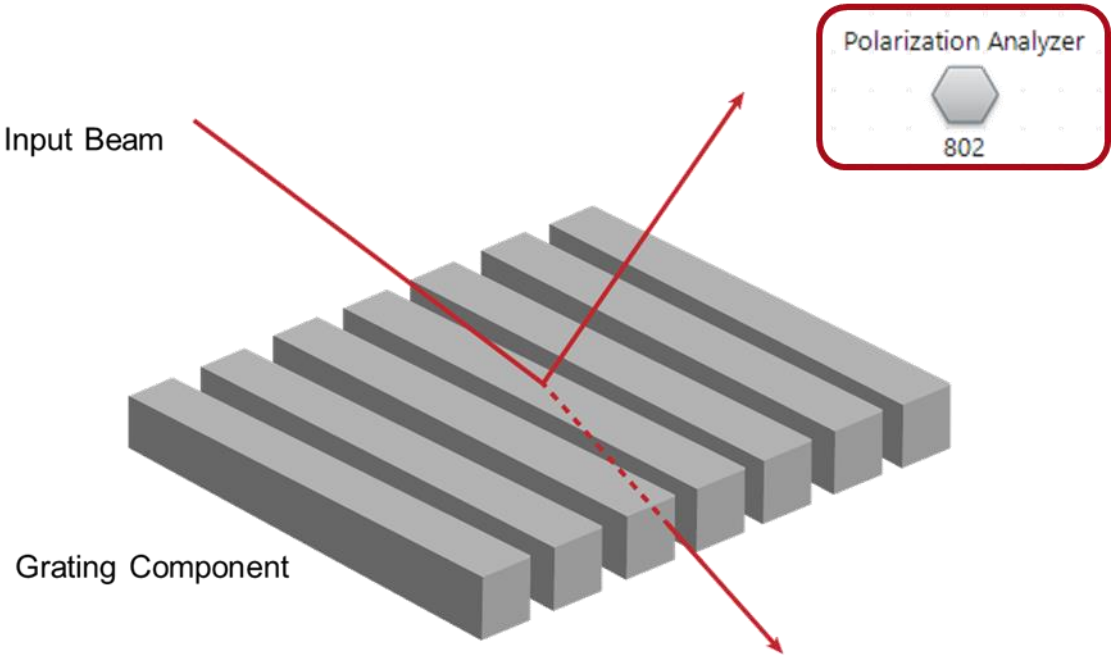
Polarization Analyzer

Abstract



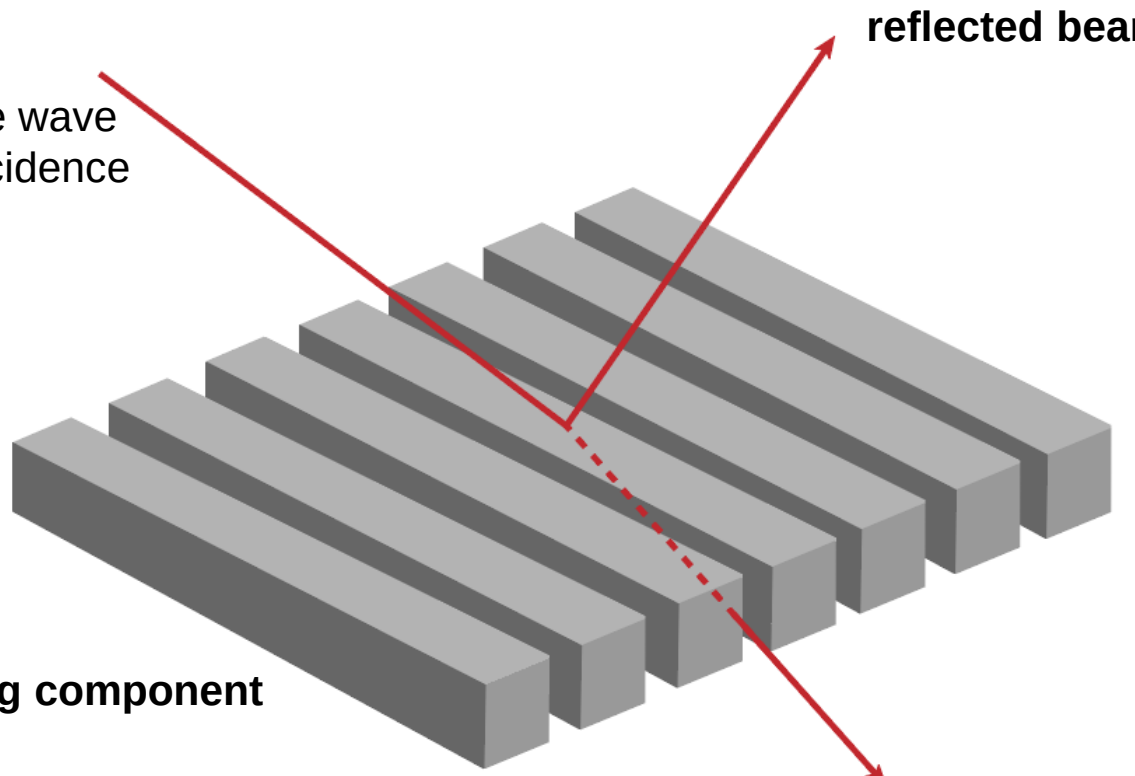
Wire-grid polarizers, which can create a linear polarization state of the transmitted light, are a common type of optical element in numerous applications. Due to their structure in the sub-wavelength range, a rigorous treatment of the light propagation is necessary. VirtualLab's polarization analyzer with its inbuilt RCWA enables the detailed analysis and optimization, not only of polarizers, but also anti-reflection structures and other types of gratings. It provides polarization-dependent information about reflected and/or transmitted diffraction orders, while the efficiency also can be analyzed with respect to the wavelength and/or incident angles.

