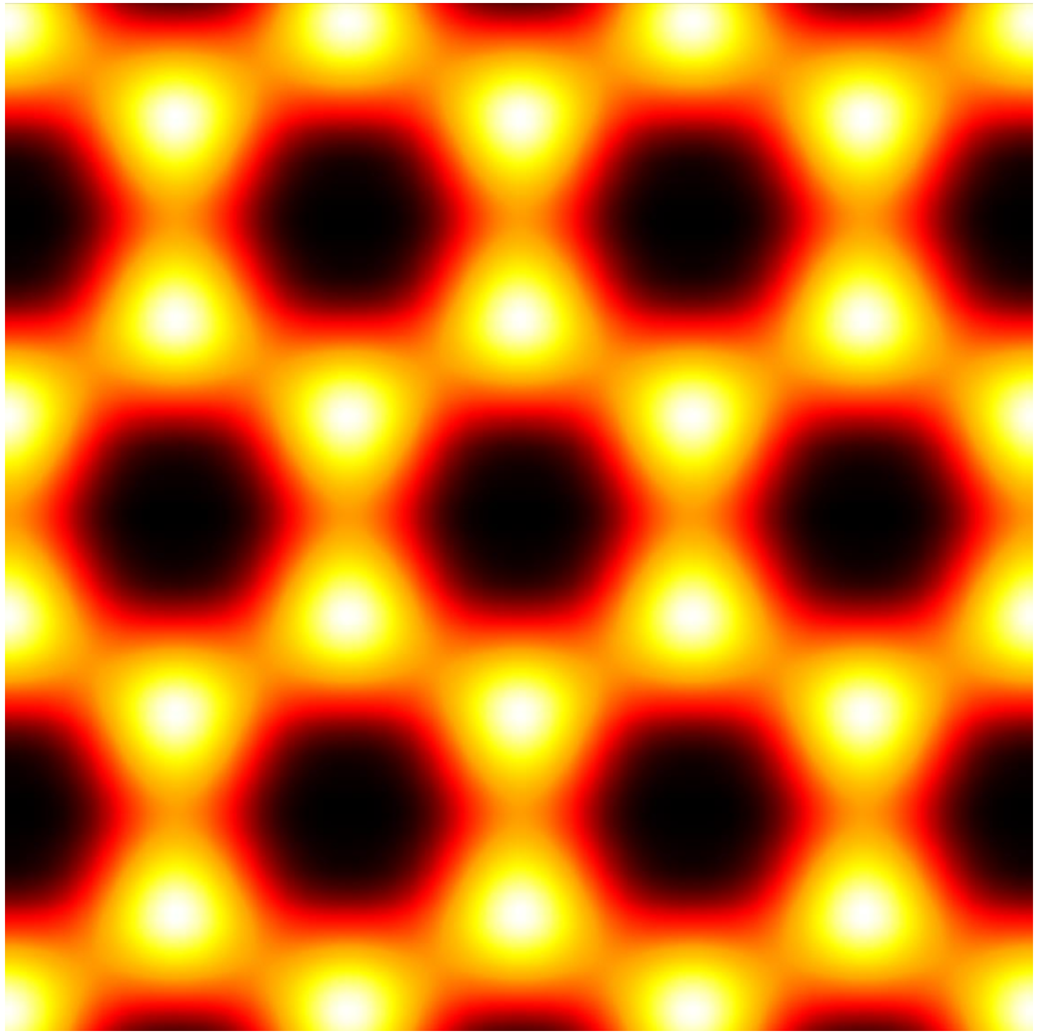
Unpolarized Light for Grating Simulation – Discussion at Examples

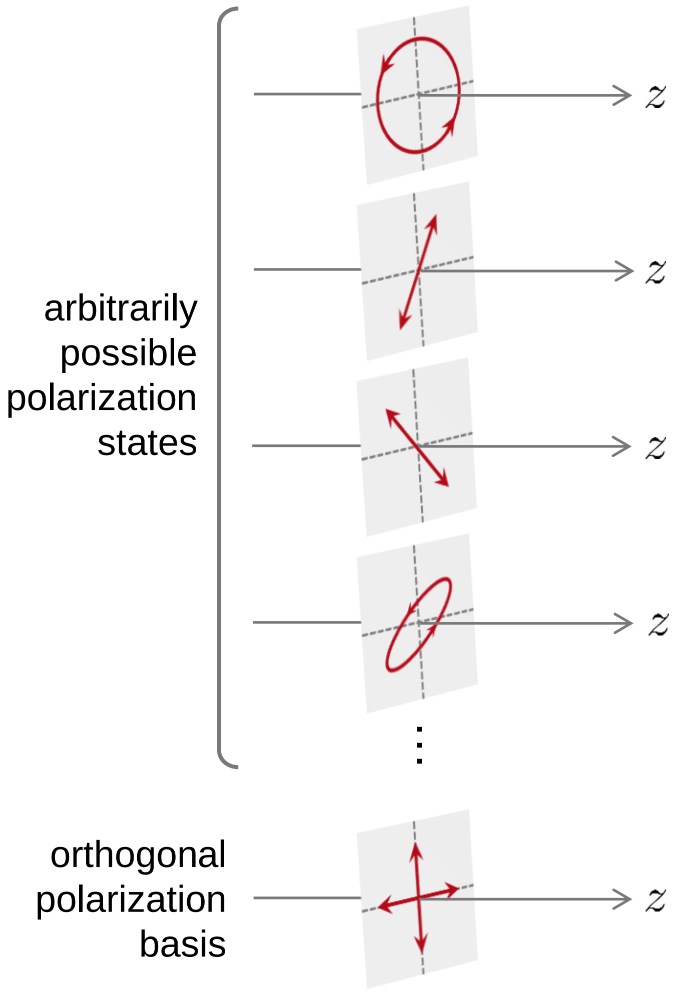
Abstract



Optical devices like gratings are sensitive to the polarization of the light. Thus, it is important to properly consider the polarization of light in the simulation. In practice, gratings sometimes work with unpolarized light as input. We show how to model such unpolarized light, as the average of two orthogonal polarization states, for grating simulation in VirtualLab Fusion. Examples are provided to illustrate the corresponding settings in the software.

