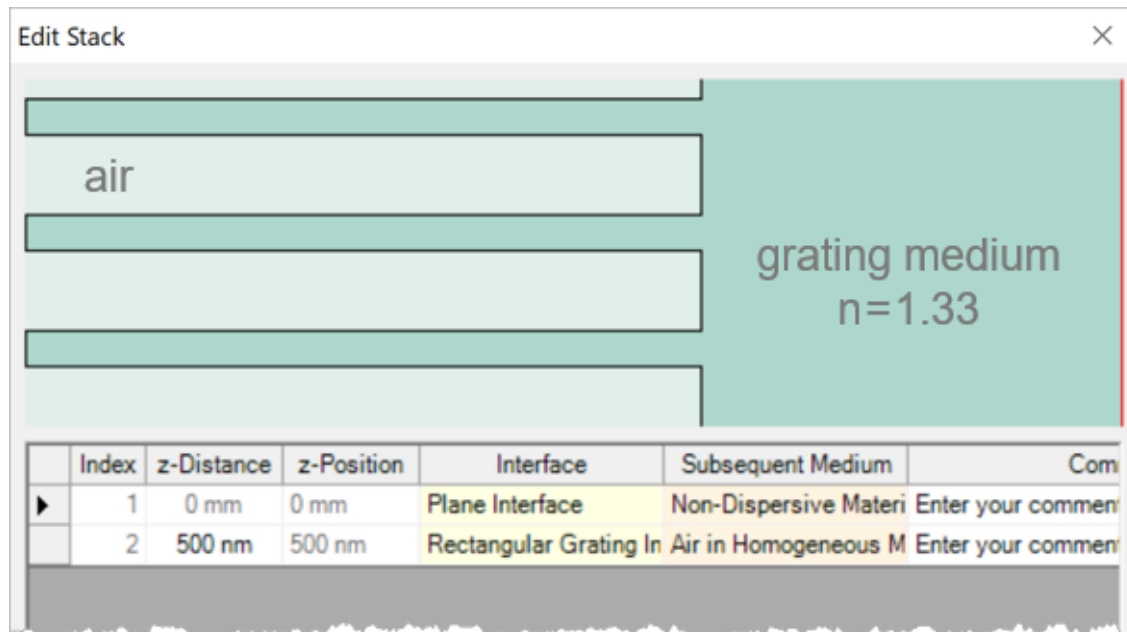


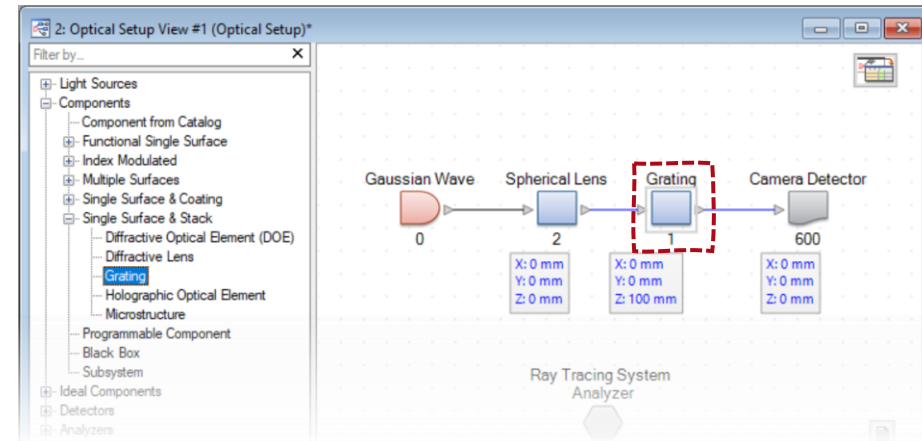
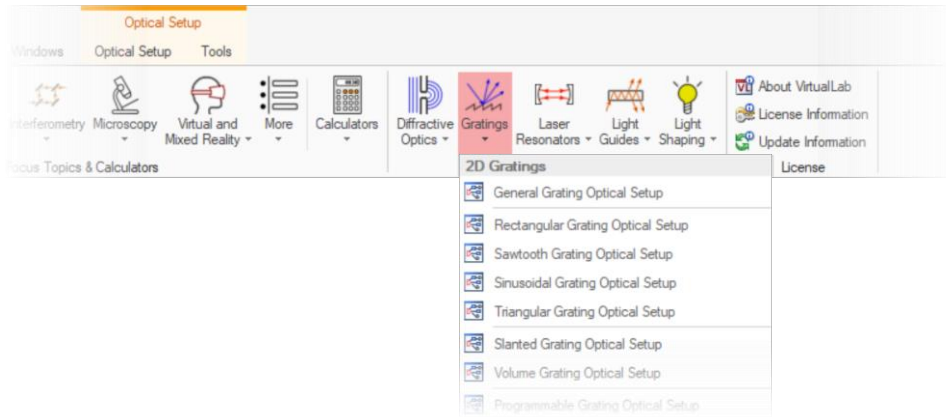
# **Modeling of Gratings within Optical System – Discussion at Examples**

# Abstract



Gratings are probably the most used diffraction optics elements in optics. Nowadays, they are often employed in complex systems and work together with other components. In such cases, there is a strong need to analyze gratings within the system and so to evaluate the system performance. We will explain, at examples, how to model gratings within system in VirtualLab Fusion. Topics like the alignment of the grating, the settings of grating order channels, and the angular response are to be discussed.

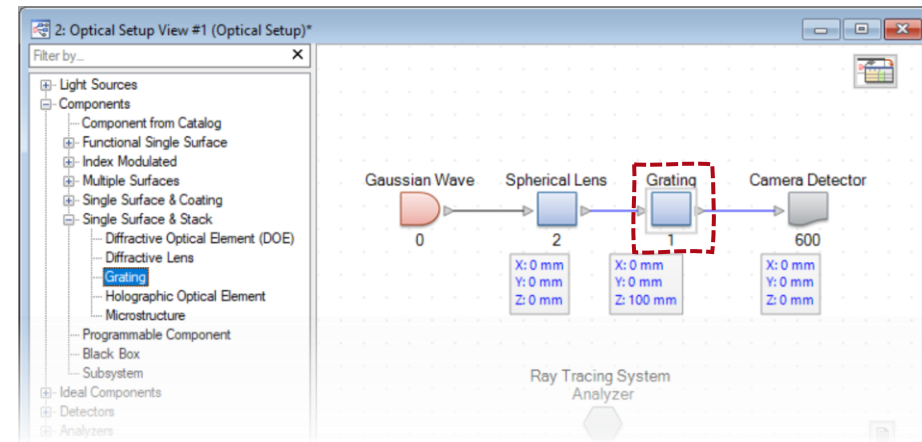
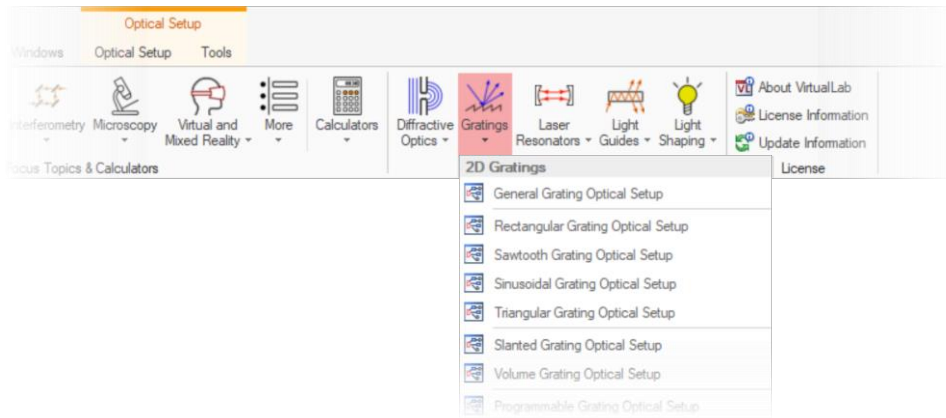
# Grating Modeling in VirtualLab Fusion – An Overview



- Single grating analysis
  - Via the main window “Gratings” menu, one can enter a special evaluation environment for gratings only.
  - It helps analyze and visualize grating diffraction properties, like the diffraction angles and efficiencies.

- Grating modeling within system
  - In a general optical setup, a grating component can be inserted in any position of the system.
  - This enables the modeling of gratings within a system and so to evaluate the system performance, with the possible effects of the grating considered.

