

G.001a

Near Field and Efficiency Analysis of a Sinusoidal Grating

Keywords: grating, near field, diffraction efficiency analysis, sinusoidal, range of the wavelength

Required Toolboxes: Grating Toolbox

Related Tutorials: FS.003_Introduction_to_the_Parameter_Run

Related Application Scenarios: Scenario_246.01_Sinusoidal_Grating_with_Coating

by Hartwig Crailsheim



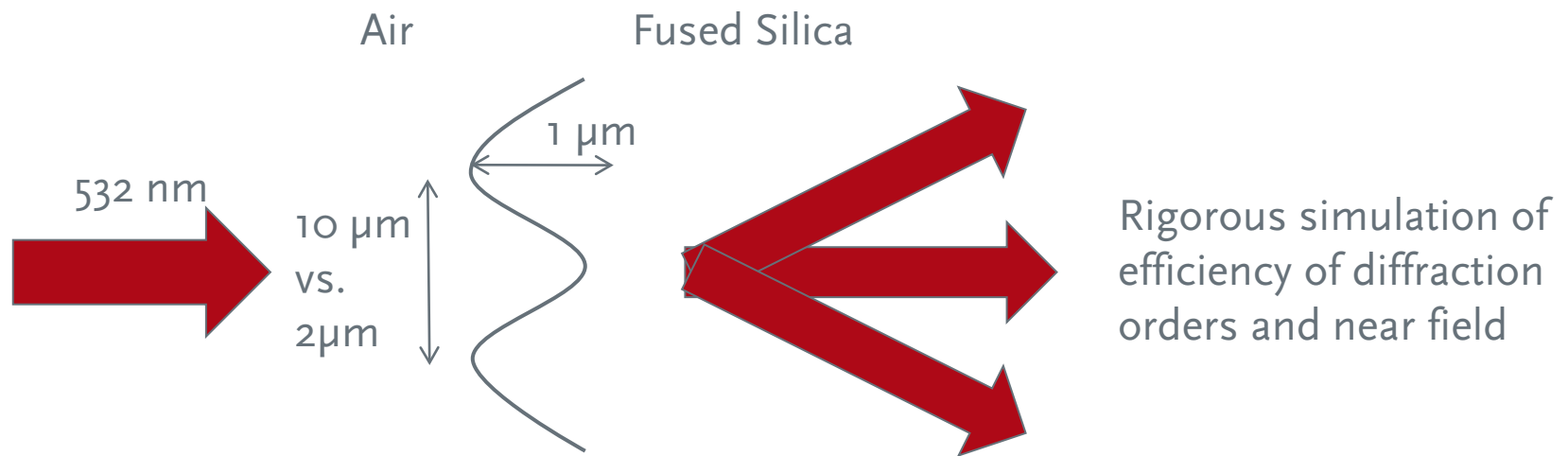
Abstract

VirtualLab (VL) provides a well guided way to create an optical setup for analyzing desired gratings.

This tutorial demonstrates the basic investigation of the near field and the diffraction efficiencies of the orders created by a sinusoidal grating.

This is shown for two gratings: On the one hand with a period distinctly above and on the other hand with a period in the range of the wavelength.

Modeling Task



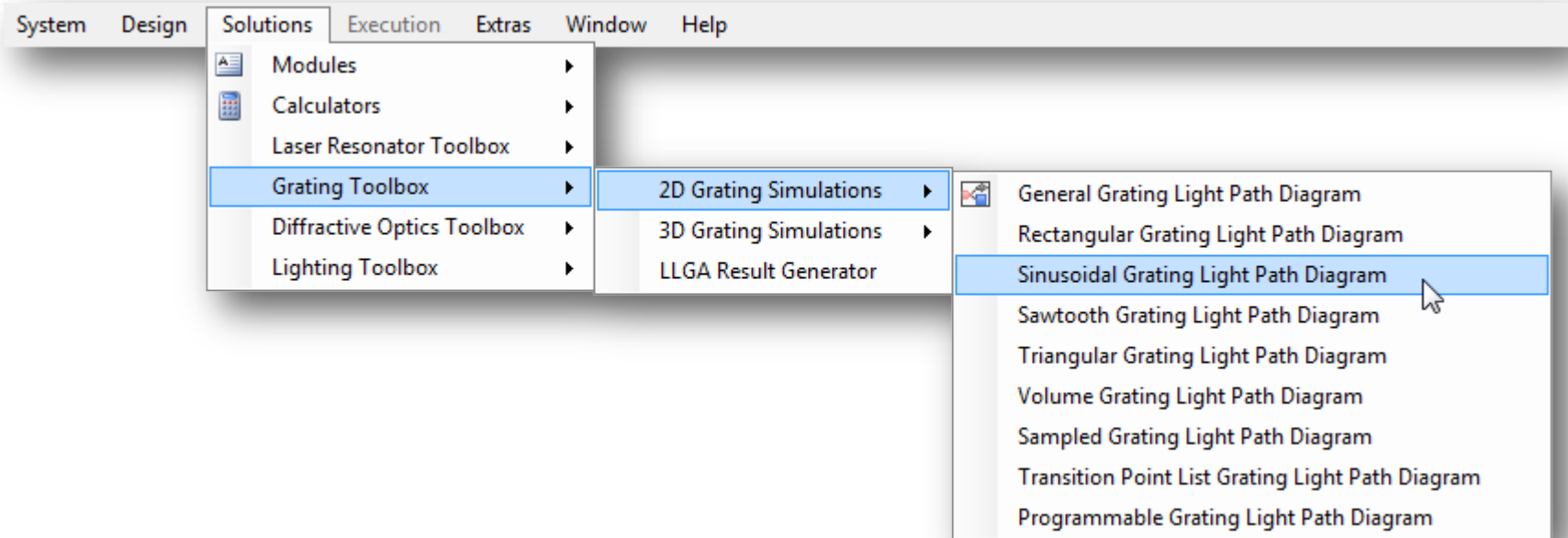
Demonstrated Steps

1. Configuration of an example grating setup.
2. Analysis of the near field.
3. Analysis of the efficiencies of the propagating orders.
4. Same investigations of a grating with a period in the range of the wavelength.

STEP 1

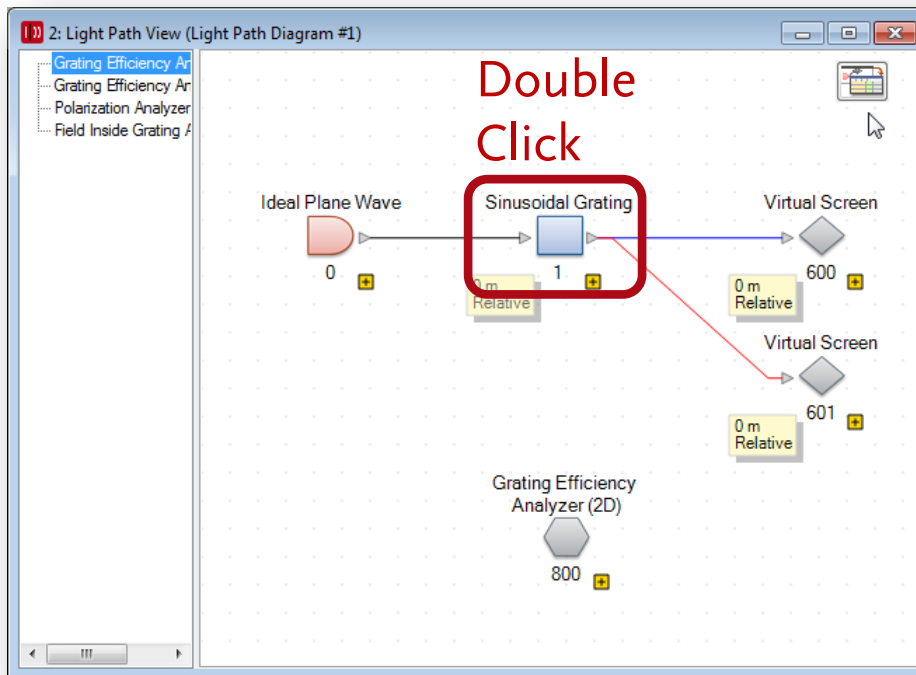
Configuration of the Grating Setup

Opening a Template Light Path Diagram



- Select the template “Sinusoidal Grating Light Path Diagram” from the Grating Toolbox.

Base LPD



- A Light Path Diagram (LPD) with its Editor (LPE) is opened which has two virtual screens.
- The blue line connects the detector for the transmission (T), the red line for the reflection (R).