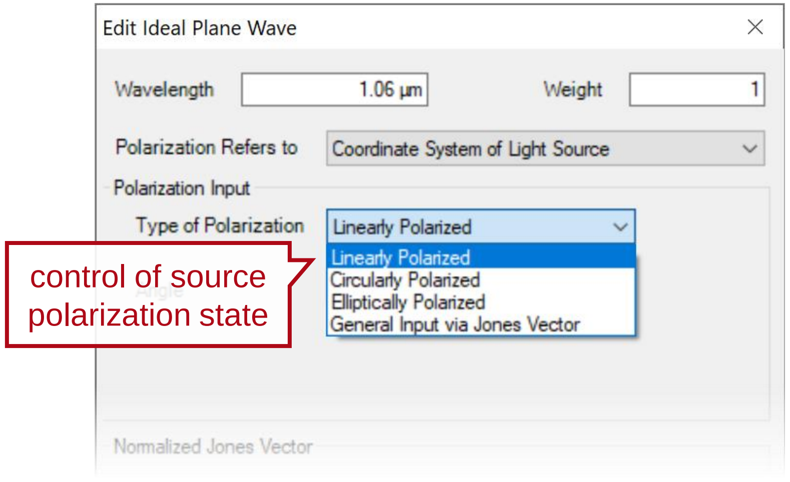
Unpolarized Light in Grating Simulation

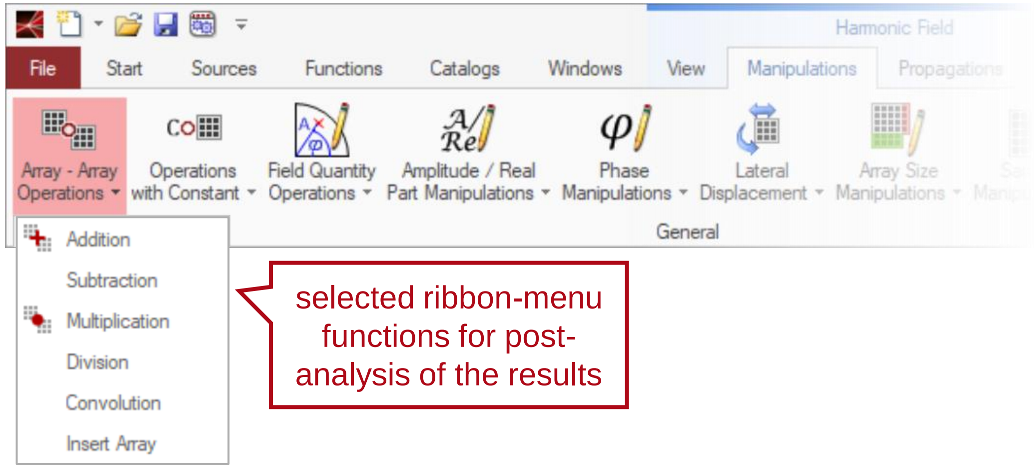
- Grating analysis
  - For single grating analysis with the Fourier modal method (FMM / RCWA), plane wave incidence is used to calculate e.g. the diffraction efficiencies as the intrinsic properties of the grating under investigation.
- Unpolarized plane wave
  - Considering a plane wave along the z direction, unpolarized light can be thought of as that which, statistically, may take any polarization state at one time.
  - An arbitrary polarization state can be projected on two orthogonal states; unpolarized light gives, statistically, equal projections along the two states forming this orthogonal basis.
  - Thus, we can use the average of the two orthogonal states, in an incoherent manner, to represent unpolarized light.



Light Source Settings in Grating Simulation

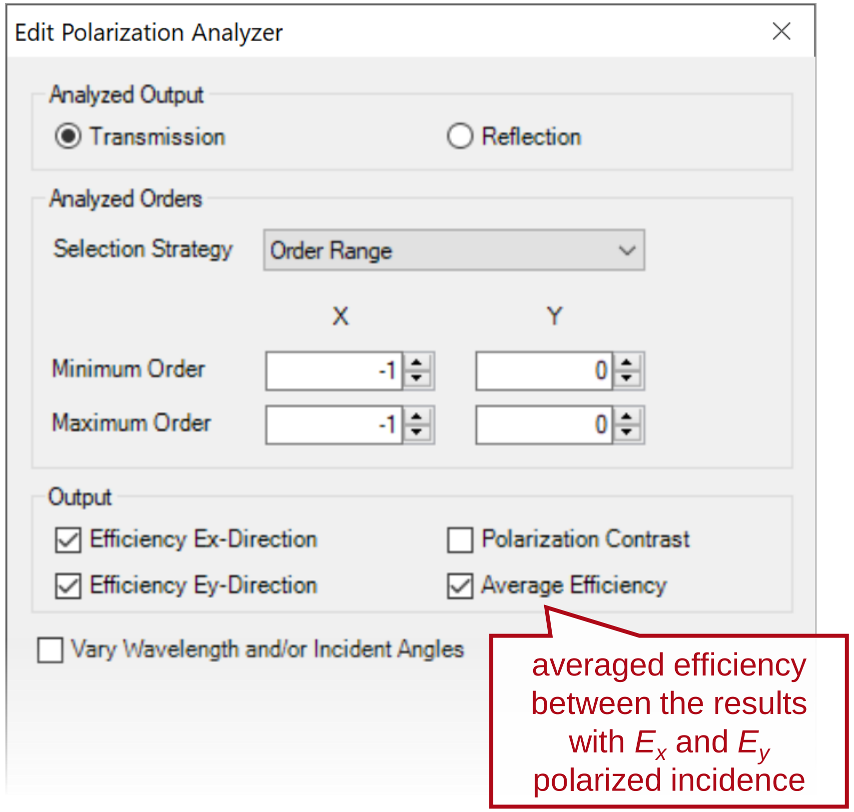
- Manual control of source polarization states
  - Light is always represented in vectorial form in VirtualLab Fusion and the user has full control over the polarization state in the source settings.
  - Following the basic concept, one can perform grating simulations with specific input polarization states as needed for unpolarized light. For example, by choosing TE and TM polarizations as the two orthogonal basis states, we can perform the grating simulation independently for both configurations, and then manually average the results via ribbon-menu functions (as explained in what follows).





