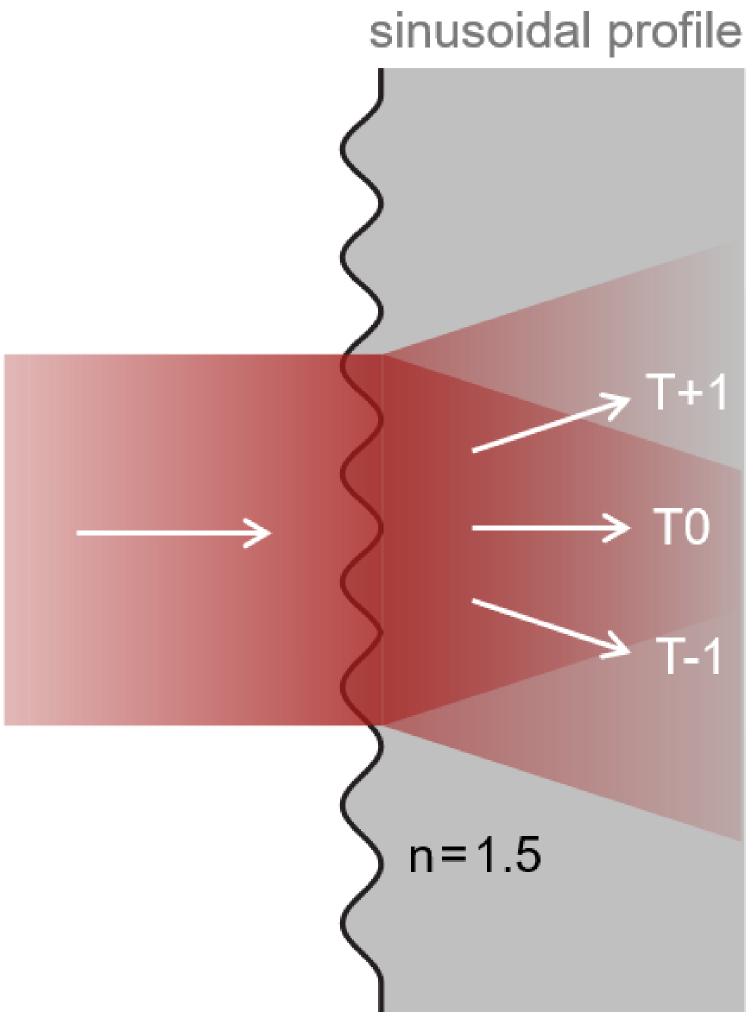
Thin Element Approximation (TEA) vs. Fourier Modal Method (FMM) for Grating Modeling

Abstract

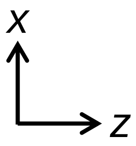


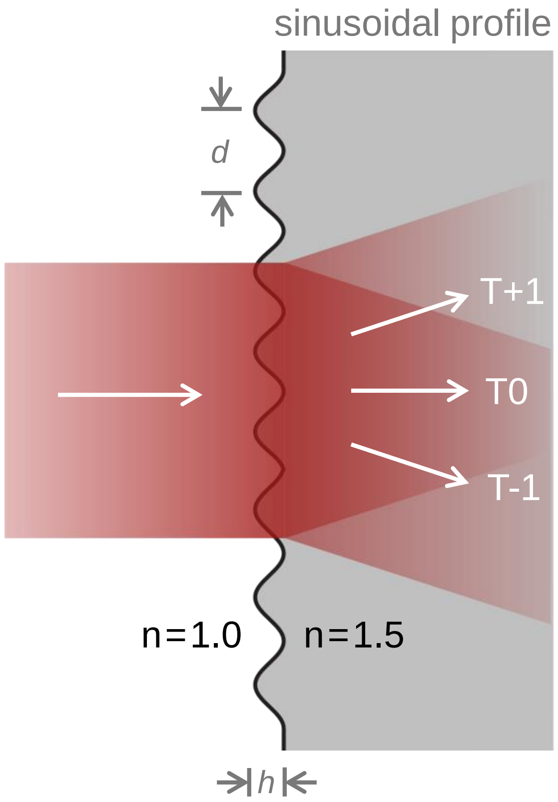
The Thin Element Approximation (TEA) is a widely-used method in e.g. Fourier optics to calculate the diffraction efficiency of gratings. It is however also known that the approximation becomes inaccurate for relatively small grating period. In this example, two types of transmission gratings are selected: sinusoidal and blazed. We use both TEA and FMM (also known as RWCA, which is rigorous) to analyze such gratings with varying period, and by comparing the results, we investigate the behaviors of the two methods.

Modeling Task

input plane wave

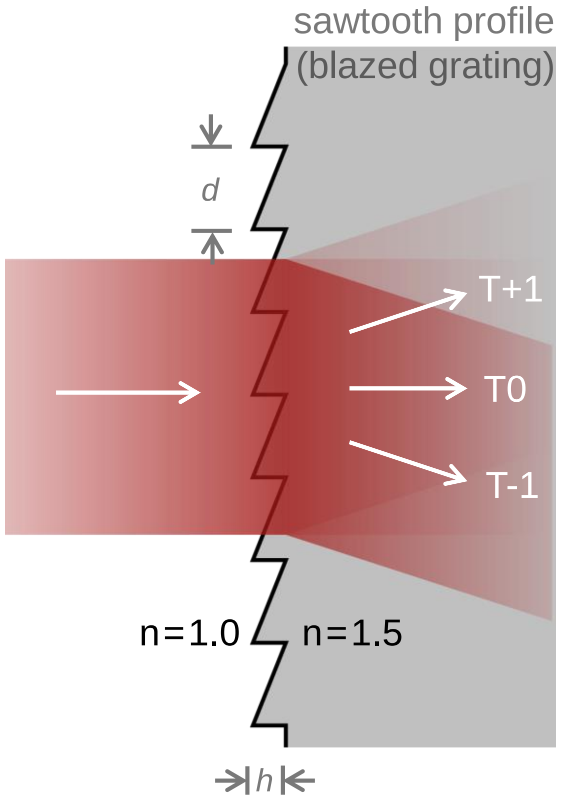
- wavelength λ=532nm
- polarization in TE





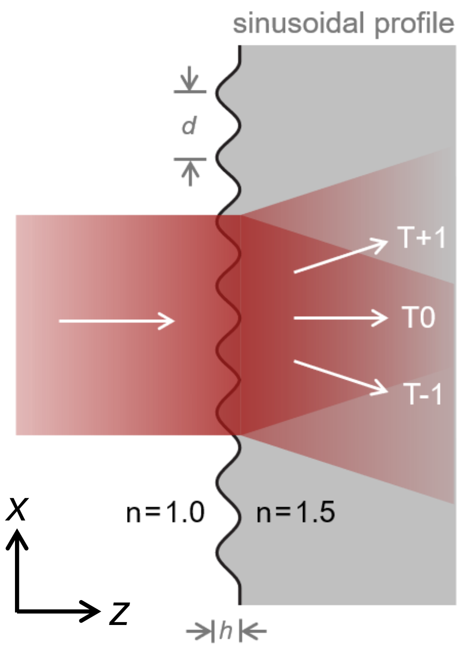
grating parameters

- grating period *d*
- grating height *h*



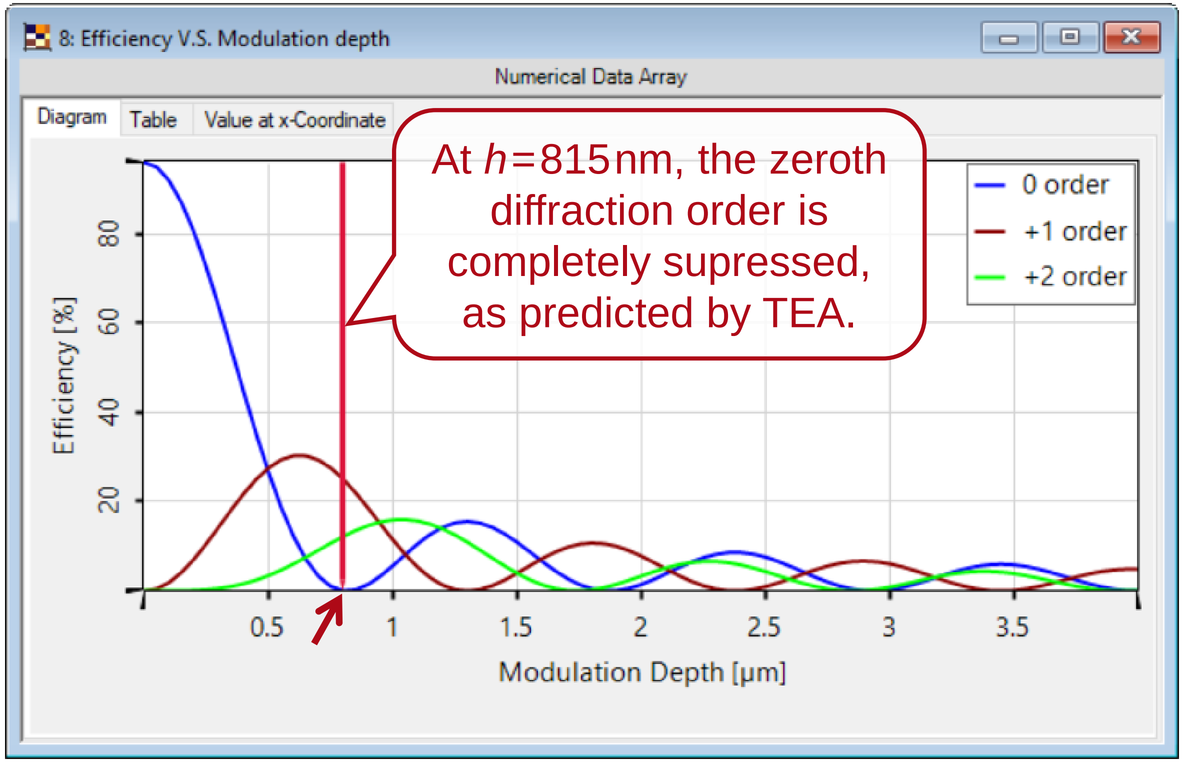
For both the sinusoidal and the blazed gratings, we analyze the gratings with TEA and FMM, and compare/analyze the results from both methods.