Task Description

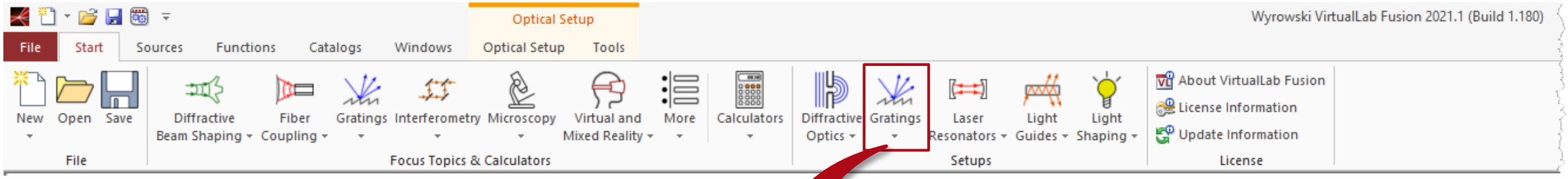
The topic of this document is the investigation of the polarization state of the diffracted orders of a grating using the *Polarization Analyzer*.

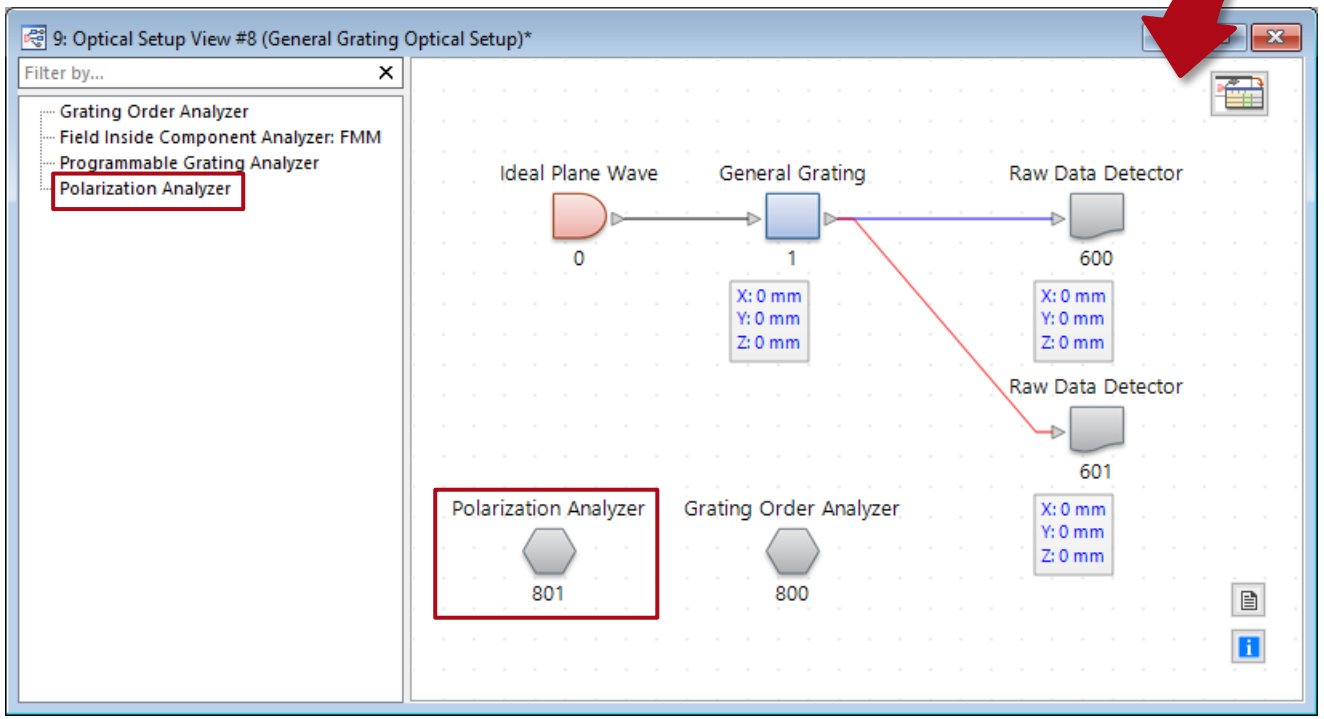
input beam

- ideal plane wave
- oblique incidence



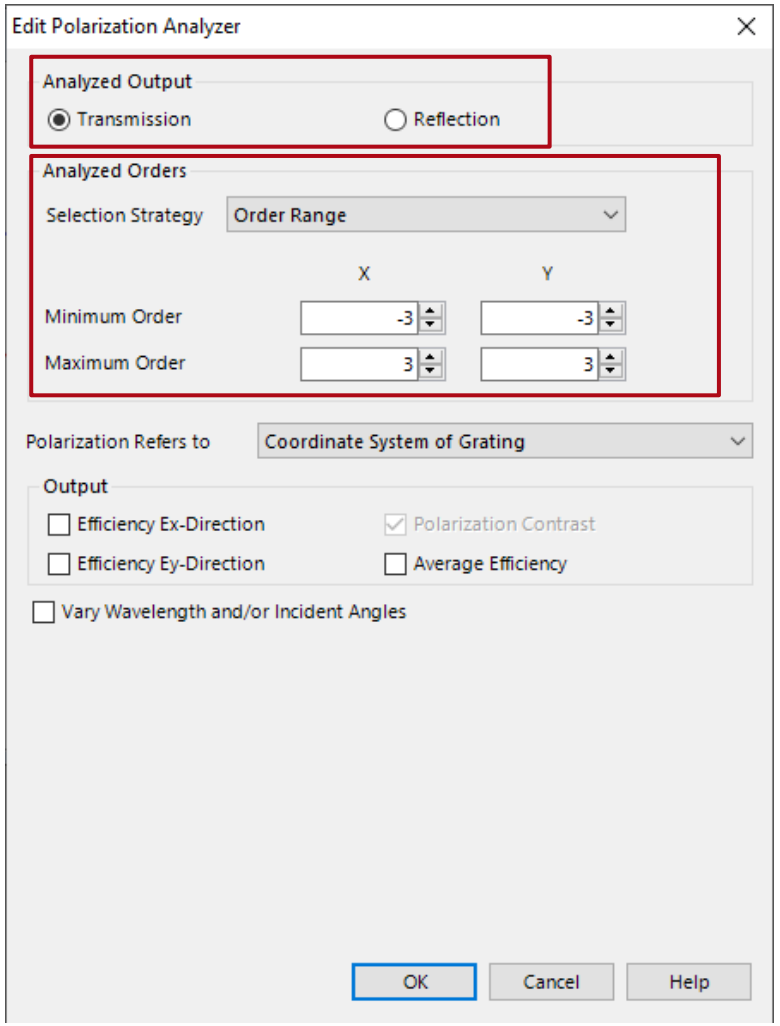
Polarization Analyzer in Grating Optical Setup





