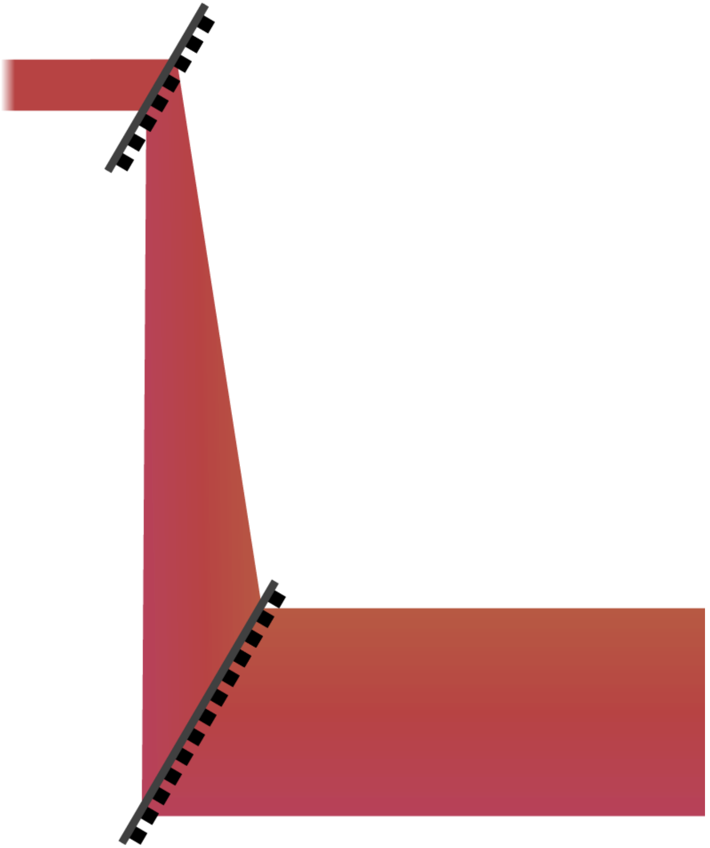
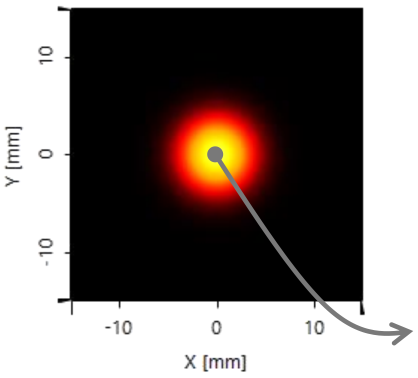
Stretching or Compression of Ultrashort Pulses with Highly Efficient Transmission Gratings

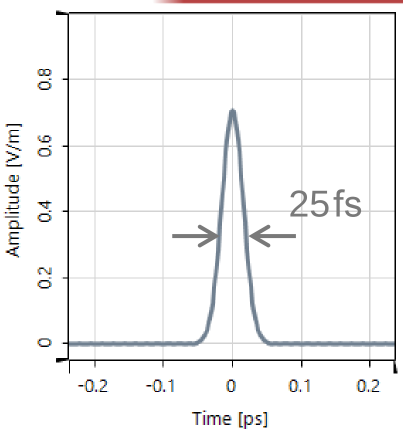
Abstract

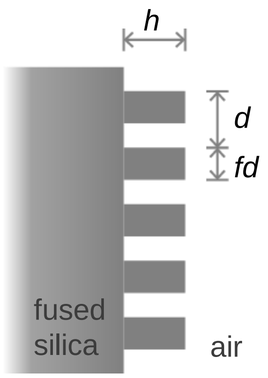


Precise control over the ultrashort pulses is of importance for various applications. Prisms and gratings are typical optical components that are used for manipulating the temporal behavior of pulses. In this example, we use two transmission gratings, according to the work of T. Clausnitzer *et al*., to build up a stretching / compressing system for ultrashort pulses. Particularly, we analyze the polarization-dependent effects that is caused by the gratings, and we optimized the gratings to obtain a polarization-independent system with high efficiency.

Task Description







initial grating parameters

grating structure	value
grating depth *h*	1.54 µm
grating period *d*	800 nm
fill factor *f*	45%

Gratings parameters follows from T. Clausnitzer, *et al*., Appl. Opt. 42, 6934-6938 (2003)

