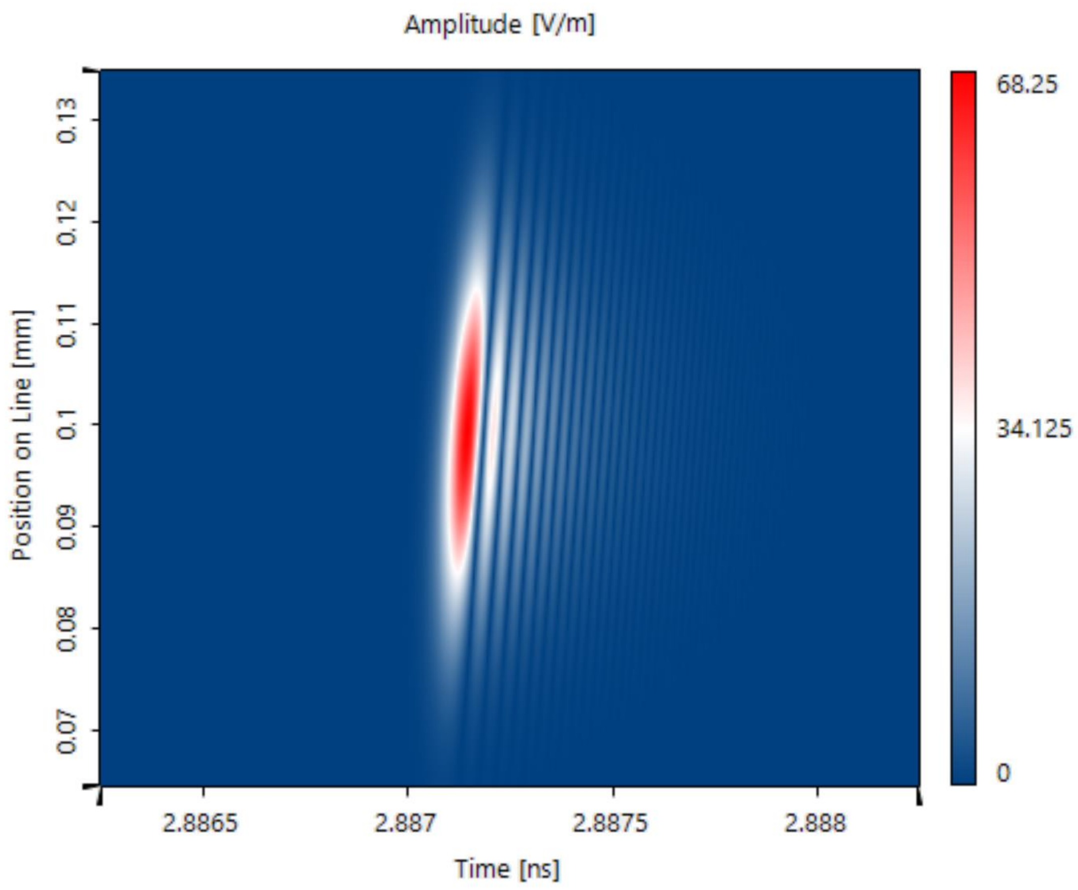
Pulse Front Tilt in SSTF – Setups

Abstract

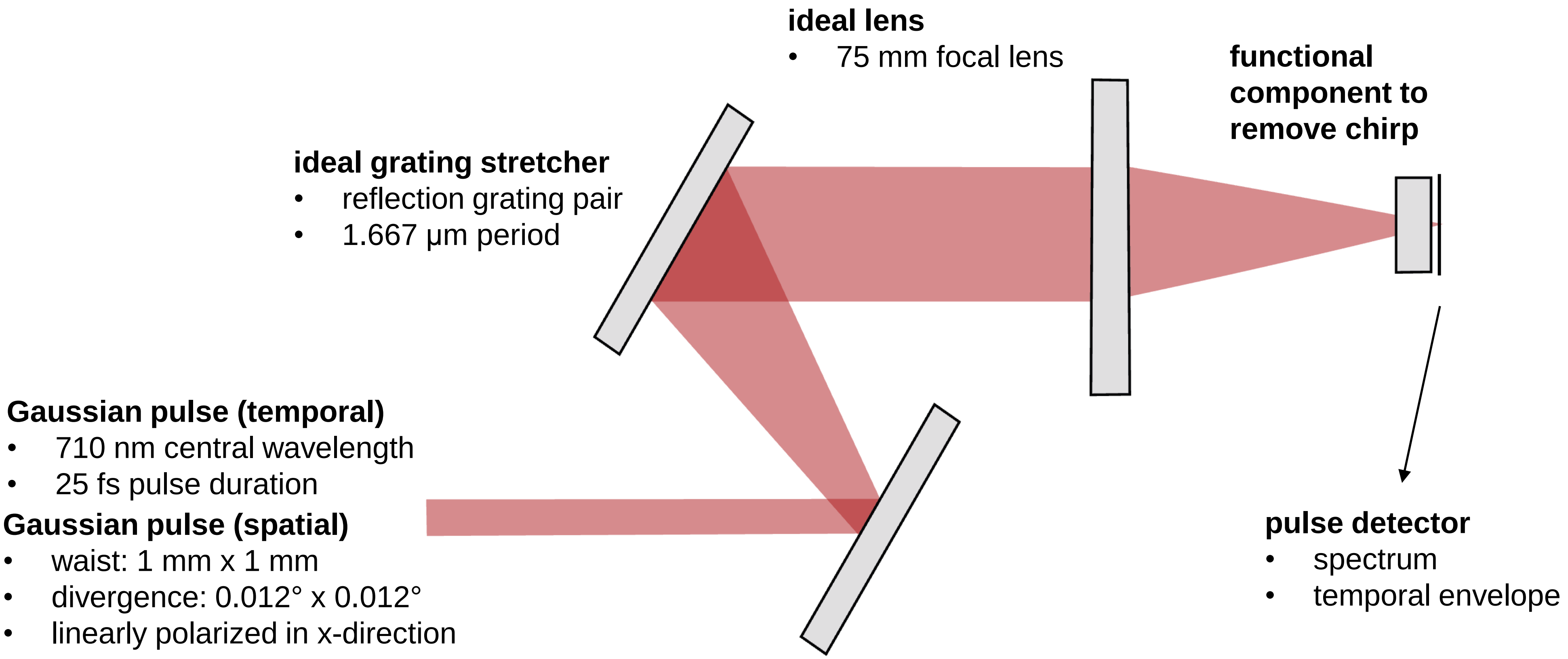


It is of high importance to have most of the field energy focused on a singular spot in various disciplines such as material processing, biology, and medicine. A promising procedure to achieve this is the "simultaneous spatial and temporal focusing" (SSTF) where light is spectrally widened with a stretcher setup and is then focused with a lens to get a focal spot that has a minimal size in space and time domain. While in some applications this effect is unwanted, in certain optical regimes such as nonlinear frequency conversion or terahertz generation it can be advantageous.

