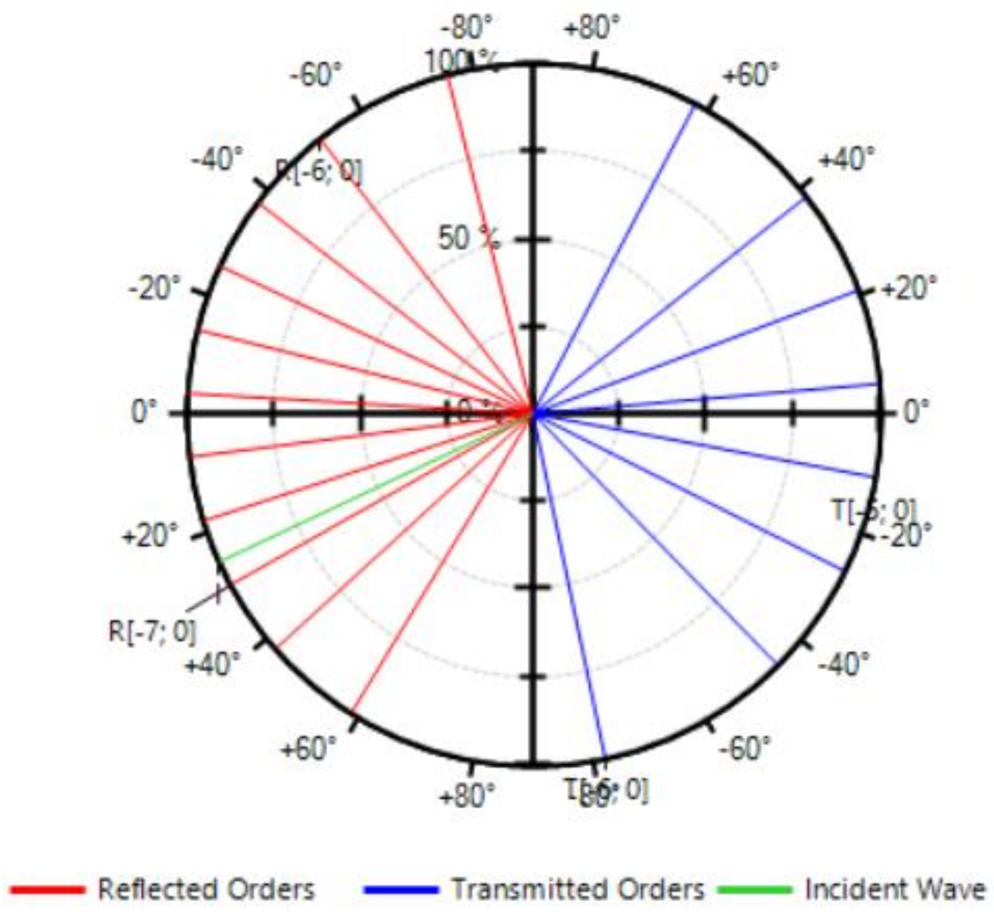
Diffraction Angle Calculator

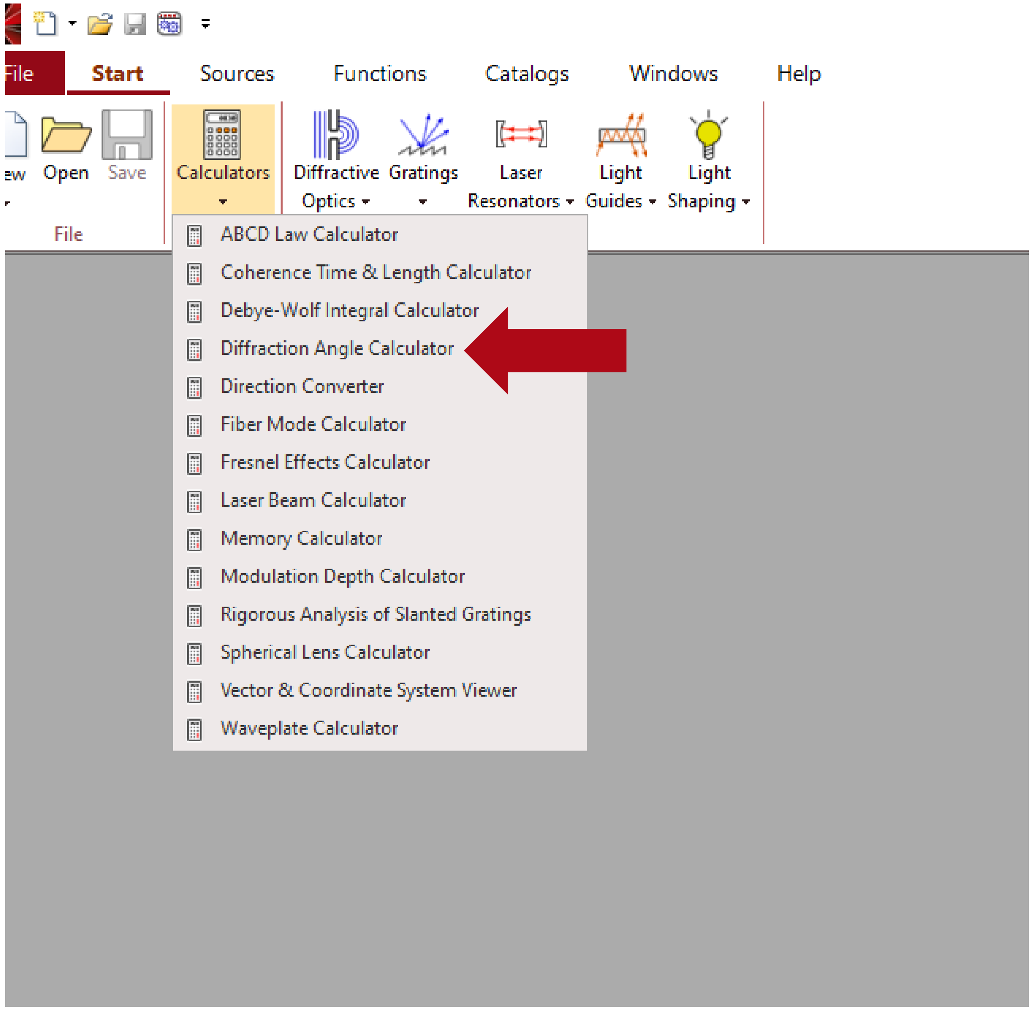
Abstract



The defining characteristic of diffraction gratings is the periodicity of their structure which, as predicted by Fourier theory, causes incident light to be split into a discrete set of orders, both in transmission and reflection. How many of these propagating orders there are, as well as the deflection angle of each of them, depends on the wavelength of the radiation, the refractive indices of the media in front of and behind the grating, the period of the structure, and the angle of incidence. This dependence is mathematically encoded in the grating equation. In this use case we present the Diffraction Angle Calculator of VirtualLab Fusion, a convenient tool for calculations involving the grating equation.

Open the Diffraction Angle Calculator

The *Diffraction Angle Calculator* can be accessed through the *Calculators* drop-down list under the *Start* tab.