1: Light Path Editor (Light Path Diagram #1)

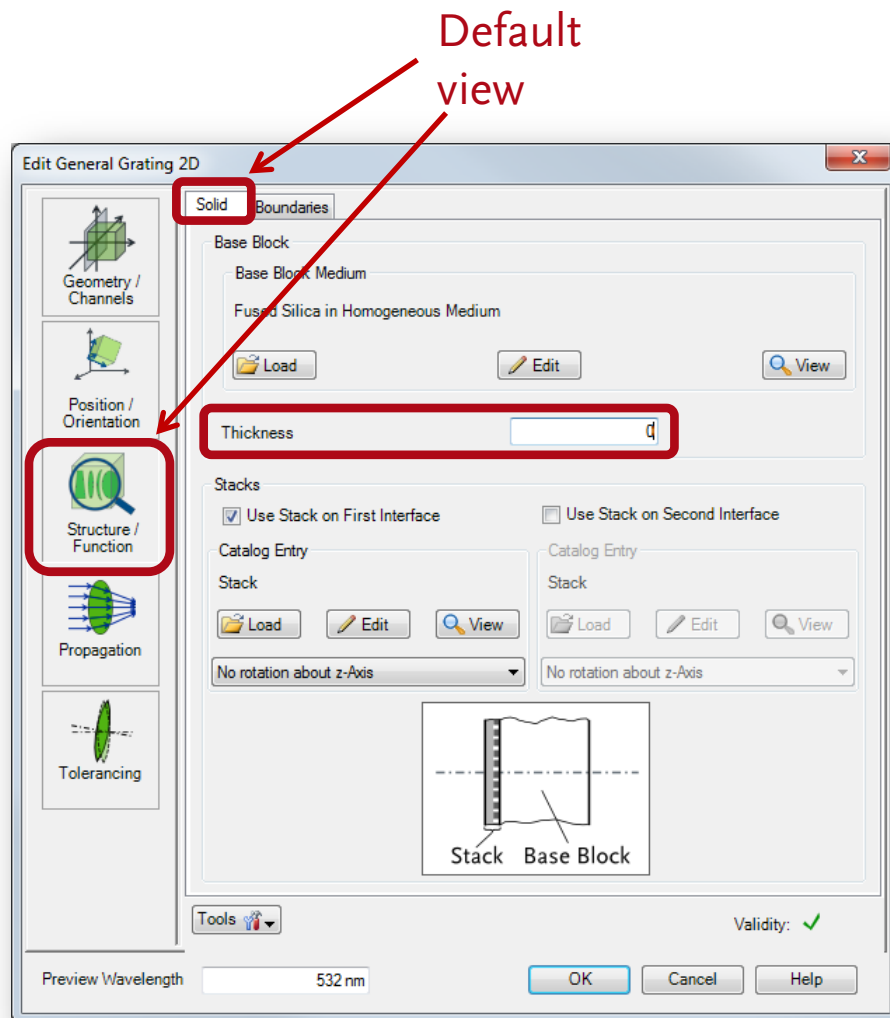
Path Detectors Analyzers

Detector		Last Light Path Element				Linkage			
Index	Type	Index	Type	Channel	Medium	Sum	Propagation Method	On/Off	Color
600	Virtual Screen	1	Sinusoidal Grating	T	Standard Air in	No	Near Field Propagation (behind)	On	Blue
601	Virtual Screen	1	Sinusoidal Grating	R	Standard Air in	No	Near Field Propagation (behind)	On	Red

Tools Re-Use Automatic Settings Simulation Type: Field Tracing Go!

- Double click on the Grating Component.

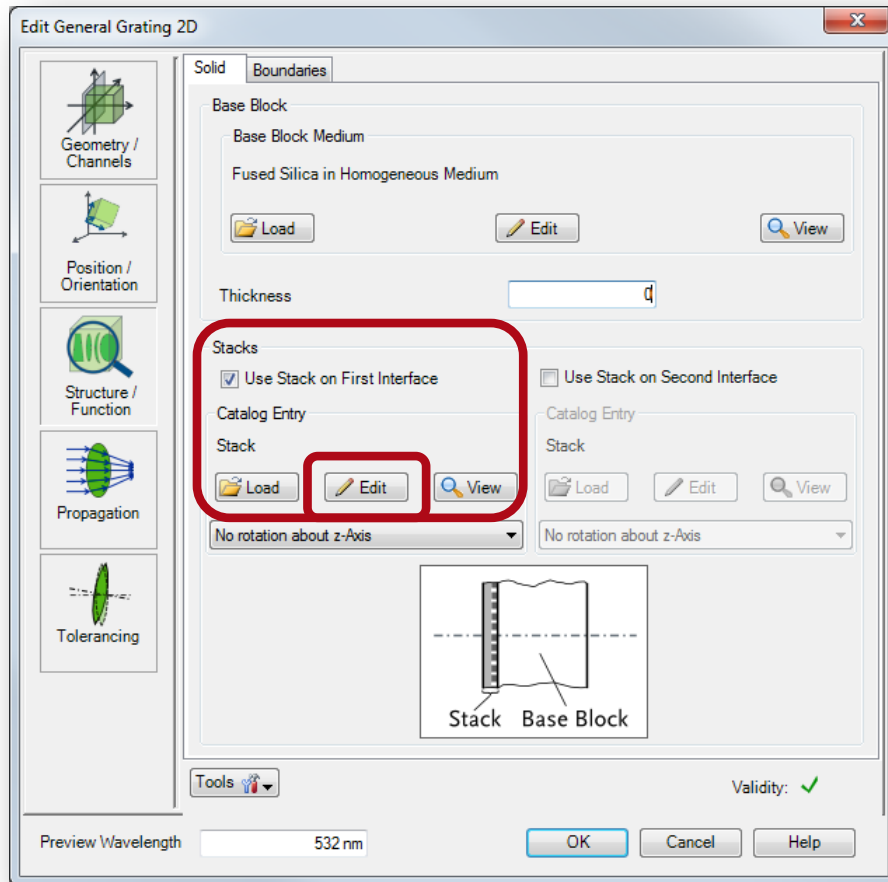
Configuration of the Grating Component 1



In the so opened dialog you have access to all relevant settings and information regarding the grating component.

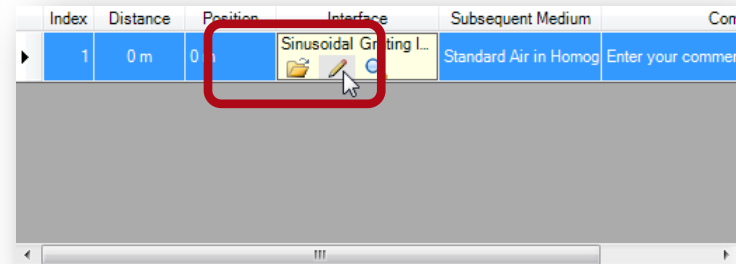
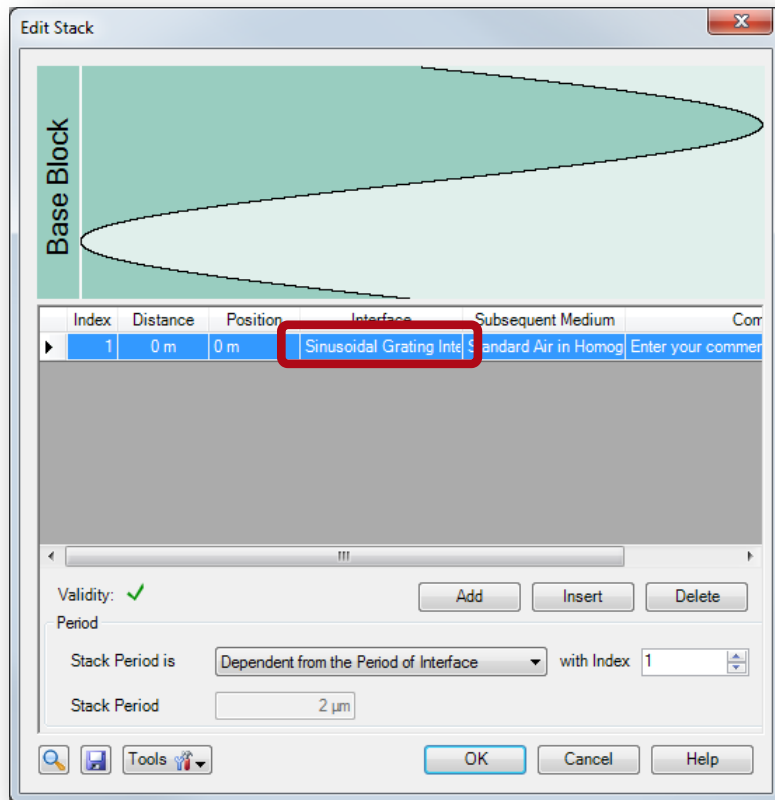
- Change the thickness of the base block to “0” as we are interested in the field behind the grating structure without further propagation through a base block.

Configuration of the Grating Component 2



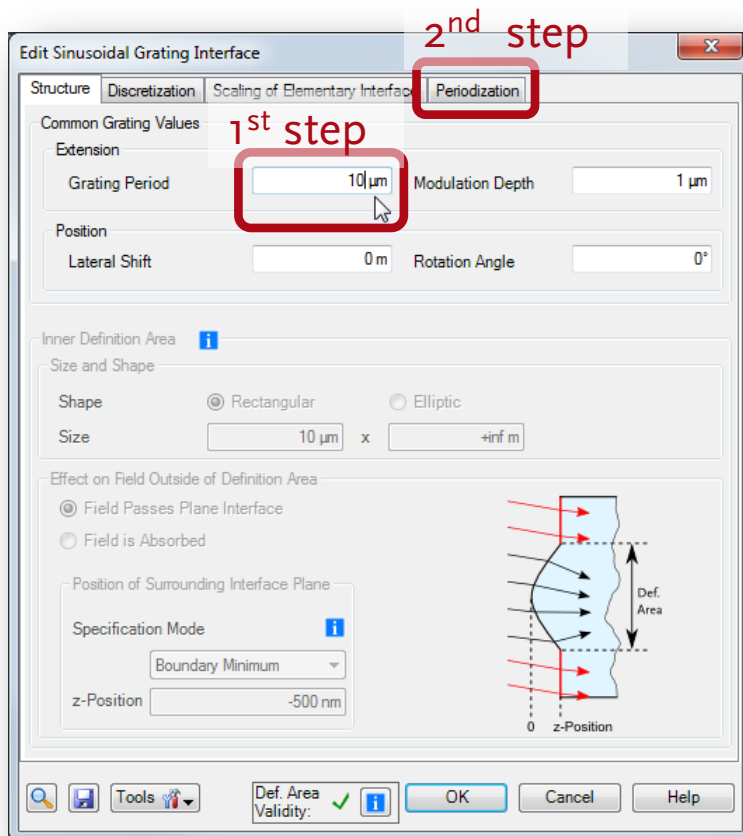
- VL handles gratings over so-called stacks.
- Click the “Edit” button for the stacks of the first interface, i.e. the left side of the base block is used for the modeling of the sinusoidal surface.