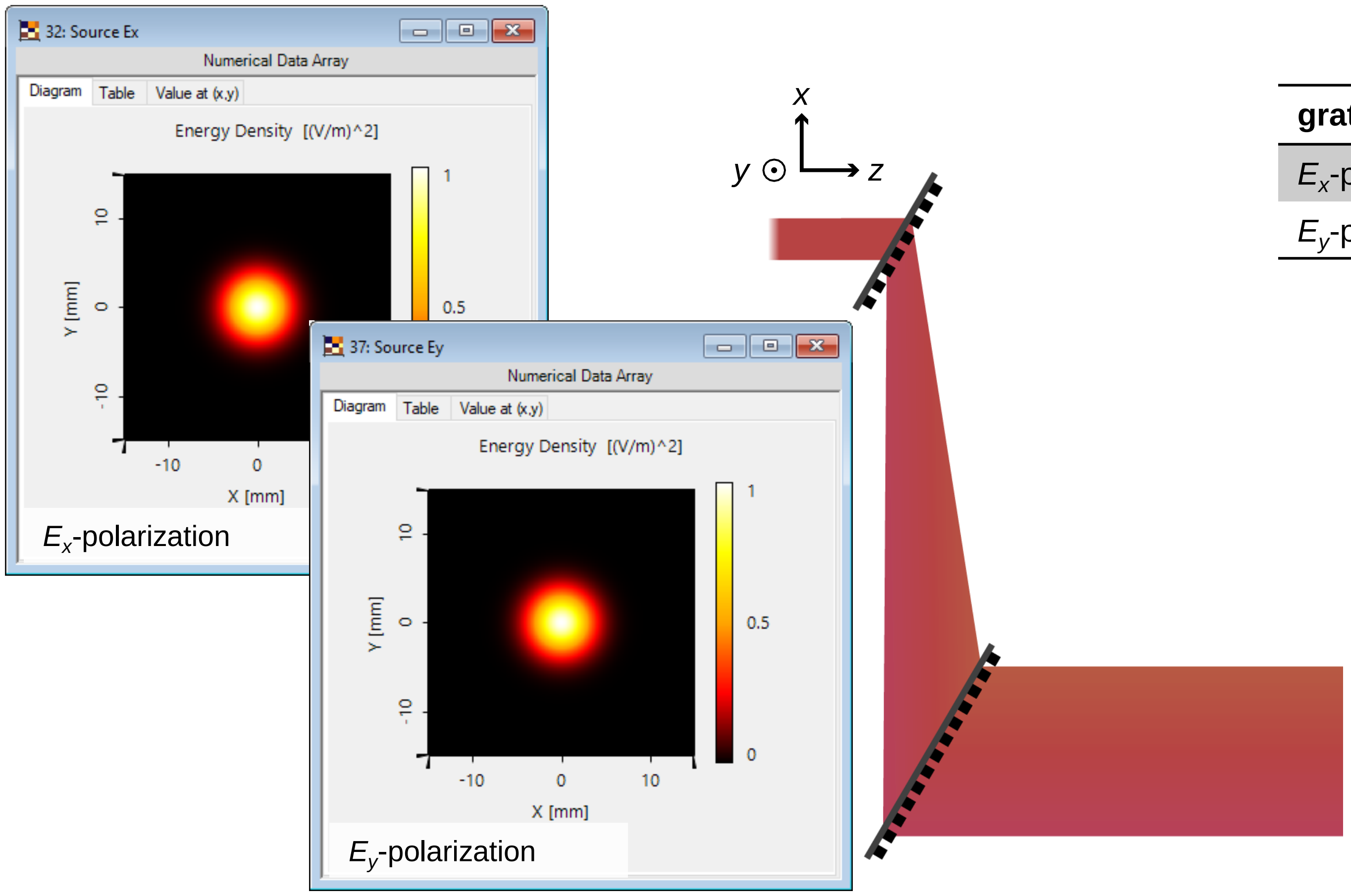
gratings pair

- rotation angle 41.49° (Littrow configuration)
- working in -1[st] order (transmission)
- distance between two gratings 25 mm

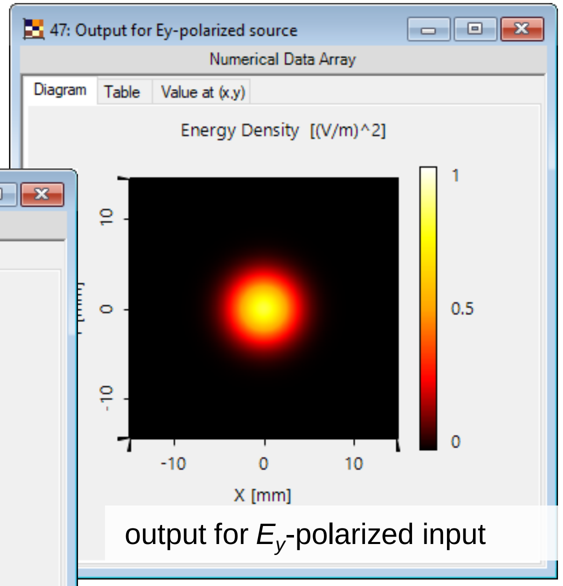
input beam pulse

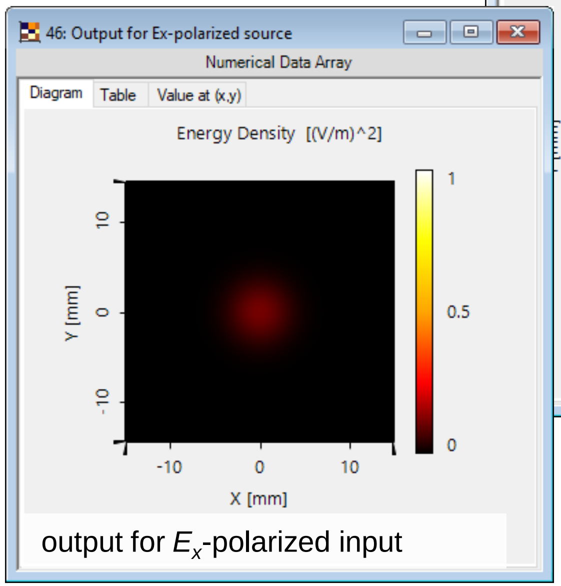
- carrier wavelength 1060 nm
- Gaussian spatial profile [collimated]
- unpolarized (using two orthogonal linear polarizations, E_x and E_y, to check the effects)

Spatial Property of Output Beams (@Carrier Wavelength)



grating efficiencies	value
E_x-polarization	34.37%
E_y-polarization	97.15%

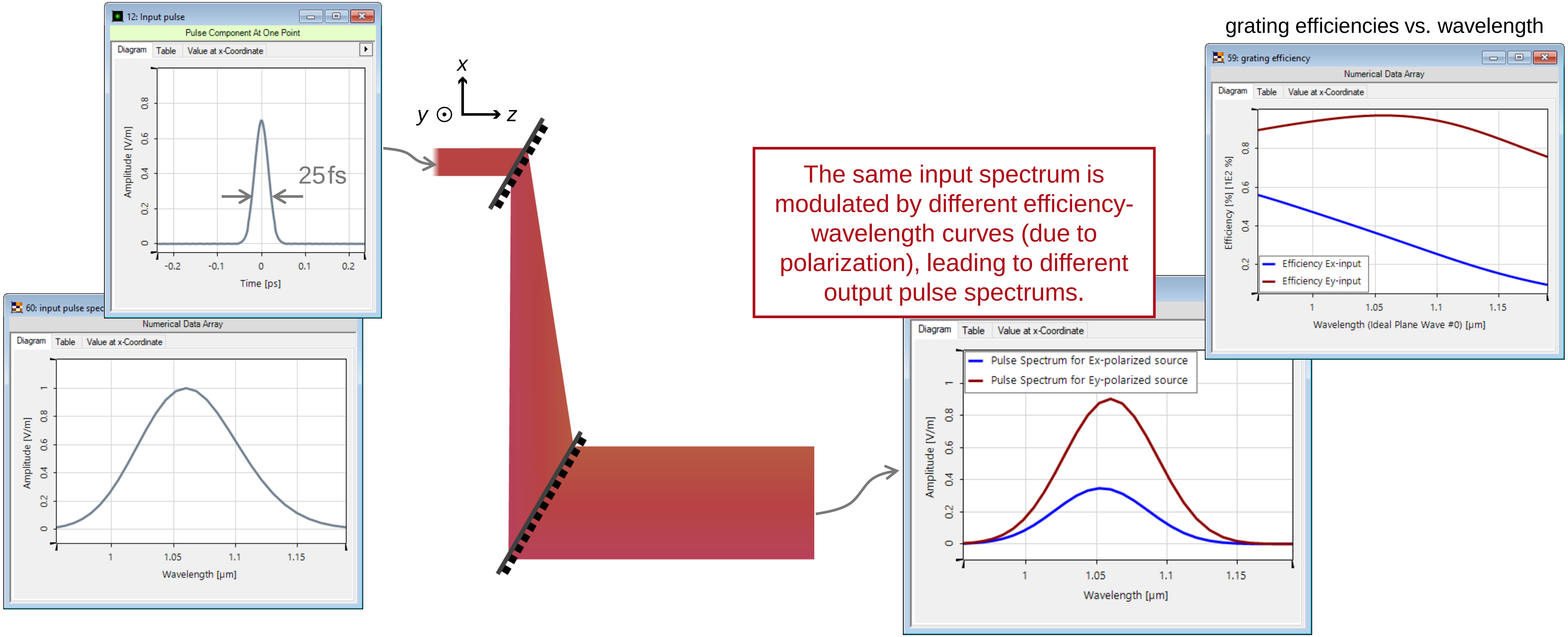




Energies of output beams for E_x- and E_y-polarized inputs are different, because the grating efficiency is polarization dependent.