Scenarios

Scenario 1: System Configuration

a) ideal system with removed chirp



Scenario 2: System Configuration

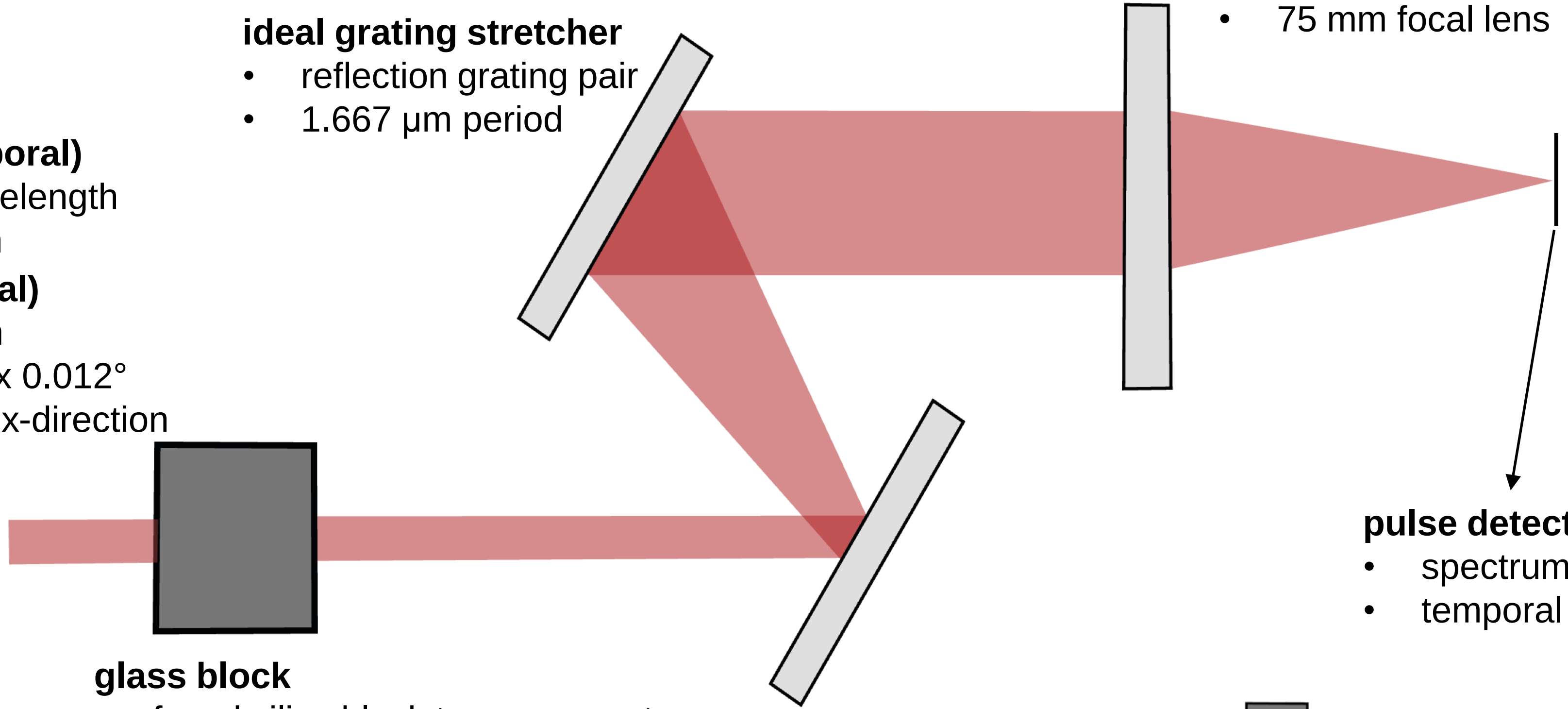
b) system with chirp compensation

Gaussian pulse (temporal)
- 710 nm central wavelength
- 25 fs pulse duration

Gaussian pulse (spatial)
- waist: 1 mm x 1 mm
- divergence: 0.012° x 0.012°
- linearly polarized in x-direction

ideal grating stretcher
- reflection grating pair
- 1.667 µm period

ideal lens
- 75 mm focal lens



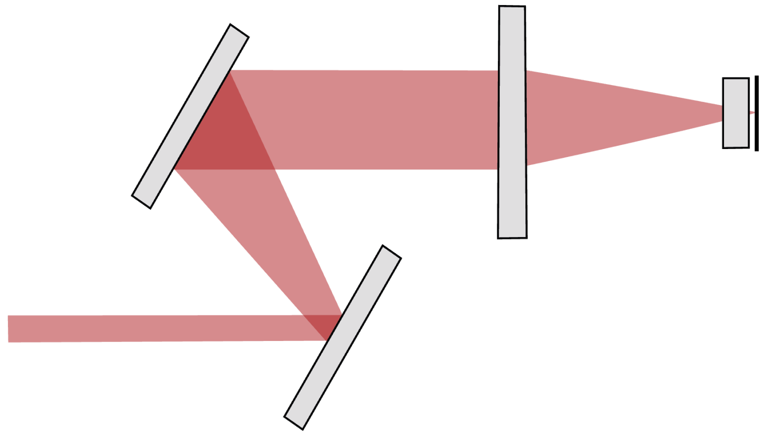
glass block
- fused silica block to compensate chirp generated by grating pair

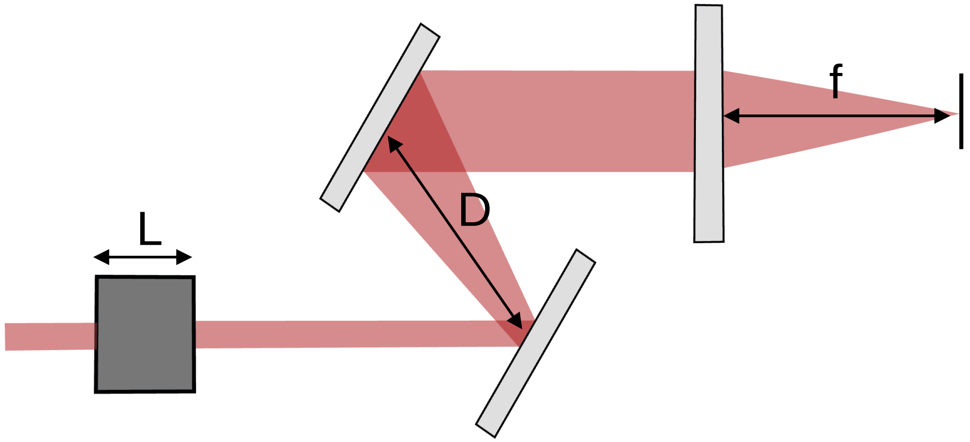
pulse detector
- spectrum
- temporal envelope

real component

ideal/functional component

Scenario: Task Description





Scenario 1 - System with removed chirp:

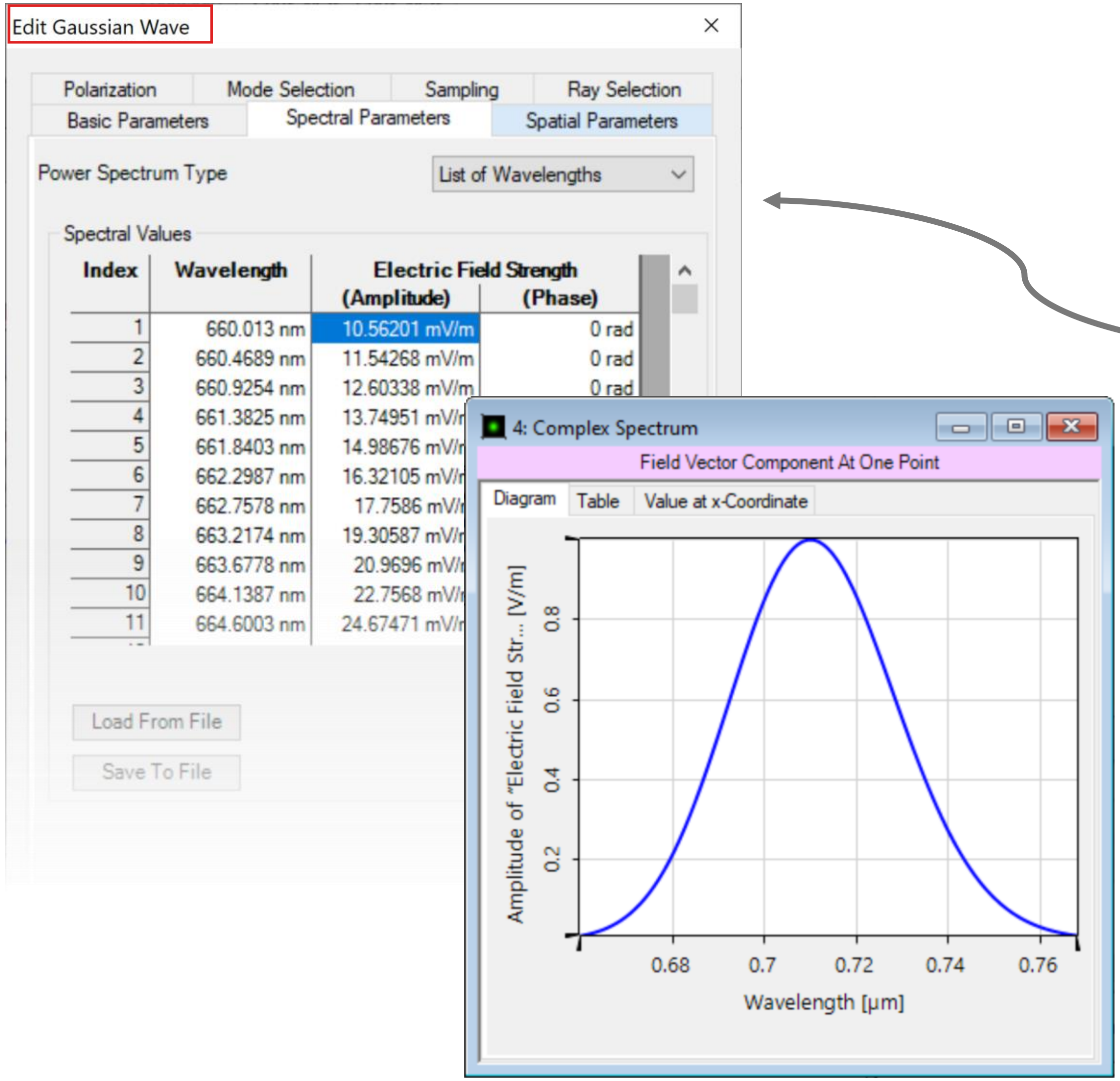
- Simulate the first system to visualize the effect of an ideal SSTF on the focal field

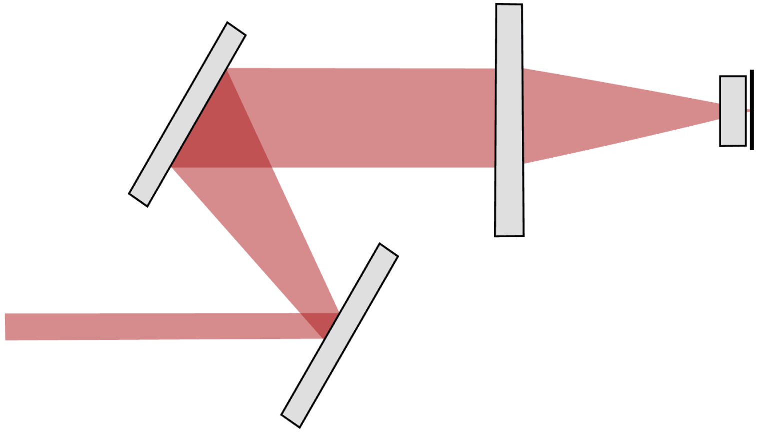
Scenario 2 - System with compensated chirp:

- Adjust the block length (L) to compensate the chirp generated by system
- Vary the distance of the grating pair (D) to determine the effect on the pulse front tilt
- Vary the focal length (f) to determine the effect on the pulse front tilt