Sinusoidal Grating – Efficiency vs. Height (TEA Only)



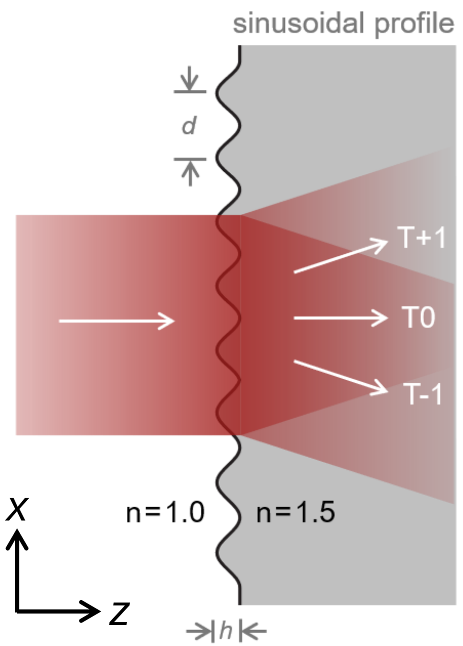
fixed period $d=1\mu m$
fixed TE polarization
varying height *h*

It is often efficient to use TEA as a fast design tool for searching proper grating parameters. However, the limitation of the method shall be noticed.



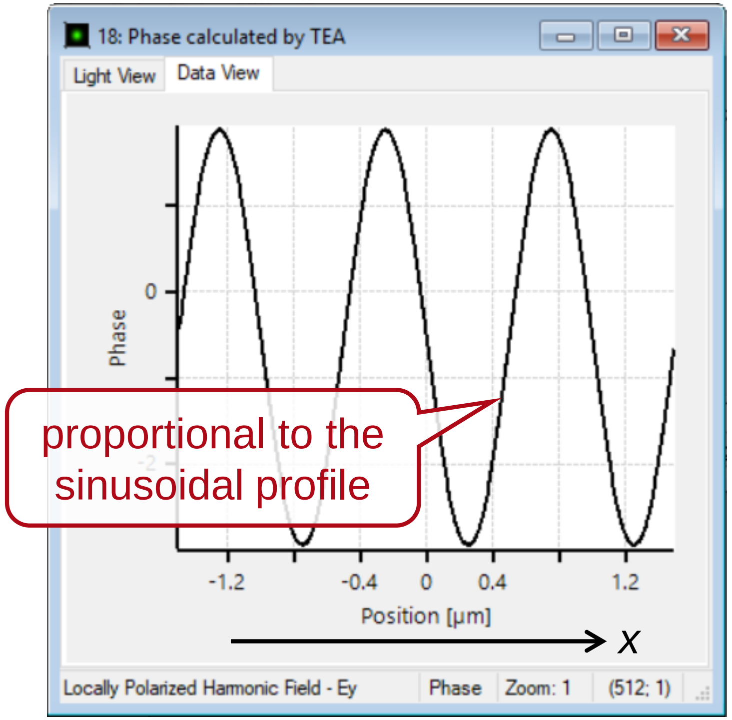
To have symmetric diffraction effect without zeroth order, we pick up $h=815$nm as the grating height.

Sinusoidal Grating – Transmitted Phase Profiles

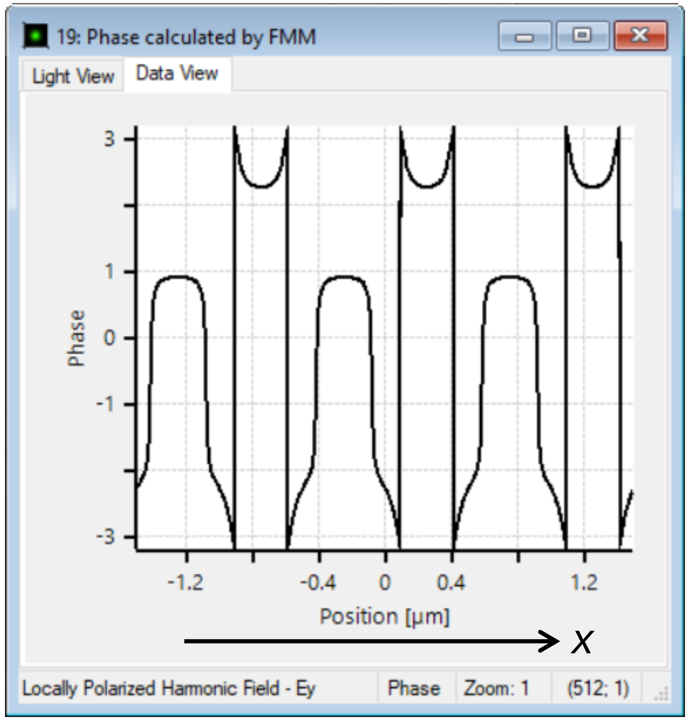


fixed period $d=1\,\mu m$
fixed TE polarization
fixed height $h=815\,nm$

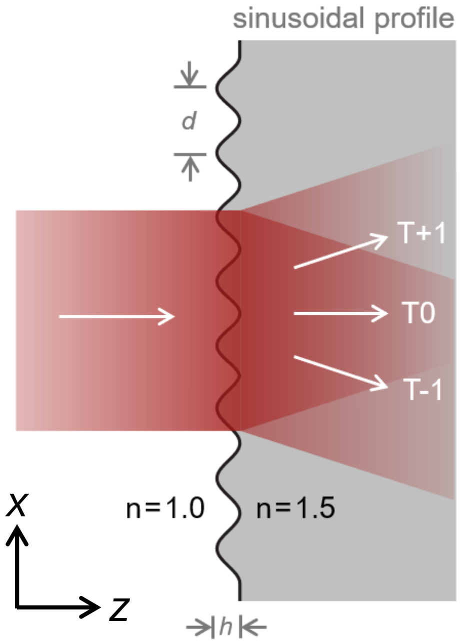
phase behind grating (TEA)



phase behind grating (FMM)

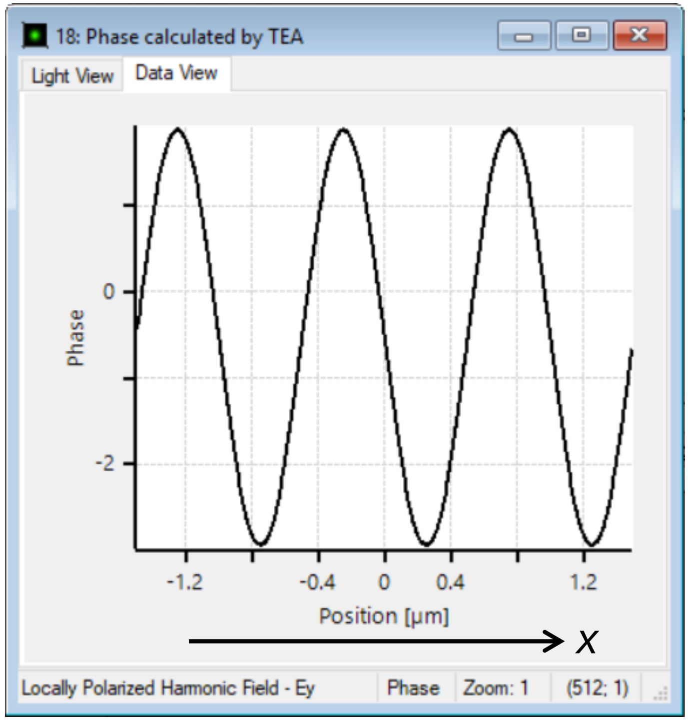


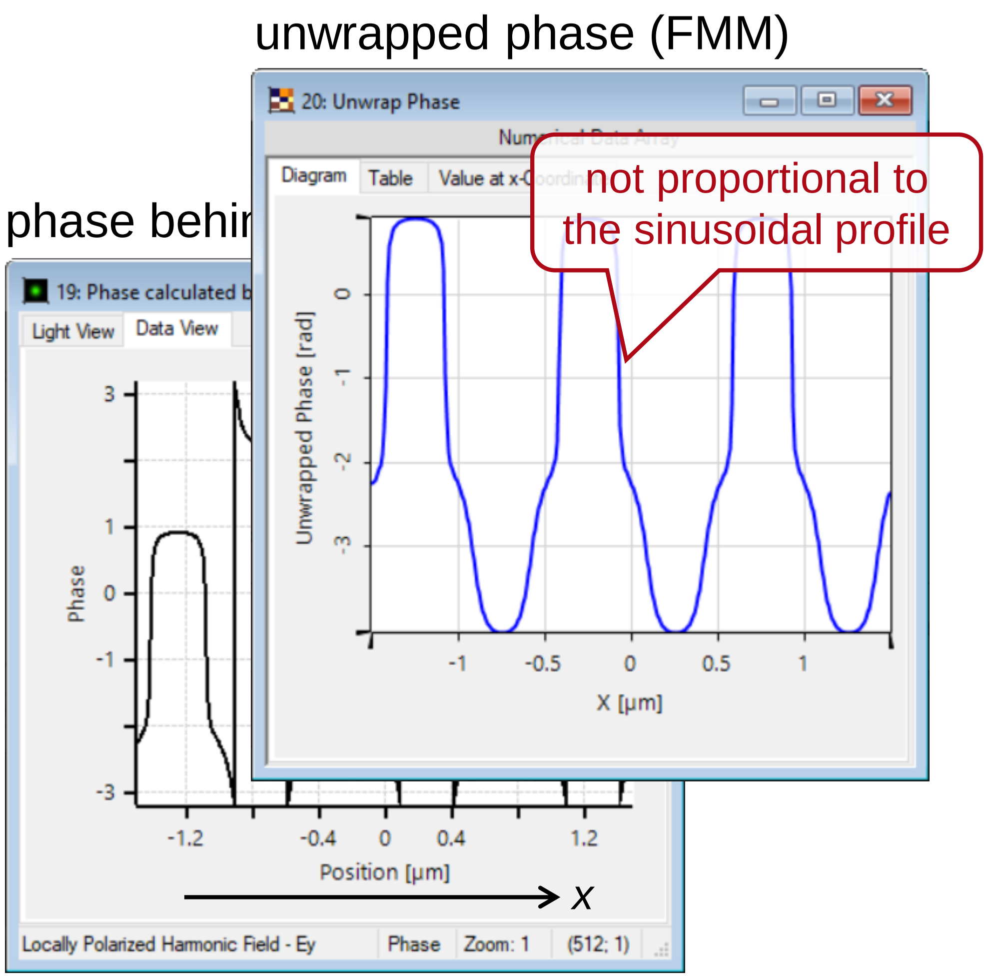
Sinusoidal Grating – Transmitted Phase Profiles



