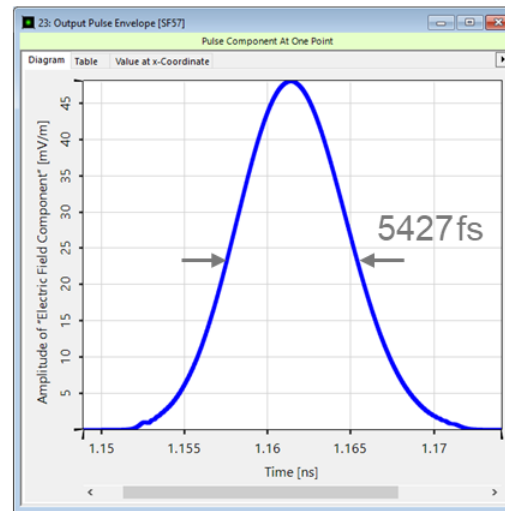
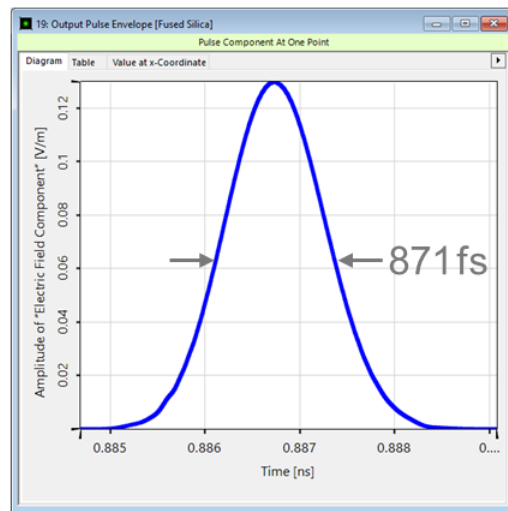
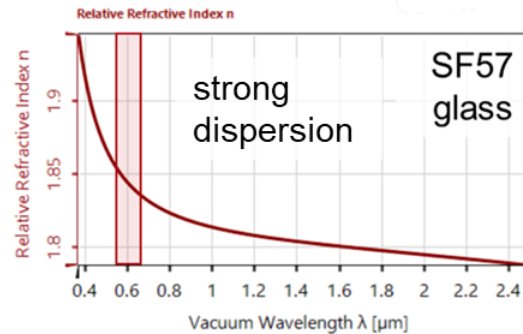
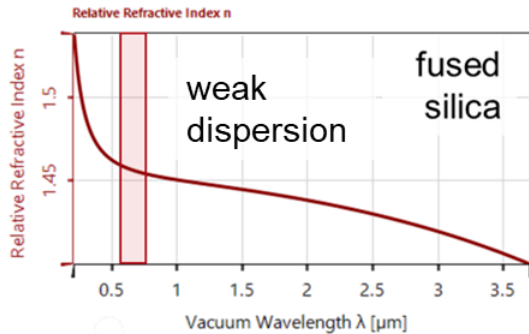