Building the System in VirtualLab Fusion

Scenario 1: System Building Blocks - Source

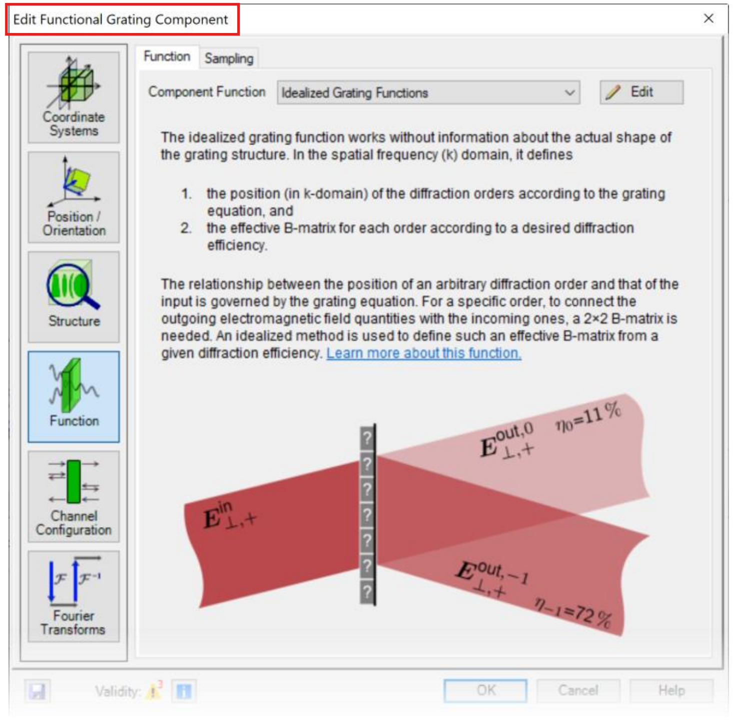


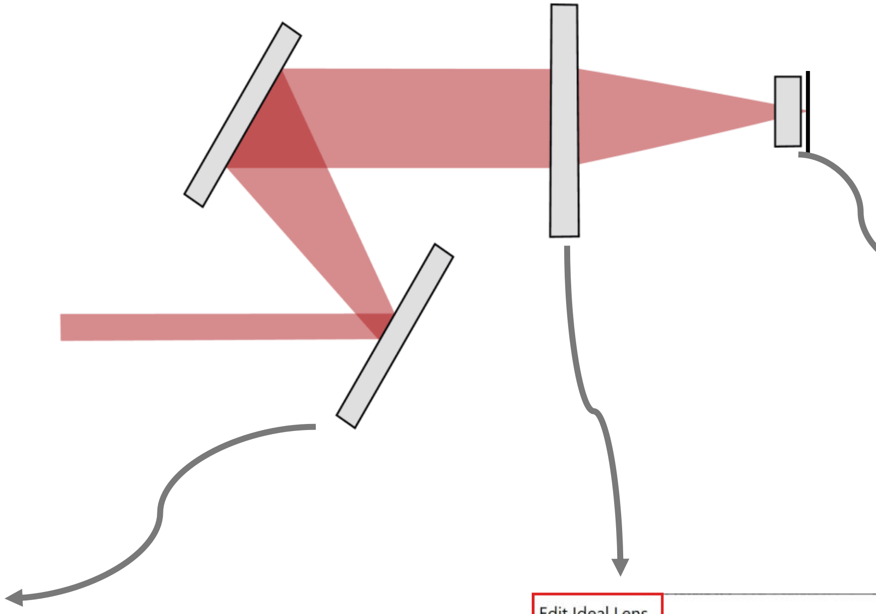


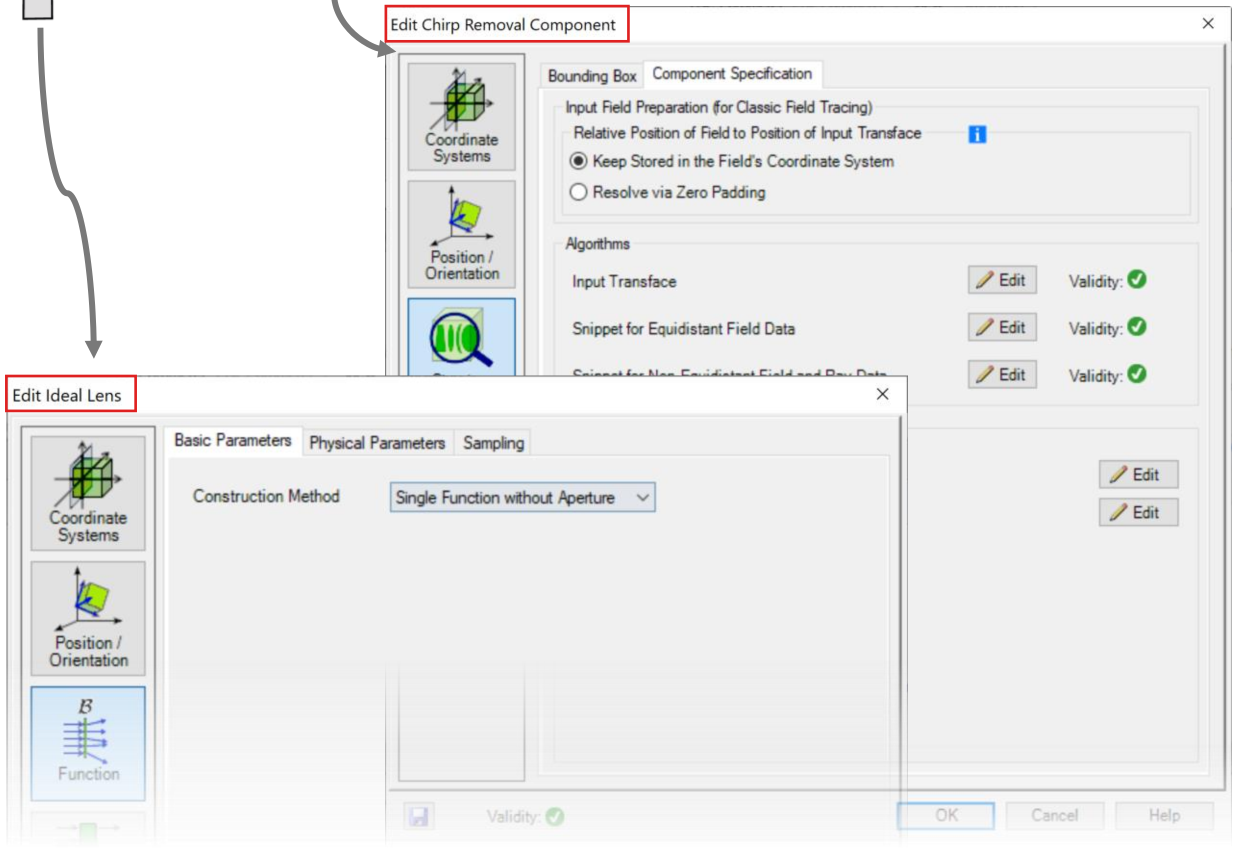
The source is modeled by applying a gaussian spectrum onto a two-dimensional gaussian distribution in space.

Scenario 1: System Building Blocks - Components

The chirp generated by the components of the system generally broadens the pulse. This effect can be negated by multiplying the negative residual phase onto the field.

