VirtualLab Fusion Applications, Technology & Workflows

Simulation of Interferometric Setups with VirtualLab Fusion

LightTrans International
Speaker: Olga Baladron-Zorita

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  - Day after the webinar
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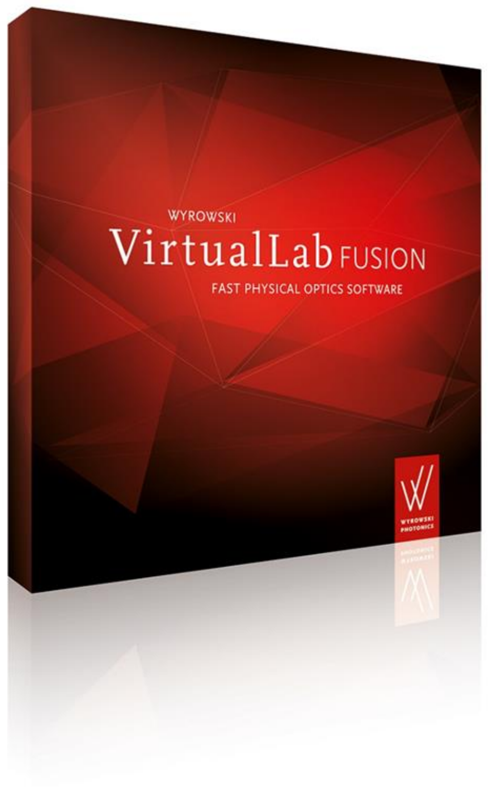
(since 2014)

photo from wikitravel

Optical Design Software and Services



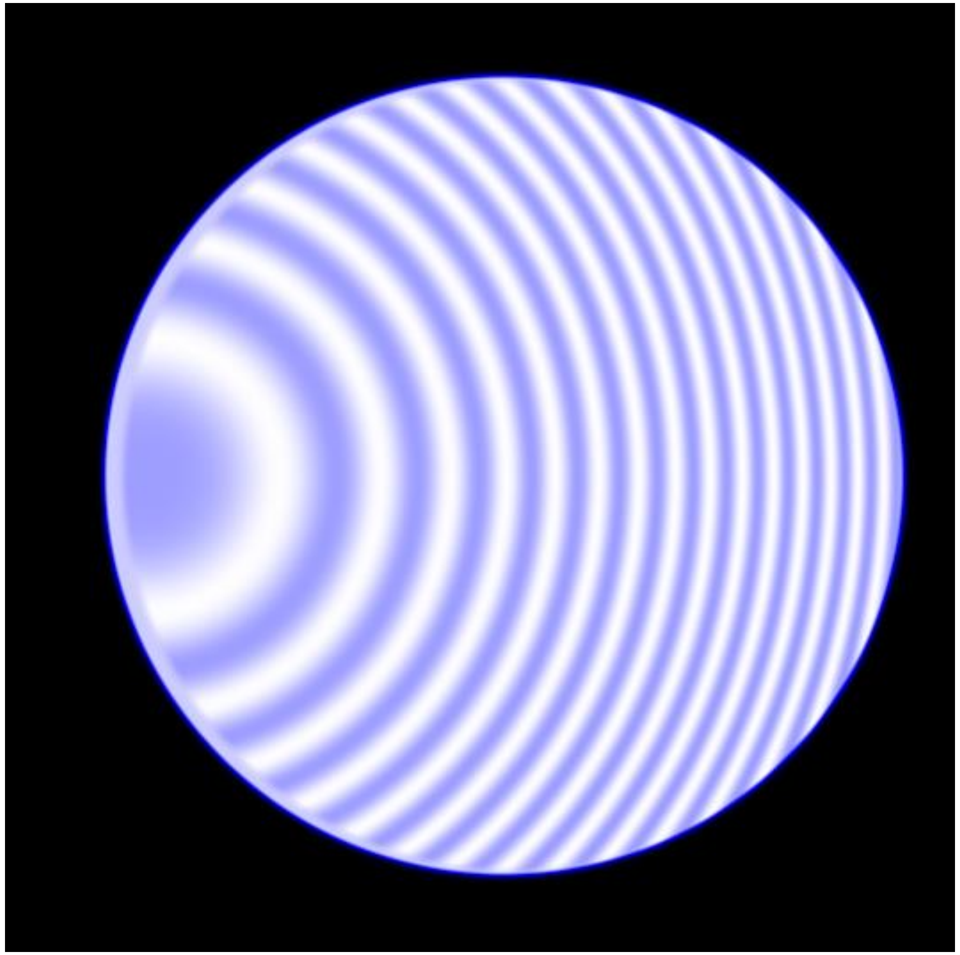
VirtualLab Fusion Applications, Technology & Workflows

Simulation of Interferometric Setups with VirtualLab Fusion

LightTrans International
Speaker: Olga Baladron-Zorita

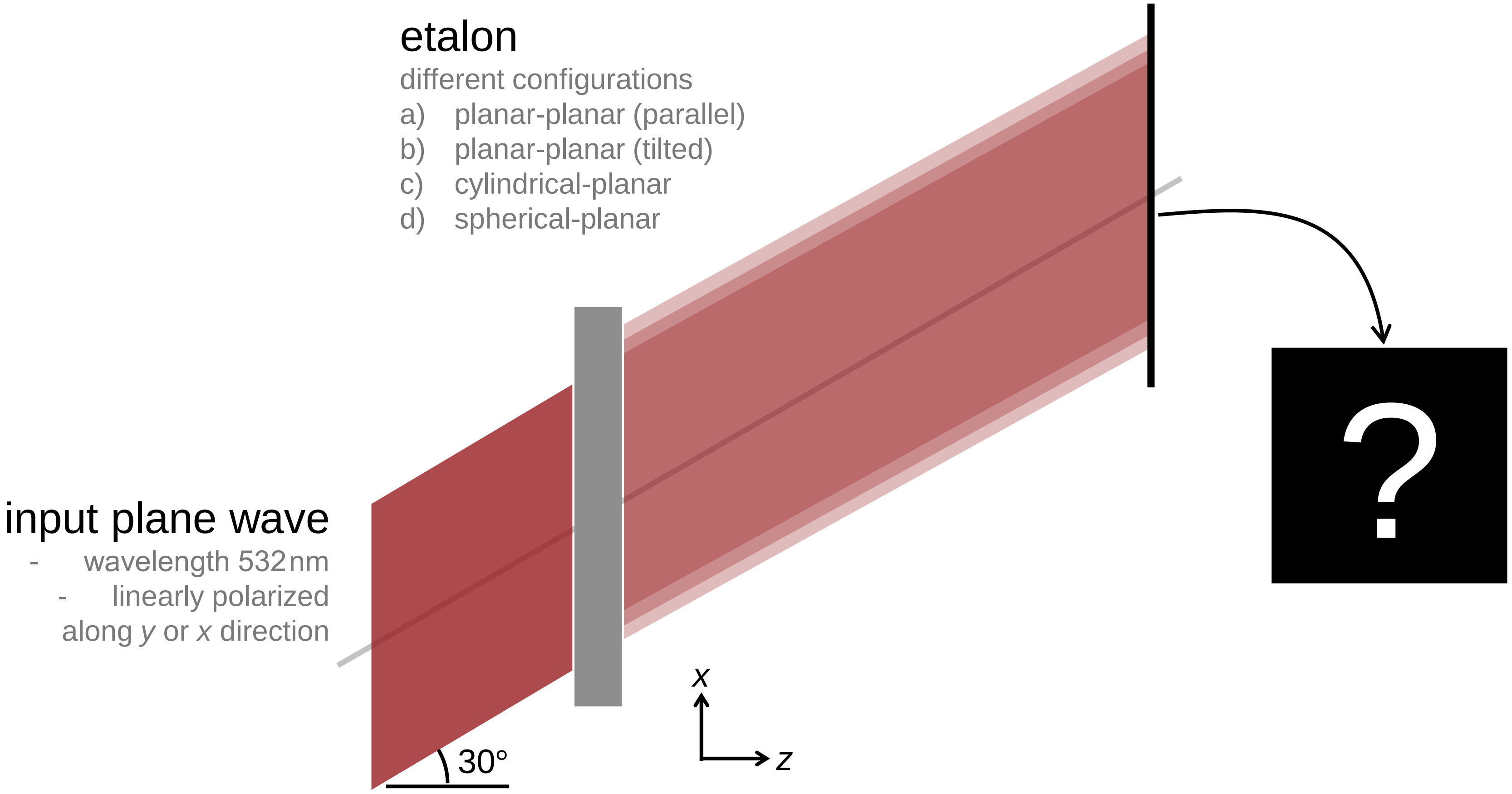
Modeling of Etalon with Planar or Curved Surfaces

Abstract



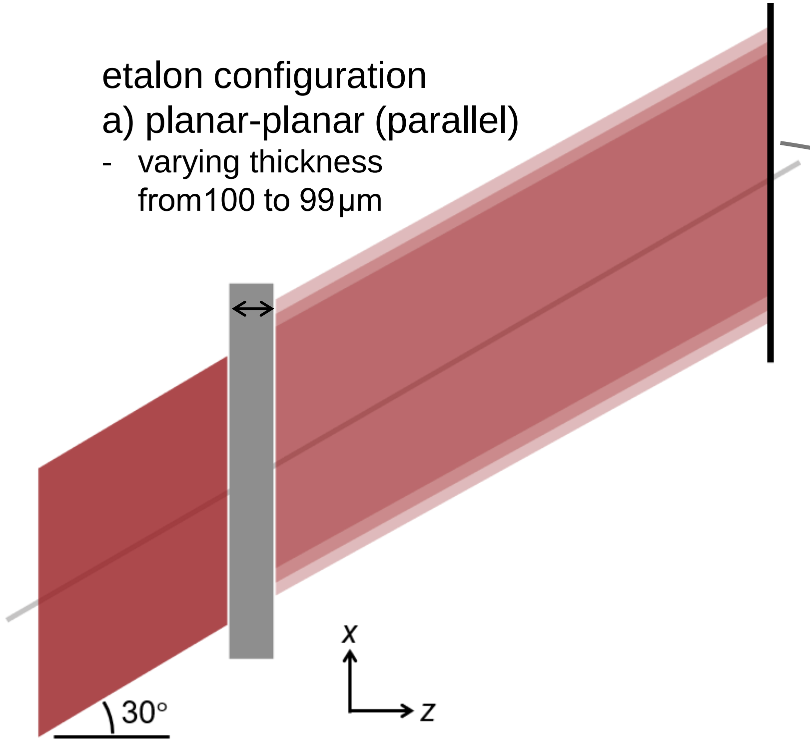
The simplest form of an optical etalon is a transparent plate with parallel surfaces. Such a structure forms a resonator, and the transmittance and reflectance vary with the thickness of etalon. Beside the simplest structure, etalons with other configurations, with e.g. non-parallel surfaces and curved surfaces, are designed and used for different applications. With the non-sequential field tracing technique, several configurations of etalons are analyzed, and the differences in the output interference fringes are investigated.

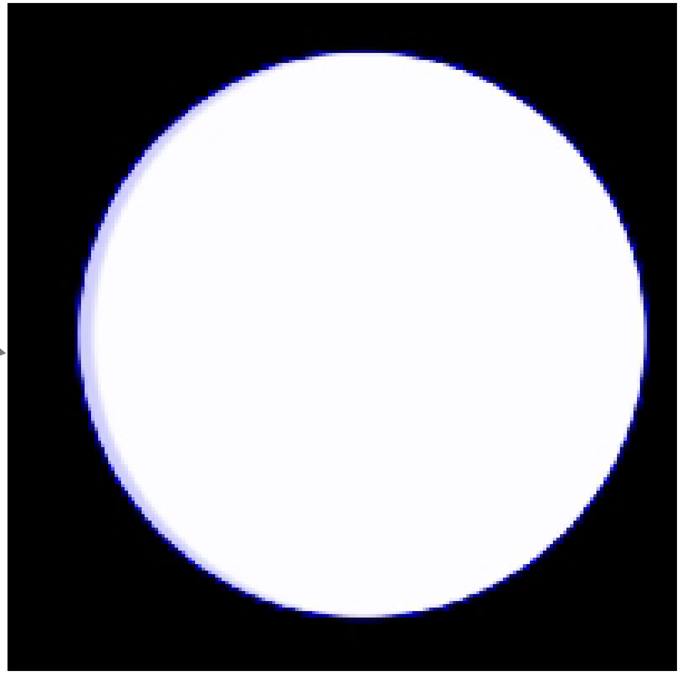
Modeling Task



How to calculate the interference fringes for etalons with different configurations?

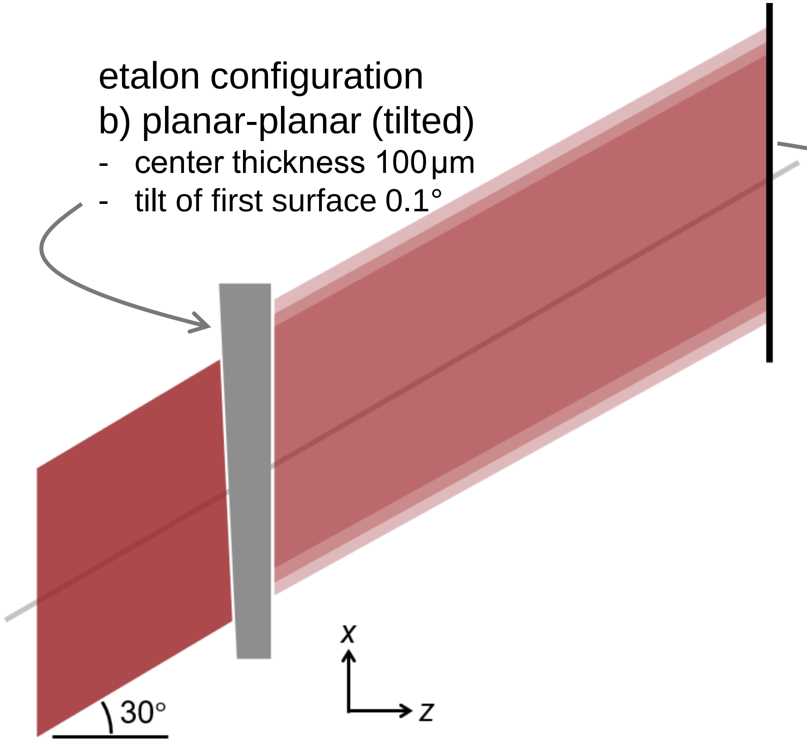
Parallel Planar-Planar Surfaces

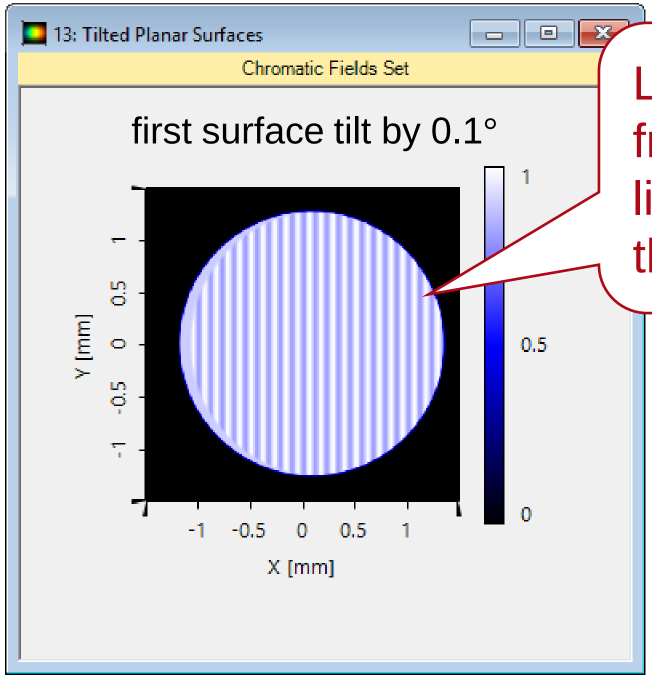




Constructive and destructive interference alternatively shows up when the thickness of etalon varies.

