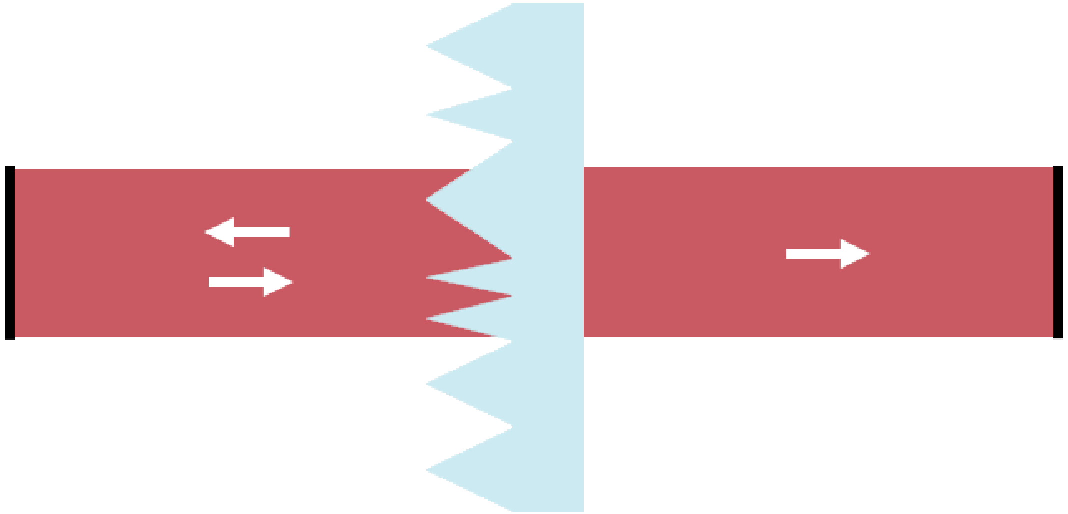
Statistical Anti-reflection Structures (Random Moth-Eye Structures)