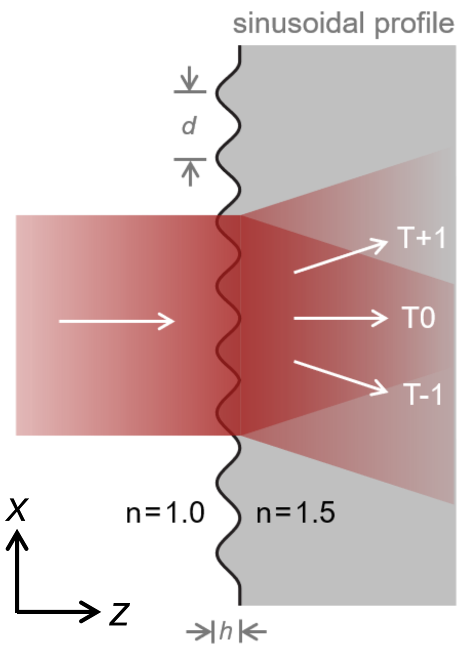
fixed period d=1µm
fixed TE polarization
fixed height h=815nm

phase behind grating (TEA)



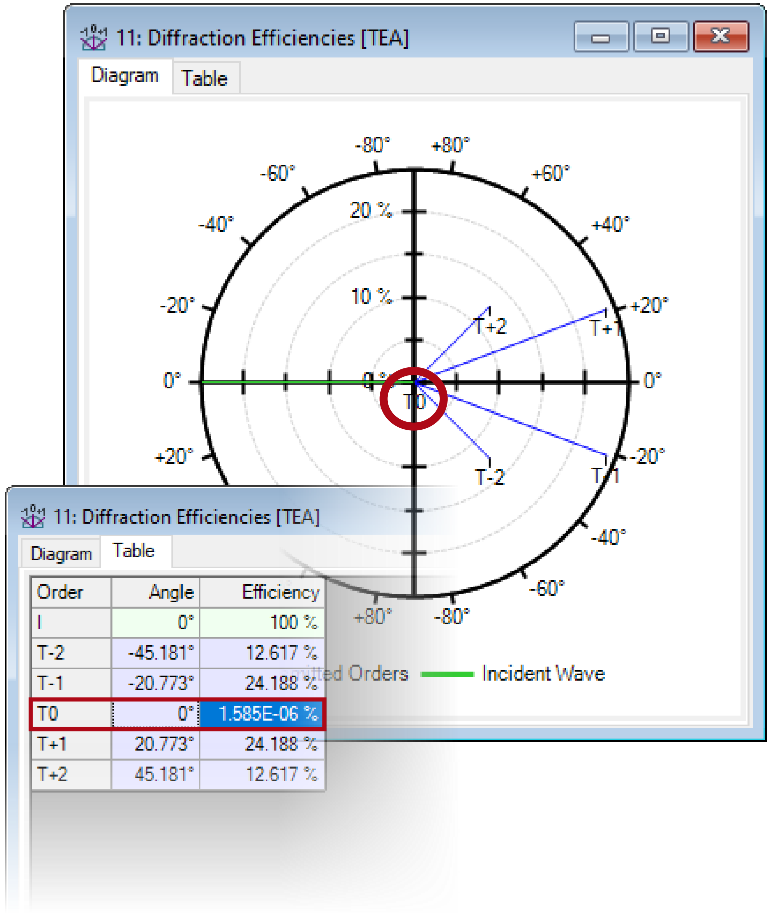


Sinusoidal Grating – Diffraction Efficiencies



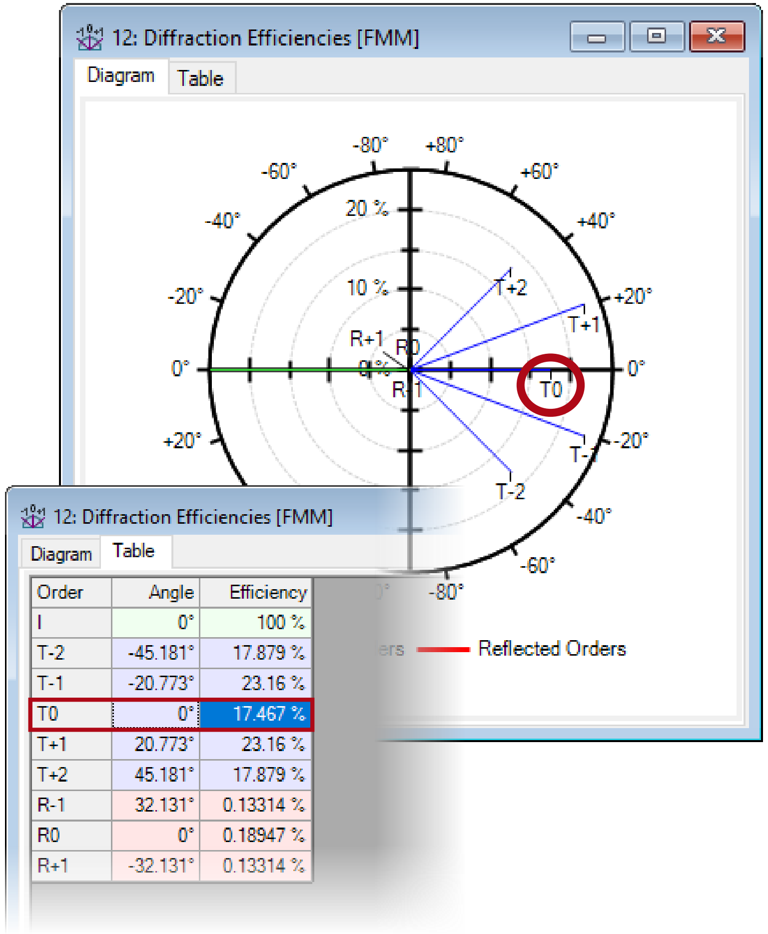
fixed period d=1µm
fixed TE polarization
fixed height h=815nm

diffraction efficiencies (TEA)



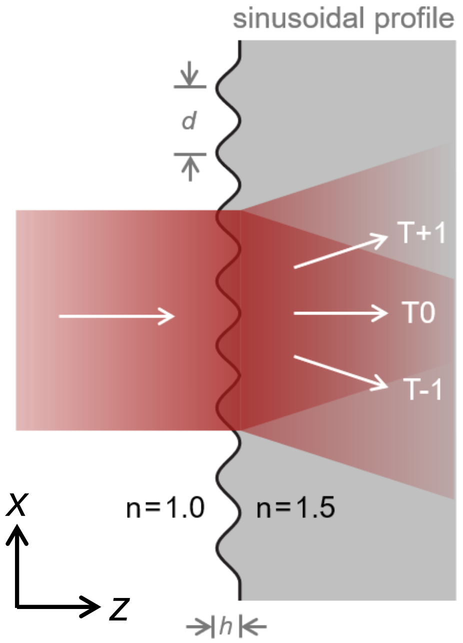
Order	Angle	Efficiency
I	0°	100 %
T-2	-45.181°	12.617 %
T-1	-20.773°	24.188 %
T0	0°	1.585E-06 %
T+1	20.773°	24.188 %
T+2	45.181°	12.617 %

diffraction efficiencies (FMM)



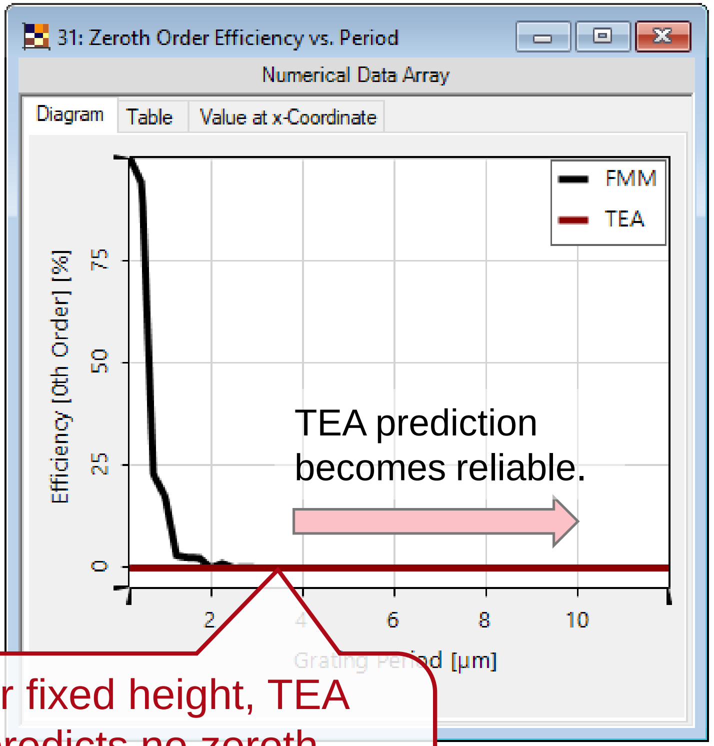
Order	Angle	Efficiency
I	0°	100 %
T-2	-45.181°	17.879 %
T-1	-20.773°	23.16 %
T0	0°	17.467 %
T+1	20.773°	23.16 %
T+2	45.181°	17.879 %
R-1	32.131°	0.13314 %
R0	0°	0.18947 %
R+1	-32.131°	0.13314 %

