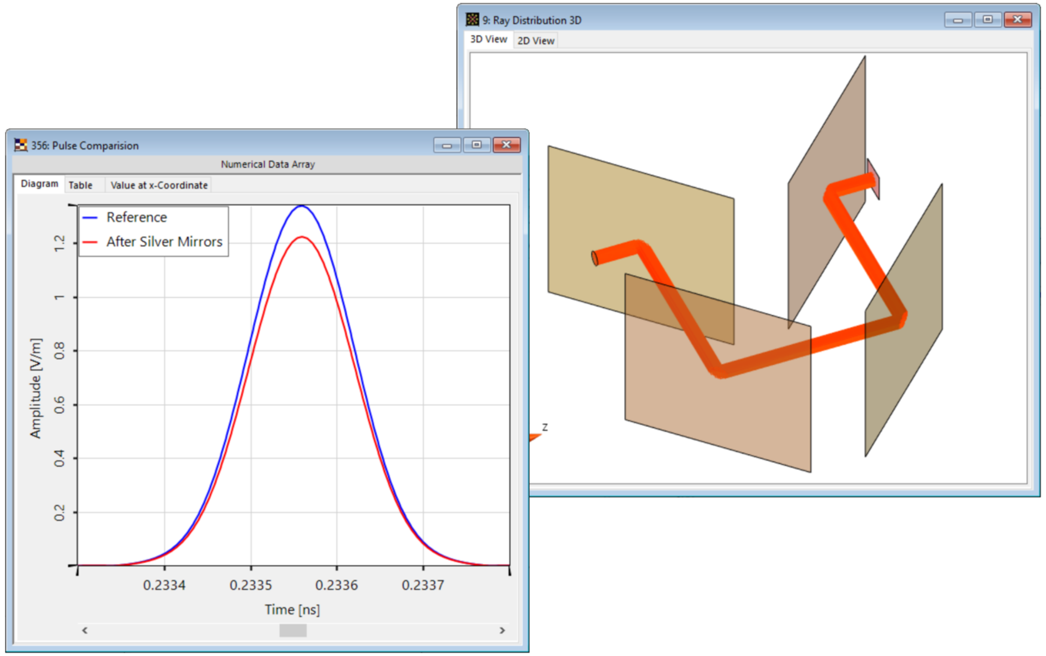
Effects of Mirror Coating on Pulse Characteristics

Abstract

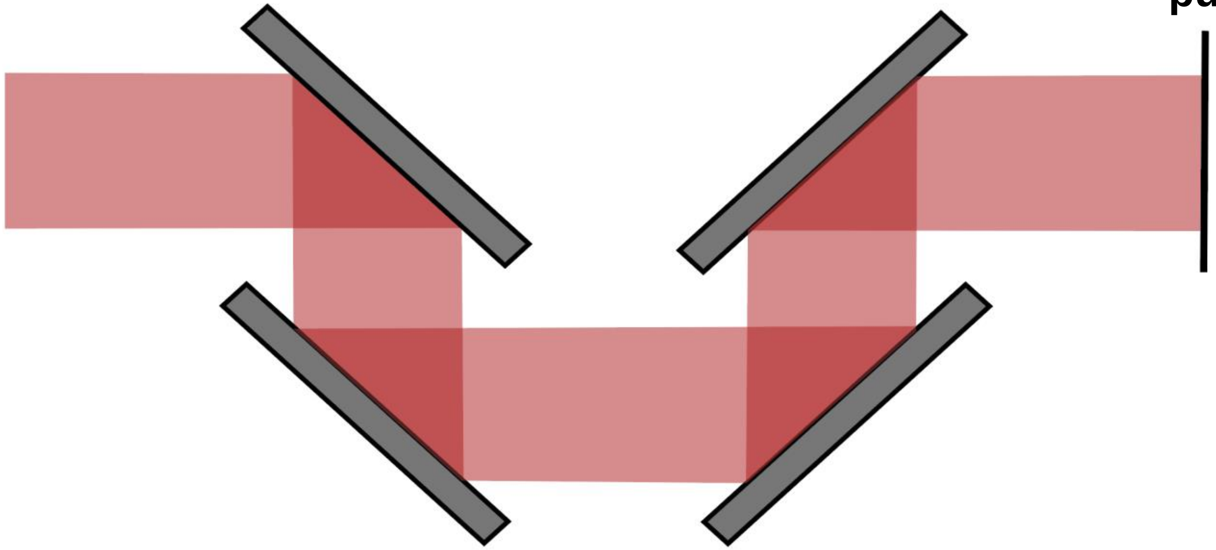


With the advent of new technologies in the area of ultrafast optics, it has become an ever more important task to deliver ultrashort pulses to their target. It is common, to use mirrors with metallic or dielectric layer-based coatings for that purpose. Therefore, an investigation of occurring effects on the characteristics of the propagated pulse which are introduced by the chosen type of mirror, are of particular interest. In this use case, we illustrate this effect by comparing the pulse propagation in systems with silver mirrors and high-reflection (HR) dielectric coated mirrors as examples.

Modeling Task

gaussian wave (spatial)
- 2 mm × 2 mm diameter

gaussian pulse (temporal)
- 632.8 nm central wavelength
- 30 fs & 100 fs pulse duration

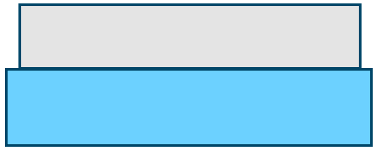


pulse detector
- temporal envelope at point
- peak amplitude
- full width half maximum (FWHM)

<u>task</u>
Investigate effects of different mirror types on pulse parameters (peak amplitude and pulse duration) after propagation through the system.

