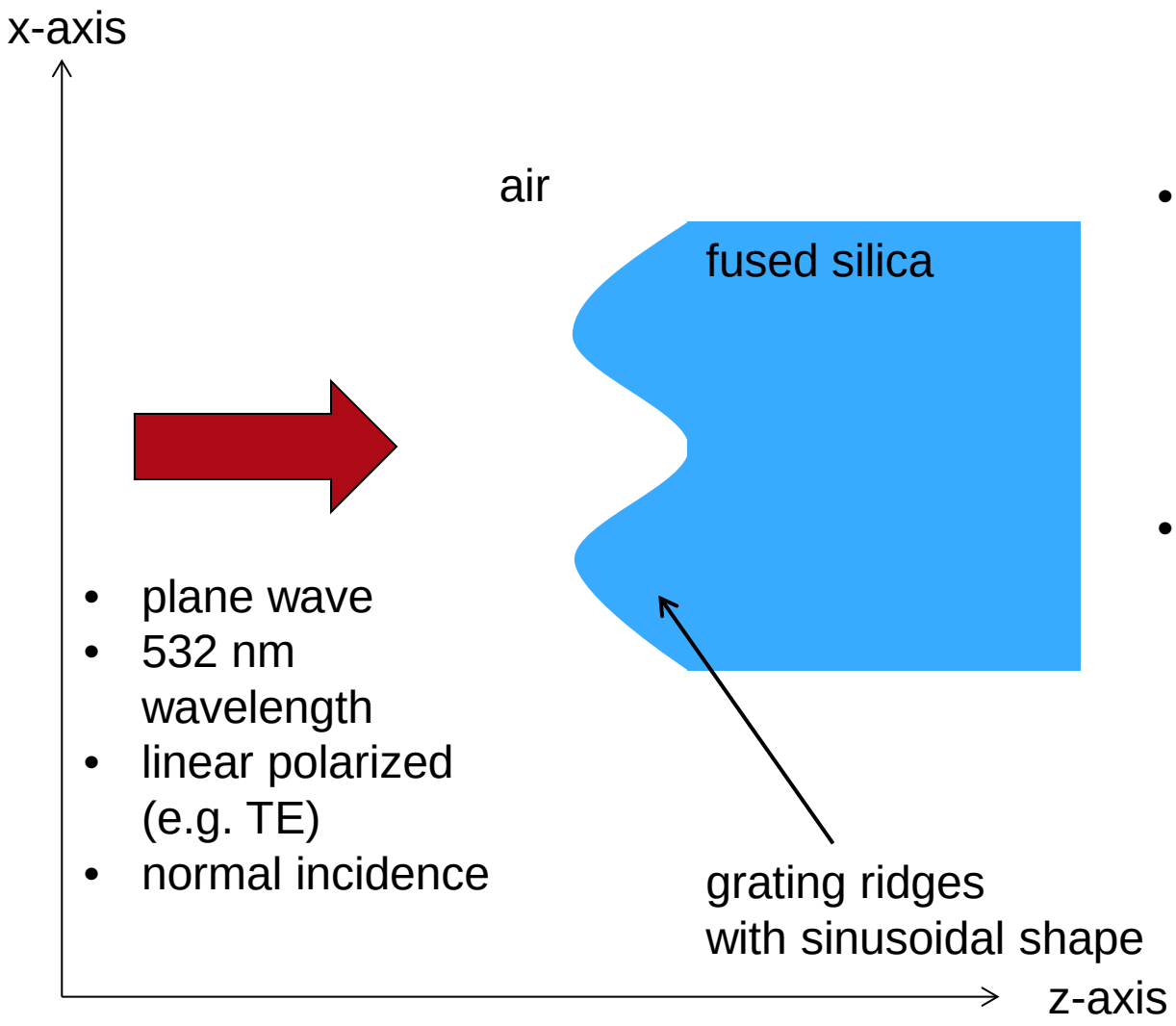
Scenario 087 (5.0)

Analysis of Grating Order Efficiencies Affected by a Rough Grating Surface

This scenario demonstrates the simulation of a sinusoidal grating structure exhibiting a random surface variation evoked by a structure roughness. In addition, the influence on the order specific diffraction efficiency is analyzed.