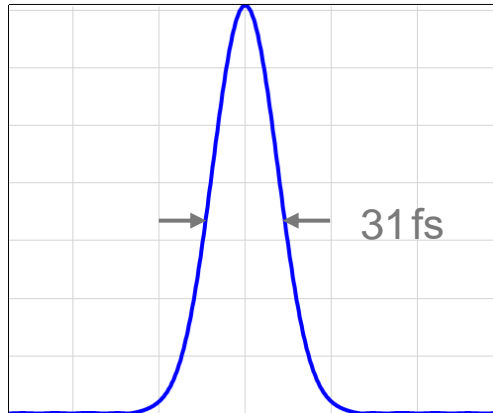
# Pulse Broadening in Dispersive Media

# Abstract



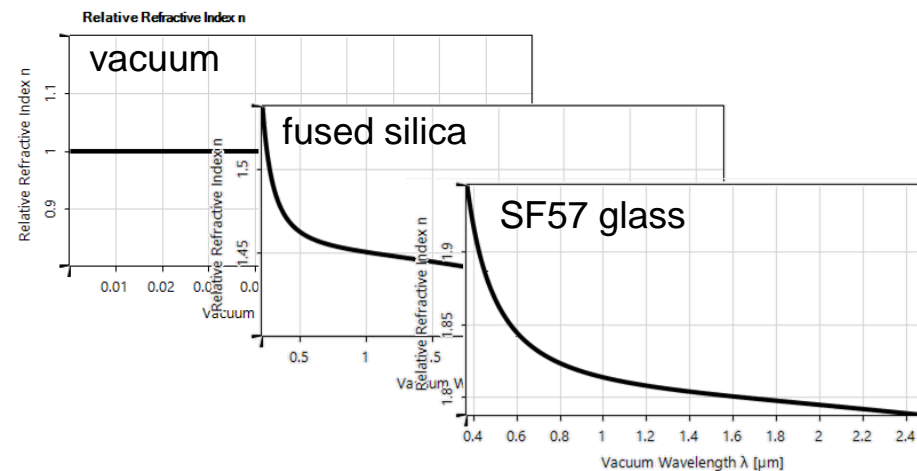
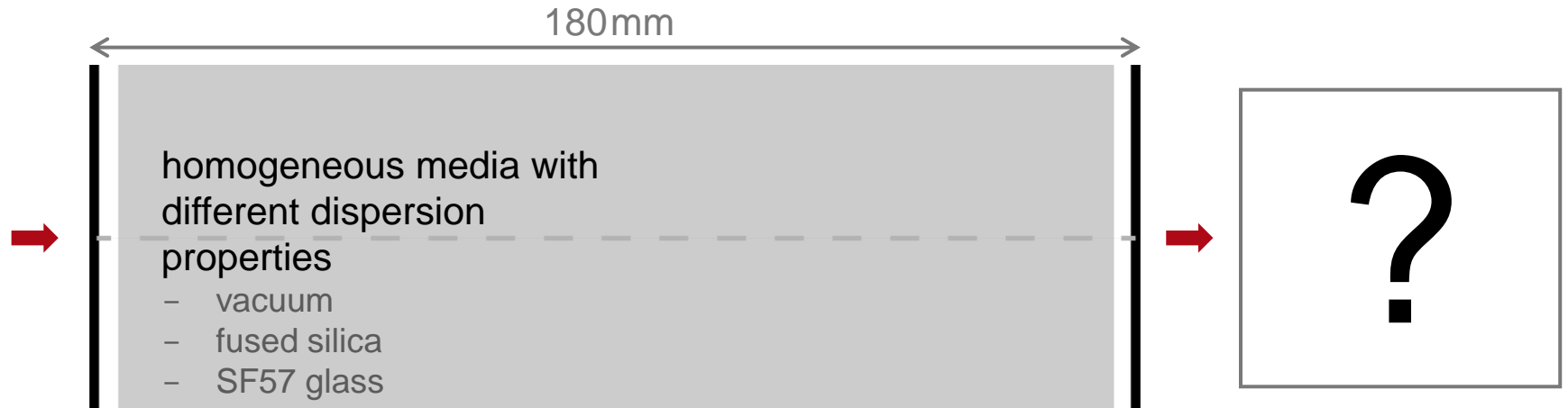
Ultrashort pulses are a promising tool for laser material processing applications. On the one hand, ultrashort pulses often show superiority in e.g. heat control and precision; on the other hand, due to dispersive effects, it can be challenging to maintain the pulse duration after propagation through a complete optical system. In this example, we investigate the relationship between pulse broadening and material dispersion, based on selected examples.

# Modeling Task



input pulse

- carrier wavelength 619nm
- temporal duration 31 fs
- Gaussian spatial profile [collimated]



How do the dispersion properties of different media affect the pulse after propagation over a certain distance?

# System Building Blocks – Source

Wyrowski VirtualLab Fusion 2021.1 (Build 1.180)

File Start Sources Functions Catalogs Windows View Manipulations Detectors

Basic Source Models: Gaussian Wave, Plane Wave, Quadratic Wave, Spherical Wave, Super-Gaussian Wave, Stored Lateral Field

Partially Coherent Source Models: Customized Mode Planar Source, Gaussian Type Planar Source, Grid Gaussian Planar Source, Multimode Gaussian Source

Spectra: Black Body Spectrum, Gaussian Spectrum, Homogeneous Spectrum, Lorentzian Spectrum, Databased Spectrum, Programmable Spectrum, Gaussian Pulse Spectrum

**Gaussian Pulse Spectrum**

Pulse Specification

- ☒ Definition by FWHM
- ☐ Definition by 1/e Diameter

Pulse Duration: 31 fs

Carrier Wavelength: 619 nm

Carrier Frequency: 484.3173796 THz

Estimated Increase of Time Window: 5

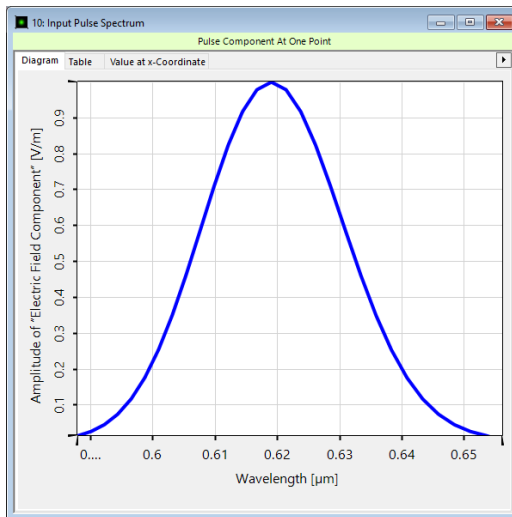
Numerical Settings

- Squared Amplitude Truncation (Frequency Domain): 0.01 %
- Resulting Size of Angular Frequency Window: 326.0234719 THz
- Squared Amplitude Truncation (Time Domain): 0.01 %
- Resulting Size of Time Window: 565.0108759 fs
- Resulting Samples: 29