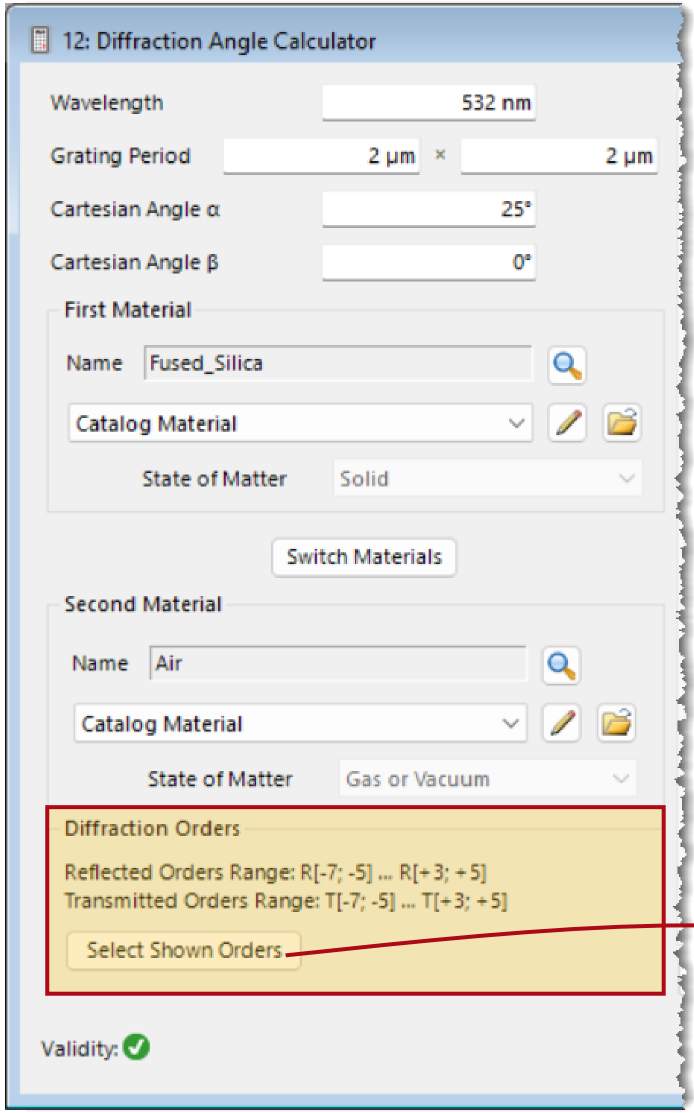


Setting the Input Parameters

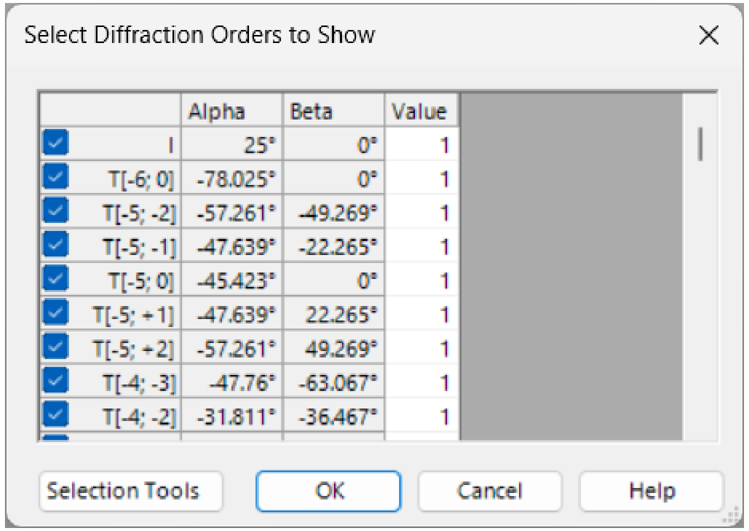
The user needs to input values for the *Grating Period*, *Cartesian Angle* (which refer to the incident angle), *Wavelength*, and define the materials in front of and behind the grating. The incident wave and the reflected orders reside in the *First Material*, while the transmitted orders are in the *Second Material*.

The *Switch Materials* button can be used to swap the two materials.