Configuration of the Grating Component 3



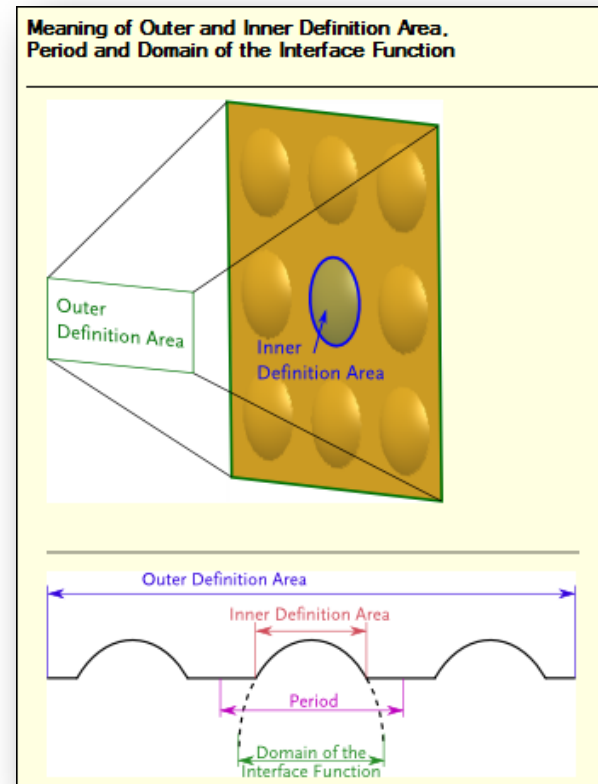
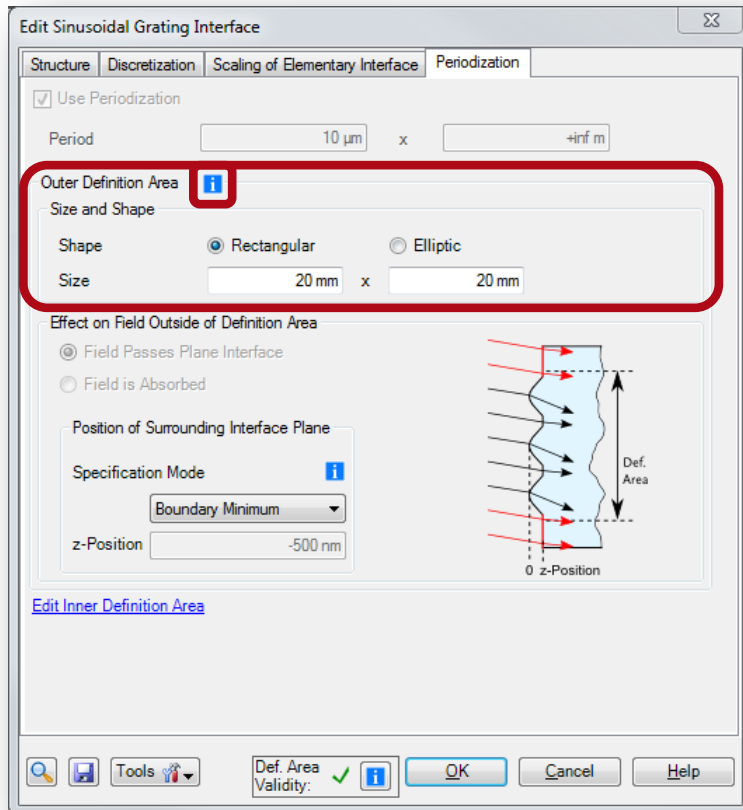
- Move with the mouse over the writing in the blue line “Sinusoidal Grating ...”.
- Click the so appearing edit button (pencil symbol).

Configuration of the Grating Component 4



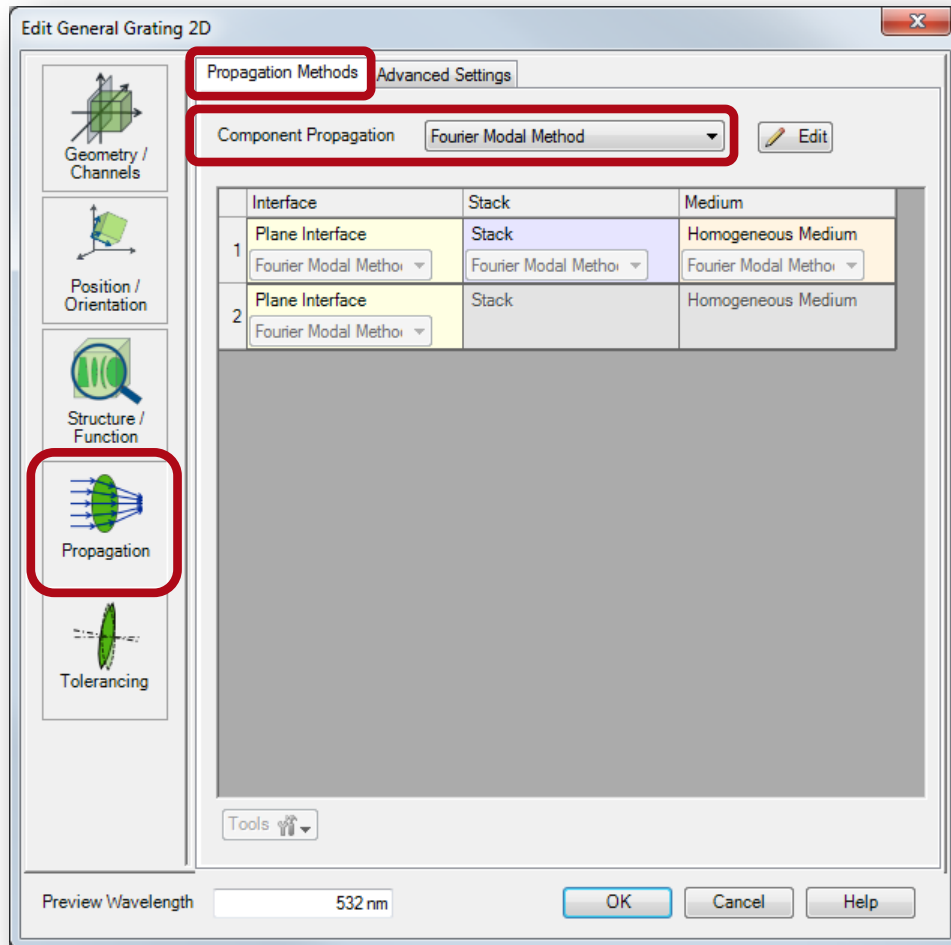
- Change the Grating Period to “10 μm”.
- Then go to the Periodization Tab.

Configuration of the Grating Component 5



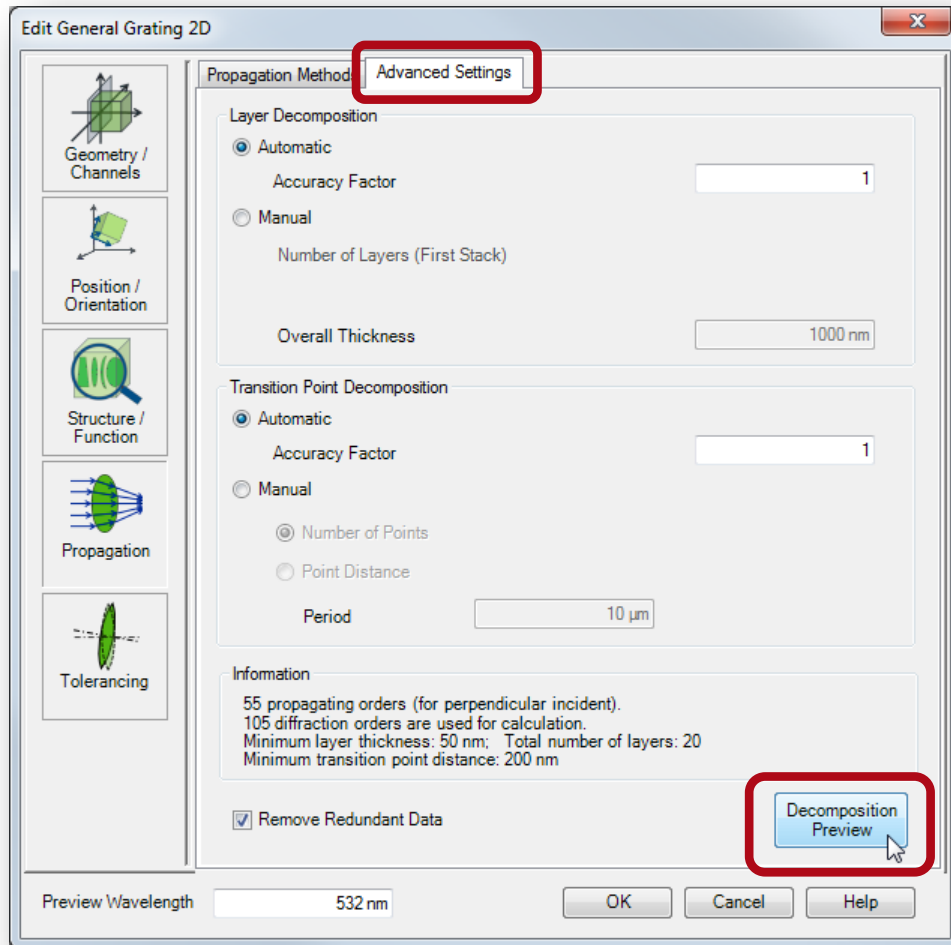
- Here you see the default size of the so-called “Outer Definition Area” whose definition is illustrated when the mouse is moved over the blue “i” symbol. Confirm the dialogs with “OK”.