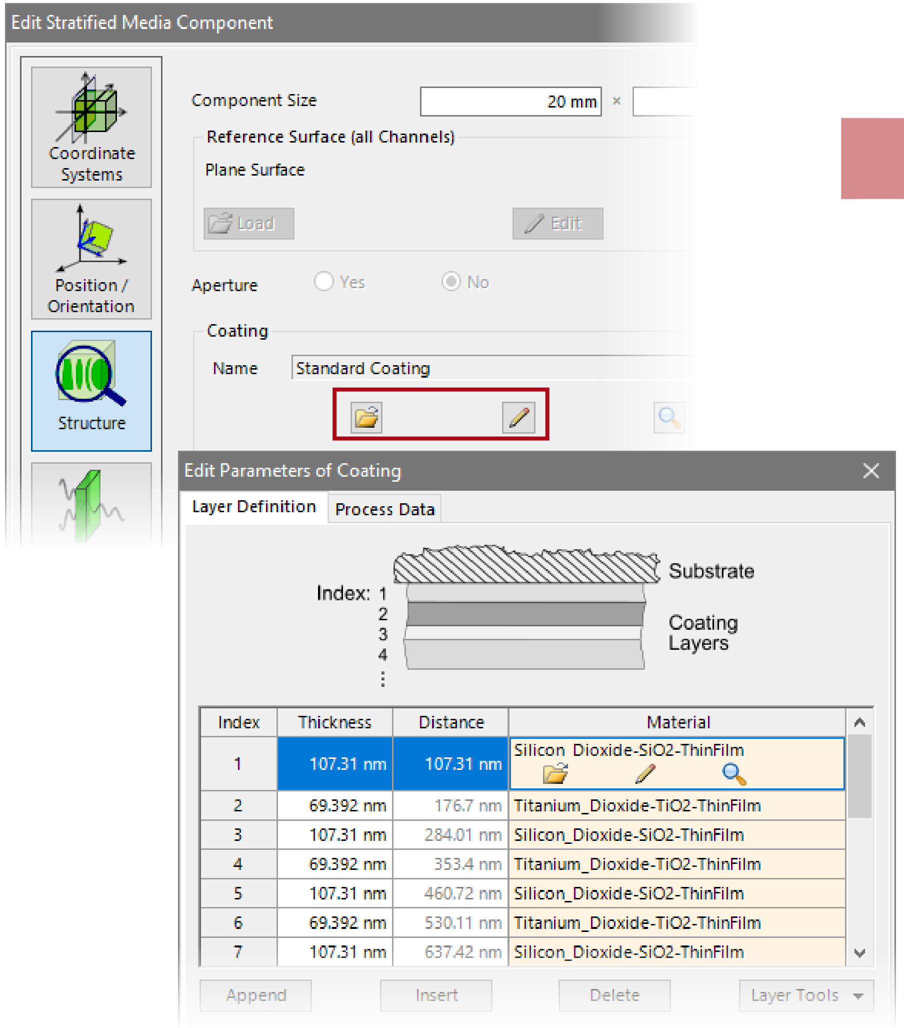
mirrors:

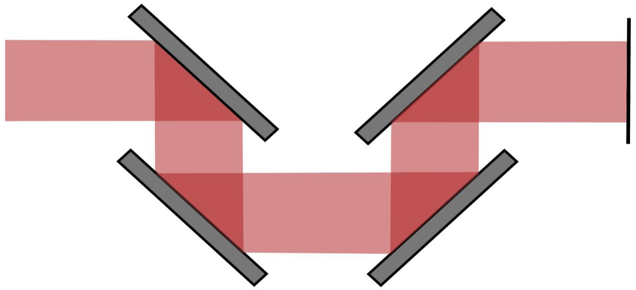
a) fused silica with silver coating



b) fused silica with high-reflective (HR) dielectric coating (alternating titanium and silicon dioxide)