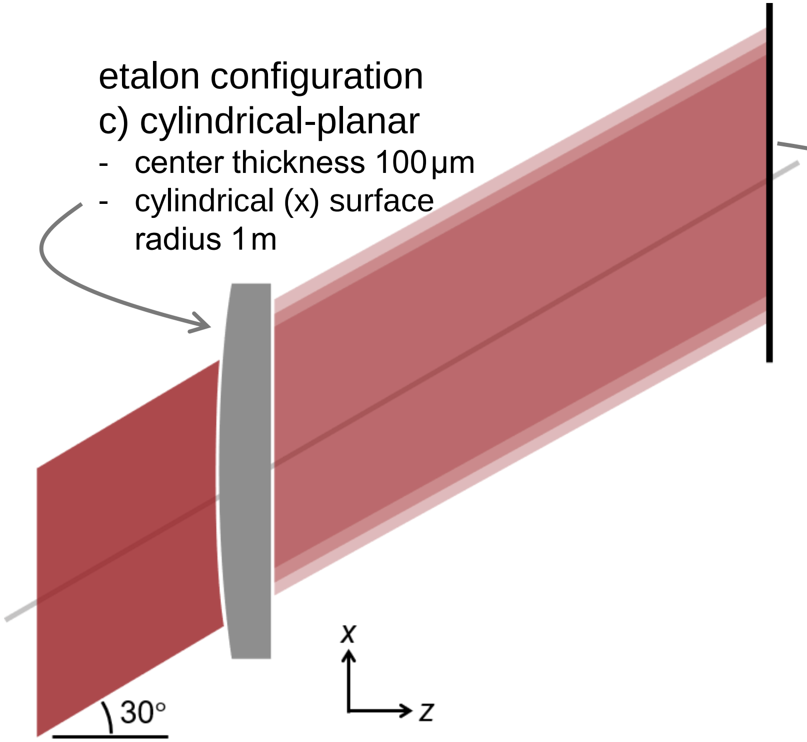
Tilted Planar-Planar Surfaces

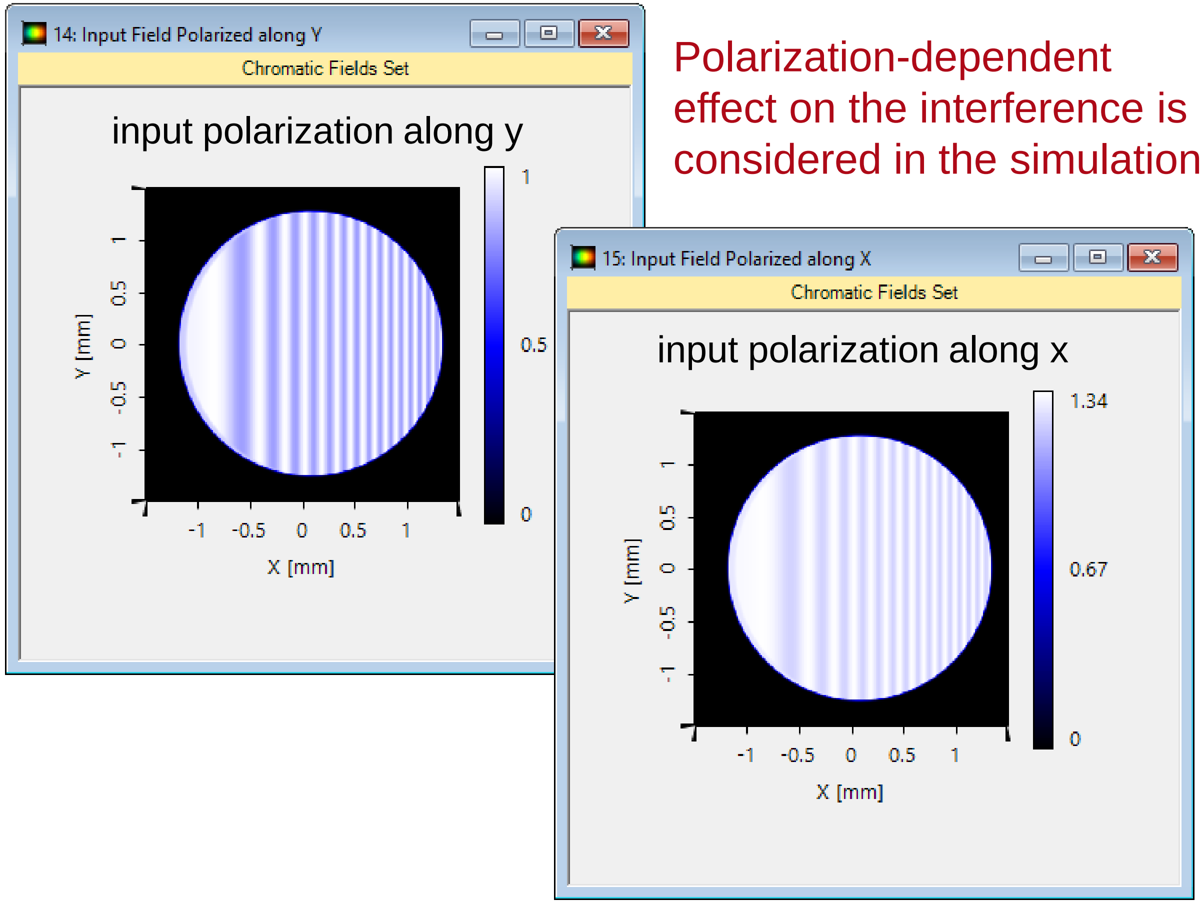




Linear interference fringes appear due to linear change of etalon thickness.

Cylindrical-Planar Surfaces

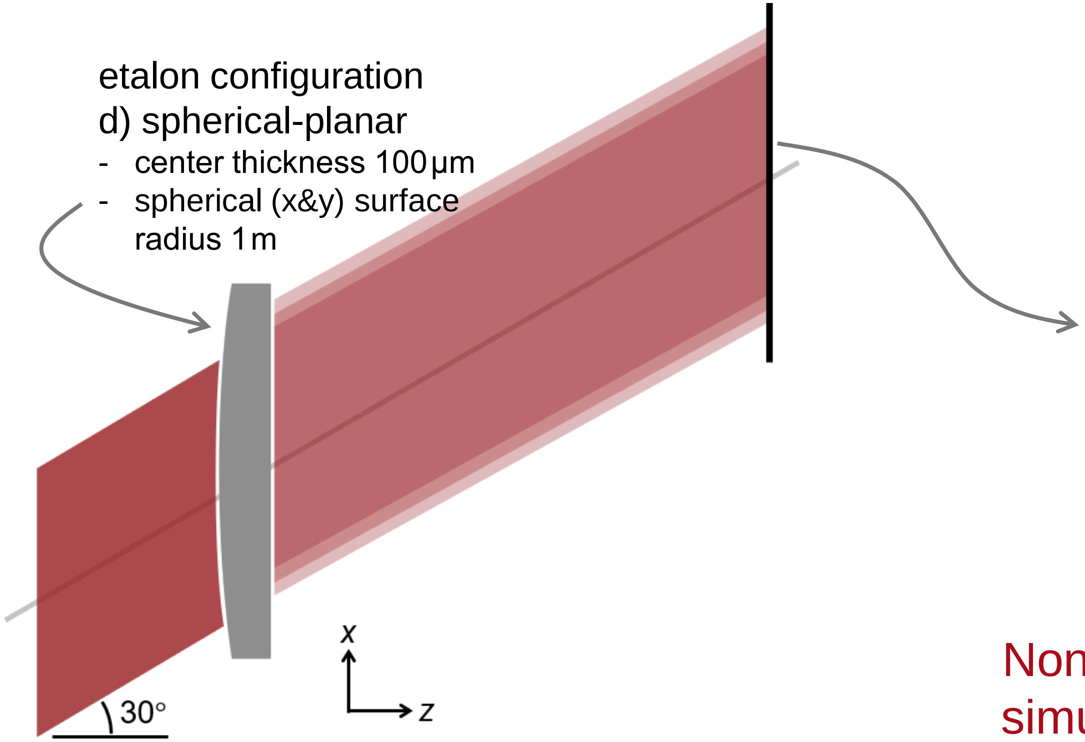


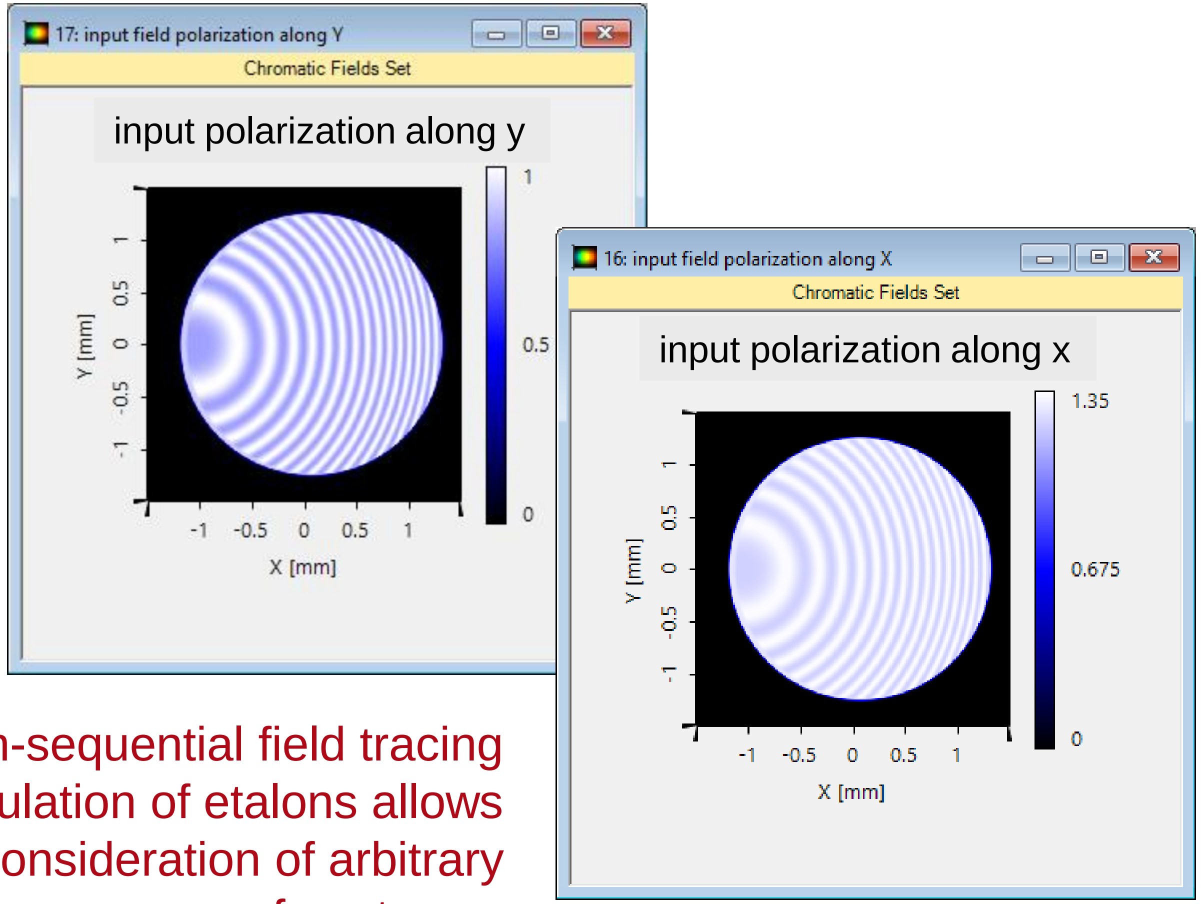


Polarization-dependent effect on the interference is considered in the simulation.

Spherical-Planar Surfaces

etalon configuration
d) spherical-planar
- center thickness 100 µm
- spherical (x&y) surface radius 1 m

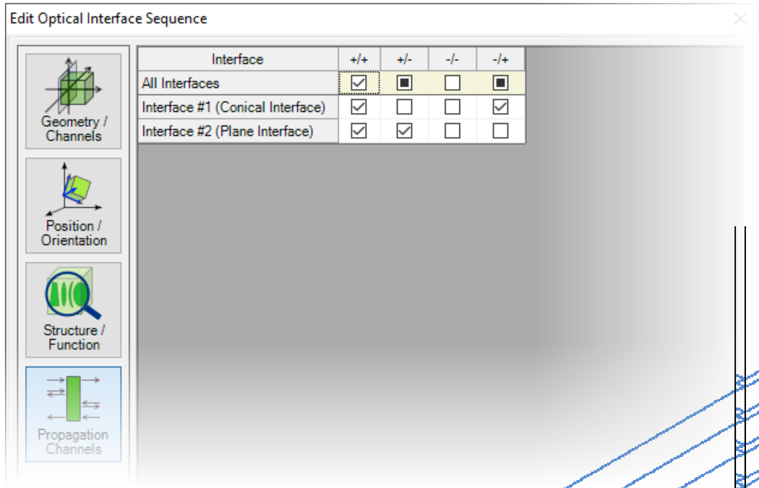


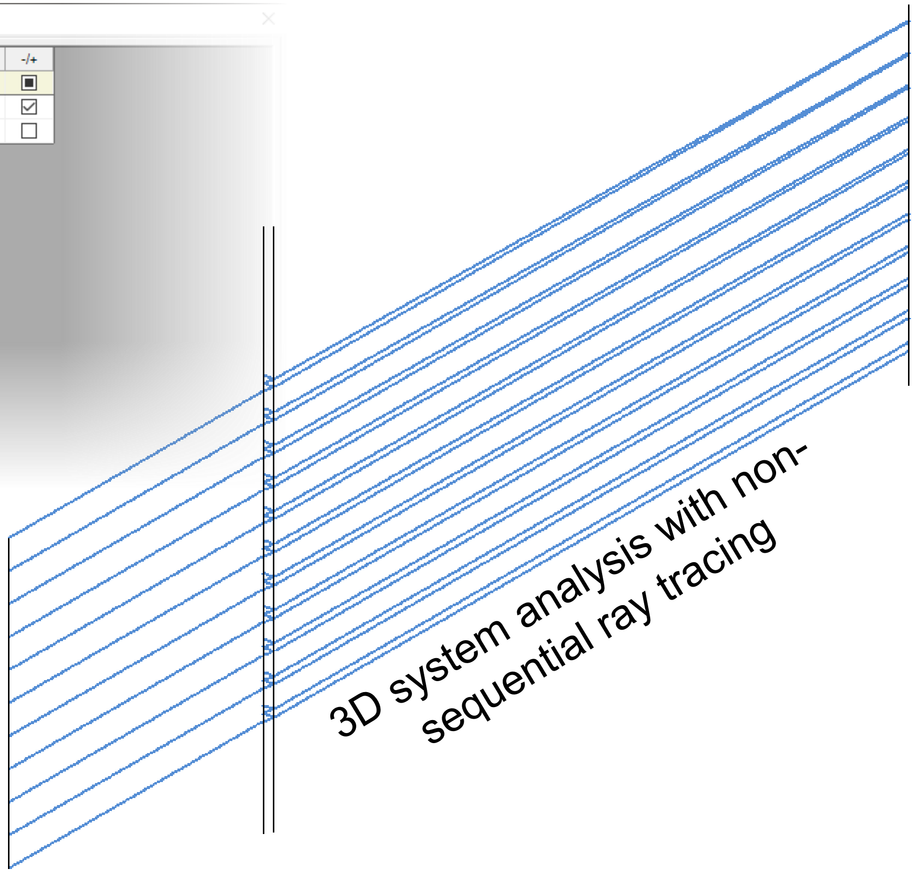


Non-sequential field tracing simulation of etalons allows the consideration of arbitrary surface types.

Peek into VirtualLab Fusion

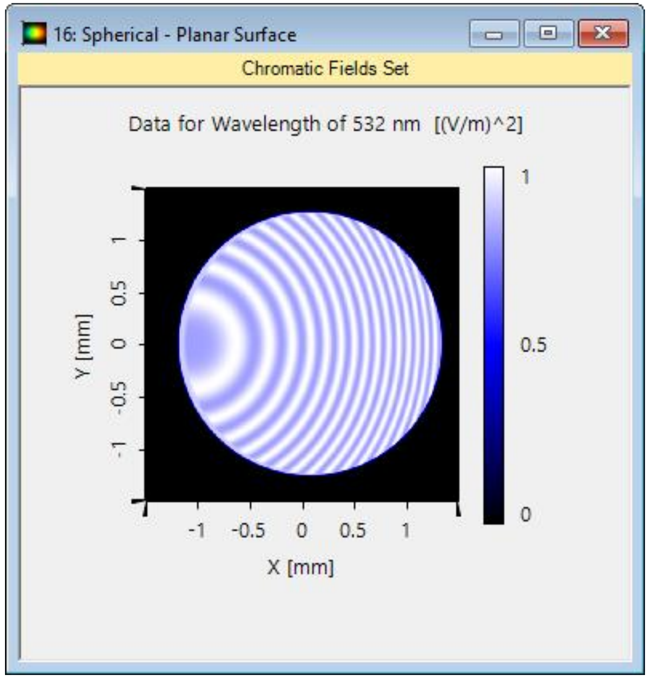
flexible channel settings





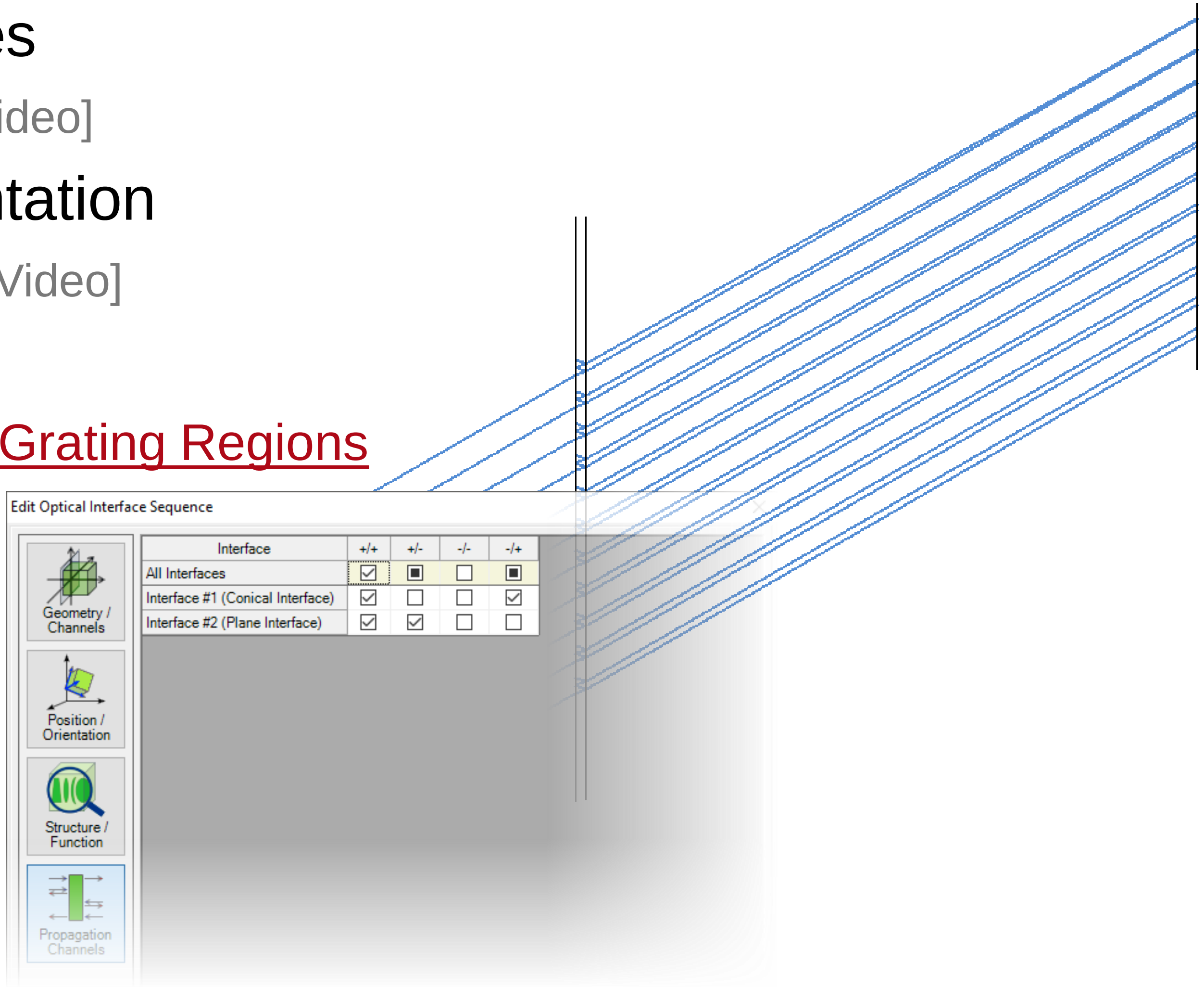
3D system analysis with non-sequential ray tracing