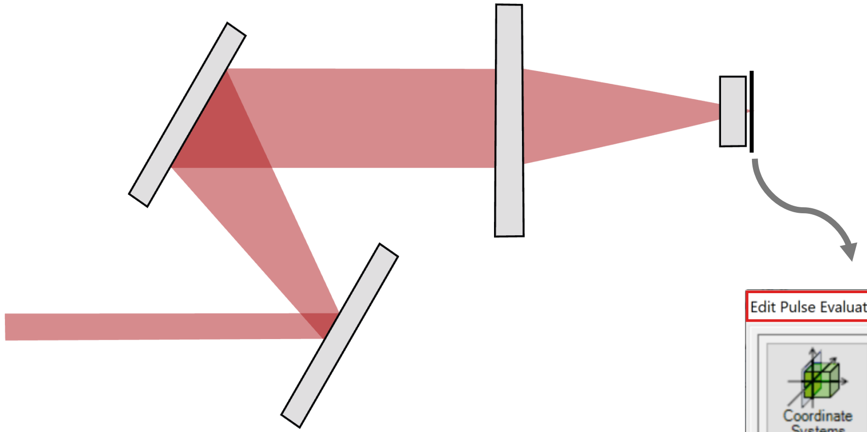




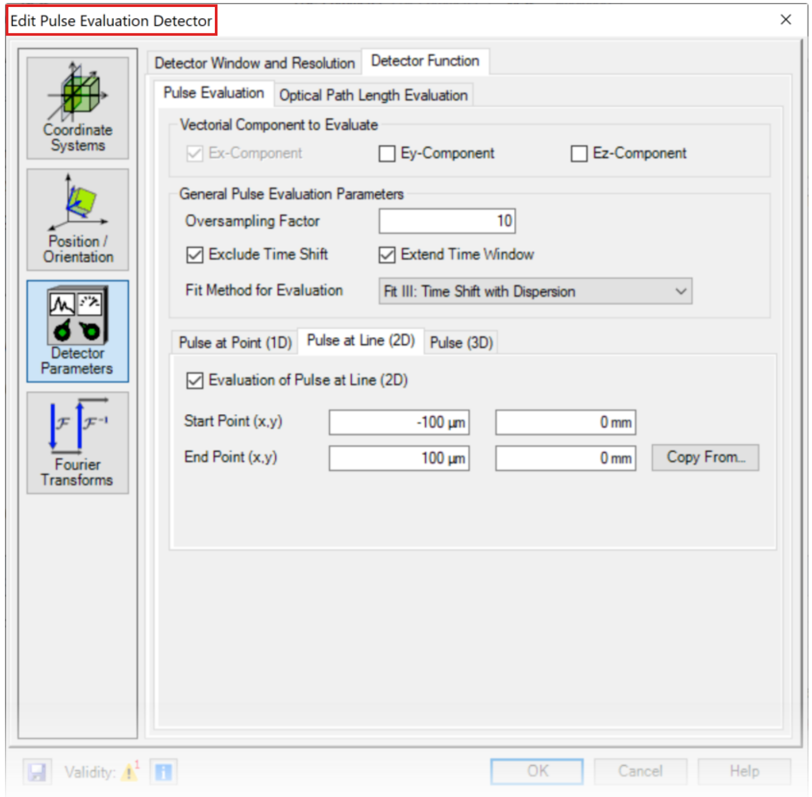


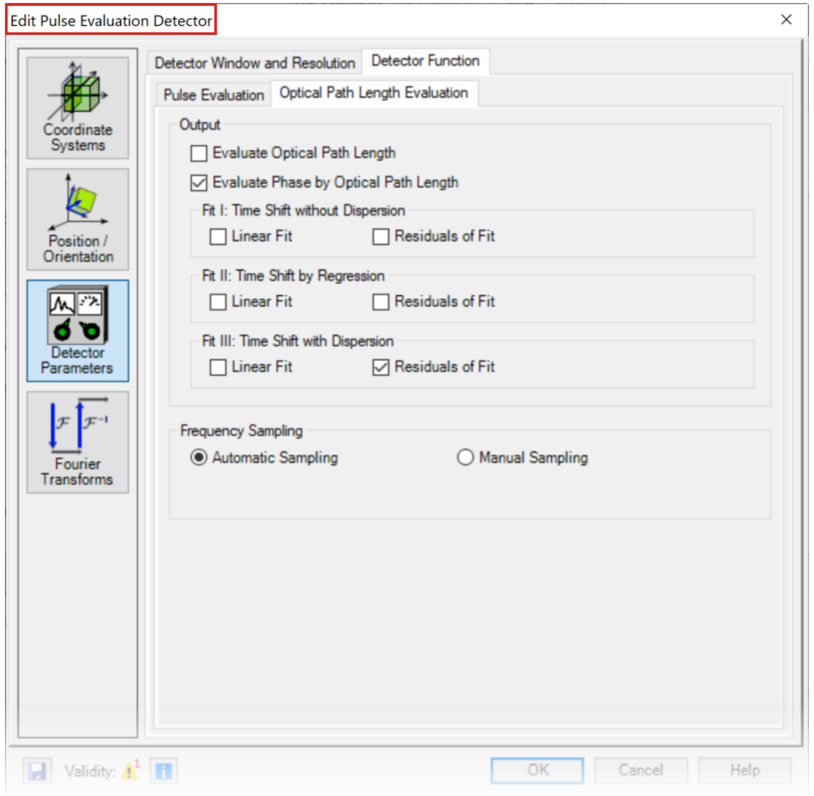
The ideal grating component allows for the direct definition of the grating orders and efficiencies by the user.

Scenario 1: System Building Blocks - Detectors



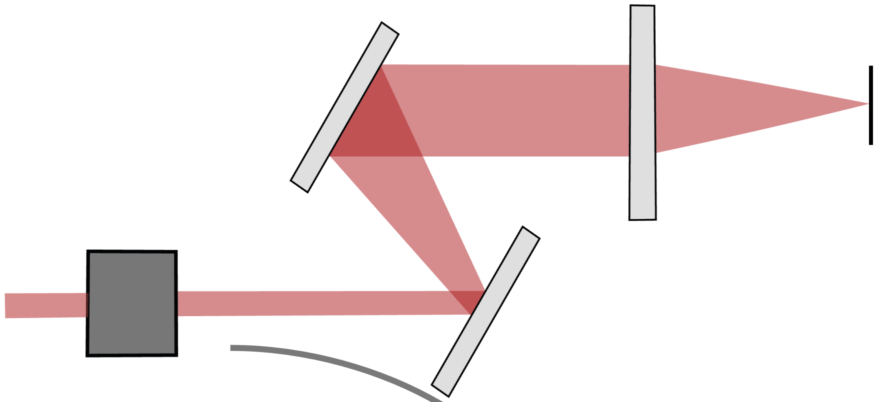
The detector automatically calculates the electromagnetic field in wavelength and time domain at a predefined point, line, or cube. It can also evaluate additional information like the optical path length and residual phase.



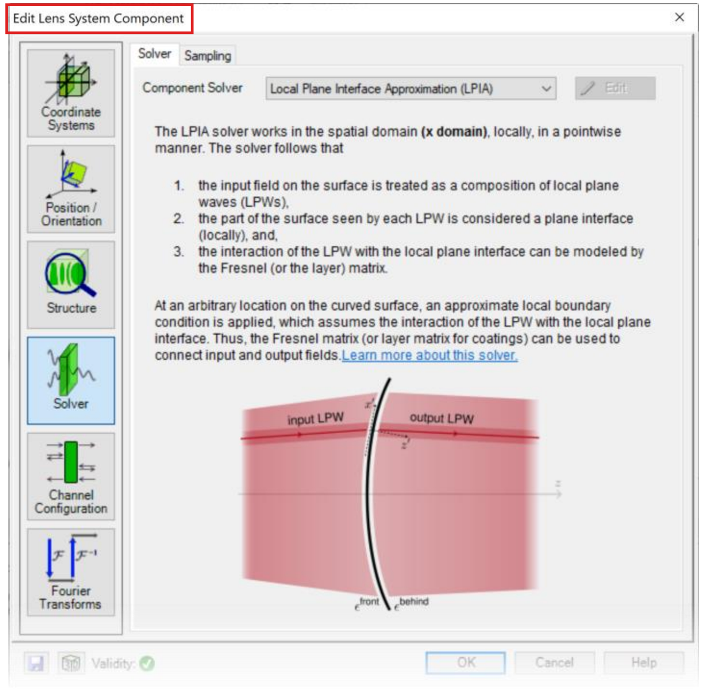


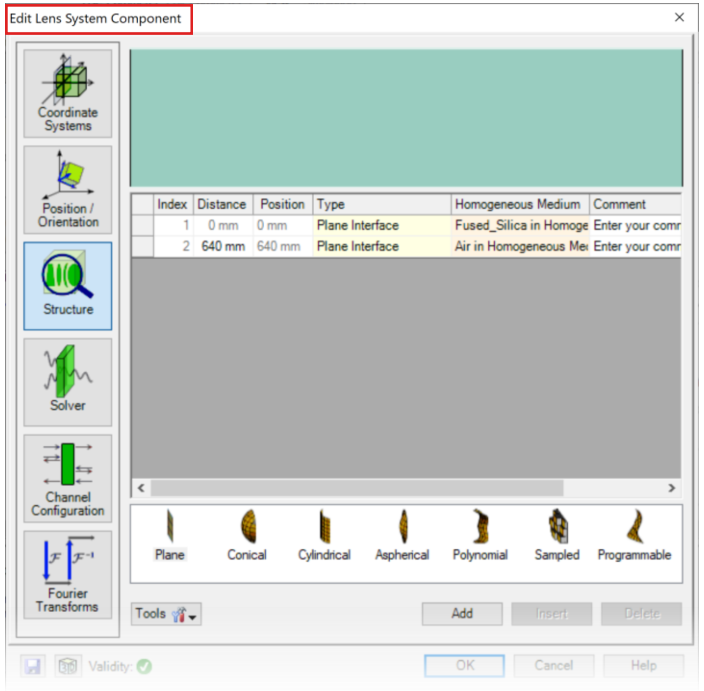
Scenario 2: System Building Blocks - Components