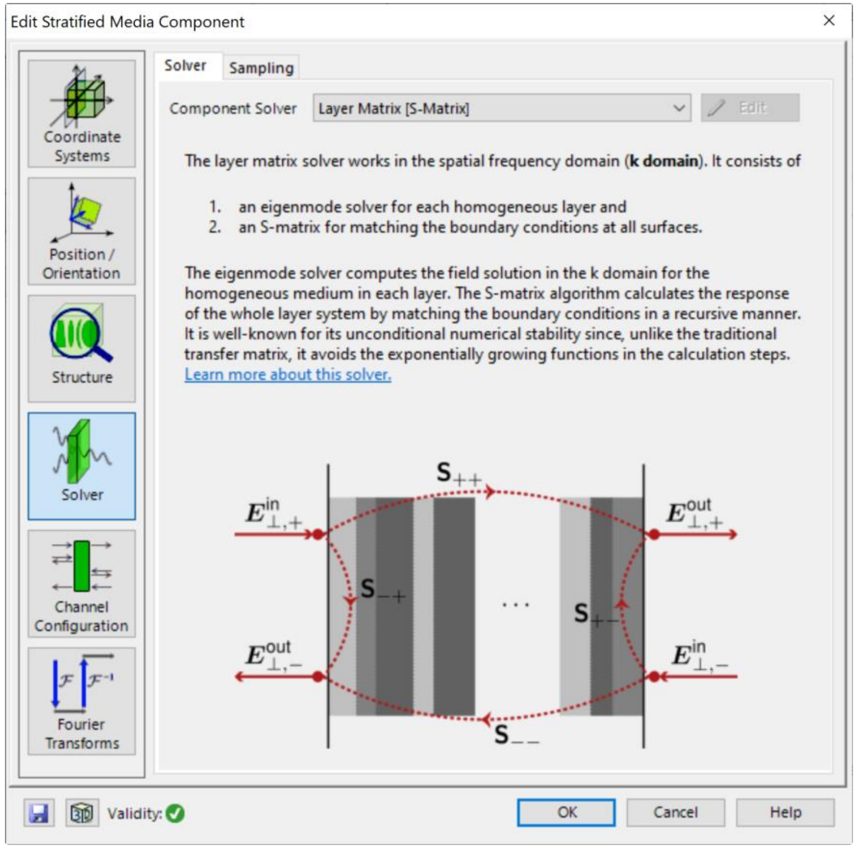
System Building Blocks – Components



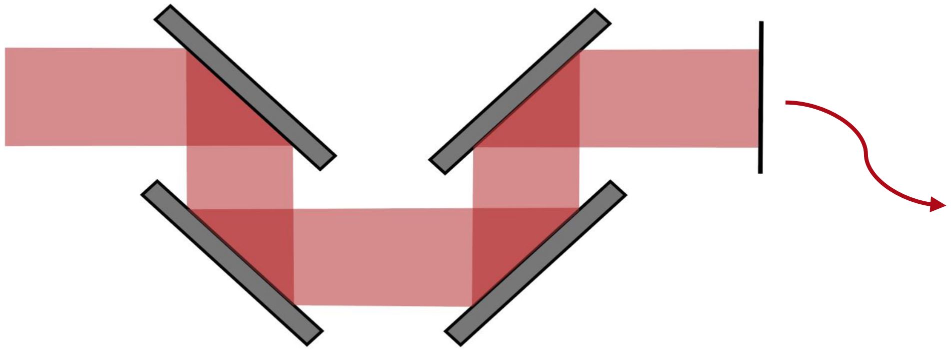


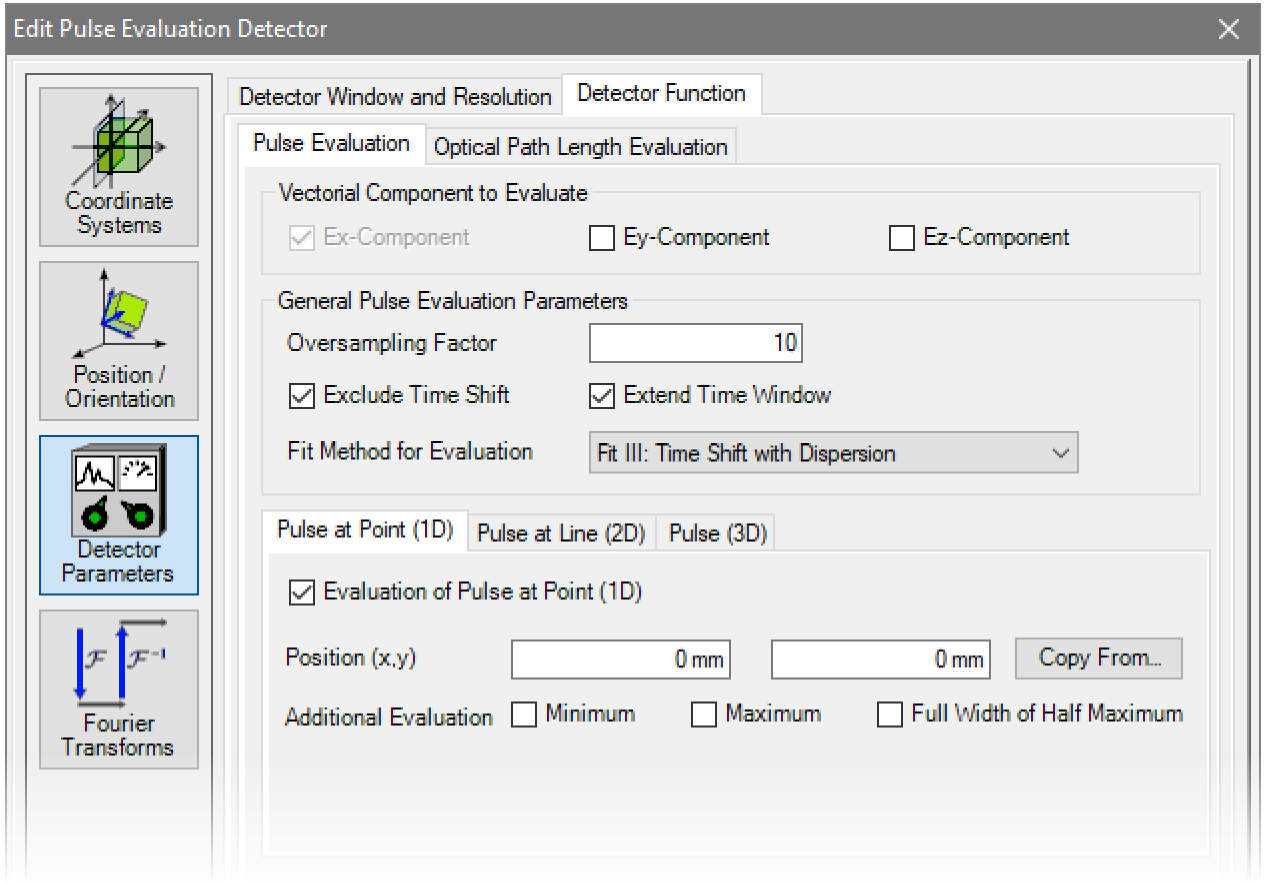
For the coated mirrors we employ the *Stratified Media Component*, since it provides a fast solution for *x*, *y*-invariant layer stacks. An HR dielectric coating, consisting of alternating layers of titanium dioxide (TiO_2) and silicon dioxide (SiO_2), is selected from the coating catalog of VirtualLab Fusion.

For the propagation through the component, we use the *Layer Matrix* field solver.



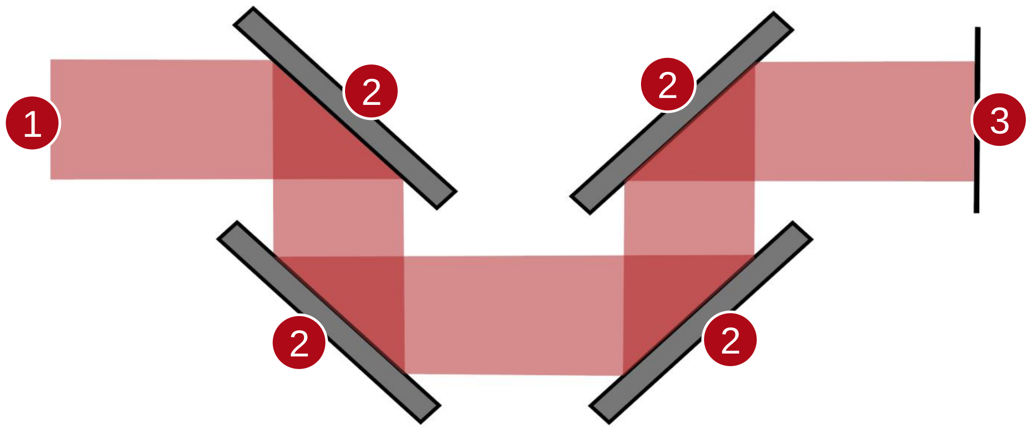
System Building Blocks – Detectors





The *Pulse Evaluation Detector* automatically calculates the electromagnetic field in wavelength and time domain at a given point, line, or plane for 1D, 2D or 3D evaluations, respectively.
It provides various output options, e.g. maximum or FWHM of the squared amplitude of the pulse.

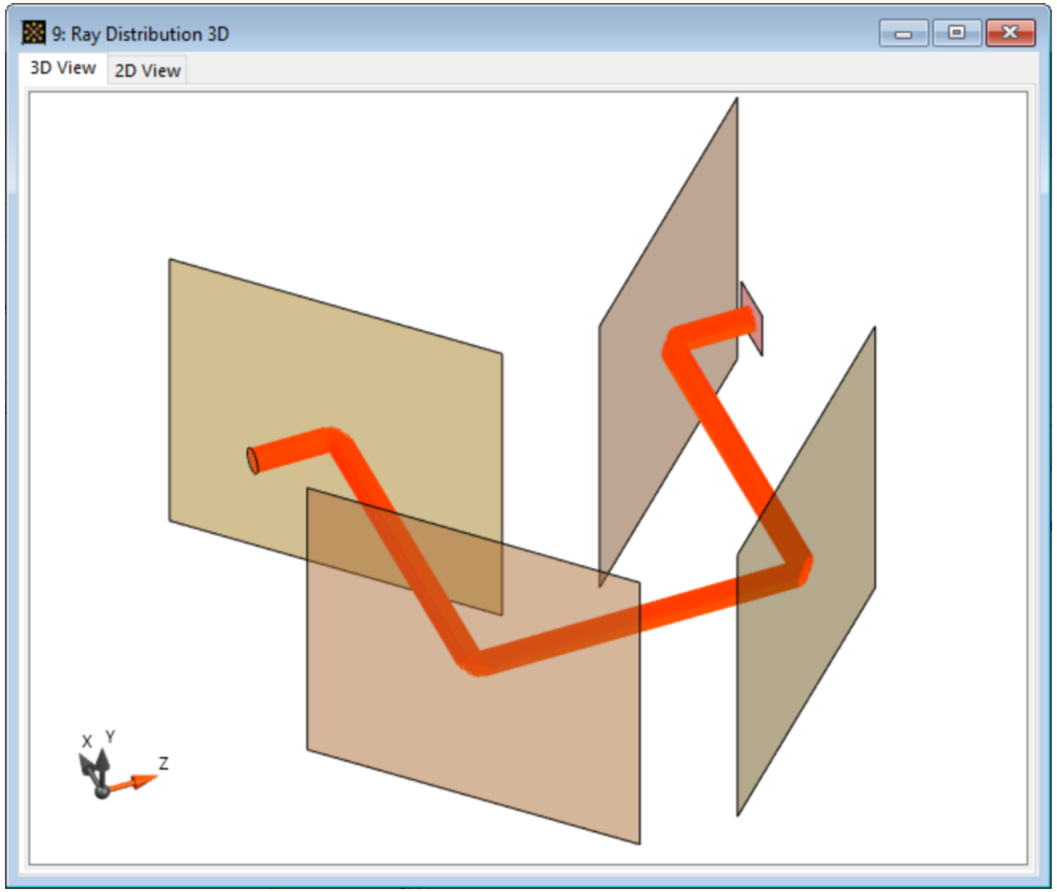
Summary – Components...