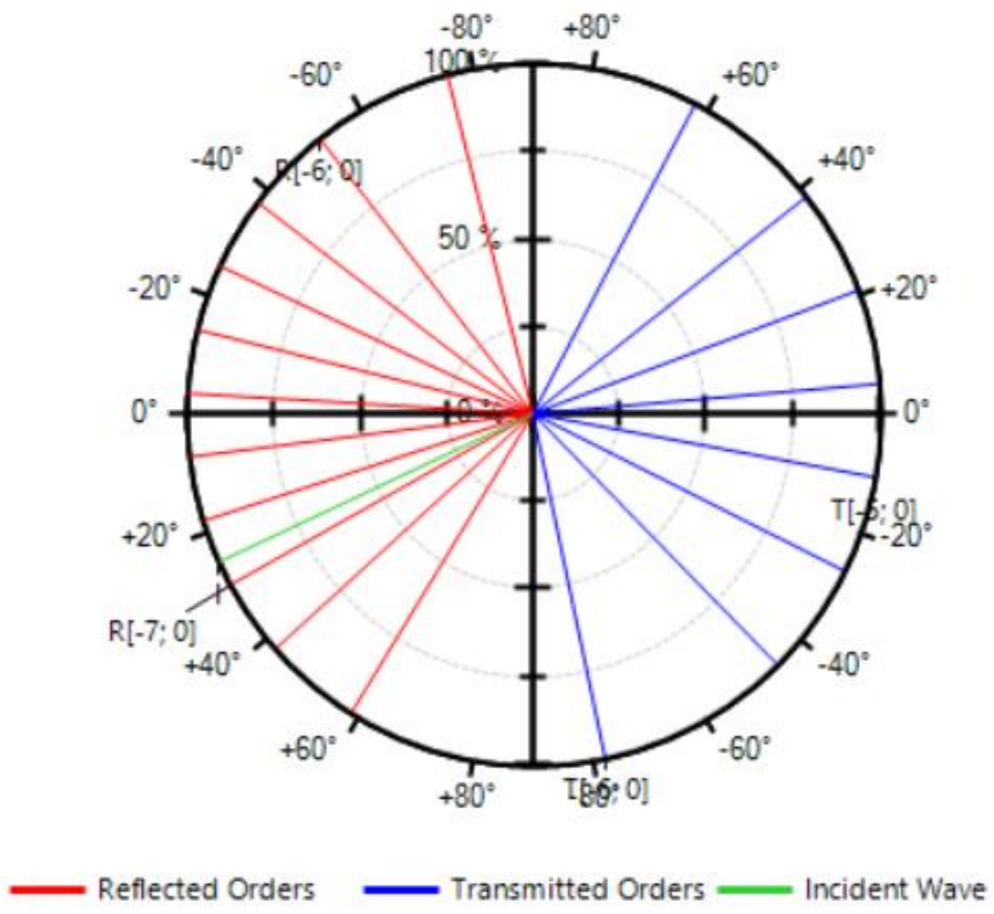
Select Diffraction Orders to Show



Within the *Diffraction Orders* box, you have the option to select the propagating orders that will be visible. The minimum and maximum propagating orders, for both reflection and transmission, are displayed as the *Reflected Orders Range* and *Transmitted Orders Range*.



Grating Equation



The *Diffraction Angle Calculator* calculates the diffraction angles