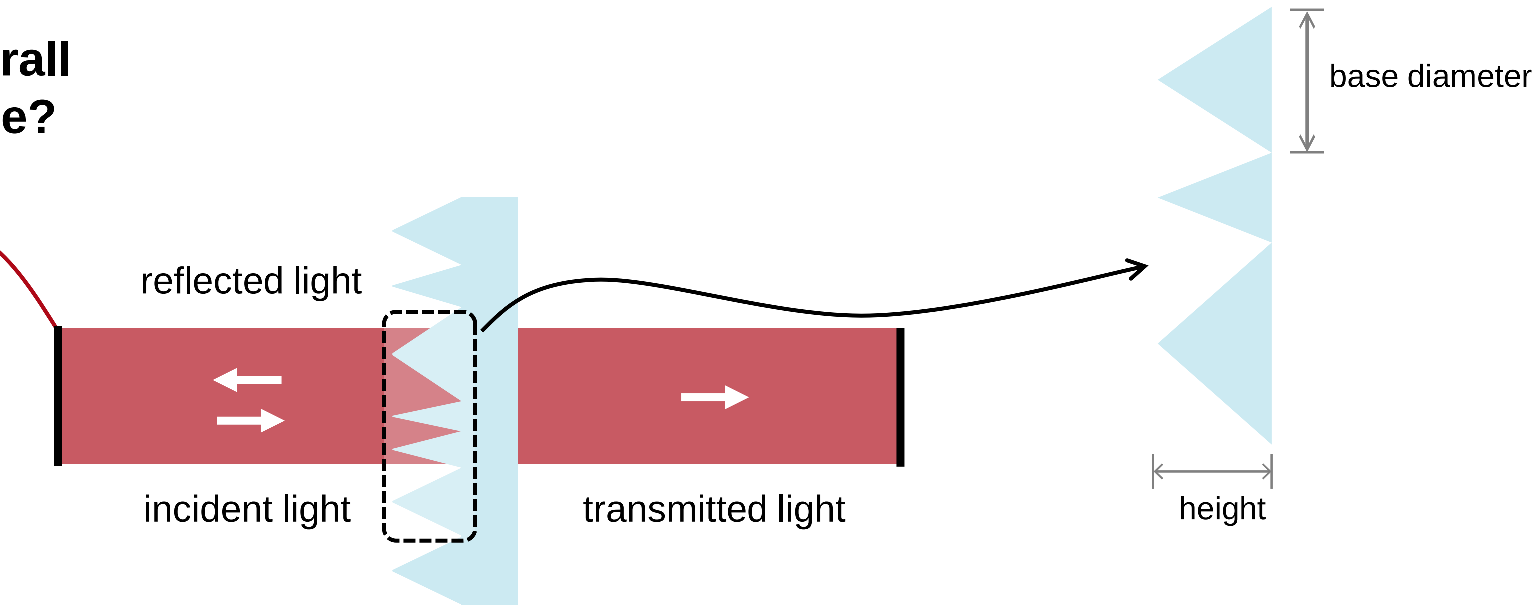
Abstract



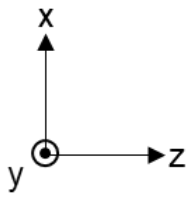
Minimizing reflection on optical surfaces is of great importance for various optical applications. An intriguing method to mitigate surface reflection involves the employment of nano- and micro-structures designed to counteract reflection, drawing inspiration from natural phenomena such as moth-eye structures. In this use case, we intend to investigate the overall reflection of such a structure by applying tolerance analysis within the framework of VirtualLab Fusion.

Modeling Task

How does the overall reflectance change?



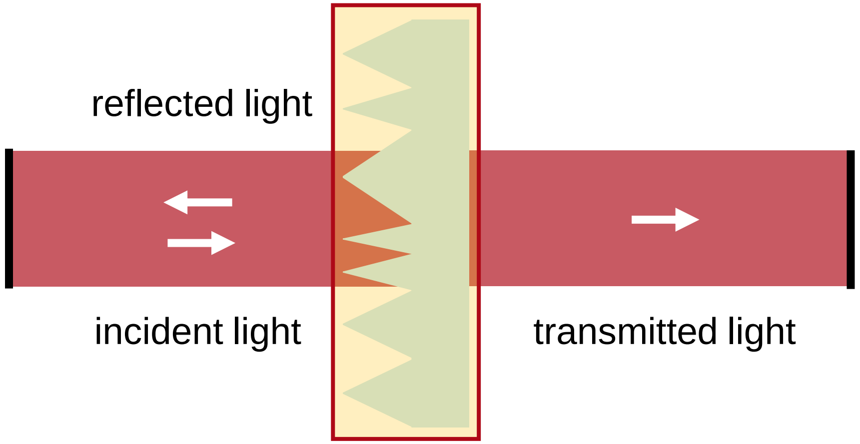
plane wave
- wavelength: 532 nm
- linearly polarized along-x



AR moth-eye structure [fixed values]
- base material: fused silica
- base thickness: 1 mm
- surrounding medium: air
- cone base diameter variance: 100 nm

AR moth-eye structure [varying parameters]
- number of cones: (50 – 500)
- cone height: (100 nm – 1 µm)
- cone base diameter: (50 nm – 500 nm)

