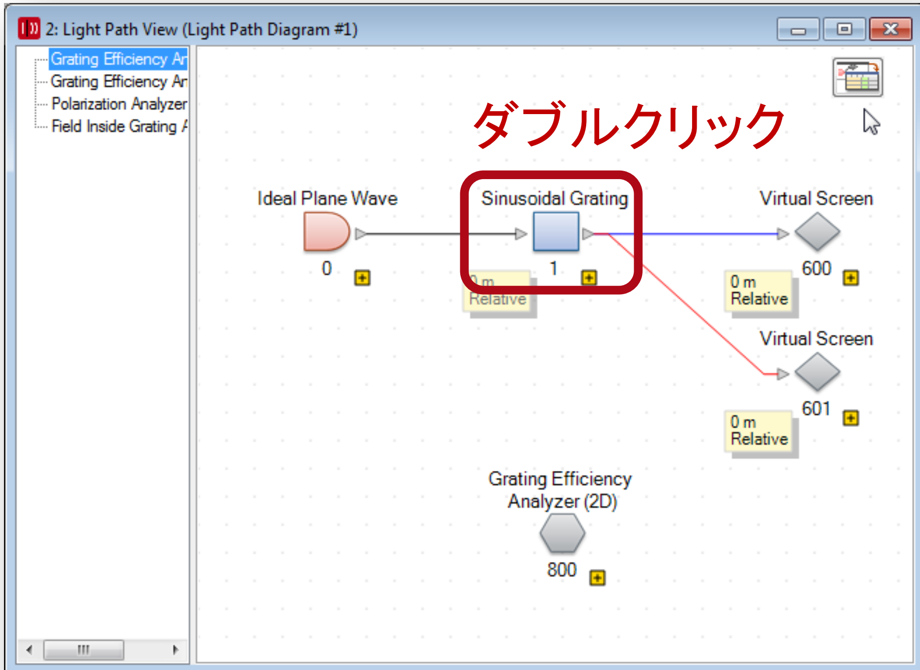
グレーティングの設定

Light Path Diagramのテンプレート



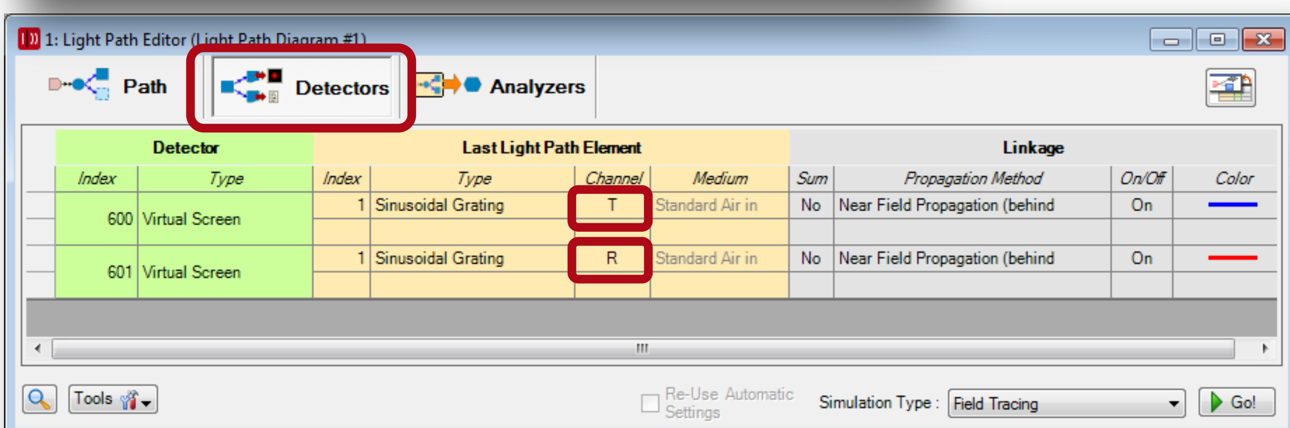
- Grating Toolboxの“Sinusoidal Grating Light Path Diagram”のテンプレートをメニューから選択します

LPDの基礎



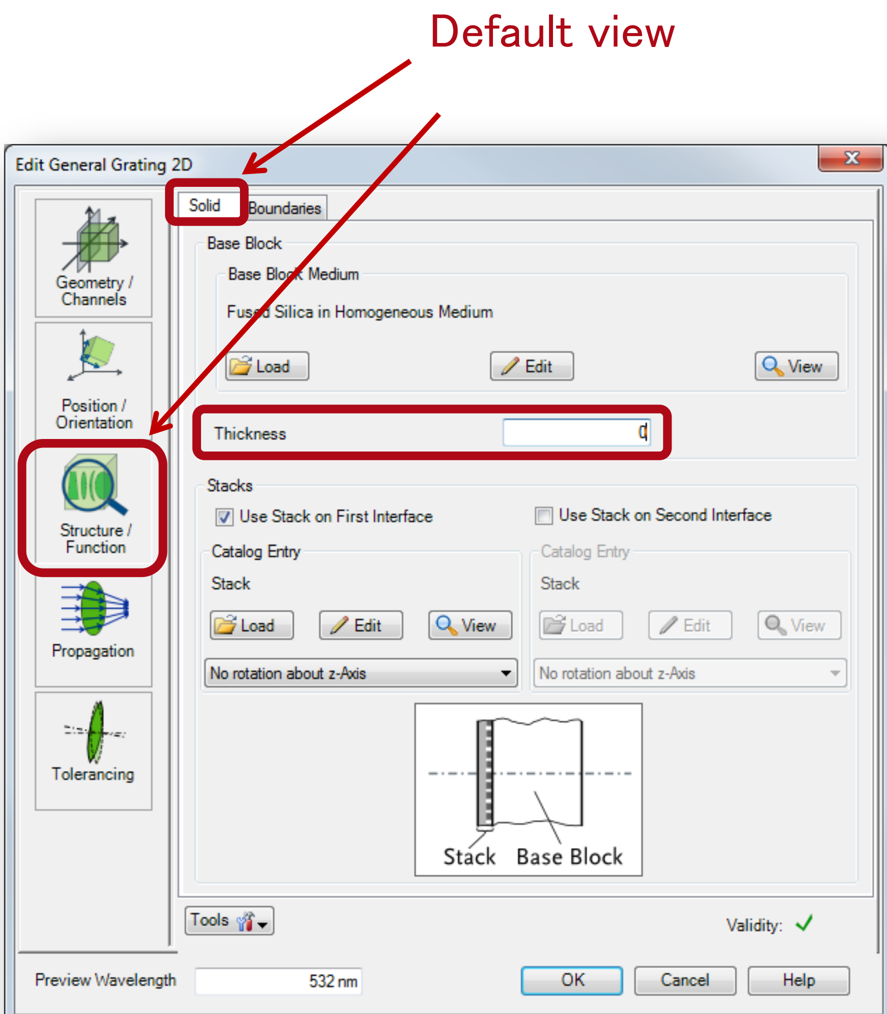
- Light Path Diagram (LPD) と編集画面(LPE) の2つの画面が開かれます

- 青線はディテクターに透過(T)として結合し、赤線は反射(R)となります



- グレーティング素子上でダブルクリックします

グレーティング素子の設定



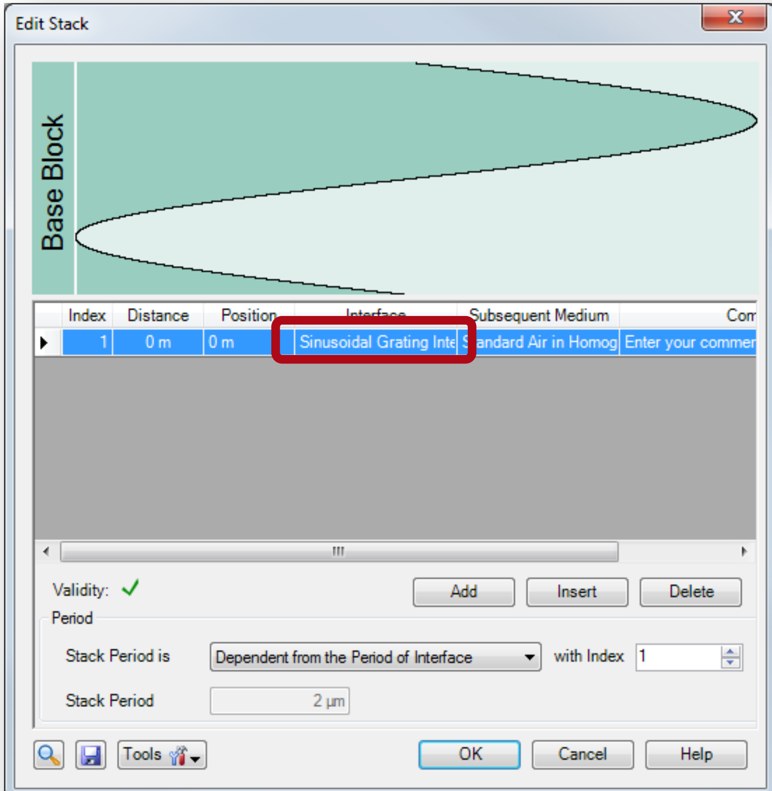
開かれたダイアログにて、
グレーティングの設定に必要な全ての
項目があります

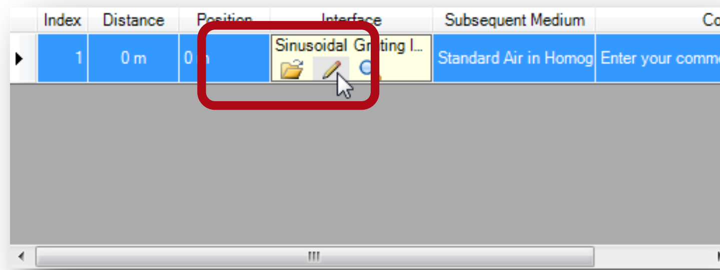
- グレーティング構造の後ろの伝播に興味があるので、ベースブロックの厚みを”0”とします

