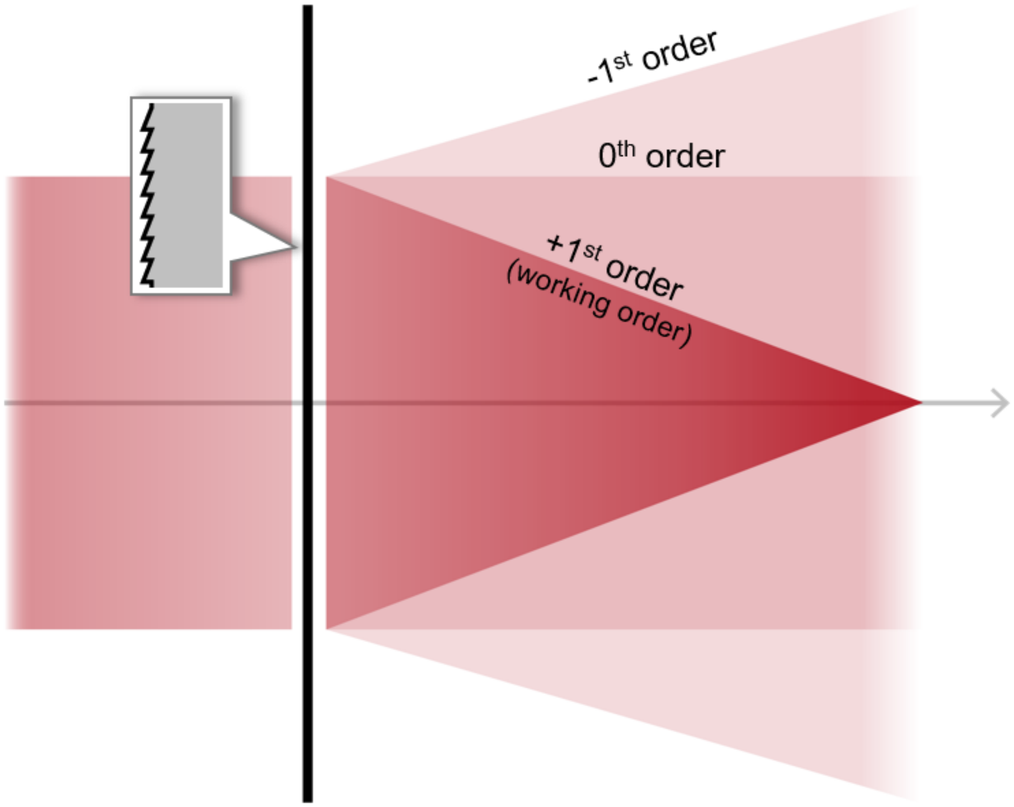
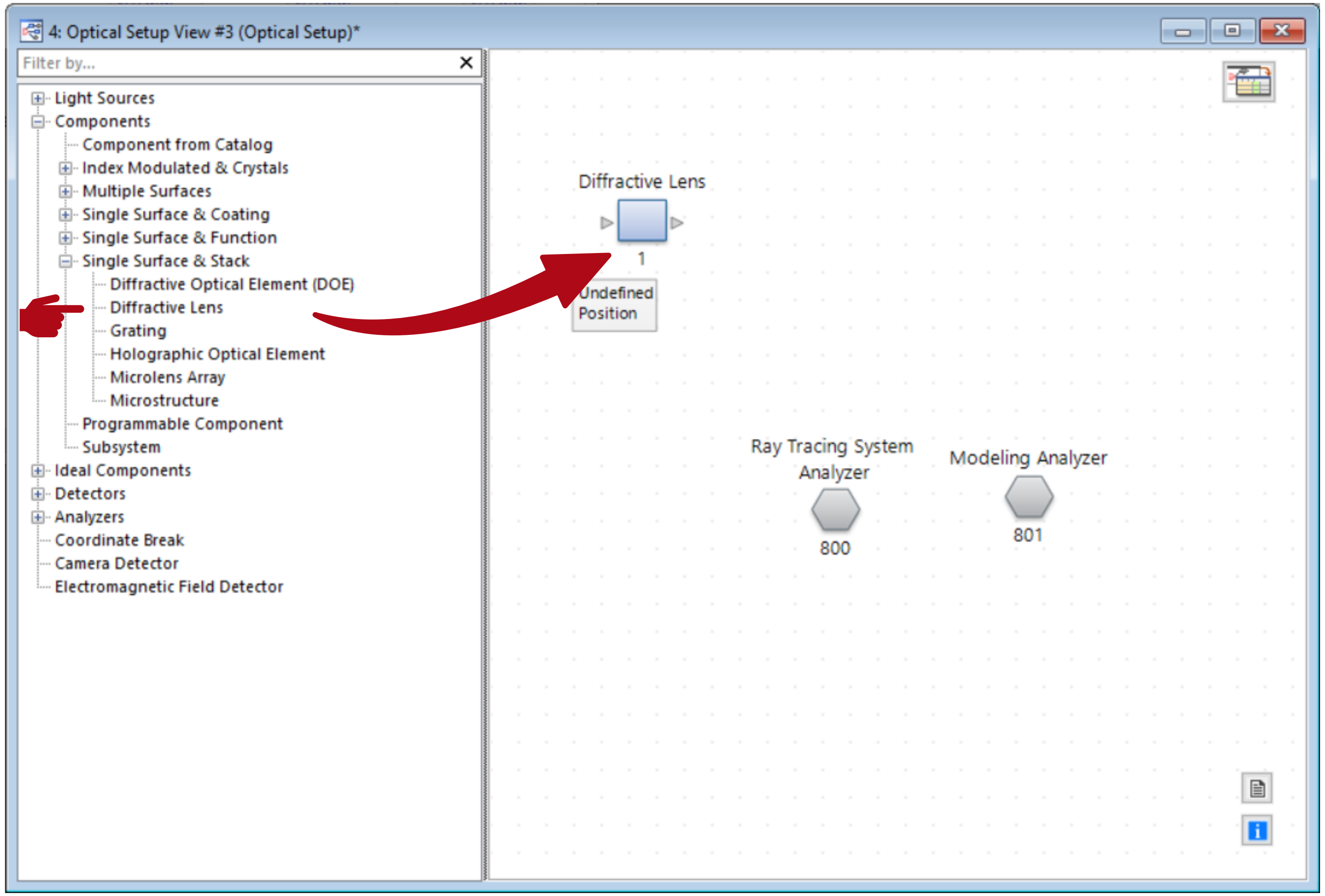
Diffractive Lens Component