Interference from multiple reflections between arbitrary surface types

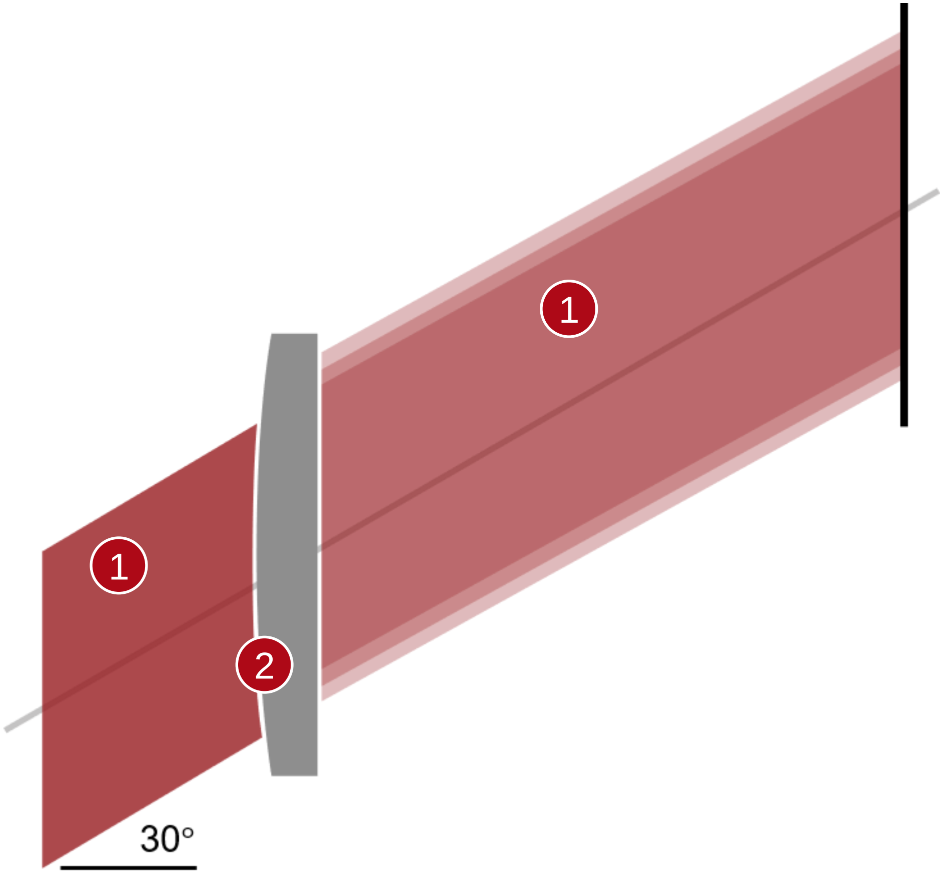


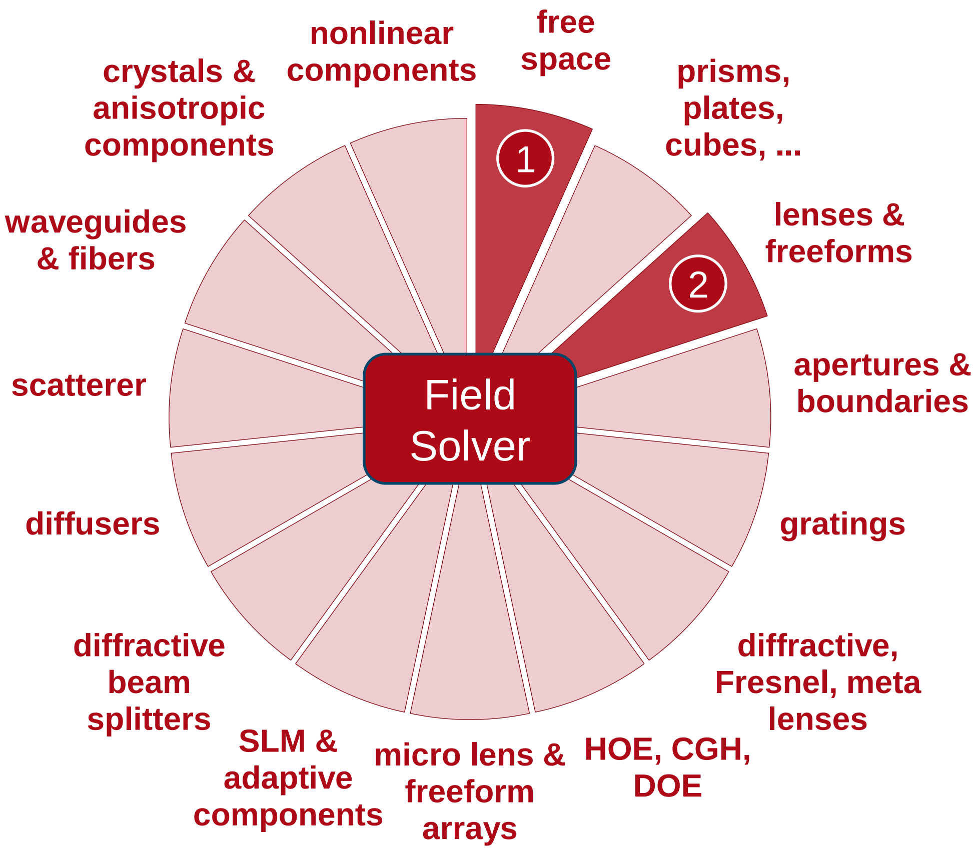
Workflow in VirtualLab Fusion

- Construct component using interfaces
  - Catalogs II: Interfaces Catalog [Tutorial Video]
- Set up component position and orientation
  - LPD II: Position and Orientation [Tutorial Video]
- Adjust channels for surfaces
  - Channel Configuration for Surfaces and Grating Regions [Use Case]



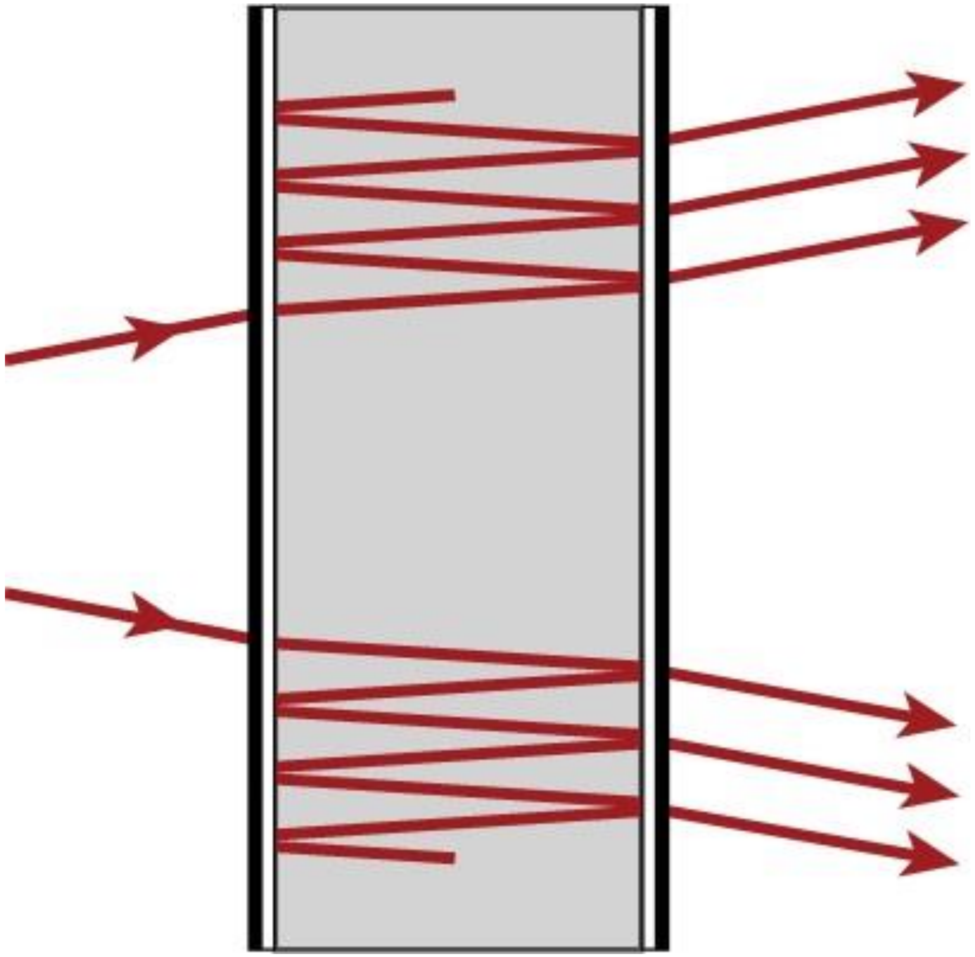
VirtualLab Fusion Technologies





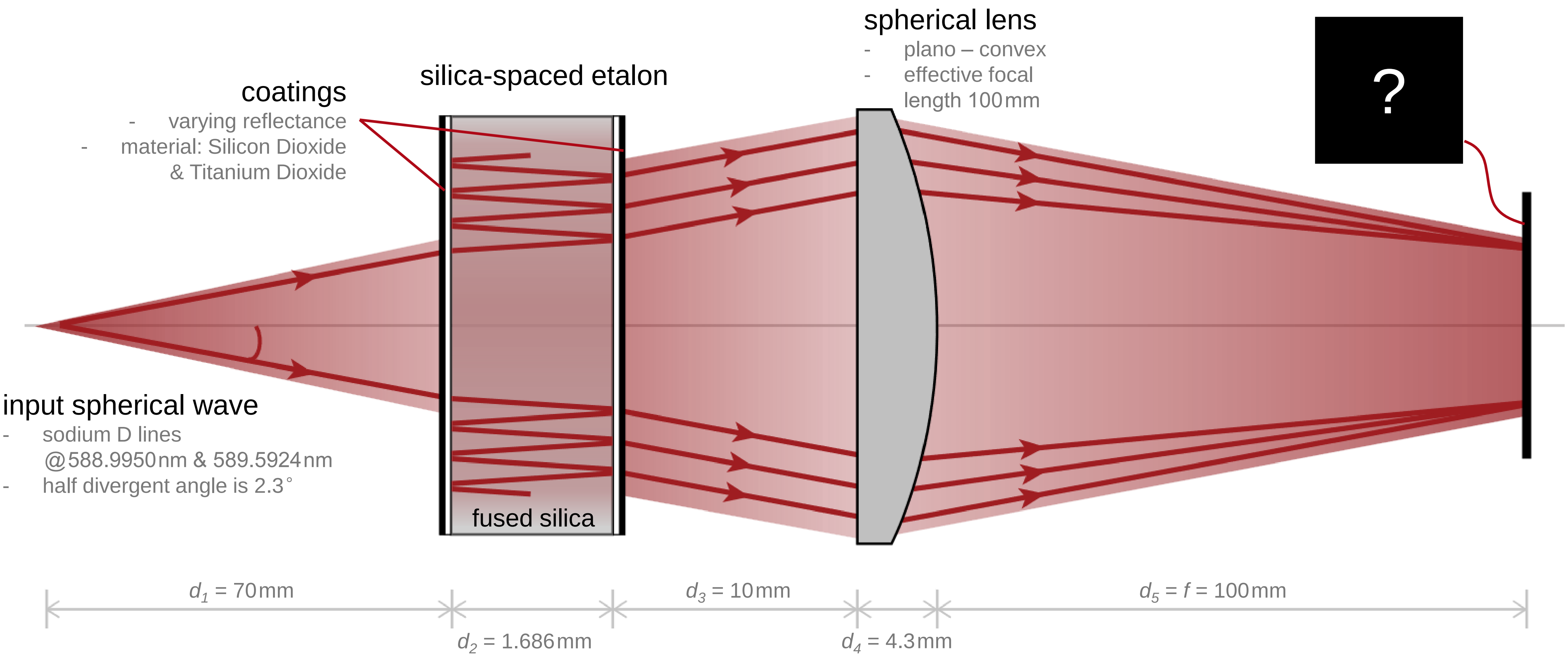
Examination of Sodium D Lines with Fabry-Pérot Etalon

Abstract

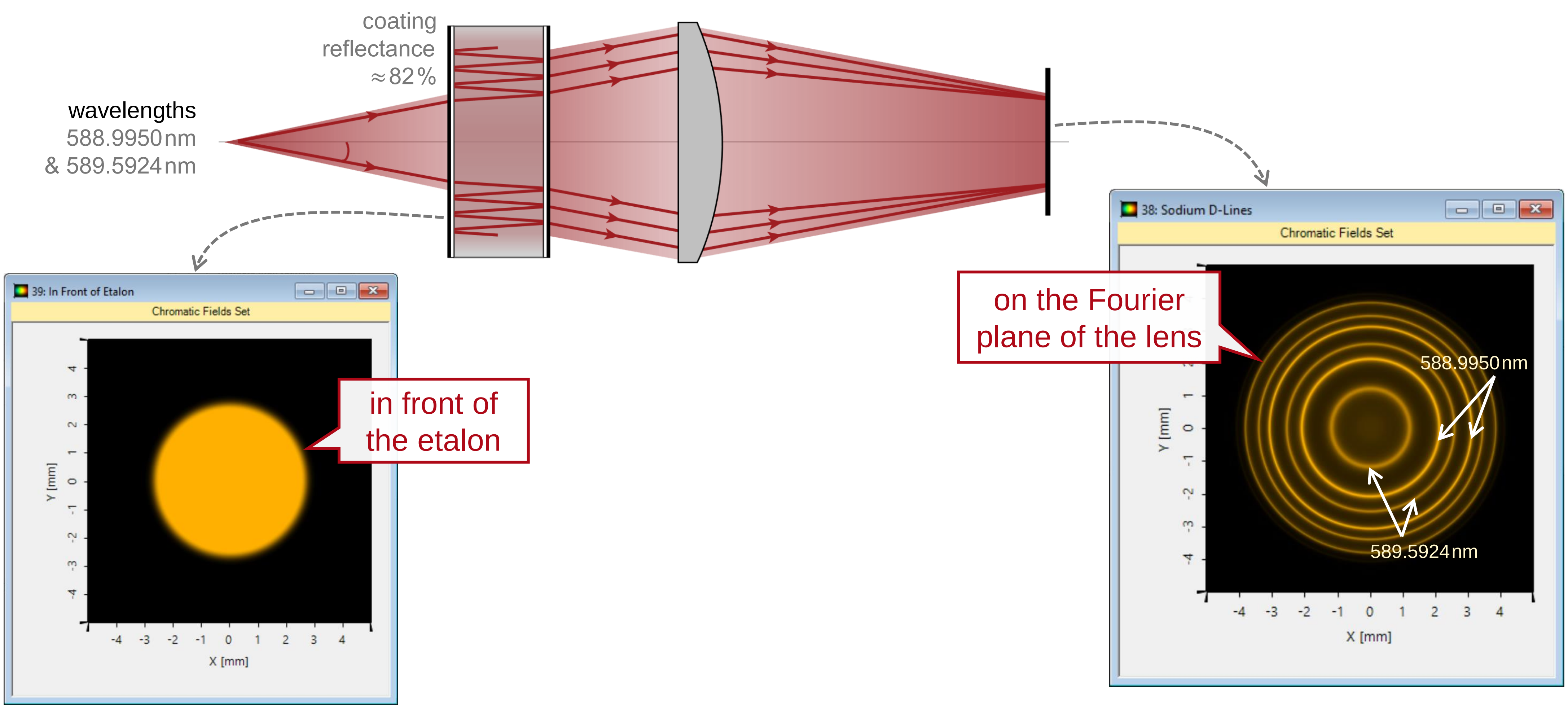


Fabry-Pérot etalons are widely used in laser resonators and spectroscopy for wavelength selection. Typically they are composed of two high-reflection (HR) coated surfaces with air or glass in between. In this example, an optical metrology system with a silica spaced etalon is set up to measure the sodium D lines in VirtualLab Fusion. With the non-sequential field tracing technique, the interference due to multiple reflections in the etalon is fully considered, and the influence from the coating reflectance on the fringe contrast is investigated.

