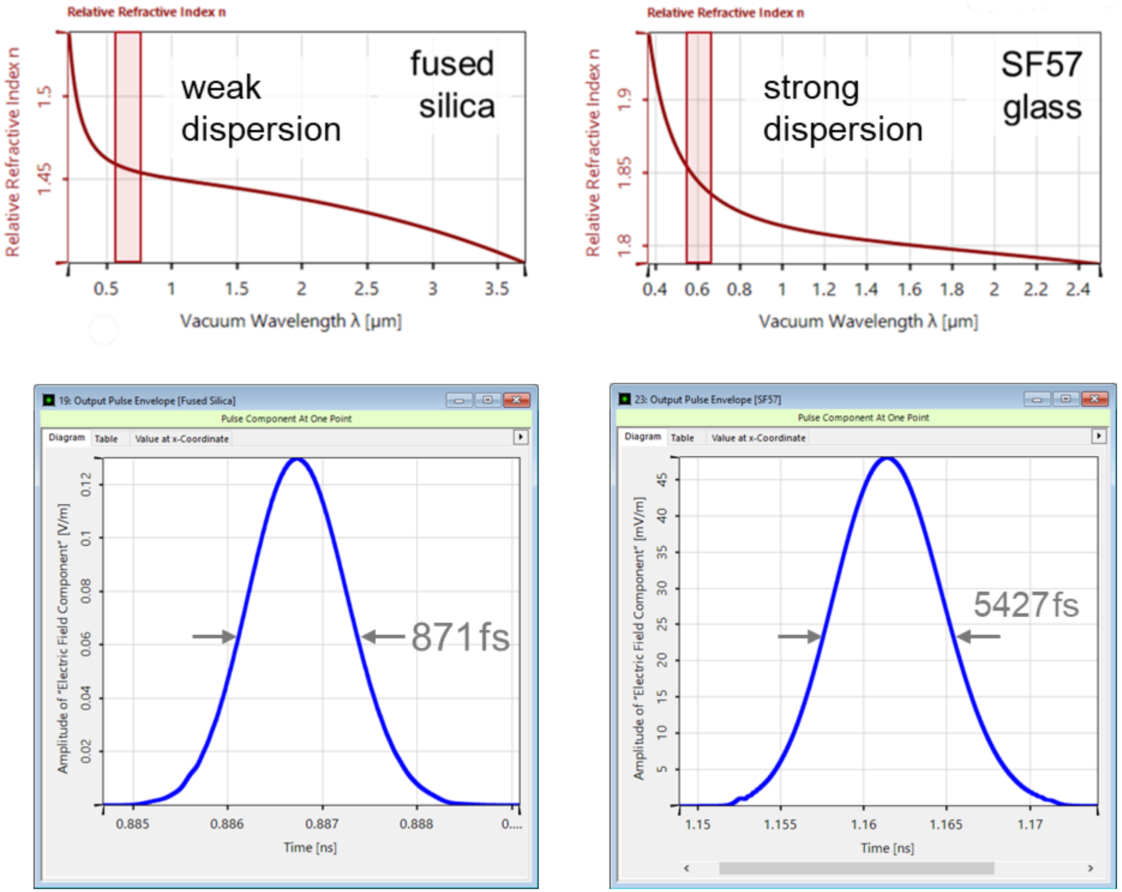
Pulse Broadening in Dispersive Media

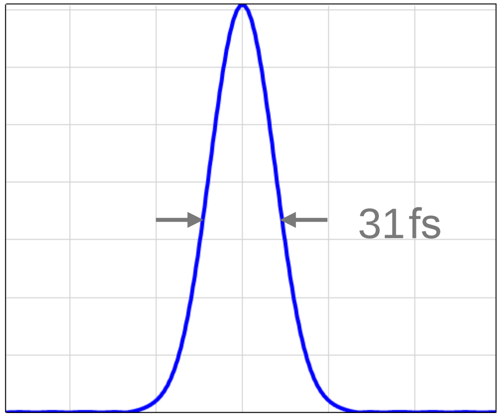
Abstract



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

180 mm



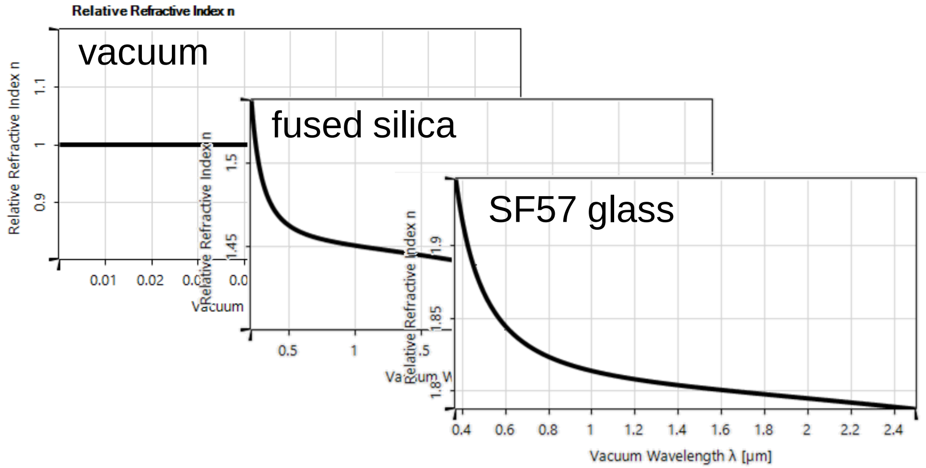
input pulse

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

homogeneous media with different dispersion properties

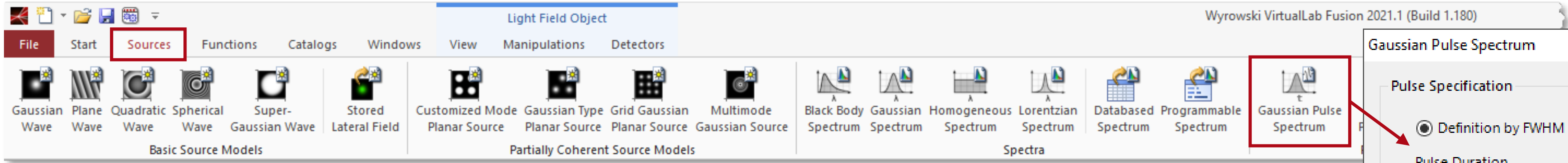
- vacuum
- fused silica
- SF57 glass

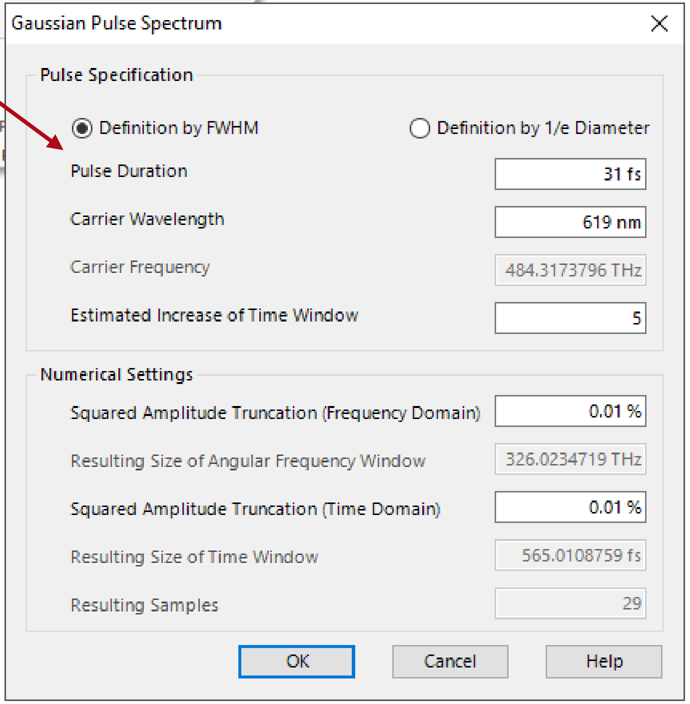