グレーティング素子の設定 2

- 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。

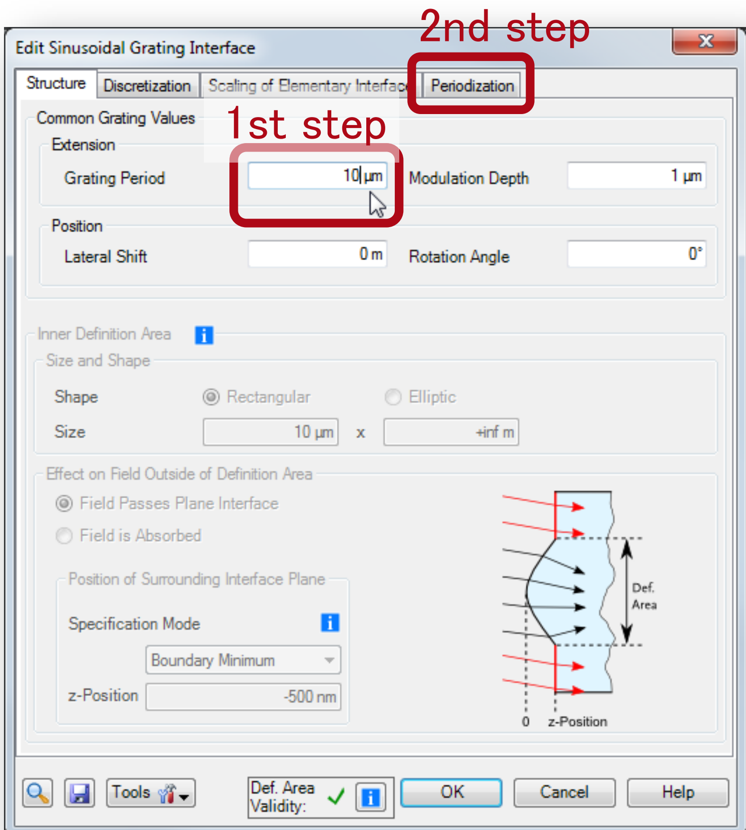
グレーティング素子の設定 3





- 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

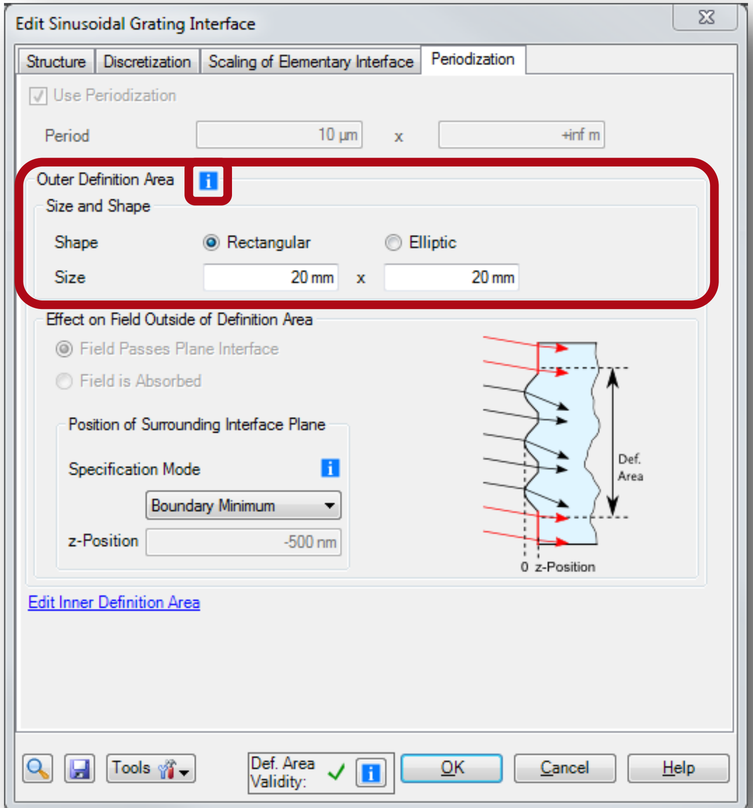
グレーティング素子の設定 4

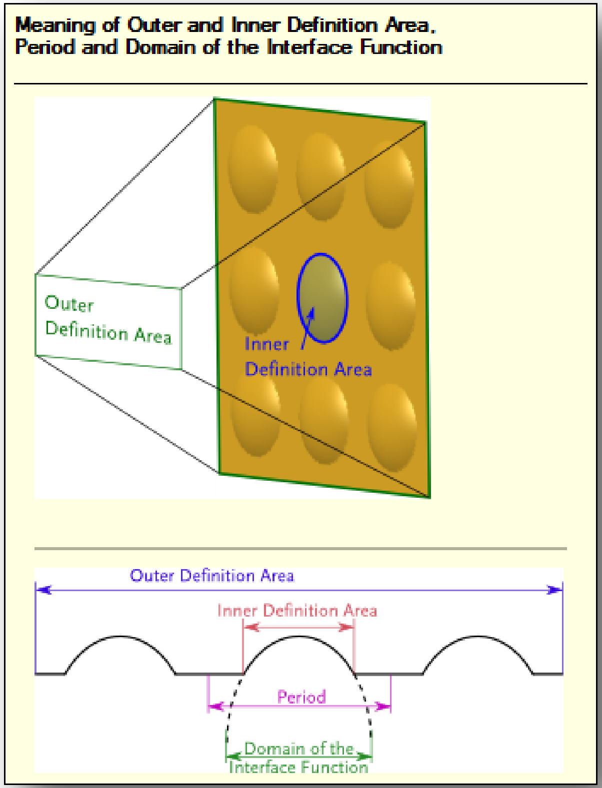


- Grating Period (グレーティング周期)を“10 µm”にします

Periodizationタブに移行します

グレーティング素子の設定 5

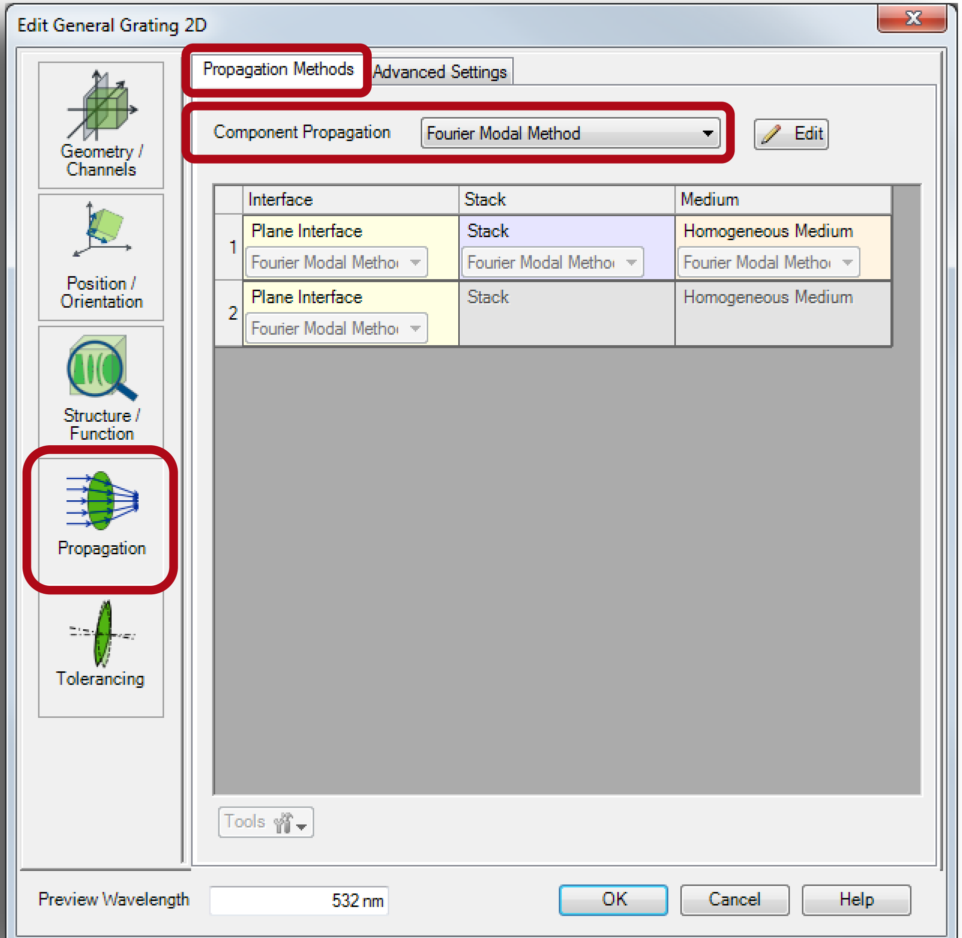