# Grating Modeling in VirtualLab Fusion – An Overview



- Single grating analysis

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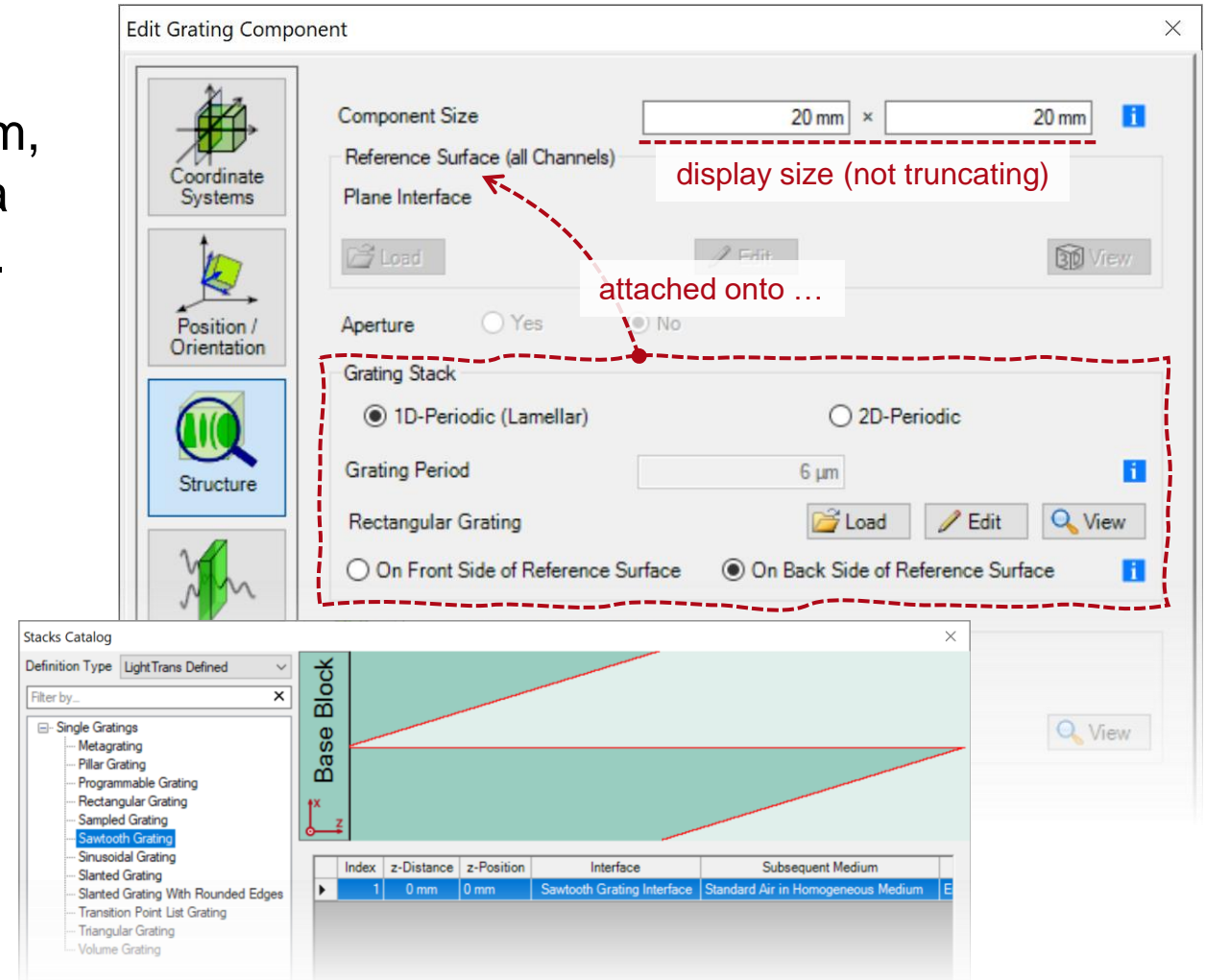
- Grating modeling within system

- In a general optical setup, a grating component can be inserted in any position of the system.
- This enables the modeling of gratings within a system and so to evaluate the system performance, with the possible effects of the grating considered.

Both ways of modeling can often be used together, for example, optimize the grating structure itself first and then insert it into a system.

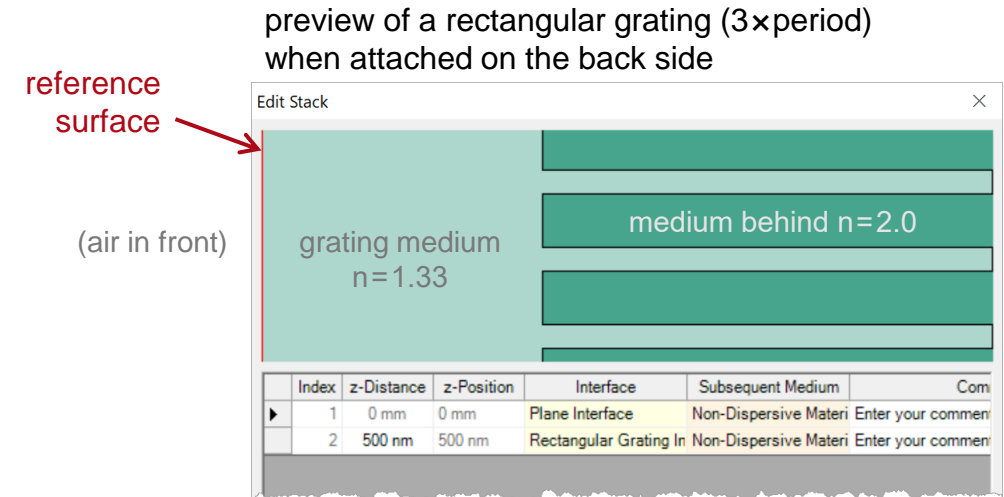
# Grating Alignment in System

- Attaching grating stack
  - To describe the grating within a system, a grating stack is always attached to a reference virtual surface (planar only).
  - The reference surface can be visualized in the 3D system view and help align the grating.
- Stack orientation
  - A grating stack can be attached onto either the front or back side of the reference surface.

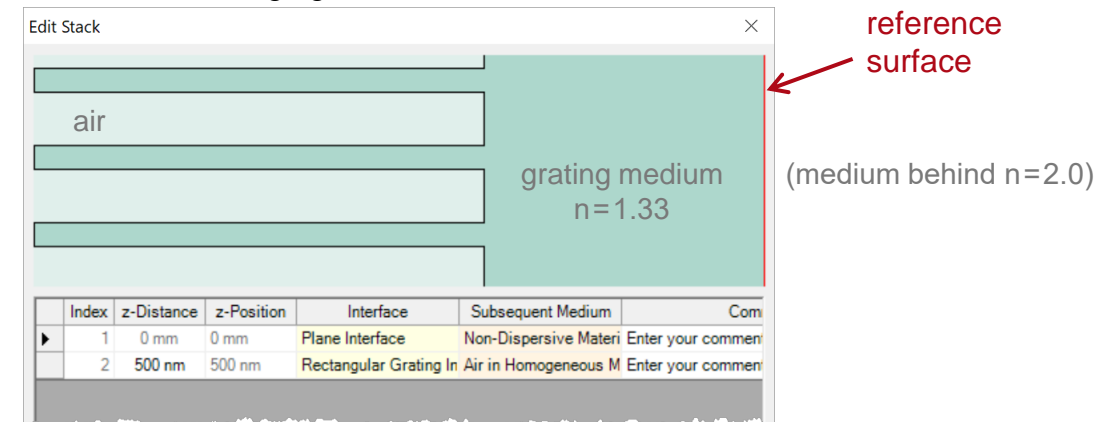


# Grating Alignment in System

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- Stack orientation
  - A grating stack can be attached onto either the front or back side of the reference surface.
  - One must pay attention to the embedding medium setting when changing this option.

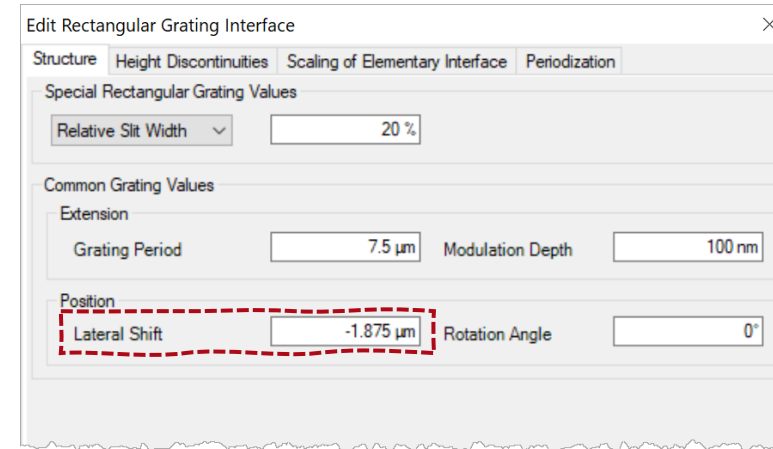


... and after changing it to the front side



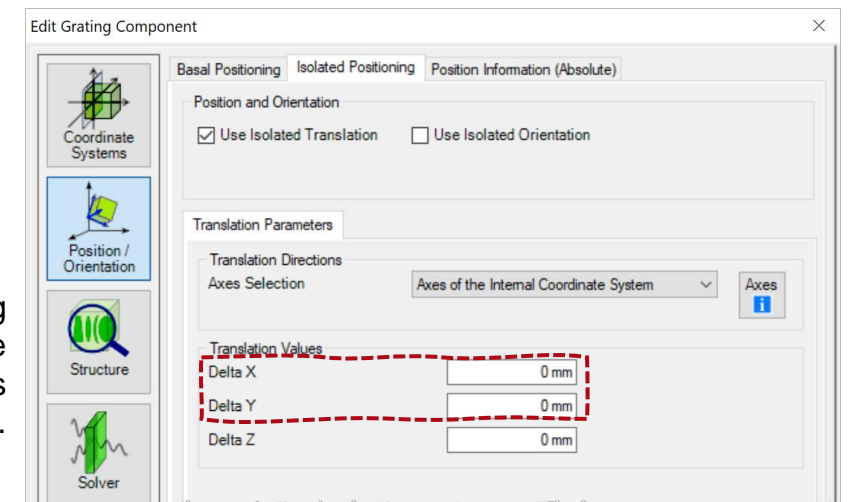
# Grating Alignment in System

- Lateral positioning
  - When modeling the interaction of a general field with gratings in a system, the lateral position of the grating must be considered.
  - For example, the effect may be very different whether a laser beam is (tightly) focused on the stripe or the air gap of a linear grating.
  - The lateral position of gratings can be adjusted either
    - in the stack settings (options may differ for different gratings), or
    - via the component positioning options.