Spectral Property of Output Pulses

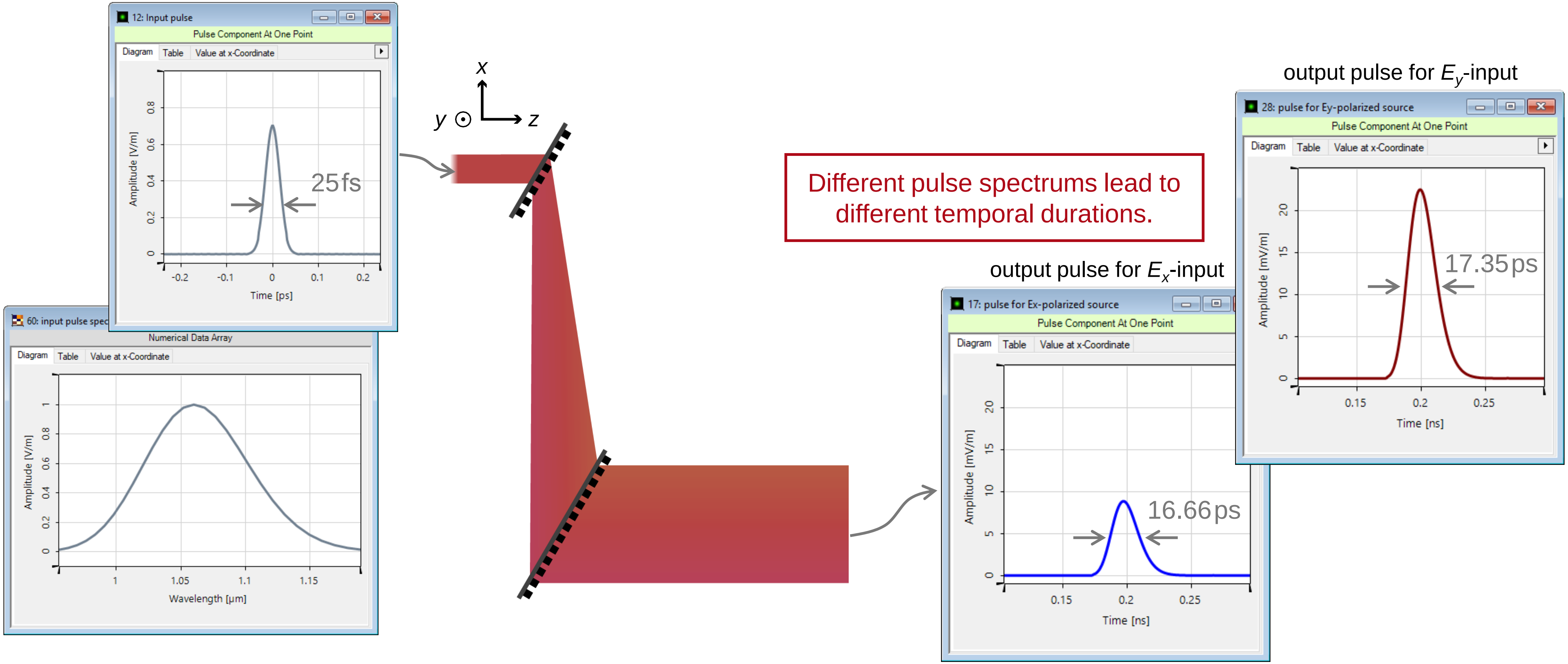
grating efficiencies vs. wavelength



The same input spectrum is modulated by different efficiency-wavelength curves (due to polarization), leading to different output pulse spectrums.

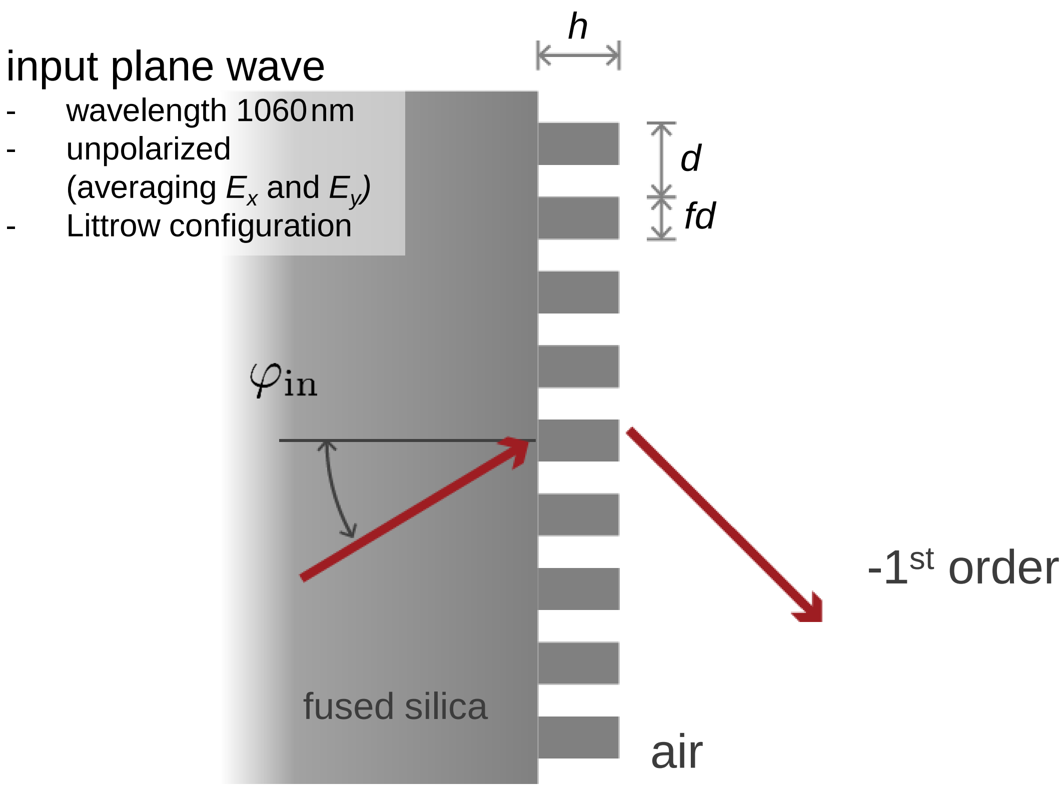
output pulse spectrums

Temporal Property of Output Pulses



Different pulse spectrums lead to different temporal durations.

Polarization-Independent Grating Design for Carrier Wavelength



reference: T. Clausnitzer, *et al.*, Proc. SPIE **5252**, 174-182 (2003)

How to use paramatric optimization to maximize the diffraction efficiency of -1st transmission order, for unpolarized input light?