- ここでは“Outer Definition Area” のディフォルトサイズを示します。 マウスを“i”アイコン上に置くと、表示されます

このダイアログの内容を“OK”にて承認します

グレーティング素子の設定 6

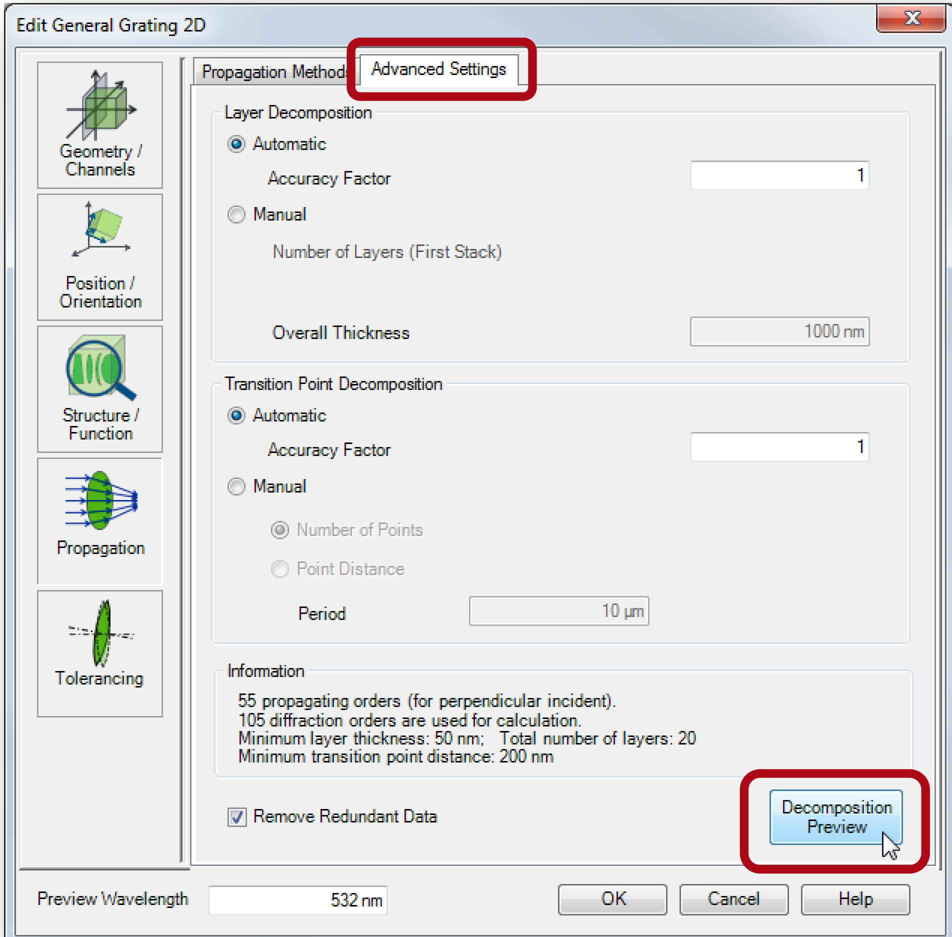


- “Edit General Grating 2D” ダイアログに戻り、“Propagation” を選択します

- “Propagation Methods”タブにて伝播法を選択する事が可能です

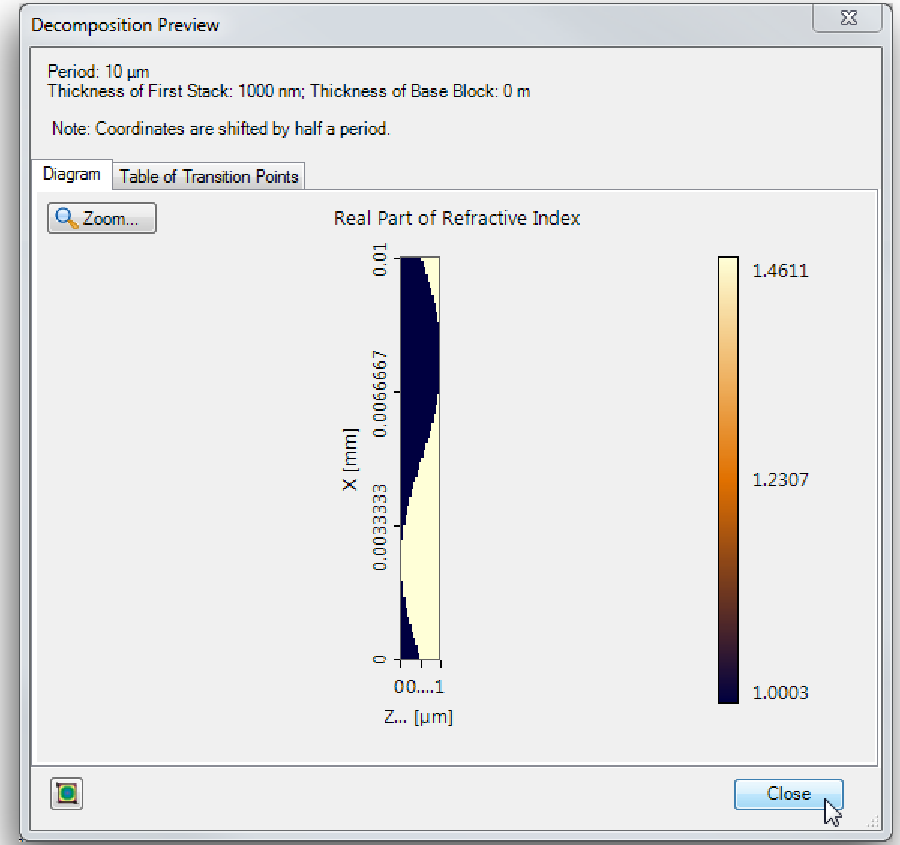
- ディフォルトとして“Fourier Modal Method”(FMM)が設定されており、グレーティングの厳密解析を可能としております

グレーティング素子の設定 7



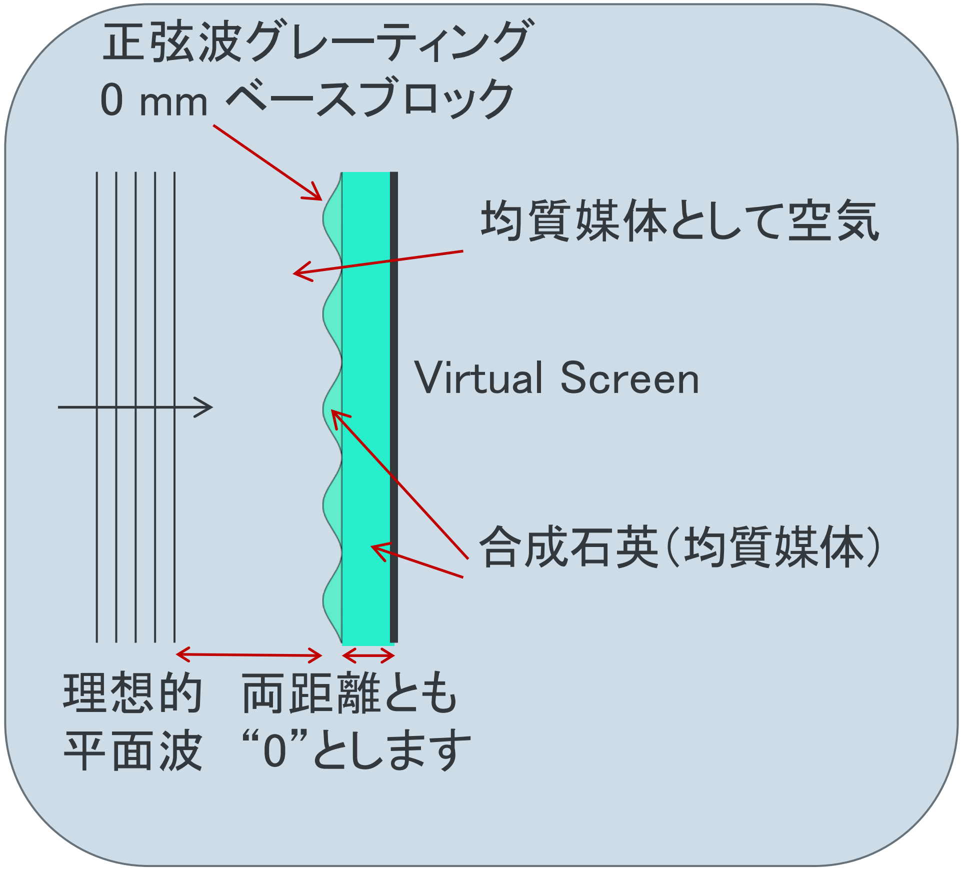
- “Advanced Settings”タブを選択し、“Decomposition Preview”をクリックします