?



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

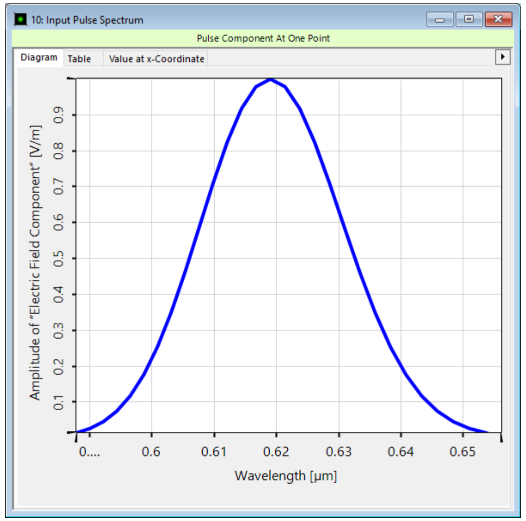
System Building Blocks – Source



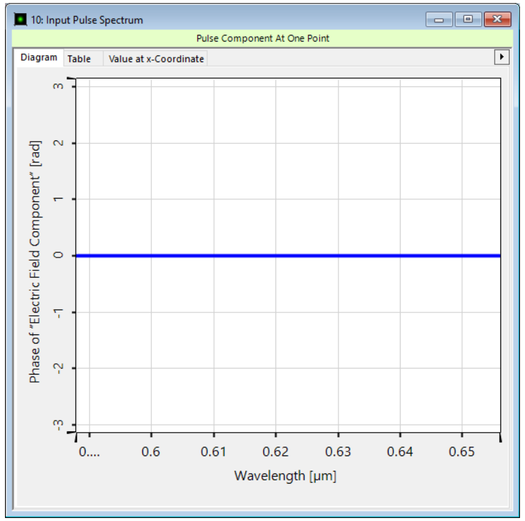


The input pulse can be defined as a Gaussian Pulse Spectrum, via *Source* > *Gaussian Pulse Spectrum*, which is intended to generate an ultra-short pulse with a Gaussian envelope. As a result, you obtain a spectrum with a Gaussian shape if the amplitudes are plotted over frequency.