Additional System Building Blocks for the **system with the chirp compensation**:

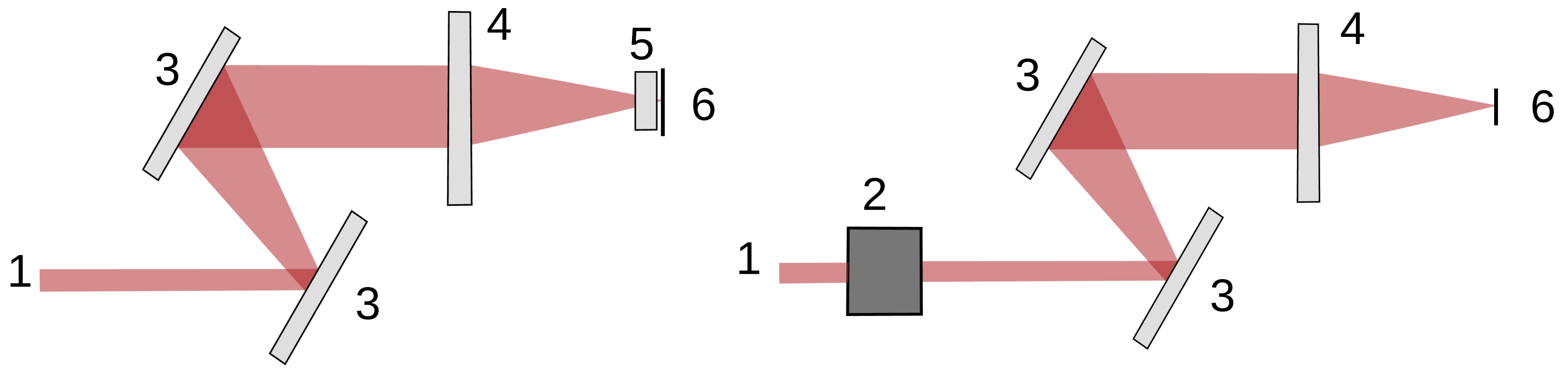


In scenario 2 the source and the detector are completely identical to the ones in scenario 1. Therefore, they use the same system building blocks.





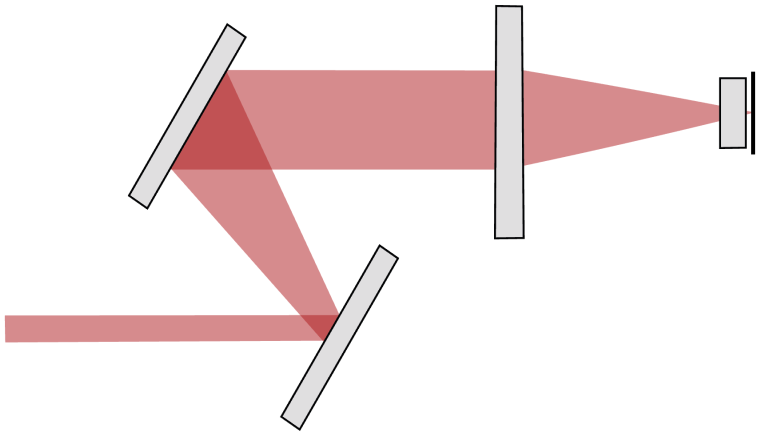
Summary – Components ...



… of Optical System	… in VirtualLab Fusion	Source Model/Component Solver
1. Source	Gaussian Pulse Source	Temporal & Spatial Gaussian Function
2. Glass Block	Lens System Component	Local Plane Interface Approximation
3. Grating	Functional Grating	Grating Function
4. Lens	Ideal Lens	Wavefront Response
5. Chirp Removal Component	Programmable Component	-
6. Detector	Pulse Evaluation Detector	-

Simulation Results

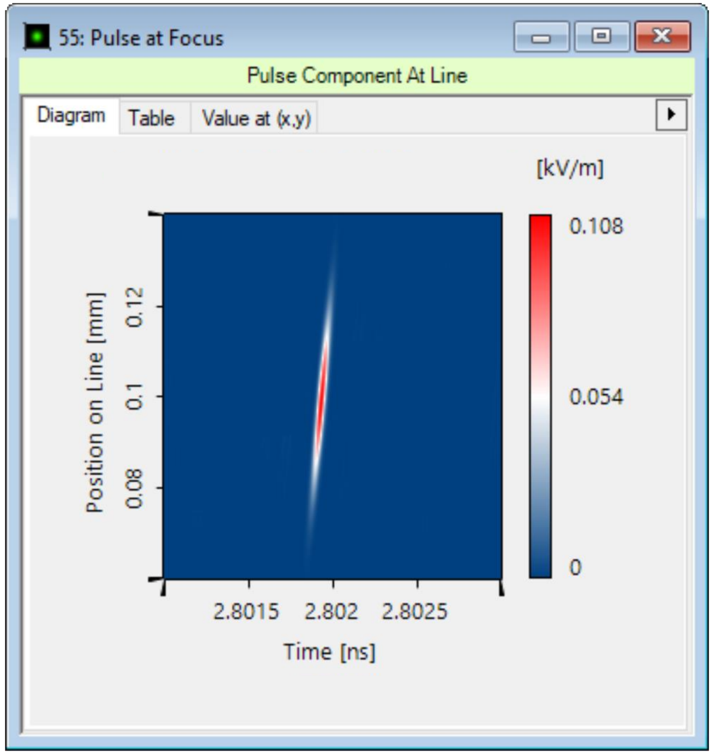
Scenario 1: Field Tracing Simulation Results



Scenario 1 Tasks:

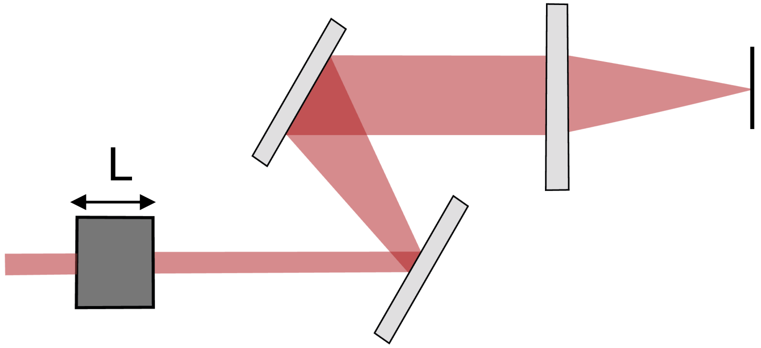
- **Simulate first system to visualize the effect of an ideal SSTF on the focal field**

$|E_x|$



When the chirp generated by the system is functionally removed, the pulse in the focus shows a clear tilt. The angle of this tilt is depended on the focal length of the lens and the parameters of the stretcher.