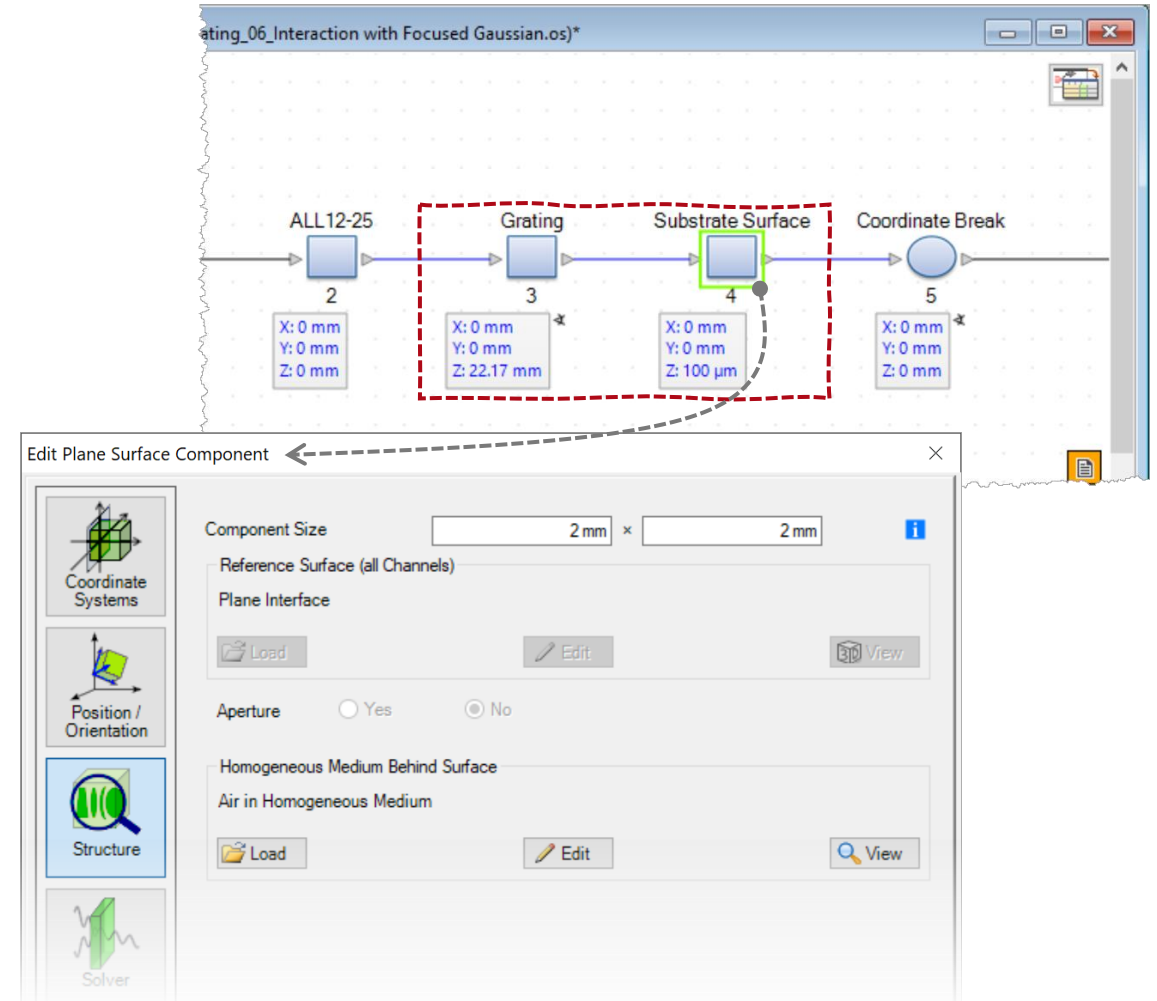
Options for lateral shift are available for e.g. the rectangular grating interface

The whole grating component can be laterally shifted, as a general option.



# Handling of Substrate, Fresnel Loss, and Diffraction Angle

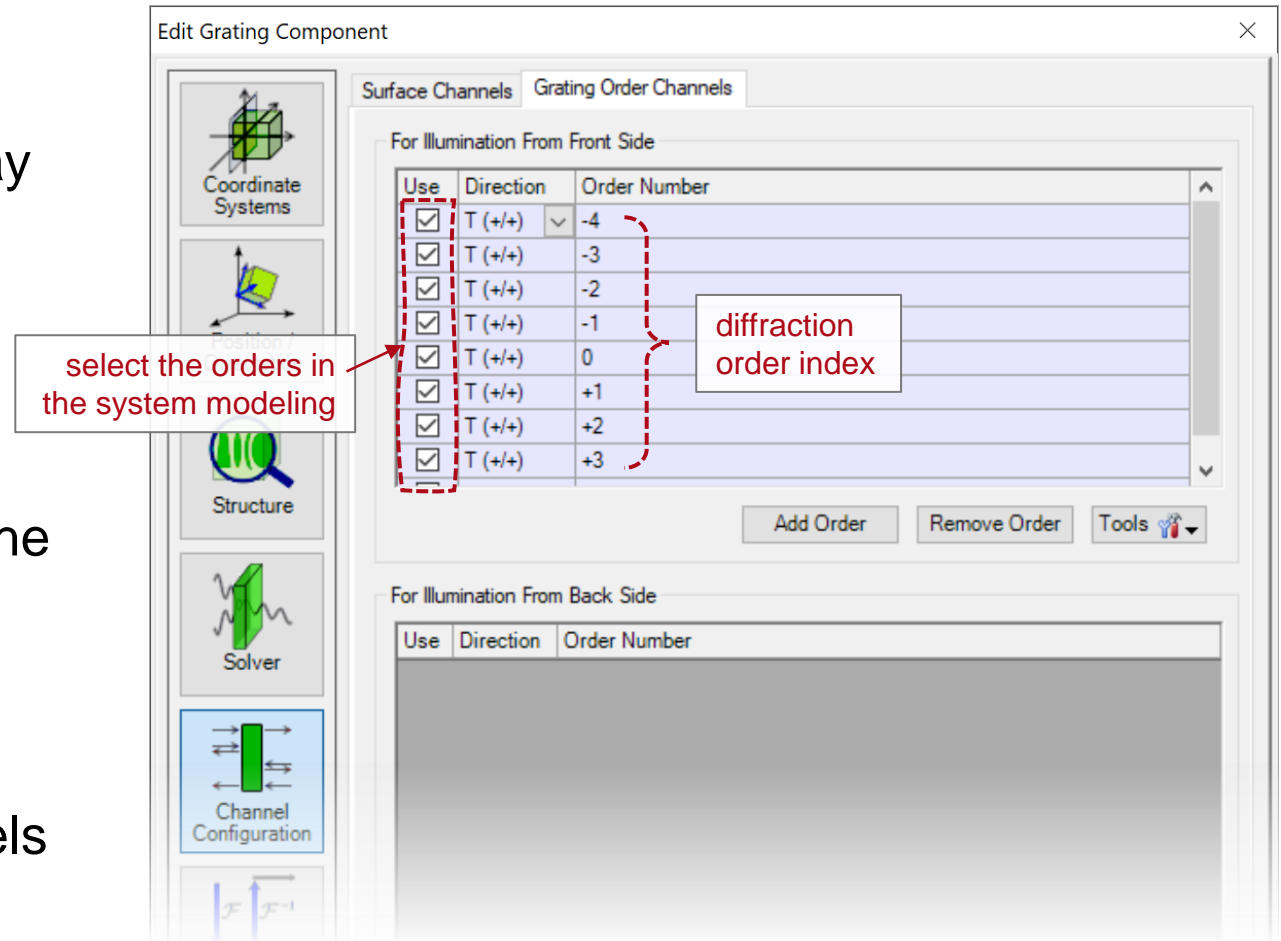
- Single grating analysis
  - As a convention, the effect of substrate is often omitted for e.g. the diffraction efficiency calculation.
- Grating modeling within system
  - But, any realistic grating structure rests on a substrate and we use a plane surface component together with a free-space in between to model it.
  - The plane surface modeling includes the Fresnel loss, but is not coupled with the FMM calculation of grating stacks.
  - It also help handle the diffraction angles in different media.