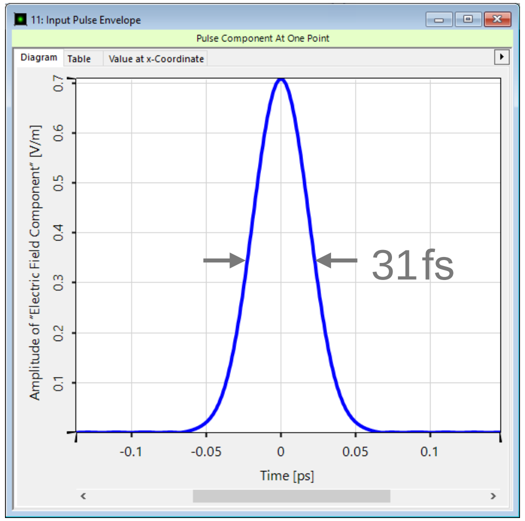
spectrum domain (amplitude)



spectrum domain (phase)

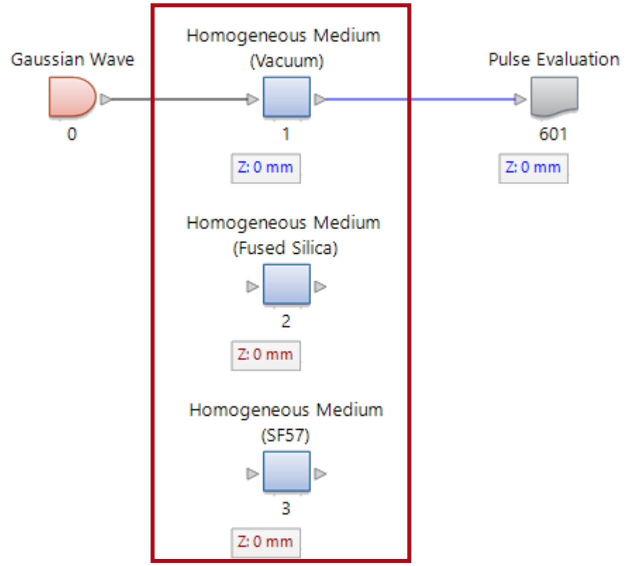


time domain
(squared amplitude)