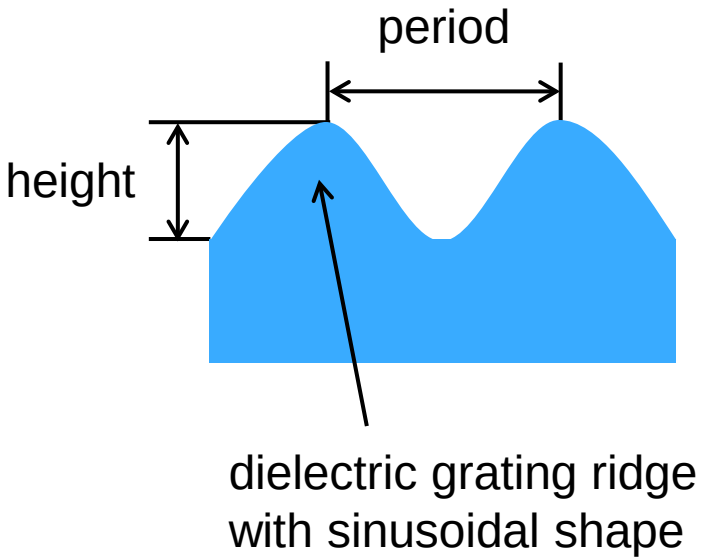
Modeling Task



- Rigorous analysis of the efficiencies of different diffraction orders of a grating with sinusoidal shape.
- For this simulation, the Fourier Modal Method is applied.

Modeling Task: Sinusoidal Grating

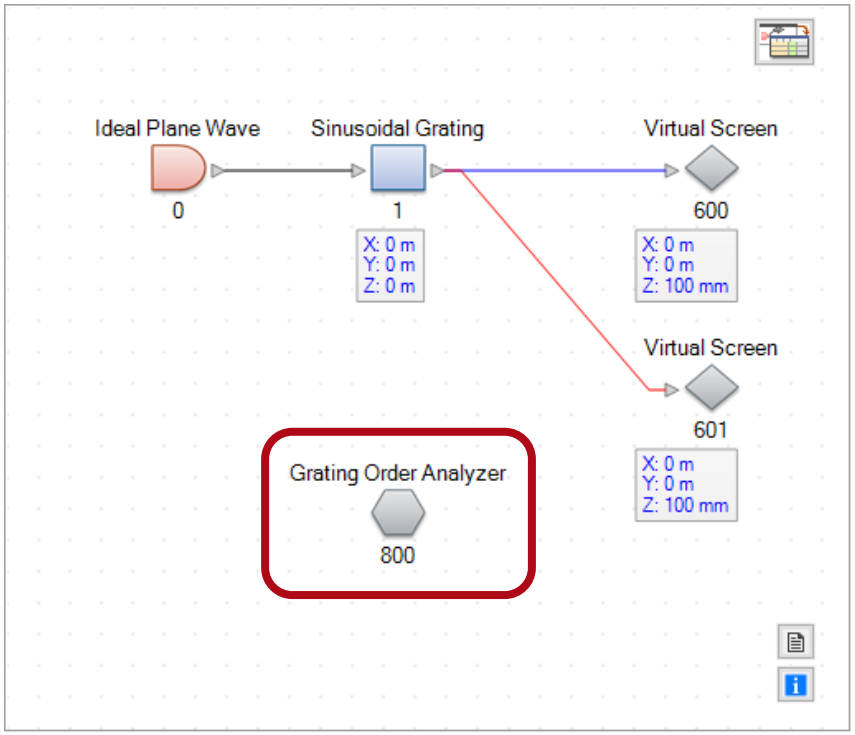
- x-z direction (cross sectional view):



- grating parameters:
  - period: 0.908µm
  - height: 1.15µm

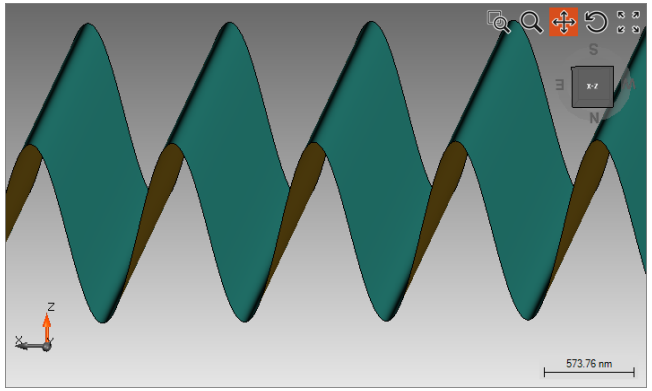
(These parameters provide an uniformly distributed transmission efficiency of the 0^{th} and $\pm 1^{st}$ diffraction orders, see Scenario 341 for further information.)