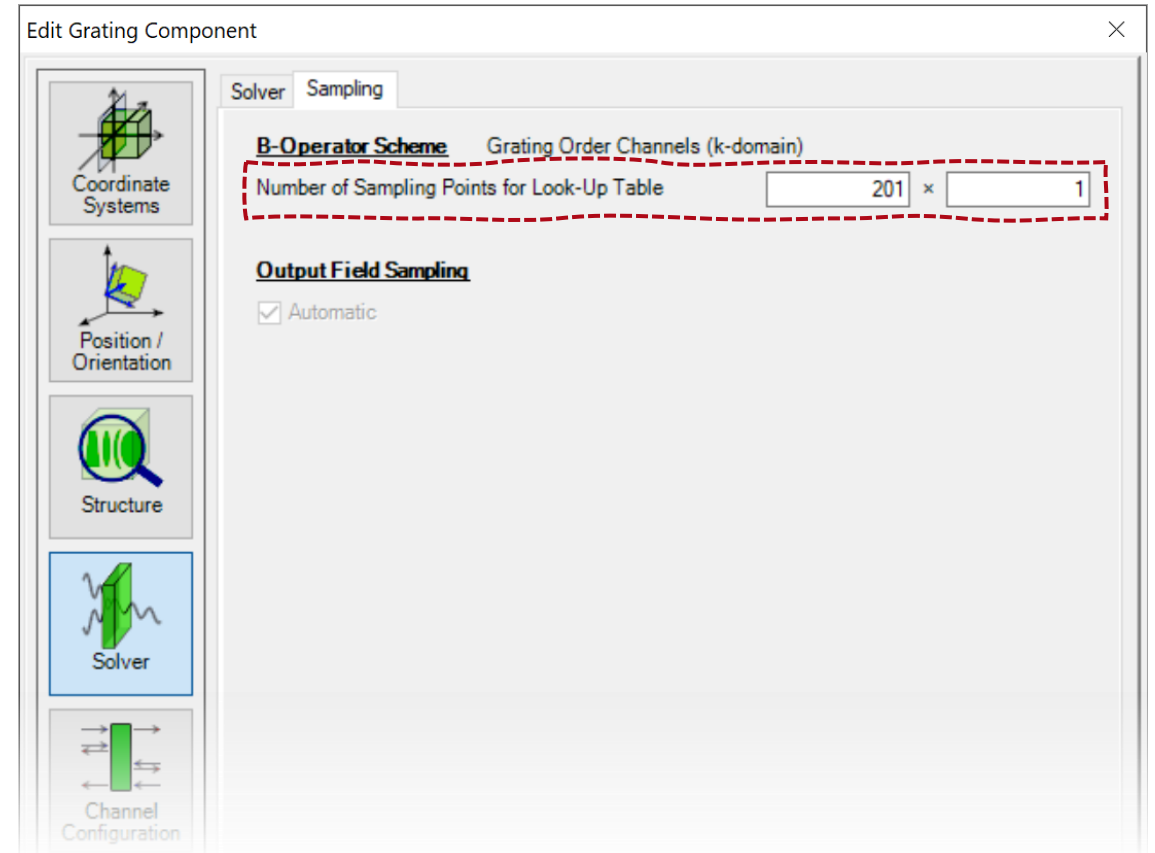
# Grating Order Channel Selection

- Directions
  - Input field may illuminate the grating from either front or back side and may get reflected or transmitted.
- Diffraction order selection
  - For a direction combination, there might be multiple diffraction orders.
  - It is not always needed consider all the diffraction orders and we suggest to use only those of interests.
- Remark
  - Selection of the grating order channels does not affect the number of diffraction orders in FMM calculation.



# Angular Response of Grating

- Diffraction property dependency
  - For a given grating, its diffraction property is related to the input field.
  - With different wavelength / polarization, the diffraction efficiency differs, and the same for different input angles.
  - To resolve the angle-dependent diffraction behavior, one may need to specify the sampling points k-domain (equivalent to angular space).
  - For a given input field, VirtualLab Fusion automatically determines the angular range.

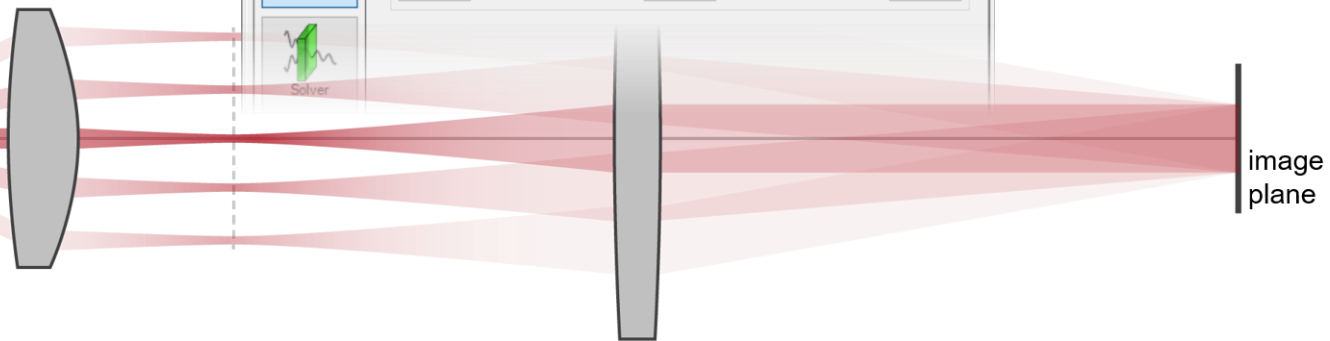
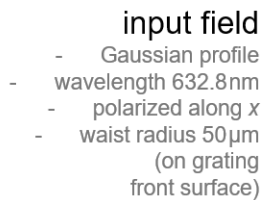
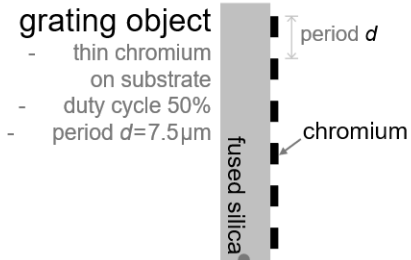
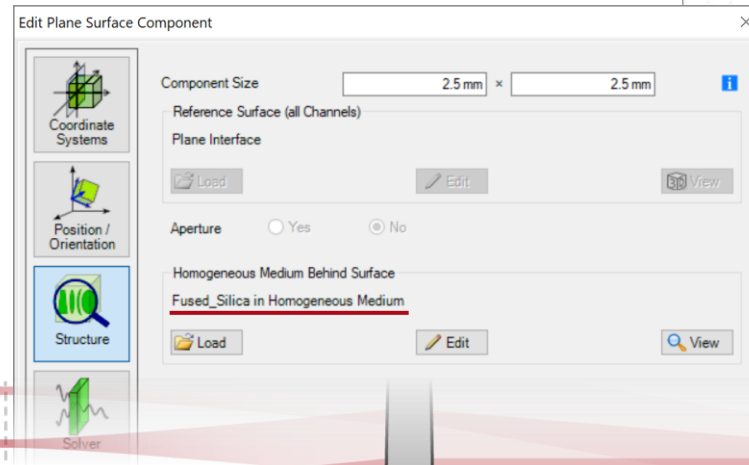
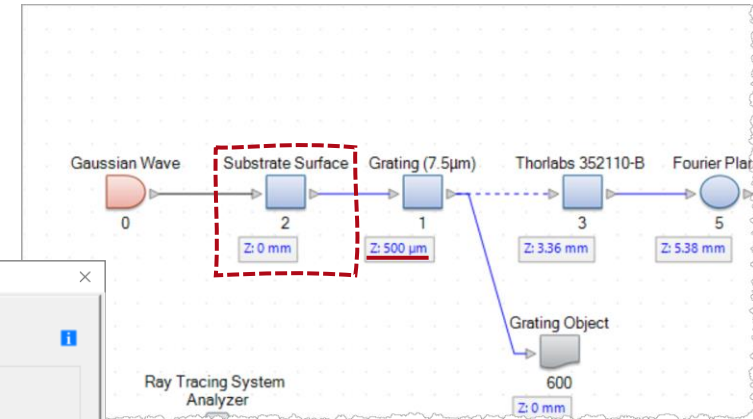


## **Example #1: Imaging Formation of a Grating Object**

# Substrate Handling

For the consideration of substrate, we

- use a plane surface component to model the front surface of the substrate layer,
- set the medium behind to fused silica, and
- set the distance to the next component to 500 $\mu\text{m}$ , equal to the thickness of the substrate.