Abstract



Nowadays, diffractive lenses are used in various applications of modern optics. Micro-structured surfaces are used to replace bulky optical elements, benefitting from reduced size and weight in comparison with traditional lenses. In the fast physical optics software VirtualLab Fusion, such structures can be modeled either in an idealized form, with pre-defined orders and efficiencies, or more realistically, including the accurate analysis of the actual micro-structured surfaces. In this document, VirtualLab Fusion’s diffractive lens component is introduced together with the available options and applied modeling methods.

Where to find the Component?



The *Diffractive Lens* component can be found under *Components > Single Surface & Stack.*

Wavefront Phase Response

A *Diffractive Lens* component consists of single plane surface, on which the transmission function is described by a polynomial wavefront response.

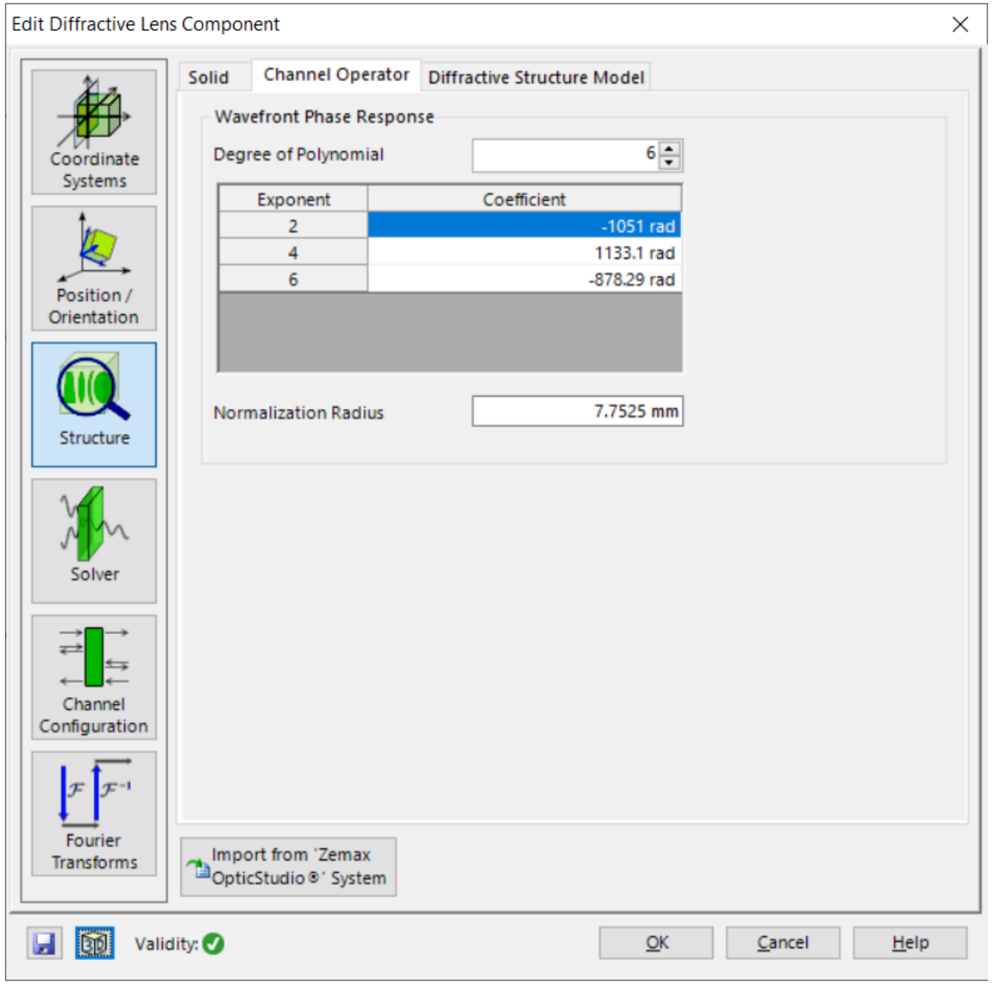
The *Wavefront Phase Response* introduced by the diffractive lens is defined in the *Channel Operator* tab. If the diffractive lens is imported from Zemax OpticStudio® the data will be automatically filled in (the model is in conformity with *Binary 2* surface from Zemax OpticStudio®).

The channel operator adds the following phase ϕ (in radians) to the phase of the incident light:

$$\phi = M\sum_i A_i \cdot \rho^{2i}$$

M is the index of the diffraction order, A_i the *Coefficient*$^{\boxed{\text{PV}}}$ of the i^{th} monomial, $2i$ is the *Exponent*, and ρ the normalized radius (the distance from the optical axis divided by the *Normalization Radius*$^{\boxed{\text{PV}}}$).
The *Degree of Polynomial* sets the maximum exponent $2i$.

(from VirtualLab Fusion Manual)