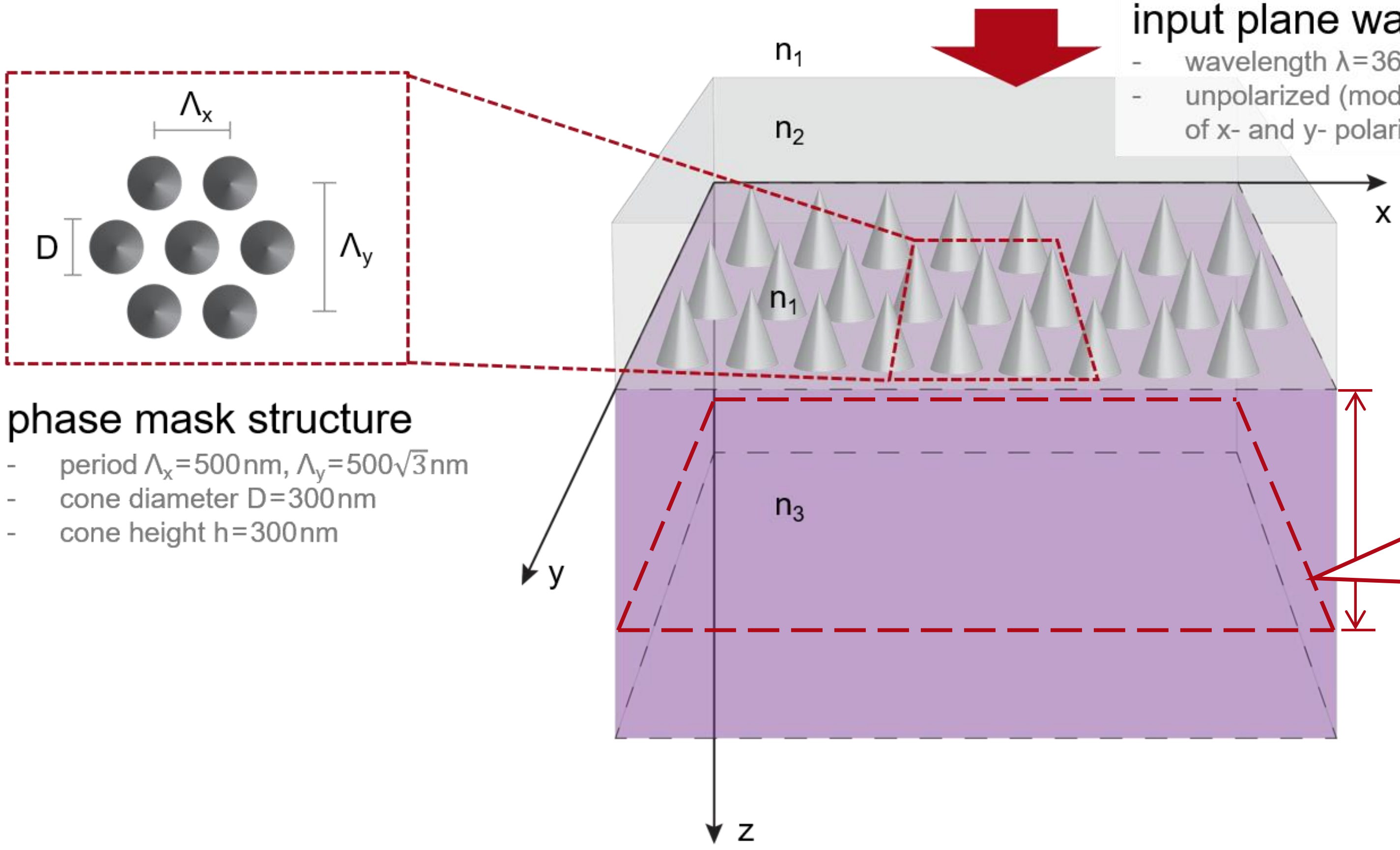
Polarization-Dependent Analyzer in Grating Simulation

- Polarization analyzer for gratings
  - For grating diffraction efficiency calculation, VirtualLab Fusion provides the Polarization Analyzer, for the investigation of polarization-dependent effects.
  - The polarization analyzer, in comparison to the grating order analyzer, has additional control over the polarization states of the incidence.
  - The polarization settings in the polarization analyzer work independently from the source settings in the optical setup.



Example #1: Talbot Images with Unpolarized UV Light

Modeling Task



input plane wave

- wavelength λ=365nm
- unpolarized (modeled as average of x- and y- polarizations)

phase mask structure

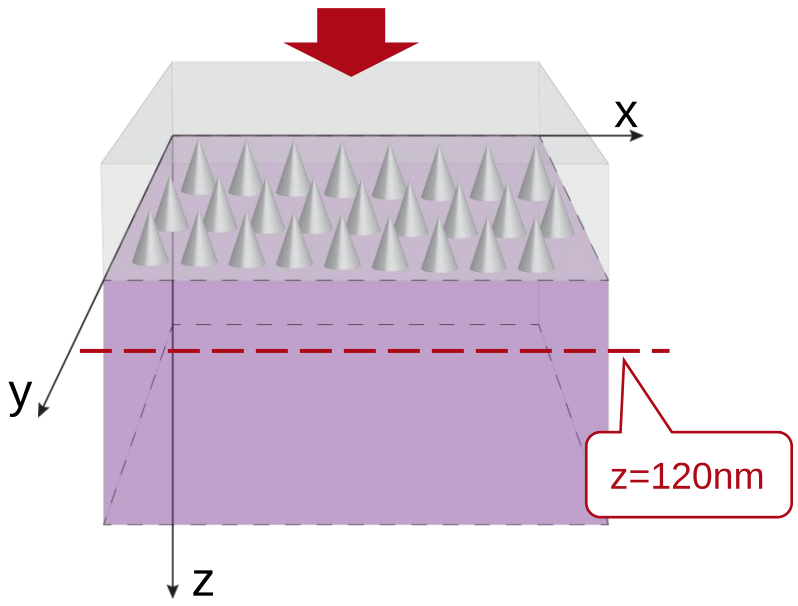
- period Λ_x=500nm, Λ_y=$500\sqrt{3}$nm
- cone diameter D=300nm
- cone height h=300nm

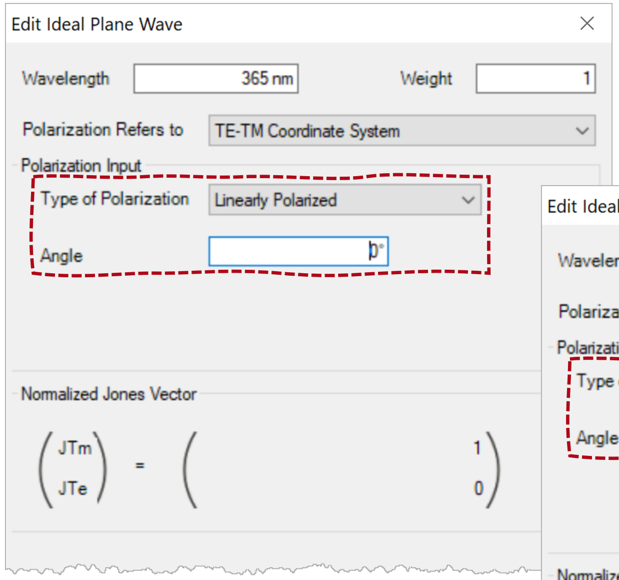
The Talbot image $||\boldsymbol{E}||^2$ of the phase mask is to be calculated at a selected position, with unpolarized UV light illumination.