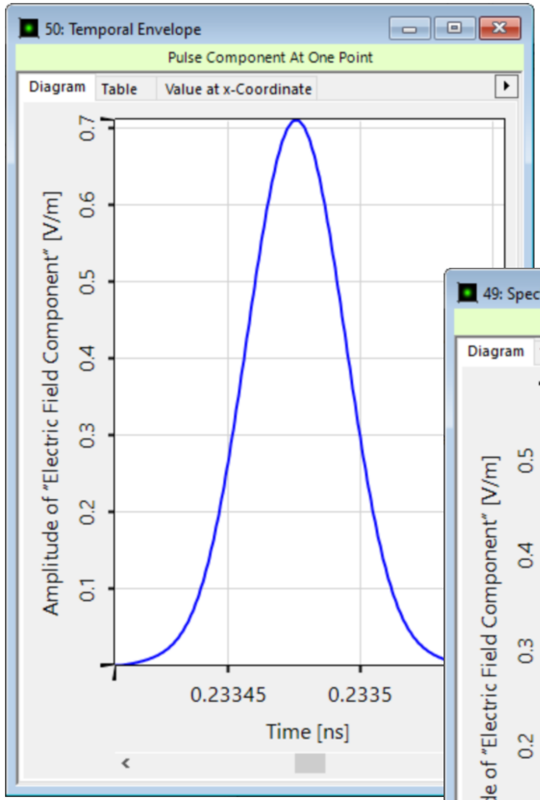


… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. source	*Plane Wave* source with *Gaussian Pulse Spectrum*	truncated ideal plane waves with Gaussian spectrum
2. mirror	*Stratified Media* component	layer matrix
3. detector	*Pulse Evaluation Detector*	spectrum & temporal shape

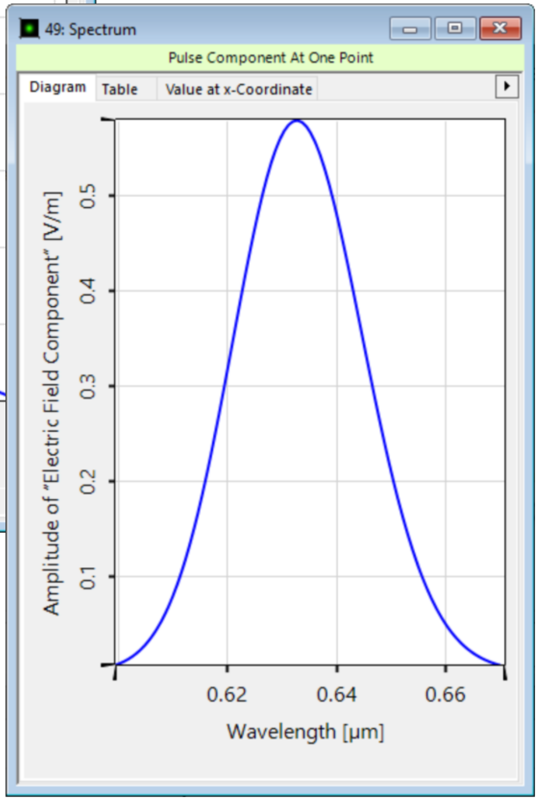
Ray & Field Tracing Result Impressions

visualization of System using 3D Ray Tracing

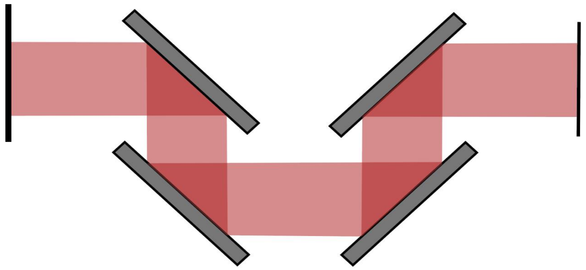




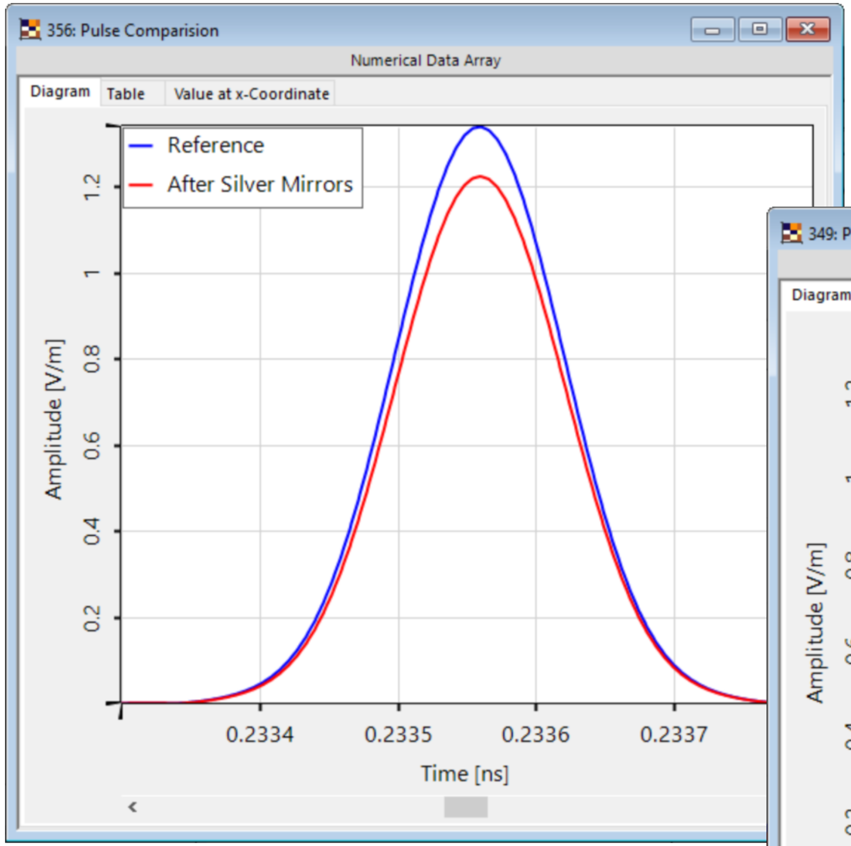
spectral and temporal form of the pulse at detector plane