グレーティング素子の設定 8



- 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

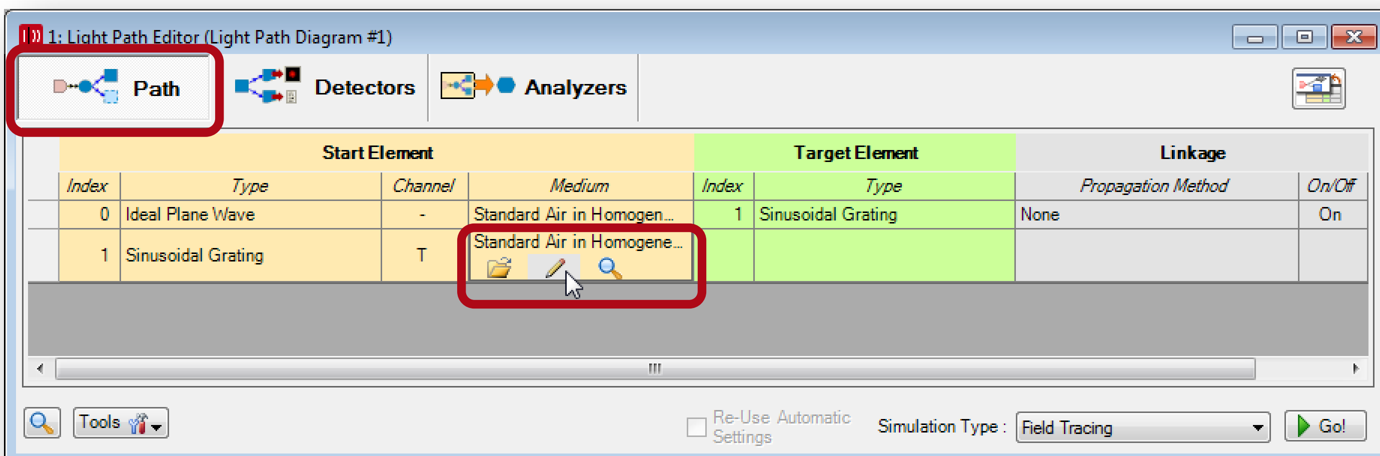


- 光源とグレーティング素子の距離
  グレーティング素子とVirtual Screen
  の距離はゼロに設定します。
  媒体も設定します。

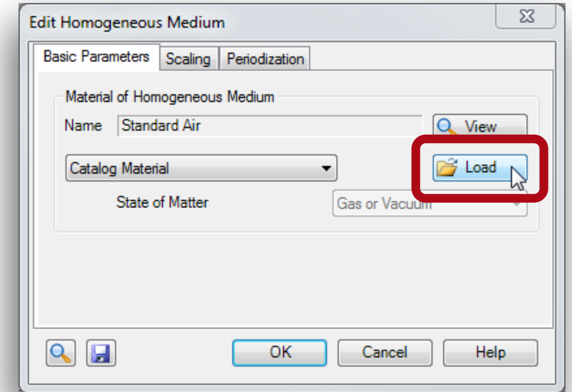
- この設定は、グレーティング構造直後の状況を解析すると言う意味となります

測定コンディションの設定

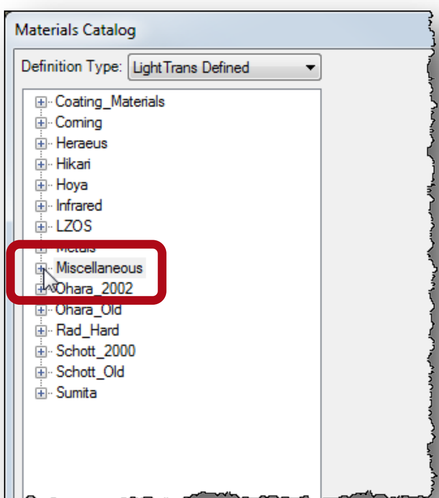
- ニアフィールドと効率の解析を行います
- 両方を測定する上で、グレーティング素子の媒体は共通とします
- 外郭媒体は空気、グレーティングの媒体は合成石英です
- Light Path Editorの正弦波グレーティング（2行目）の“Medium” コラム内の鉛筆アイコンをクリックします



媒体のLoading 1



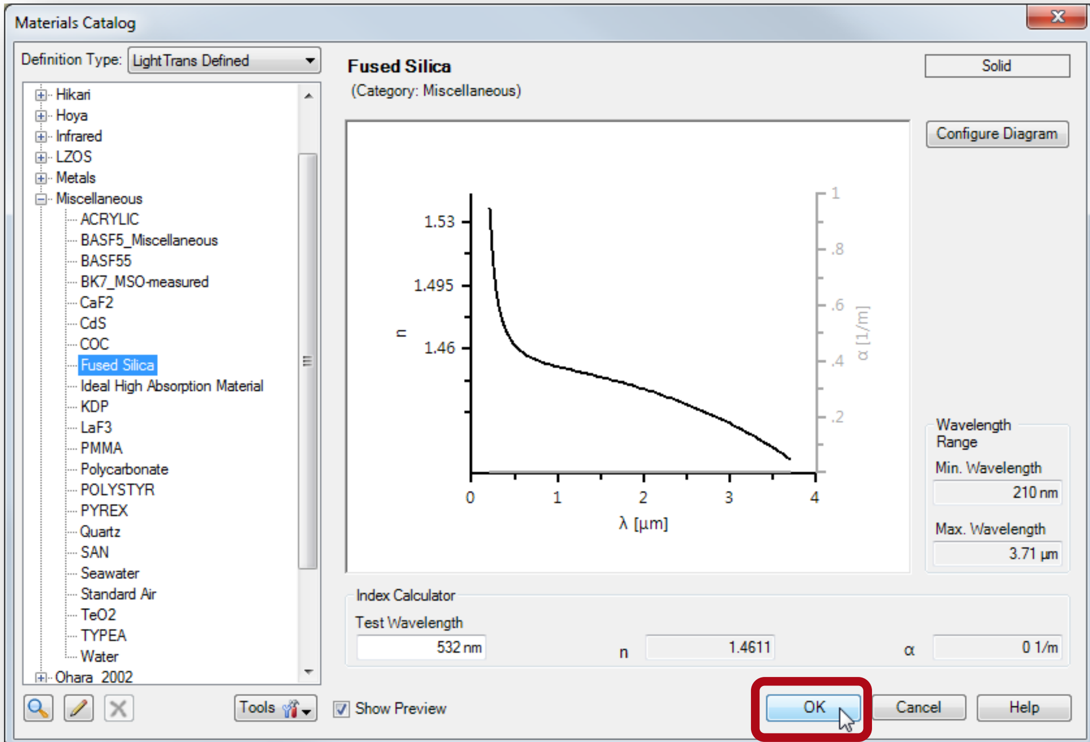
つづく



1. “Edit Homogeneous Medium” ダイアログにて “Load”をクリックします

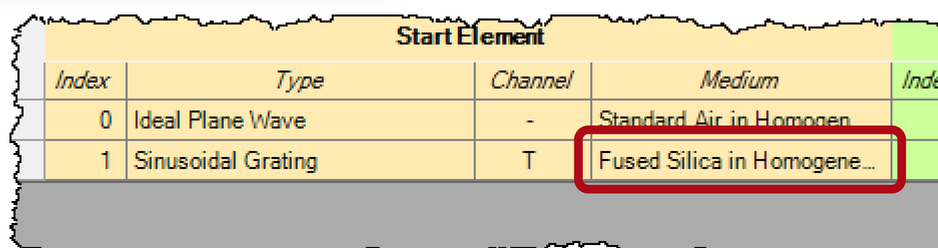
2. “+” をクリックし、“Miscellaneous”を選択します

媒体のLoading 2



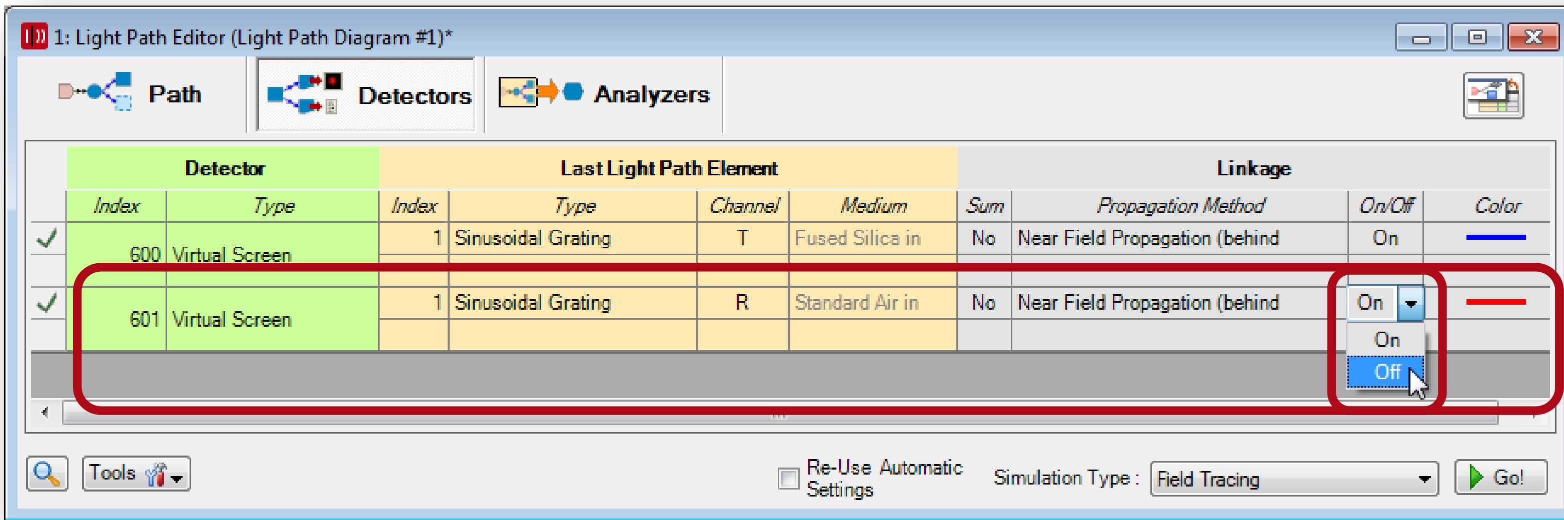
・“Fused Silica”を選択し“OK”にて承認します

つづく



Start Element				
Index	Type	Channel	Medium	Inde
0	Ideal Plane Wave	-	Standard Air in Homogen	
1	Sinusoidal Grating	T	Fused Silica in Homogene...	