[see the full Application Use Case](#)

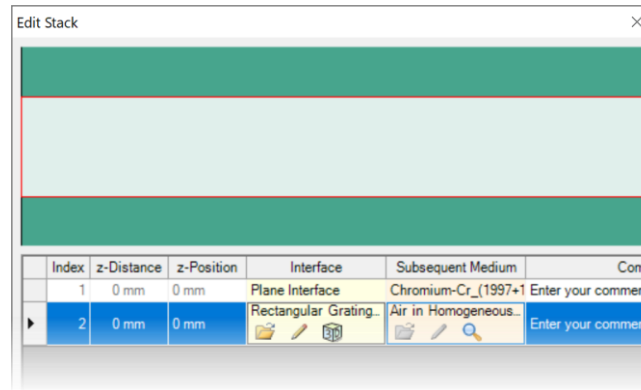
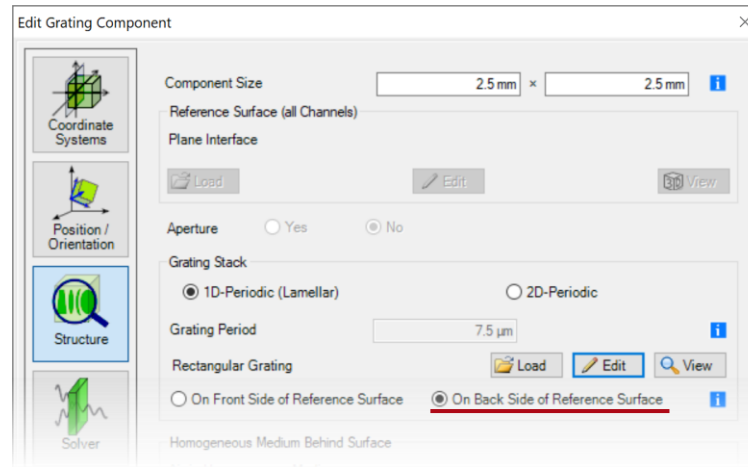
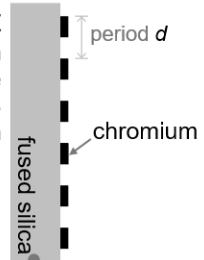
# Grating Configuration and Alignment

Following the sketch of the setup, we

- set the grating on the back side of the reference surface, and
- use a rectangular grating stack to represent the chromium stripes.

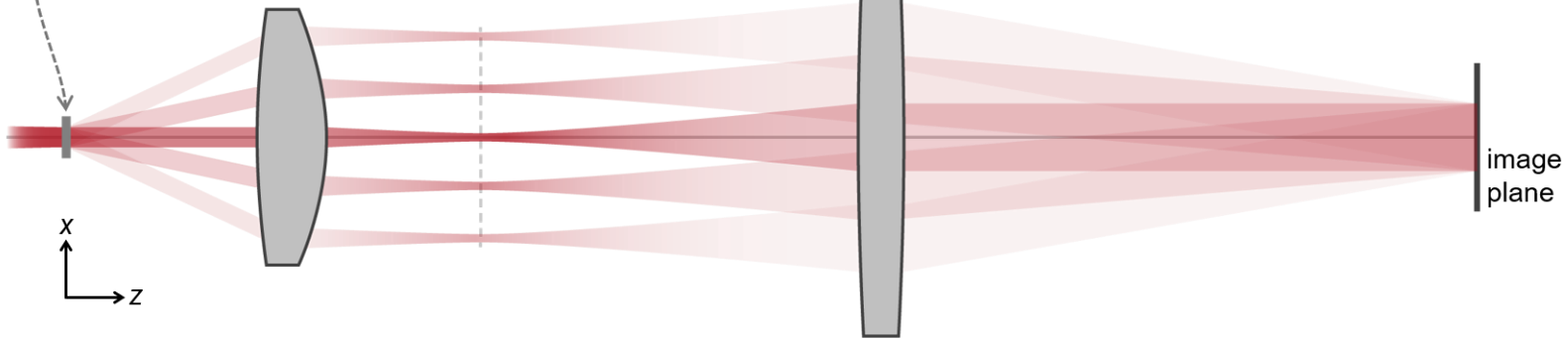
grating object

- thin chromium on substrate
- duty cycle 50%
- period  $d=7.5\mu\text{m}$

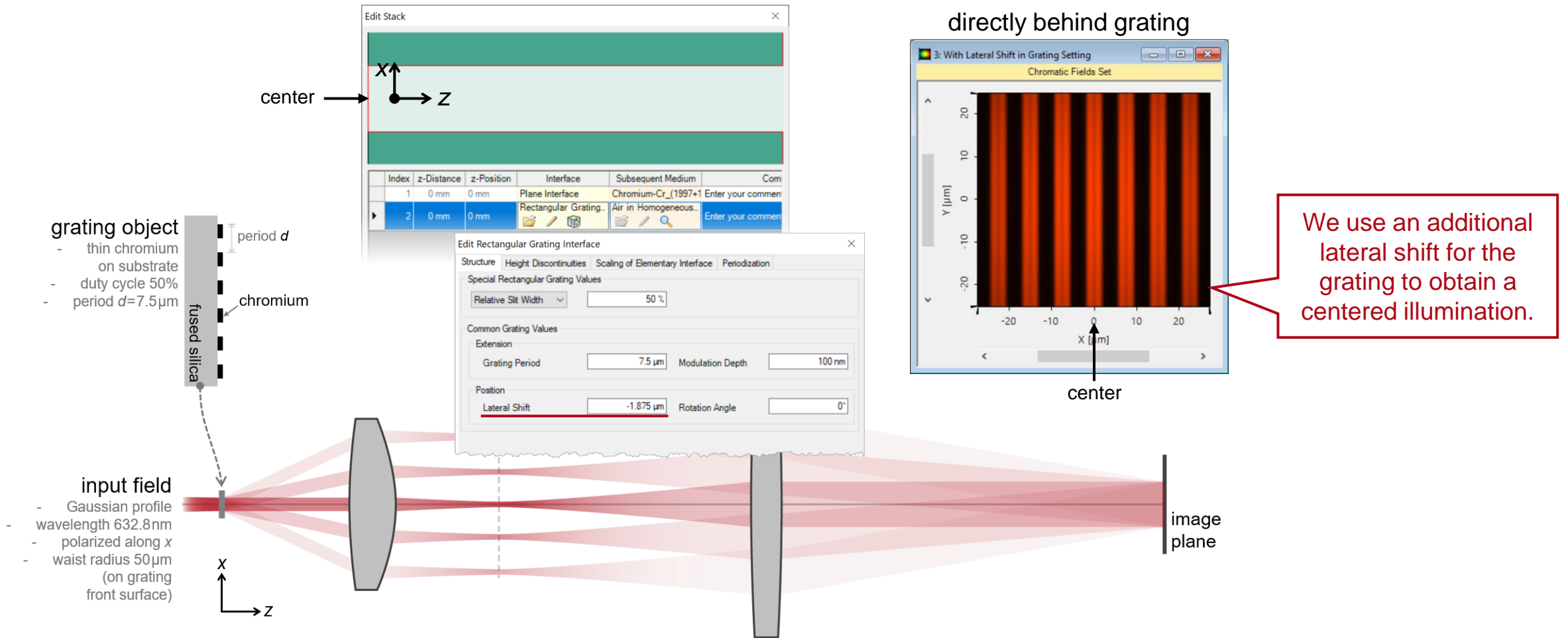


input field

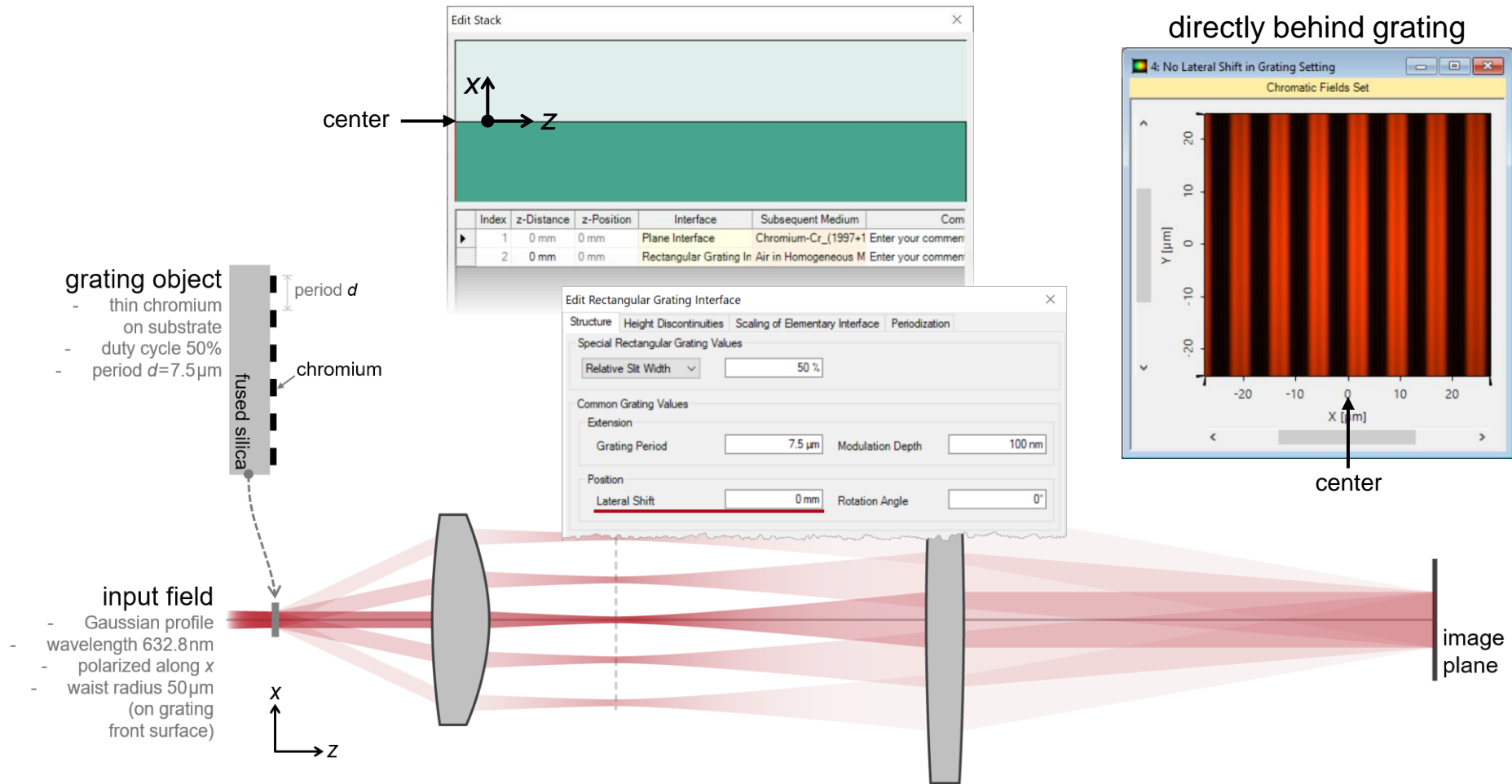
- Gaussian profile
- wavelength 632.8 nm
- polarized along x
- waist radius 50 μm (on grating front surface)



# Grating Configuration and Alignment



# Grating Configuration and Alignment



Attention shall be paid to the lateral position of the grating: it has an influence when illuminated by general fields with limited sizes.