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

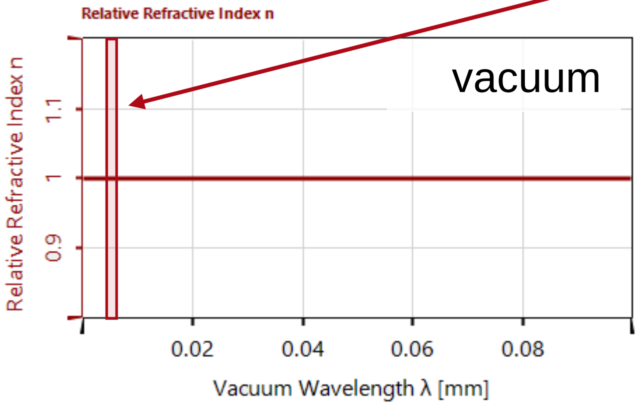
System Building Blocks – Components

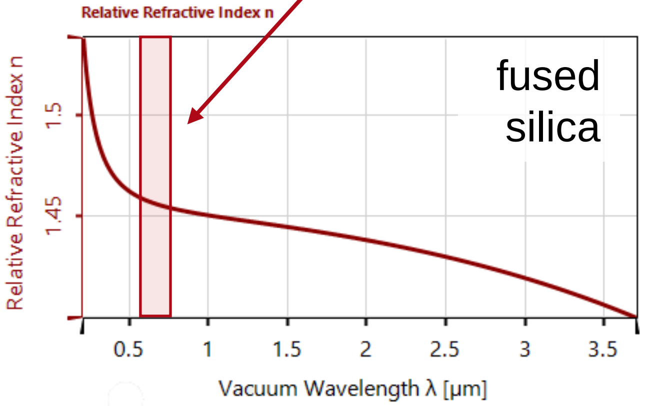


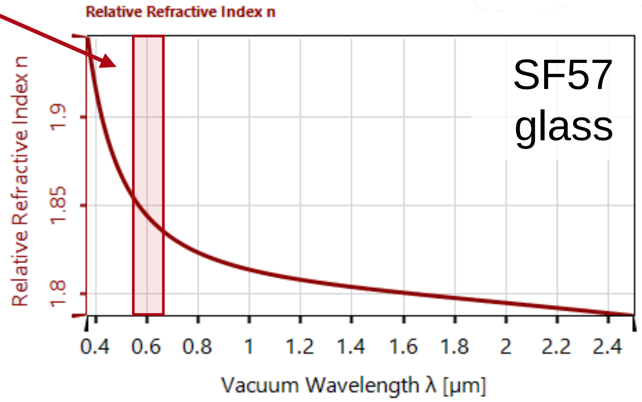
The dispersion properties of different materials are listed in the table. In this example, the homogeneous media are modeled by a *Lens System* with a block of material sandwiched between two plane interfaces.