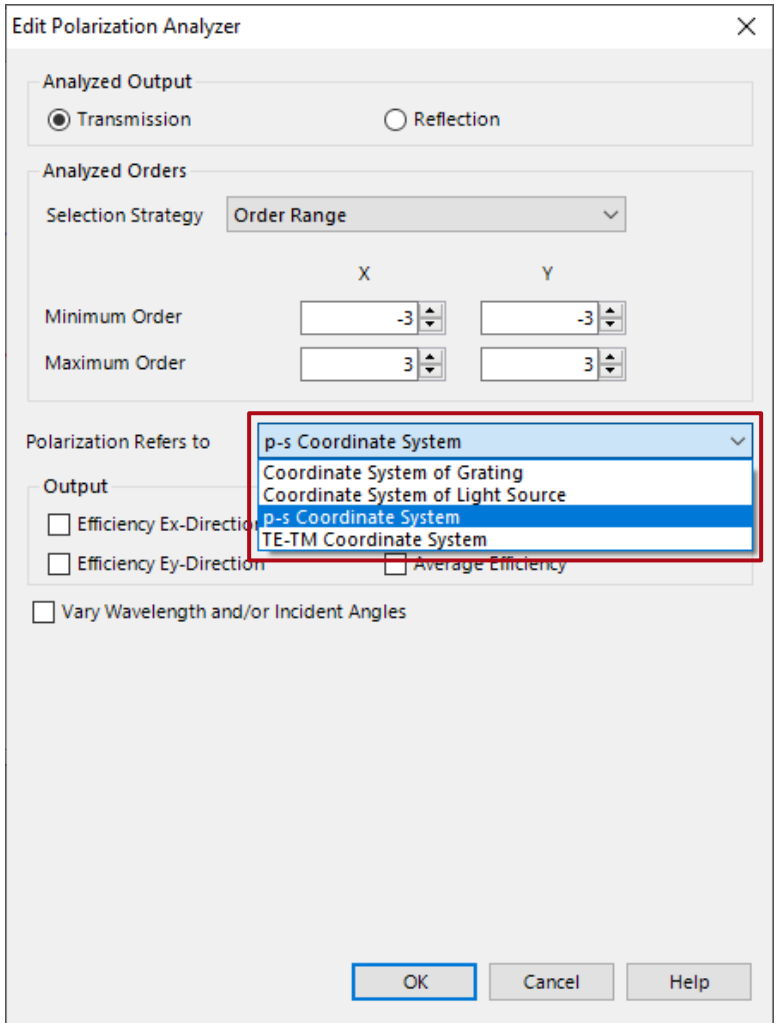
The *Polarization Analyzer* is specifically developed for the analysis of gratings. It is only available in the *Grating Optical Setup*.

Edit Polarization Analyzer



- This analyzer computes the summed efficiency (either in transmission or reflection) for two orthogonal polarization states per diffraction order of the defined structure.
- To this end, the grating configured in the grating component of the corresponding system is used.
- The summed efficiency is either calculated from all (propagating) orders or from a user-defined order range.

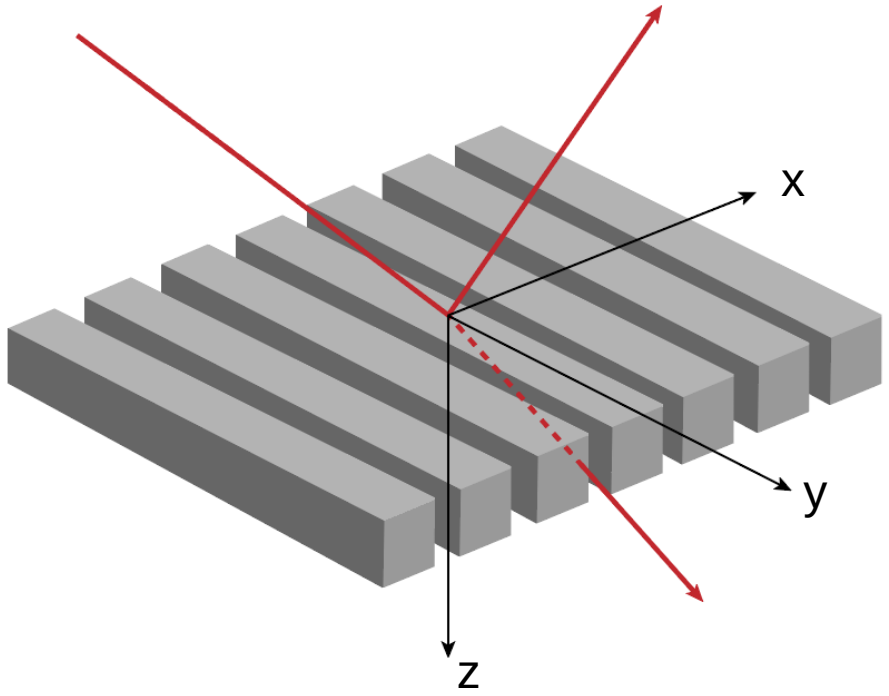
Edit Polarization Analyzer



- The polarization states of the incident beam can be defined according to the following coordinate systems:
  a. coordinate system of grating
  b. coordinate system of light source
  c. p-s coordinate system
  d. TE-TM coordinate system