Pulse Evaluations – Silver Mirror Amplitude

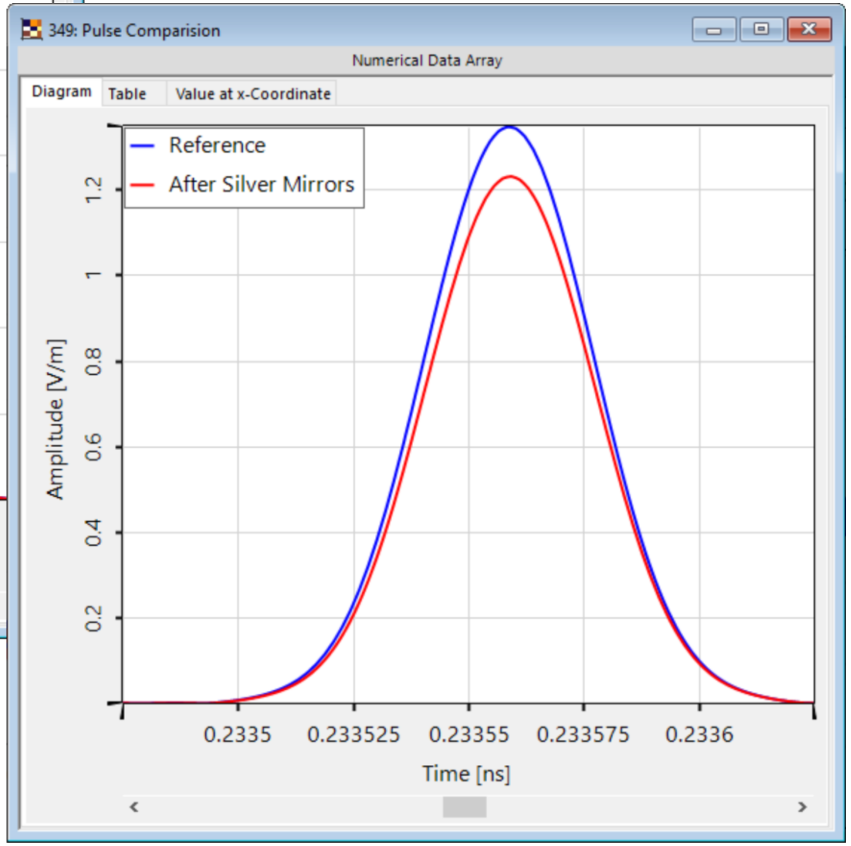


After reflection at four silver mirrors, the amplitude of the pulse decreases significantly. The decrease is proportional to the number of used mirrors.