ニアフィールド解析の選択



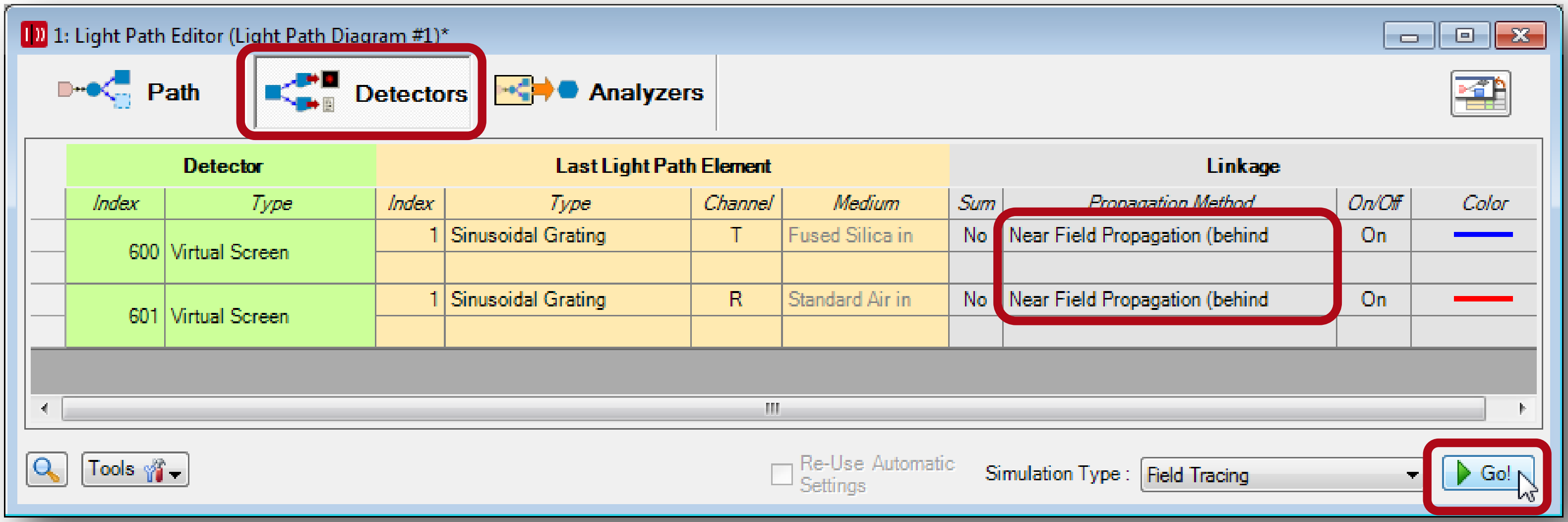
- フィールドの解析は、トランスミッションに着目します
- 反射のVirtual Screenを解除します（これにより、Light Path Diagramの赤線が波線表示になります）

STEP 2

ニアフィールドの解析

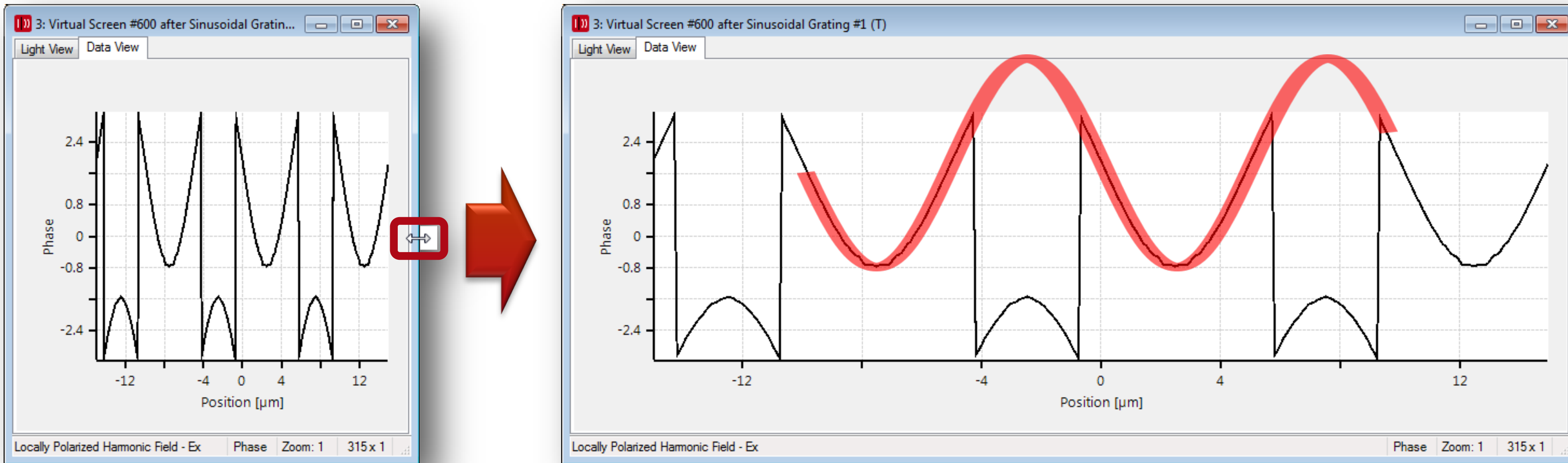
First Near Field Simulation

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

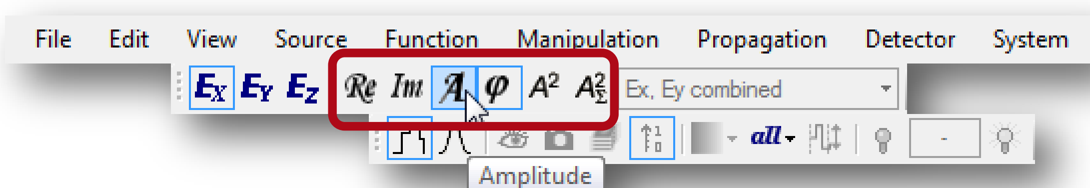


- In order to calculate the near field click “Go!”.

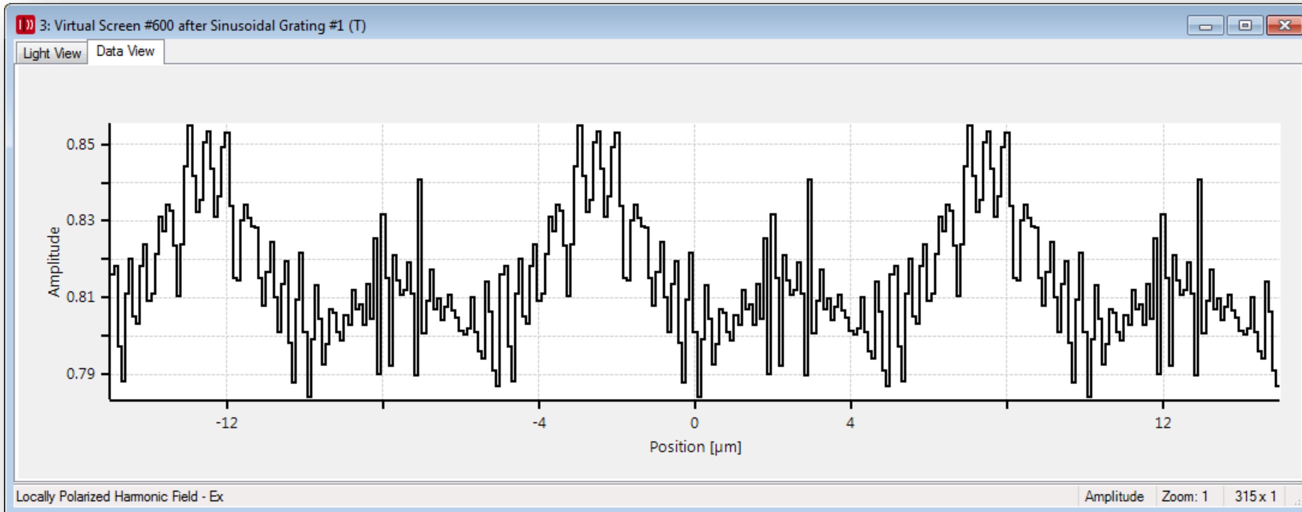
First Near Field Results 1



- 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.