see the full Application Use Case

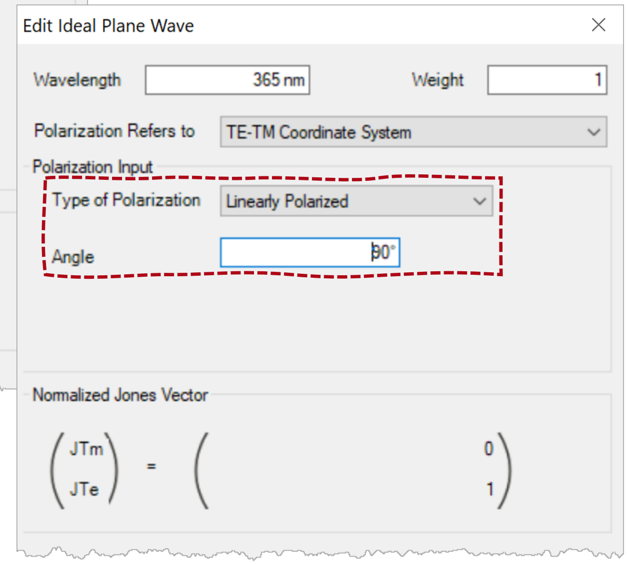
Detected Fields at a Certain Position

unpolarized plane wave
modeled as combination of
- x-polarized (TM)
- y-polarized (TE)



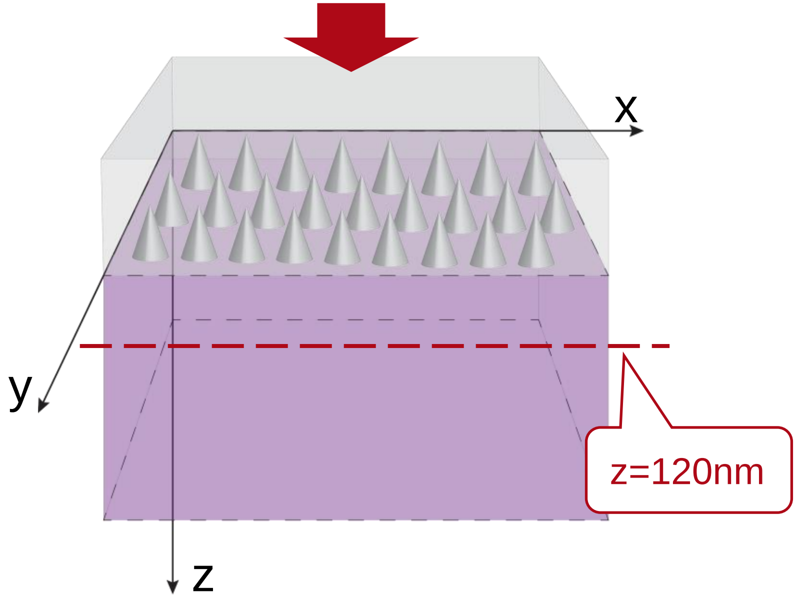


We set the incident plane wave in the TE-TM coordinate system, with linear polarization angles 0° and 90°, here for normal incidence, exactly along x- and y-direction.