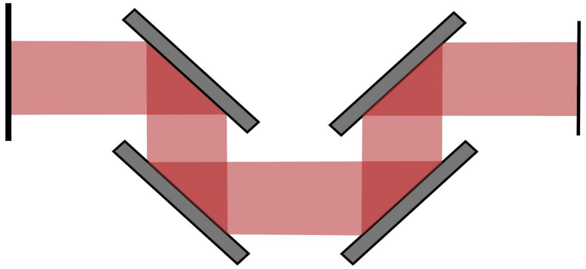


Comparison for 100fs pulse

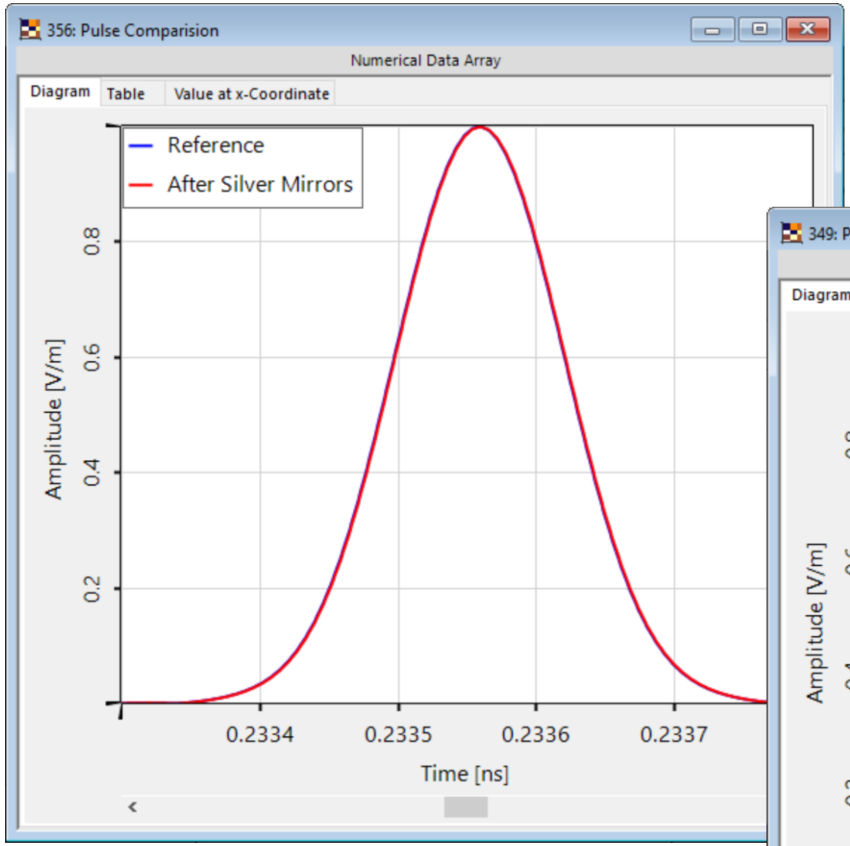
Comparison for 30fs pulse



Pulse Evaluations – Silver Mirror FWHM

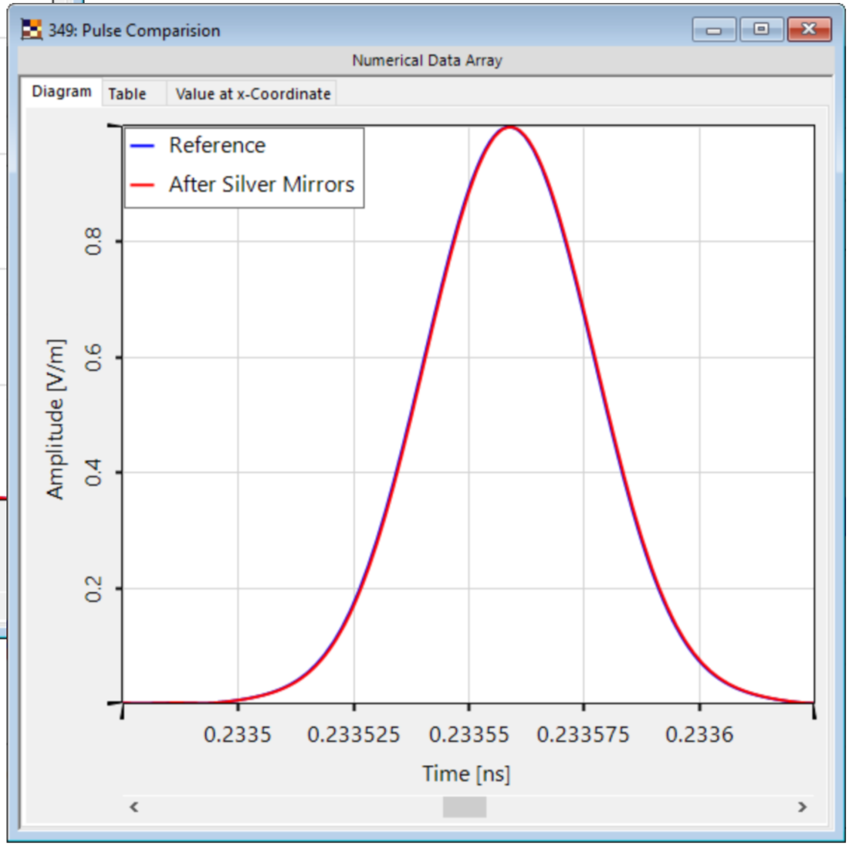


The pulse duration is stable after interacting with multiple silver-coated mirrors as metallic surfaces exhibit low dispersive effects over a wide range of frequencies (due to very shallow skin depth).