Modeling Task

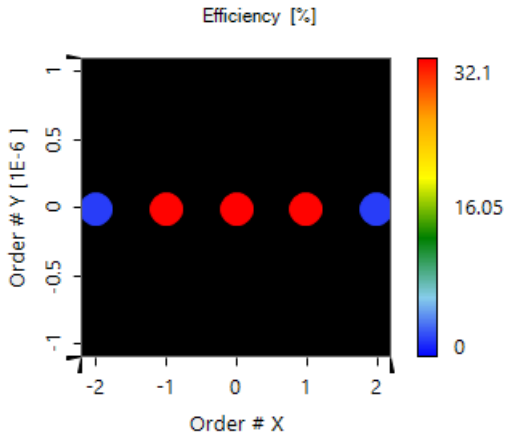


- VirtualLab's Grating Toolbox provides the Grating Order Analyzer, which allows for the rigorous computation of e.g. the grating diffraction efficiency.

- By using this analyzer, also the efficiencies for each appearing diffraction order can be computed separately.



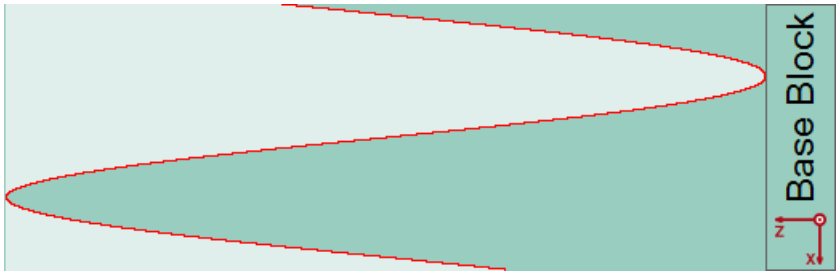
Analysis of a Smooth Structure



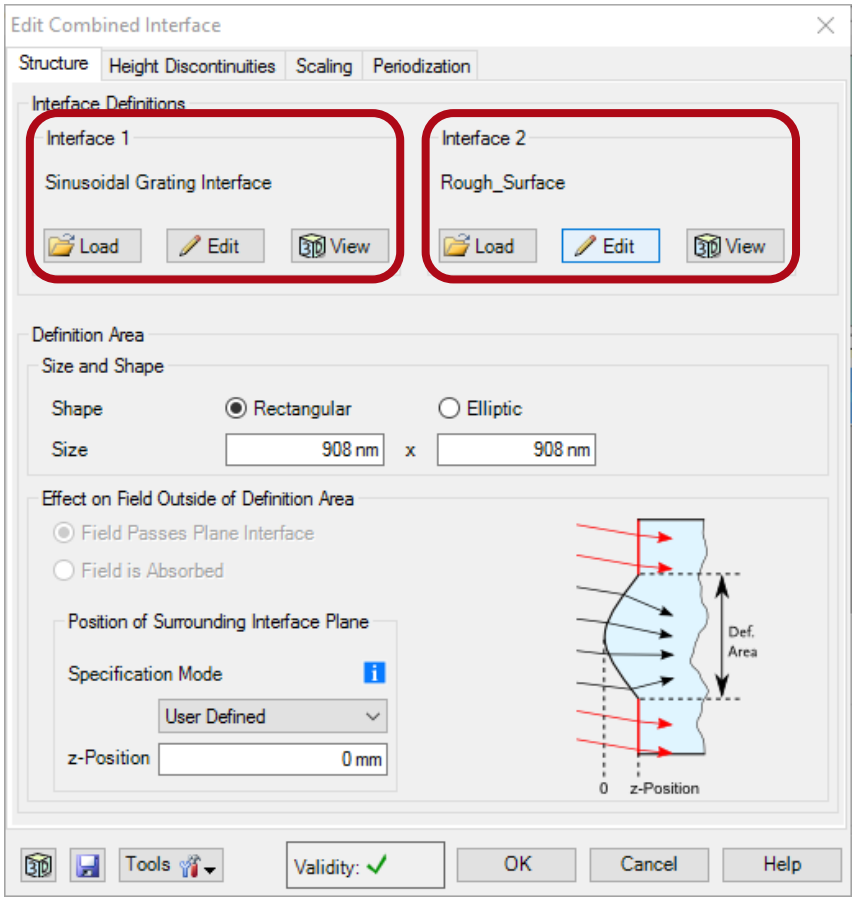
Index	Order # X	Order # Y	Efficiency (Amplitude)
1	-2	0	1.927 %
2	-1	0	31.977 %
3	0	0	32.091 %
4	1	0	31.977 %
5	2	0	1.927 %

- After computing the diffraction efficiencies, the results can be depicted, e.g. in a so called Order Collection diagram.