and visualizes them together with the incident angle. All these angles can be calculated from the wave vector and vice versa.

Quantitatively, the wave vector $\boldsymbol{k}_{\text{out}}$ of a diffraction order (l, m) is calculated by the grating equation,

$$k_{\text{out,x}} = k_{\text{in,x}} + \frac{2\pi l}{P_{\text{x}}}$$

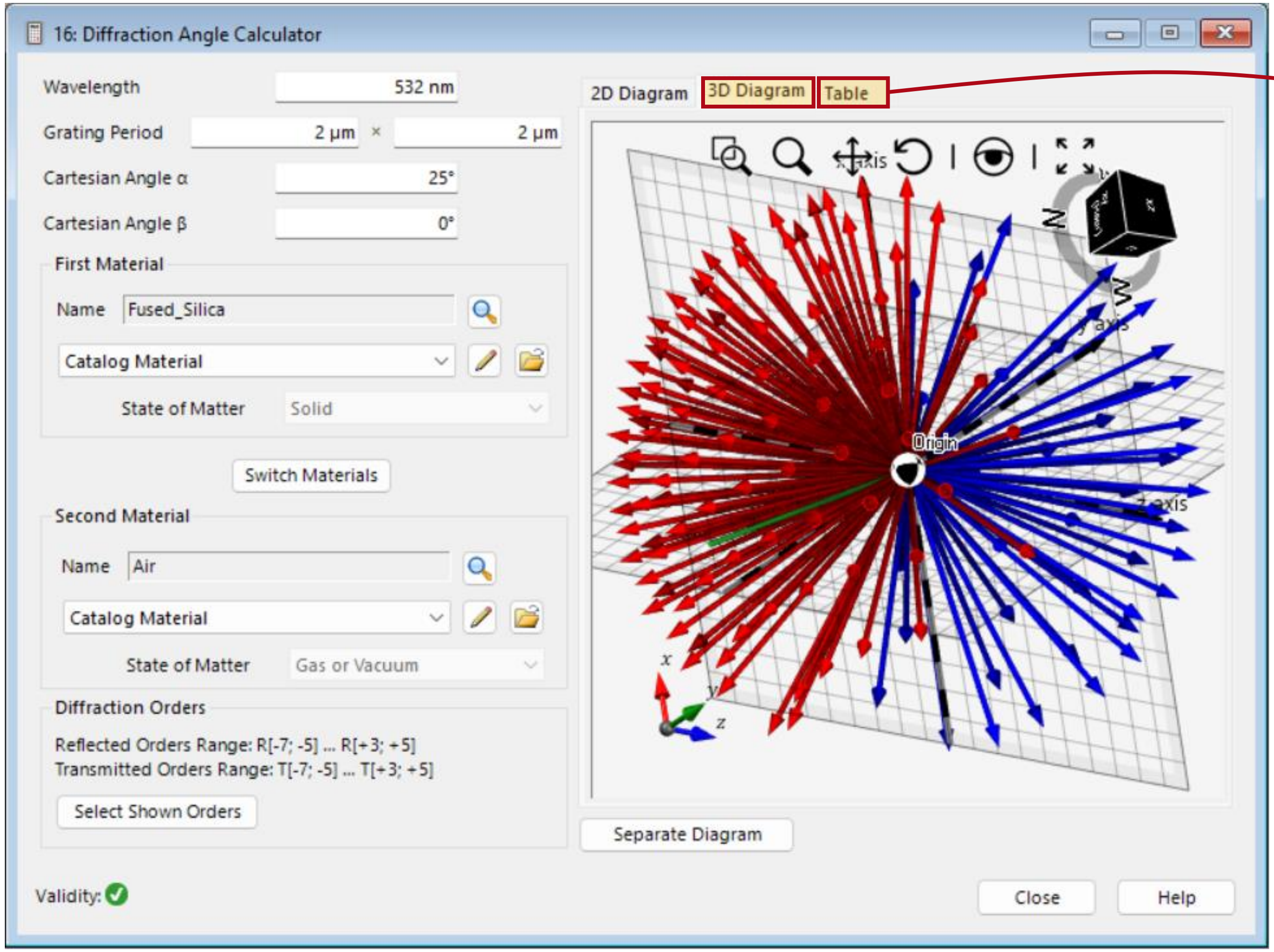
$$k_{\text{out,y}} = k_{\text{in,y}} + \frac{2\pi m}{P_{\text{y}}}$$