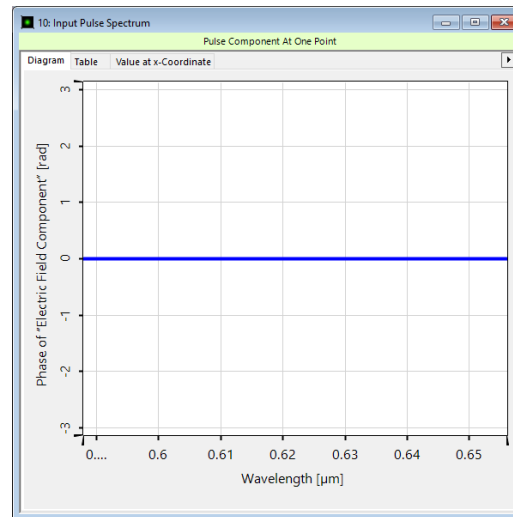
OK Cancel Help

The input pulse can be defined as a Gaussian Pulse Spectrum, via *Source > Gaussian Pulse Spectrum*, which is intended to generate an ultra-short pulse with a Gaussian envelope. As a result, you obtain a spectrum with a Gaussian shape if the amplitudes are plotted over frequency.

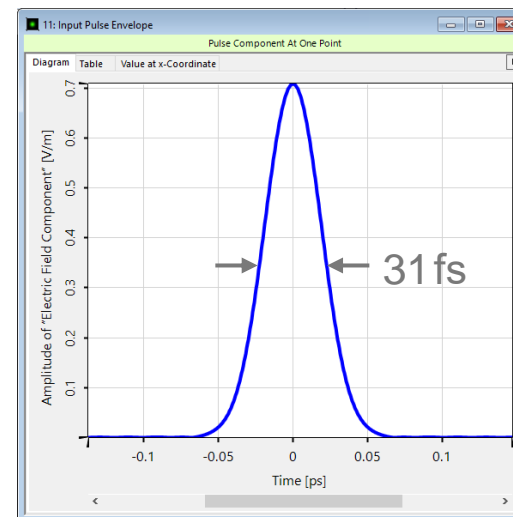
spectrum domain (amplitude)



spectrum domain (phase)

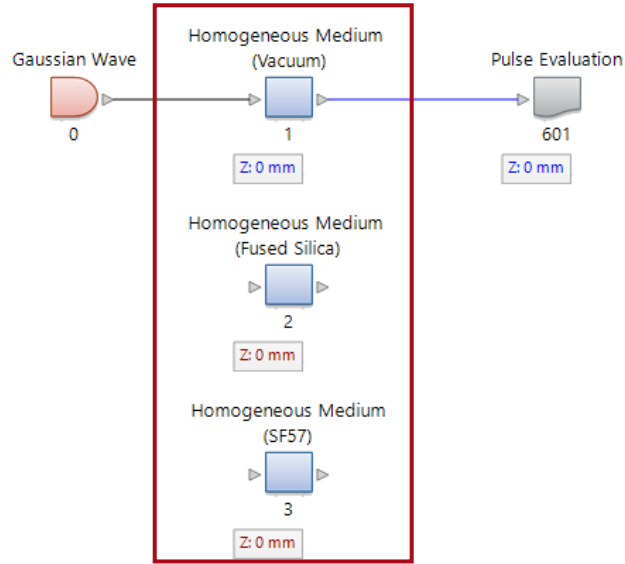


time domain  
(squared amplitude)



Constant phase over wavelength implies transform-limited pulse, with the minimum possible temporal duration.