Sinusoidal Grating – Efficiencies vs. Period



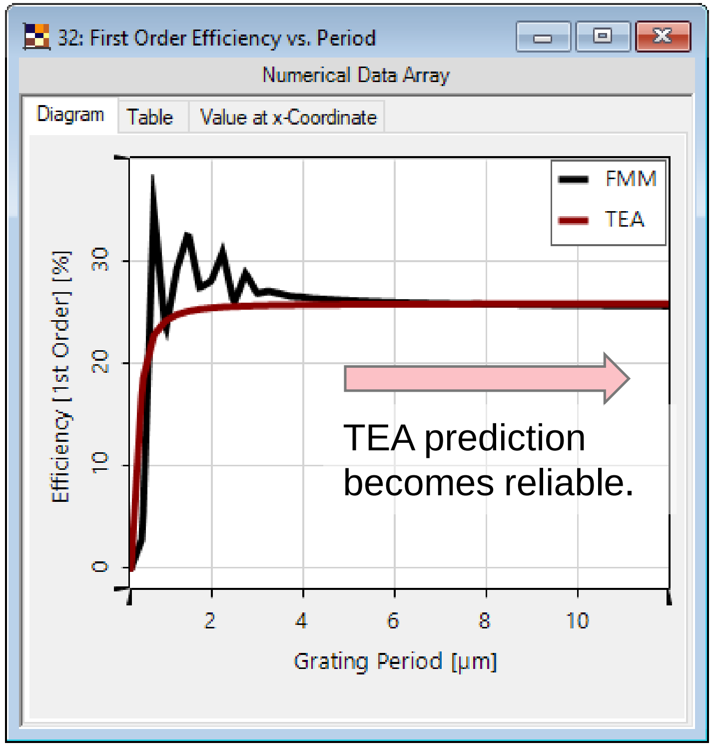
varying period *d*
fixed TE polarization
fixed height h=815nm

diffraction efficiencies – 0th order

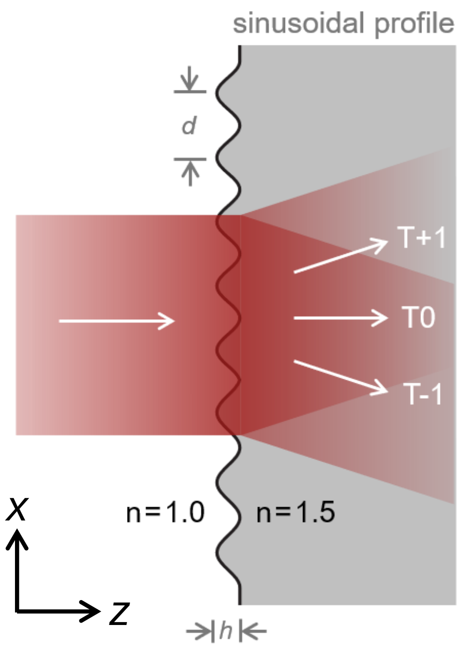


For fixed height, TEA predicts no zeroth diffraction order regardless of the grating period.

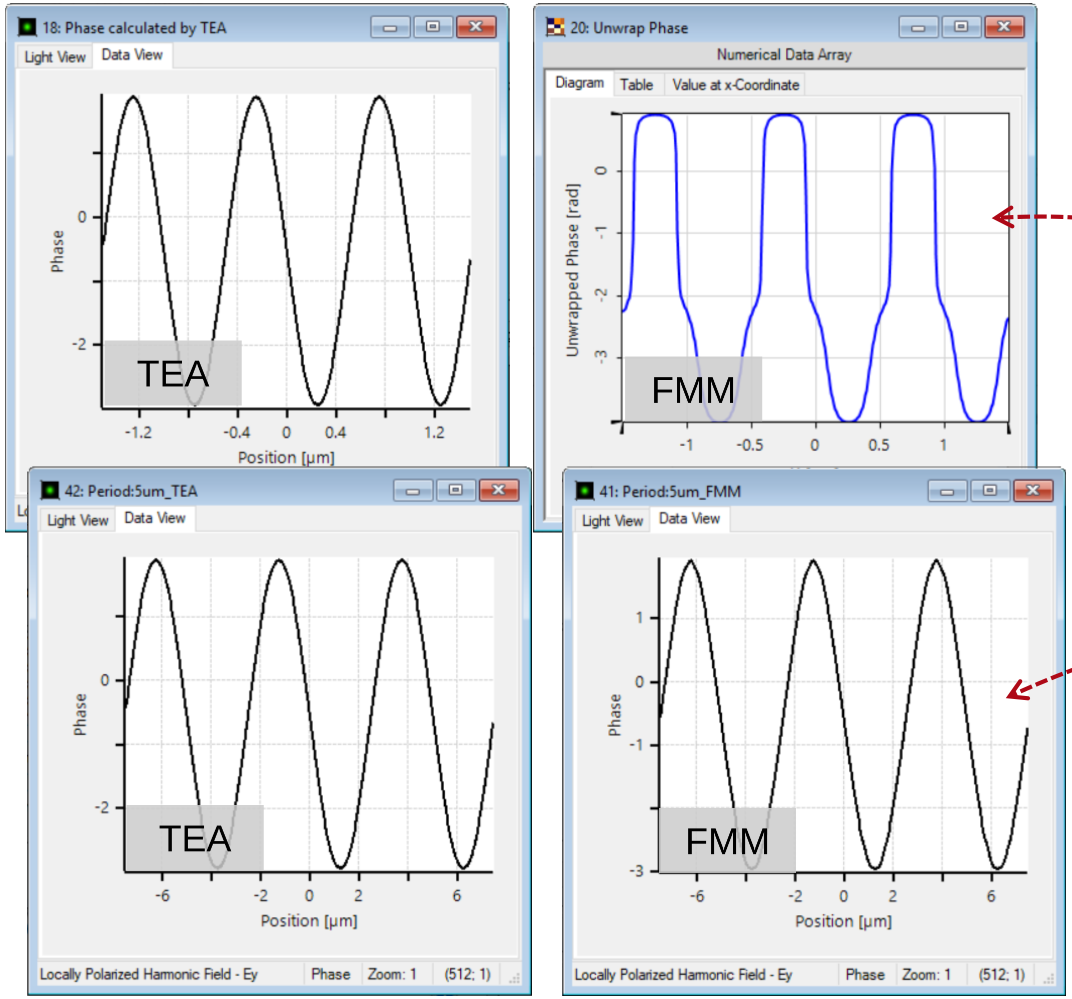
diffraction efficiencies – 1st order



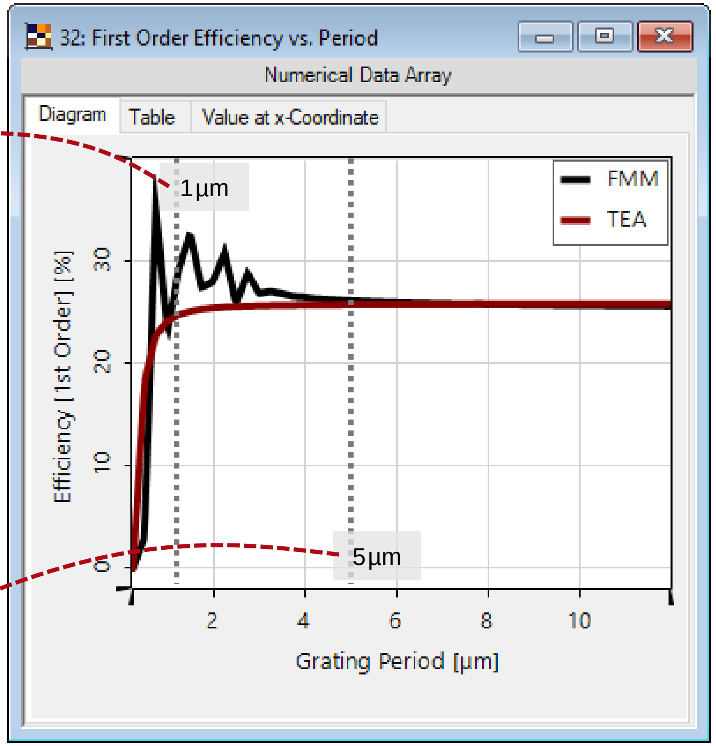
Sinusoidal Grating – Phase Profiles at Selected Periods