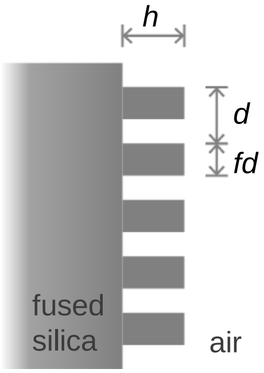
variables	**value range**
grating depth *h*	0.1-10 µm
fill factor *f*	20-80%

merit function	**target**
average efficiency $=0.5(\eta_x+\eta_y)$	100%

$\eta_{x/y}$ is the efficency of -1st diffraction order for E_x- / E_y- polarized input

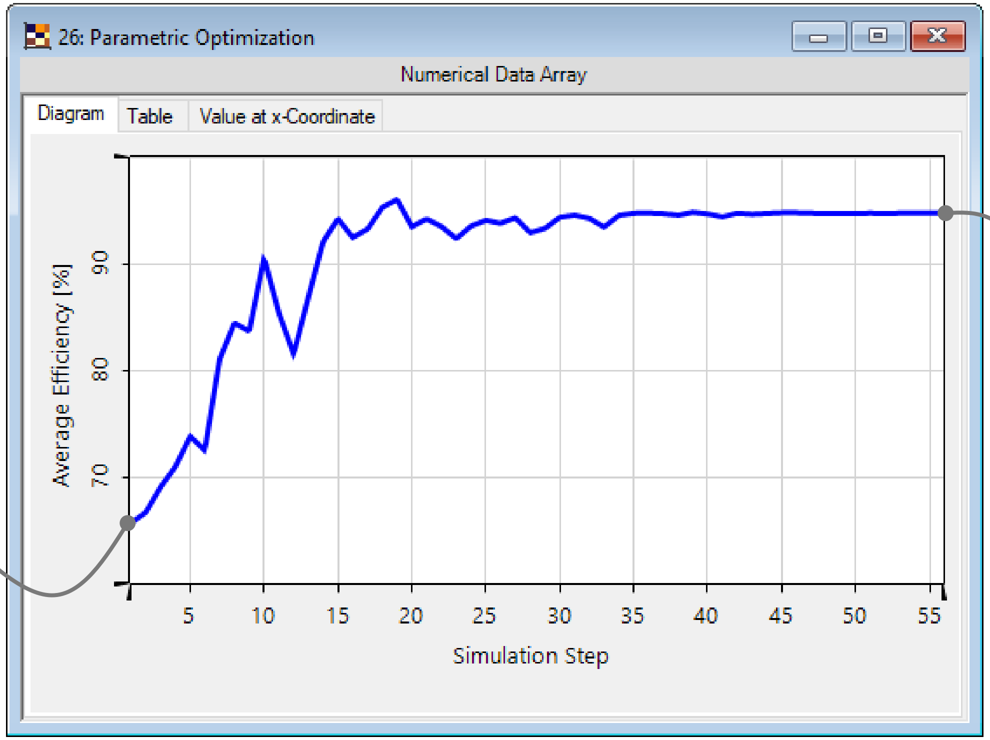
Parametric Optimization

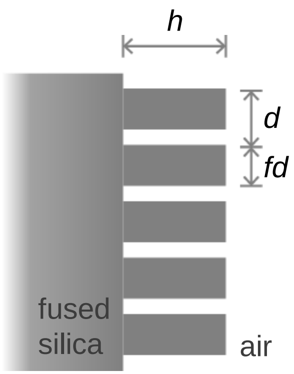
downhill simplex optimization with FMM / RCWA
for grating diffraction efficiency calculation



initial grating

grating structure	value
grating depth *h*	1.54 µm
fill factor *f*	45%

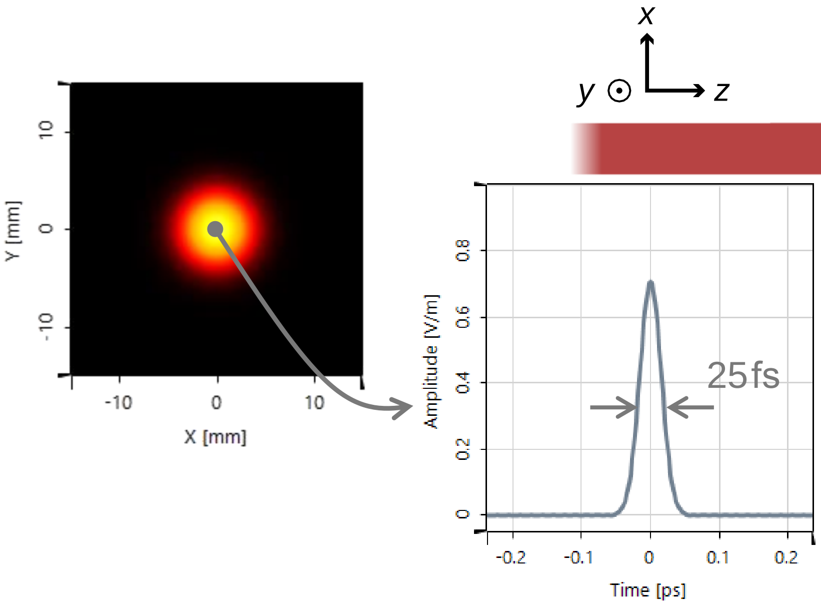




optimized grating

grating structure	value
grating depth *h*	2.732 µm
fill factor *f*	71.443%

Task Description



optimized grating parameters

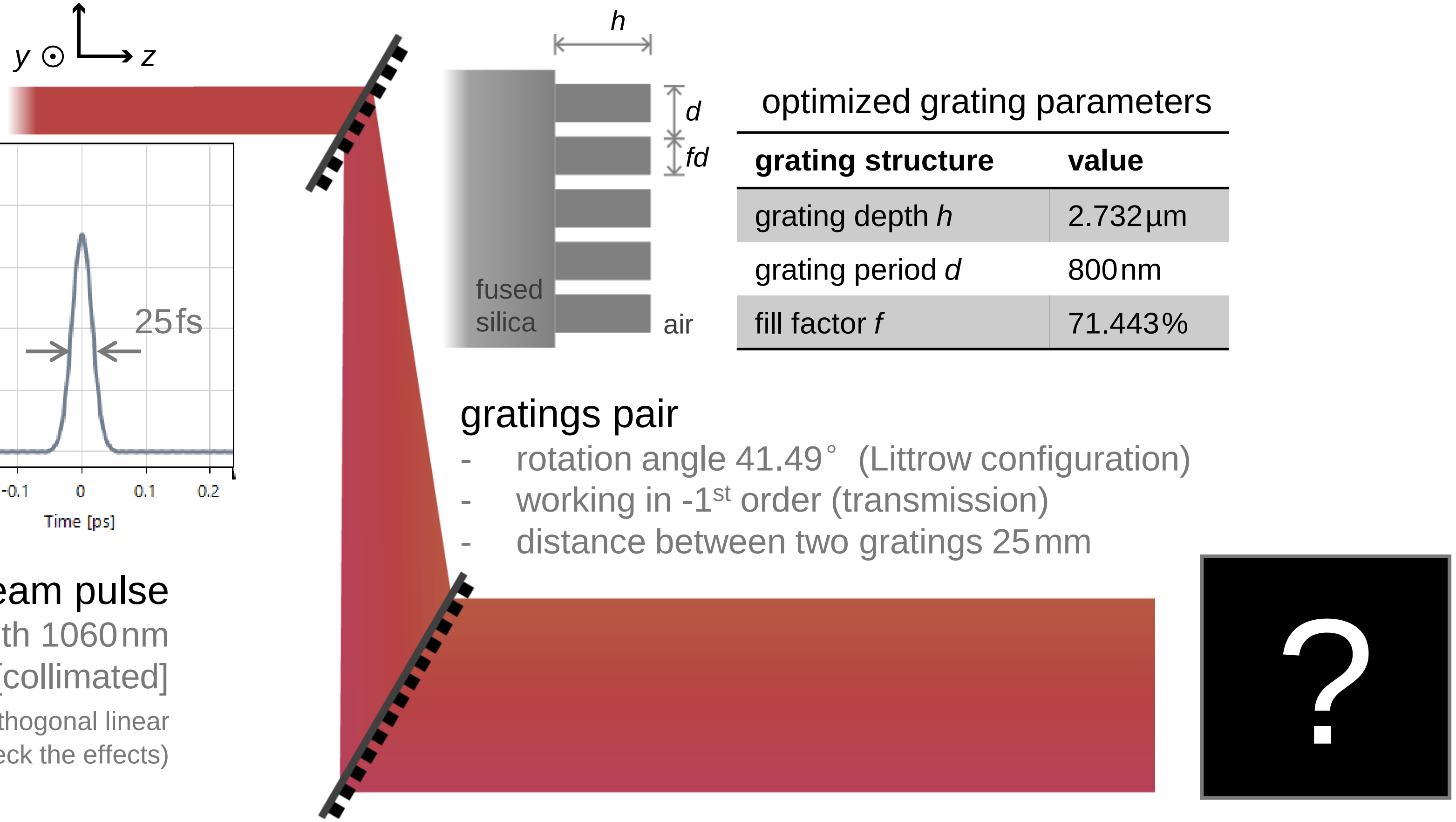
grating structure	value
grating depth *h*	2.732 µm
grating period *d*	800 nm
fill factor *f*	71.443%