- For the smooth, unperturbed structure parameters, the 0^{th} and $\pm 1^{st}$ diffraction orders exhibit about 32% transmission efficiency each.

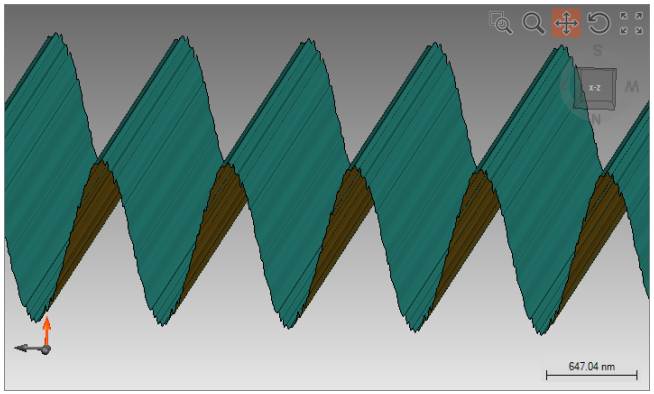


Adding a Surface Roughness

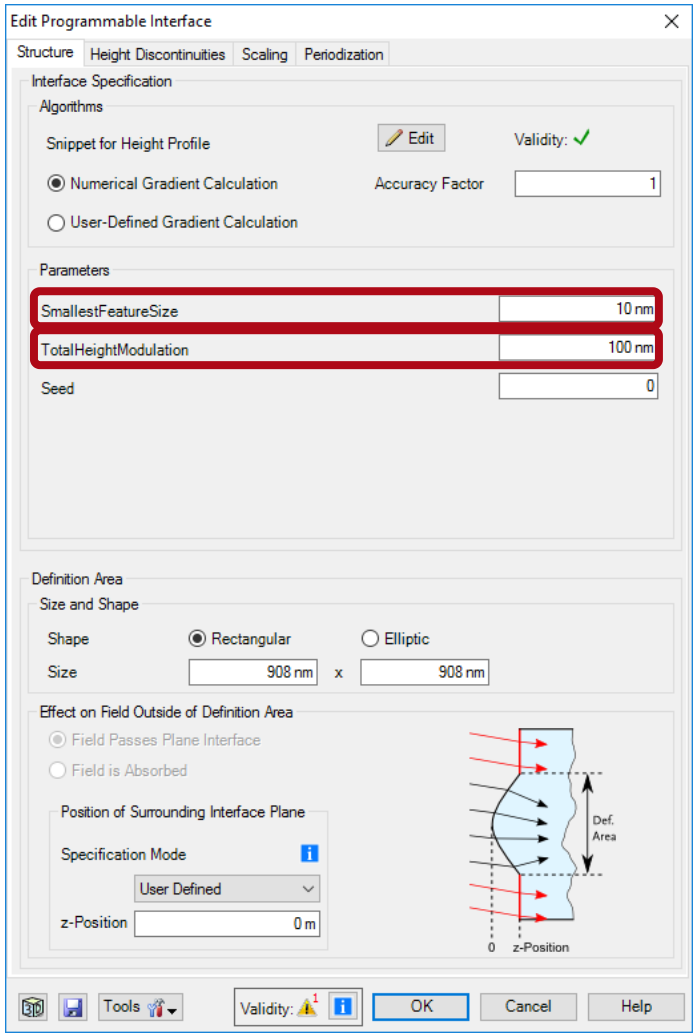


- VirtualLab's Grating Toolbox enables for the combination (i.e. addition) of two interfaces.