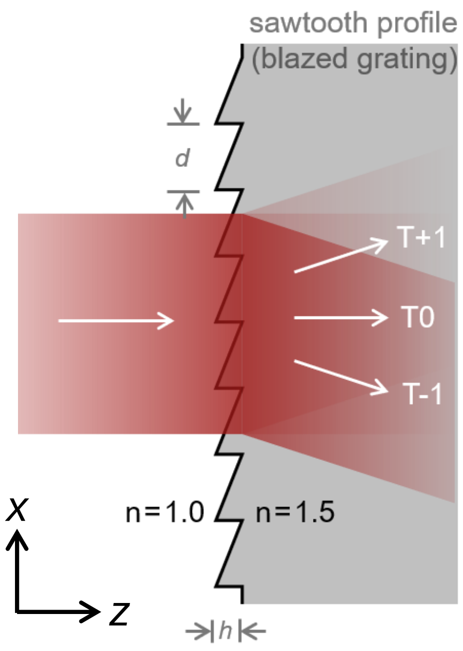
period *d*=1µm or 5µm
fixed TE polarization
fixed height *h*=815nm



diffraction efficiencies – 1st order

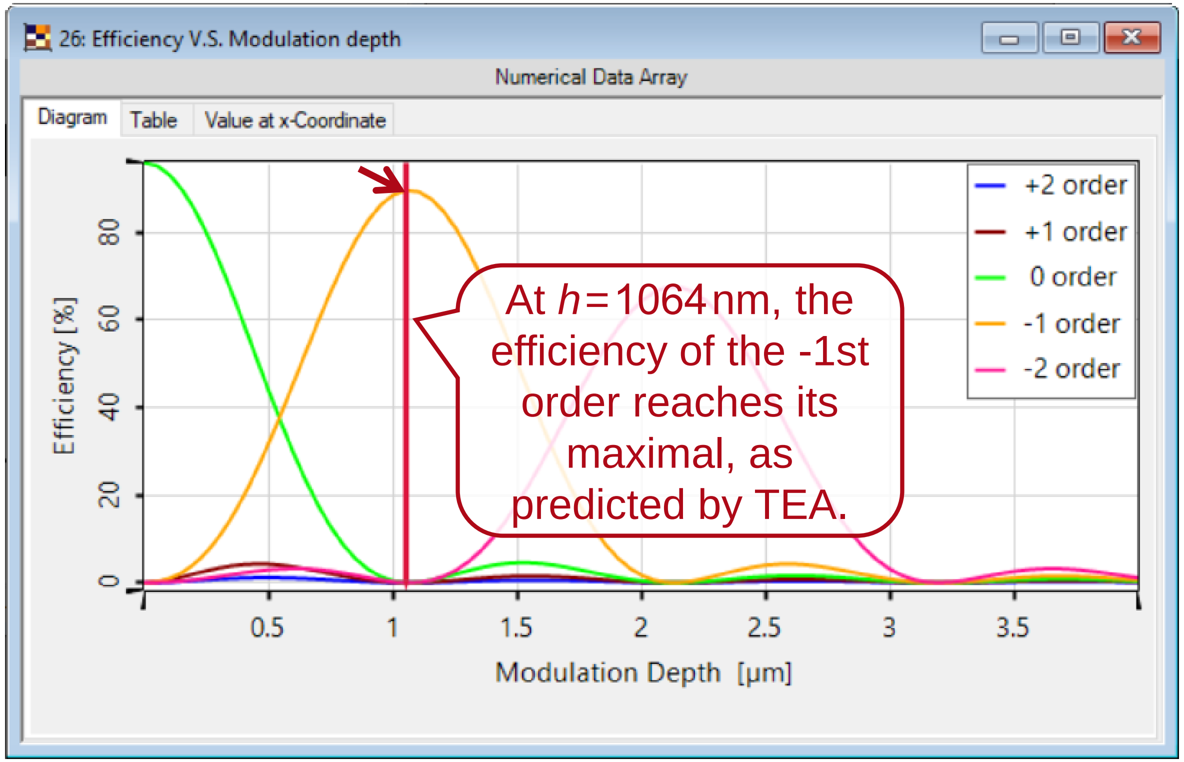


Blazed Grating – Efficiency vs. Height (TEA Only)



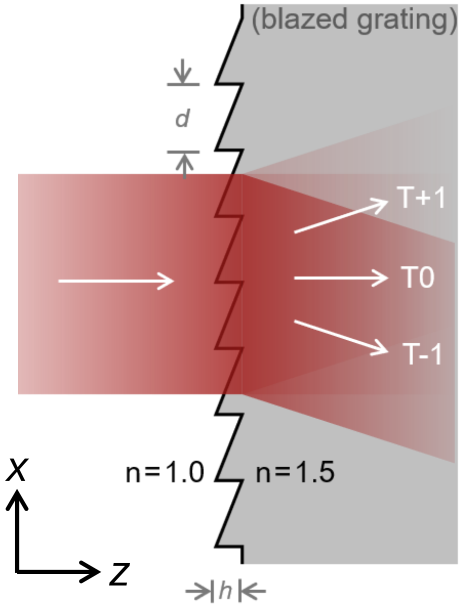
fixed period $d = 1\,\mu m$
fixed TE polarization
varying height *h*

It is often efficient to use TEA as a fast design tool for searching proper grating parameters. However, the limitation of the method shall be noticed.



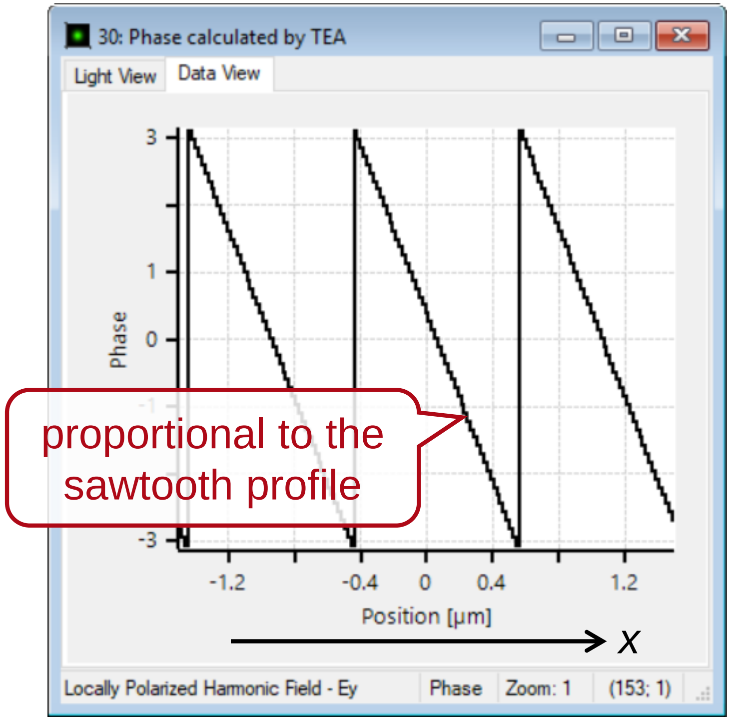
To maximize the diffraction efficiency of the -1st order, we pick up $h = 1064\,nm$ as the grating height.

Blazed Grating – Transmitted Phase Profiles

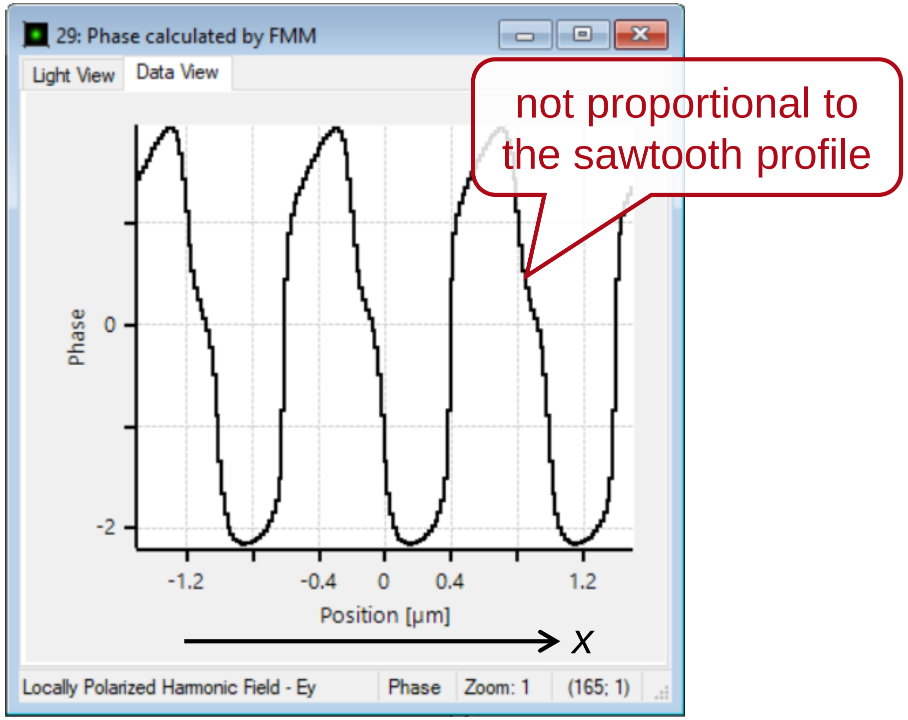


fixed period d=1µm
fixed TE polarization
fixed height h=1064nm

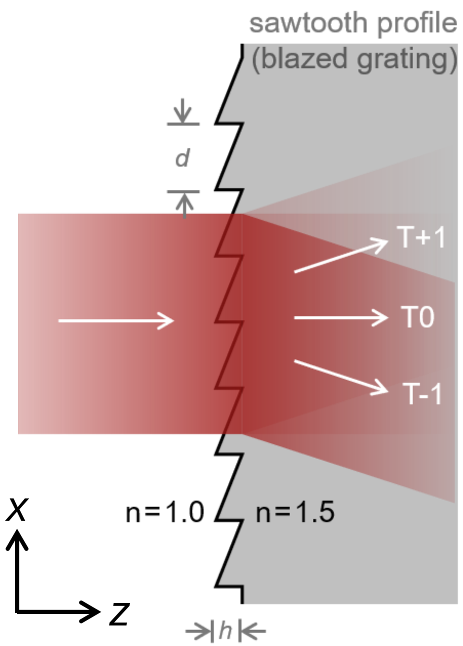
phase behind grating (TEA)



phase behind grating (FMM)