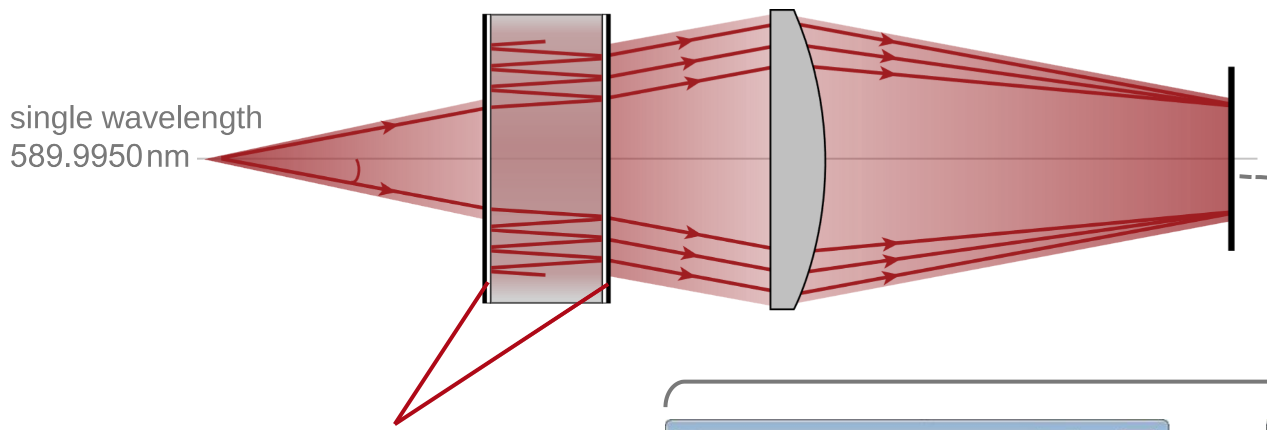
Modeling Task



Visualization of Both Spectrum Lines

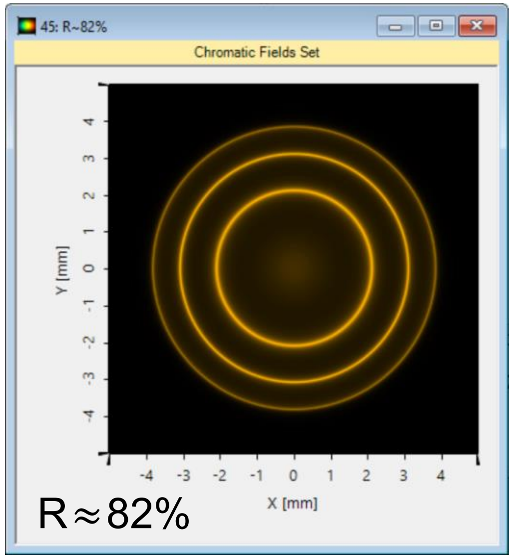


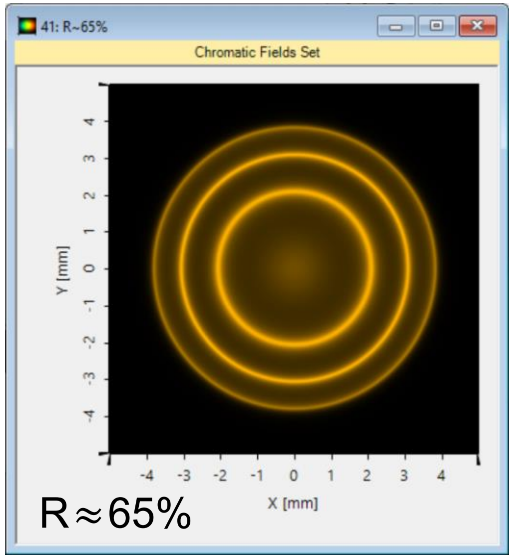
Finesse vs. Coating Reflectance

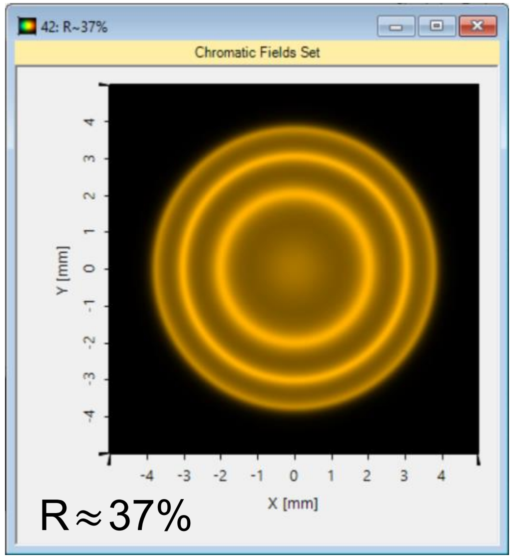


- varying reflectance: 82%, 65%, 37%

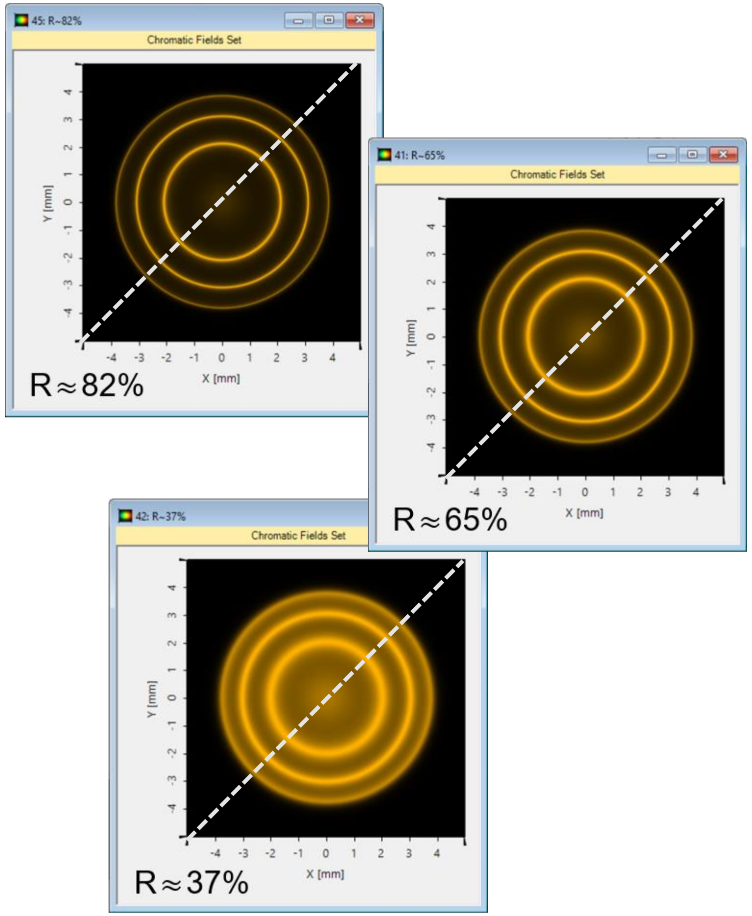
Sharpness of the interference fringes depends on the reflectance of the coatings on the etalon.





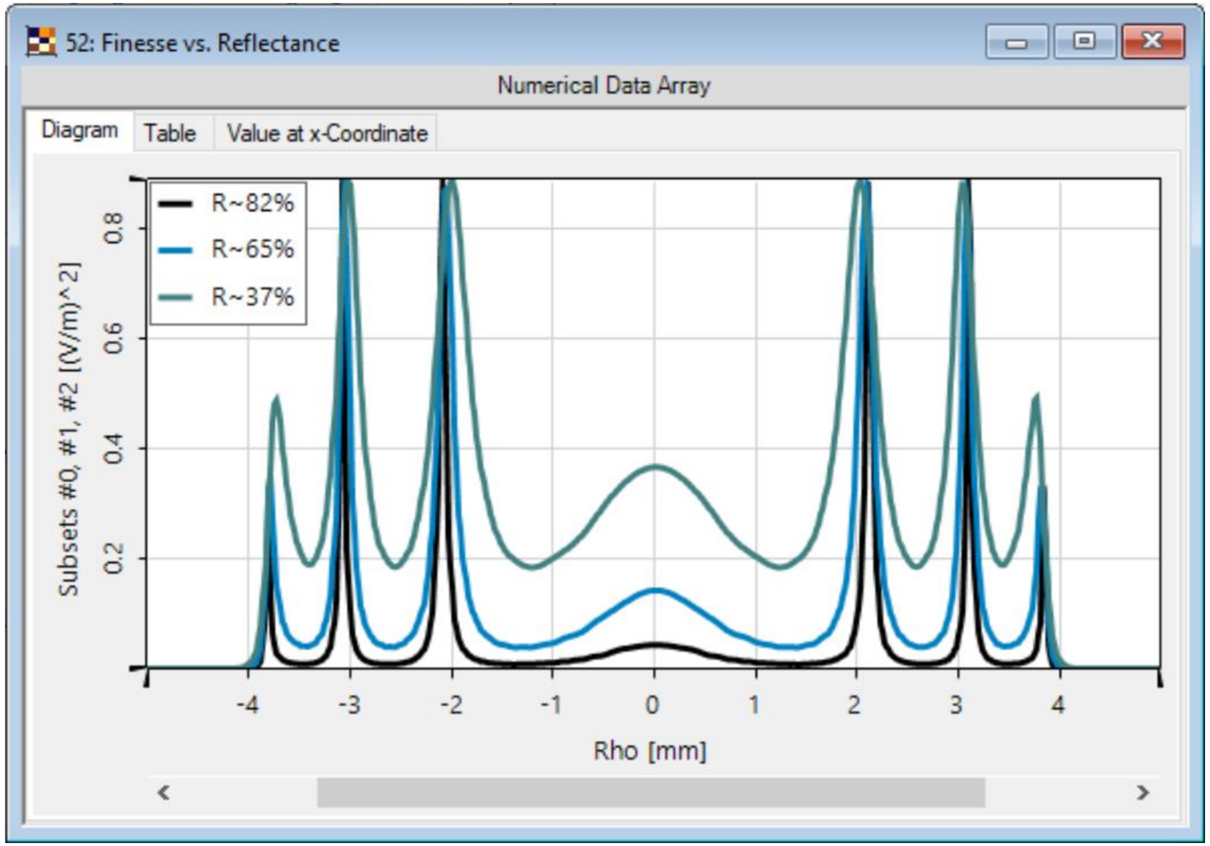


Finesse vs. Coating Reflectance



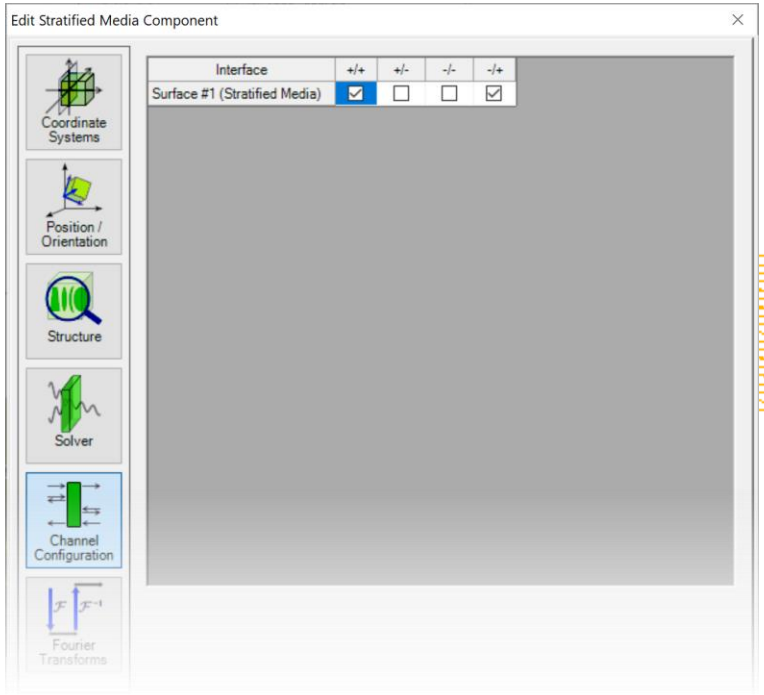
1D measurements along the radial direction

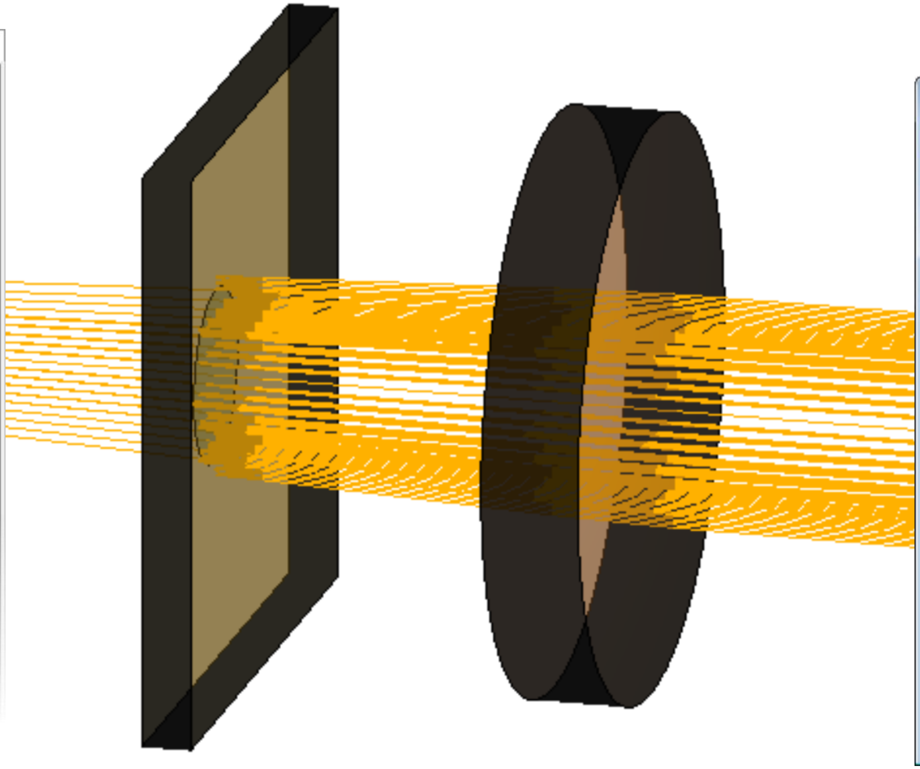
the higher the reflectance, the higher the finesse



Peek into VirtualLab Fusion

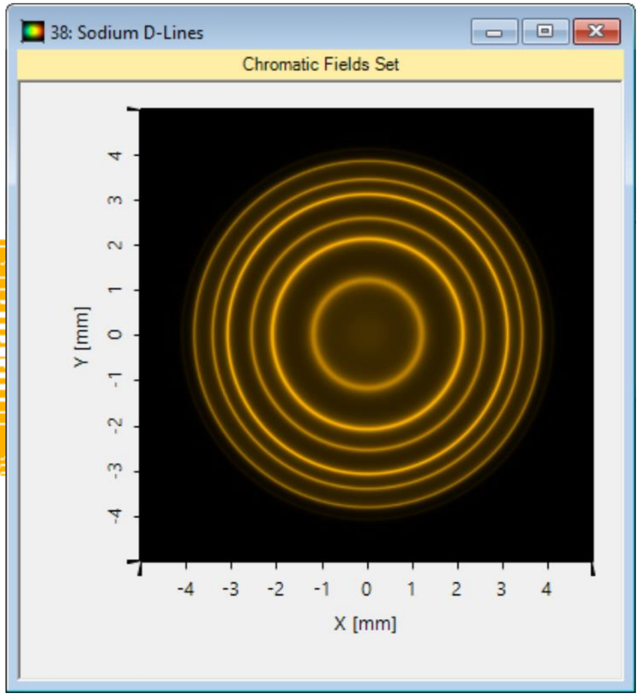
flexible configuration of channels





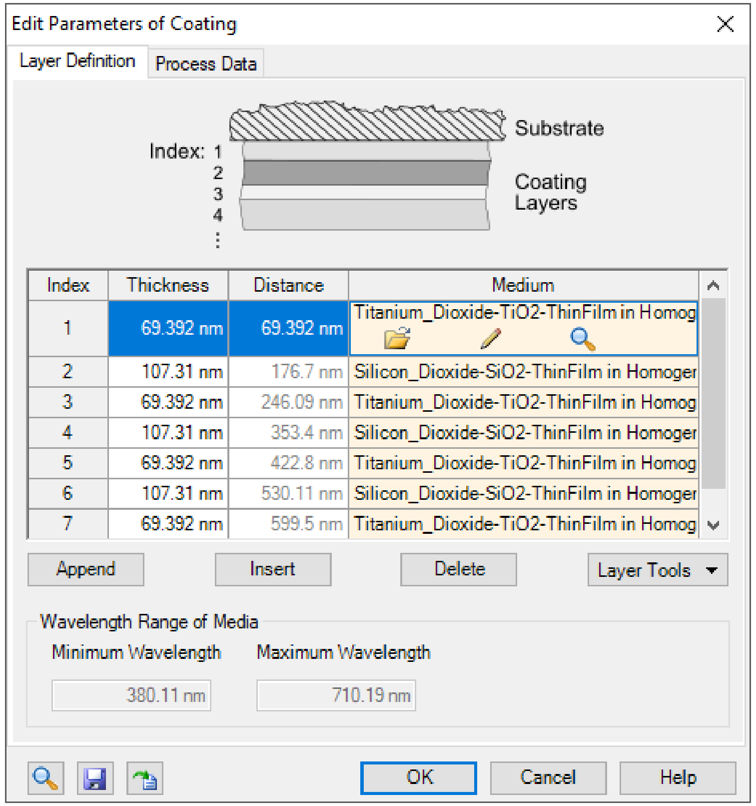
ray tracing analysis and
visualization of the optical system