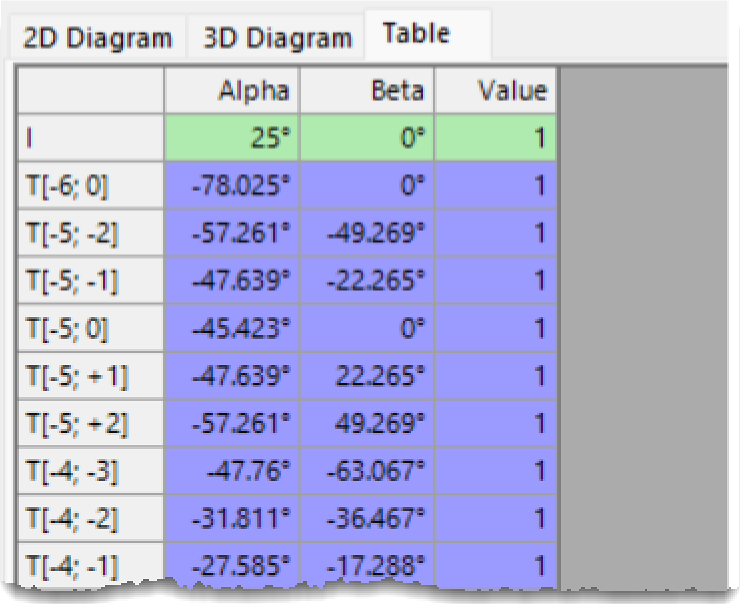
$$k_{\text{out,z}} = \text{sign}(n_{\text{out}}) \sqrt{\left(\frac{2\pi n_{\text{out}}}{\lambda}\right)^2 - k_{\text{out,x}}^2 - k_{\text{out,y}}^2}$$

where P is the grating period, n is the refractive index, λ is the vacuum wavelength.

$2\pi/P$ is often referred to as the grating vector.