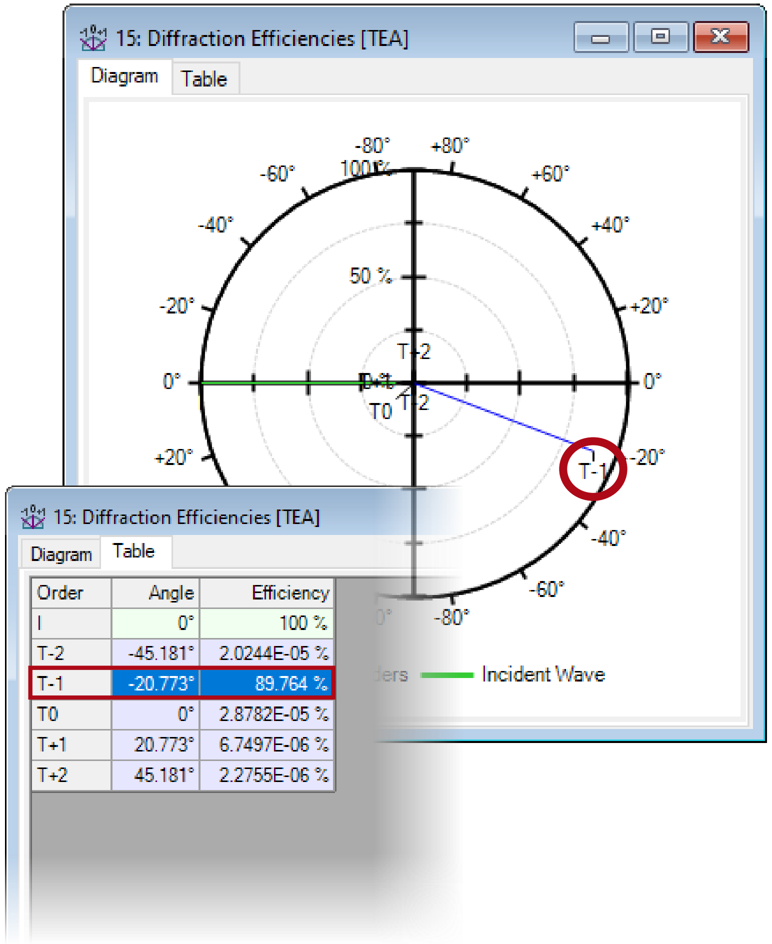


Blazed Grating – Diffraction Efficiencies



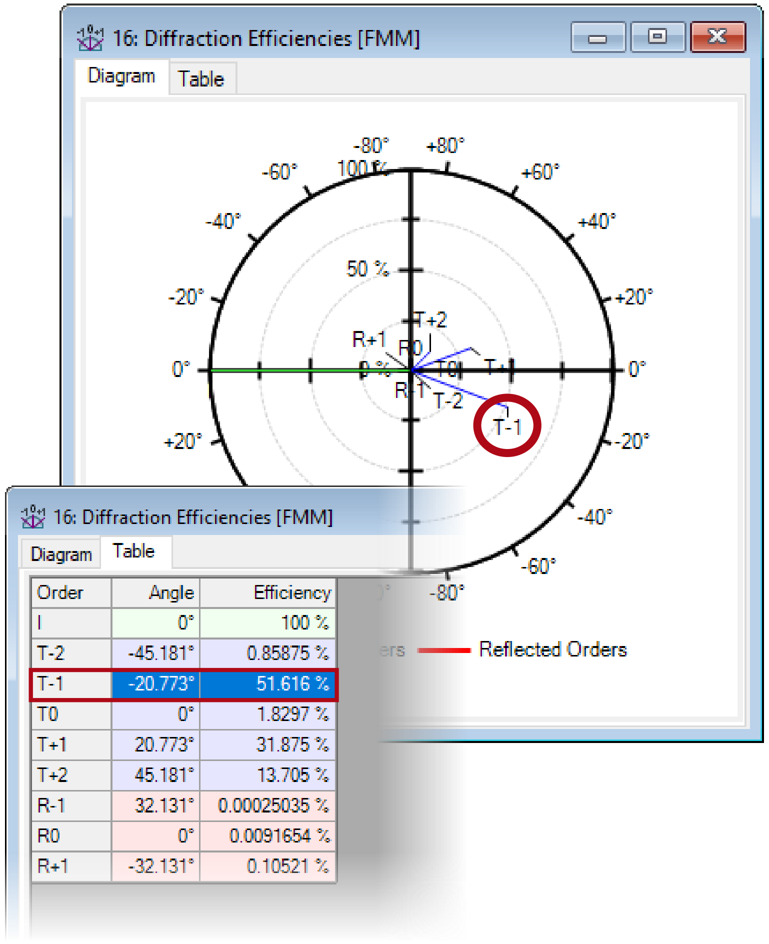
fixed period d=1µm
fixed TE polarization
fixed height h=1064nm

diffraction efficiencies (TEA)



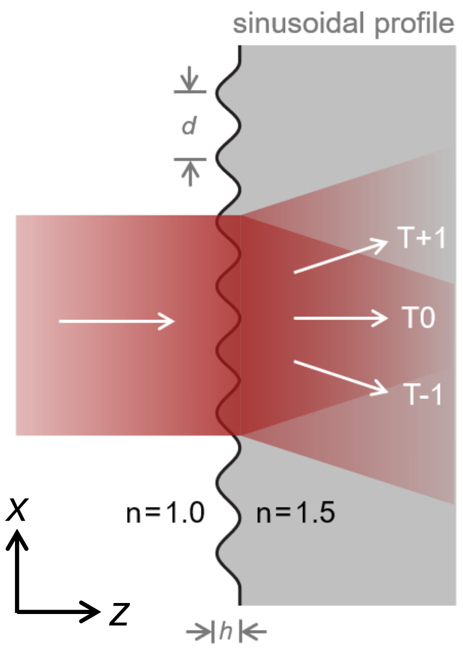
Order	Angle	Efficiency
I	0°	100 %
T-2	-45.181°	2.0244E-05 %
T-1	-20.773°	89.764 %
T0	0°	2.8782E-05 %
T+1	20.773°	6.7497E-06 %
T+2	45.181°	2.2755E-06 %

diffraction efficiencies (FMM)



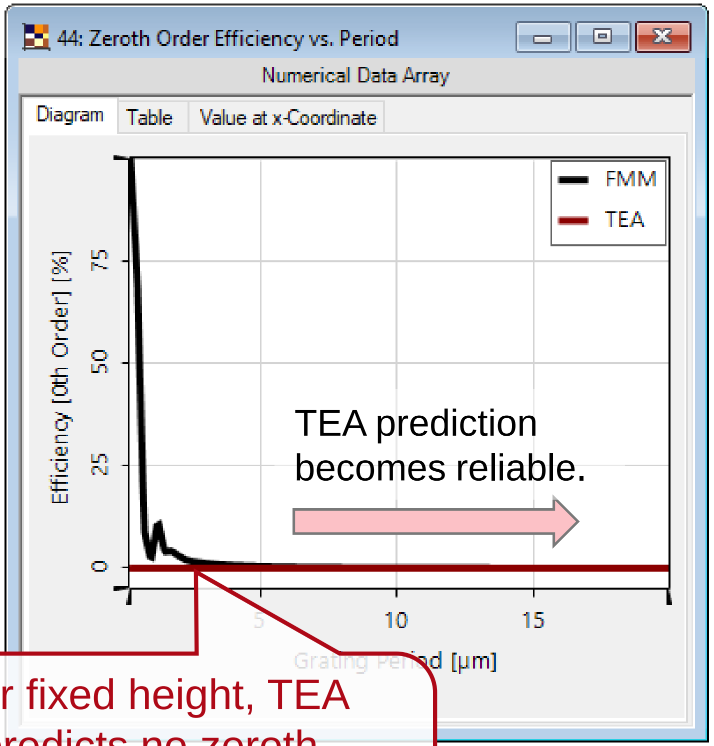
Order	Angle	Efficiency
I	0°	100 %
T-2	-45.181°	0.85875 %
T-1	-20.773°	51.616 %
T0	0°	1.8297 %
T+1	20.773°	31.875 %
T+2	45.181°	13.705 %
R-1	32.131°	0.00025035 %
R0	0°	0.0091654 %
R+1	-32.131°	0.10521 %

Blazed Grating – Efficiencies vs. Period



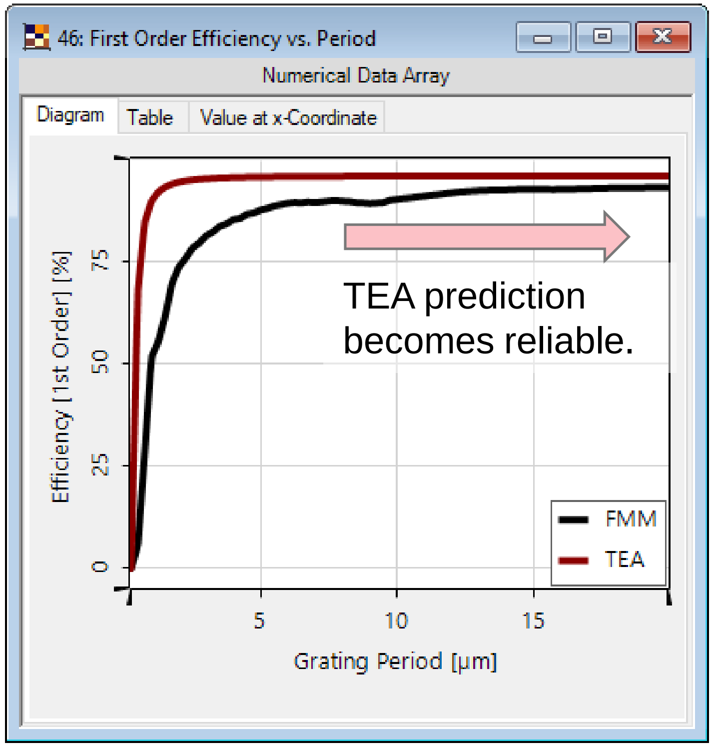
varying period *d*
fixed TE polarization
fixed height h=1064nm

diffraction efficiencies – 0^{th} order

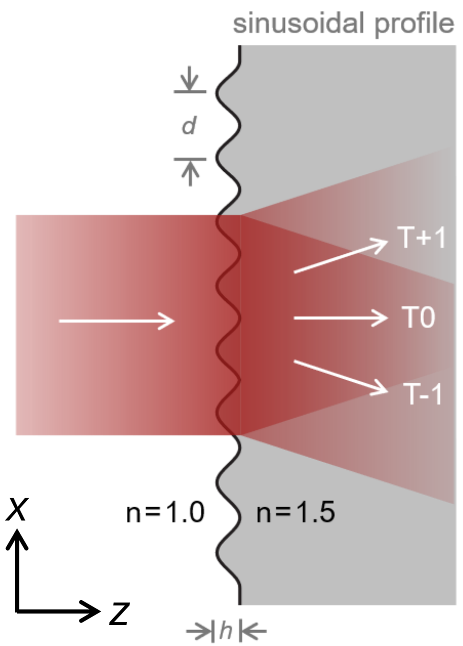


For fixed height, TEA predicts no zeroth diffraction order regardless of the grating period.