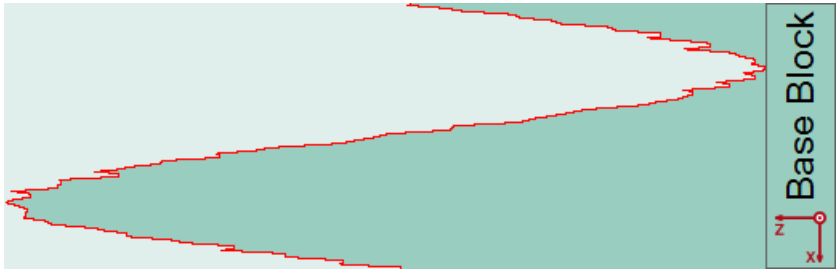
- Thus an arbitrary grating shape (e.g. sinusoidal) can be combined with a rough surface, resulting in a rough grating shape.



Adding a Surface Roughness

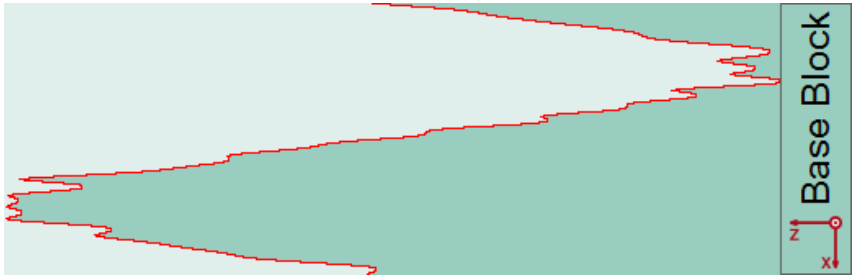


- The rough surface has several options to configure the surface variation (e.g. periodization).
- The first important physical parameter is the so called “Smallest Feature Size”.
- The second physical parameter determines the “Total Height Modulation”.

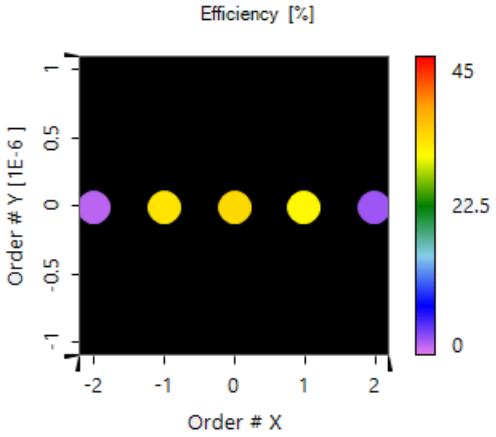


Influence on the Diffraction Order Efficiencies

- Roughness Parameters:
  - Smallest Feature Size: 20nm
  - Total Height Modulation: 200nm
- Height Profile:



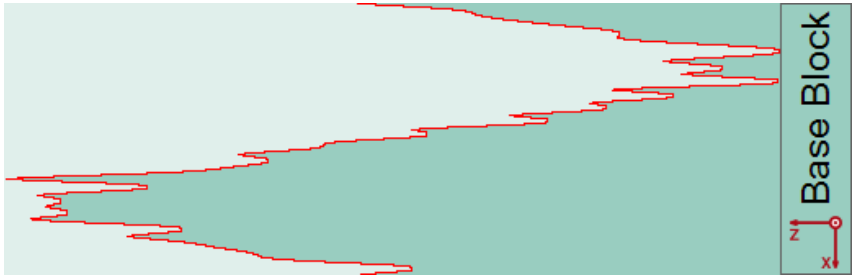
- Efficiency:



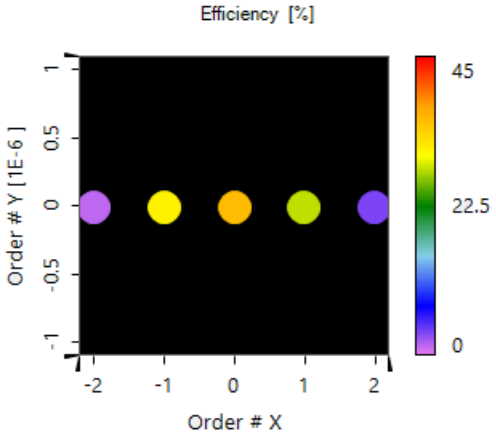
- The computed efficiencies exhibit only minor influences.