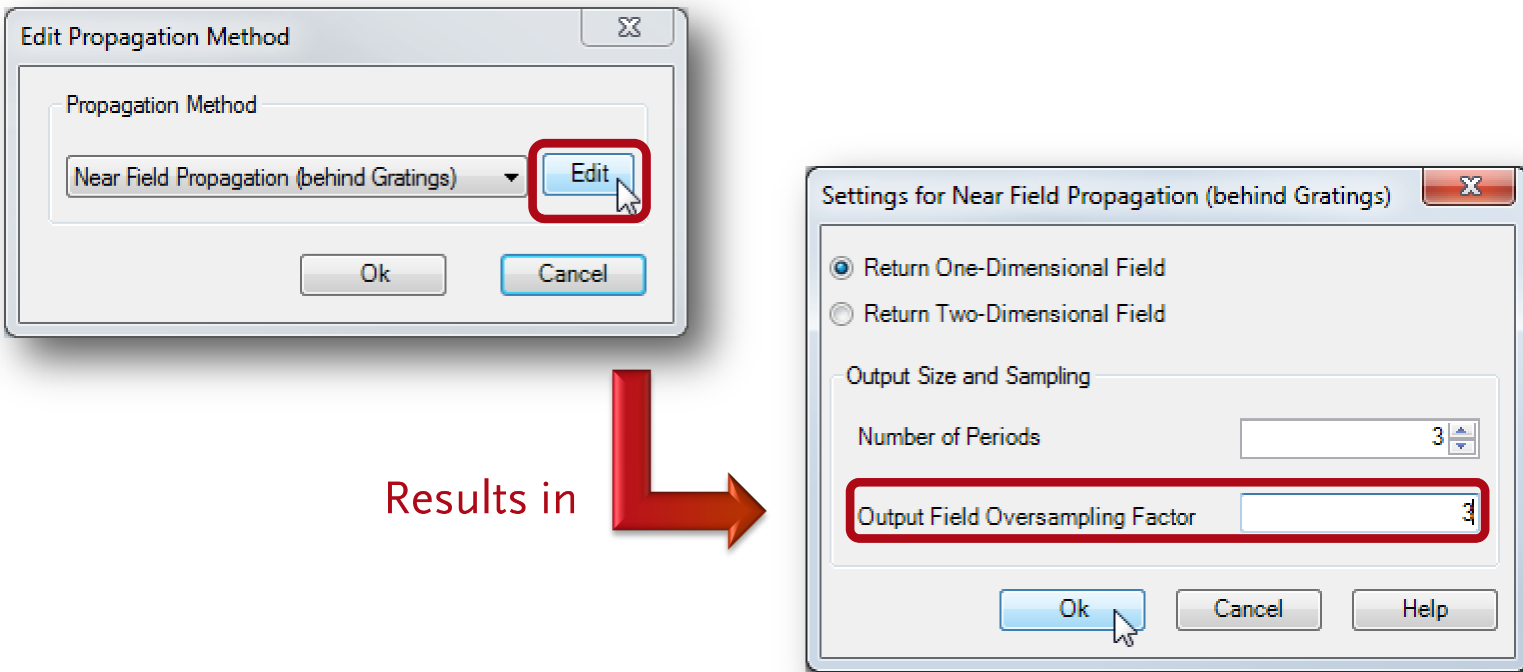
First Near Field Results 2



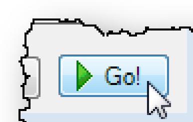
- The amplitude of the field is also varying a bit.
- To increase the resolution go to the 1st line in the “Detector” tab in the Light Path Diagram and double click in the column “Propagation Method”.

	Index	Type	Index	Type	Channel	Medium	Sur	Propagation Method	On/Off	Color
	600	Virtual Screen	1	Sinusoidal Grating	T	Standard Air in	No	Near Field Propagation (behind	On	
	601	Virtual Screen	1	Sinusoidal Grating	R	Standard Air in	No	Near Field Propagation (behind	Off	

First Near Field Results 3

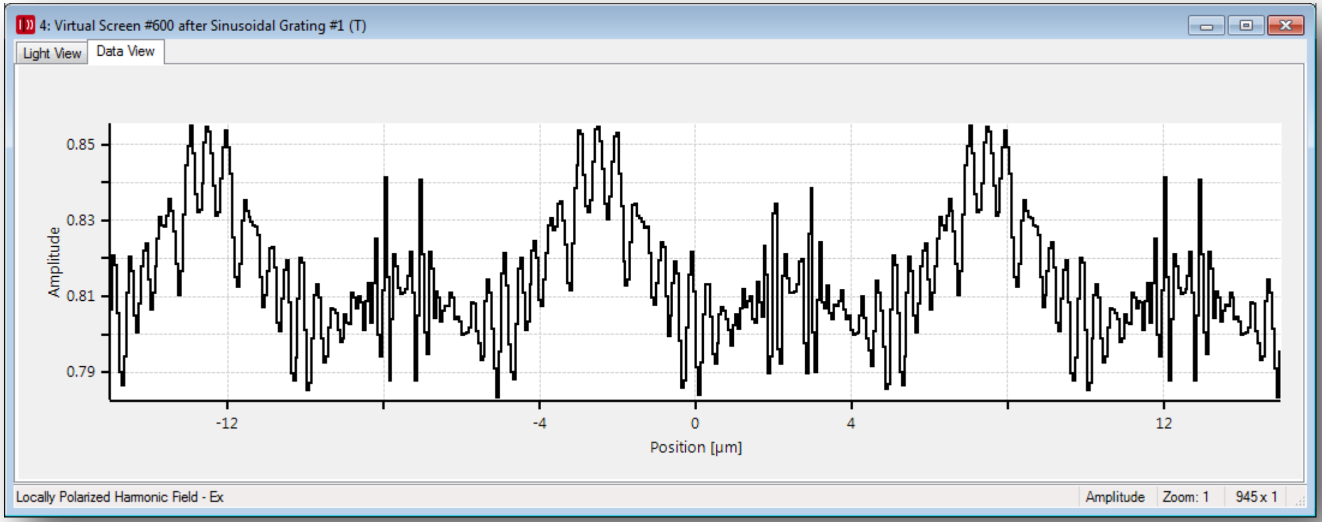


- Click “Edit”.
- Change the resolution by a factor of 3.
- Confirm both dialogs with “Ok”.
- Then repeat the simulation with “Go!”.



First Near Field Results 4

- 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.



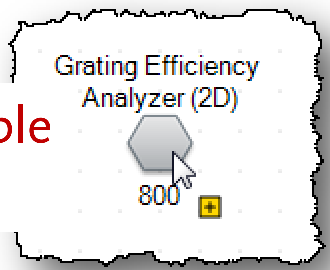
STEP 3

Analysis of the Efficiencies of the Propagating Orders

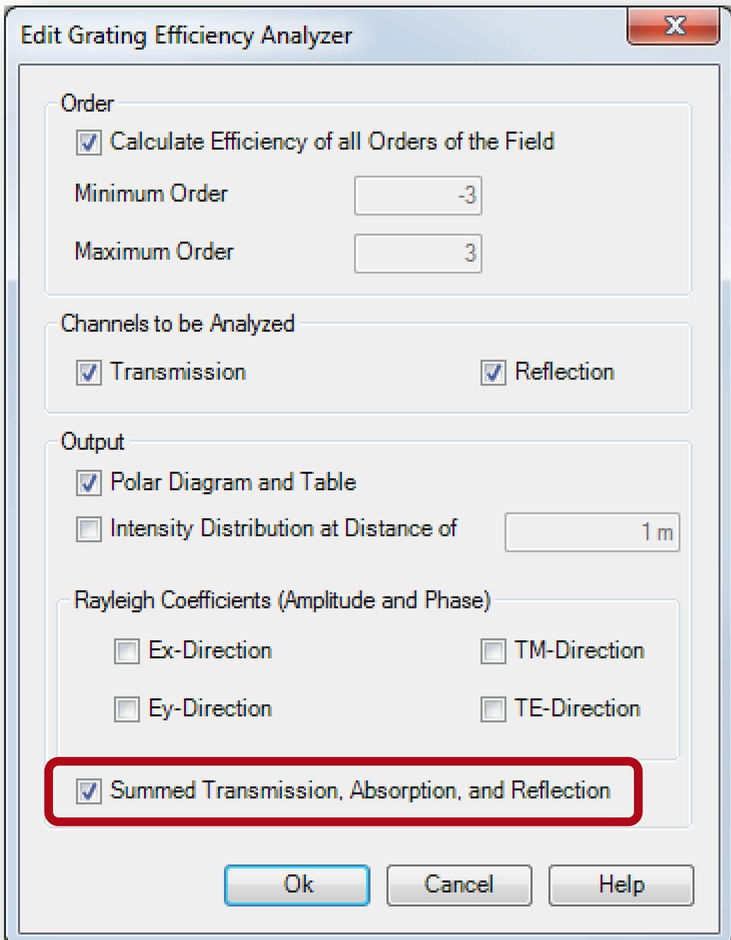
Configuration for Efficiency Analysis 1

- 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.