# Grating Order Channel Selection

ray tracing system analysis

grating object

- thin chromium on substrate
- duty cycle 50%
- period  $d=7.5\mu\text{m}$

chromium

fused silica

period  $d$

input field

- Gaussian profile
- wavelength 632.8nm
- polarized along x
- waist radius  $50\mu\text{m}$  (on grating front surface)

x

z

Edit Grating Component

Surface Channels Grating Order Channels

For Illumination From Front Side

Use	Direction	Order Number
<input checked="" type="checkbox"/>	T (+/+)	-4
<input checked="" type="checkbox"/>	T (+/+)	-3
<input checked="" type="checkbox"/>	T (+/+)	-2
<input checked="" type="checkbox"/>	T (+/+)	-1
<input checked="" type="checkbox"/>	T (+/+)	0
<input checked="" type="checkbox"/>	T (+/+)	+1
<input checked="" type="checkbox"/>	T (+/+)	+2
<input checked="" type="checkbox"/>	T (+/+)	+3

Add Order Remove Order Tools

For Illumination From Back Side

Use	Direction	Order Number
-----	-----------	--------------

Coordinate Systems  
Position / Orientation  
Structure  
Solver  
Channel Configuration

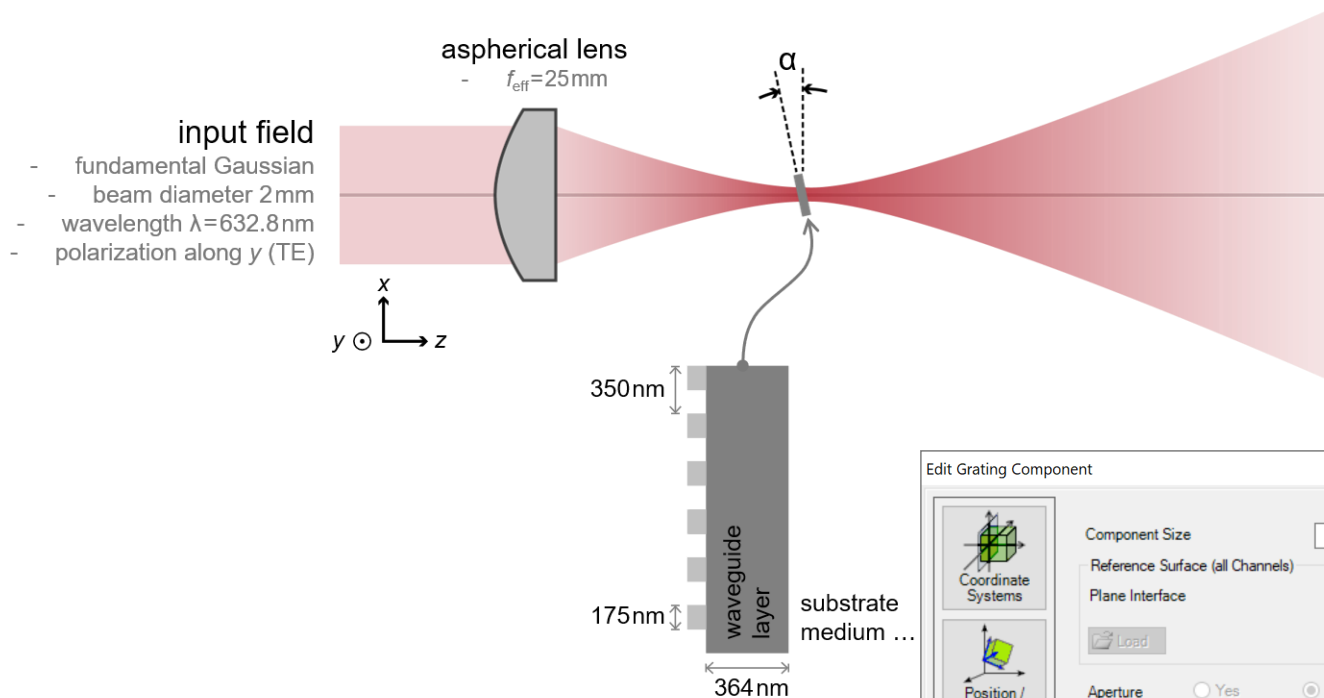
It is not always needed to consider all the diffraction orders in a system, we

- use ray tracing system analyzer to help visualize and determine the acceptance of the imaging system, and
- choose only those diffraction orders that can enter the imaging system.



## **Example #2: Angular Sensitivity Testing for a Waveguide Resonant Grating**

# Grating Configuration and Alignment



Following the sketch of the setup, we

- set the grating on the front side of the reference surface, and
- use a rectangular grating interface, with two plane interfaces, to construct the resonant waveguide grating.

Edit Grating Component

Component Size: 2 mm

Reference Surface (all Channels): Plane Interface

Aperture:  Yes  No

Grating Stack:  1D-Periodic (Lamellar)  2D-Periodic

Grating Period: 350 nm

Resonant Waveguide Grating:  On Front Side of Reference Surface  On Back Side of Reference Surface

Homogeneous Medium Behind Surface: Non-Dispersive Material First 1D in Homogeneous Medium

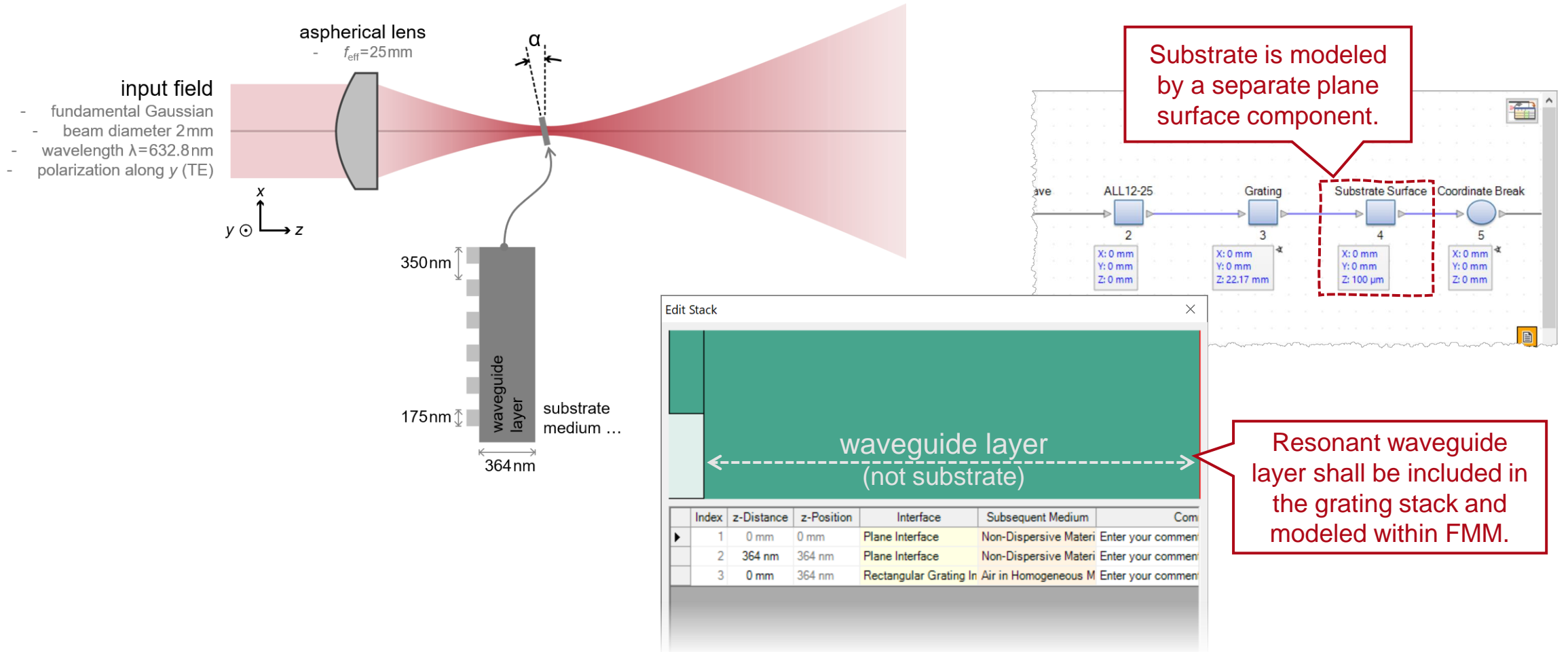
Edit Stack

waveguide layer (not substrate)