visualization of interference

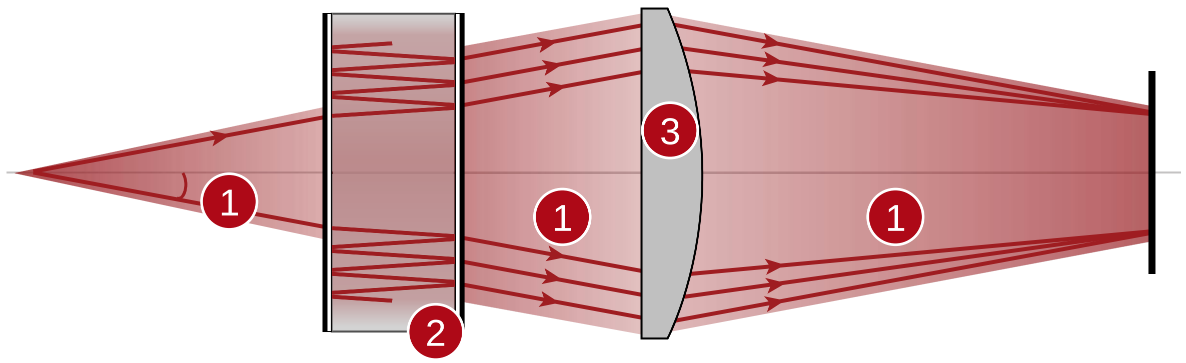


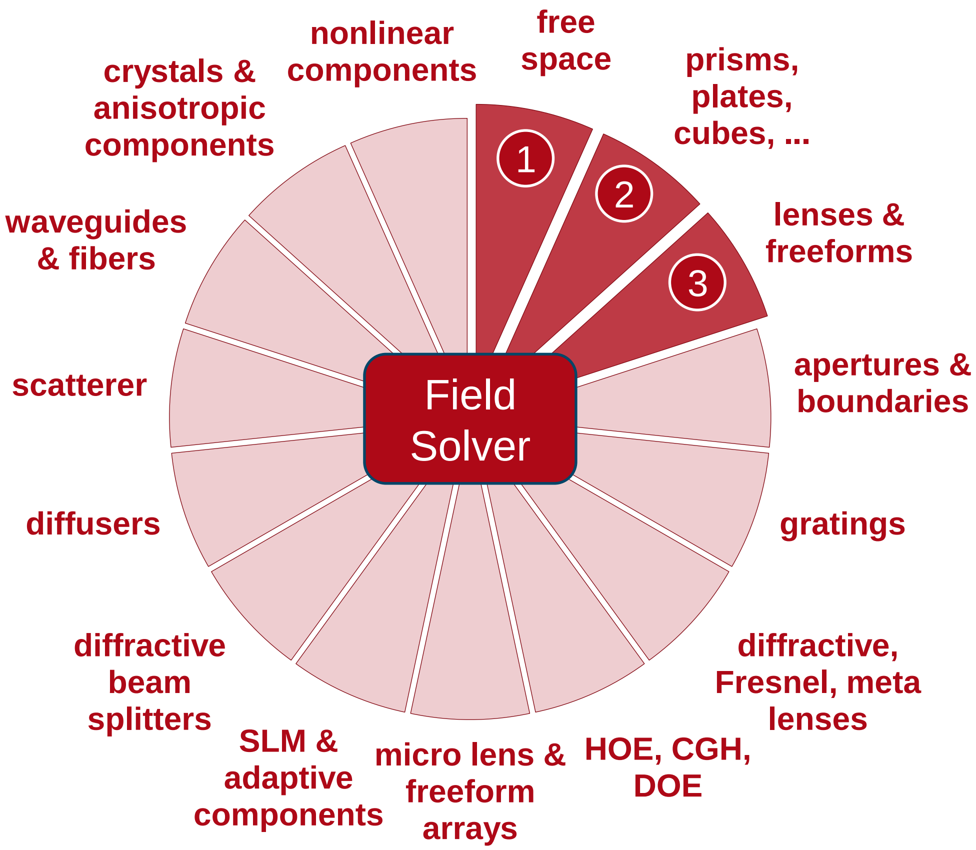
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set the HR coating
  - Catalogs III: Coatings Catalog [Tutorial Video]
- Set the non-sequential channels of components
  - Channel Configuration for Surfaces and Grating Regions [Use Case]



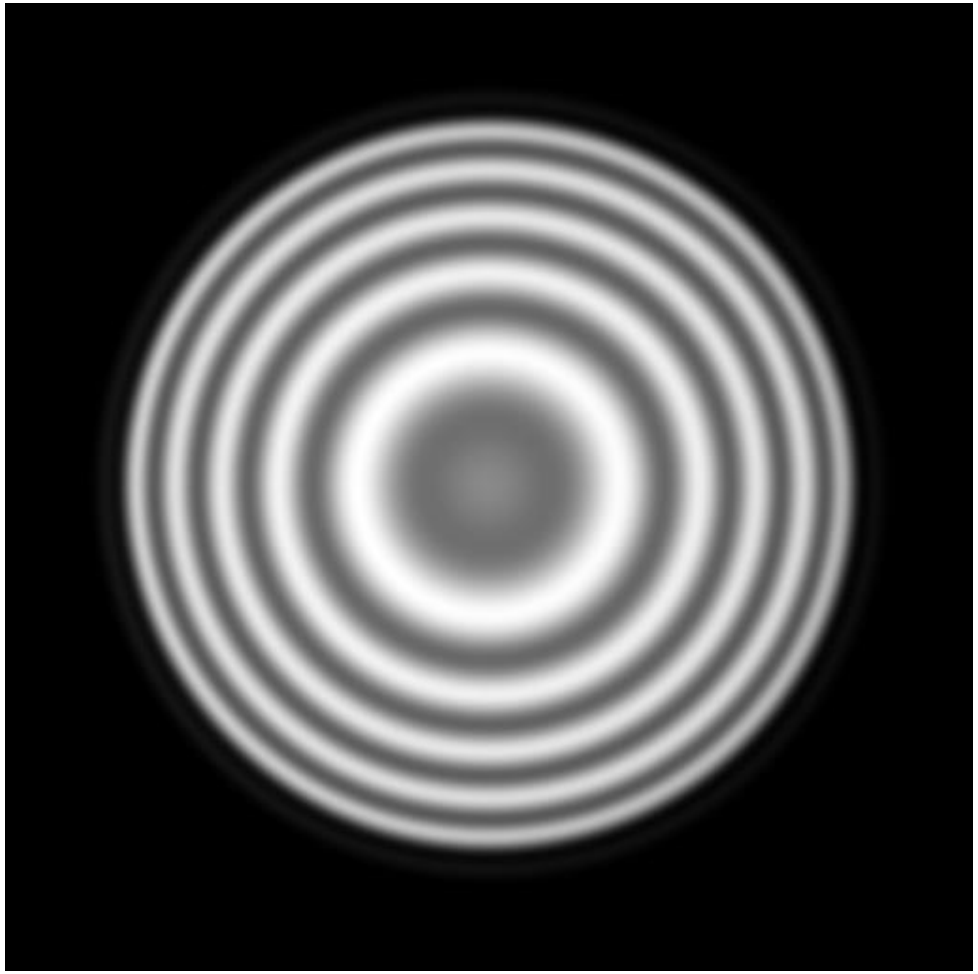
VirtualLab Fusion Technologies





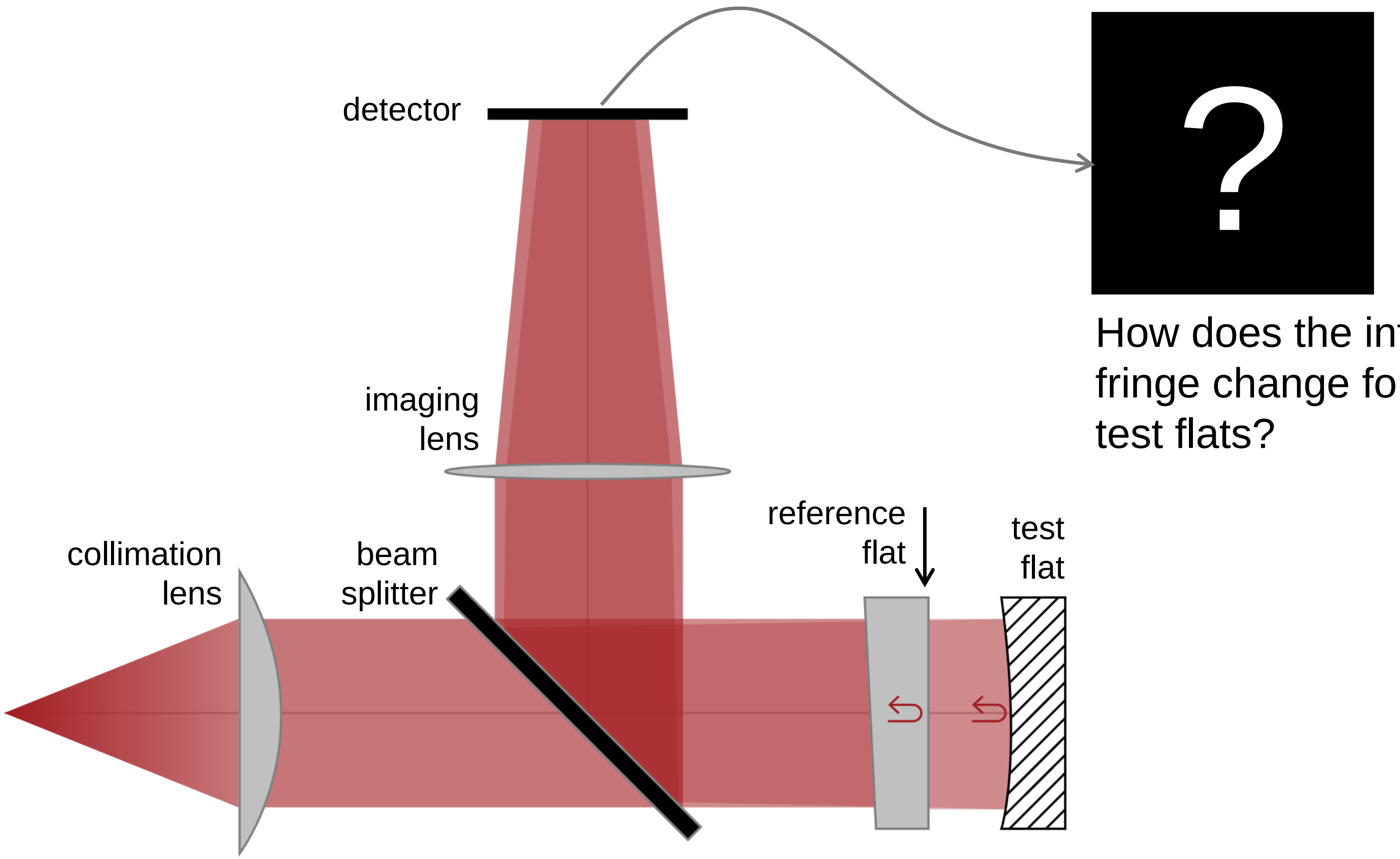
Fizeau Interferometer for Optical Testing

Abstract



Fizeau interferometers are a common type of optical metrology devices in the industry, and they are often used to test the quality of optical surfaces with high precision. With the help of the channel configuration in VirtualLab Fusion, we build up a Fizeau interferometer, and use it for testing different optical surfaces e.g. cylindrical and spherical ones. It can be shown that the resulting interference fringes are sensitive to the surface profile.

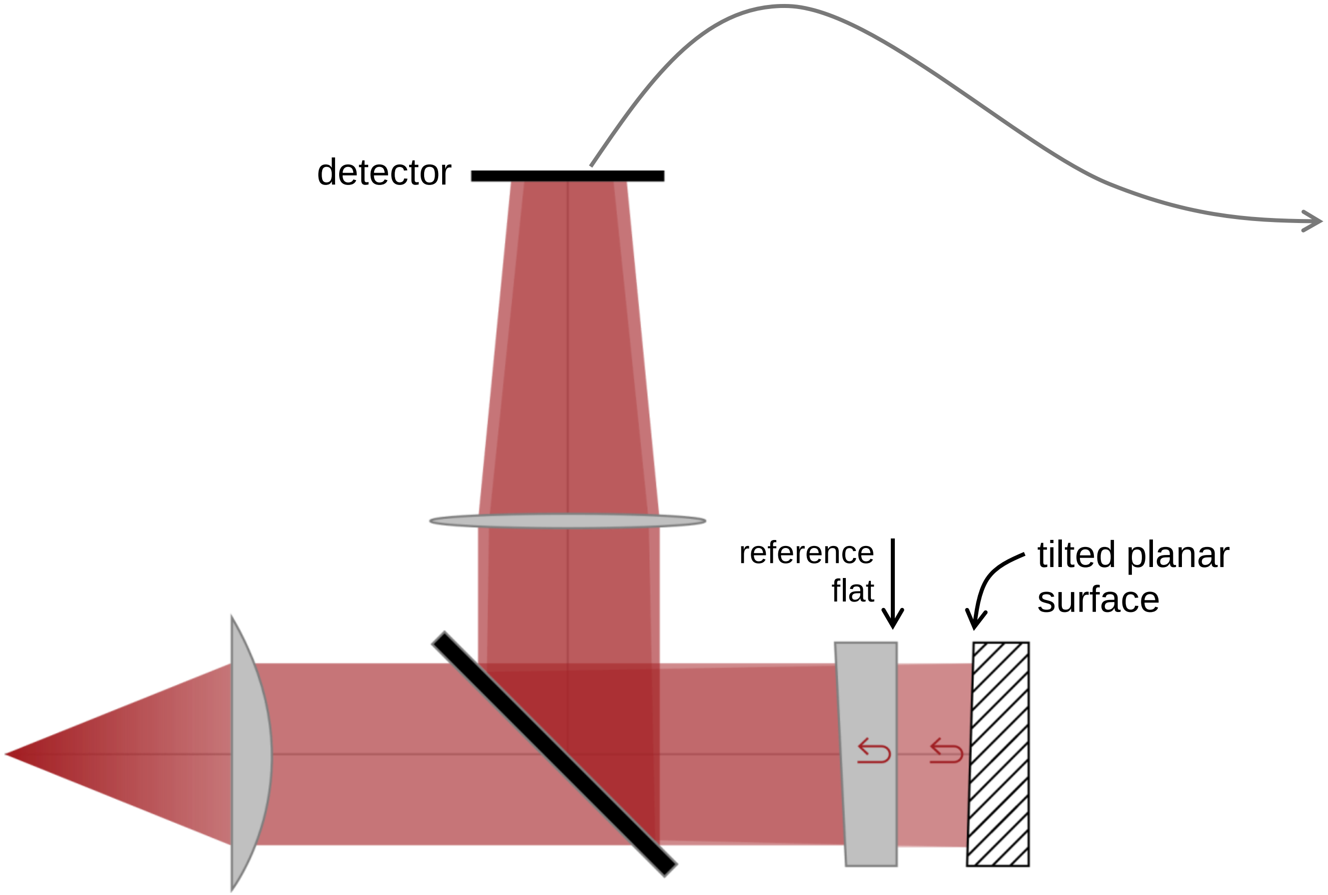
Modeling Task

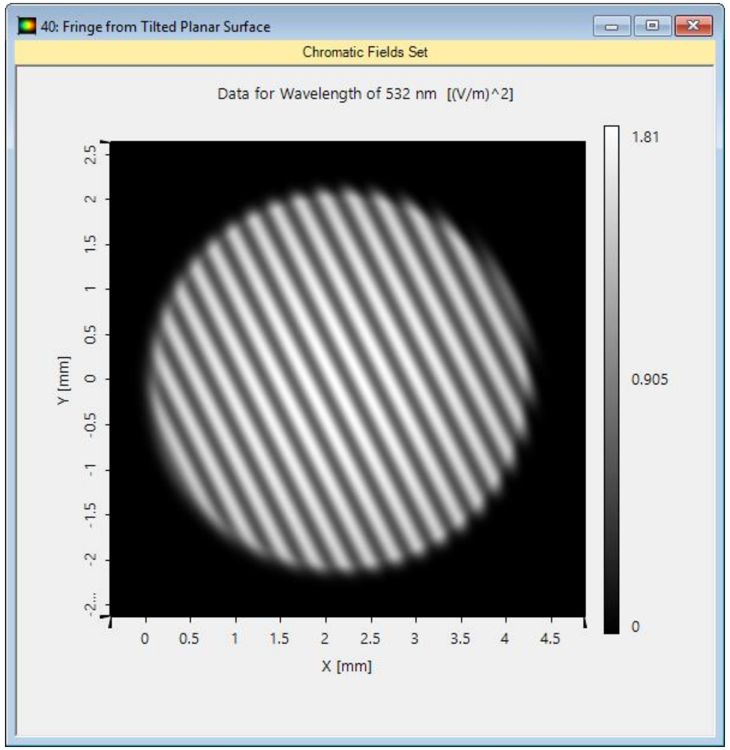


How does the interference fringe change for different test flats?