Configuration of the Grating Component 6



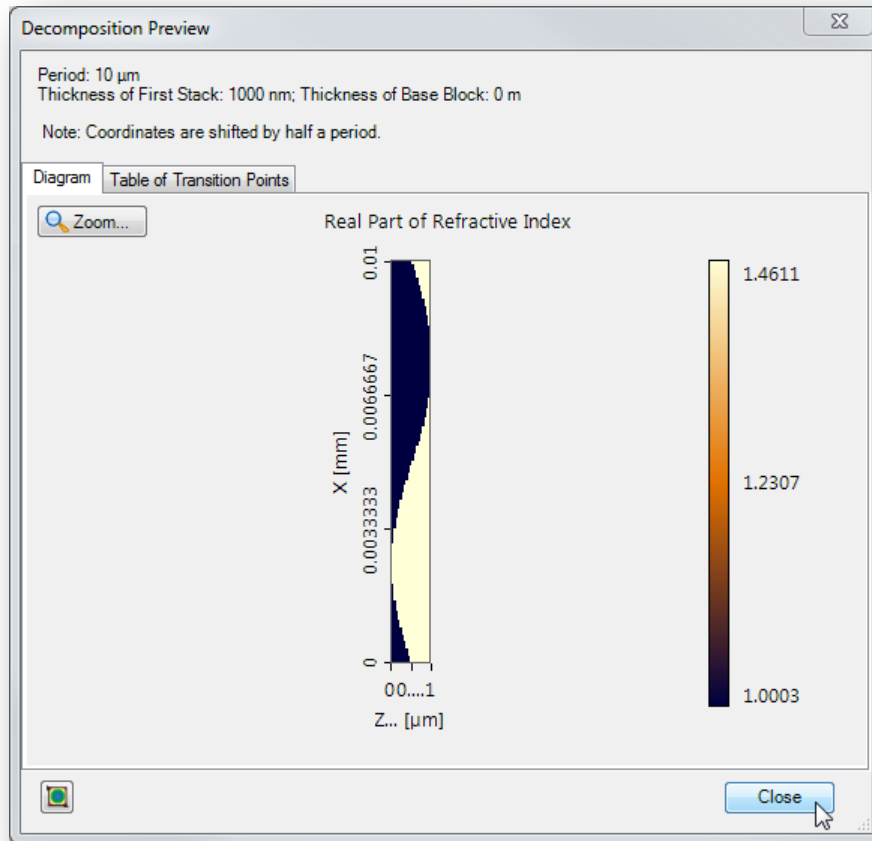
- Back in the “Edit General Grating 2D” dialog switch to “Propagation”.
- In the “Propagation Methods” tab you can select the propagation technique.
- By default a “Fourier Modal Method” (FMM) is set, which is a rigorous technique for grating analysis.

Configuration of the Grating Component 7



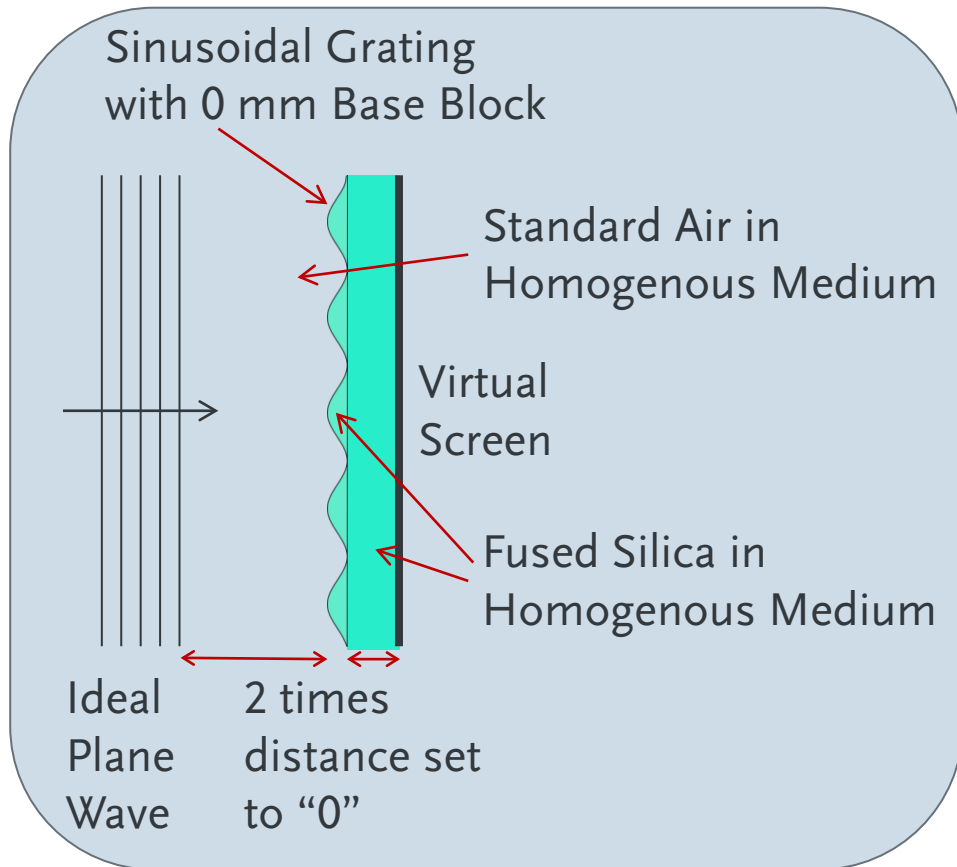
- Switch to the “Advanced Settings” tab and click “Decomposition Preview”.

Configuration of the Grating Component 8



- Here we see the grating structure decomposed into layers and transition points as the FMM can only analyze such decomposed structures.
- For the y-direction an invariant behavior is assumed.
- Click “Close” and then “OK” in the “Edit General Grating 2D” dialog.

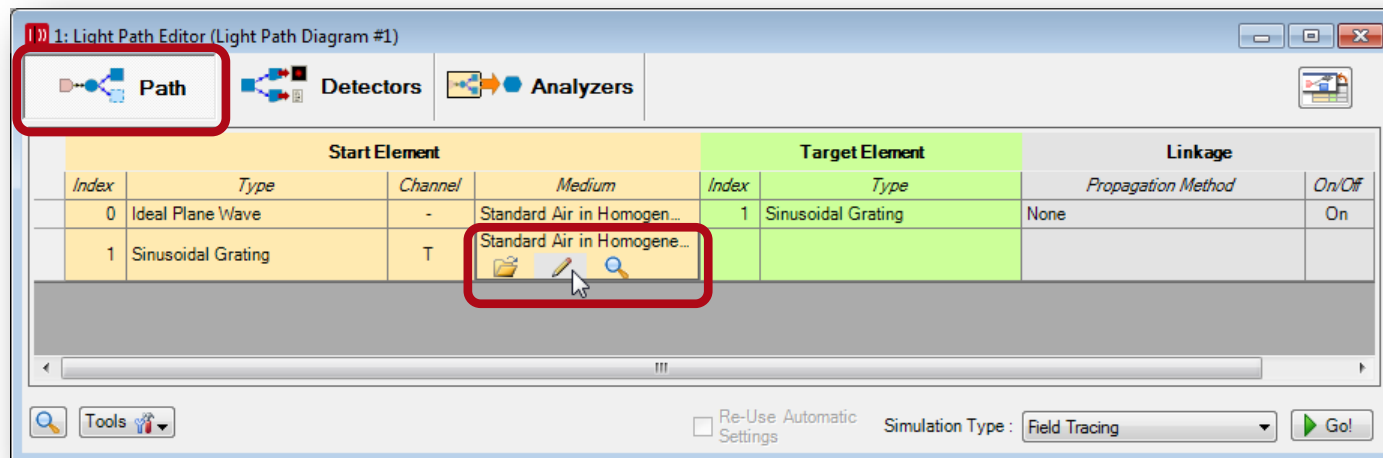
Illustration of Some Aspects of the Setup



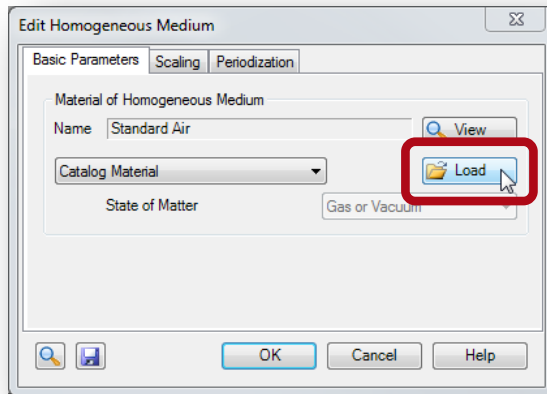
- Though the distances between Light Source and Grating Component as well as Grating Component and Virtual Screen are set to zero, the media have to be set, so that the correct transitions can be considered.
- This setup corresponds to one where the field just behind the grating structure is being analyzed.

Setup of the Measurement Conditions

- We are interested in the near field and the efficiency.
- The measurement of both is assumed to be done in the same medium as the grating component's is.
- The embedding medium is air and the grating medium is fused silica.
- Therefore go to the column “Medium” of the Sinusoidal Grating (2nd line) of the Light Path Editor and click the appearing edit button (pencil symbol).