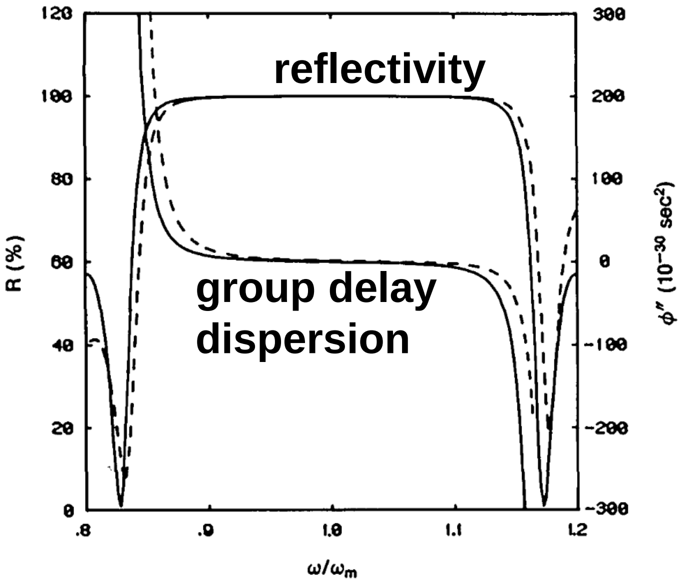
Comparison for 100fs pulse

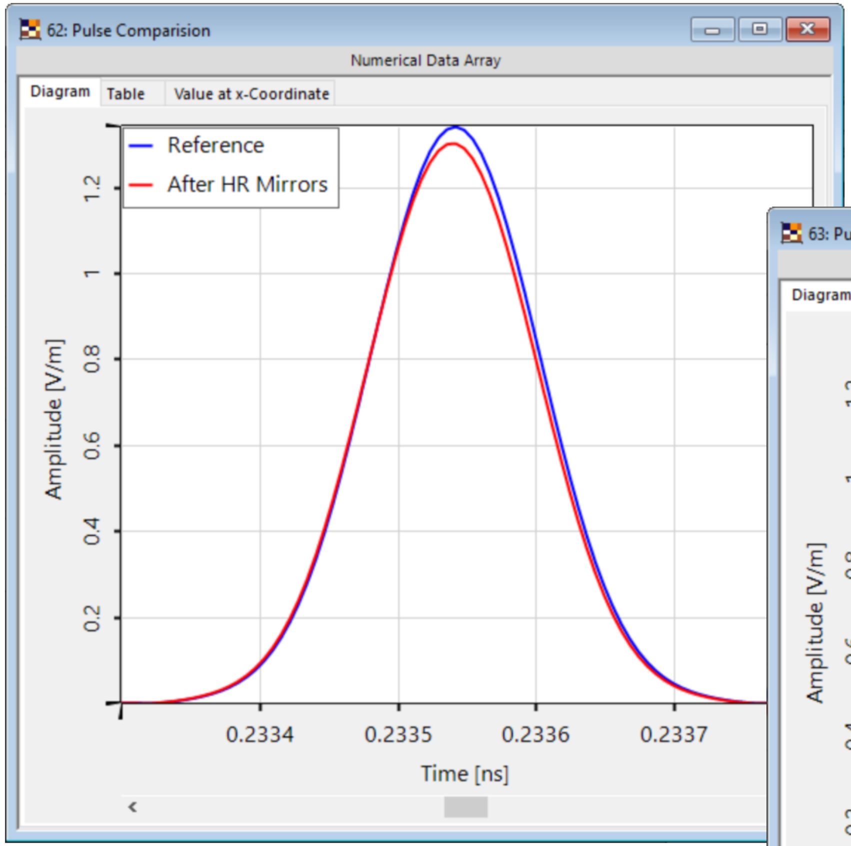
Comparison for 30fs pulse



Pulse Evaluations – Dielectric Mirror Amplitude

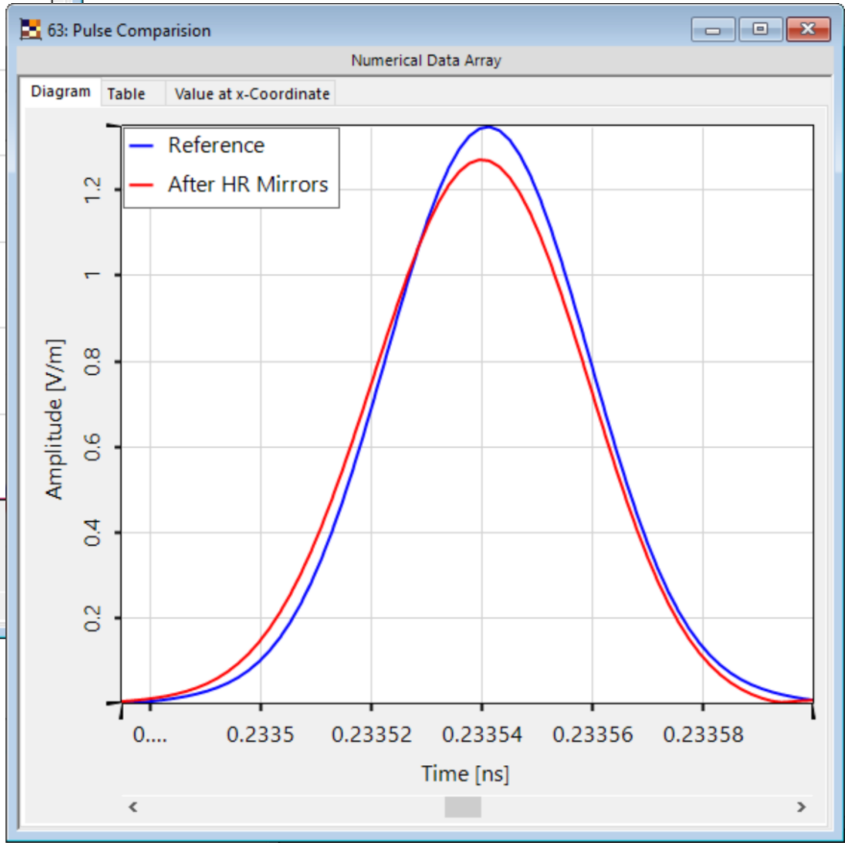
Measurements show, that the multilayer dielectric coating used, can reach high reflectivity and low dispersion effects for a specific wavelength.





Comparison for 100fs pulse

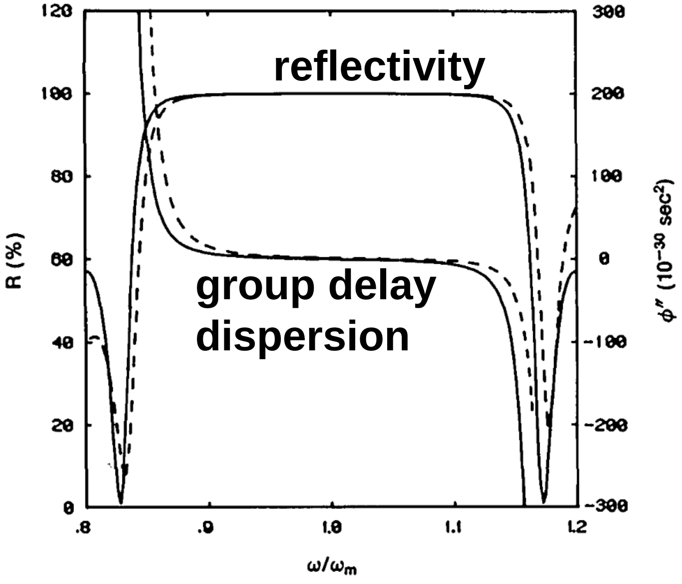
Comparison for 30fs pulse

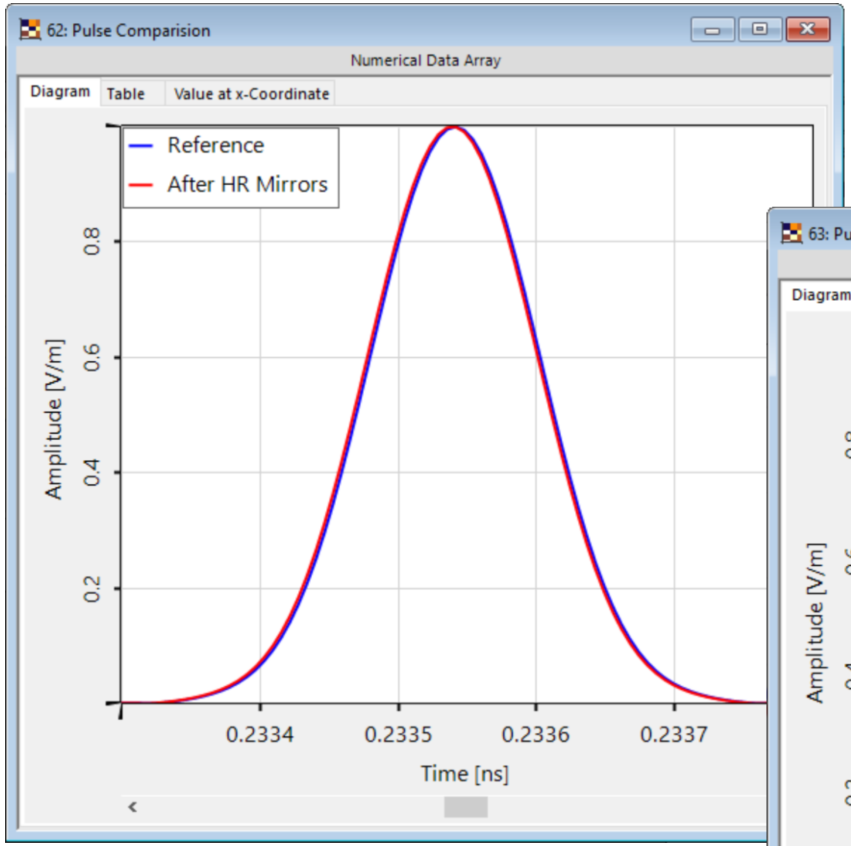


from: S. De Silvestri, P. Laporta, and O. Svelto, "Analysis of quarter-wave dielectric-mirror dispersion in femtosecond dye-laser cavities," Opt. Lett. ***9****, 335-337 (1984)*

Pulse Evaluations – Dielectric Mirror FWHM

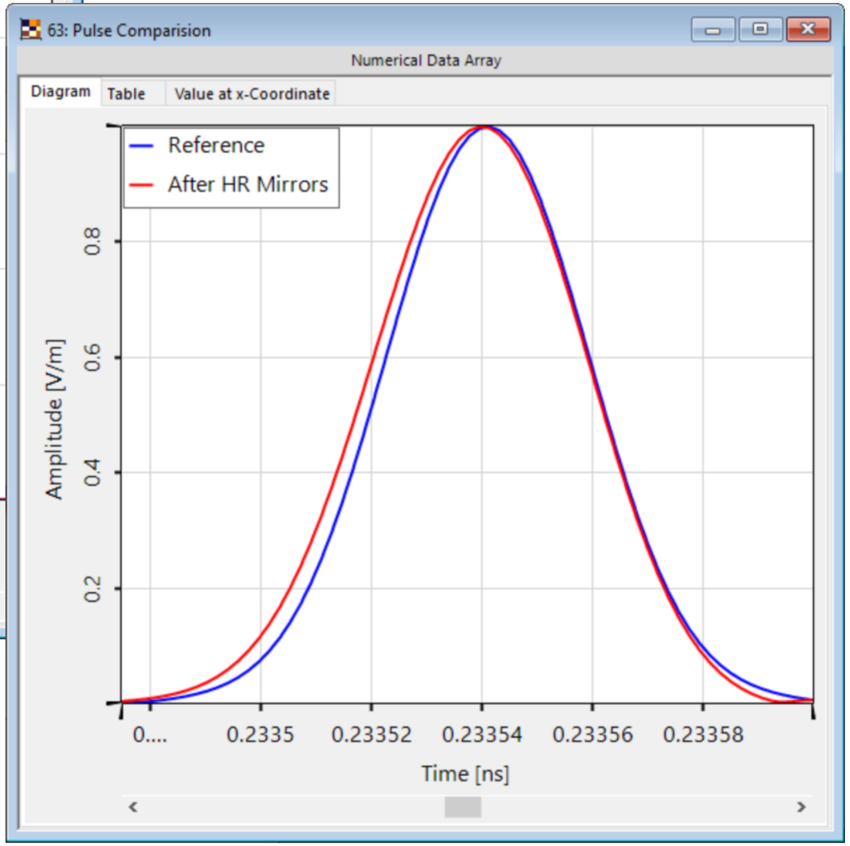
The dispersive effects are only close to zero in a certain bandwidth around a specific wavelength. Hence, for short pulses, a broadening effect can occur.