Wavefront Phase Response

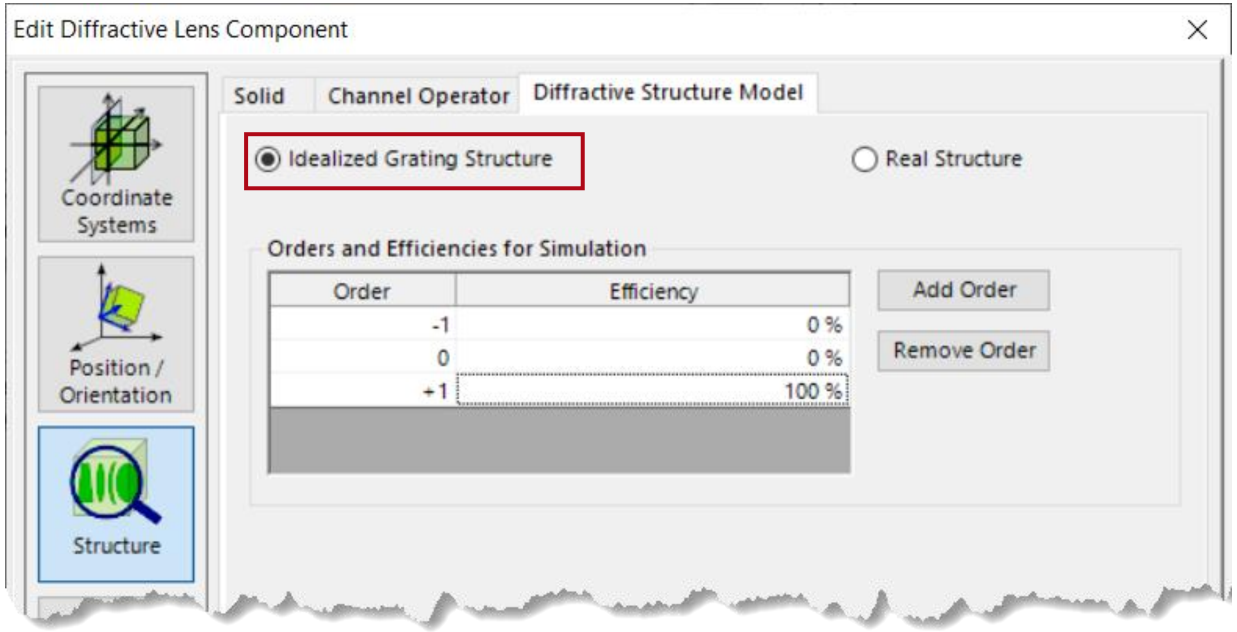
Degree of Polynomial: 6

Exponent	Coefficient
2	-1051 rad
4	1133.1 rad
6	-878.29 rad

Normalization Radius: 7.7525 mm

Parameter Setting of Idealized Diffractive Lens

The user then has the option in the *Diffractive Structure Model* tab to either define the diffractive lens model as idealized or with a real surface, the difference mainly being in how the efficiencies of the orders are calculated. In case of an idealized function, the desired diffraction orders and their efficiency have to be defined manually.



● Idealized Grating Structure ○ Real Structure

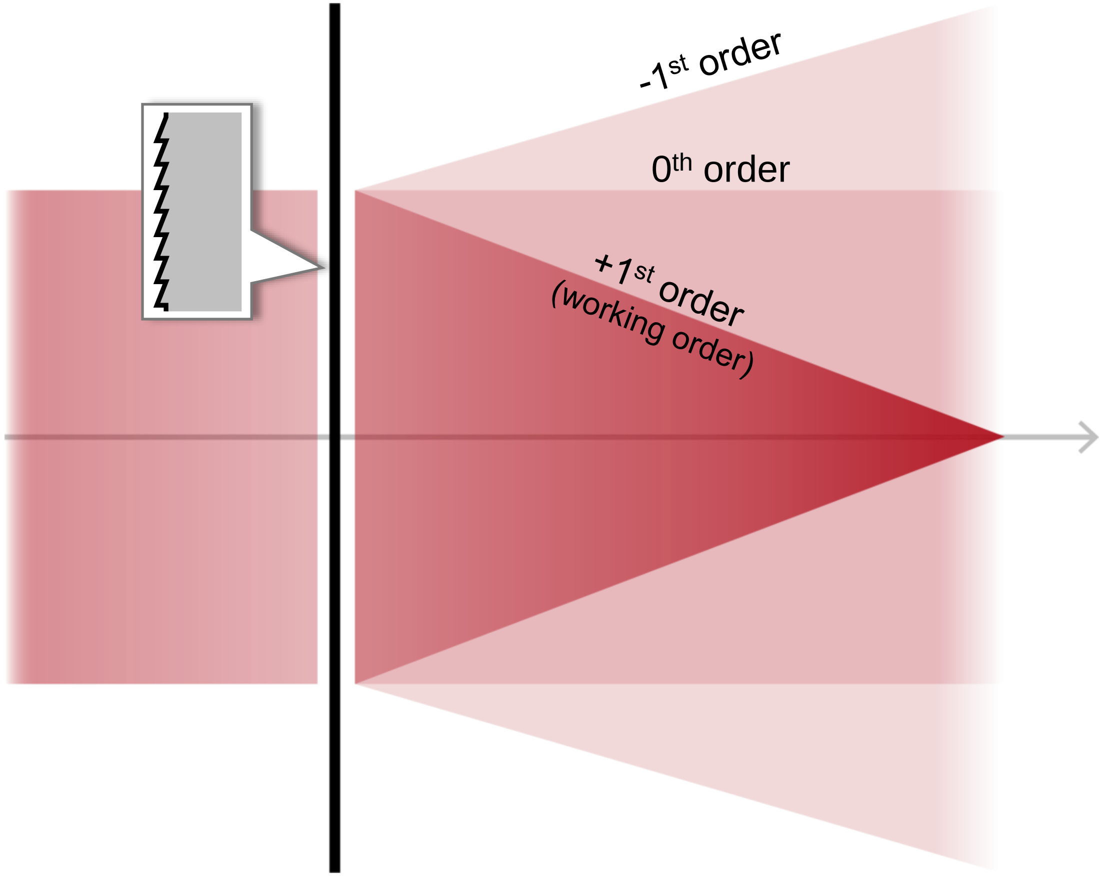
Orders and Efficiencies for Simulation

Order	Efficiency
-1	0 %
0	0 %
+1	100 %

Summary: Computation Method of Idealized Diffractive Lens

The local linear grating approximation (LLGA) with idealized grating function is used to compute the idealized diffractive lens surface. The steps are:

1. The input field on the surface is treated as a composition of local plane waves (LPWs).
2. The part of the surface seen by each LPW is considered a linear grating (locally).
3. The interaction of the LPW with the local linear grating is modeled by the idealized grating function.
4. The idealized grating function is determined by the diffraction orders, the diffraction of each order and the wavefront phase response of the diffractive lens. It works without giving information about the actual shape of the lens (idealized diffractive lens).