gratings pair

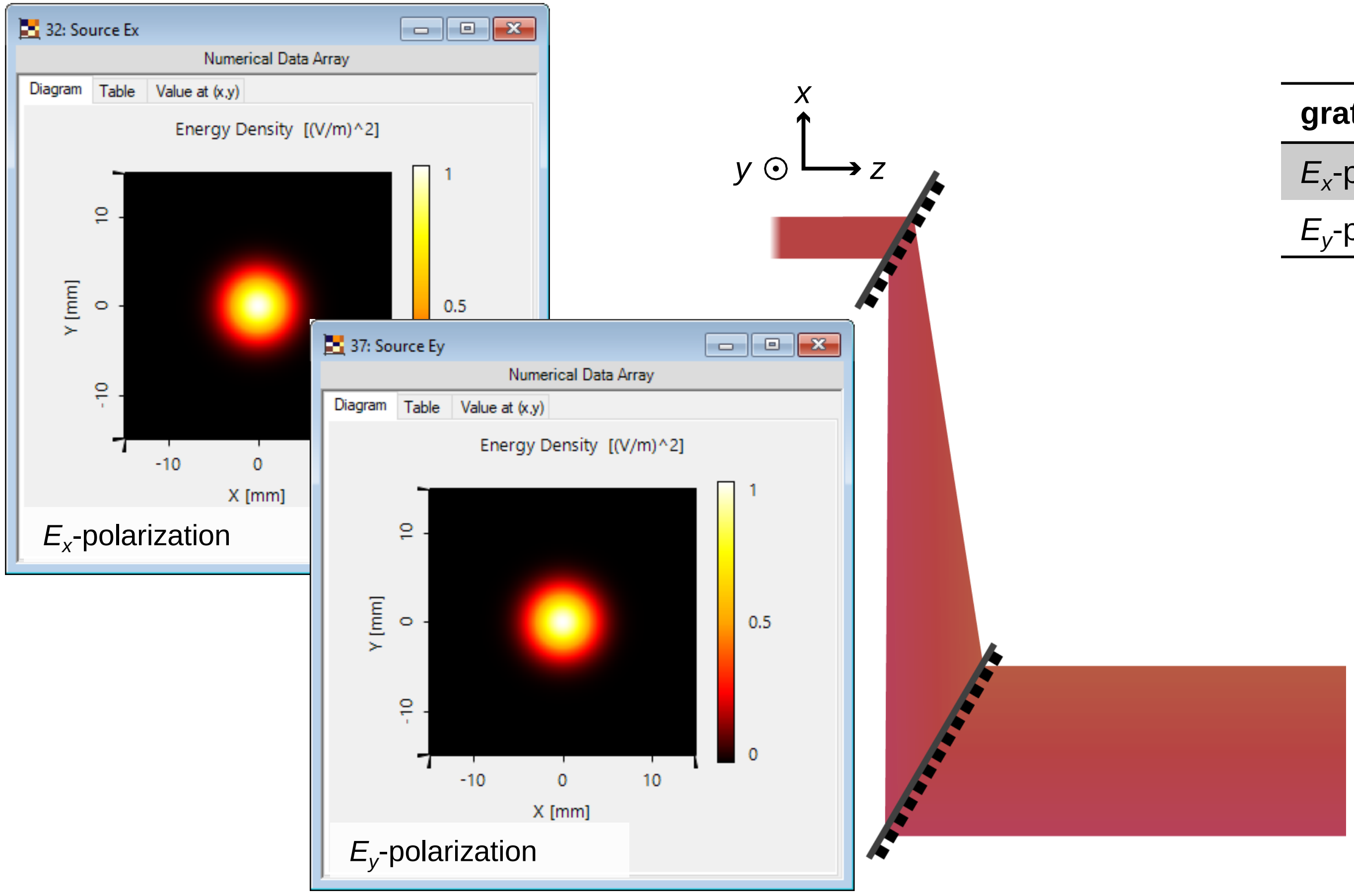
- rotation angle 41.49° (Littrow configuration)
- working in -1st order (transmission)
- distance between two gratings 25 mm

input beam pulse

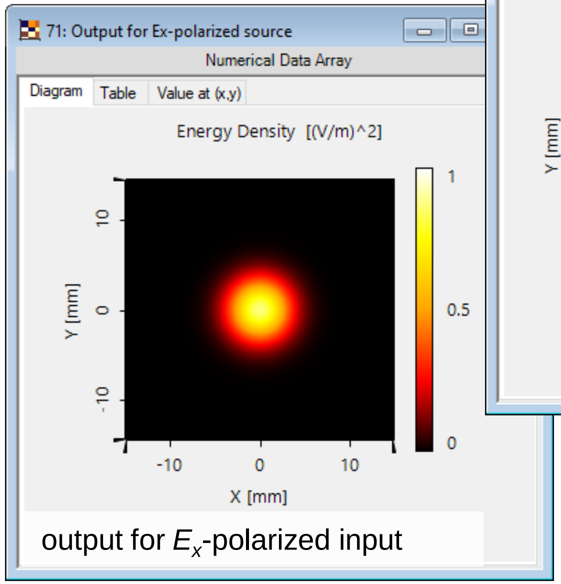
- carrier wavelength 1060 nm
- Gaussian spatial profile [collimated]
- unpolarized (using two orthogonal linear polarizations, E_x and E_y, to check the effects)