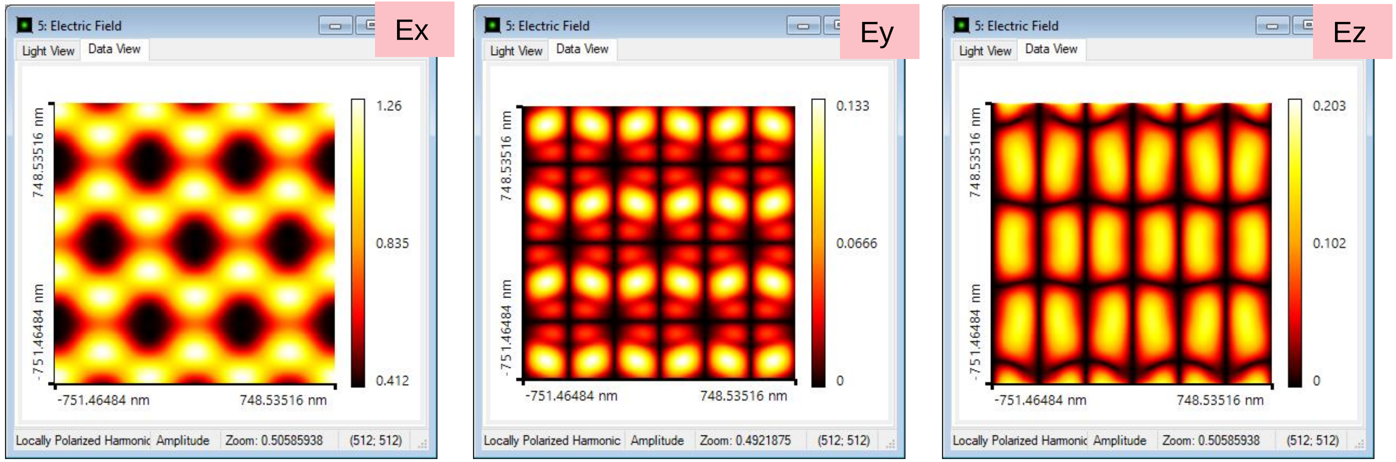


Detected Fields at a Certain Position

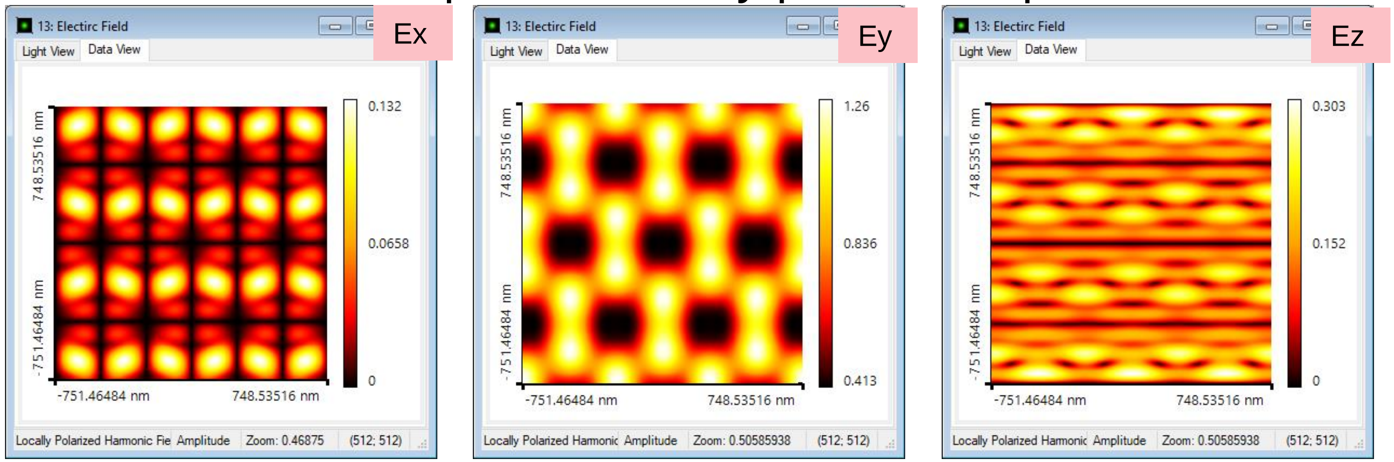
unpolarized plane wave modeled as combination of
- x-polarized (TM)
- y-polarized (TE)



transmitted field components from x-polarized input

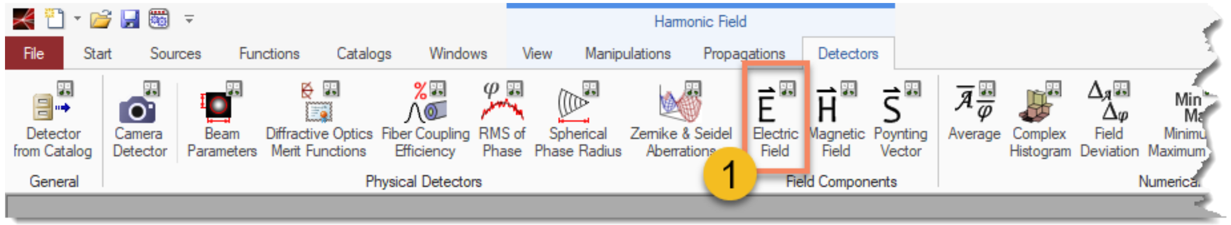


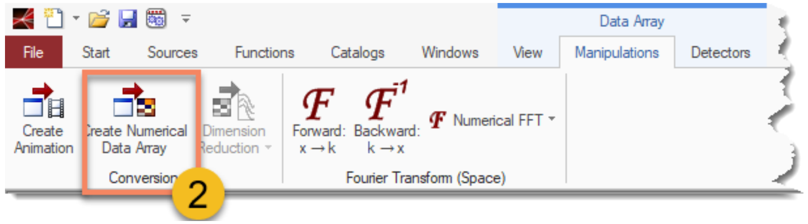
transmitted field components from y-polarized input



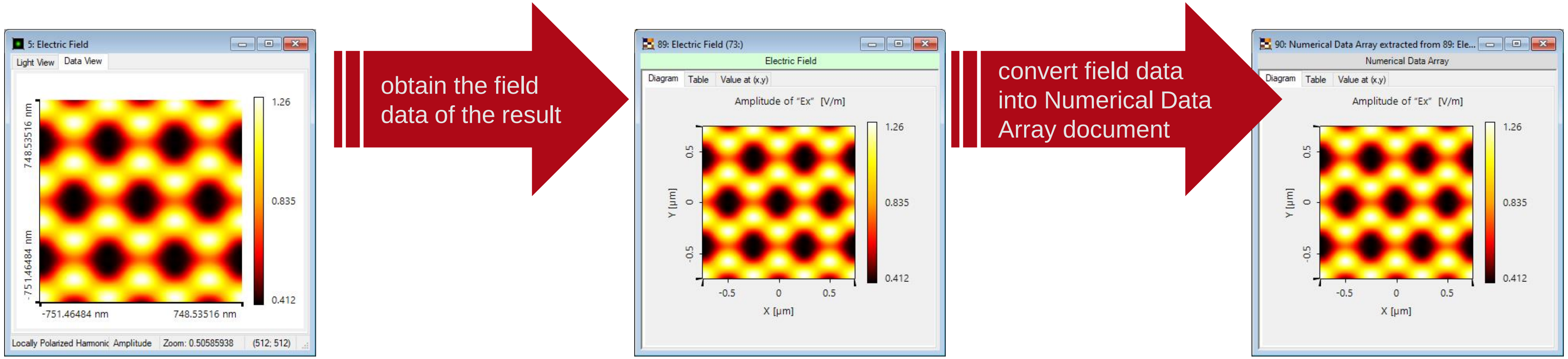
Incoherent Summation

- The incoherent summation of the results from two linearly polarized input beams can be done via ribbon-menu functions.
- To perform the incoherent summation, one should convert the intensity data into a Numerical Data Array document.





The result from the x-polarized input is taken as an example to show the document conversion steps