Connected Modeling Techniques: Moth-Eye Structure

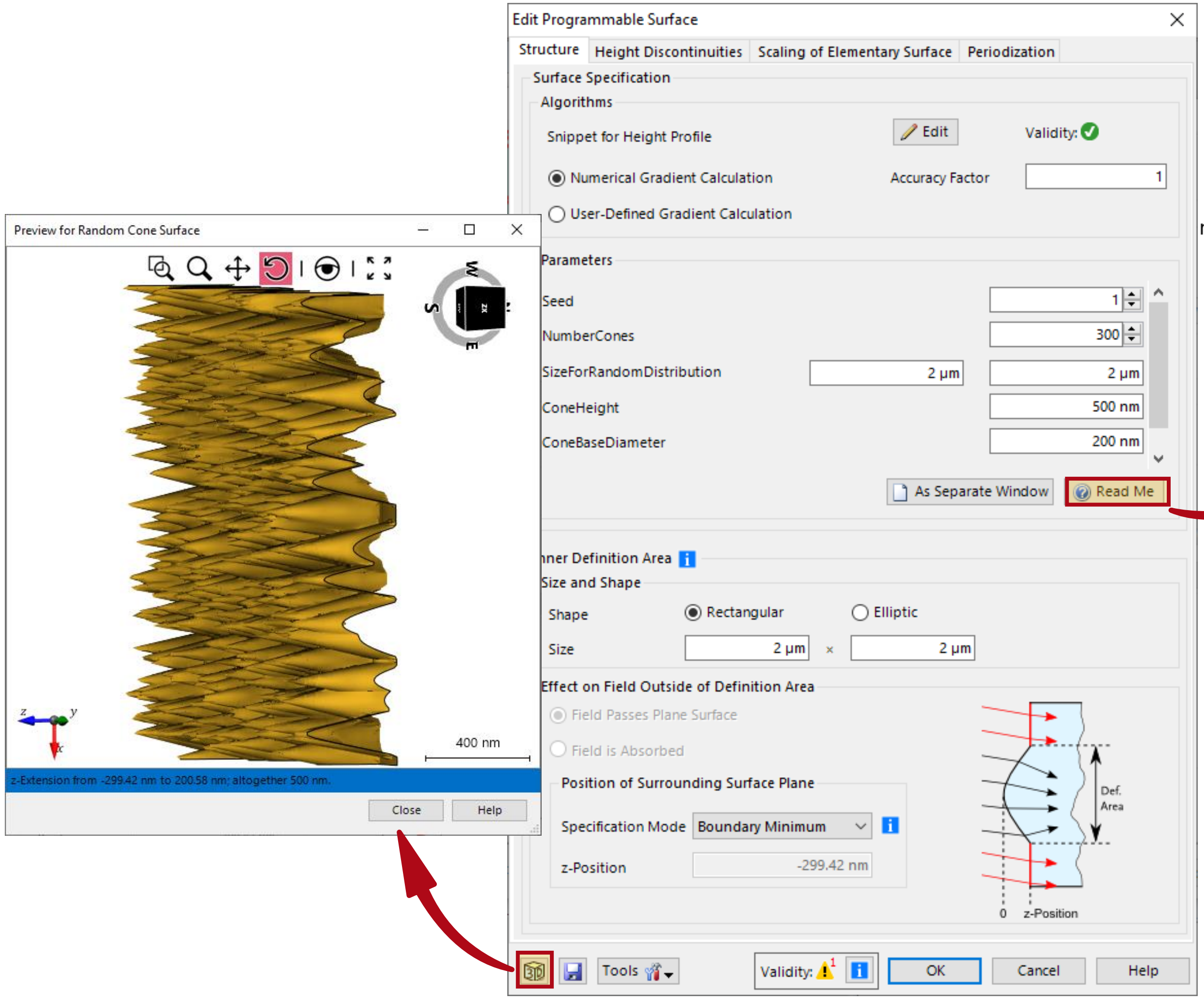


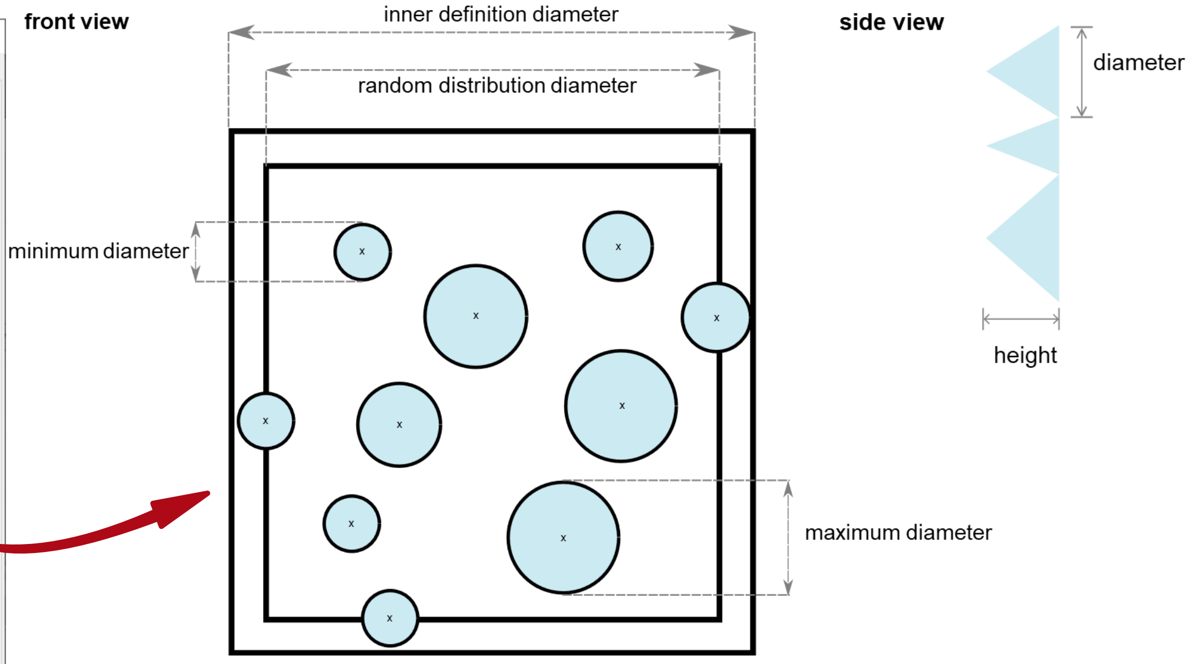
Available modeling techniques for microstructures:

Methods	Preconditions	Accuracy	Speed	Comments
Functional Approach	-	low	very high	diffraction angles acc. to grating equation; manual efficiencies
Thin Element Approximation (TEA)	smallest features > ~10λ	high	very high	inaccurate for larger NA and thick elements; x-domain
	smallest features < ~2λ	low	very high	
Fourier Modal Method (FMM)	period < ~ (5λ × 5λ)	very high	high	rigorous solution; fast for structures and periods similar to the wavelength; more demanding for larger periods; k-domain
	period > ~ (15λ × 15λ)	very high	slow	

Due to the small feature sizes (compared to the wavelength of light), the **Fourier Modal Method (FMM)** provides a very accurate and fast solution and is therefore is used for the analysis.

Random Cone Interface



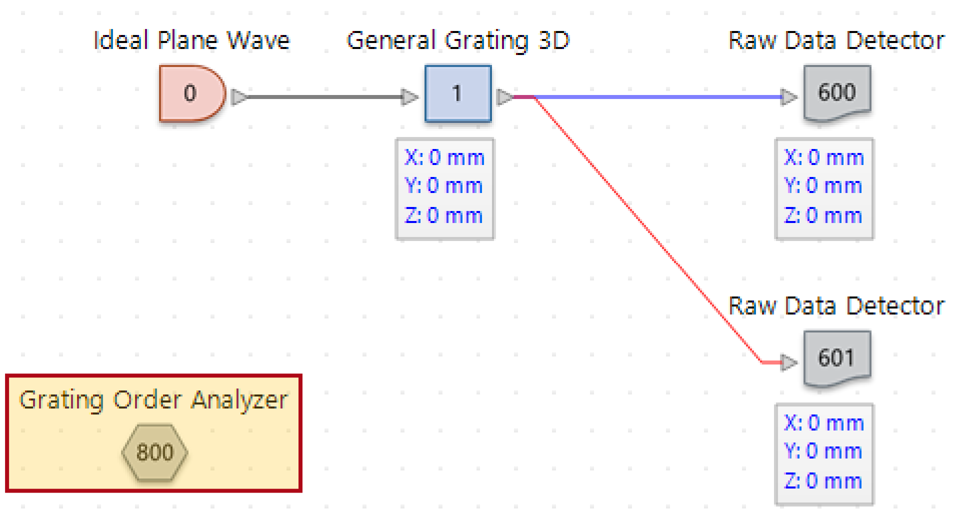


This programmable surface allows to randomly distribute cones with various base diameters. The user can define the number, max. height and size of the cones. Cone base diameter will vary according to:

maximum diameter = base diameter + 0.5 · base diameter variance

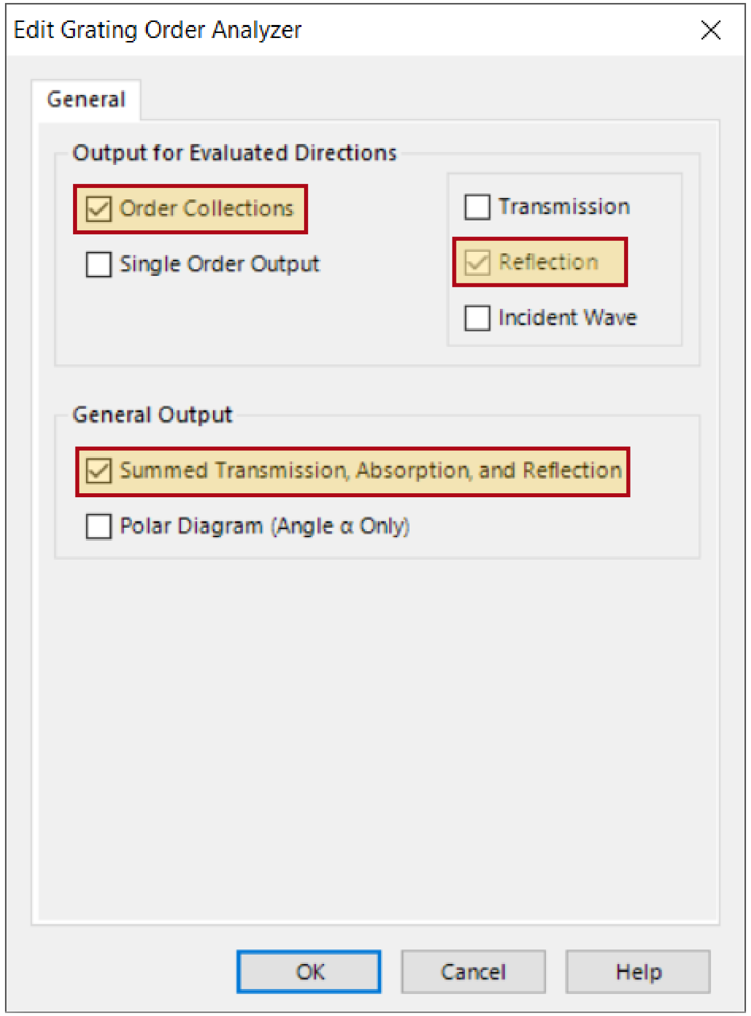
minimum diameter = base diameter - 0.5 · base diameter variance