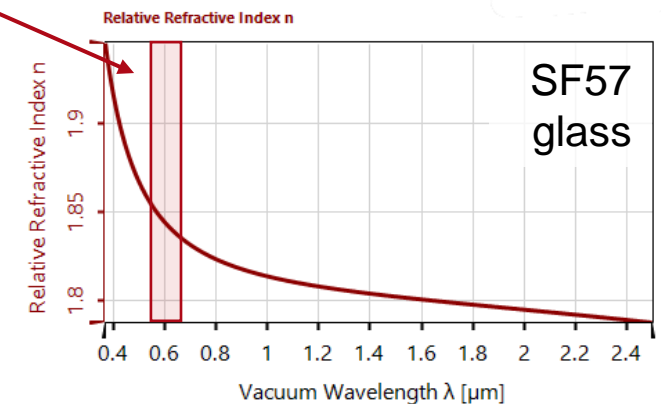
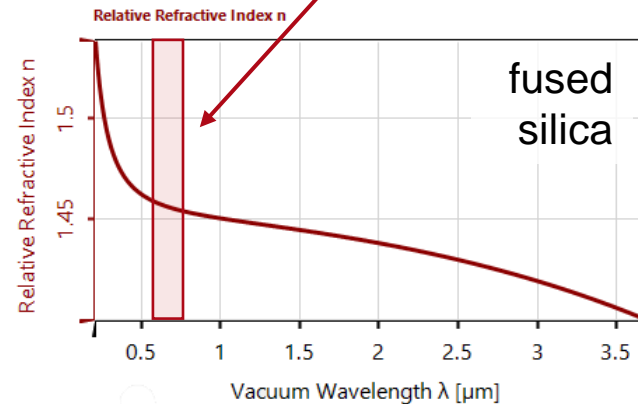
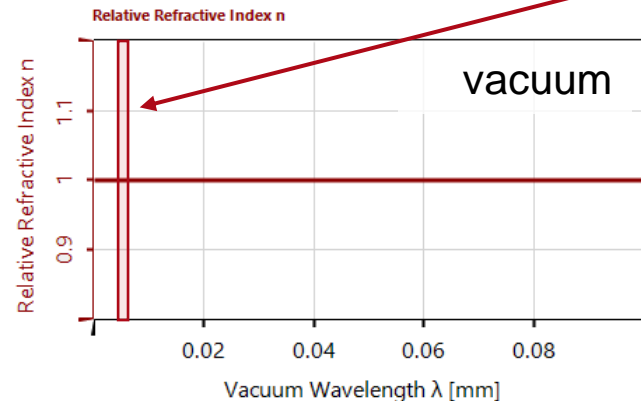
# System Building Blocks – Components



The dispersion properties of different materials are listed in the table. In this example, the homogeneous media are modeled by a *Lens System* with a block of material sandwiched between two plane interfaces.

	vacuum	fused silica	SF57
$n$ @ 588nm	1	1.4585	1.8466
$n$ @ 653nm	1	1.4565	1.8369
$\Delta n$ (588~653nm)	0	$2.0 \times 10^{-3}$	$9.1 \times 10^{-3}$