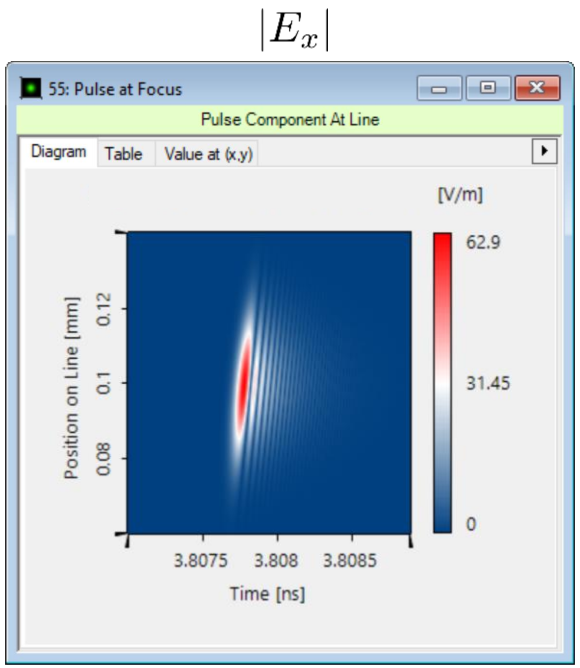
Scenario 2: Chirp Compensation



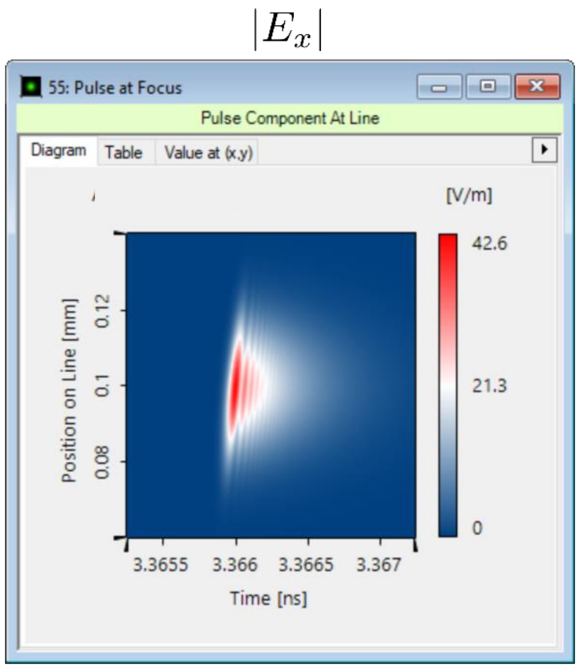
The grating pair introduces a chirp onto the field. If it is not compensated it will widen the pulse in time and therefore overlay the tilt.

Scenario 2 Tasks:

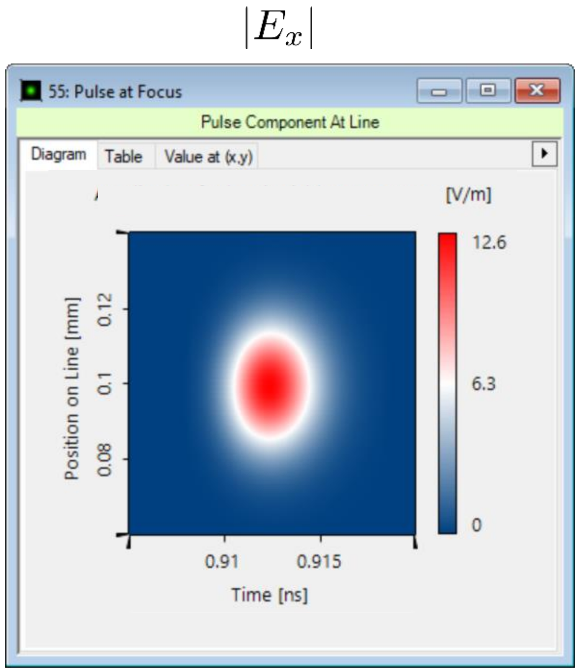
- **Adjust block length (L) to compensate the chirp generated by grating pair**
- Vary distance of the grating pair (D) to determine the effect on the pulse front tilt
- Vary focal length (f) to determine the effect on the pulse front tilt



L= 640 mm (optimized)

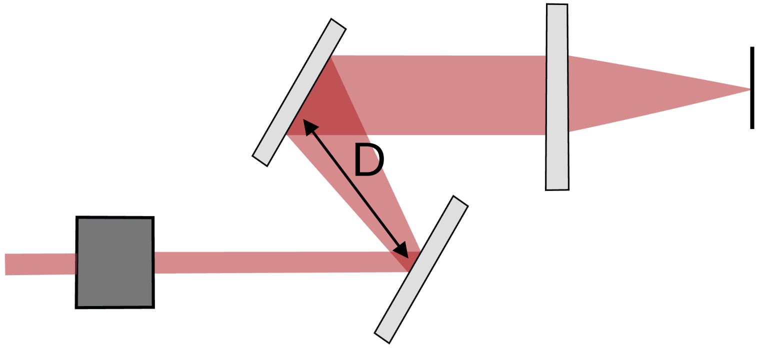


L= 550 mm



L = 50 mm

Scenario 2: Variation of the Stretcher Distance



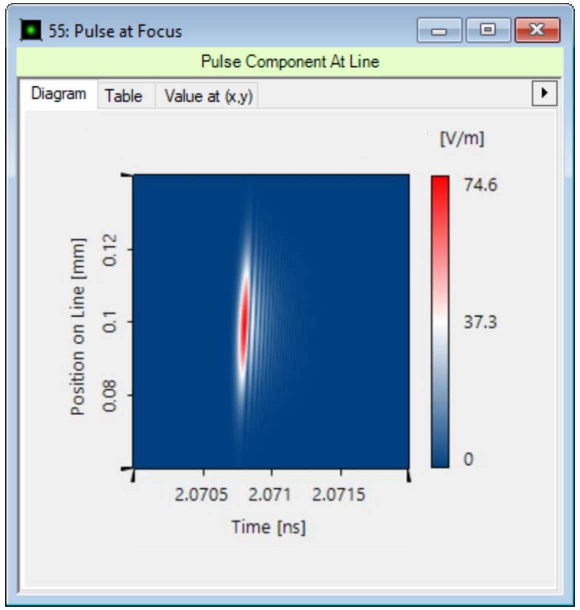
A higher distance between the gratings leads to a wider spectral separation which increases the tilt of the pulse front in the focus!

Note: For each setup, the length of the chirp compensation block needs to be adjusted for optimal compression!