diffraction efficiencies – 1^{st} order

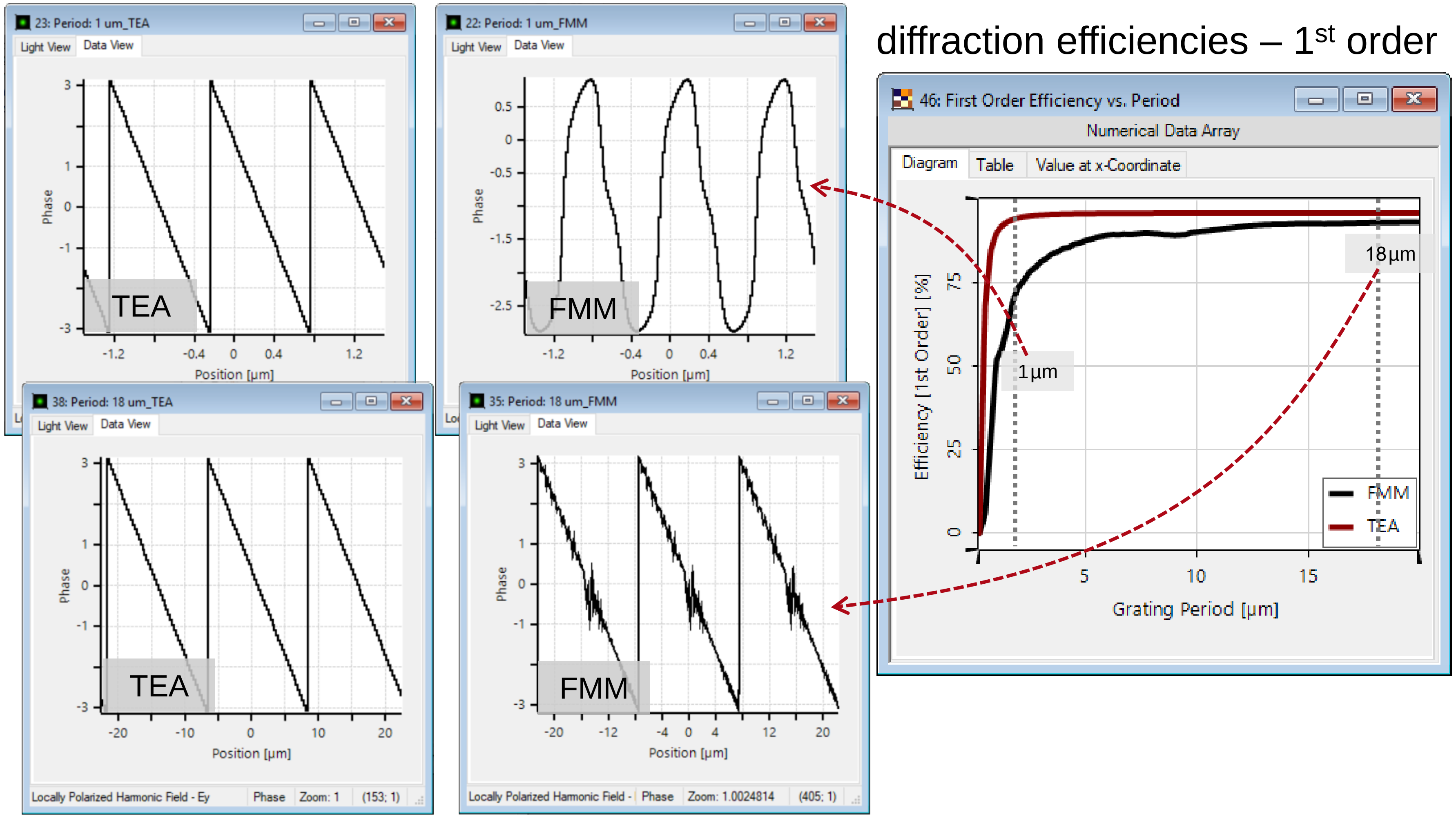


Sinusoidal Grating – Phase Profiles at Selected Periods



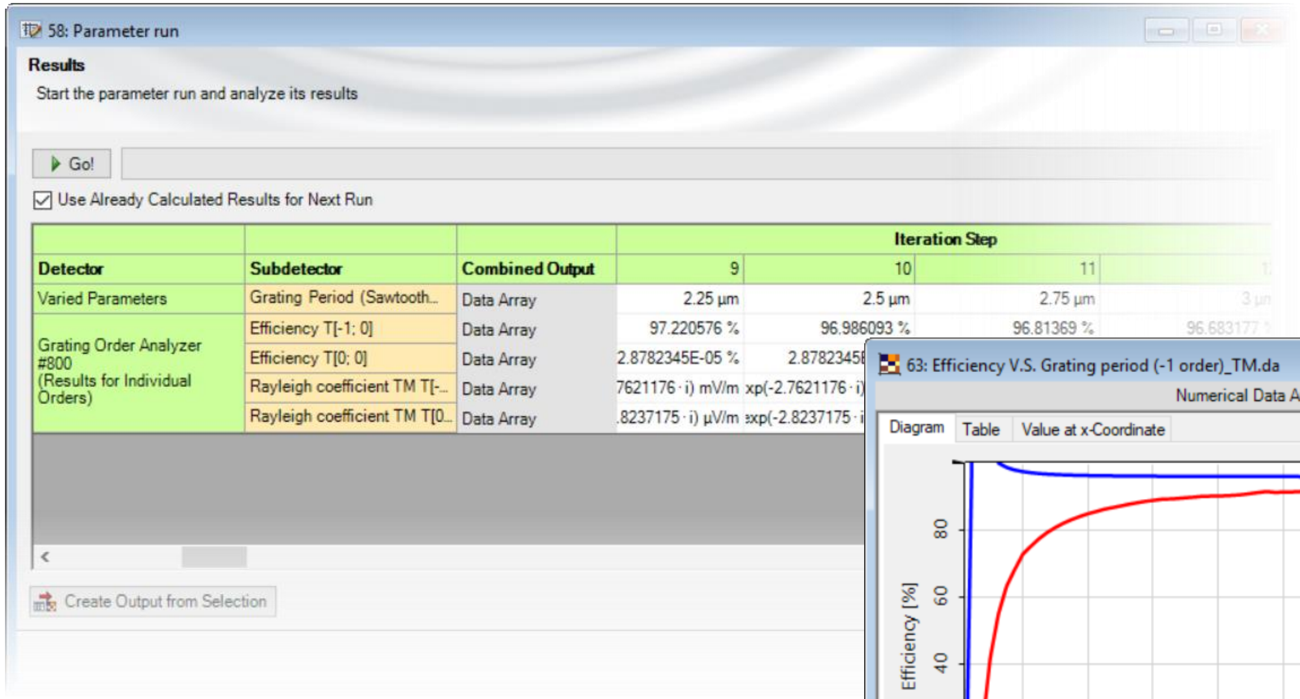
period *d*=1µm or 18µm
fixed TE polarization
fixed height *h*=1064nm