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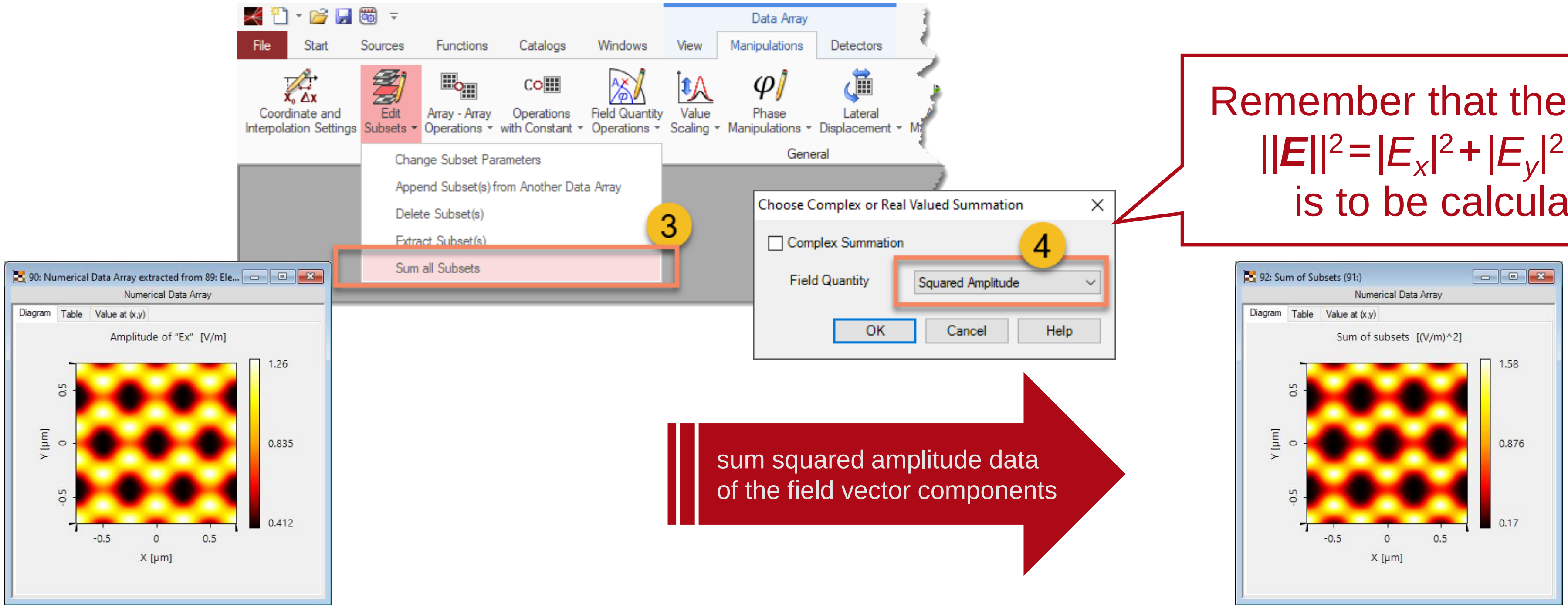
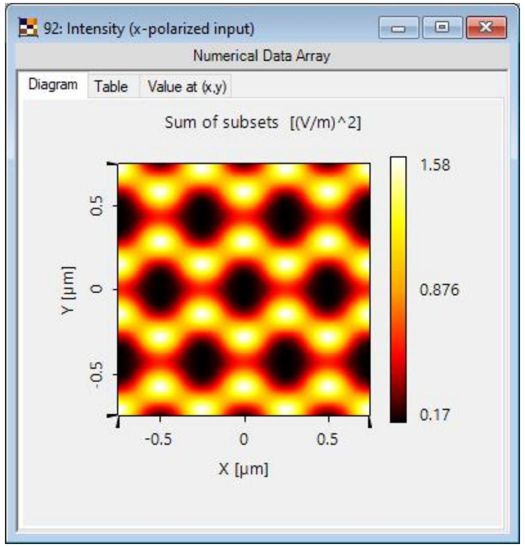
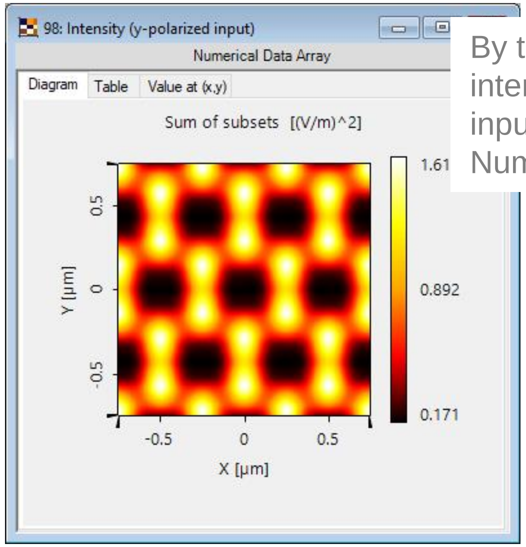


Remember that the quantity
$||\boldsymbol{E}||^2 = |E_x|^2 + |E_y|^2 + |E_z|^2$
is to be calculated.

Incoherent Summation

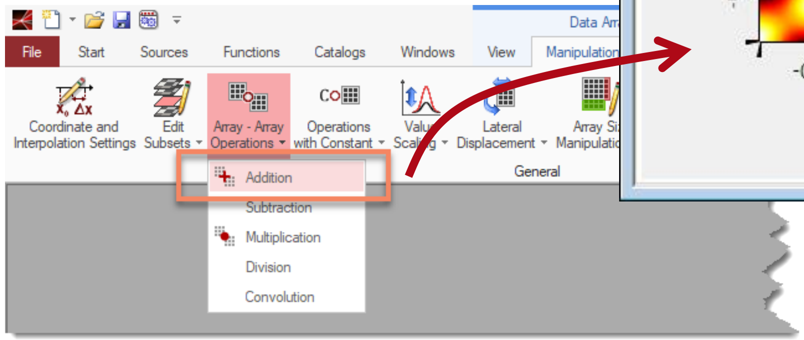


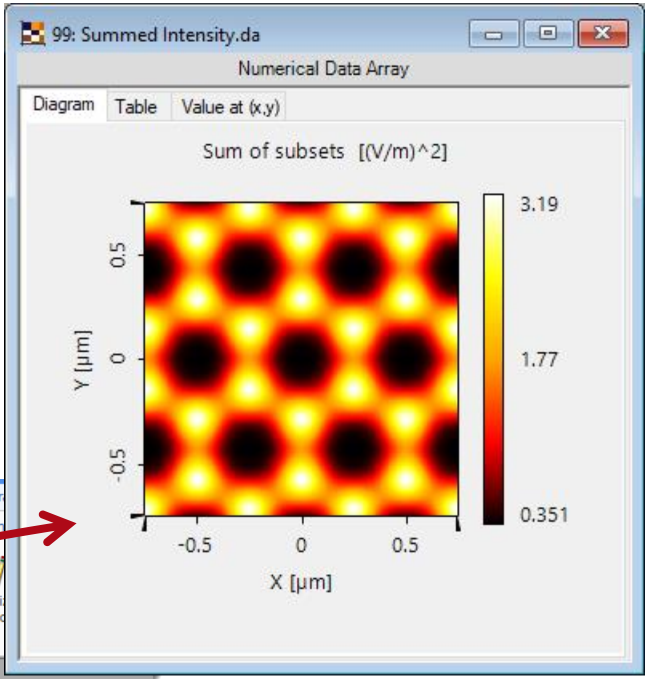


By the same process, the intensity from the y-polarized input is also converted into a Numerical Data Array document.