Grating Order Analyzer

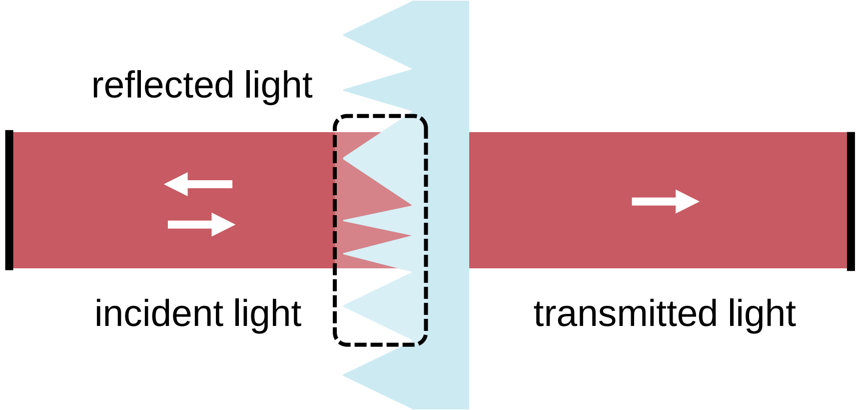


The *Grating Order Analyzer* can be used to investigate the efficiency of the diffraction orders of a given grating. Find more information under:

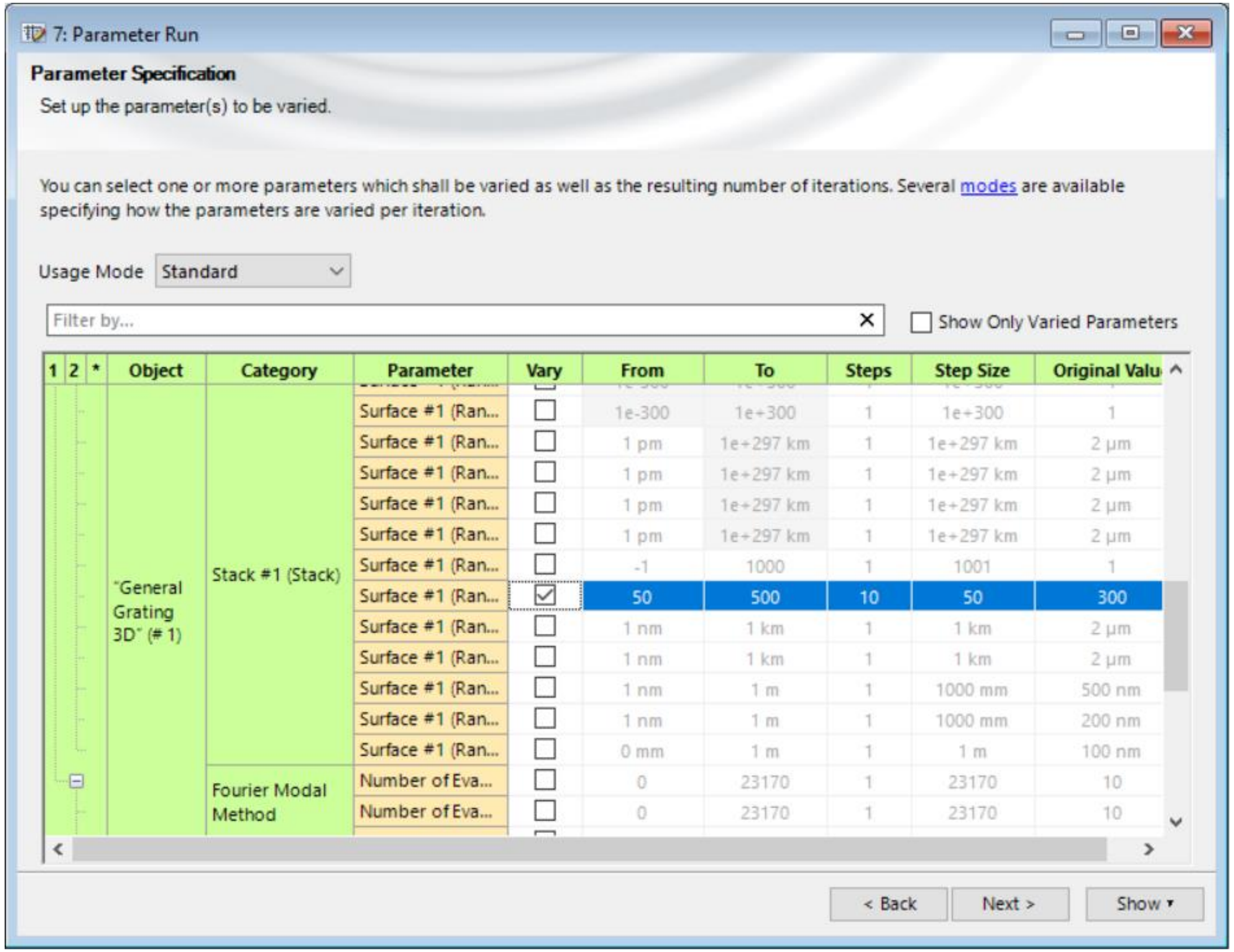
Grating Order Analyzer



Parameter Run

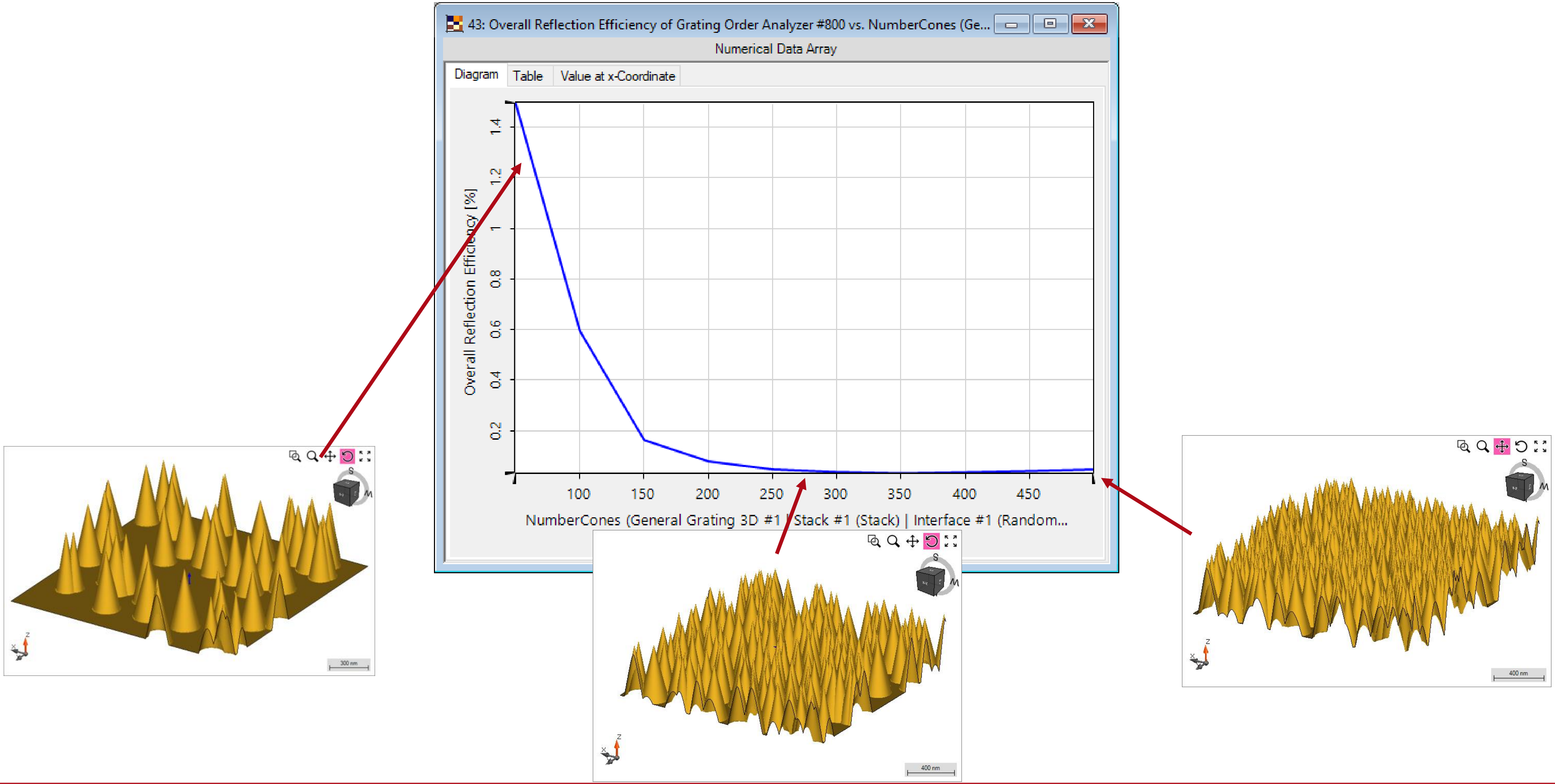


The overall reflectance is evaluated by varying the number of cones, height of