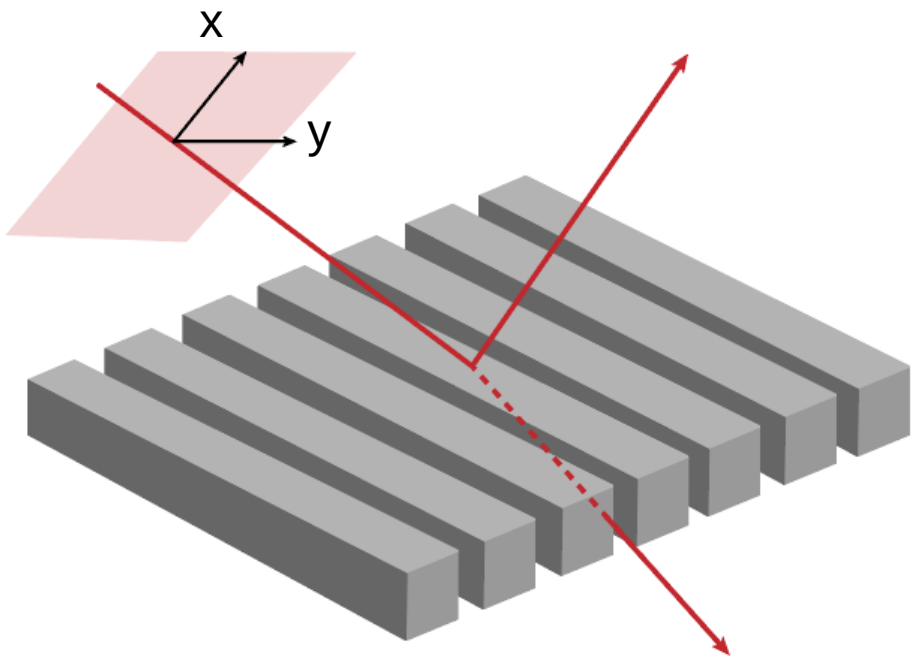
Polarization Directions

a. coordinate system of grating:



The Jones vector describes the electric field along the x- and y-axes of the grating component, respectively.

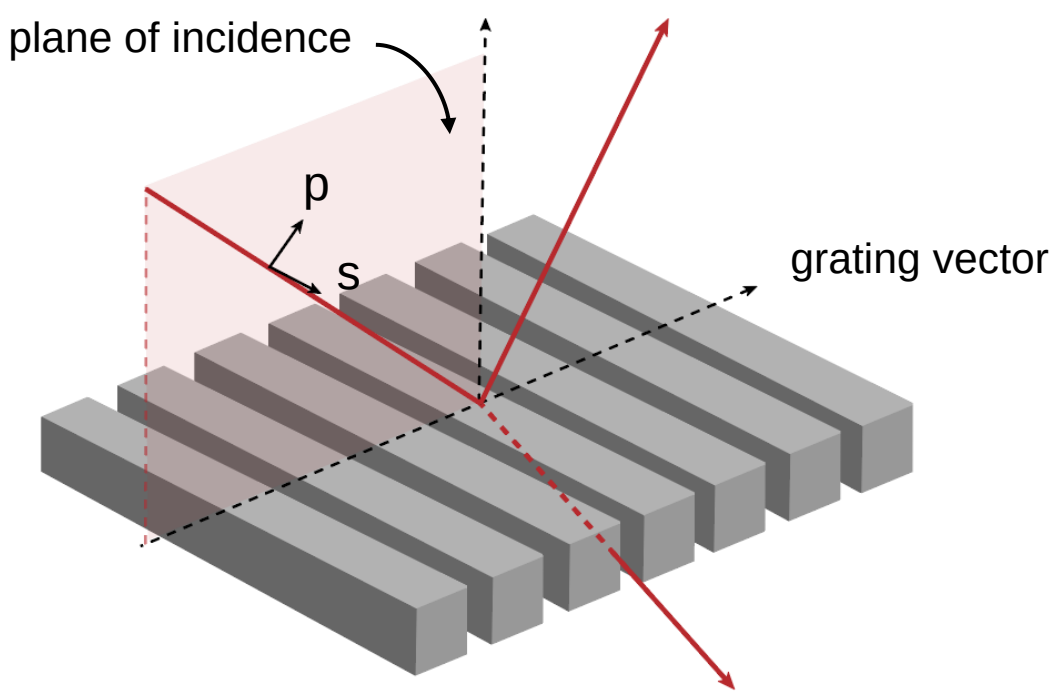
b. coordinate system of light source:



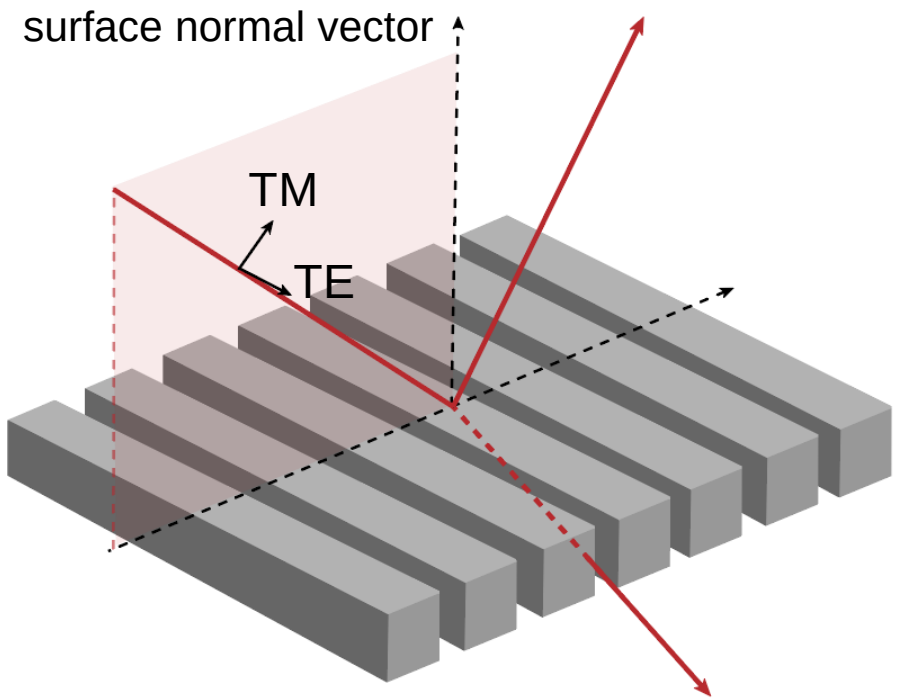
The Jones vector describes the electric field along the x- and y-axes of the light source, respectively.