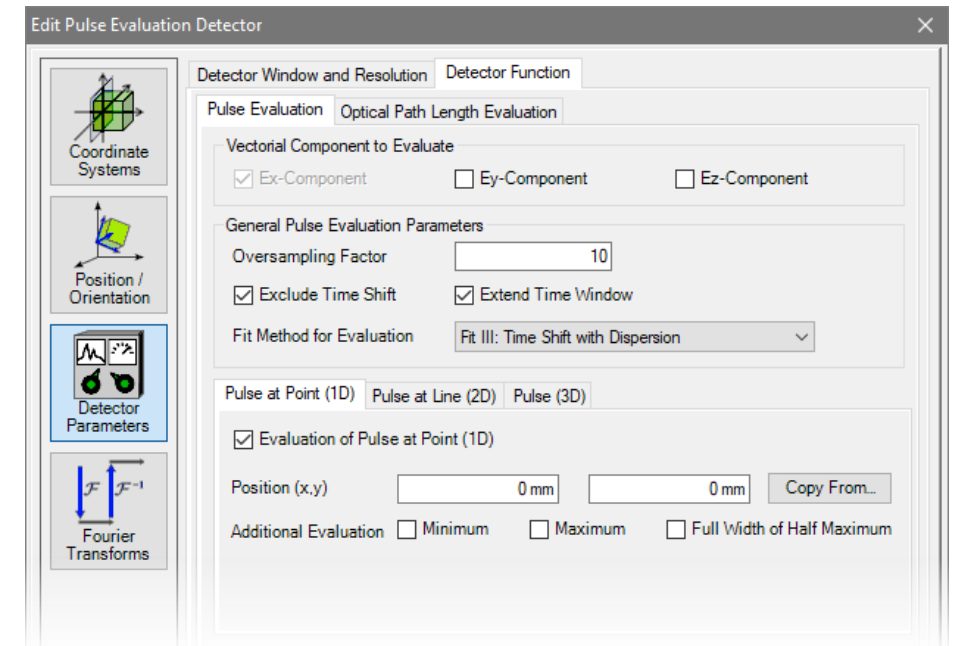
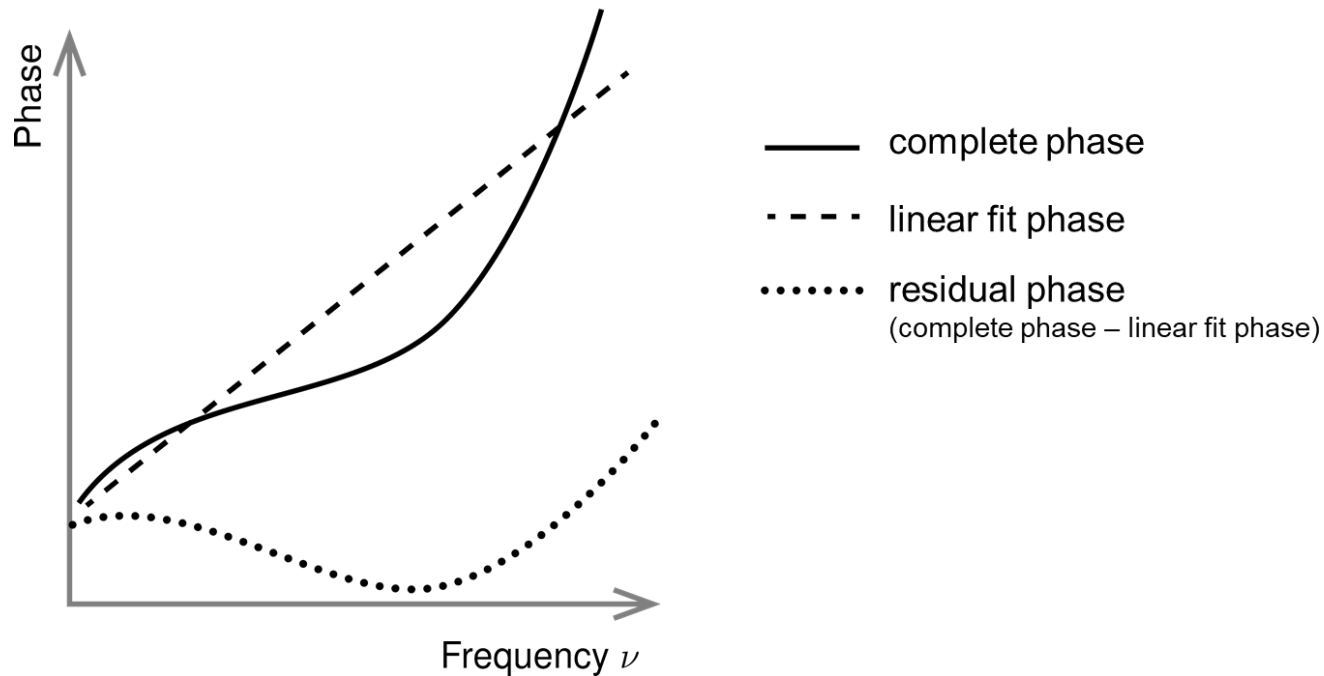
pulse spectrum range from 588nm to 653nm



# System Building Blocks – Detectors

The *Pulse Evaluation Detector*, used in this example, automatically calculates the electromagnetic field in wavelength and time domain at a predefined point.

- Complete phase vs. frequency can be analyzed at a given spatial position.
- A linear fitting of the phase as a function of frequency is always strong and therefore dominates the complete phase, but only contains information about the temporal shift. Besides, a strong linear phase leads to a high number of sampling points.
- Thus, the residual phase (extracting a linear fit from the complete phase) is evaluated, which determines the temporal pulse profile with lower numerical effort.