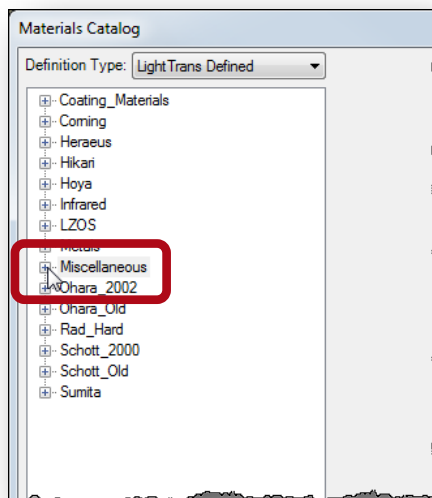


Loading of a Medium 1



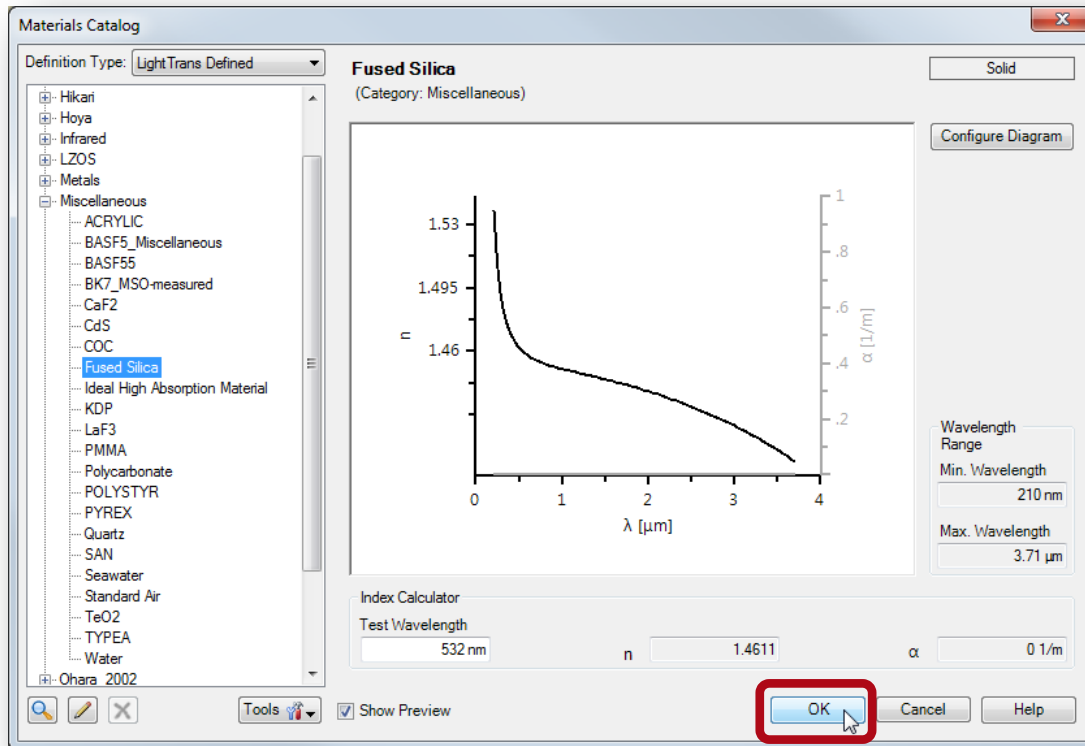
1. In the dialog “Edit Homogeneous Medium” click “Load”.

Results in



2. Click the “+” symbol of the entry “Miscellaneous”.

Loading of a Medium 2



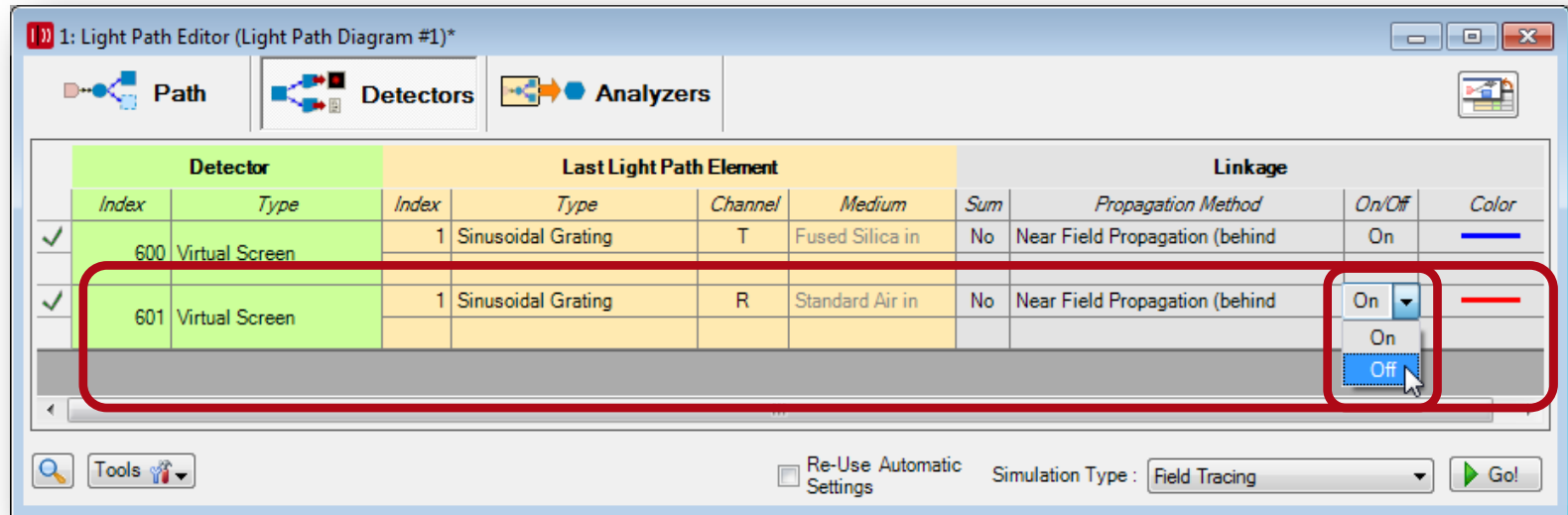
- Select “Fused Silica” and confirm the open dialogs with “OK”.

Results in



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

Selection of Near Field's Evaluation



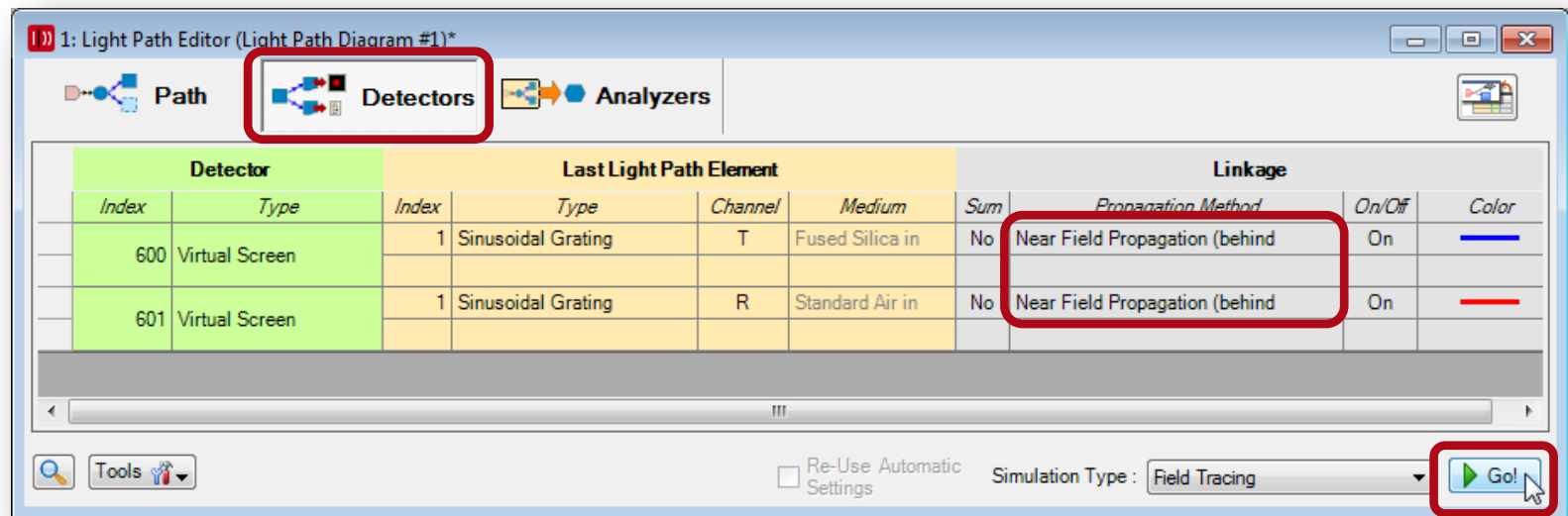
- Regarding the evaluation of the field let's concentrate on the transmission.
- Thus turn off the Virtual Screen regarding the reflection. (As a consequence the continuous red transmission linkage in the Light Path Diagram becomes dashed.)