diffraction efficiencies – 1st order

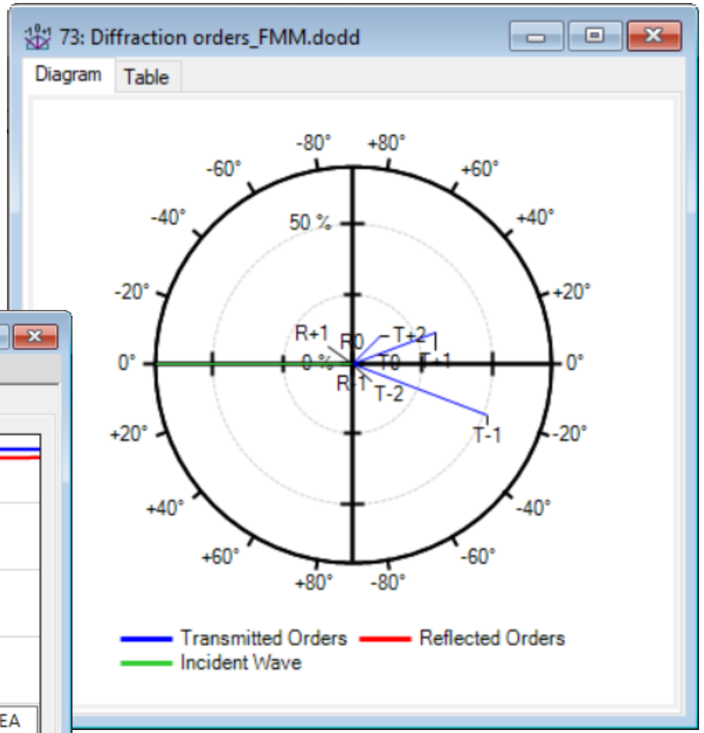


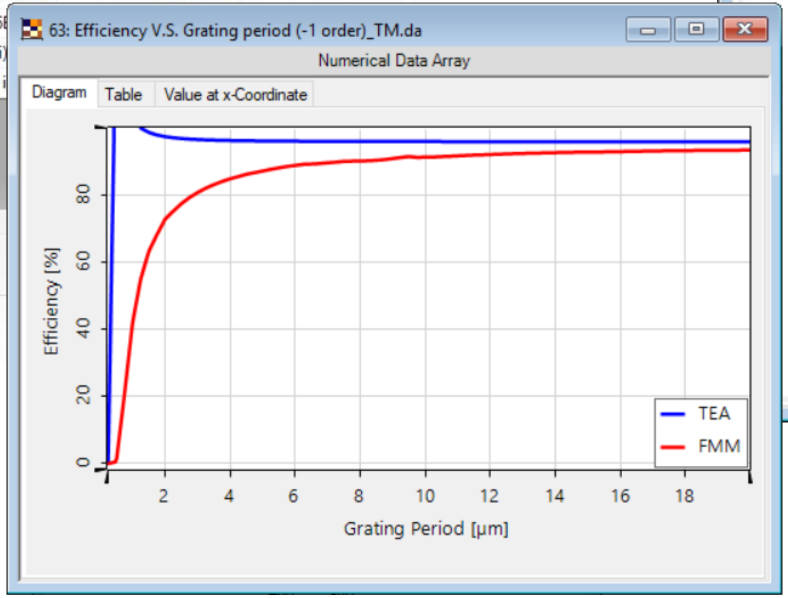
Peek into VirtualLab Fusion

scanning of diffraction efficiency vs. specific parameter(s)



diffraction efficiency analysis and visualization in polar diagram

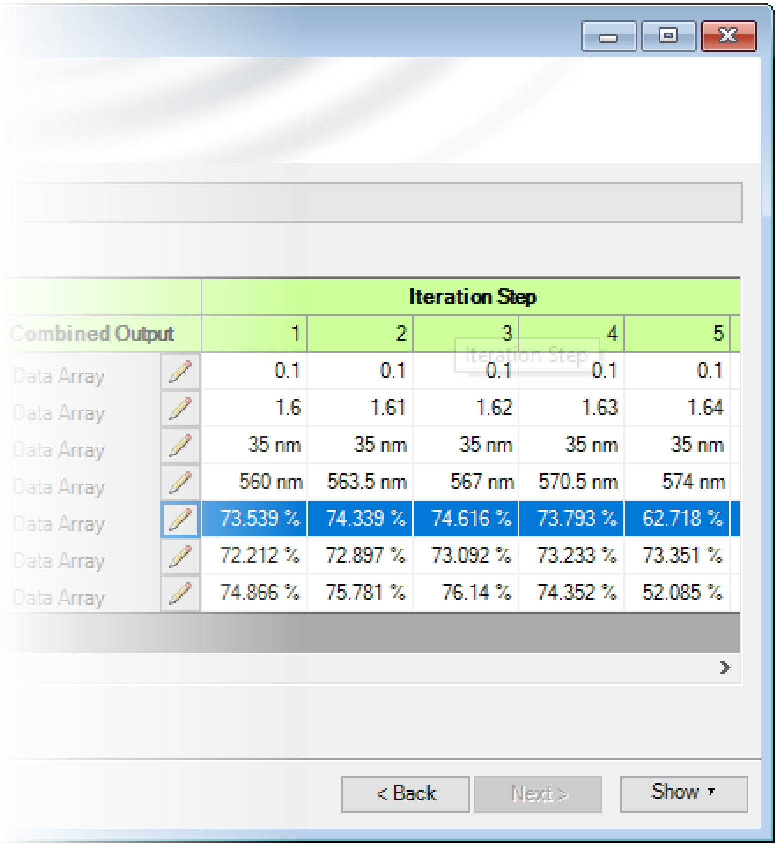




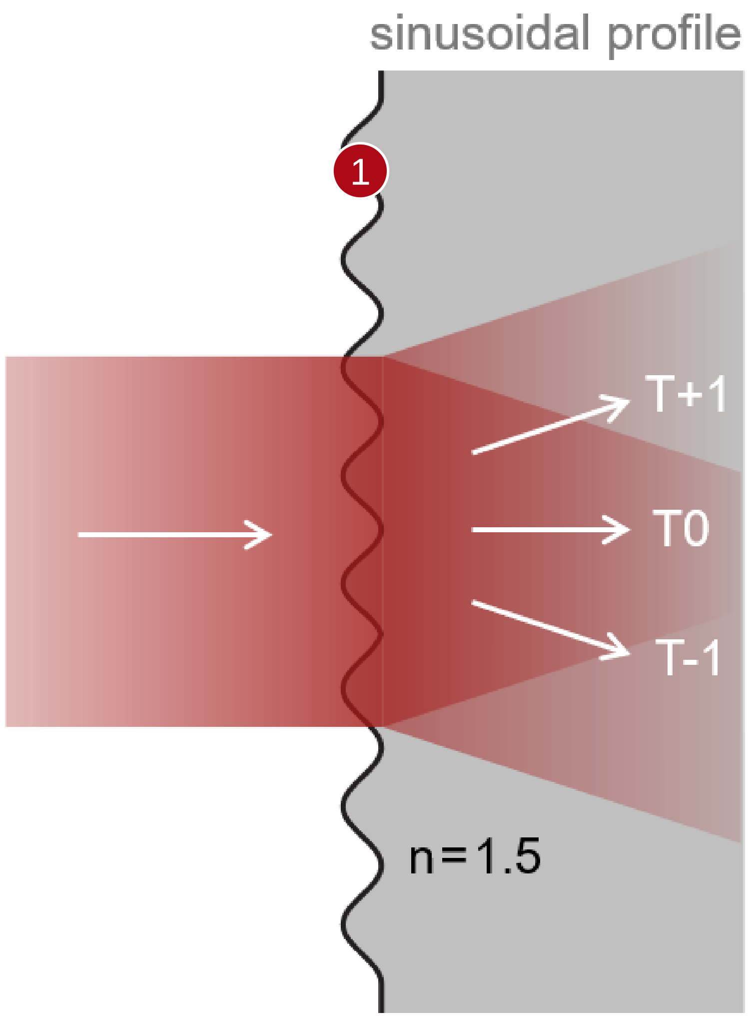
different methods to model gratings – TEA or FMM

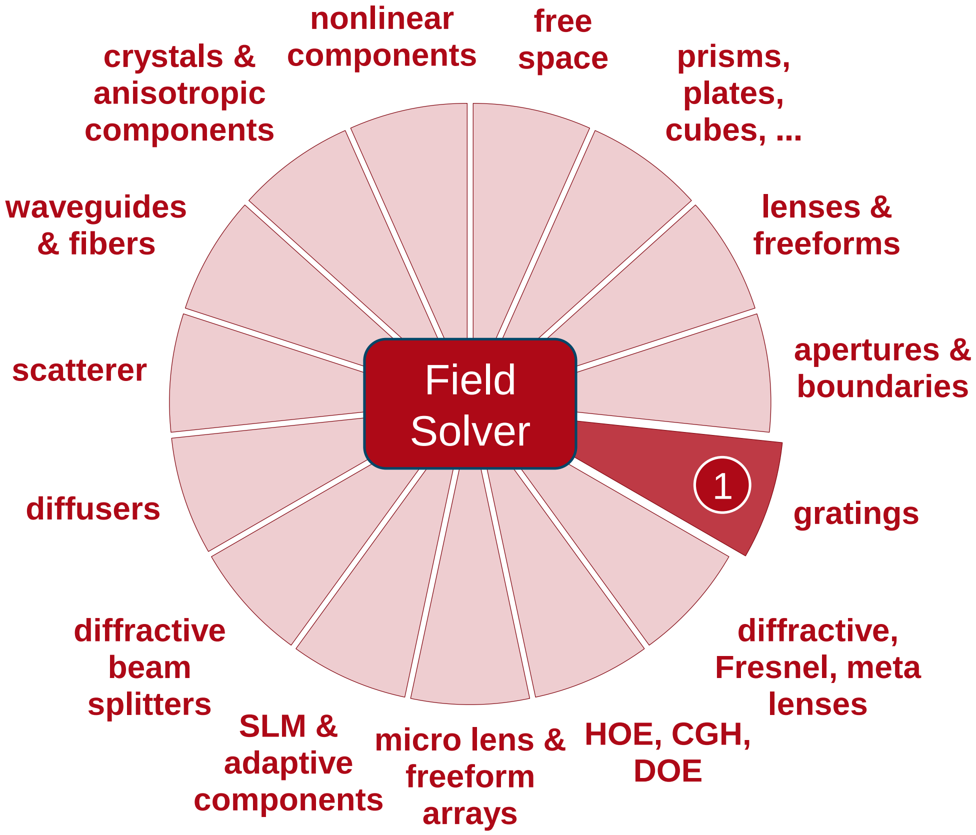
Workflow in VirtualLab Fusion

- Construct grating structure
  - Configuration of Grating Structures by Using Interfaces [Use Case]
- Analyze grating diffraction efficiency
  - Grating Order Analyzer [Use Case]
- Check influence from different parameters with Parameter Run
  - Usage of the Parameter Run Document [Use Case]



VirtualLab Fusion Technologies





Document Information

title	Thin Element Approximation (TEA) vs. Fourier Modal Method (FMM) for Grating Modeling
document code	GRT.0019
version	1.1
toolbox(es)	Grating Toolbox
VL version used for simulations	VirtualLab Fusion Summer Release 2019 (7.6.1.18)
category	Application Use Case
further reading	- Analysis of Slanted Gratings for Lightguide Coupling - Grating Order Analyzer