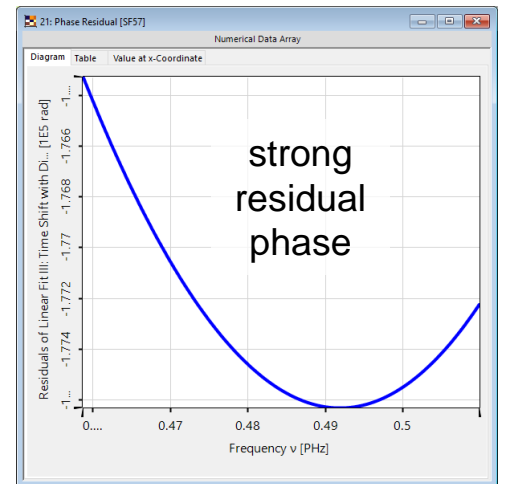
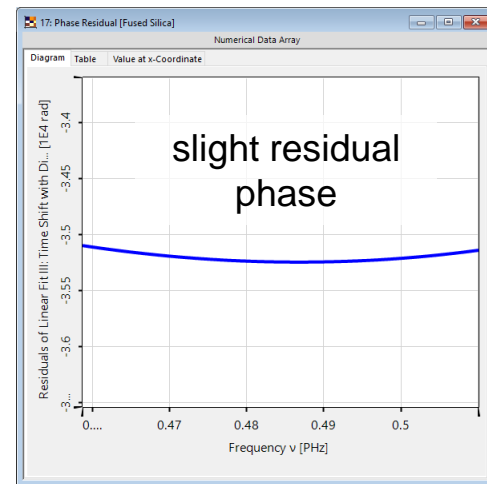
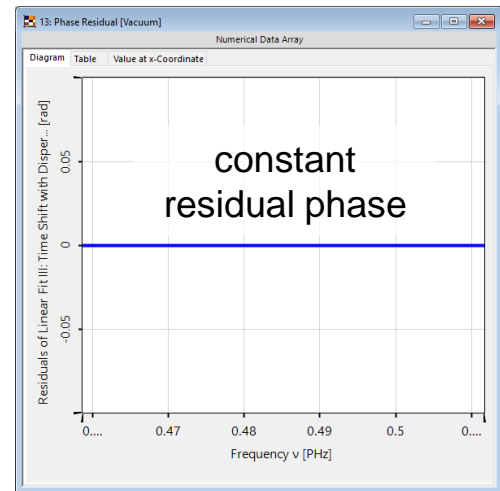
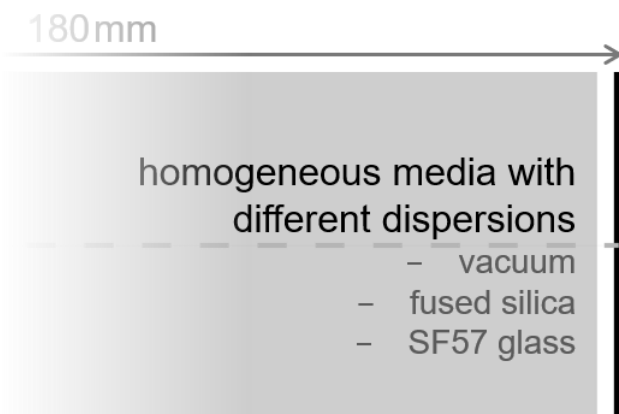
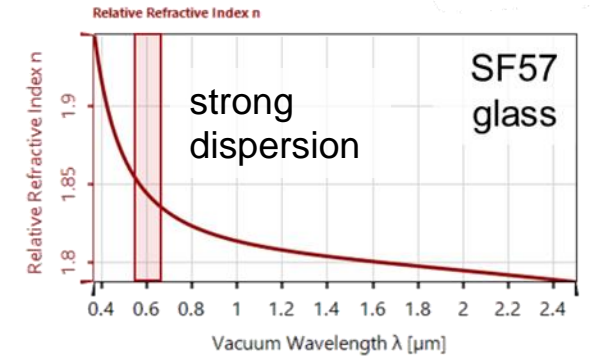
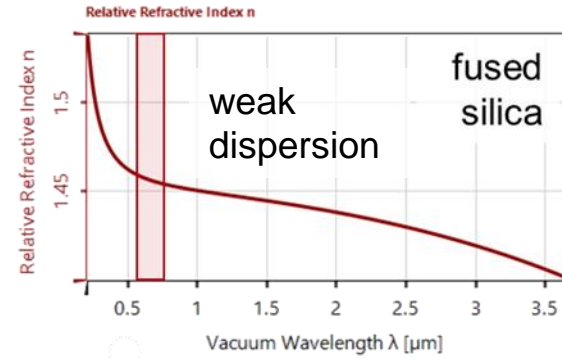
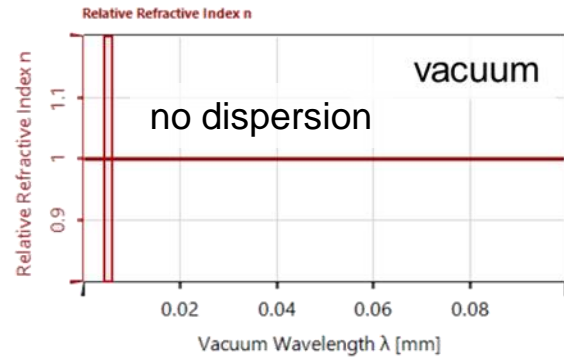