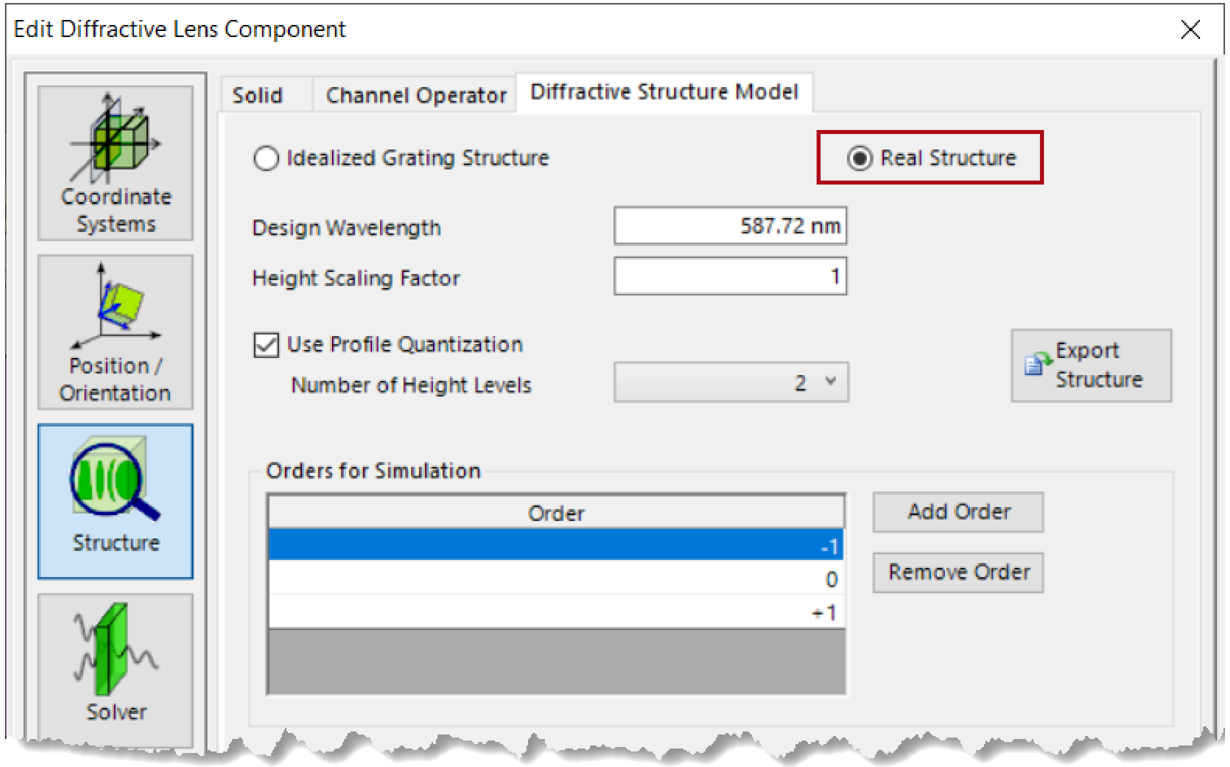


For further information:
[Local Linear Grating Approximation (LLGA)]()
[Idealized Grating Functions]()

Parameter Setting of Real Diffractive Lens

For a real structure of the diffractive lens, VirtualLab Fusion calculates the height of the lens by applying Thin-Element Approximation (TEA). Further, the order’s efficiencies are evaluated by using a combination of Thin-Element Approximation (TEA) and Fourier-Modal-Method (FMM) algorithms, automatically. In addition, the user can specify characteristics of the diffractive component like the *Design Wavelength* and a desired quantization.

It is also possible to export the designed height profile, by using the *Export Structure* button.