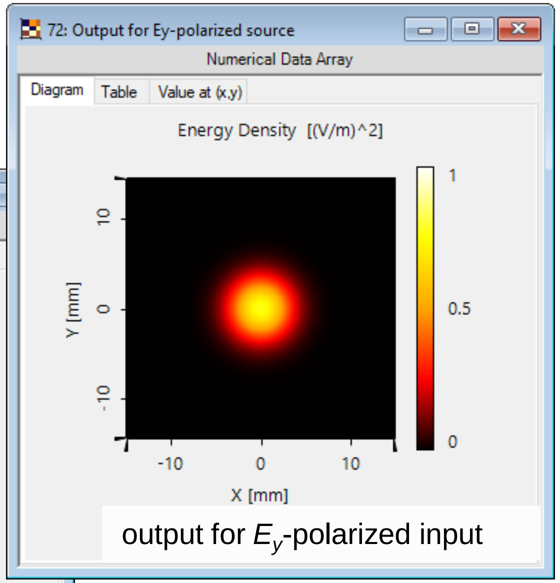


Spatial Property of Output Beam (@Carrier Wavelength)



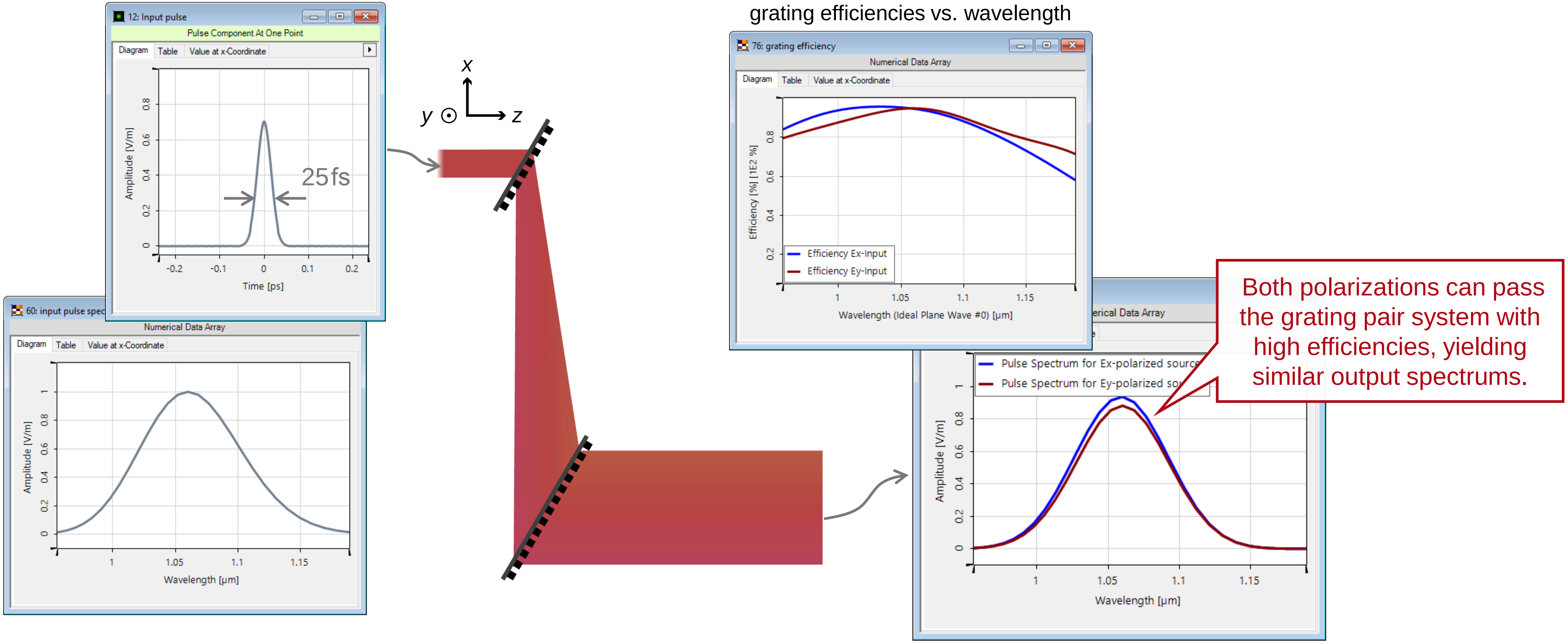
grating efficiencies	value
E_x-polarization	94.70%
E_y-polarization	94.90%





Powers of the output beams for E_x- and E_y-polarized inputs are similar, thanks to the optimized grating structure.