Diffraction Order Diagram

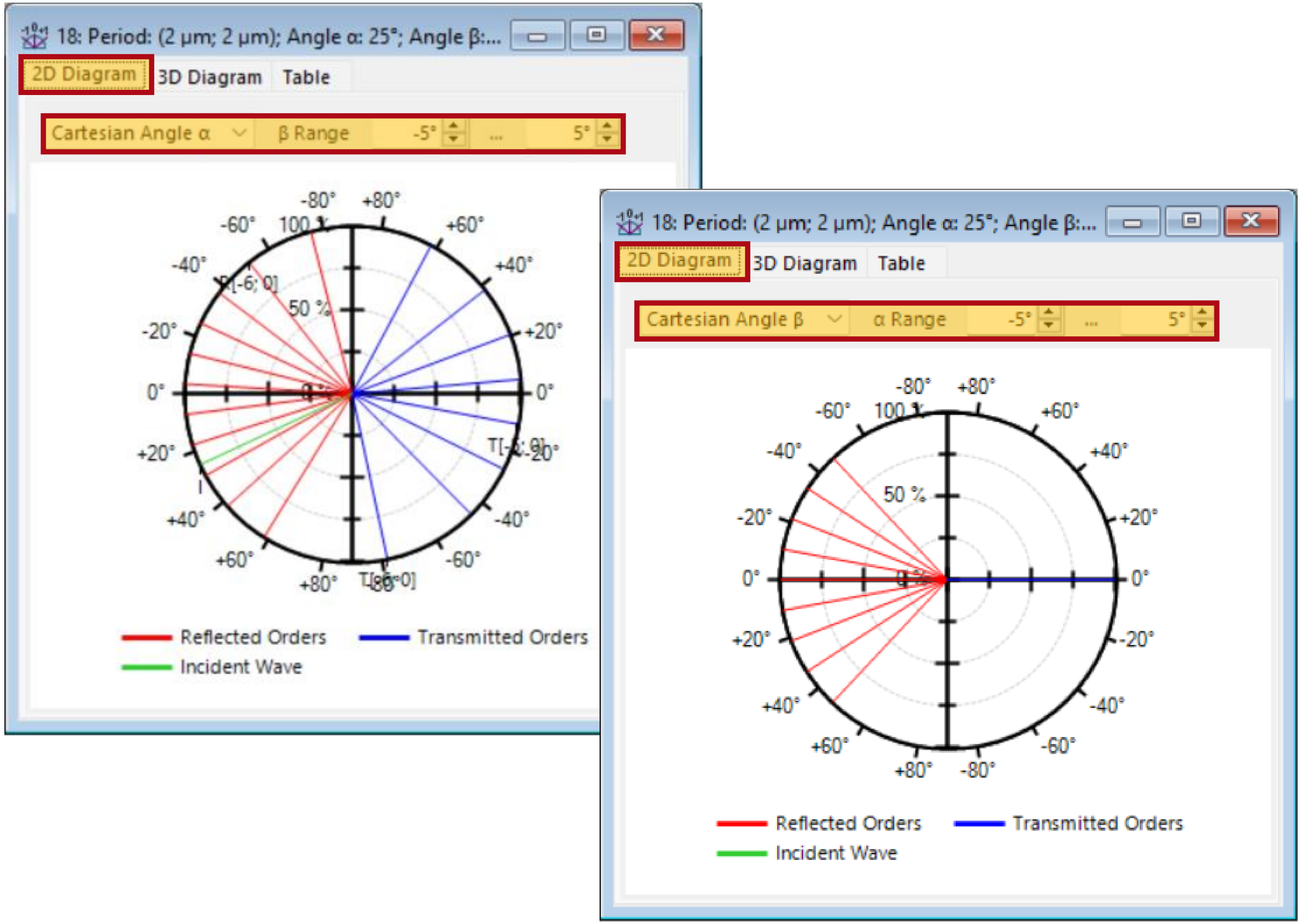



2D Diagram | 3D Diagram | Table

	Alpha	Beta	Value
I	25°	0°	1
T[-6; 0]	-78.025°	0°	1
T[-5; -2]	-57.261°	-49.269°	1
T[-5; -1]	-47.639°	-22.265°	1
T[-5; 0]	-45.423°	0°	1
T[-5; +1]	-47.639°	22.265°	1
T[-5; +2]	-57.261°	49.269°	1
T[-4; -3]	-47.76°	-63.067°	1
T[-4; -2]	-31.811°	-36.467°	1
T[-4; -1]	-27.585°	-17.288°	1