STEP 2

Analysis of the Near Field

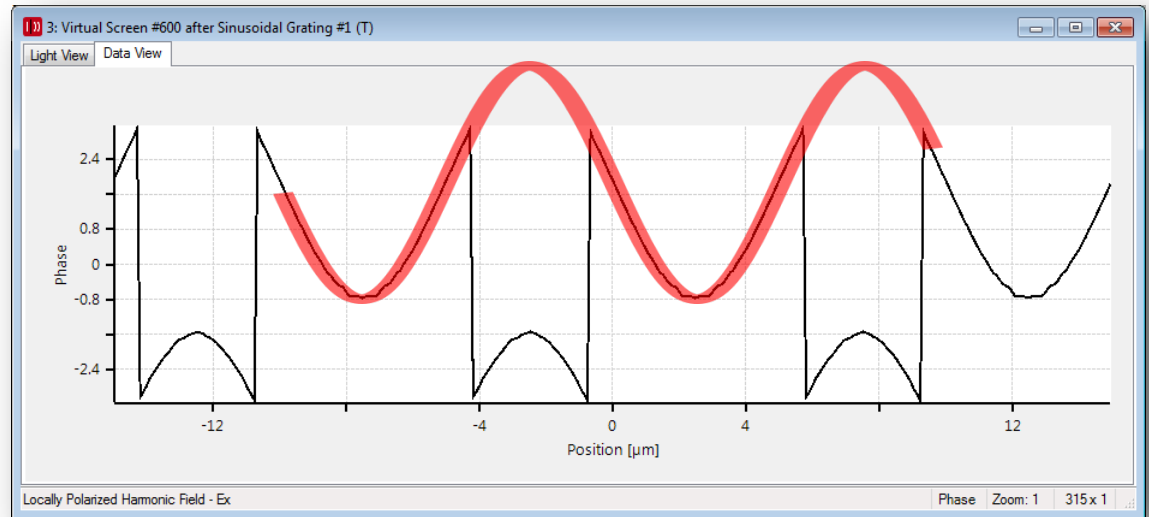
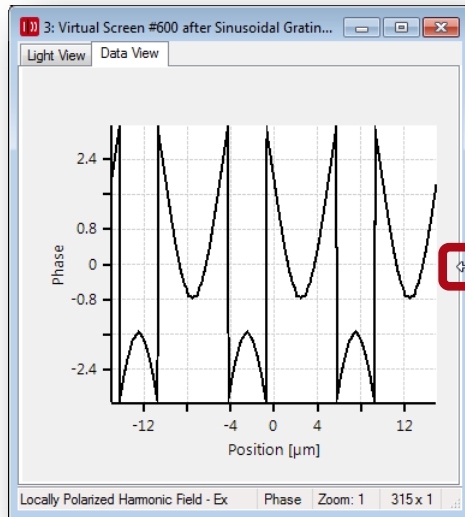
First Near Field Simulation

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

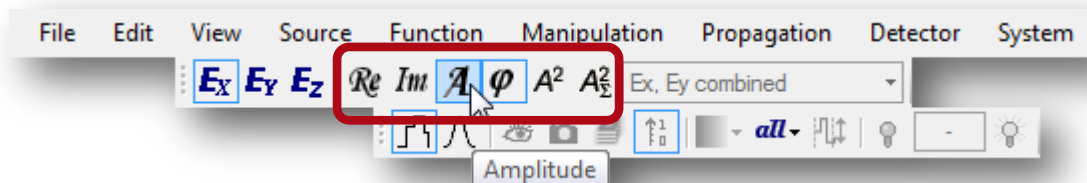


- In order to calculate the near field click “Go!”.

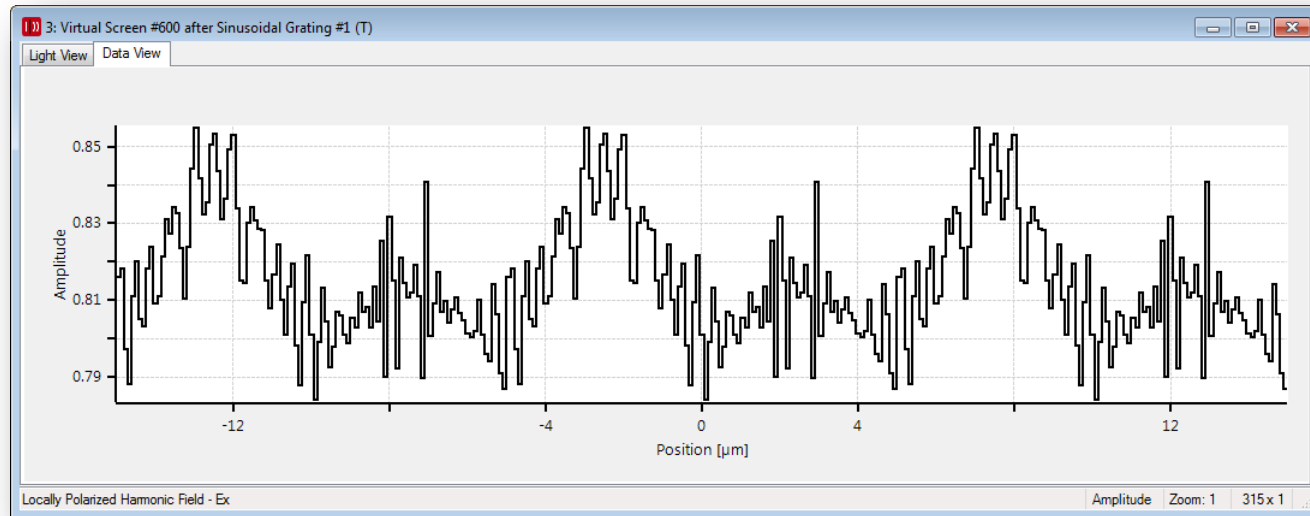
First Near Field Results 1



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



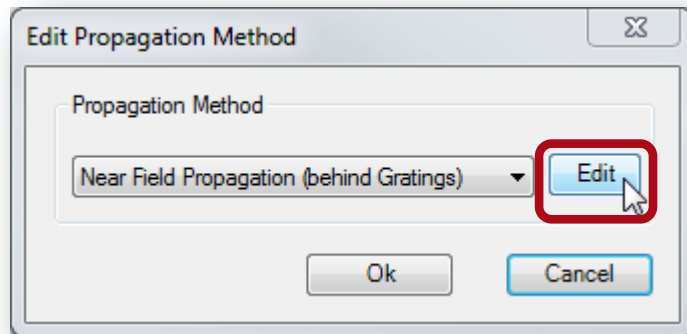
First Near Field Results 2



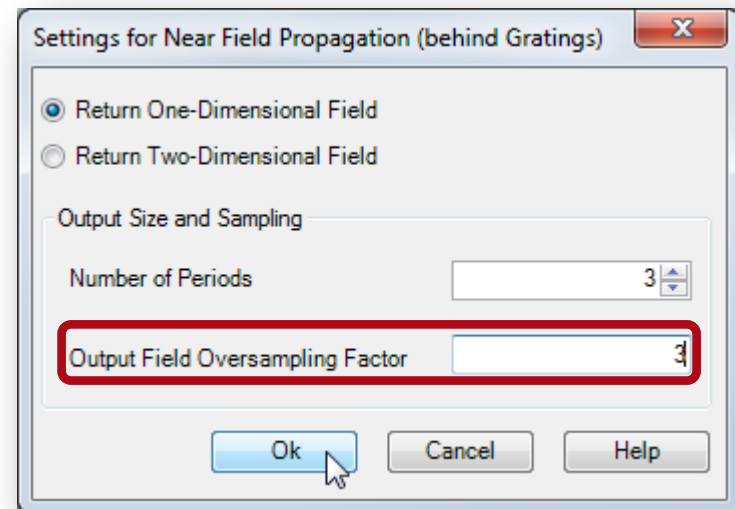
- The amplitude of the field is also varying a bit.
- To increase the resolution go to the 1st line in the “Detector” tab in the Light Path Diagram and double click in the column “Propagation Method”.

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

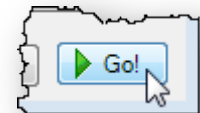
First Near Field Results 3



Results in

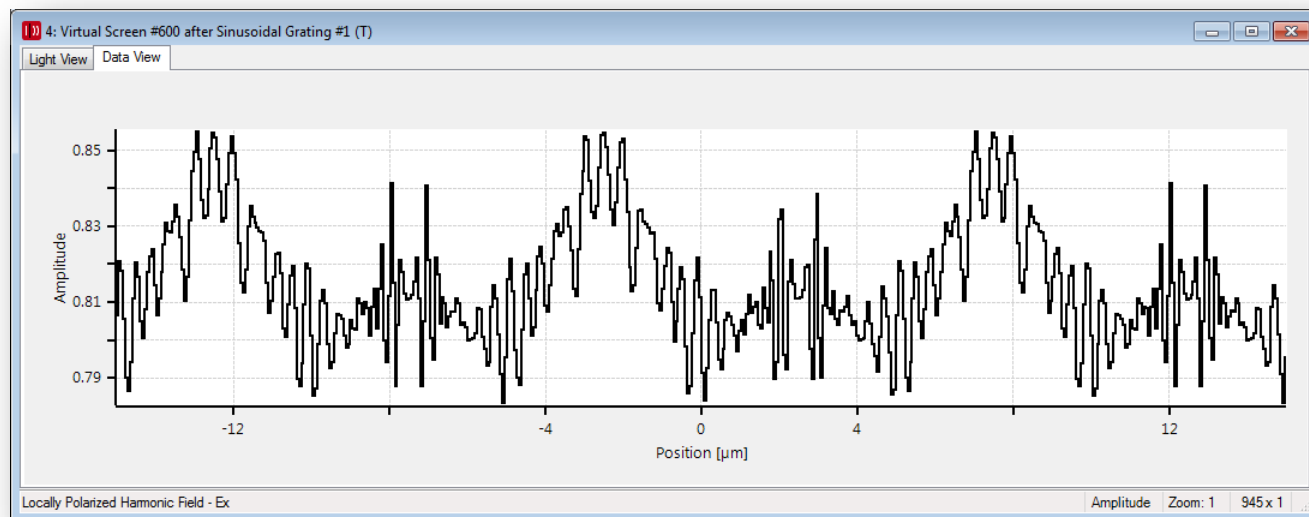


- Click “Edit”.
- Change the resolution by a factor of 3.
- Confirm both dialogs with “Ok”.
- Then repeat the simulation with “Go!”.



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.