spherical wave
- wavelength 532 nm
- half-opening angle 26.6°

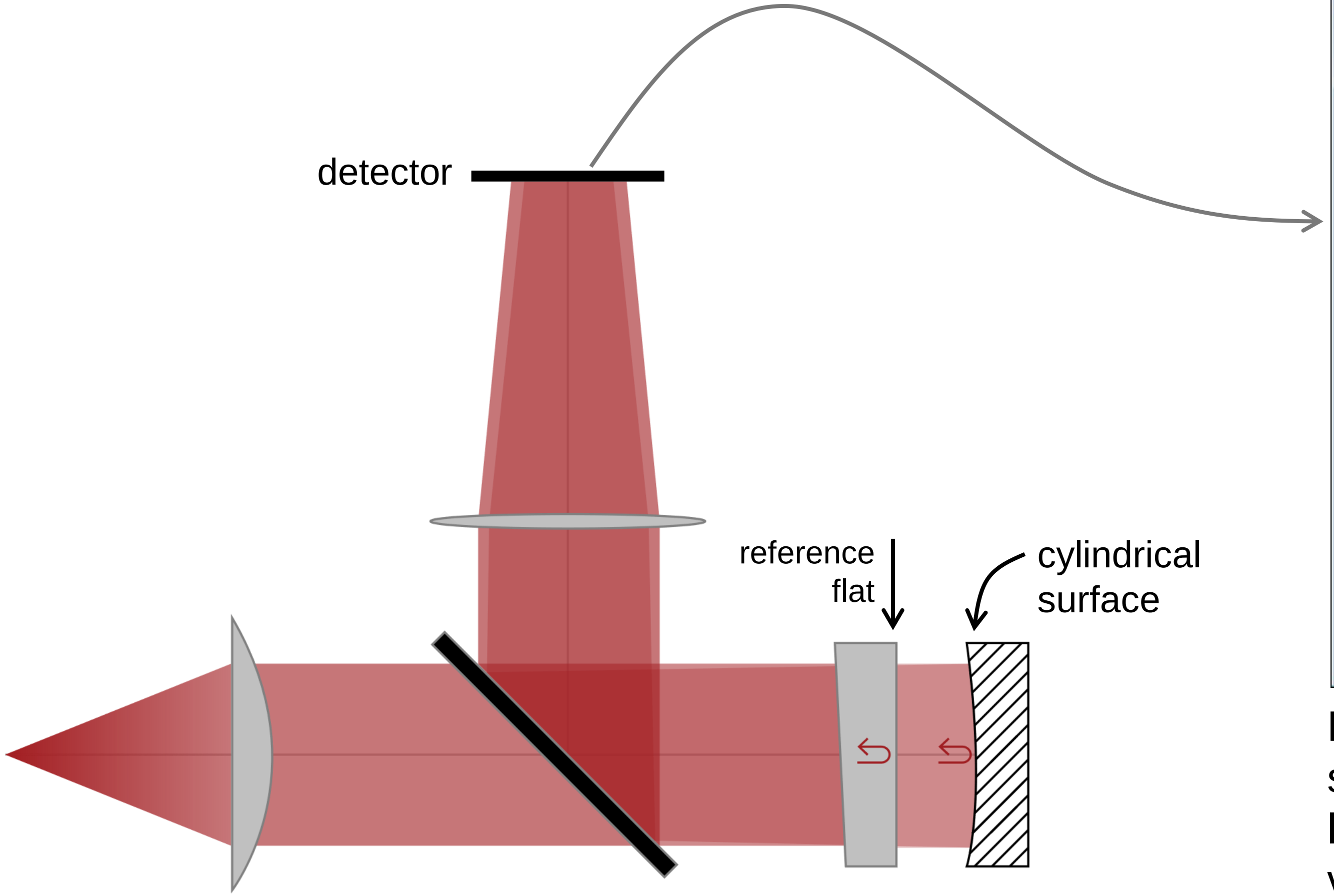
Tilted Planar Surface under Observation

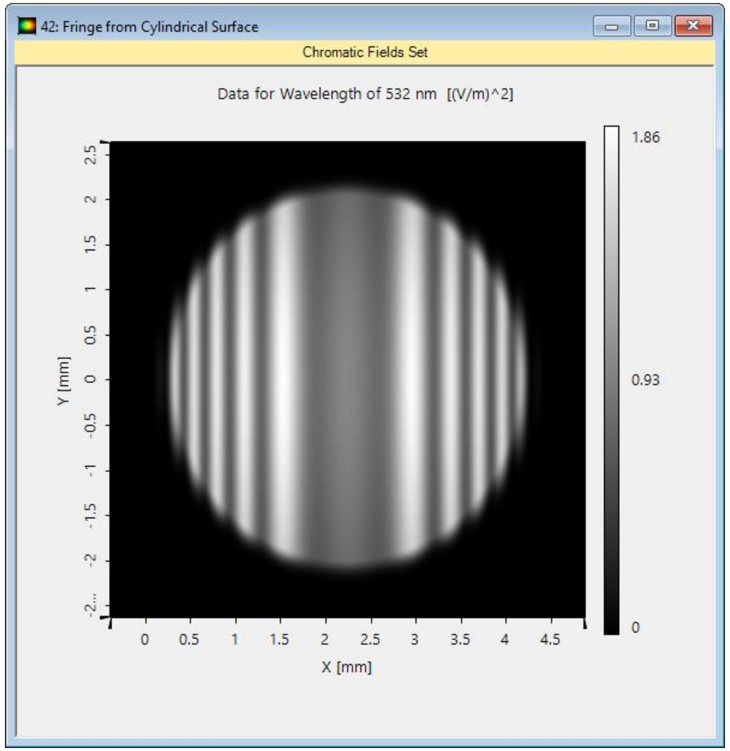




Reflection from the test planar surface remain as plane waves, but only with slightly different direction, and therefore leading to parallel striped fringes.

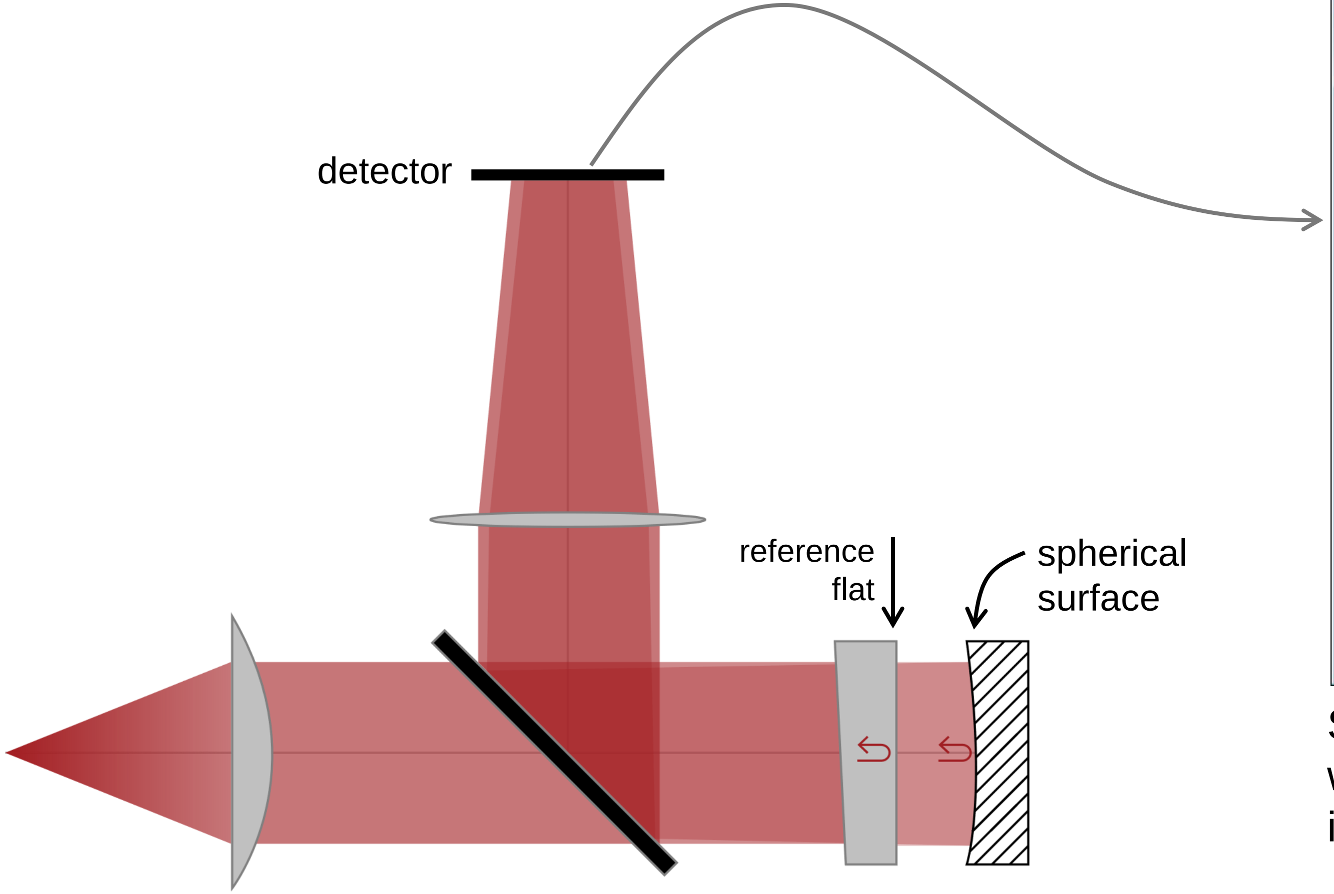
Cylindrical Surface under Observation

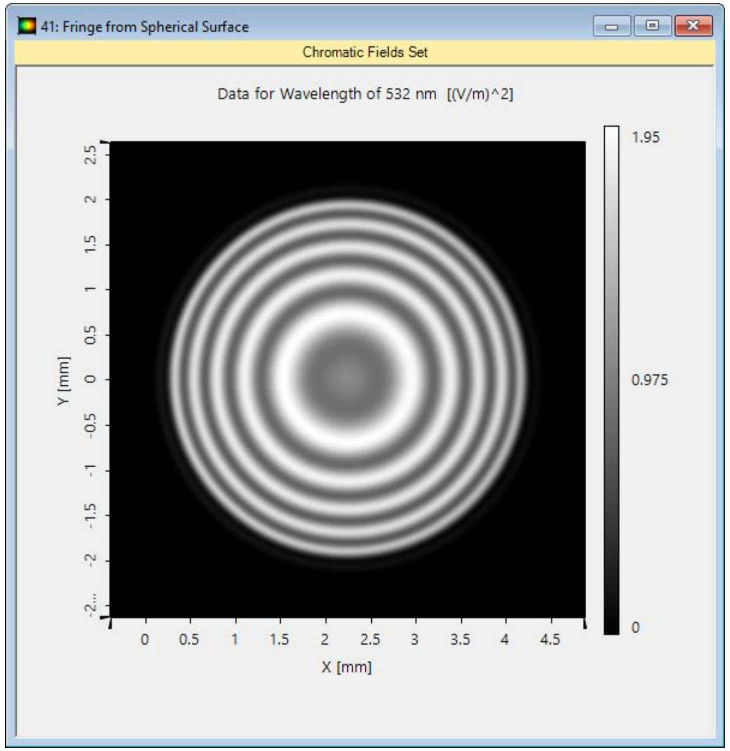




Reflected wavefront from the test cylindrical surface gets curved in one direction, therefore leading to parallel striped fringes but with varying pitch.

Spherical Surface under Observation

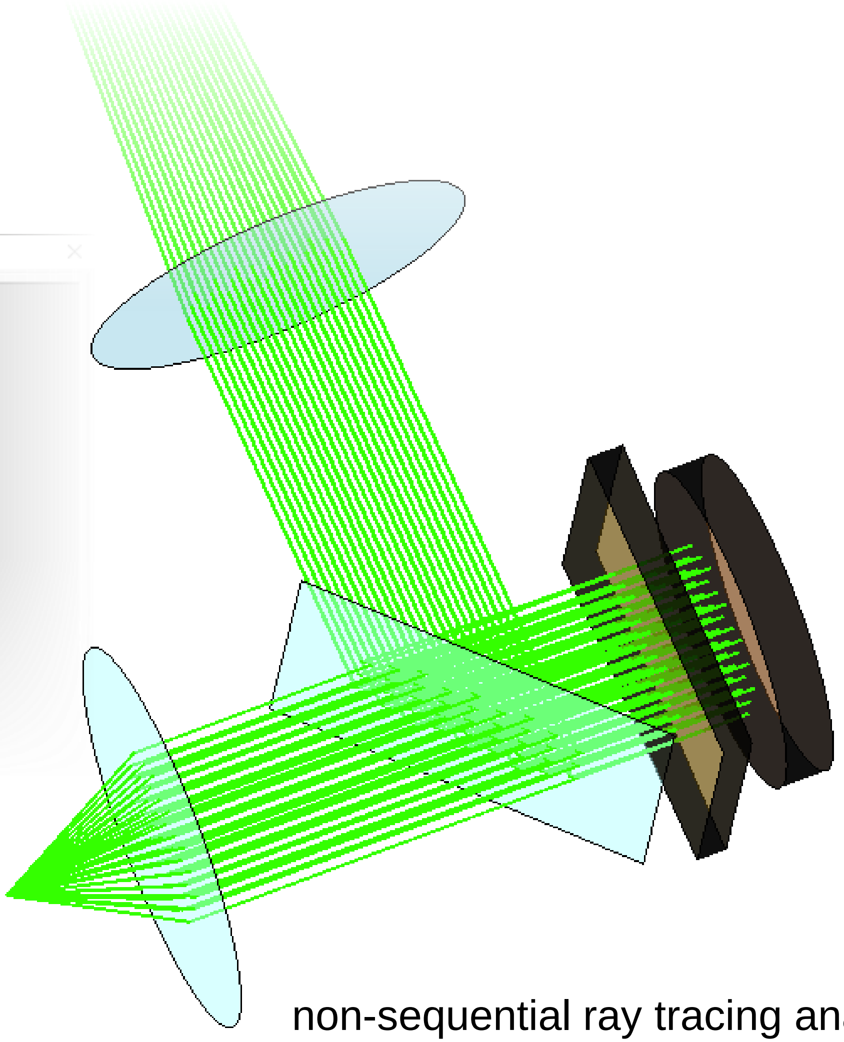


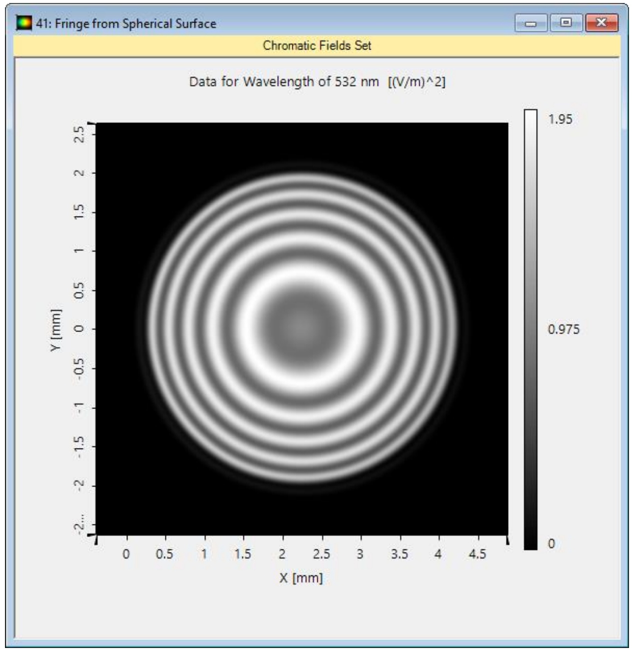


Spherical surface changes the reflected wavefront in radial direction, thus the interference fringes appears as concentric rings.

Peek into VirtualLab Fusion

flexible channel settings



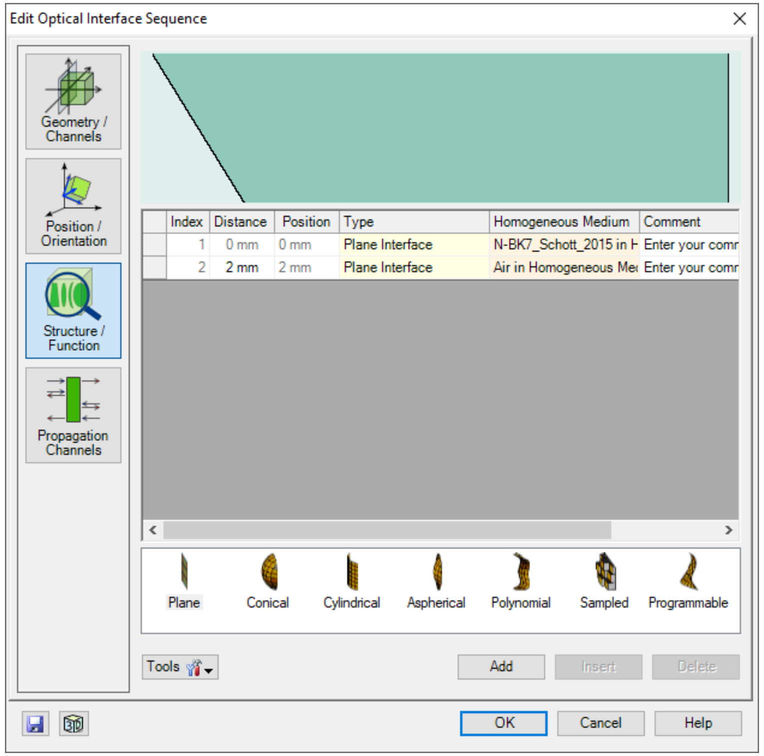


visualization and analysis of interference fringe

non-sequential ray tracing analysis

Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Construct real components using surfaces
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set channels properly for non-sequential tracing
  - Channel Configuration for Surfaces and Grating Regions [Use Case]