Edit Diffractive Lens Component

○ Idealized Grating Structure
● Real Structure

Design Wavelength: 587.72 nm

Height Scaling Factor: 1

☑ Use Profile Quantization

Number of Height Levels: 2

Orders for Simulation

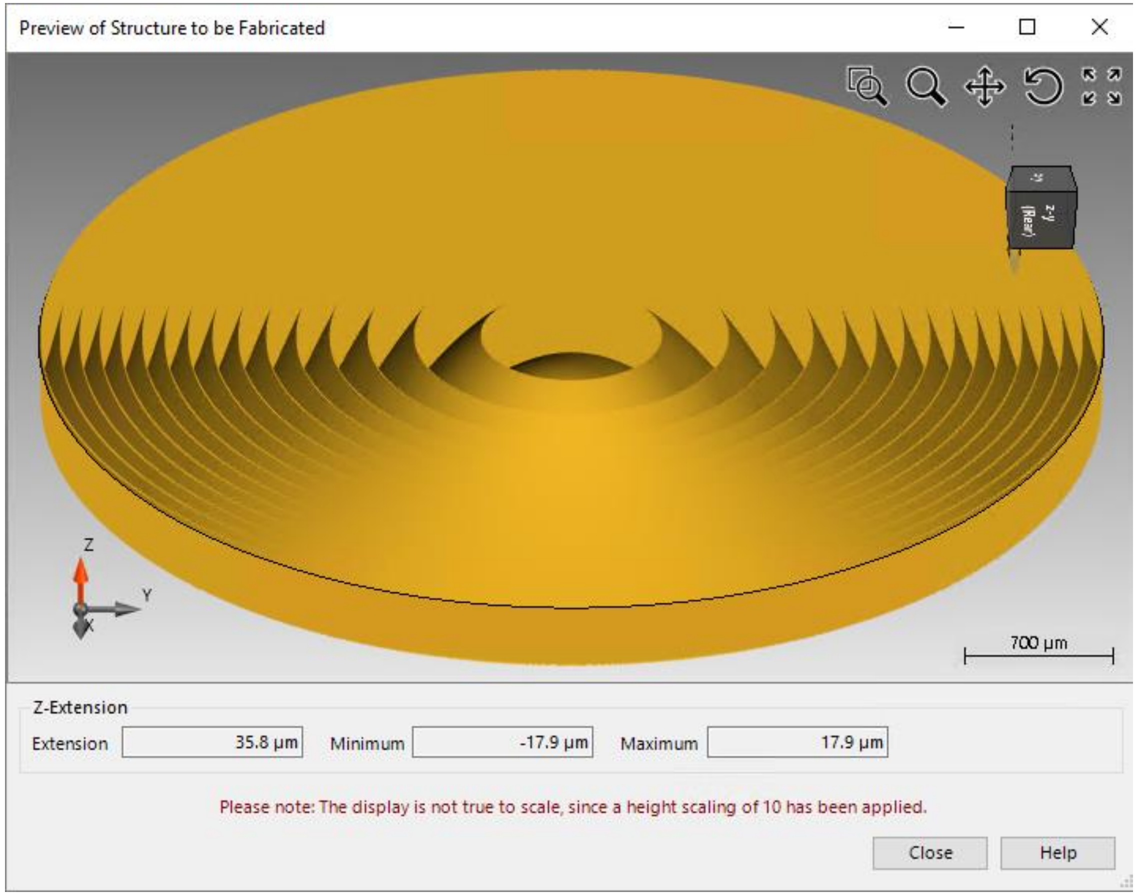
Order
-1
0
+1

Height Calculation of the Utilized Structure (by TEA)

The height structure of the diffractive surface is defined as:

$$h^{\mathrm{DOE}}(\boldsymbol{\rho}) = \alpha \cdot \frac{\lambda}{2\pi n} \cdot \Delta\psi(\boldsymbol{\rho})^{\mathrm{DOE}}$$

Where $h^{\mathrm{DOE}}(\boldsymbol{\rho})$ is the structure height profile, $\Delta\psi(\boldsymbol{\rho})^{\mathrm{DOE}}$ is the wavefront phase response, α is the height scaling factor, λ is the design wavelength, n is the refractive index of the lens material. TEA and FMM-solvers are then applied to this structure to calculate the diffraction efficiencies of the resulting orders.