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

pulse specturm range from 588 nm to 653 nm



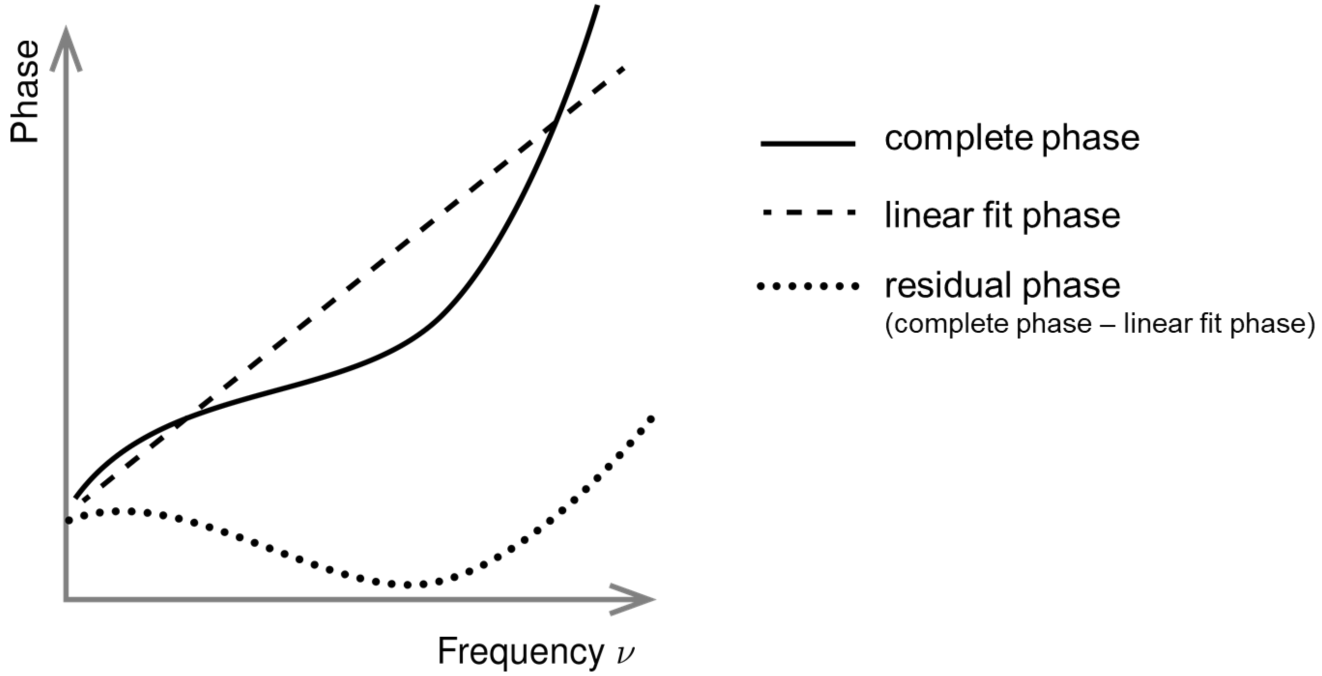


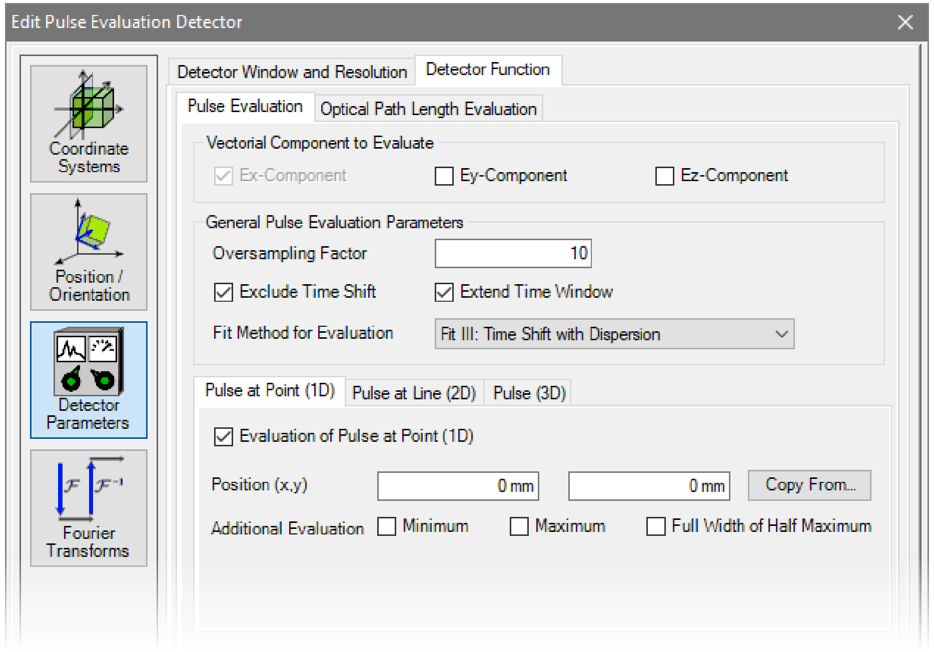


System Building Blocks – Detectors

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.

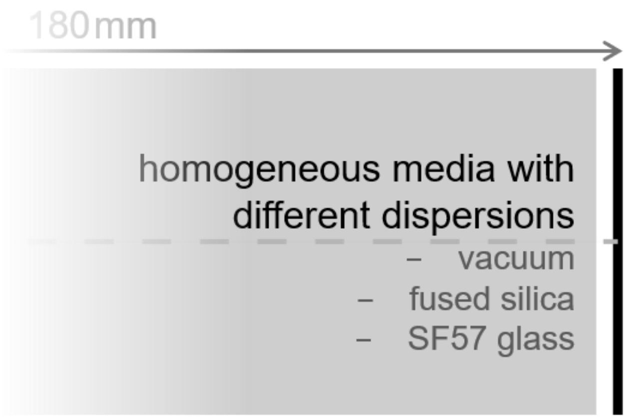


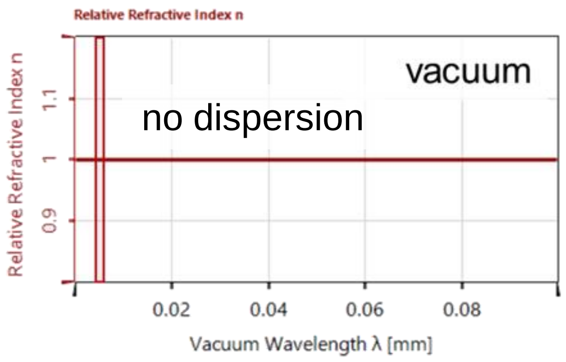


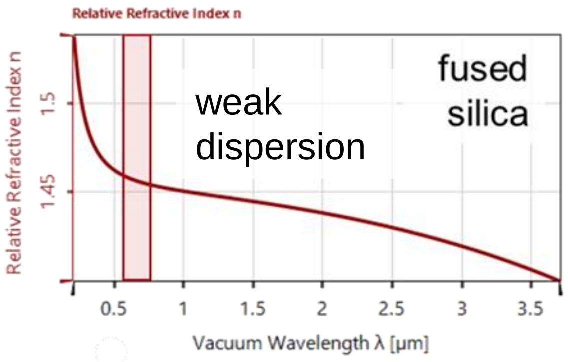
Modeling Summary – Components...

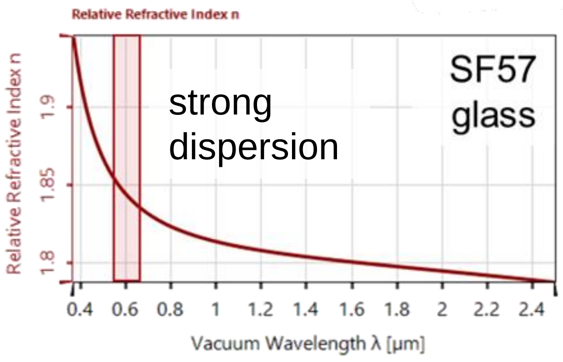
#	… of Optical System	… in VirtualLab Fusion	Model/Method/Algorithm
1	source	*Gaussian Wave* source	temporal & spatial Gaussian function
2	homogeneous material	*Lens System*	LPIA & free space propagation
3	detector	*Pulse Evaluation Detector*	spectrum & temporal shape

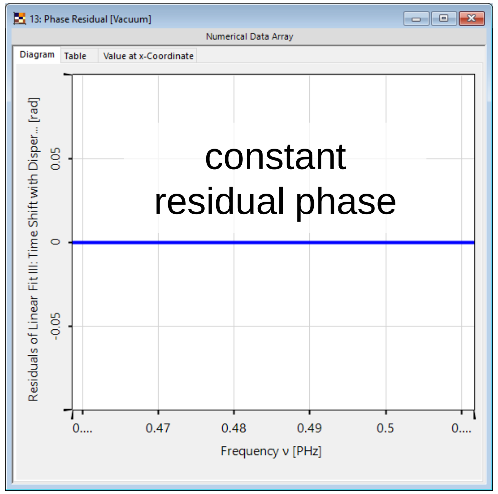
Output Pulse – Residual Phase over Frequency