The incoherent summation of both results can be done as follows:

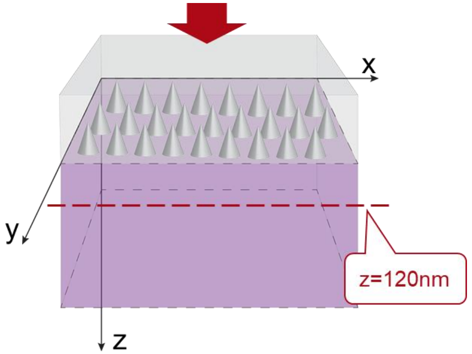
- sequentially select both documents and press "+" on the keyboard, or
- via the ribbon menu of VirtualLab Fusion:



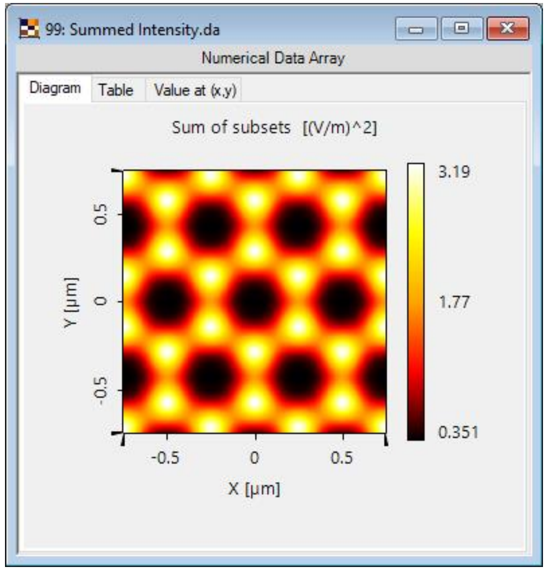


Choices of Orthogonal Polarization States

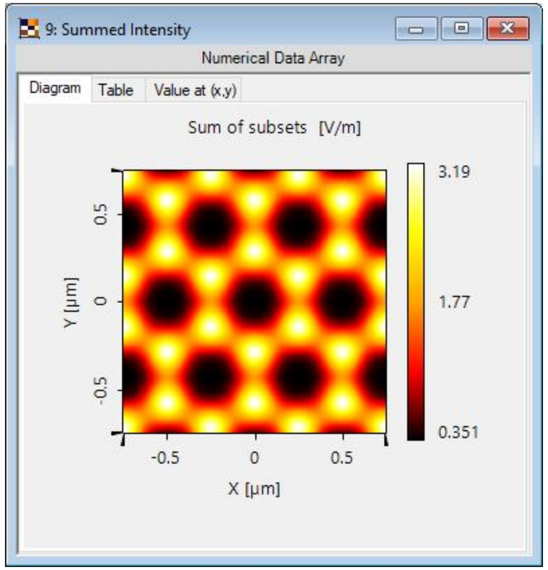
The choice of the two orthogonal input polarization states is arbitrary.



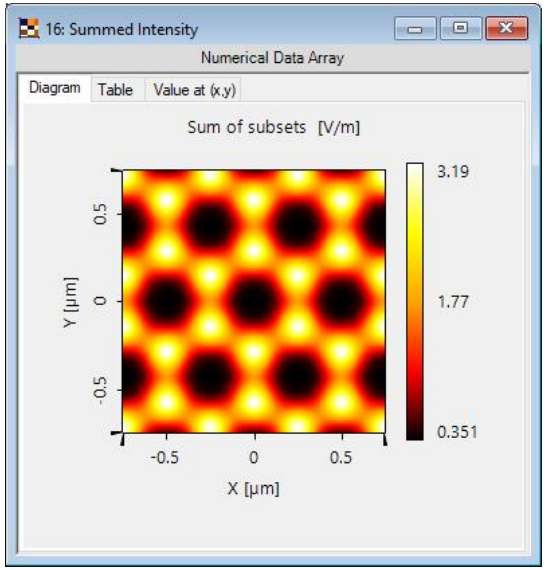
input as combination of:
- linear polarized 0°
- linear polarized 90°



input as combination of:
- linear polarized 30°
- linear polarized 120°



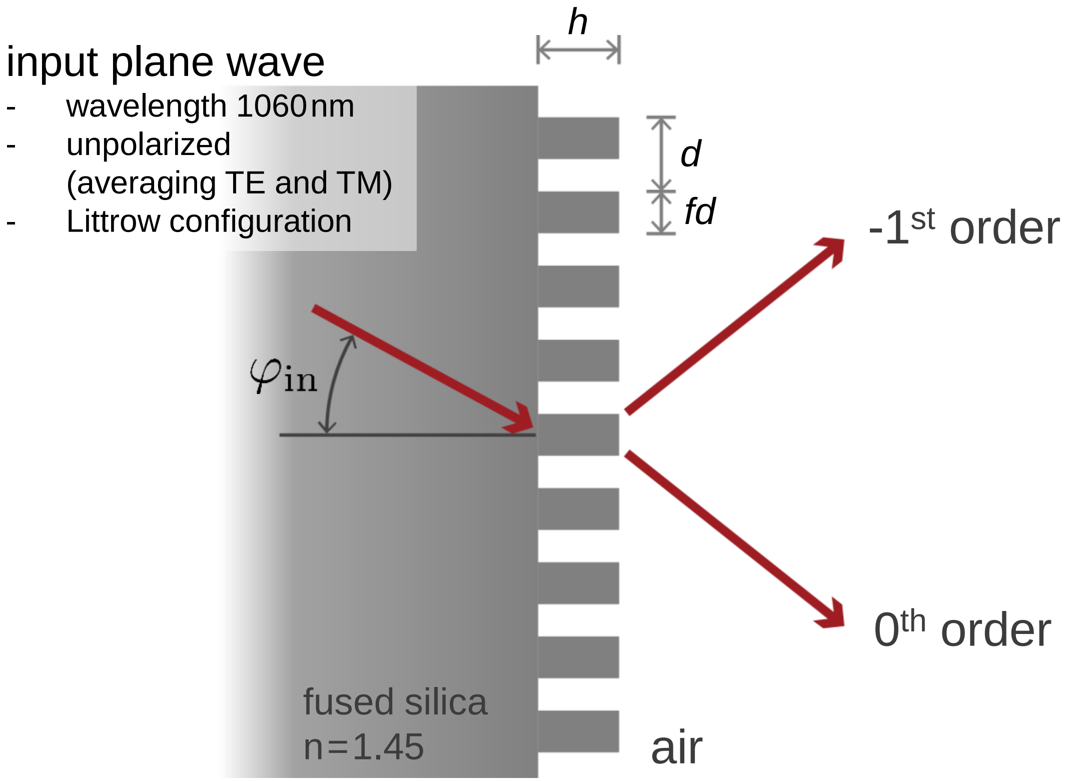
input as combination of:
- linear polarized 70°
- linear polarized 160°



The resulting Talbot images are independent of the choice of the two orthogonal input polarization states.