Preview of Structure to be Fabricated

Z-Extension

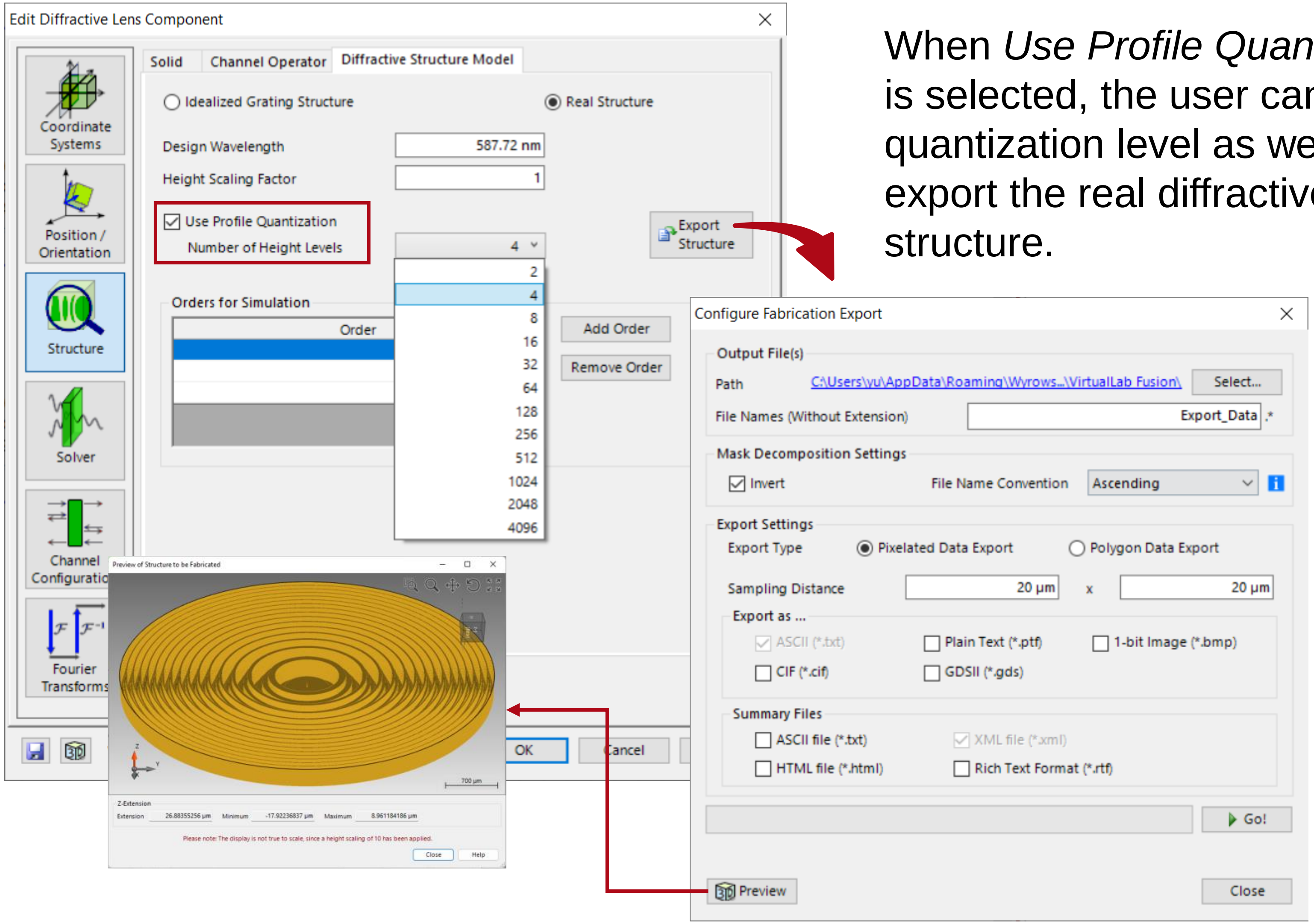
Extension 35.8 µm

Minimum -17.9 µm

Maximum 17.9 µm

Please note: The display is not true to scale, since a height scaling of 10 has been applied.

Optional Parameter - Quantization Levels



Edit Diffractive Lens Component

○ Idealized Grating Structure ● Real Structure

Design Wavelength 587.72 nm

Height Scaling Factor 1

☑ Use Profile Quantization

Number of Height Levels 4

2
4
8
16
32
64
128
256
512
1024
2048
4096

Preview of Structure to be Fabricated

Z-Extension

Extension 26.88355256 µm Minimum -17.92236837 µm Maximum 8.961184186 µm

Please note: The display is not true to scale, since a height scaling of 10 has been applied.

Configure Fabrication Export

Output File(s)

Path C:\Users\yu\AppData\Roaming\Wyrows...\VirtualLab Fusion\

File Names (Without Extension) Export_Data .*

Mask Decomposition Settings

☑ Invert

File Name Convention Ascending

Export Settings

Export Type ● Pixelated Data Export ○ Polygon Data Export

Sampling Distance 20 µm x 20 µm

Export as ...