Double Click

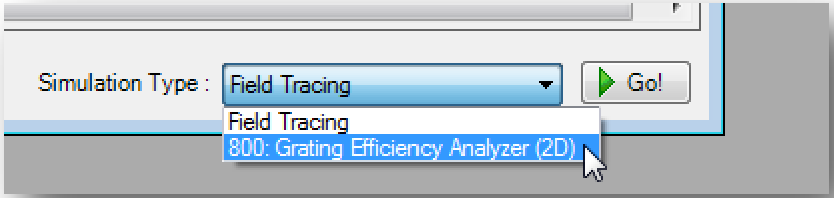


Configuration for Efficiency Analysis 2



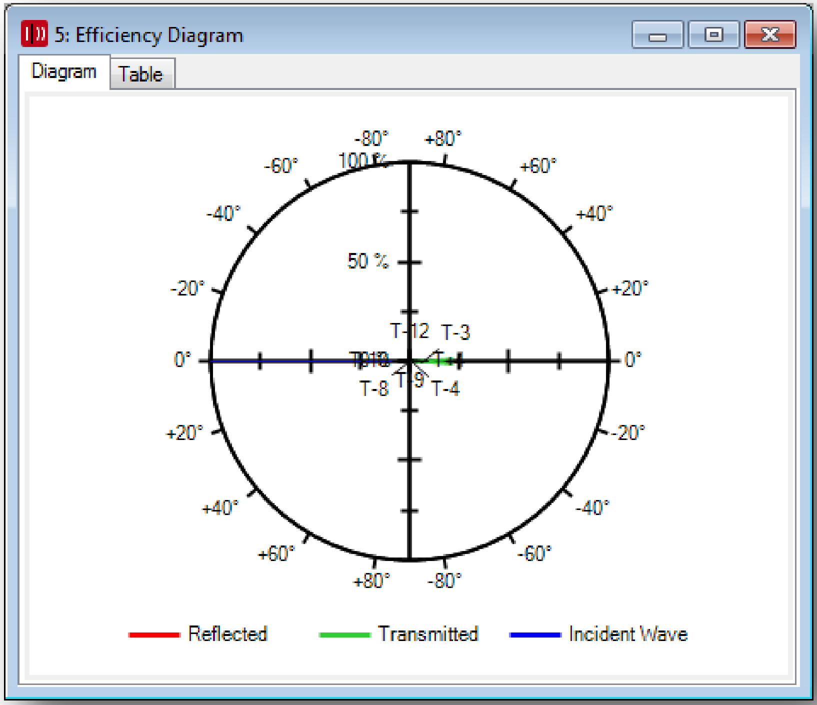
- By default the Grating Efficiency Analyzer calculates all orders of the field and the transmission as well as the reflection will be calculated and displayed in a polar diagram.
- For some further results in table form check “Summed Transmission, Absorption, and Reflection.
- Then click “Ok”.

First Efficiency Simulation



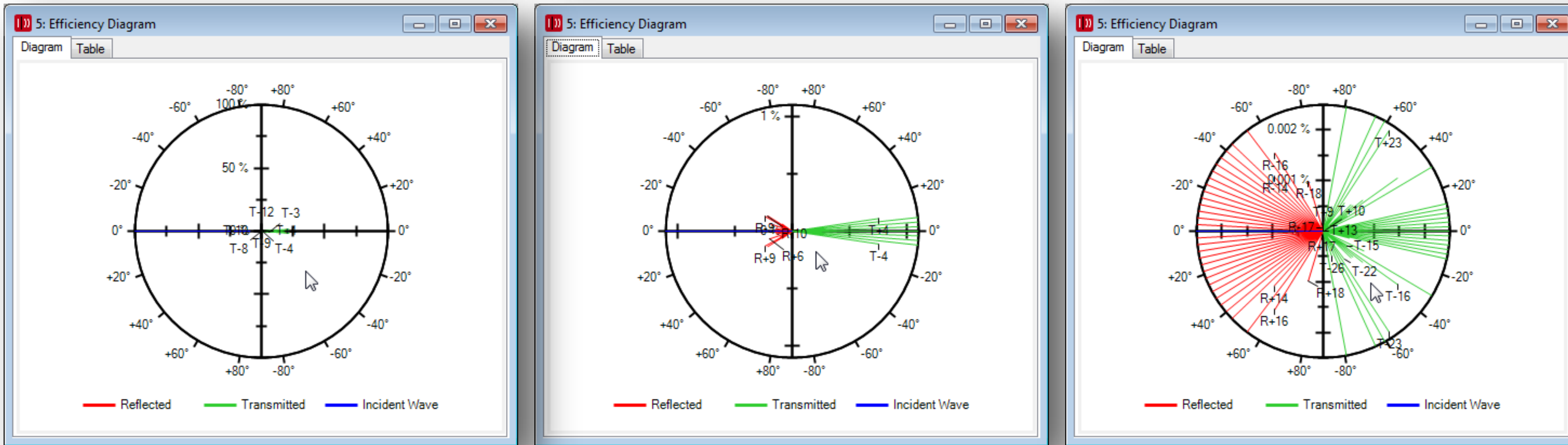
- In the Light Path Editor change the Simulation Type from "Field Tracing" to "Grating Efficiency Analyzer (2D)".
- Then click "Go!".

First Efficiency Results 1

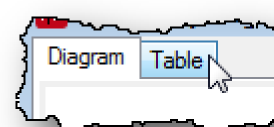


- You get a polar diagram showing the directions of the incident wave and the directions as well as the efficiencies of the reflected and transmitted orders.
- Move the mouse into the diagram and zoom in via the scroll wheel.
- At first you'll see only the strongest orders.

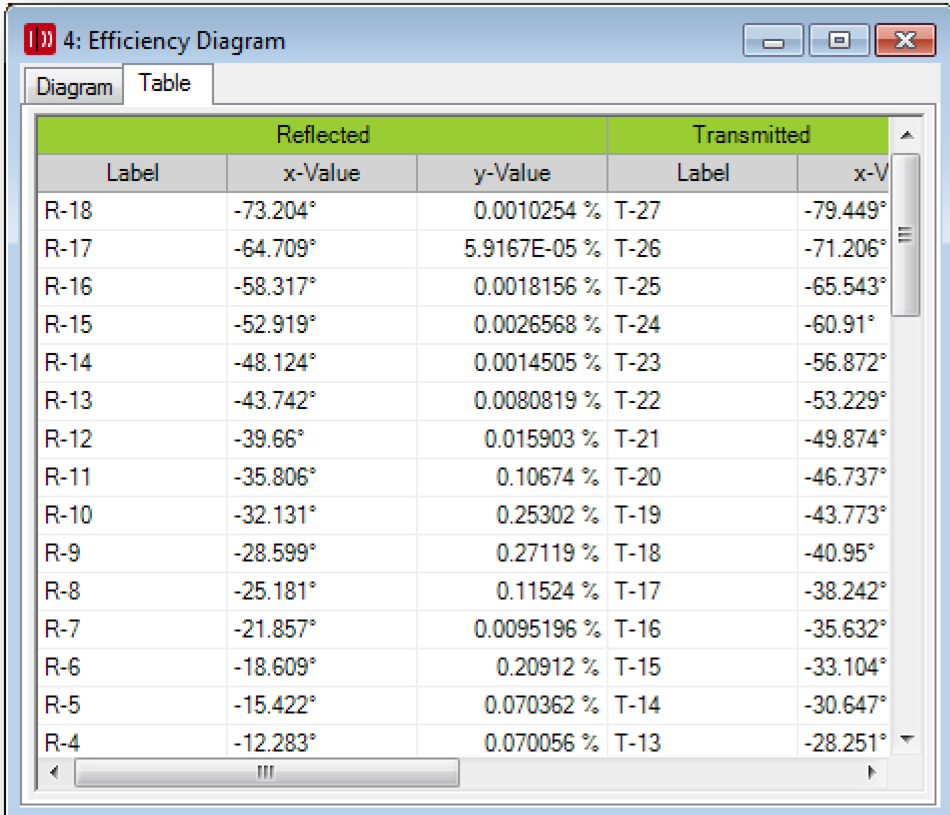
First Efficiency Results 2



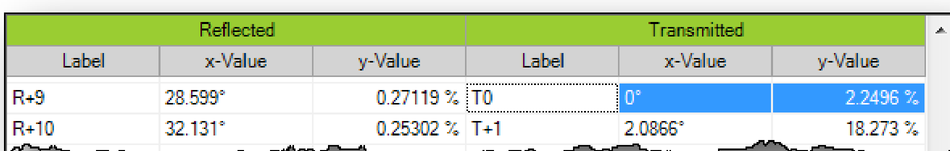
- The more you zoom in the more orders you see.
- For more details switch to the “Table” tab.



First Efficiency Results 3



Reflected			Transmitted	
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°
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°



Reflected			Transmitted		
Label	x-Value	y-Value	Label	x-Value	y-Value
R+9	28.599°	0.27119 %	T0	0°	2.2496 %
R+10	32.131°	0.25302 %	T+1	2.0866°	18.273 %

- 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).