Polarization Directions with Non-Conical Incidence

c. p-s coordinate system:



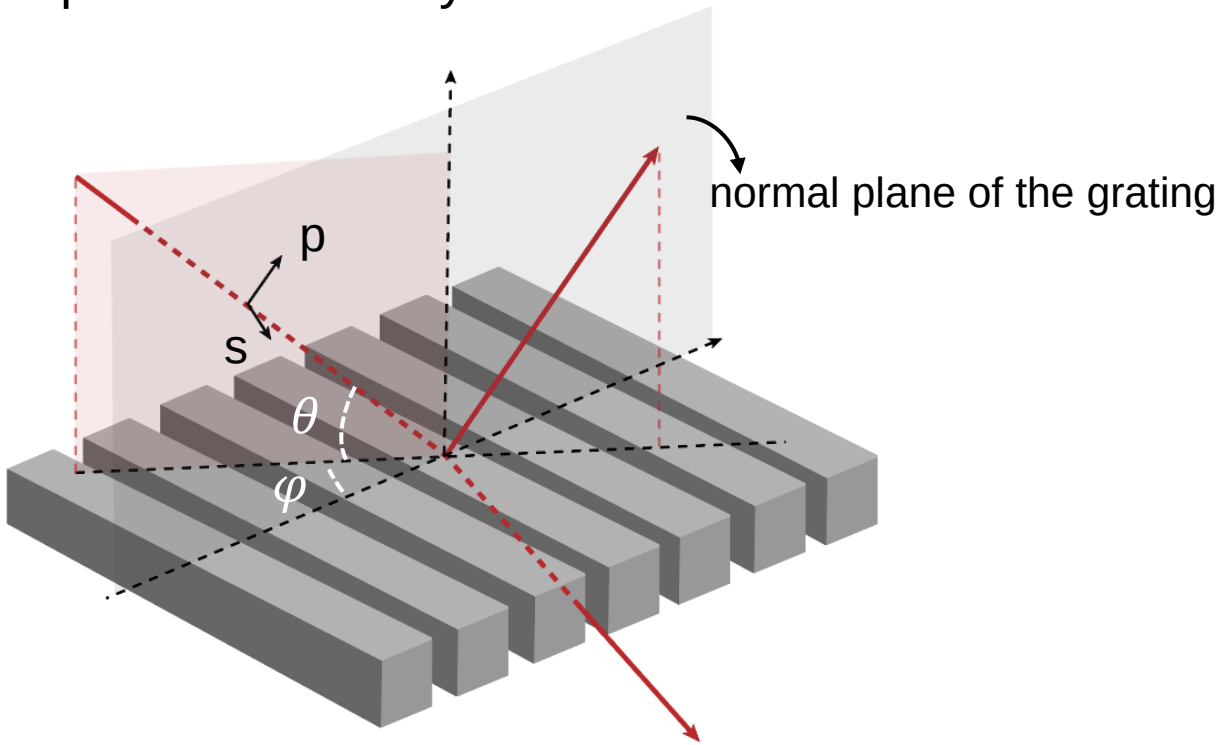
d. TE-TE coordinate system:



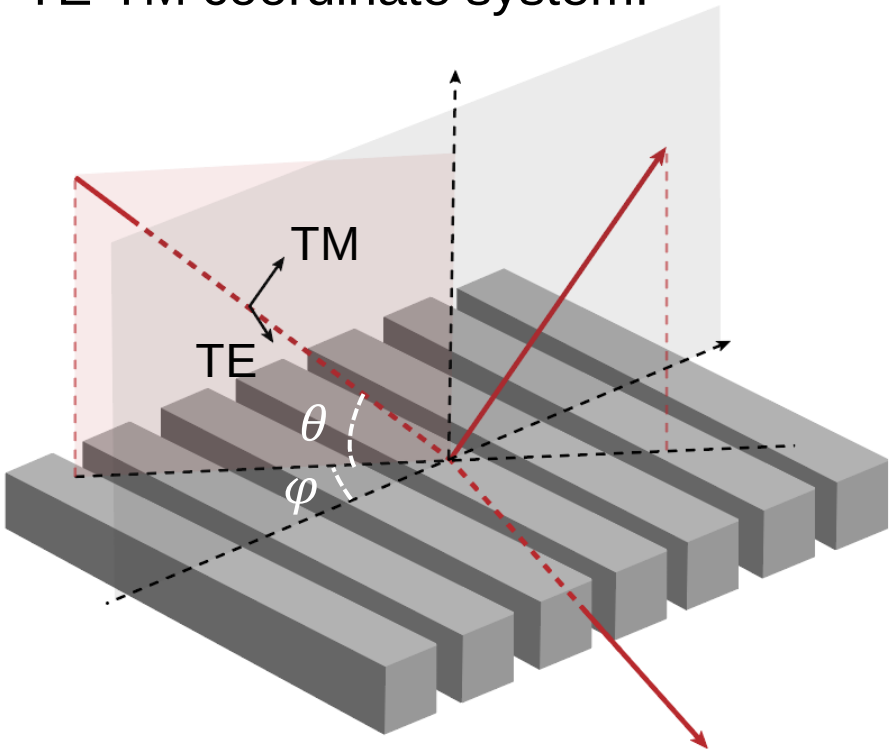
The plane of incidence is defined by the normal vector to the grating surface and the direction vector of the incident light (in the non-conical case, also the grating vector is in this plane). The p-polarization state is parallel to the plane of incidence, while the s-polarization state is perpendicular to it. For TE/TM-polarization this is valid accordingly (TM: parallel, TE: perpendicular).