# Modeling Summary – Components...



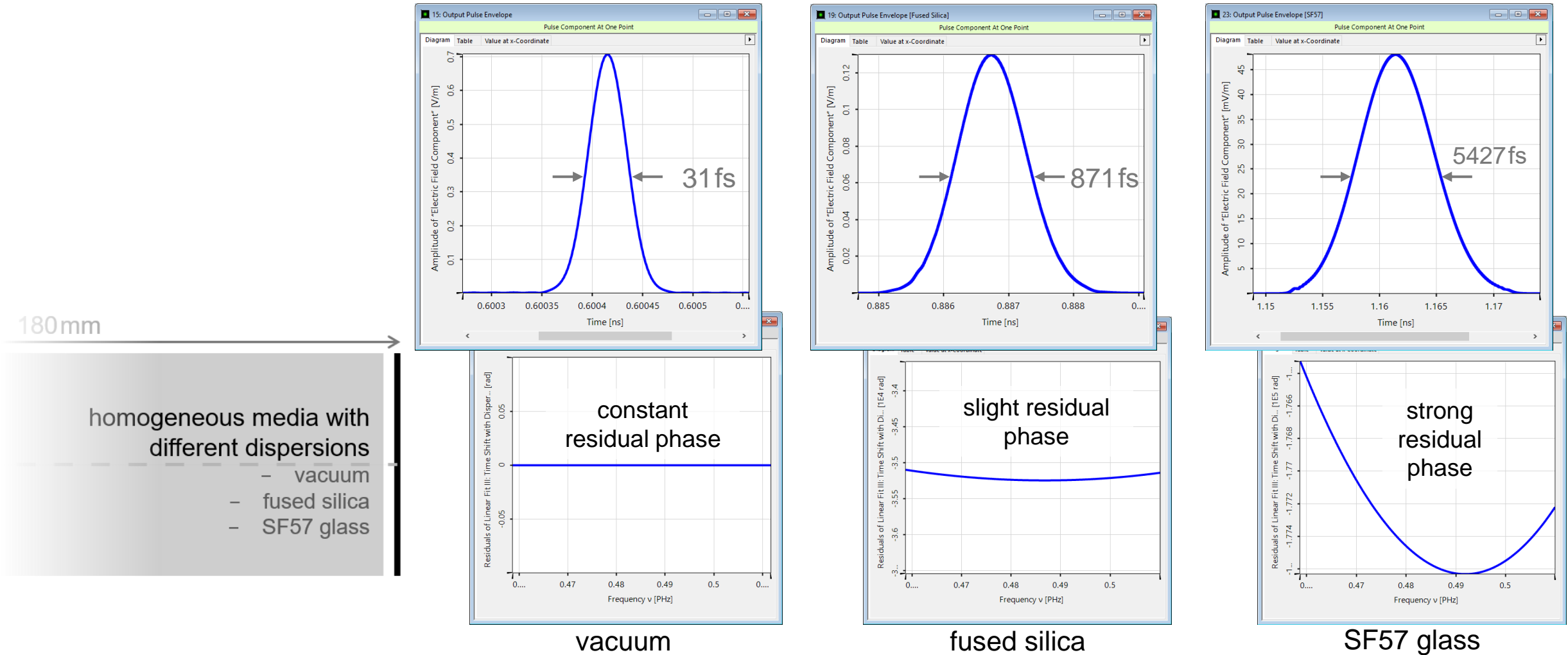
#	... of Optical System	... in VirtualLab Fusion	Model/Method/Algorithm
1	source	<i>Gaussian Wave source</i>	temporal & spatial Gaussian function
2	homogeneous material	<i>Lens System</i>	LPIA & free space propagation
3	detector	<i>Pulse Evaluation Detector</i>	spectrum & temporal shape