Example #2: Analysis of Polarization Independent Transmission Gratings

Modeling Task



The diffraction efficiency of the -1st order, with unpolarized incidence, is to be calculated.

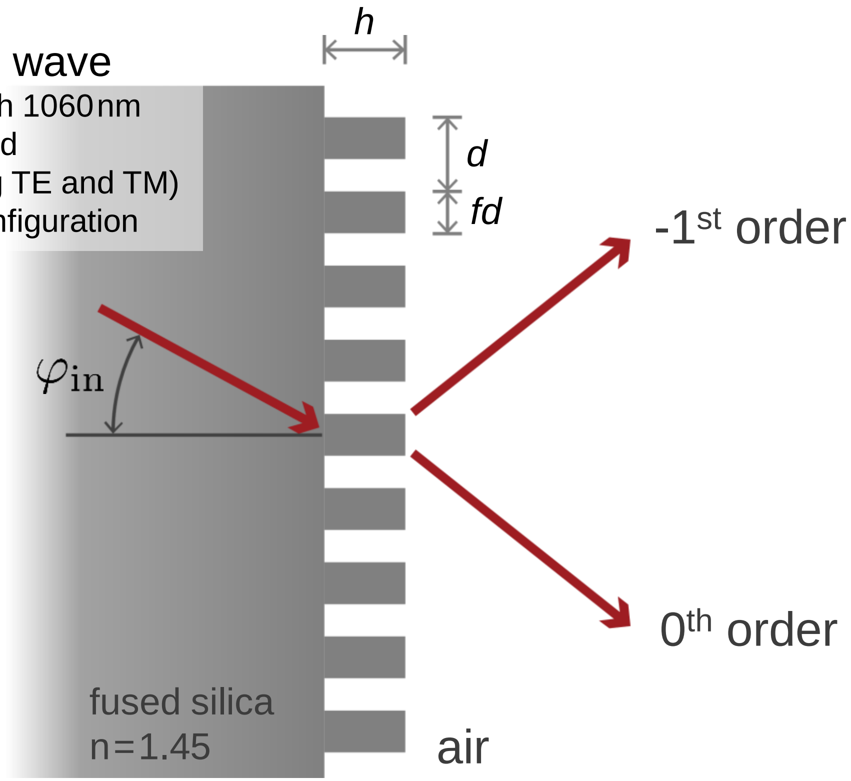
optimized grating parameters

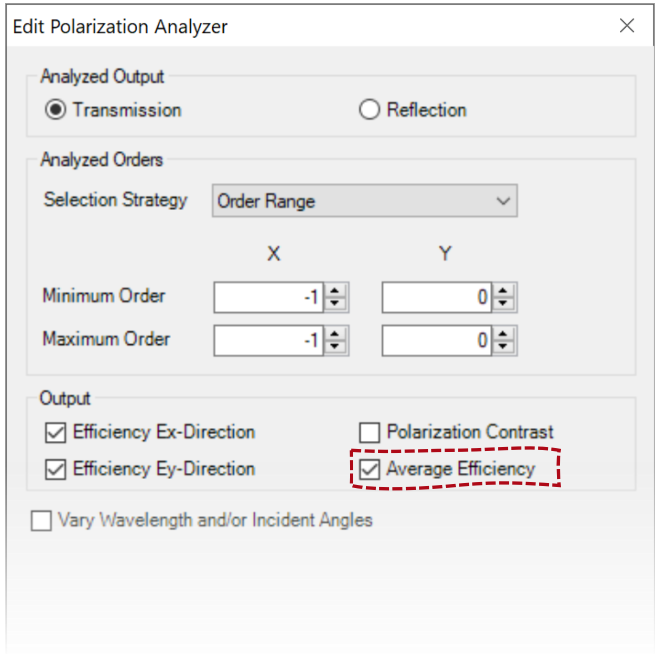
Parameter	Value
grating depth *h*	2.58 µm
grating period *d*	1024 nm
fill factor *f*	66.8%

see the full Application Use Case

Polarization Analyzer for Gratings

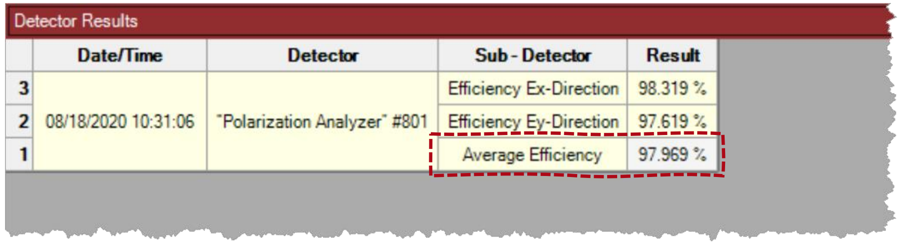
input plane wave
- wavelength 1060 nm
- unpolarized (averaging TE and TM)
- Littrow configuration





The polarization analyzer does the job of averaging the diffraction efficiencies for selected orders, with E_x and E_y polarizations as the input.

display of the results from the polarization analyzer



Detector Results

	Date/Time	Detector	Sub - Detector	Result
3			Efficiency Ex-Direction	98.319 %
2	08/18/2020 10:31:06	"Polarization Analyzer" #801	Efficiency Ey-Direction	97.619 %
1			Average Efficiency	97.969 %

Document Information

title	Unpolarized Light for Grating Simulation – Discussion at Examples
document code	GRT.0024
version	1.1
edition	VirtualLab Fusion Advanced
software version	2020.1 (Build 3.4)
category	Feature Use Case
further reading	- Talbot Images of A Conical Phase Mask - Analysis and Design of Highly Efficient Polarization Independent Transmission Gratings - Modeling and Design of Blazed Metagratings