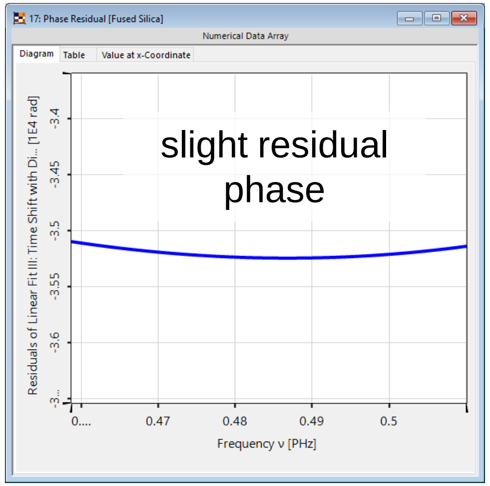




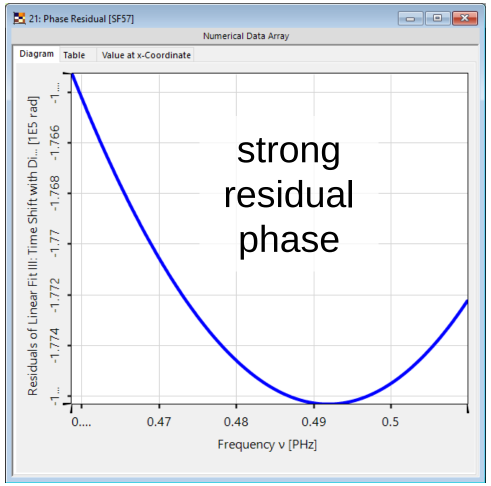




vacuum

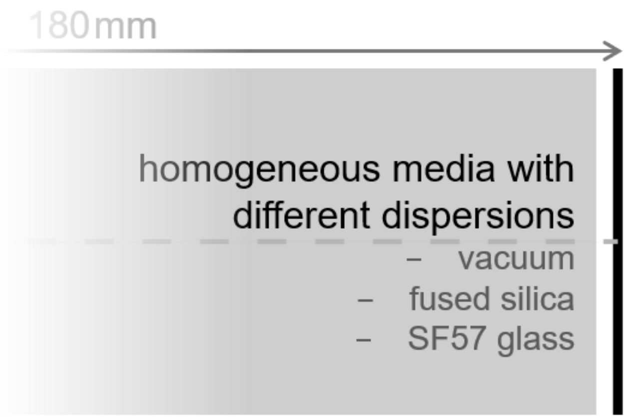


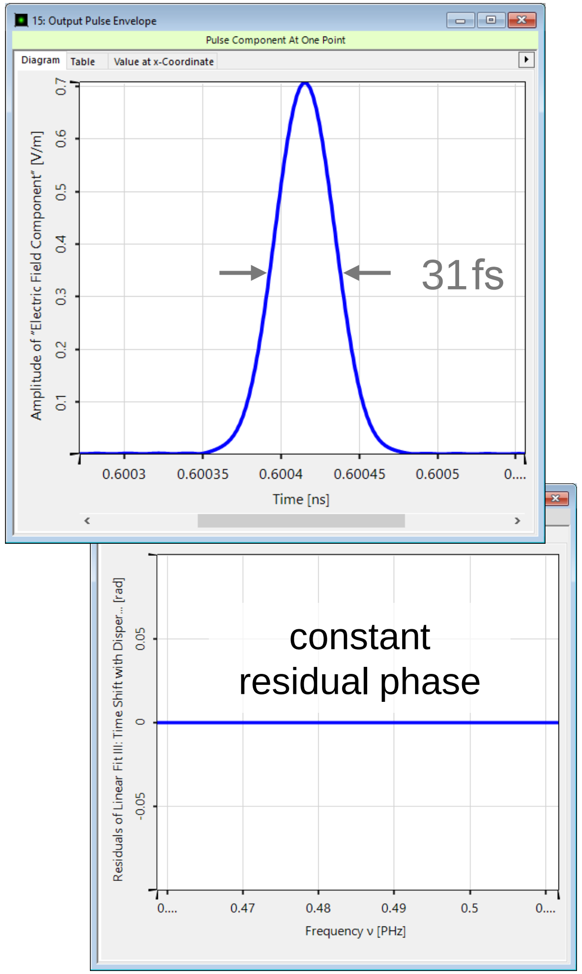
fused silica



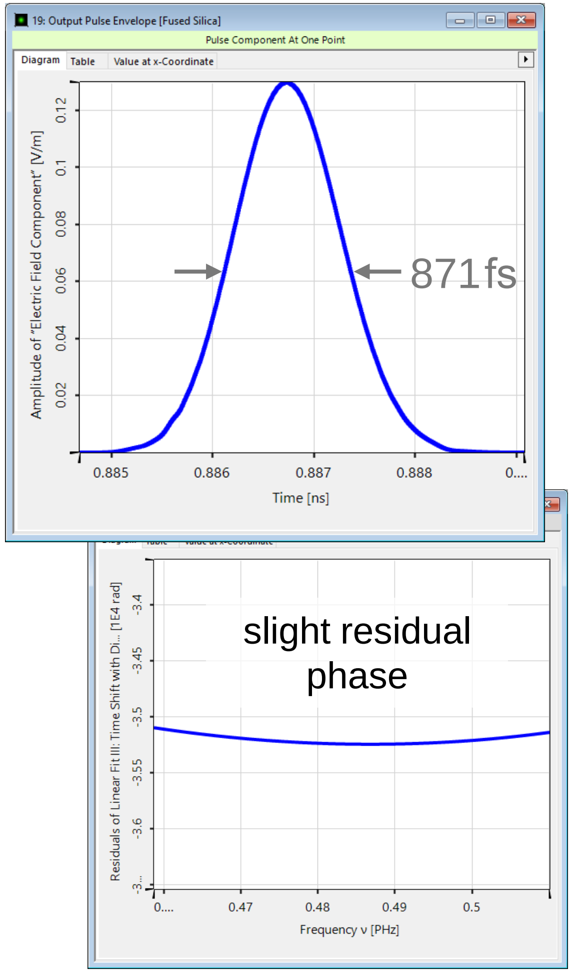
SF57 glass