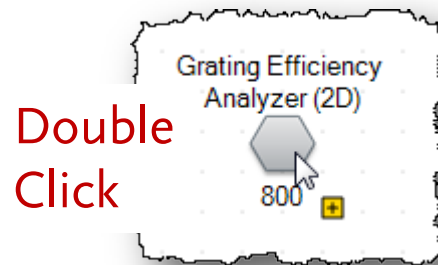


STEP 3

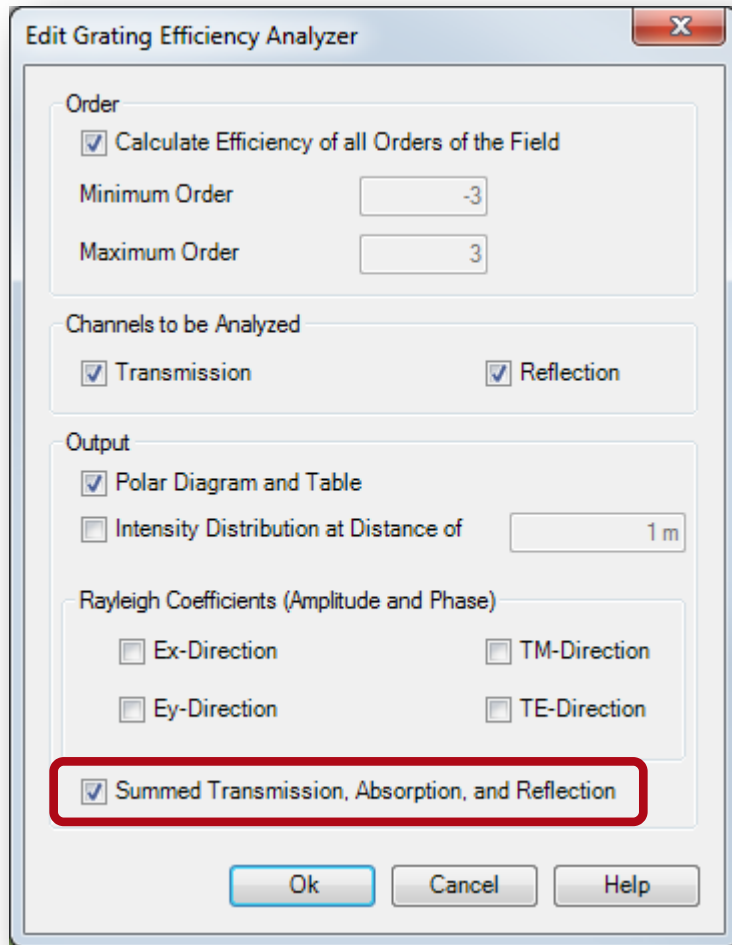
Analysis of the Efficiencies of the
Propagating Orders

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.

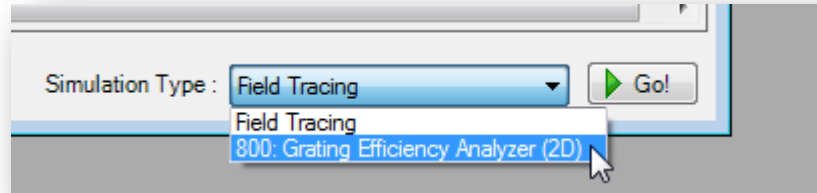


Configuration for Efficiency Analysis 2



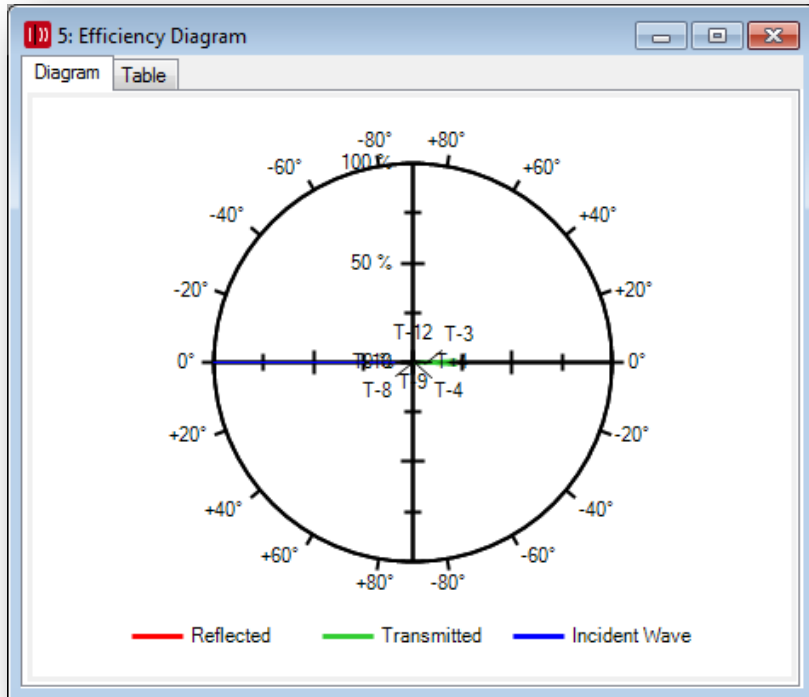
- By default the Grating Efficiency Analyzer calculates all orders of the field and the transmission as well as the reflection will be calculated and displayed in a polar diagram.
- For some further results in table form check “Summed Transmission, Absorption, and Reflection.”
- Then click “Ok”.

First Efficiency Simulation



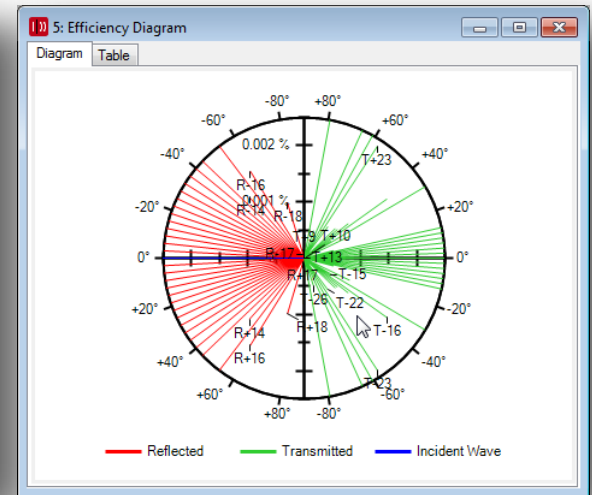
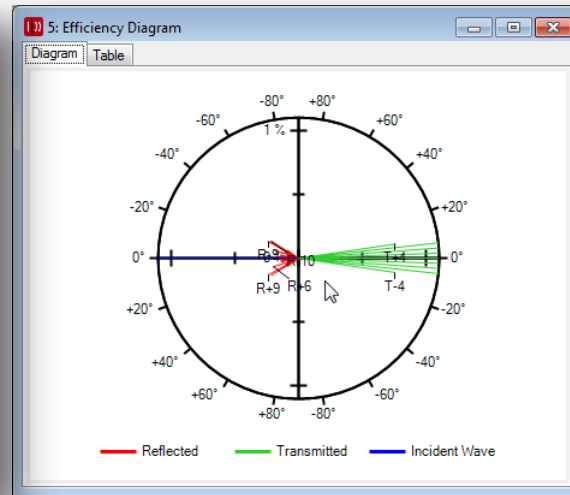
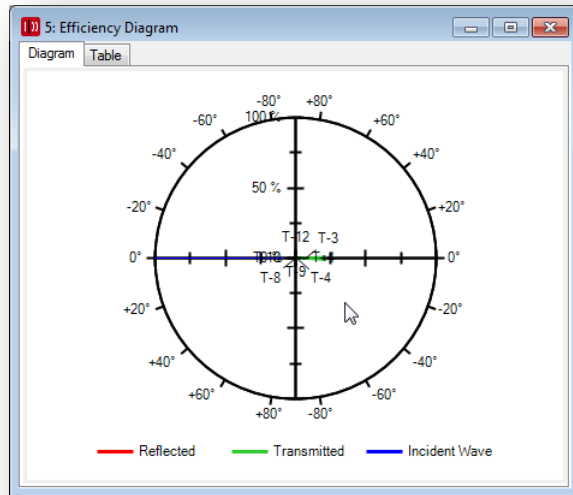
- In the Light Path Editor change the Simulation Type from “Field Tracing” to “Grating Efficiency Analyzer (2D)”.
- Then click “Go!”.

First Efficiency Results 1

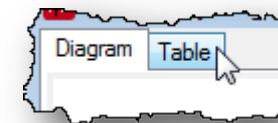


- You get a polar diagram showing the directions of the incident wave and the directions as well as the efficiencies of the reflected and transmitted orders.
- Move the mouse into the diagram and zoom in via the scroll wheel.
- At first you'll see only the strongest orders.

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

4: Efficiency Diagram

Diagram Table

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).

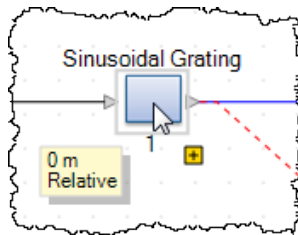
STEP 4

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

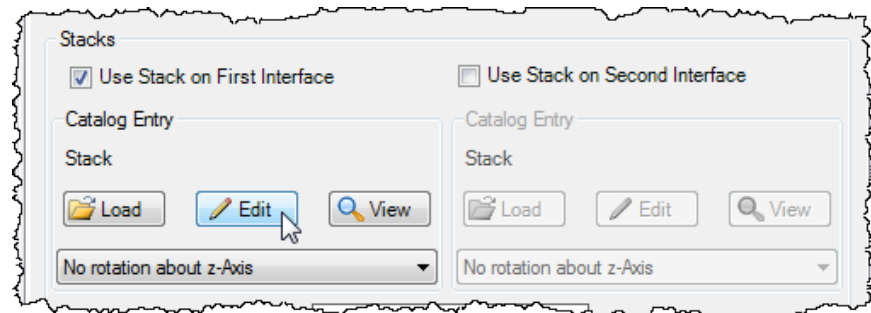
Change of the Grating Setup

- 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 "10 μm " to "1 μm ". The modulation depth remains "1 μm ".
- Thus follow some previous demonstrated steps...