Polarization Directions with Conical Incidence

c. p-s coordinate system:

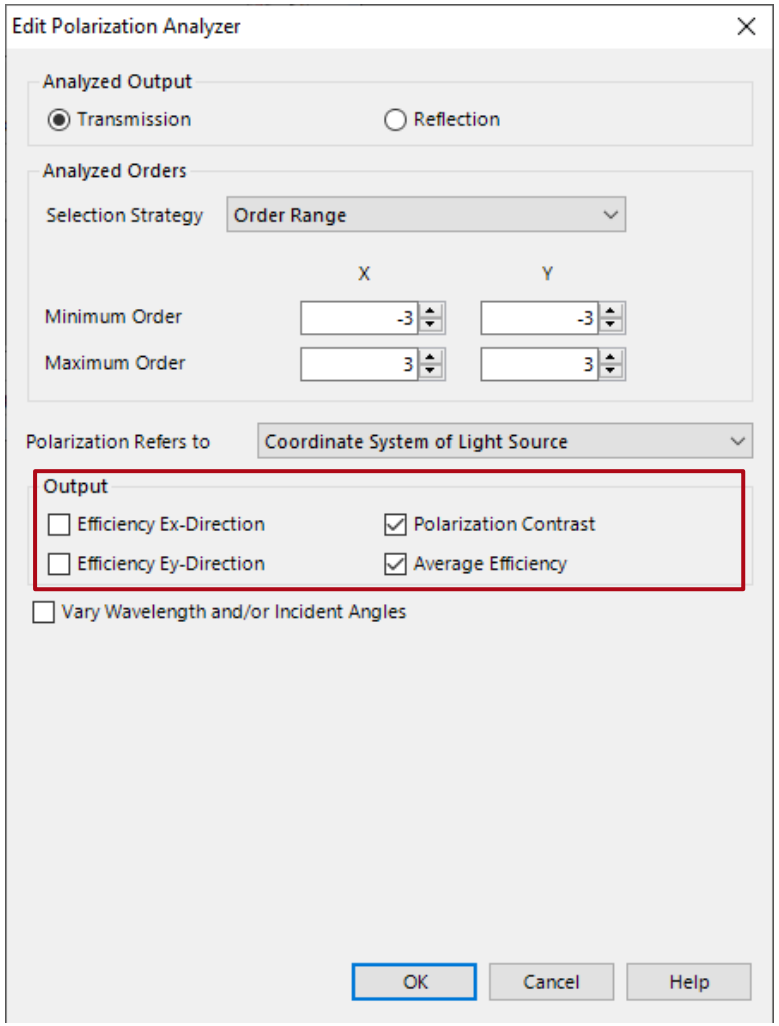


d. TE-TM coordinate system:



In the conical case, the incident direction of light is no longer inside the plane defined by surface normal and grating vector. Again, the polarization state of the impinging light is defined according to the plane of incidence, created by the direction of incidence and the normal vector of the grating surface.

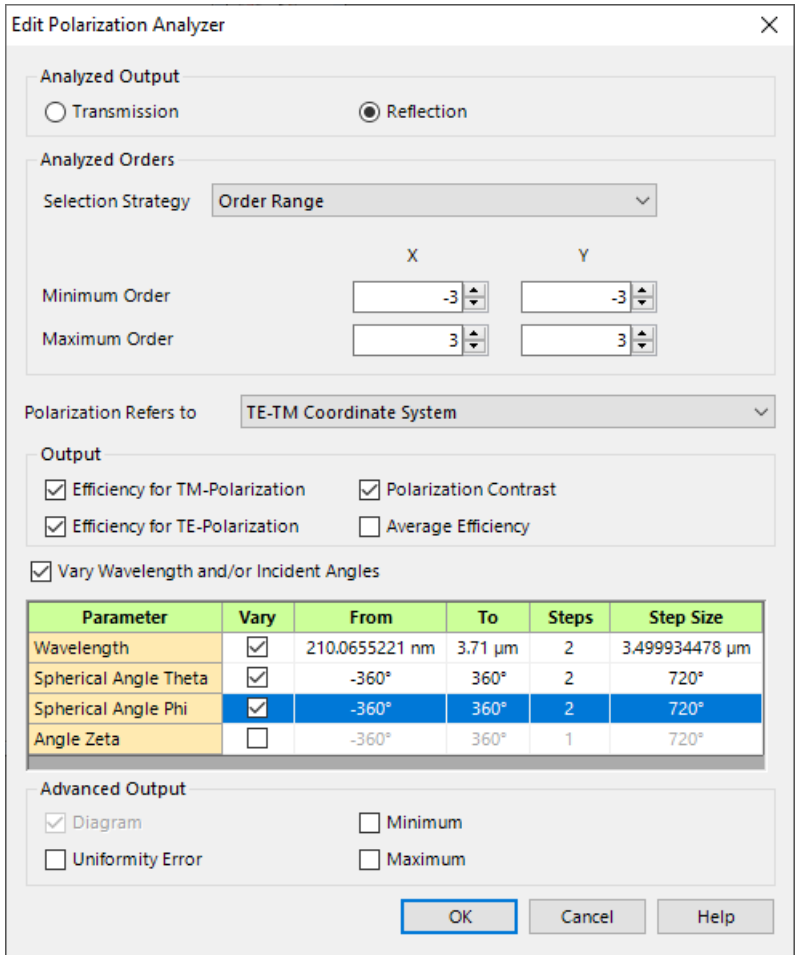
Specification of Output Data



Besides the efficiency for both orthogonal polarization directions, this analyzer also provides other merit functions like the *Polarization Contrast* and *Average Efficiency*:

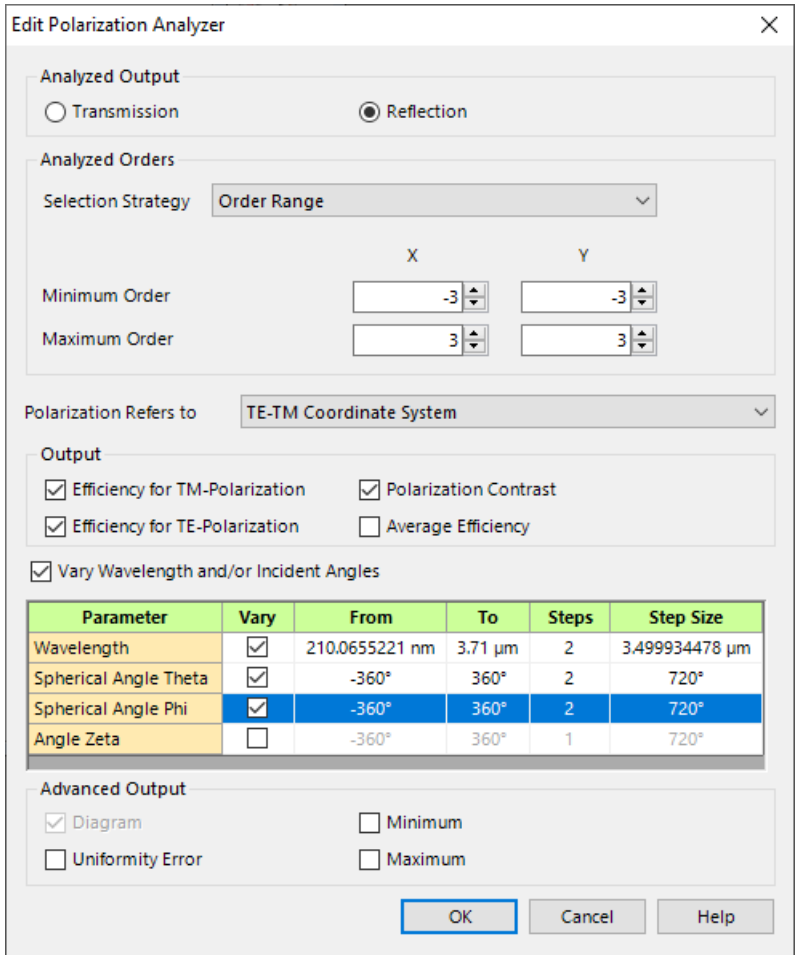
- Efficiency $\mathrm{E_x}$-Direction $\mathrm{I_x}$: the overall reflection/transmission efficiency for $\mathrm{E_x}$-polarization.
- Efficiency $\mathrm{E_y}$-Direction $\mathrm{I_y}$: the overall reflection/transmission efficiency for $\mathrm{E_y}$-polarization.
- Polarization Contrast: $\mathrm{P} = \mathrm{I_x}/\mathrm{I_y}$.
- Average Efficiency: $\mathrm{A} = \frac{\mathrm{I_x}+\mathrm{I_y}}{2}$.

Inbuilt Parameter Run Feature



- The analyzer provides an inbuilt *Parameter Run* feature for analyzing the merit functions over a specified range of wavelengths and/or angles of incidence.
- In addition, some *Advanced Outputs* are available as well, e.g. a diagram that illustrates the variation of the chosen merit functions in the defined range of wavelengths or angles.
- By activating the corresponding checkbox (likewise for the minimum, maximum and uniformity error) the corresponding additional output(s) will be generated.

Inbuilt Parameter Run Feature



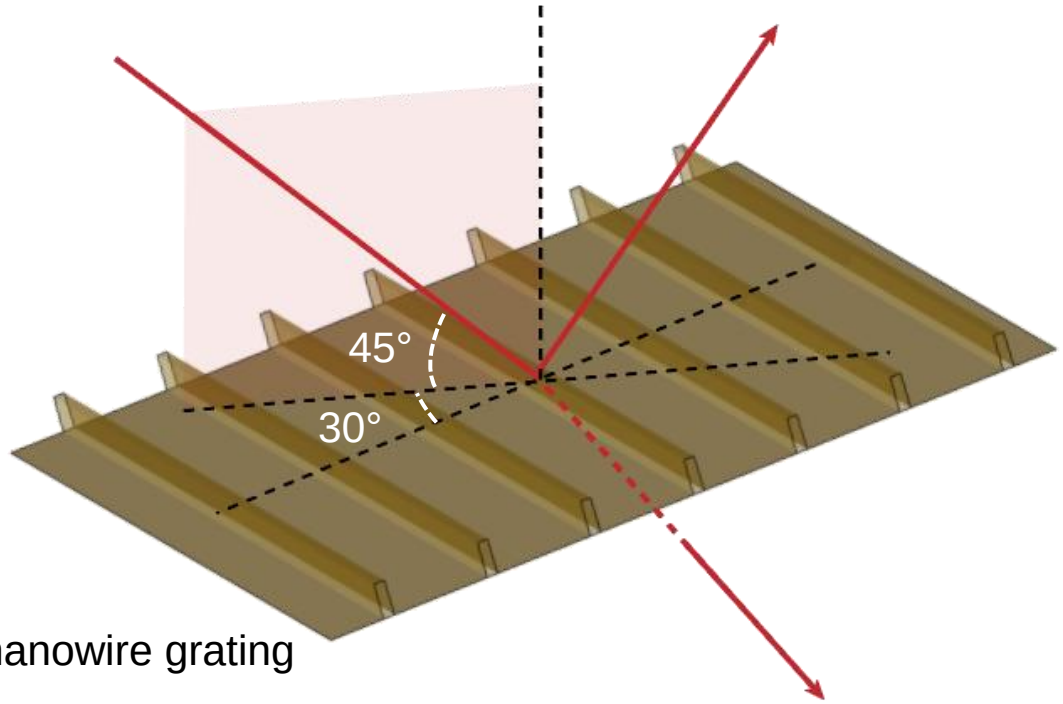
Note for the definition of angle of incidence:

If you create a new *Polarization Analyzer* in your *Optical Setup*, the definition type of the angles in the *Polarization Analyzer* are set according to the *Orientation Definition Type* of the grating component in that *Optical Setup*, namely:

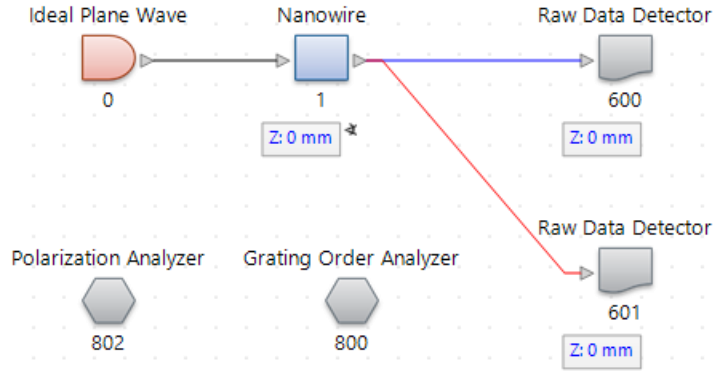
- For spherical angles, the angles Theta, Phi, and Zeta can be varied.
- For direction angles, the angle Zeta can be varied.
- For Cartesian angles, the angles Alpha, Beta, and Zeta can be varied.
- For Euler angles, the angles Psi, Theta, and Phi can be varied.