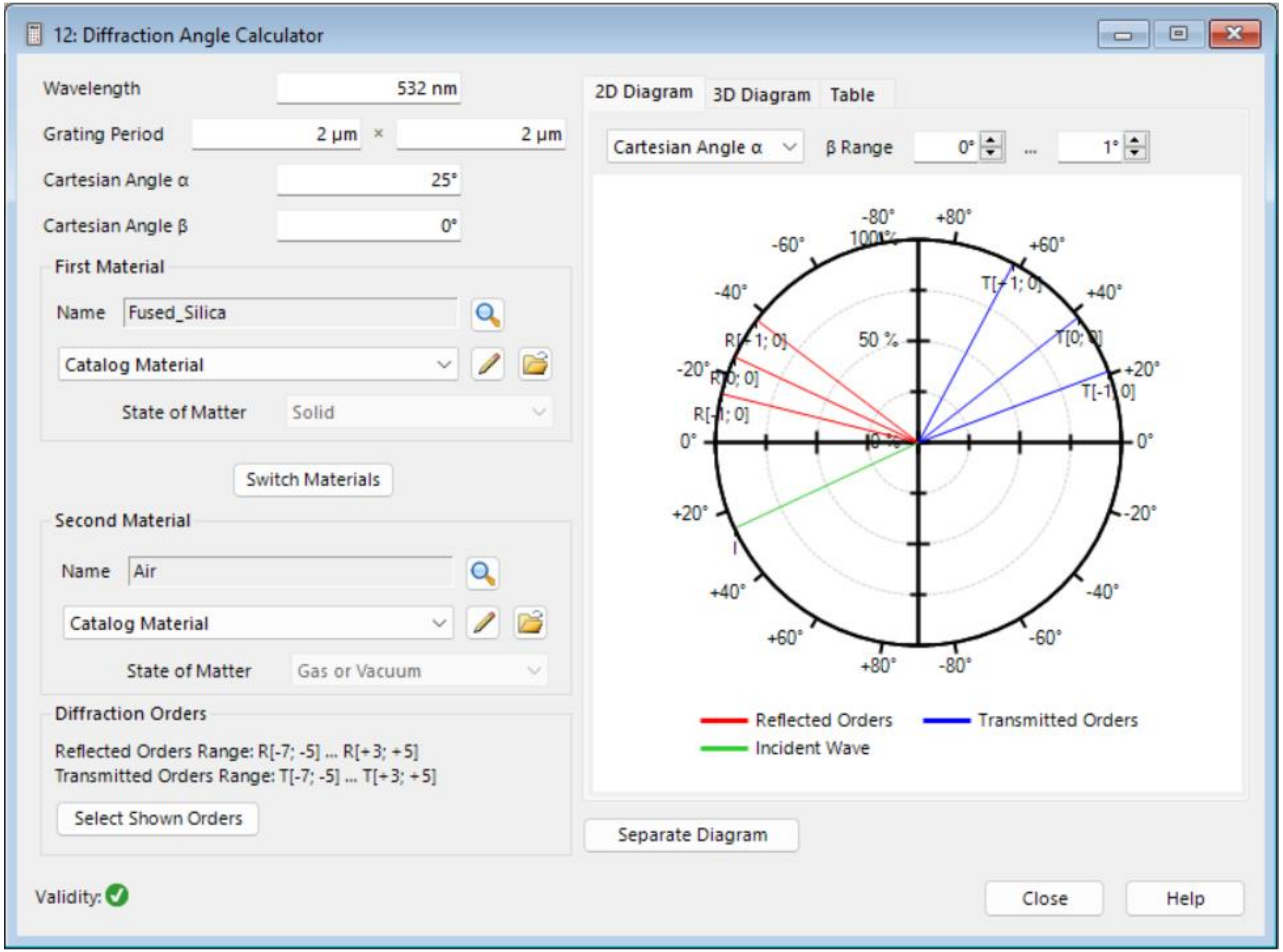
In *3D Diagram* all selected orders are shown. Additionally, a *Table* displaying the diffraction angles as well as the incident angle is also provided.

Diffraction Order Diagram



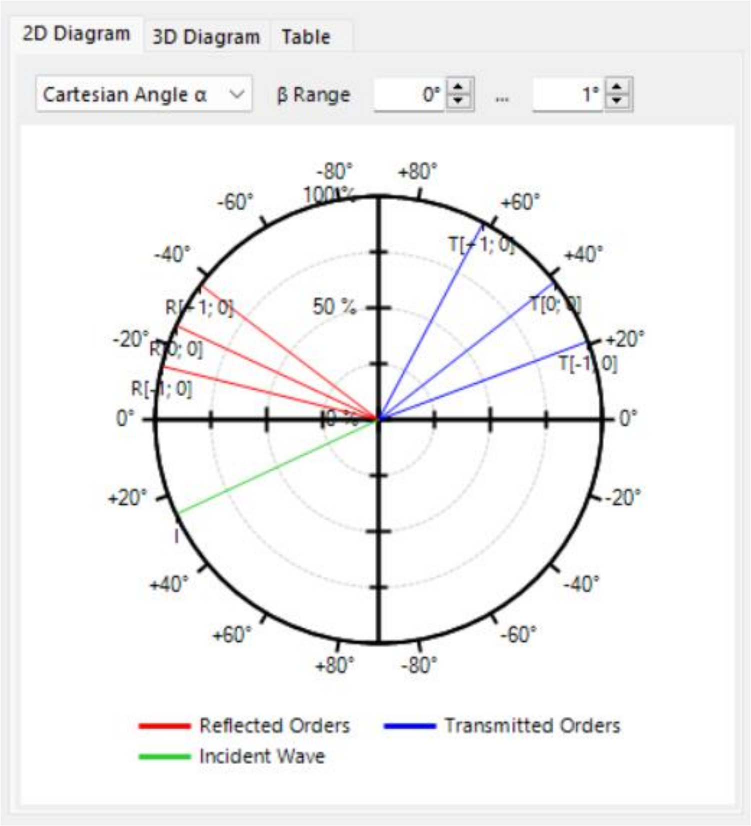
The user can generate a separate window for the diagram, which can be saved and zoomed into, by clicking on *Separate Diagram*. In the *2D Diagram*, you have the option to plot the *Cartesian Angle* α. This allows you to visualize the x-z plane, where all orders within a specified β *Range* are projected into this plane. Similarly, when you select the Cartesian Angle β option, you will observe all orders within a certain α Range projected onto the y-z plane.