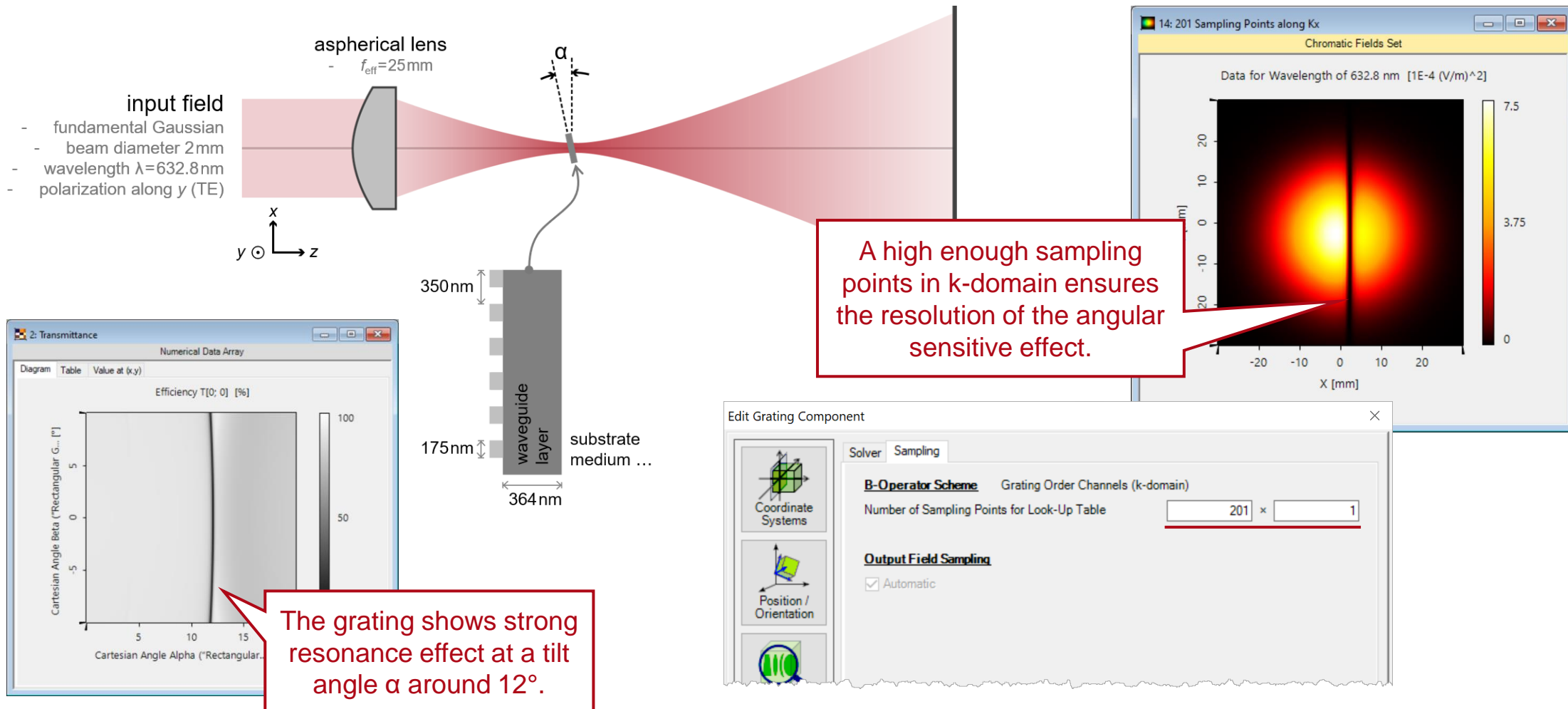
Index	z-Distance	z-Position	Interface	Subsequent Medium	Comments
1	0 mm	0 mm	Plane Interface	Non-Dispersive Materi	Enter your commen
2	364 nm	364 nm	Plane Interface	Non-Dispersive Materi	Enter your commen
3	0 mm	364 nm	Rectangular Grating In	Air in Homogeneous M	Enter your commen

[see the full Application Use Case](#)