Scenario 2 Tasks:

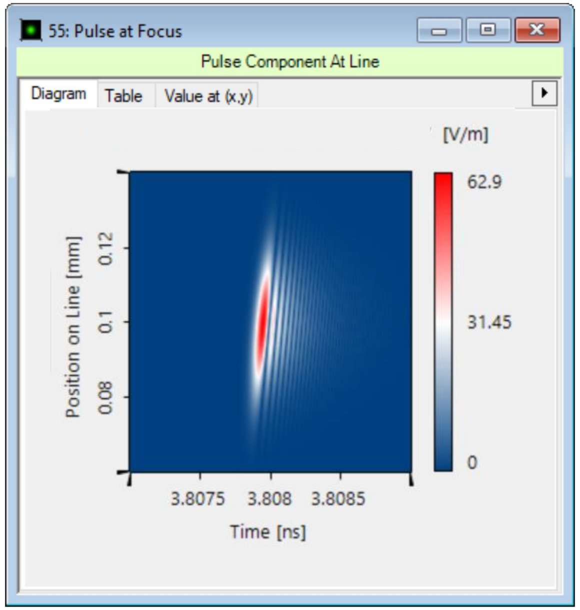
- Adjust block length (L) to compensate the chirp generated by grating pair
- **Vary distance of the grating pair (D) to determine the effect on the pulse front tilt**
- Vary focal length (f) to determine the effect on the pulse front tilt

$|E_x|$



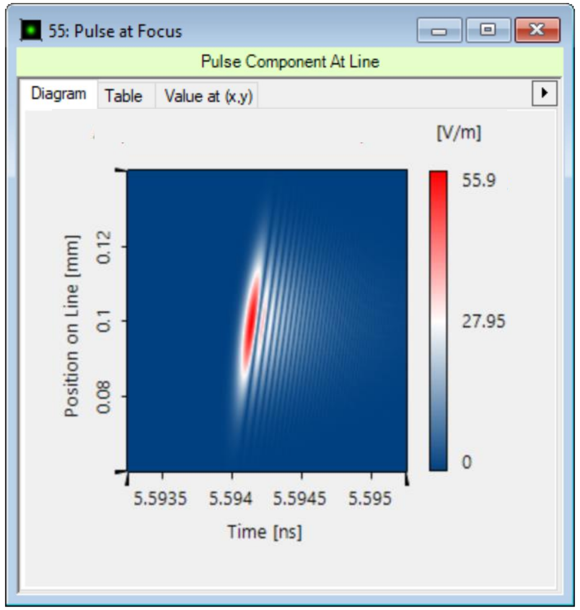
D= 50 mm

$|E_x|$



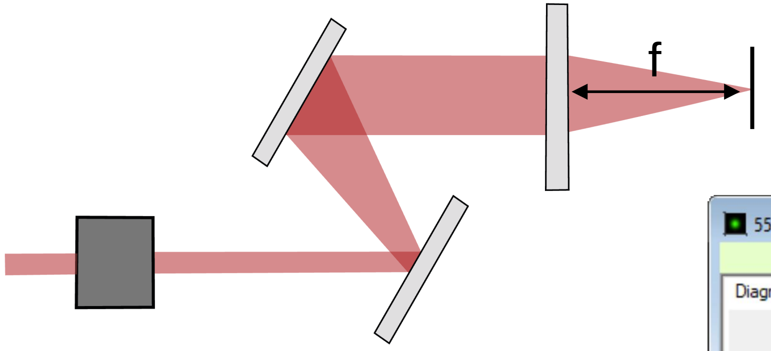
D= 100 mm

$|E_x|$



D= 150 mm

Scenario 2: Variation of Focal Length

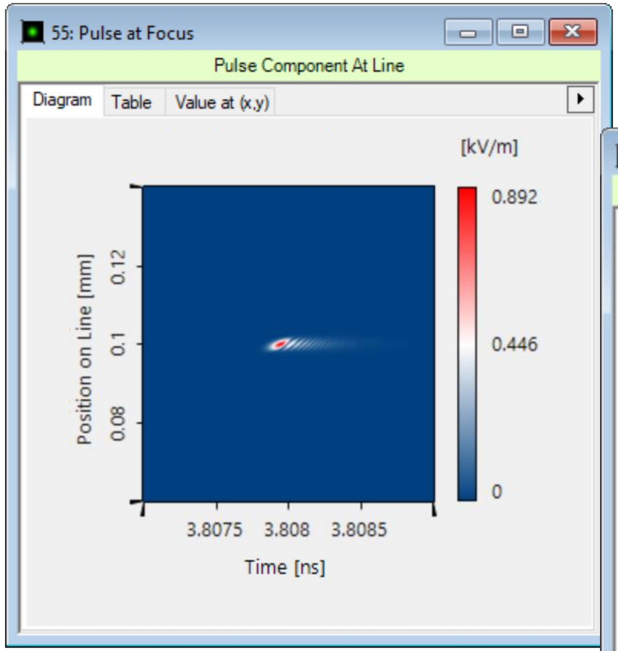


Scenario 2 Tasks:

- Adjust block length (L) to compensate the chirp generated by grating pair
- Vary distance of the grating pair (D) to determine the effect on the pulse front tilt
- **Vary focal length (f) to determine the effect on the pulse front tilt**

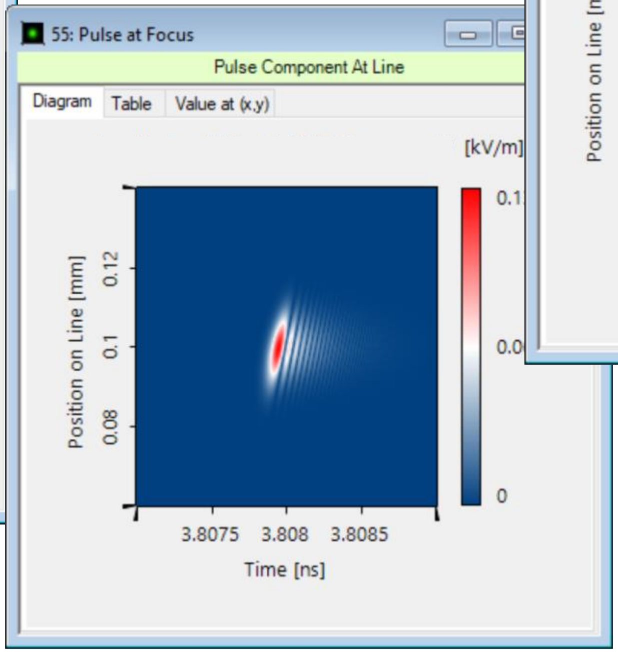
The same principle applies to a shorter focal length. Unlike previously, the chirp stays the same.

$|E_x|$



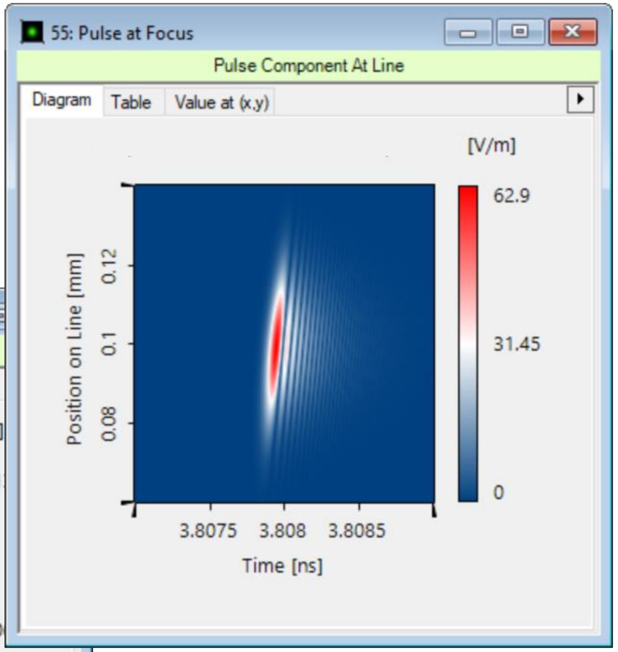
f = 5 mm

$|E_x|$



f = 35 mm

$|E_x|$



f= 75 mm

Document Information

title	Pulse Front Tilt in SSTF – Setups
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software version	2020.2 (Build 1.116)
category	Application Use Case
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