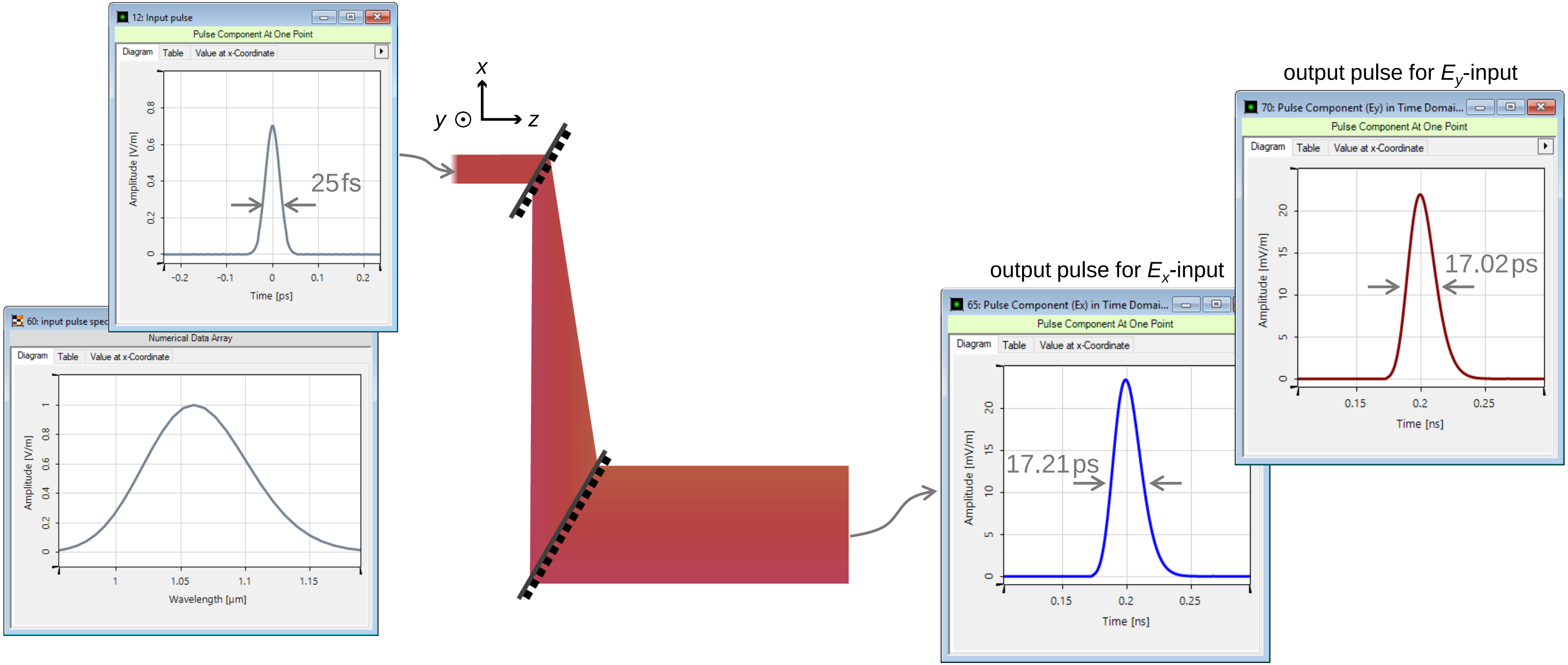
Spectral Property of Output Pulses



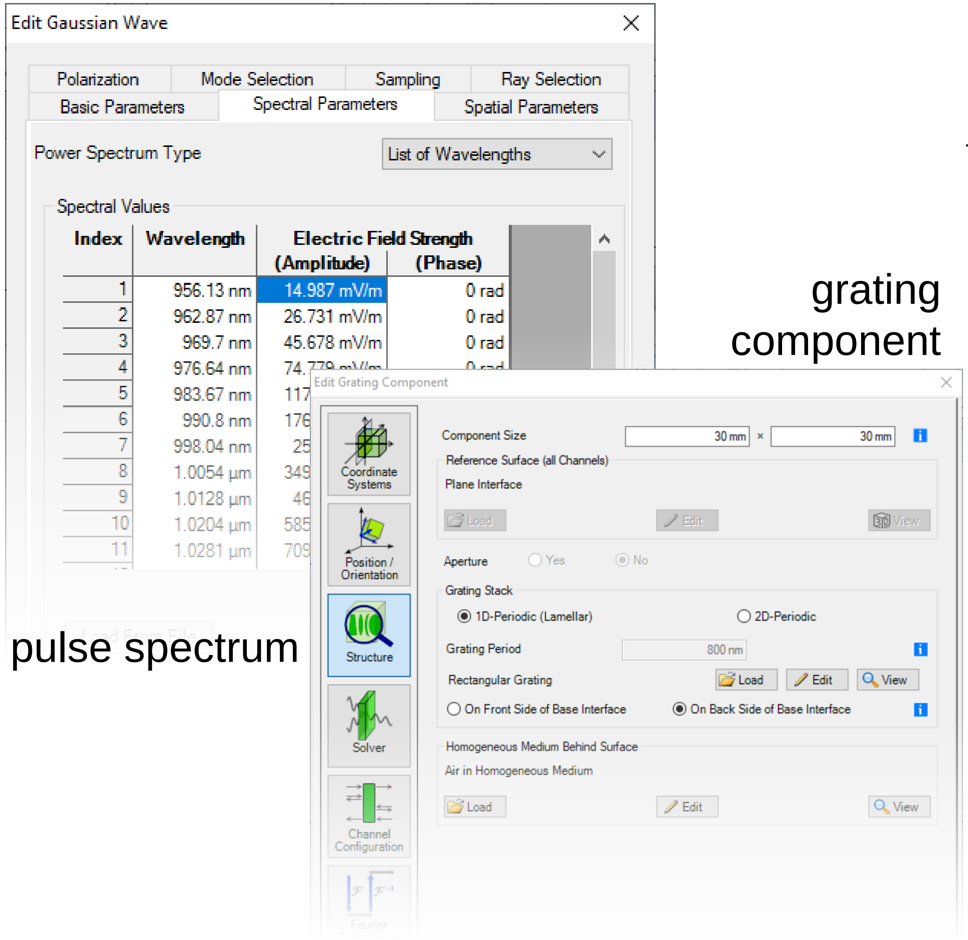
grating efficiencies vs. wavelength

output pulse spectrums

Temporal Property of Output Pulses

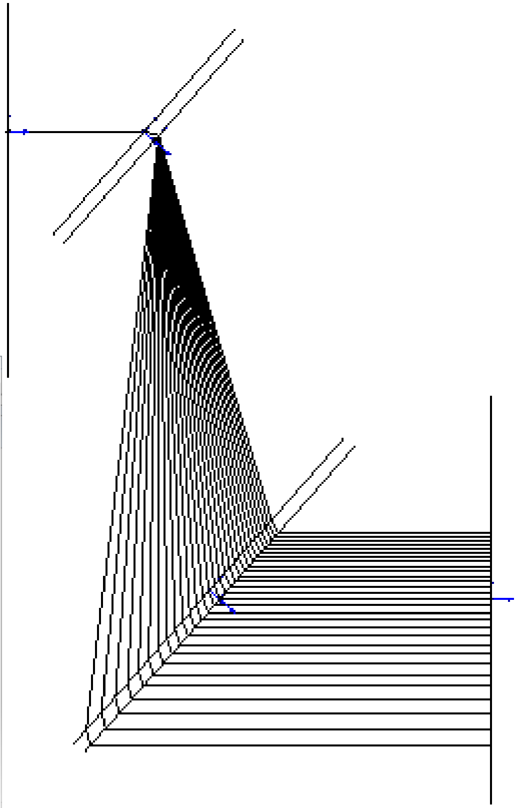


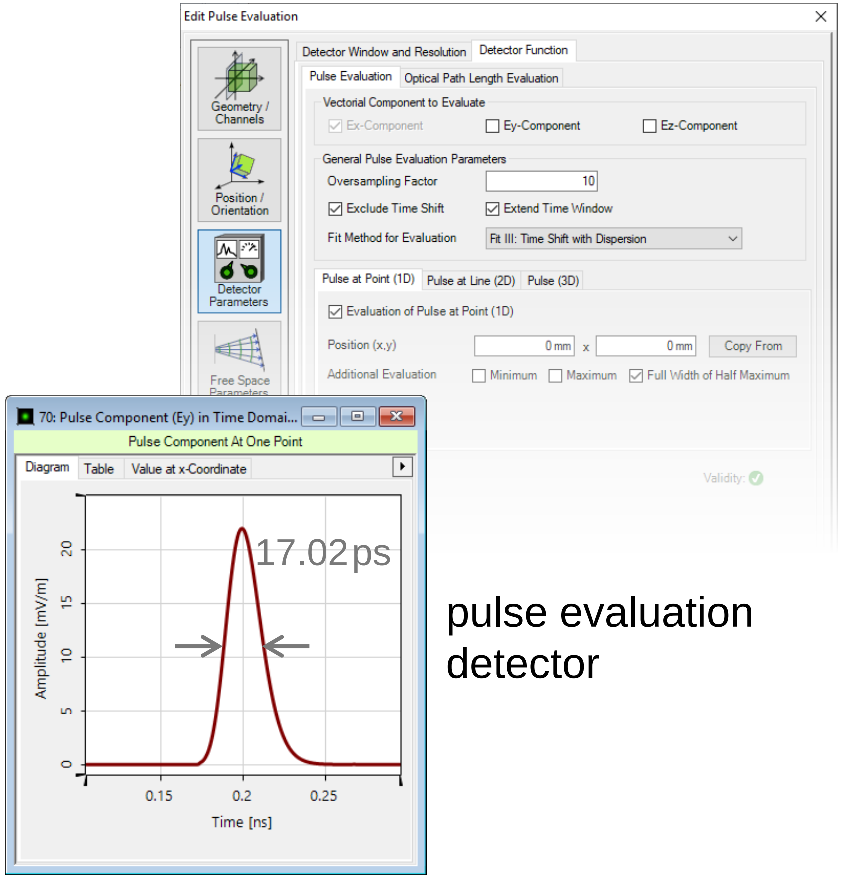
Peek into VirtualLab Fusion



pulse spectrum

grating component

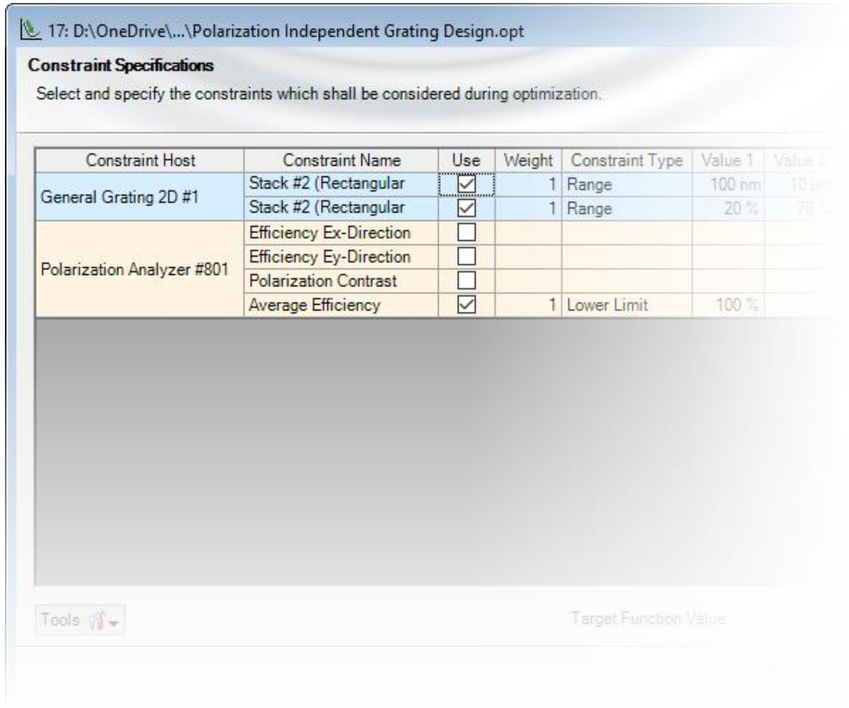




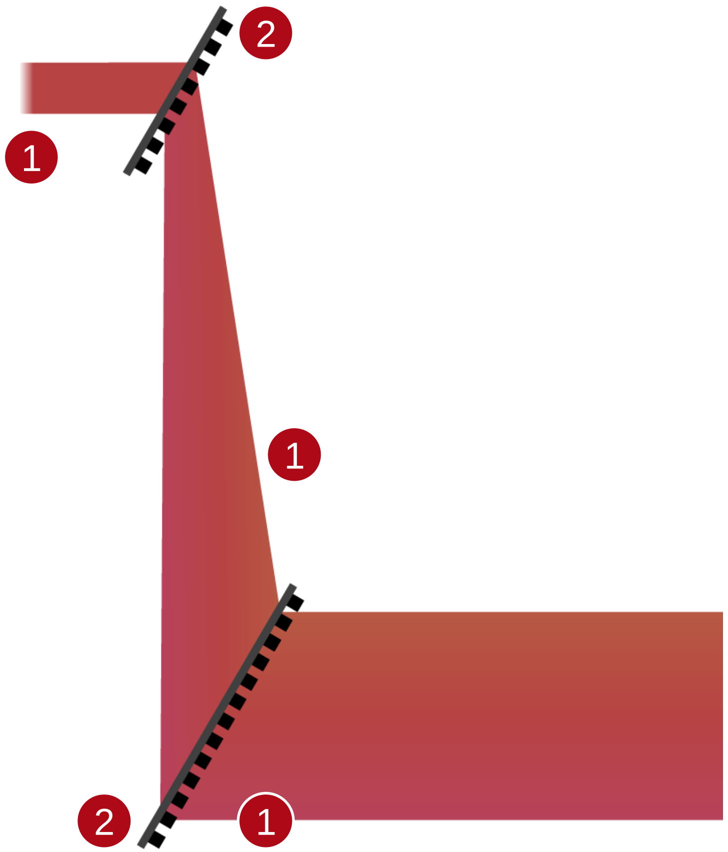
pulse evaluation detector

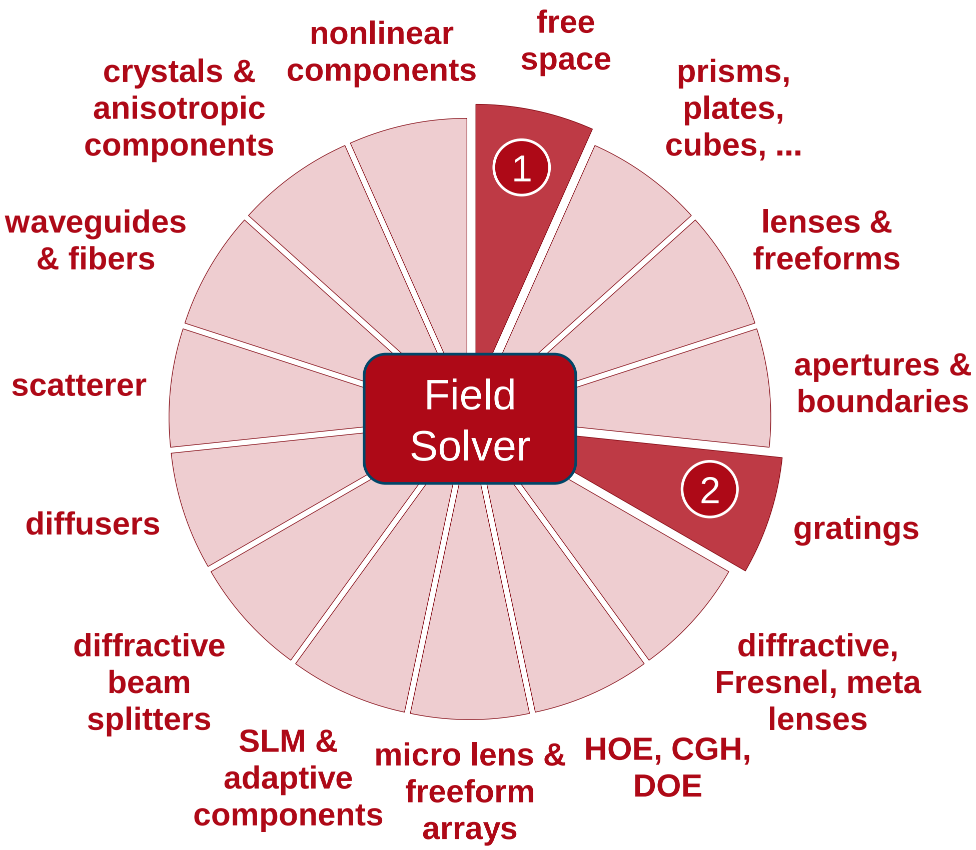
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Set up a real-structure grating and select the working diffraction order
- Select and set up the pulse evaluation detector
- Design of highly efficient polarization independent transmission gratings
  - Analysis and Design of Highly Efficient Polarization Independent Transmission Gratings [Use Case]



VirtualLab Fusion Technologies





Document Information

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software version	2020.1 (Build 2.8)
category	Application Use Case
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