Comparison for 100fs pulse

Comparison for 30fs pulse



from: S. De Silvestri, P. Laporta, and O. Svelto, "Analysis of quarter-wave dielectric-mirror dispersion in femtosecond dye-laser cavities," Opt. Lett. ***9****, 335-337 (1984)*

Comparison of Final Pulse for the Different Mirror Types

Conclusion for 100 fs Pulse

- As metallic surfaces are known to provide low dispersive effects overall, the silver coating maintains the pulse duration quite well, but exhibits a lower reflectivity.
- The HR dielectric TiO_2-SiO_2 coating keeps the peak and FWHM quite stable, as dispersion effects are nearly zero when used for its design frequency range.

Conclusion for 30 fs Pulse

- For the shorter pulse duration, the investigated HR dielectric coating yields a broadened FWHM together with a decreased peak amplitude.

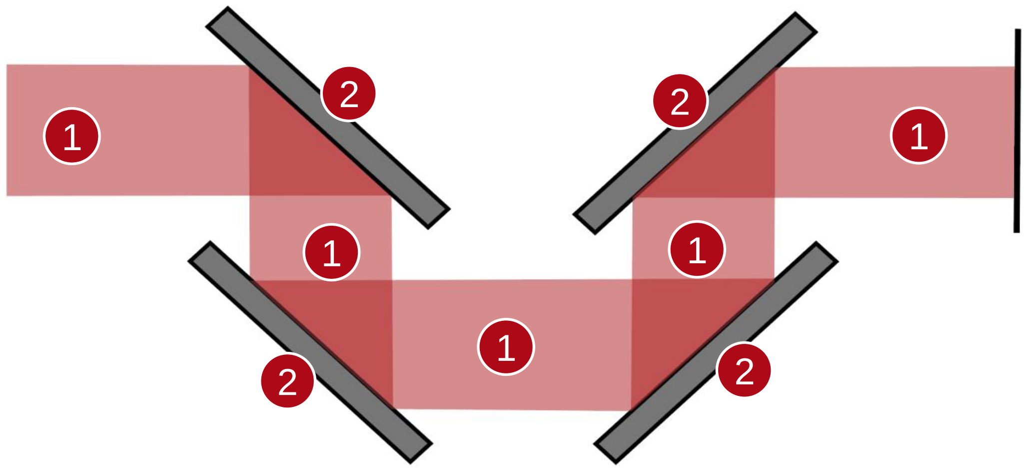
100 fs pulse

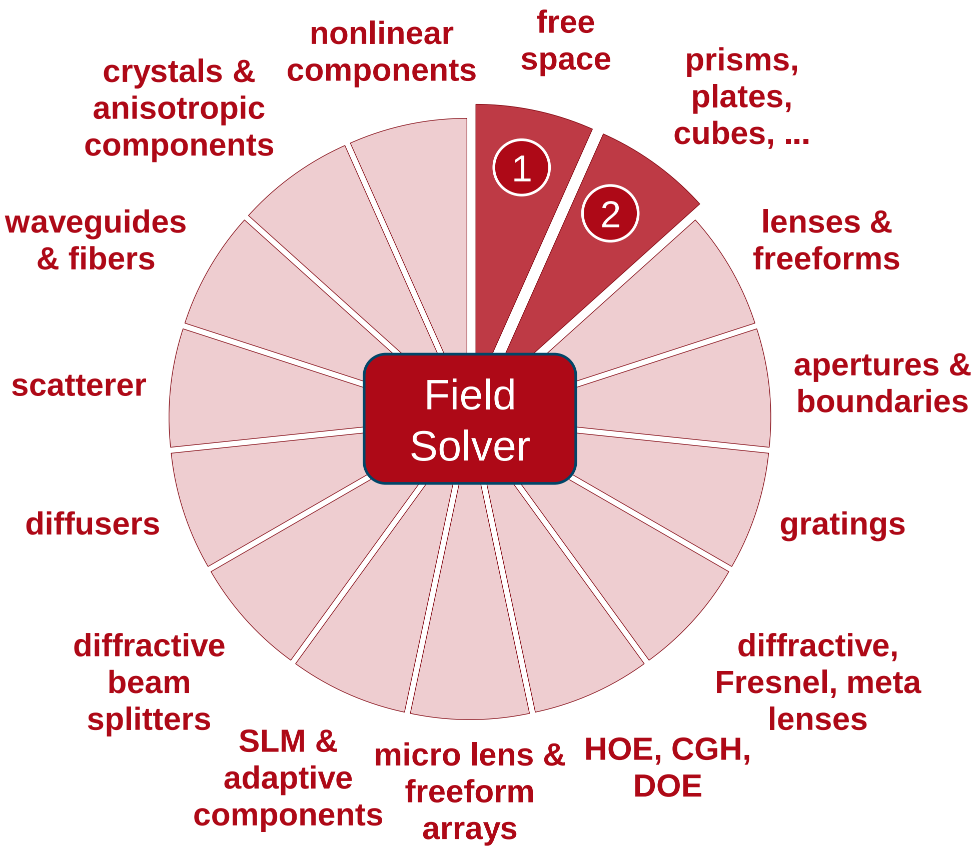
Mirror Type	Peak A^2	FWHM
reference	1.80 V/m	101 fs
with silver coating	1.50 V/m	101 fs
with dielectric coating	1.70 V/m	101 fs

30 fs pulse

Mirror Type	Peak A^2	FWHM
reference	1.80 $(V/m)^2$	30.1 fs
with silver coating	1.50 $(V/m)^2$	30.1 fs
with dielectric coating	1.62 $(V/m)^2$	32.1 fs

VirtualLab Fusion Technologies





Document Information

title	Effects of Mirror Coating on Pulse Characteristics
document code	USP.0009
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	- Pulse Broadening in Dispersive Media - Femtosecond Pulse Propagation through Dispersive Seawater - Grating Stretcher for Ultrashort Pulses