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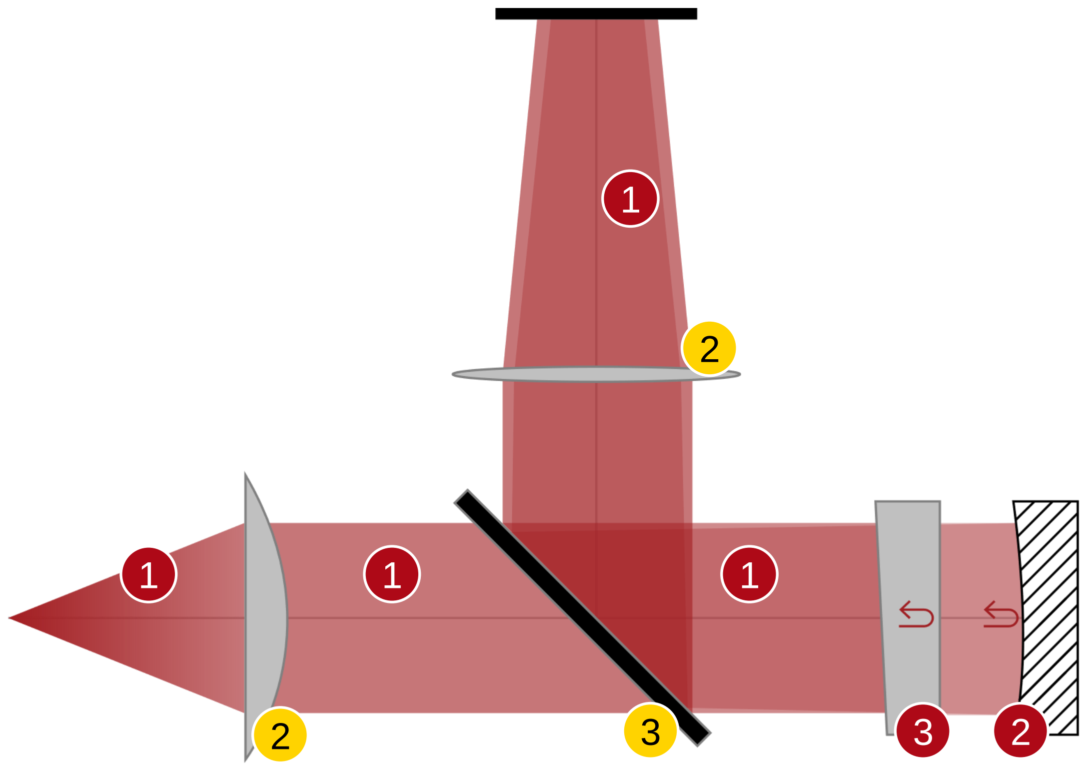
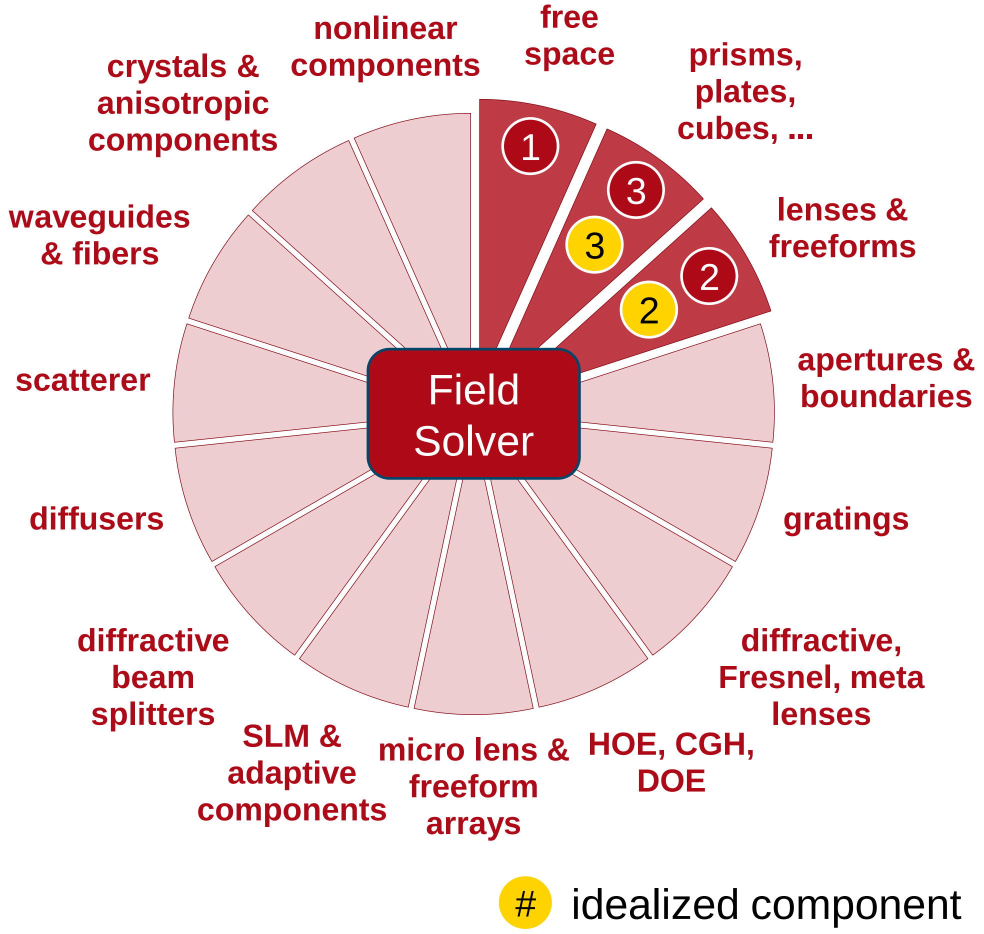
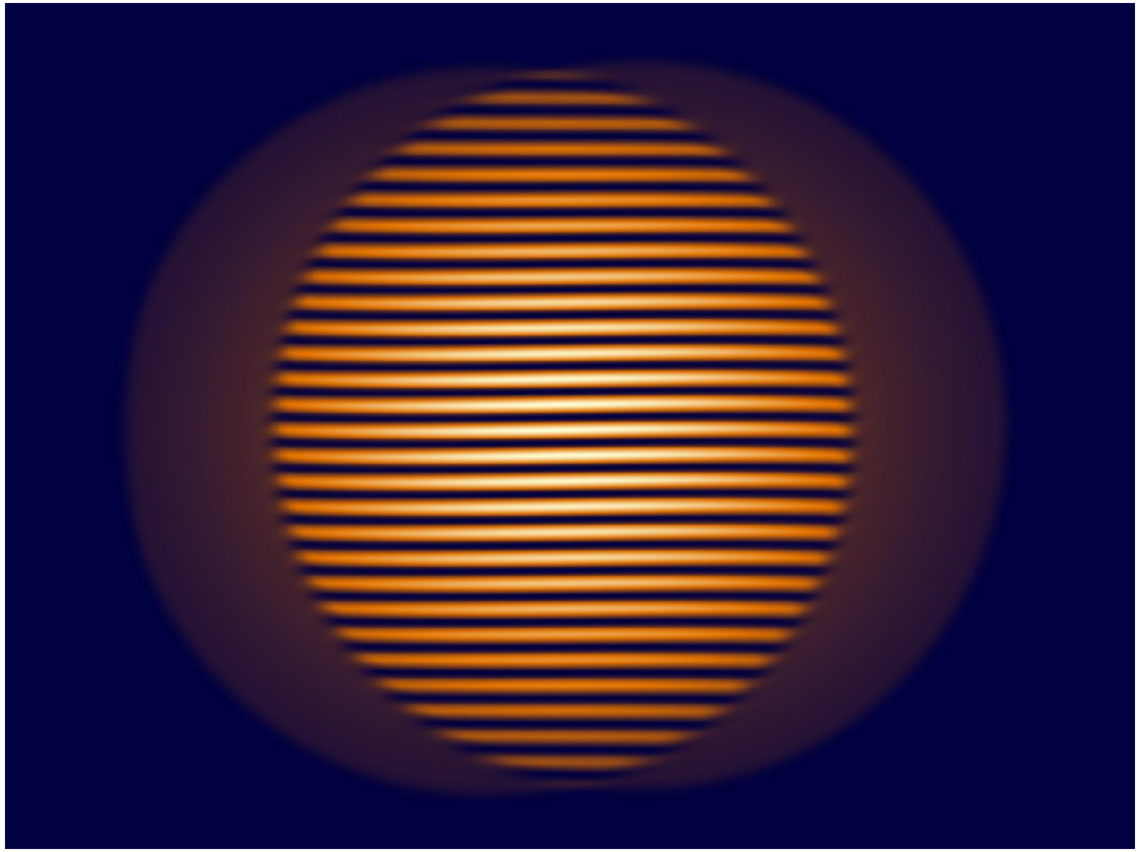




Collimation Testing with Shearing Interferometry

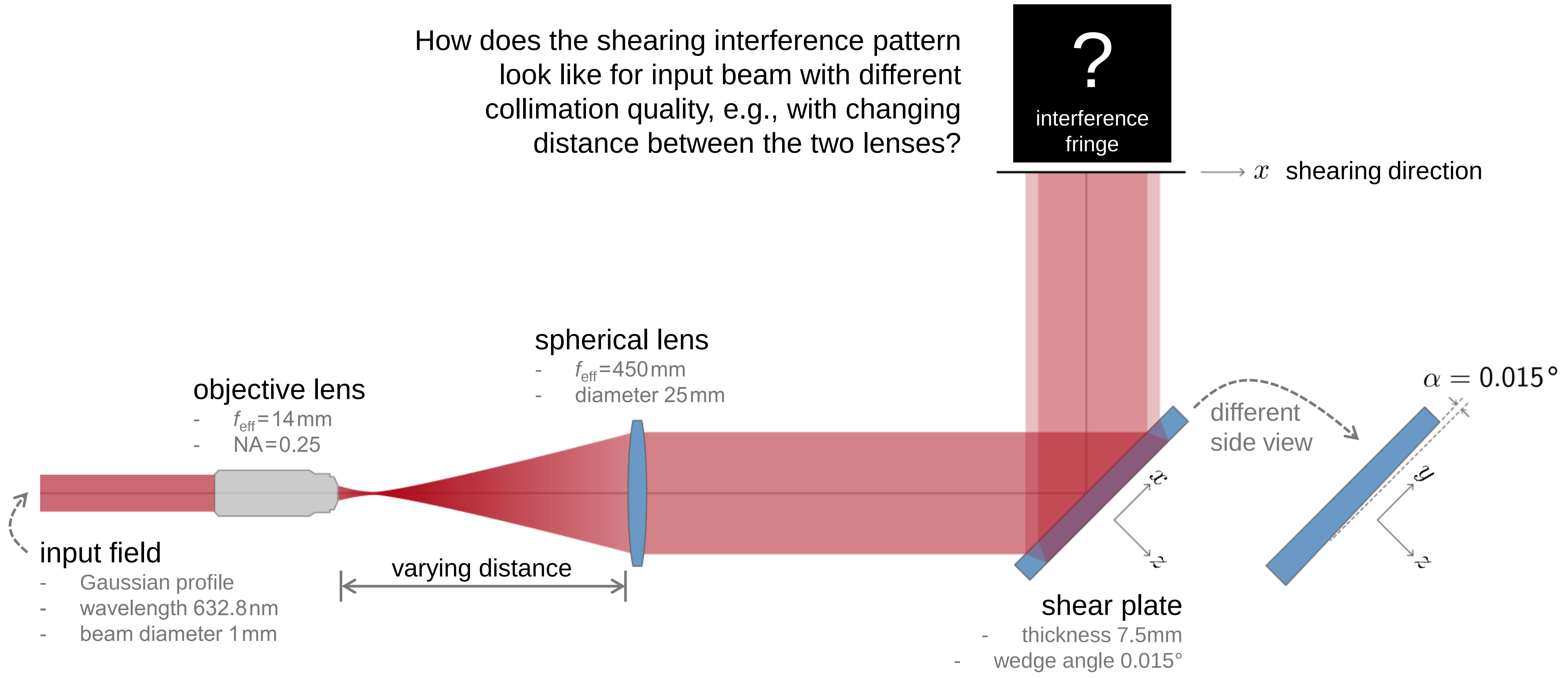
Abstract



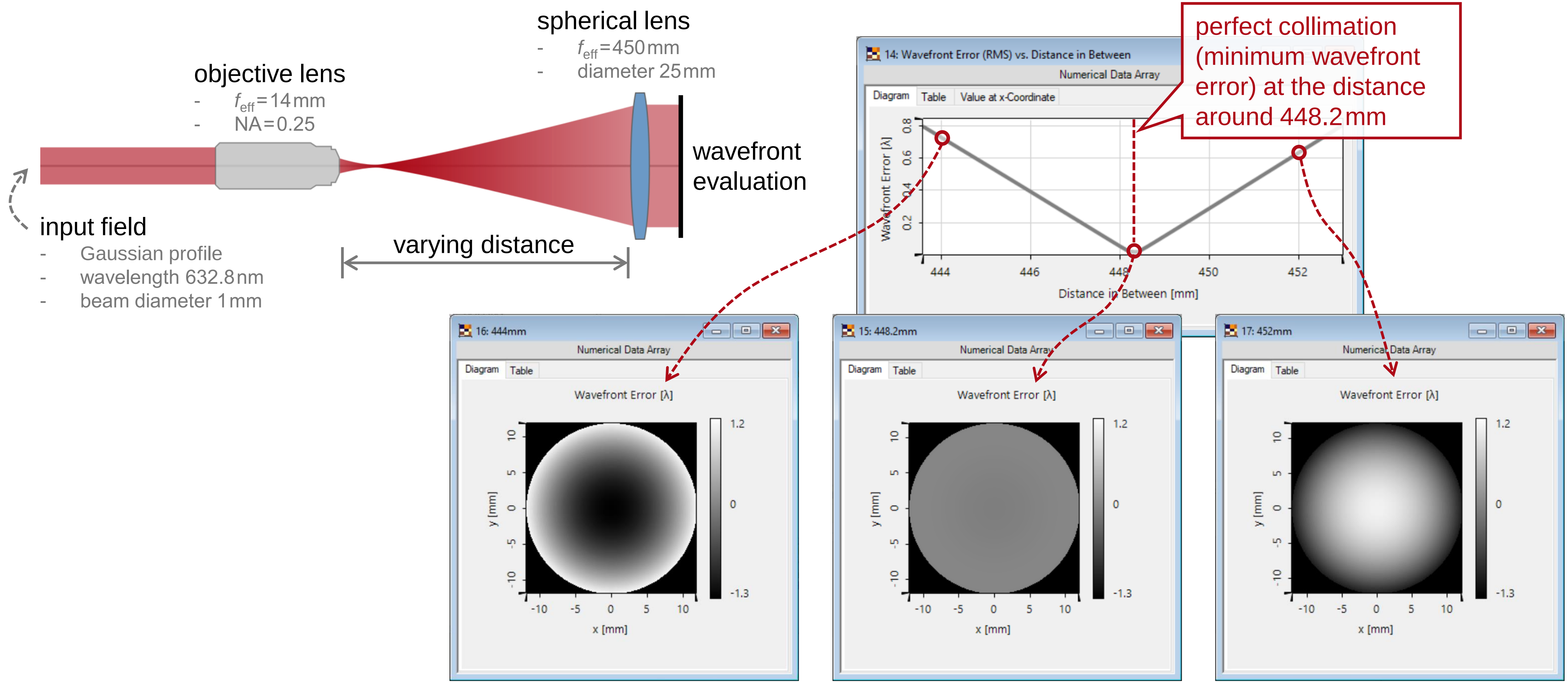
Collimation of laser beams is a fundamentally essential task for various optical applications. Testing of the collimation is therefore of significance as well, and shearing interferometry is often employed for such tasks. In this example, we demonstrate how to build up a shearing interferometer and to use it for testing the collimation. By varying the beam collimation system – in this example, the distance between the two lenses – we observe the interference fringes from the shearing interferometry.

Modeling Task

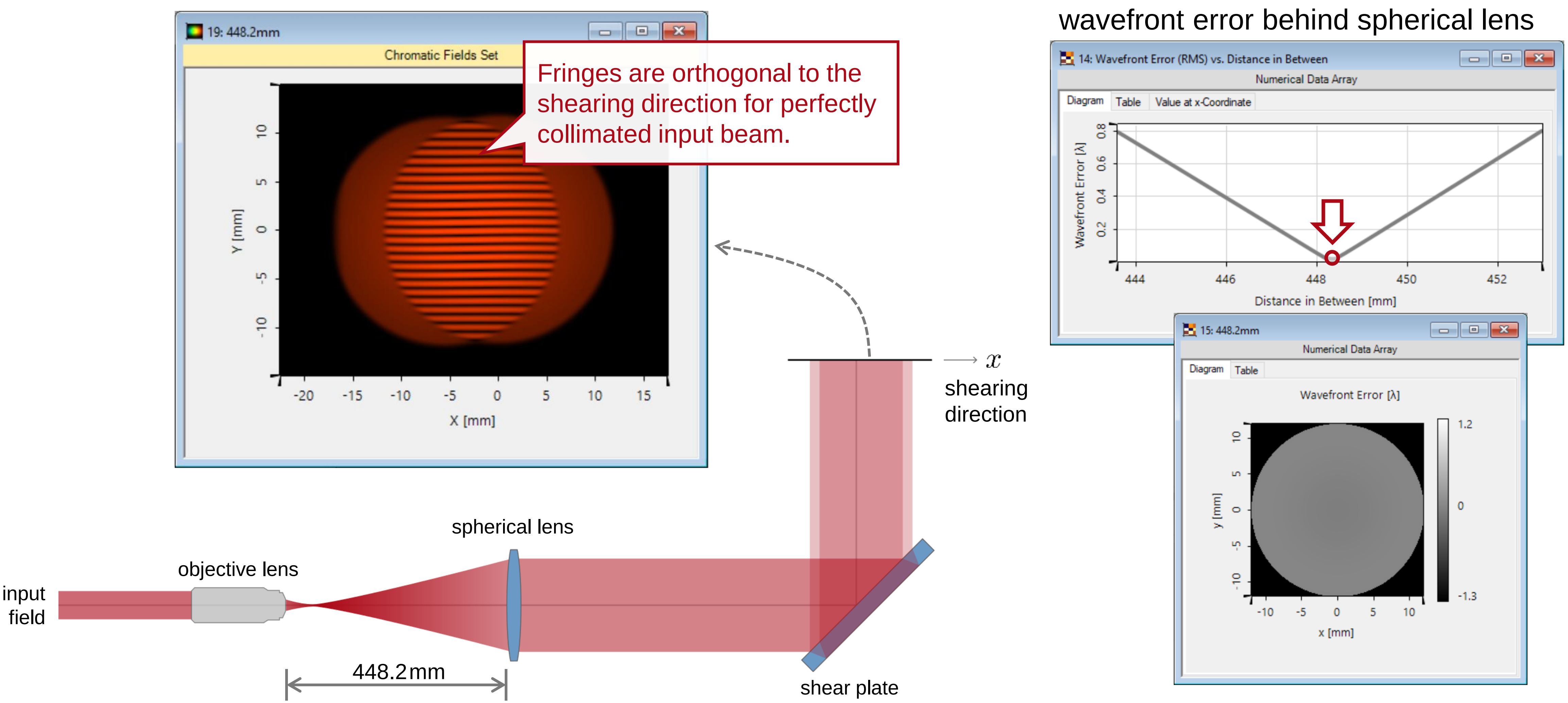
How does the shearing interference pattern look like for input beam with different collimation quality, e.g., with changing distance between the two lenses?