cones and base diameter of the cones separately. Such a variation of parameters can be achieved by a *Parameter Run.*

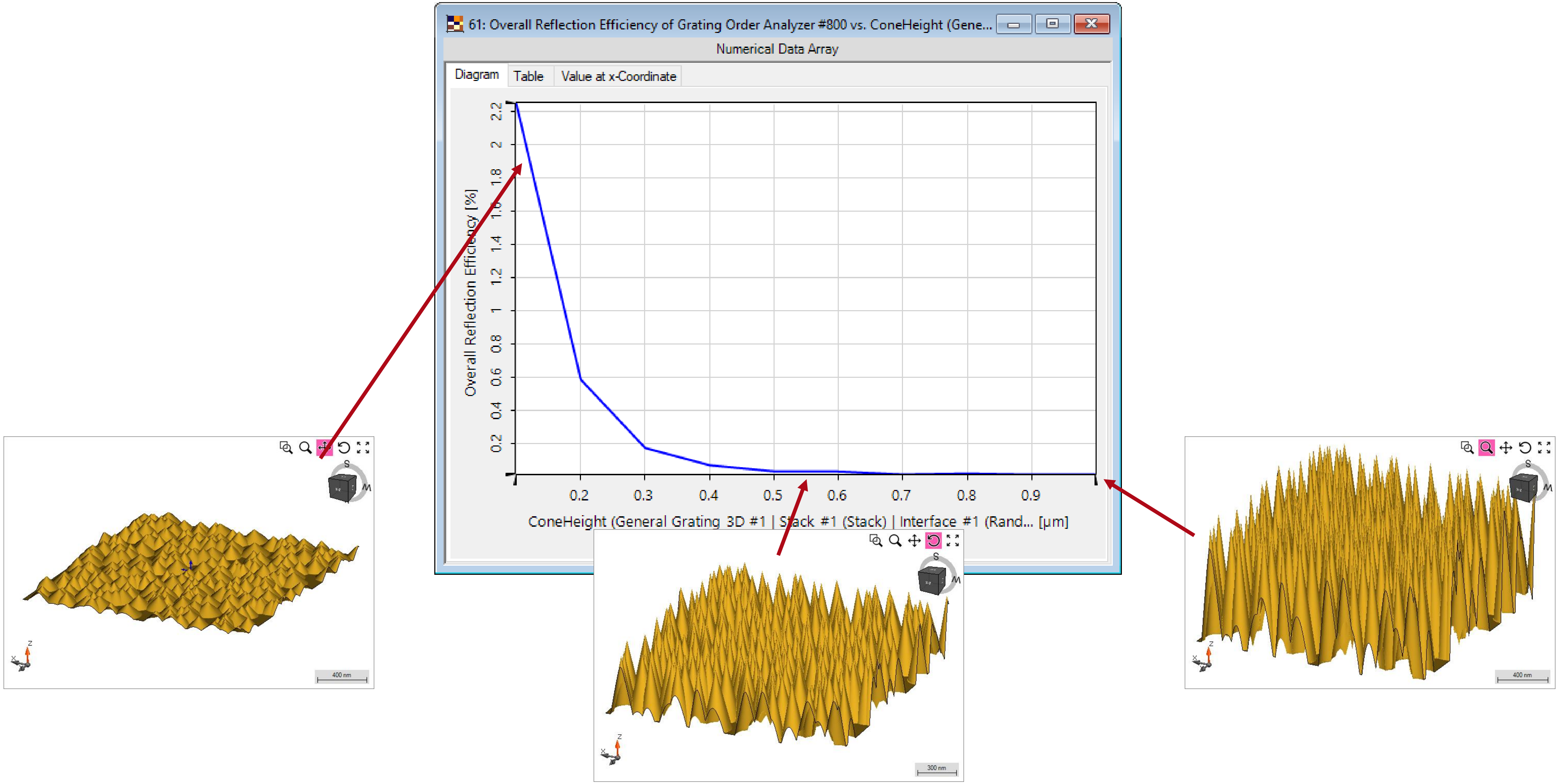


[Usage of the Parameter Run Document](#)