☑ ASCII (*.txt) ☐ Plain Text (*.ptf) ☐ 1-bit Image (*.bmp)

☐ CIF (*.cif) ☐ GDSII (*.gds)

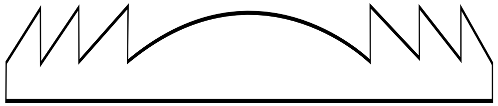
Summary Files

☐ ASCII file (*.txt) ☑ XML file (*.xml)

☐ HTML file (*.html) ☐ Rich Text Format (*.rtf)

When *Use Profile Quantization* is selected, the user can set the quantization level as well as export the real diffractive lens structure.

no quantization



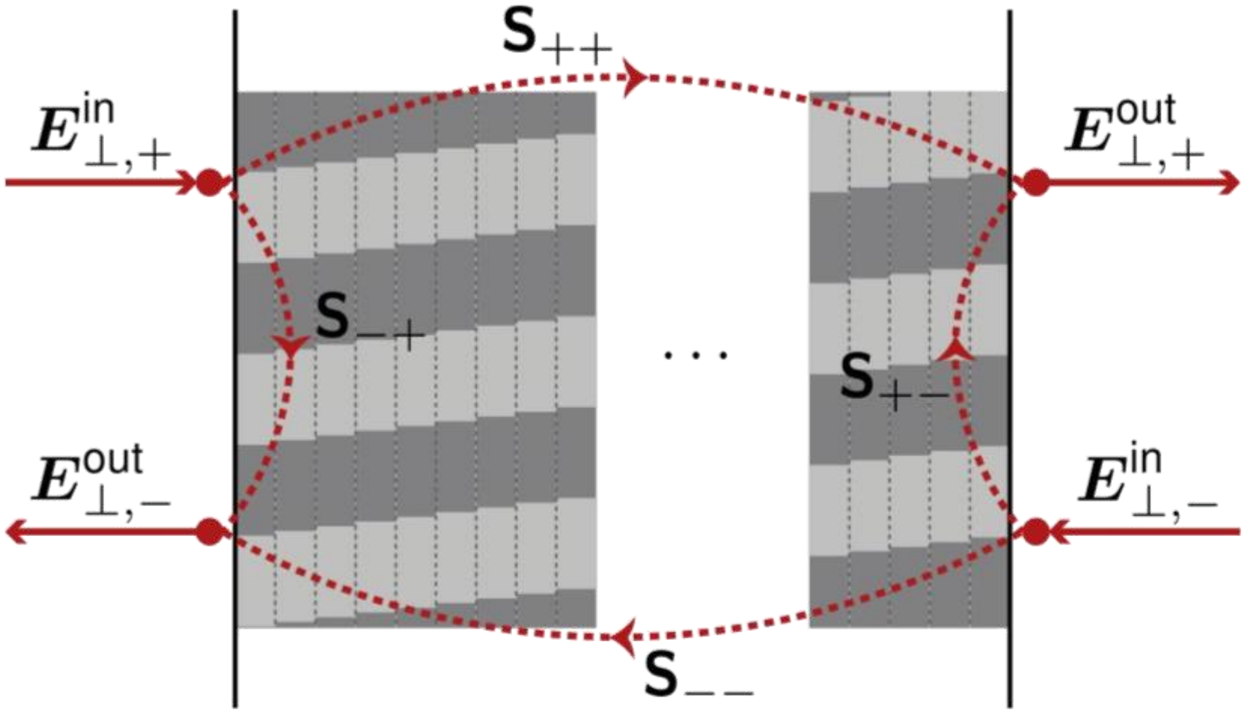
4 levels quantization

2 levels quantization

Summary: Computation Method of Real Diffractive Lens

The local linear grating approximation (LLGA) with Fourier modal method / rigorous coupled-Wave analysis (FMM/RCWA) or thin element approximation (TEA) is used to compute the real diffractive lens surface. The steps are:

1. The input field on the surface is treated as a composition of local plane waves (LPWs).
2. The part of the surface seen by each LPW is considered a linear grating (locally).
3. The interaction of the LPW with the local linear grating is modeled by FMM/RCWA, or TEA.
4. For real diffractive lens, VirtualLab Fusion chooses automatically between FMM/RCWA and TEA. If the local grating period is larger than 5 times the wavelength, TEA will be used. Otherwise FMM/RCWA will be used to model the real structure.



For further information:

Local Linear Grating Approximation (LLGA)

FMM/RCWA

Document Information

title	Diffractive Lens Component
document code	SWF.0008
document version	1.0
software edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	• Chromatic Aberration Correction by Ideal Diffractive Lens in a Hybrid Eyepiece Model • Local Linear Grating Approximation (LLGA) • Idealized Grating Functions • FMM/RCWA