Example

Input beam
- Wavelength: 854 nm
- Incident angle: $\theta = 45°,\ \varphi = 30°$



nanowire grating



Nanowire properties	
refractive index *n*	3.16
Grating period	854nm
modulation depth *h*	292nm
relative slit width	10%

Parameters are taken from reference paper: J. W. Yoon *et al*., Opt. Express **23**, 28849-28856 (2015).

Results

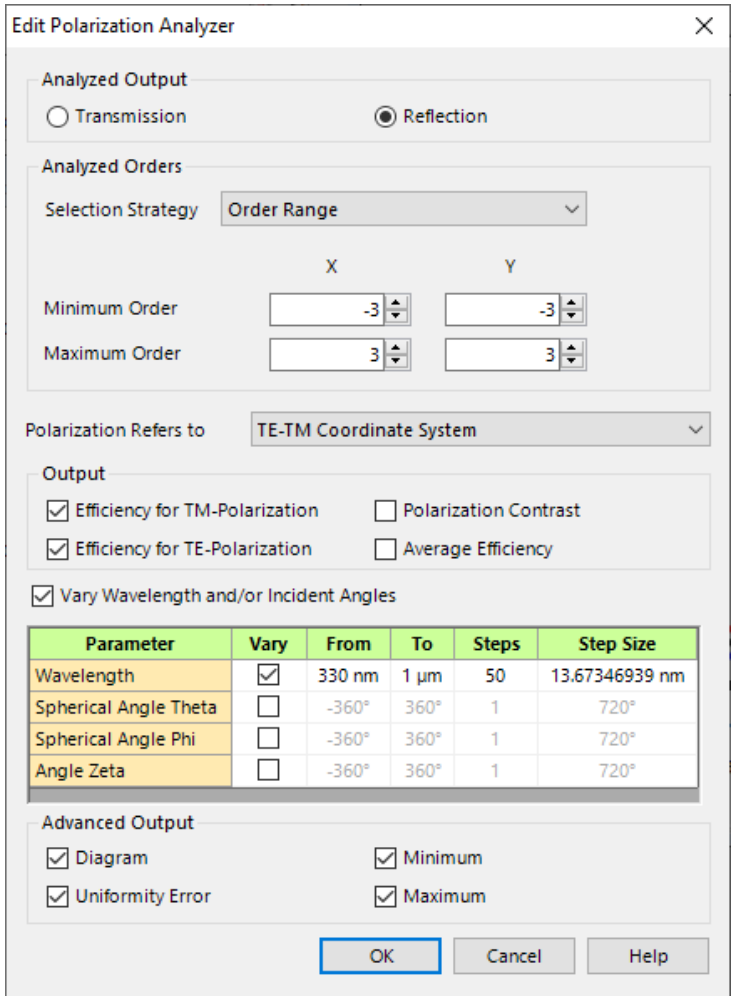
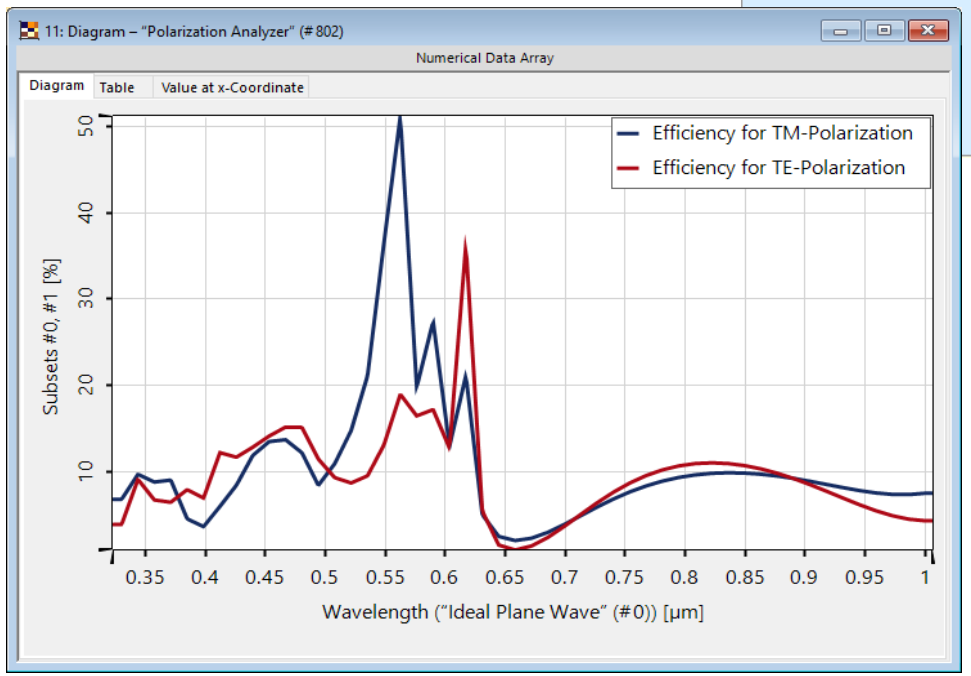


diagram from parameter scanning (efficiencies v wavelength):



result of selected outputs:

Detector	Sub - Detector	Result
"Polarization Analyzer" (# 802)	Maximum Efficiency for TM-Polarization	51.08584908 %
	Minimum Efficiency for TM-Polarization	2.138032929 %
	Uniformity Error of Efficiency for TM-Polarization	91.96588881 %
	Maximum Efficiency for TE-Polarization	36.26423096 %
	Minimum Efficiency for TE-Polarization	1.047370383 %
	Uniformity Error of Efficiency for TE-Polarization	94.38581918 %
	Maximum Polarization Contrast	2.767529638
	Minimum Polarization Contrast	0.4953406617
	Uniformity Error of Polarization Contrast	69.63773511 %
	Maximum Average Efficiency	35.05599094 %
	Minimum Average Efficiency	1.592701656 %
	Uniformity Error of Average Efficiency	91.30827572 %

Document Information

title	Polarization Analyzer
document code	GRT.0028
document version	1.0
software edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	- Investigation of Polarization State of Diffraction Orders