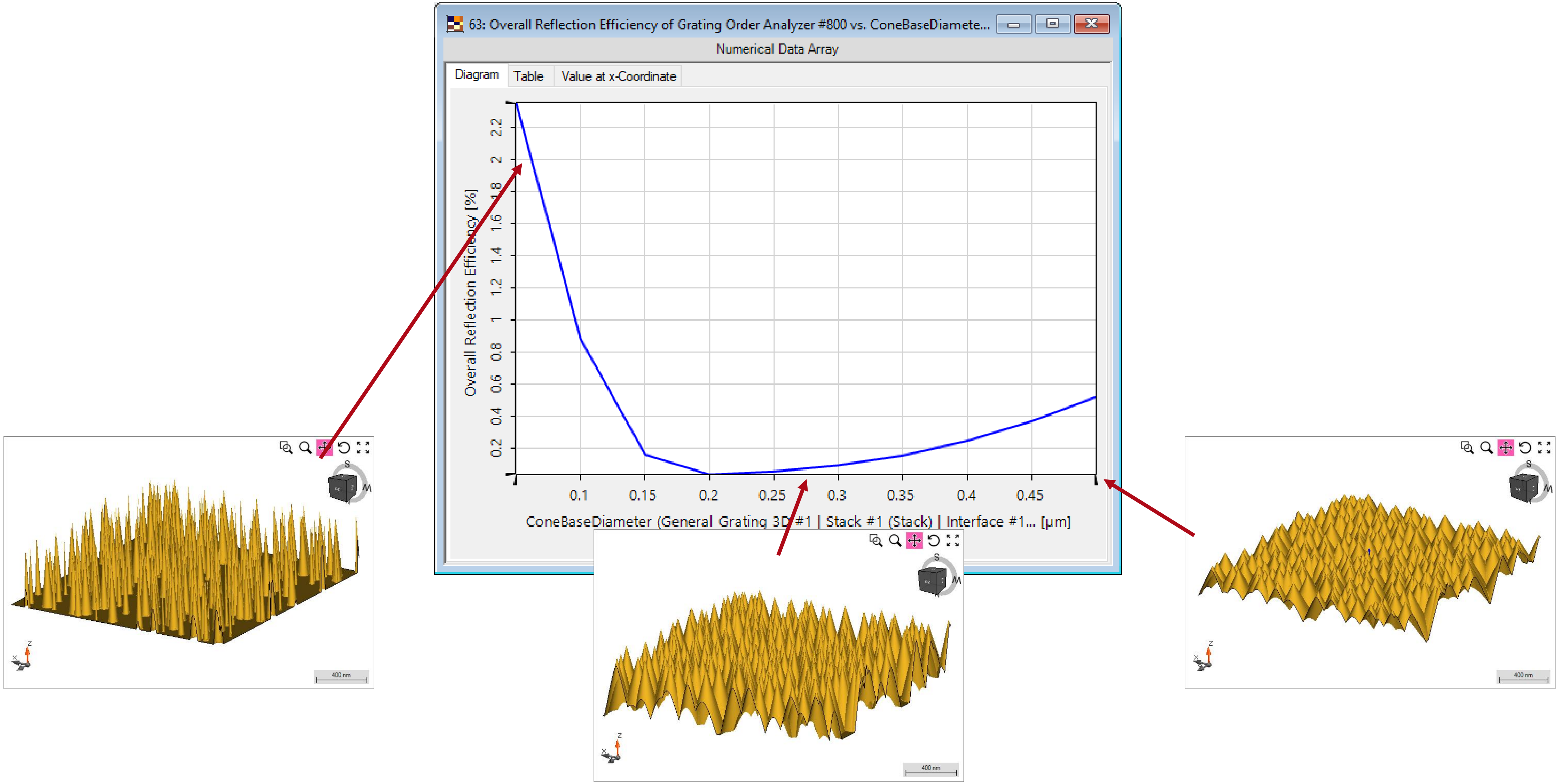
Overall Reflectance vs. Number of Cones



Overall Reflectance vs. Height of Cones



Overall Reflectance vs. Base Diameter of Cones



Document Information

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