# Output Pulse – Residual Phase over Frequency

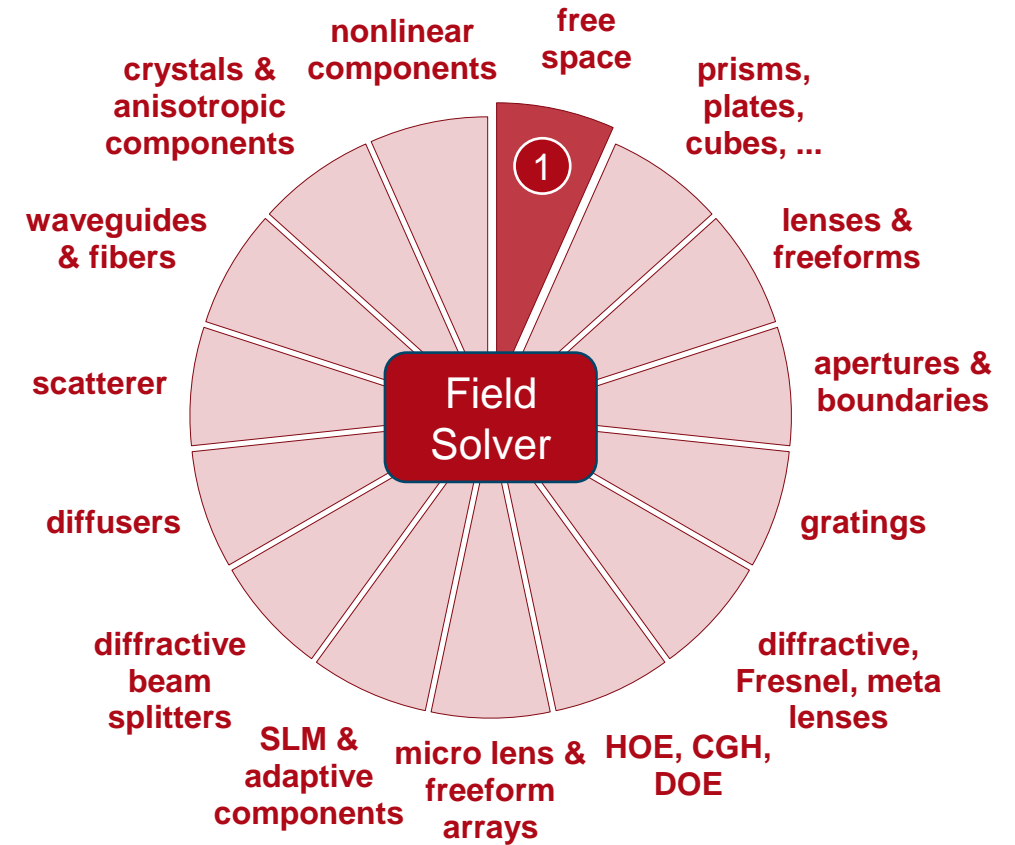
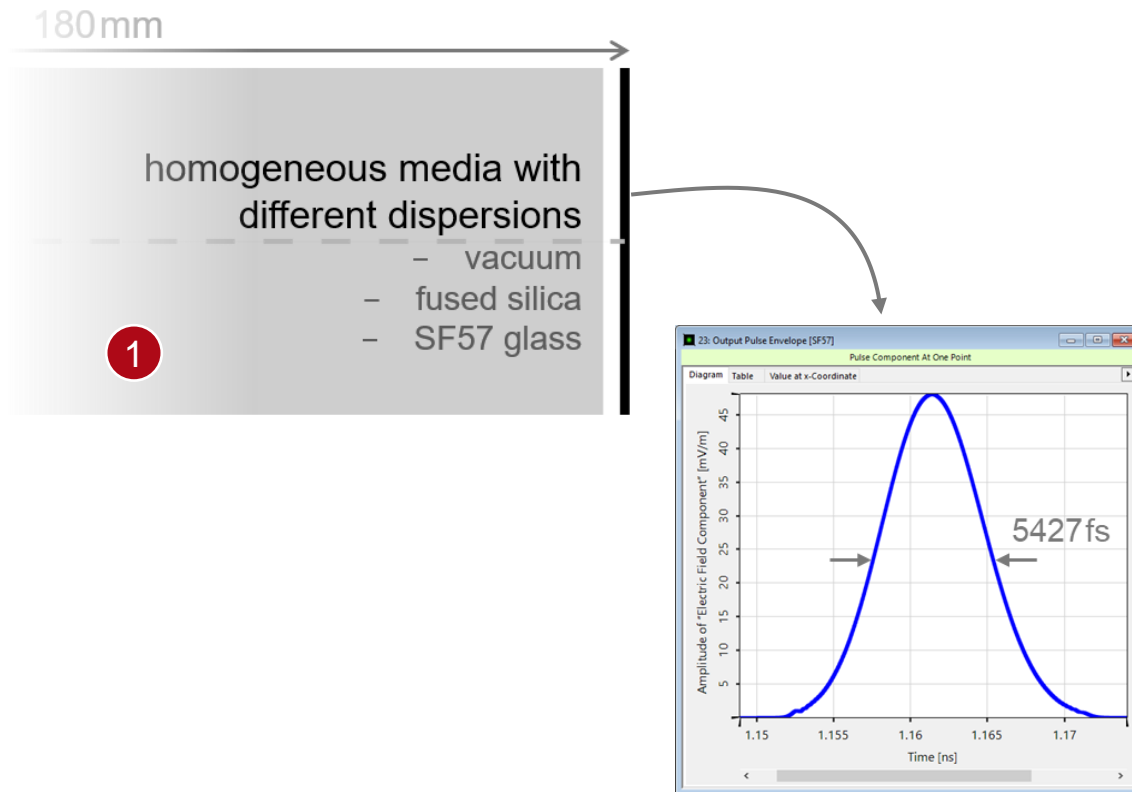




# Output Pulse – Temporal Pulse Envelope



# VirtualLab Fusion Technologies



# Document Information

title	Pulse Broadening in Dispersive Media
document code	USP.0001
document version	2.0
software edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#"><u>Focusing of Femtosecond Pulse by using a High-NA Off-Axis Parabolic Mirror</u></a></li><li>- <a href="#"><u>Pulse Focusing with High-NA Lens</u></a></li><li>- <a href="#"><u>Grating Stretcher for Ultrashort Pulses</u></a></li></ul>