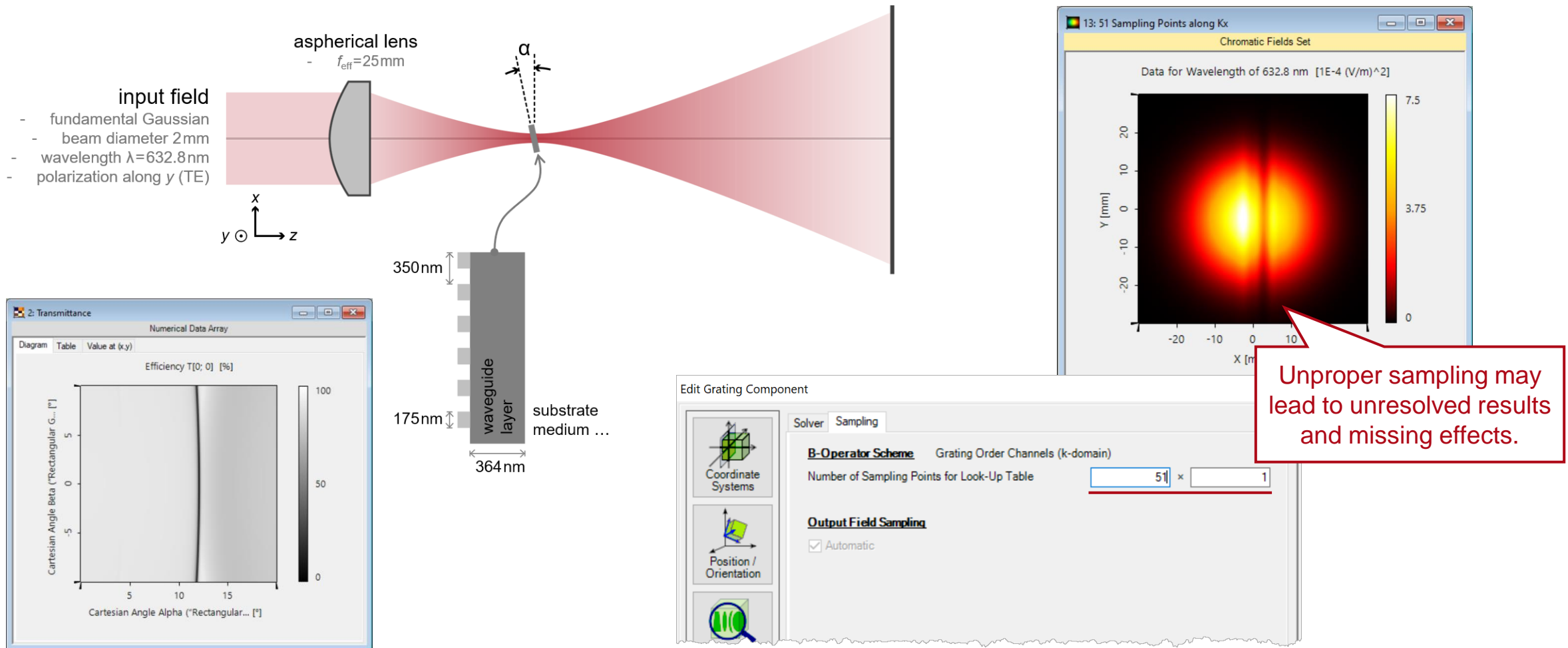
# Substrate Handling



# Angular Response of Resonant Waveguide Grating

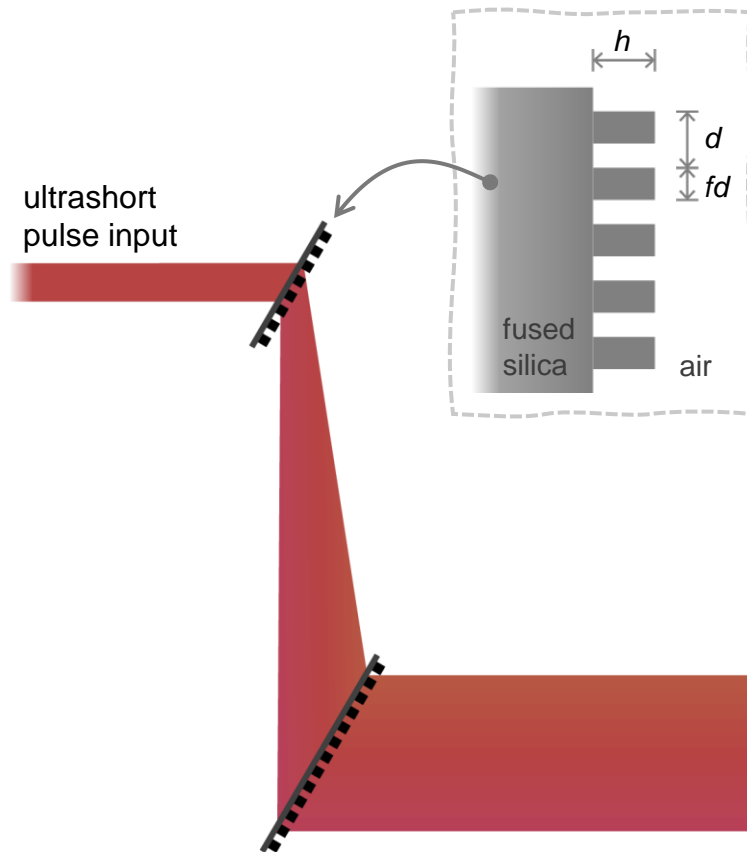


# Angular Response of Resonant Waveguide Grating



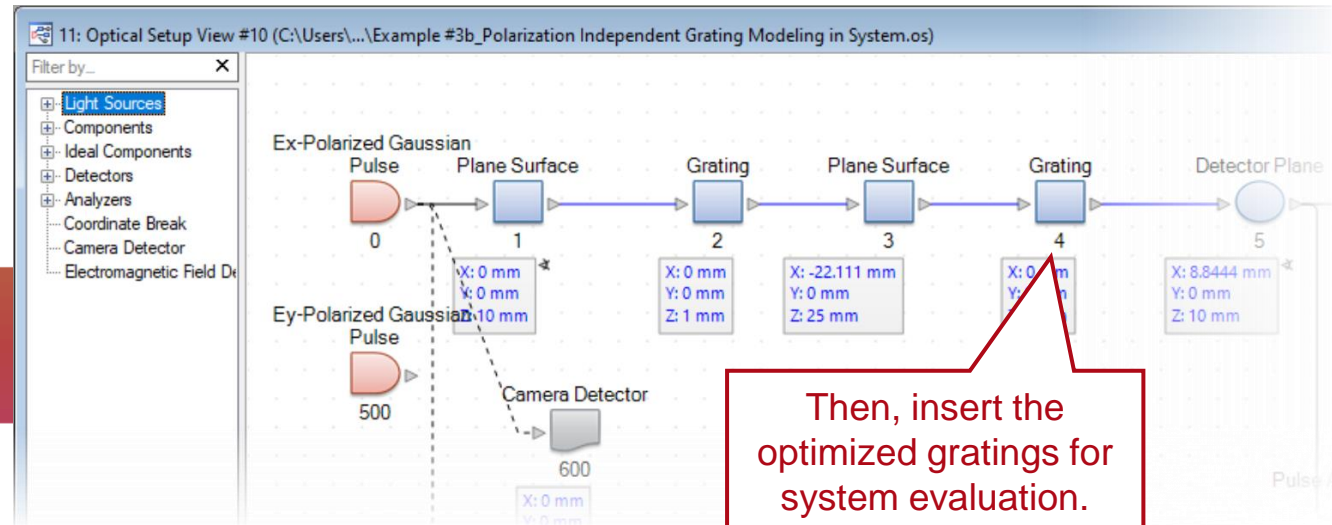
## **Example #3: Design Polarization-Independent Gratings and Usage in Ultrashort Pulse System**

# Gratings for Ultrashort Pulse Application



Gratings can often be designed / optimized separately.

general optical setup containing two (or more) grating components

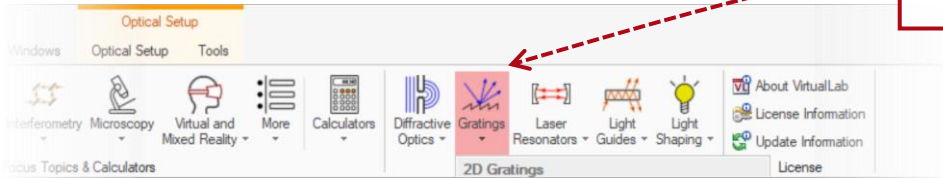


Then, insert the optimized gratings for system evaluation.

 [see the full Application Use Case](#)

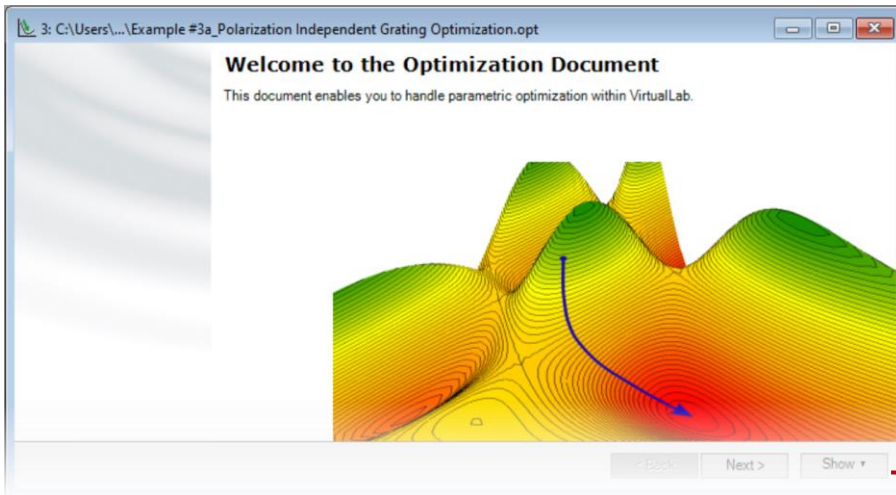
# Design and Modeling Workflow

single grating analysis

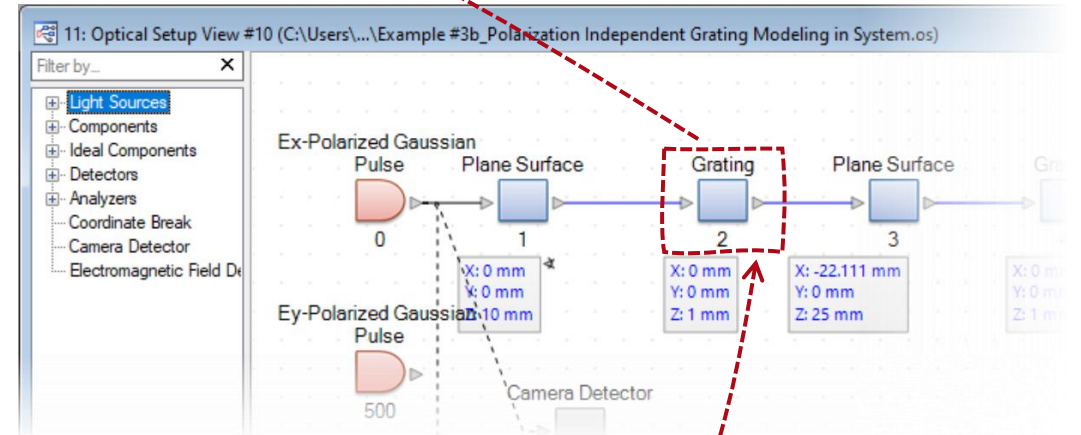


Isolate the grating for careful design / optimization.

parametric optimization



grating modeling within system



Insert the optimized grating back into system evaluation.



# Exchange Gratings between Different Setups

example: optimized grating structure

The 'Edit Stack' dialog box shows a table with the following data:

Index	z-Distance	z-Position	Interface	Subsequent Medium	Comments
1	0 mm	0 mm	Rectangular Grating In Air in Homogeneous M	Enter your comm	

The 'Save to Catalog: Specify Name and Categories' dialog box shows:

- Name: Pol-Independent Grating
- Categories: Pulse Gratings

Buttons: Ok, Cancel, Help

general optical setup containing gratings

The diagram shows an optical setup with components: Ex-Polarized Gaussian Pulse (0), Plane Surface (1), Grating (2), Plane Surface (3), and another Plane Surface (4). The Grating component is highlighted with a red dashed box.

The 'Edit Grating Component' dialog box shows:

- Component Size: 20 mm x 20 mm
- Reference Surface (all Channels): Plane Interface
- Aperture:  Yes  No
- Grating Stack:  1D-Periodic (Lamellar)  2D-Periodic
- Grating Period: 800 nm
- Rectangular Grating:  Load  Edit  View

The 'Stacks Catalog' dialog box shows:

- Definition Type: User Defined
- Filter by: My Stacks
- Stacks: Pulse Gratings
- Stack: Pol-Independent Grating

The 'Edit Stack' dialog box shows a table with the following data:

Index	z-Distance	z-Position	Interface	Subsequent Medium	Comments
1	0 mm	0 mm	Rectangular Grating Interface	Air in Homogeneous Medium	Enter yo

# Document Information

title	Modeling of Gratings within Optical System – Discussion at Examples
document code	MISC.0005
version	1.0
edition	VirtualLab Fusion Advanced
software version	2020.1 (Build 2.8)
category	Feature Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#">Configuration of Grating Structures by Using Interfaces</a></li><li>- <a href="#">Configuration of Grating Structures by Using Special Media</a></li><li>- <a href="#">VirtualLab Fusion Technology – FMM / RCWA [S-Matrix]</a></li></ul>