Influence on the Diffraction Order Efficiencies

- Roughness Parameters:
  - Smallest Feature Size: 20nm
  - Total Height Modulation: 400nm
- Height Profile:



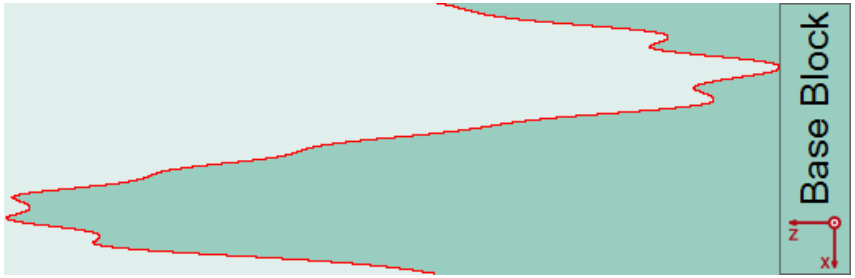
- Efficiency:



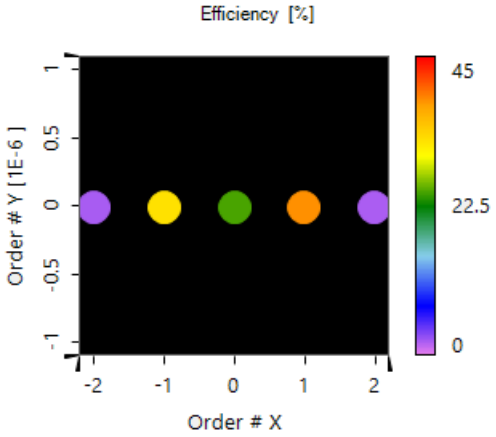
- Due to the larger total height of the roughness, a slightly asymmetry of the efficiencies considering the ±1st orders evokes.

Influence on the Diffraction Order Efficiencies

- Roughness Parameters:
  - Smallest Feature Size: 40nm
  - Total Height Modulation: 200nm
- Height Profile:



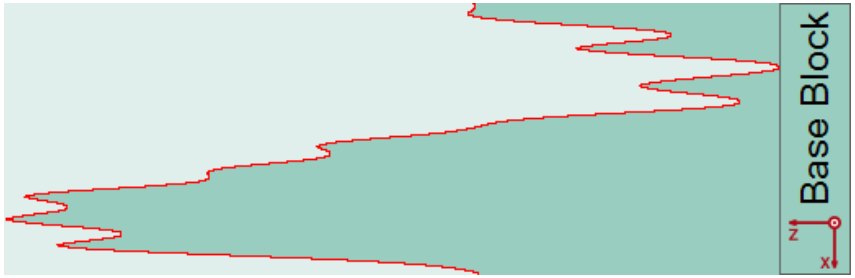
- Efficiency:



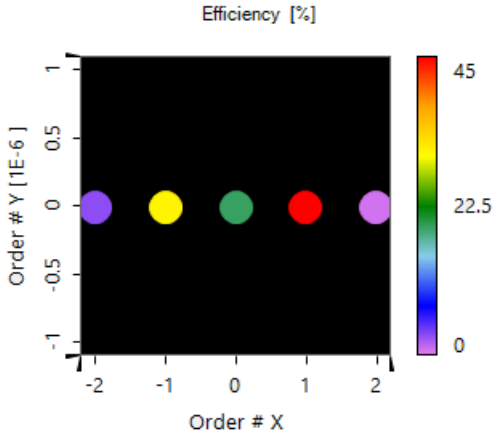
- The higher “Smallest Feature Size” causes a decreasing transmission efficiency of the 0^{th} diffraction order.

Influence on the Diffraction Order Efficiencies

- Roughness Parameters:
  - Smallest Feature Size: 40nm
  - Total Height Modulation: 400nm
- Height Profile:



- Efficiency:



- With a strong roughness the efficiency of the 0^{th} order further decreases, while the asymmetry of the $\pm 1^{st}$ order efficiencies rises.

Summary

- The Grating Toolbox of VirtualLab allows for a rigorous analysis of arbitrary shaped grating structures (e.g. sinusoidal including an additional surface roughness).

- For this type of analysis the fully vectorial Fourier Modal Method was implemented in VirtualLab.

- The Grating Order Analyzer enables the computation of either the overall or the order specific diffraction efficiency.

- With the help of VirtualLab‘s Grating Toolbox grating surface roughness's can be considered. Thus the influence of structure deviations, whose occur during element fabrication, can be estimated.