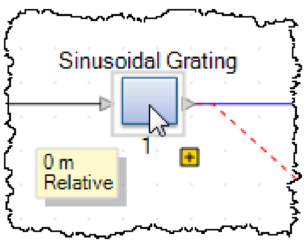
STEP 4

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

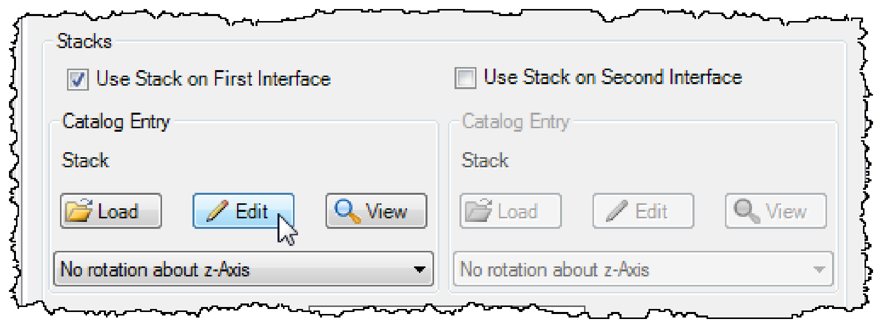
Change of the Grating Setup

- 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…

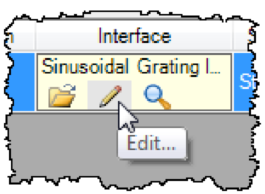
1st step



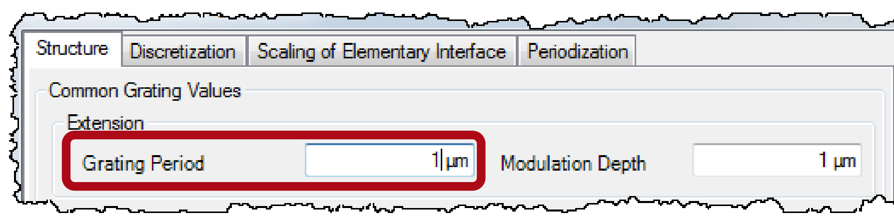
2nd step



3rd step



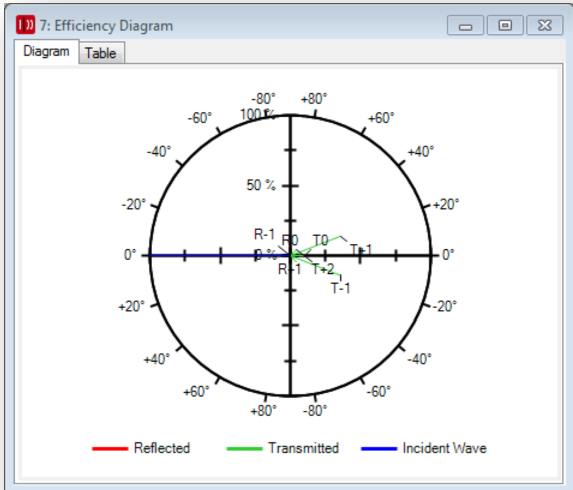
4th step

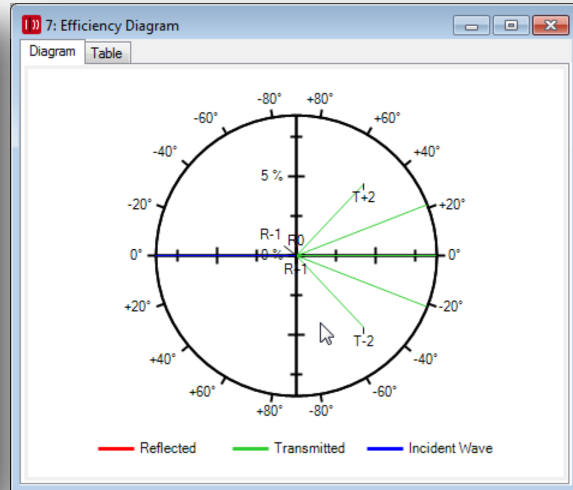


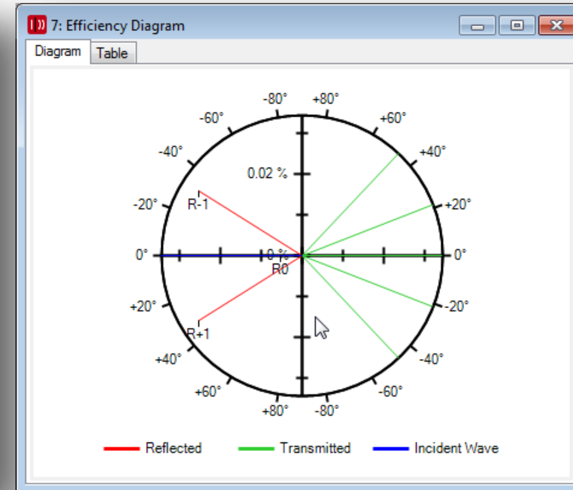
Explanations

- 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







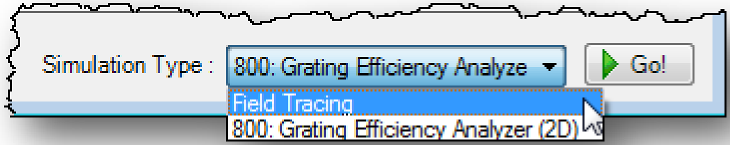
7: Efficiency Diagram

Diagram | Table

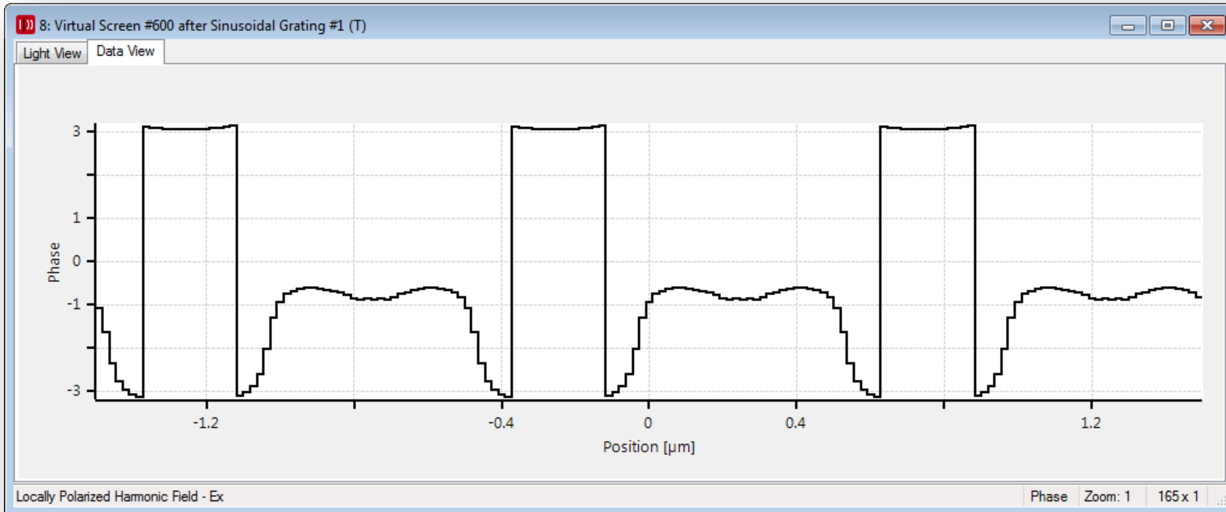
Reflected			Transmitted			Incident Wave		
Label	x-Value	y-Value	Label	x-Value	y-Value	Label	x-Value	y-Value
R-1	-32.131°	0.029906 %	T-2	-46.737°	6.1858 %	Point 1	0°	100 %
R0	8.5924E-31°	0.0052498 %	T-1	-21.353°	38.602 %			
R+1	32.131°	0.029906 %	T0	0°	10.358 %			
			T+1	21.353°	38.602 %			
			T+2	46.737°	6.1858 %			

Second Near Field Simulation

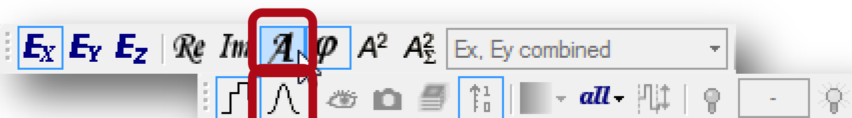
- For the near field change the simulation type back to "Field Tracing".
- Then run the simulation by clicking "Go!".



Second Near Field Results 1

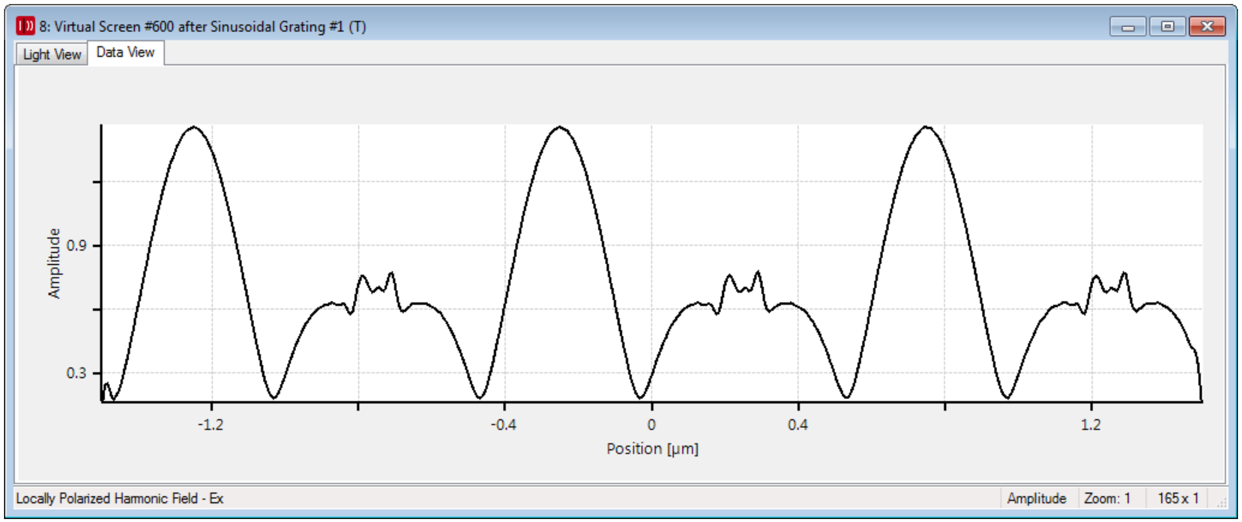


- Again 3 periods are displayed.
- With these small grating structures there is no longer a sinusoidal phase distribution because of the occurring resonance effects.
- Switch to the amplitude view and the cubic interpolation.



Results in

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.