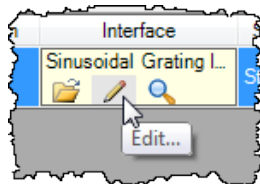
1st step



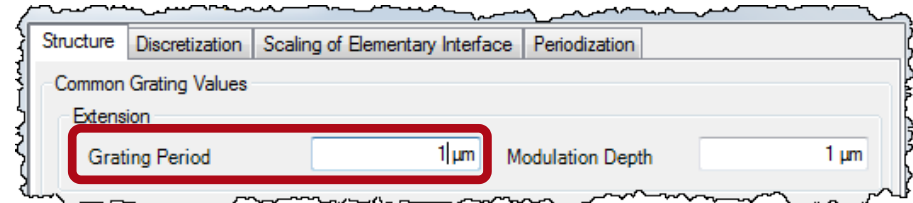
2nd step



3rd step



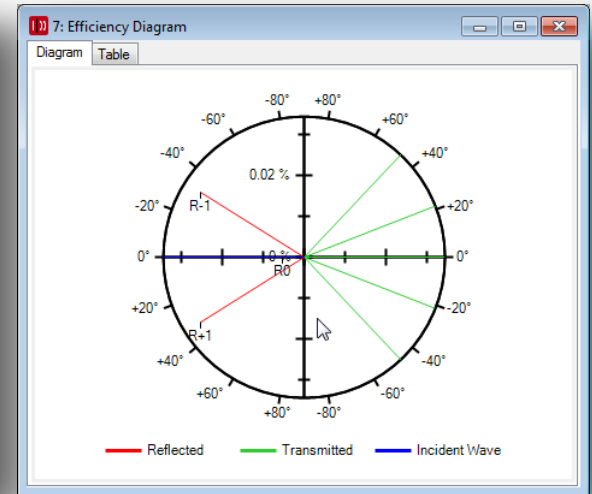
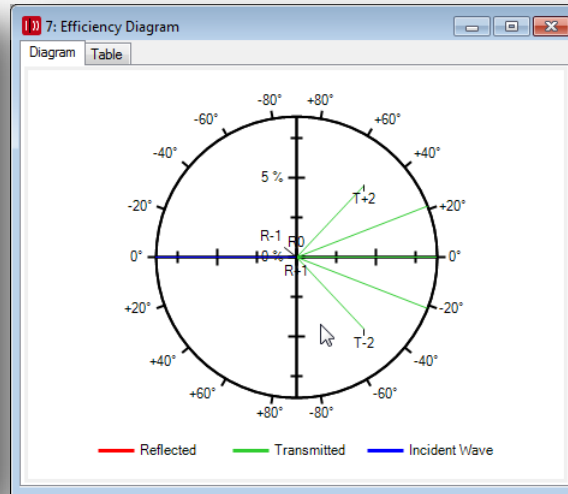
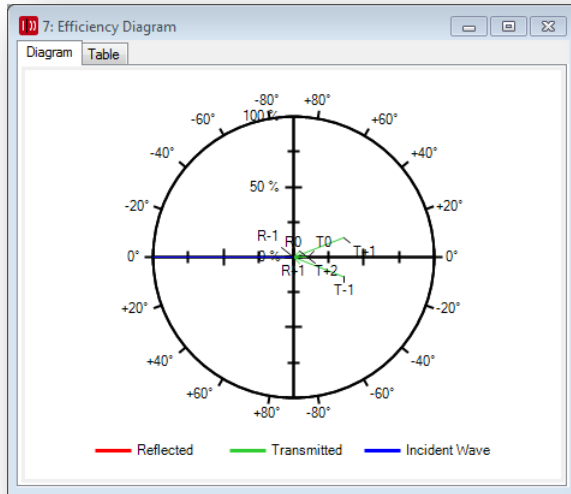
4th step



Explanations

- Scenarios like this with a wavelength of 532nm and a grating period of $1\mu\text{m}$, 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



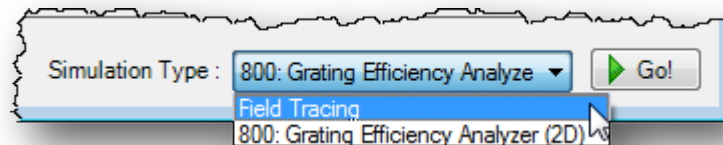
7: Efficiency Diagram

Diagram Table

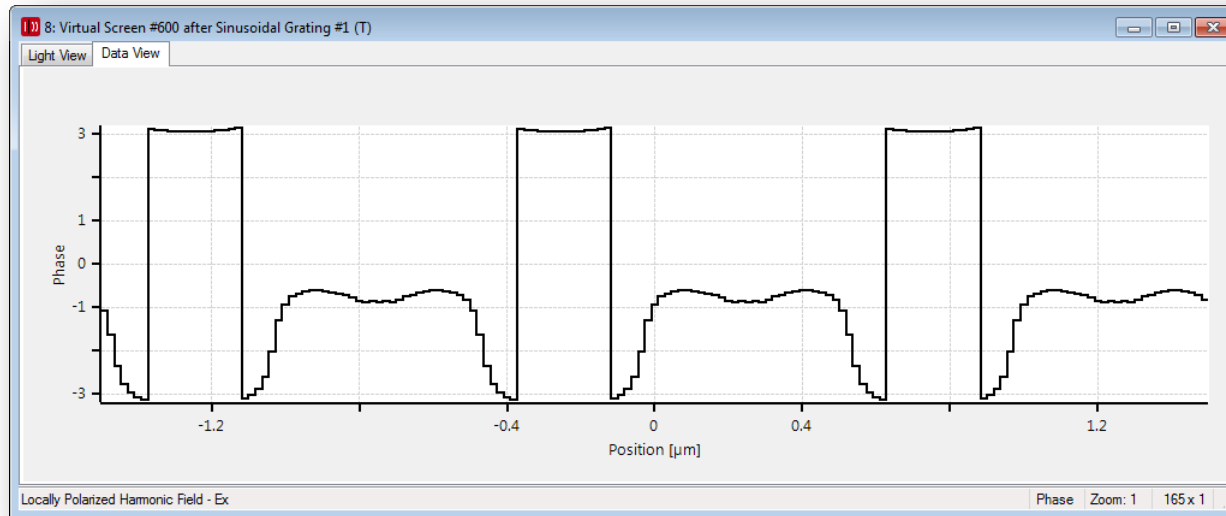
Reflected			Transmitted			Incident Wave		
Label	x-Value	y-Value	Label	x-Value	y-Value	Label	x-Value	y-Value
R-1	-32.131°	0.029906 %	T-2	-46.737°	6.1858 %	Point 1	0°	100 %
R0	8.5924E-31°	0.0052498 %	T-1	-21.353°	38.602 %			
R+1	32.131°	0.029906 %	T0	0°	10.358 %			
			T+1	21.353°	38.602 %			
			T+2	46.737°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

Second Near Field Simulation

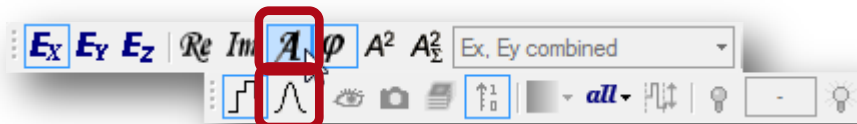
- For the near field change the simulation type back to “Field Tracing”.
- Then run the simulation by clicking “Go!”.



Second Near Field Results 1



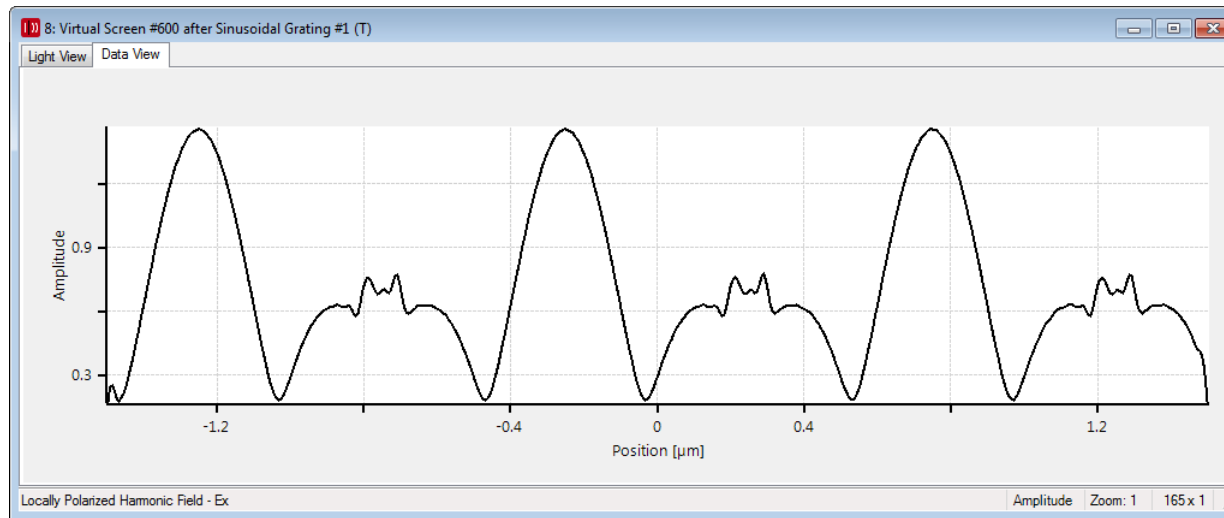
- Again 3 periods are displayed.
- With these small grating structures there is no longer a sinusoidal phase distribution because of the occurring resonance effects.
- Switch to the amplitude view and the cubic interpolation.



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.