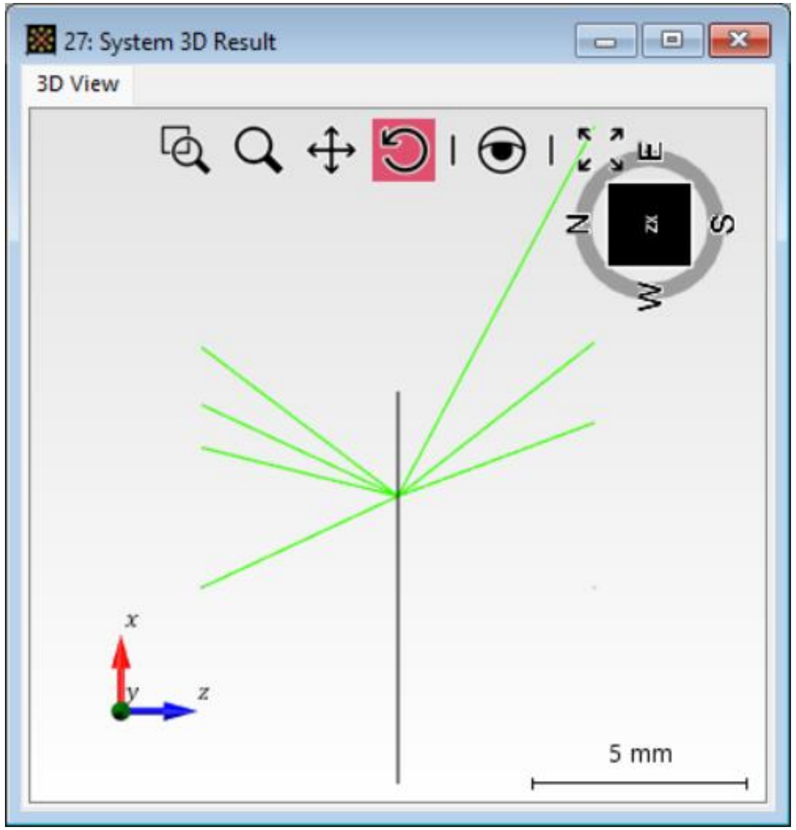
An Example

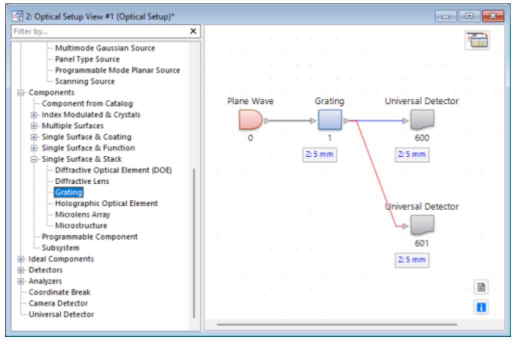


In this example, we choose the *First Material* as fused silica and the *Second Material* as air, with the *Cartesian Angle* α of 25° and β of 0°. We only select to show the orders $l \in (-1,1)$ and $m = 0$. $m = 0$ implies that the grating vector in y direction is 0.

The Example in General Optical Setup







We employ a *General Optical Setup* to simulate an analogous system. The diffraction grating is described by a *Grating Component*, using the FMM/RCWA [S-Matrix] solver. A 1D grating is specified because in this scenario ($m = 0$), there is no effect in the y-z plane. We can see that this yields the same results as the *Diffraction Angle Calculator*, where the outcome is directly computed by the grating equation.

Document Information

title	Diffraction Angle Calculator
document code	SWF.0037
document version	2.0
required packages	- (Though the Grating Component used for comparison requires VirtualLab Fusion Advanced)
software version	2024.1 (Build 1.132)
category	Feature Use Case
further reading	• Analysis of Blazed Grating by Fourier Modal Method • Thin Element Approximation (TEA) vs. Fourier Modal Method (FMM) for Grating Modeling