Output Pulse – Temporal Pulse Envelope

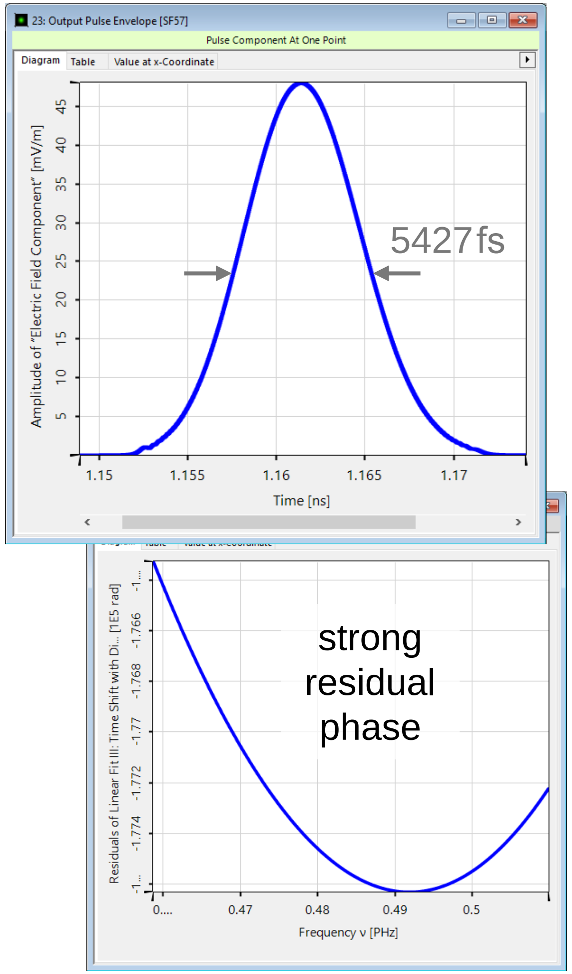




vacuum

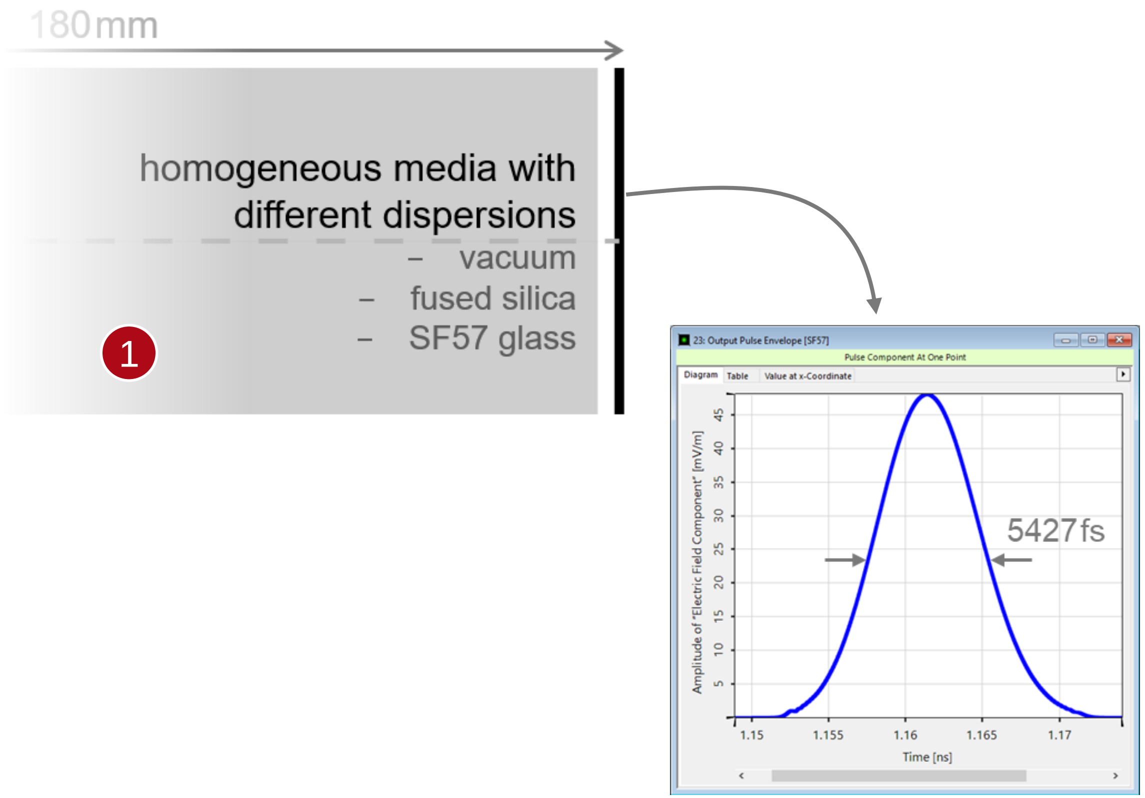


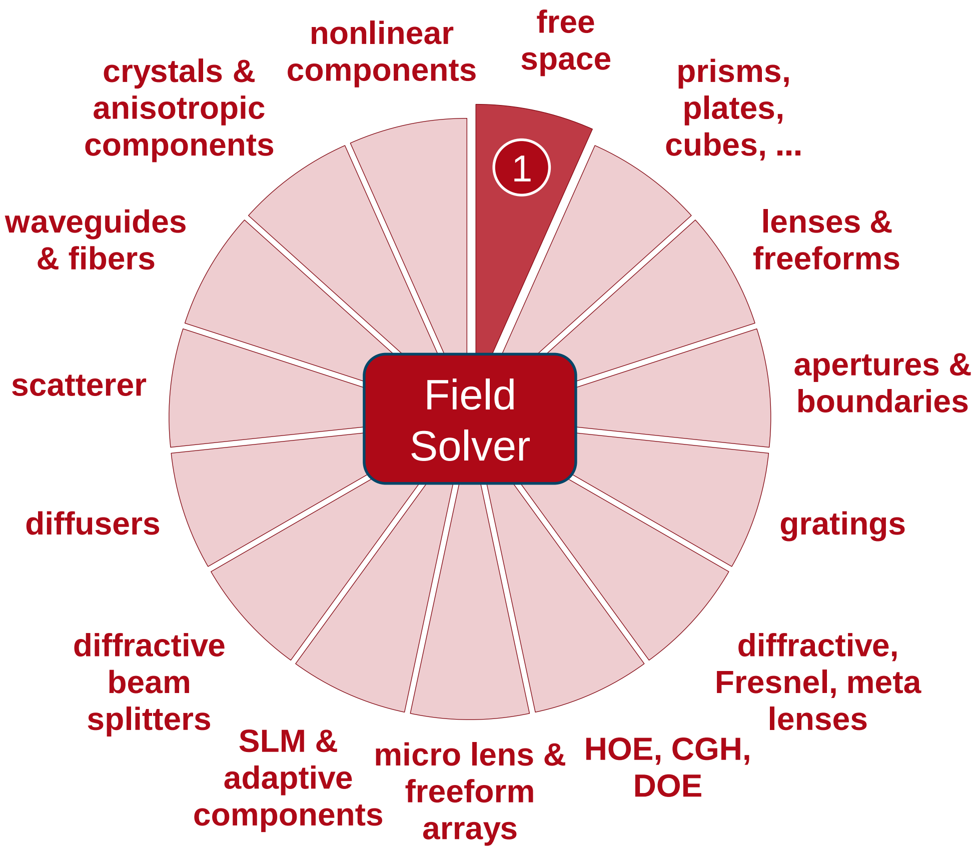
fused silica



SF57 glass

VirtualLab Fusion Technologies





Document Information

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further reading	- Focusing of Femtosecond Pulse by using a High-NA Off-Axis Parabolic Mirror - Pulse Focusing with High-NA Lens - Grating Stretcher for Ultrashort Pulses