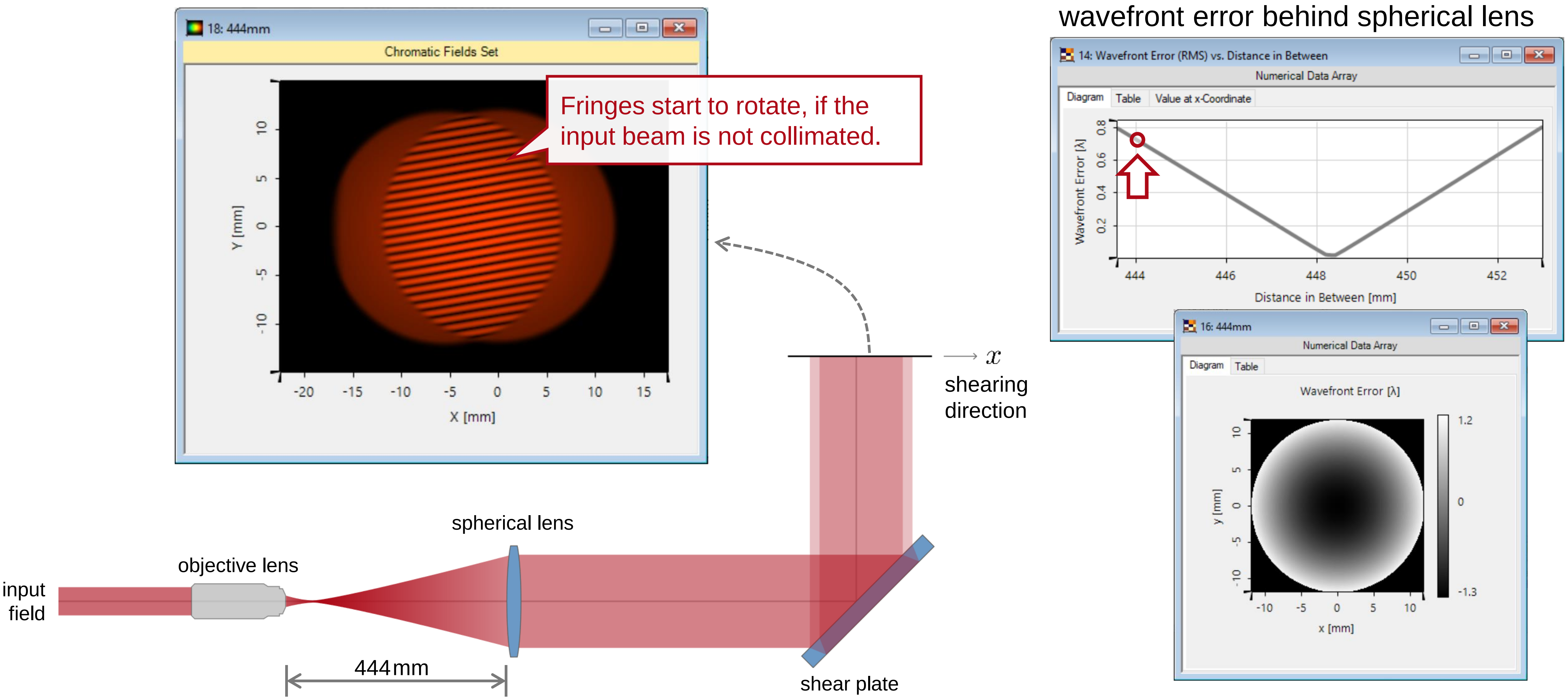
Wavefront Evaluation after Expansion and Collimation



Shear Interference Fringe

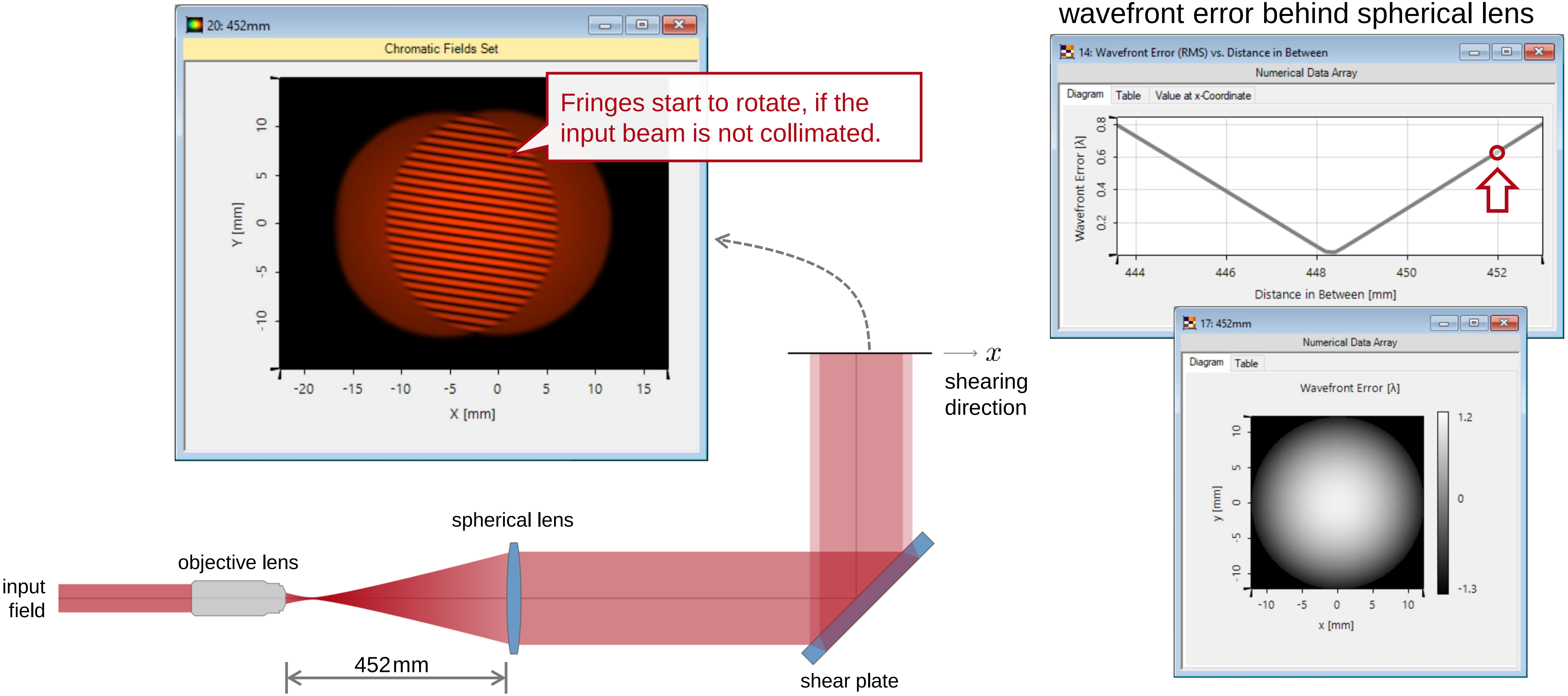


Shear Interference Fringe



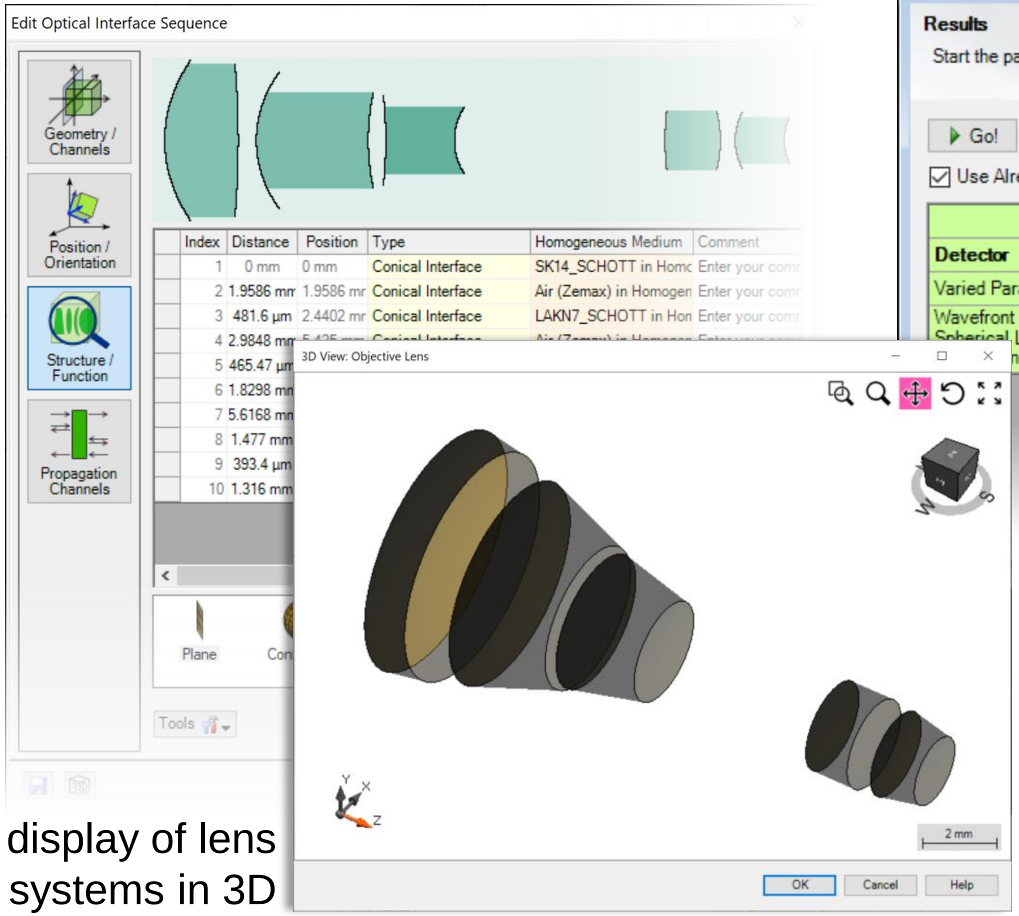
Shear Interference Fringe

wavefront error behind spherical lens

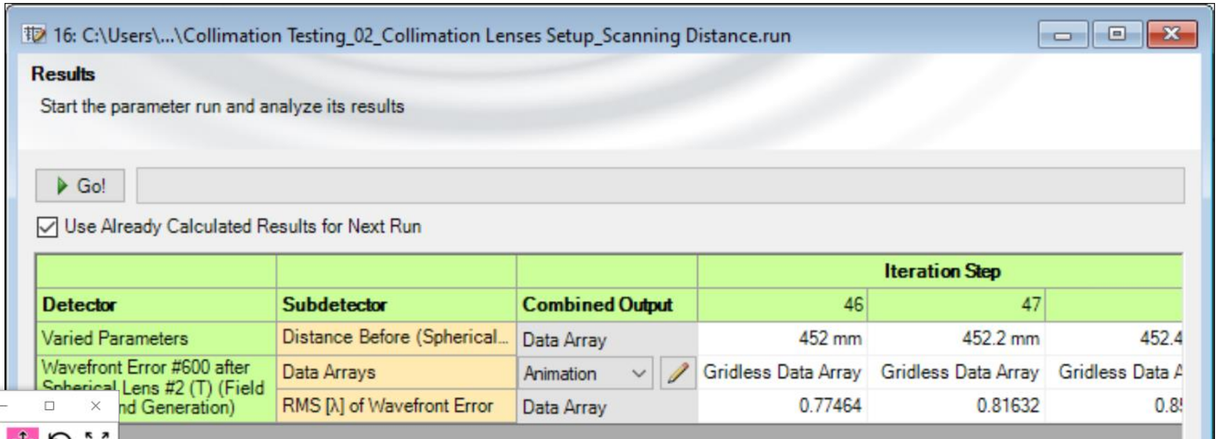


Peek into VirtualLab Fusion

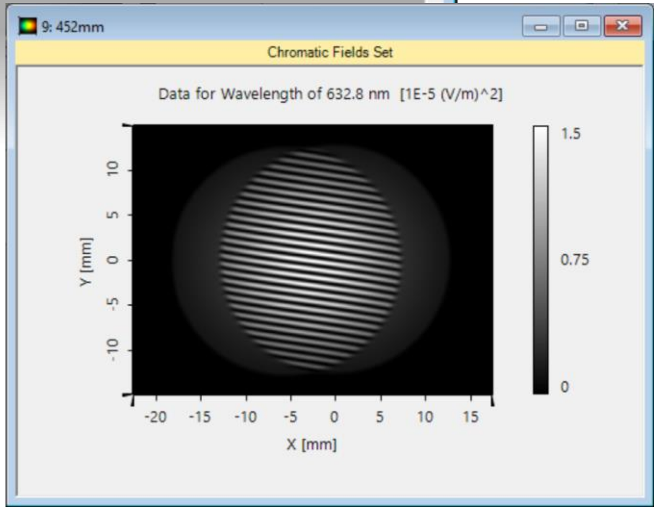
convenient definition of lens systems



display of lens systems in 3D



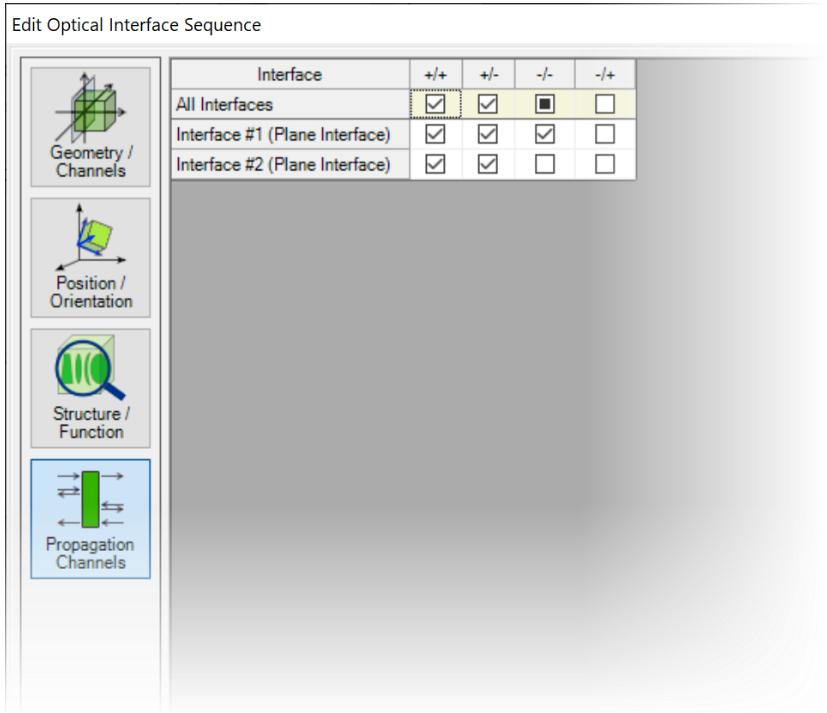
parameter sweep



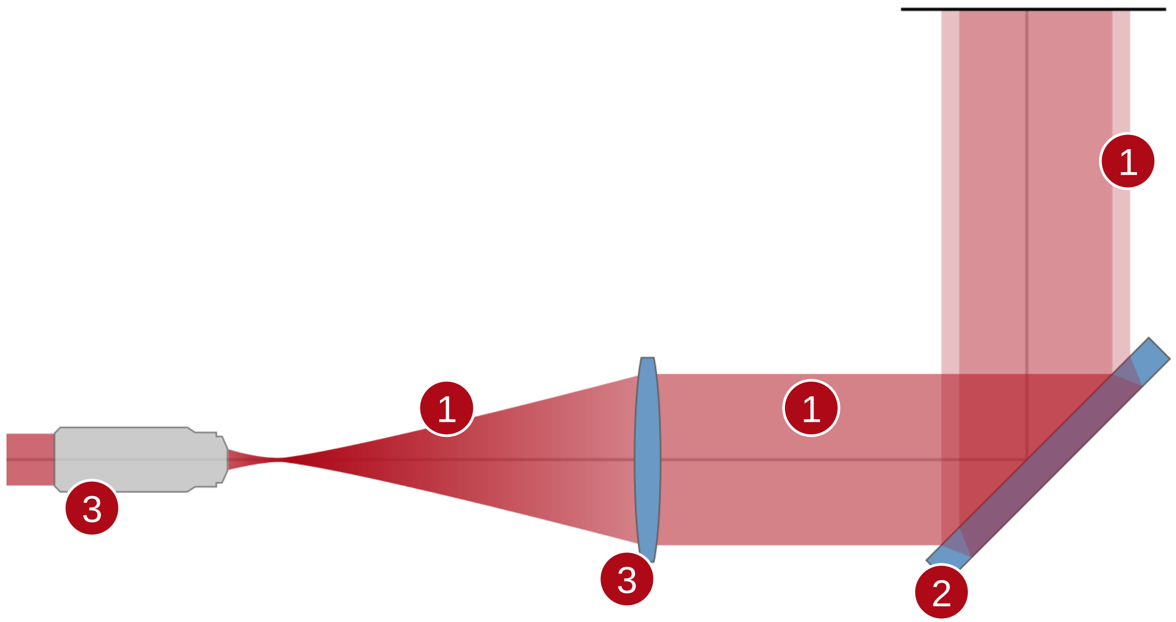
calculation of interference fringes

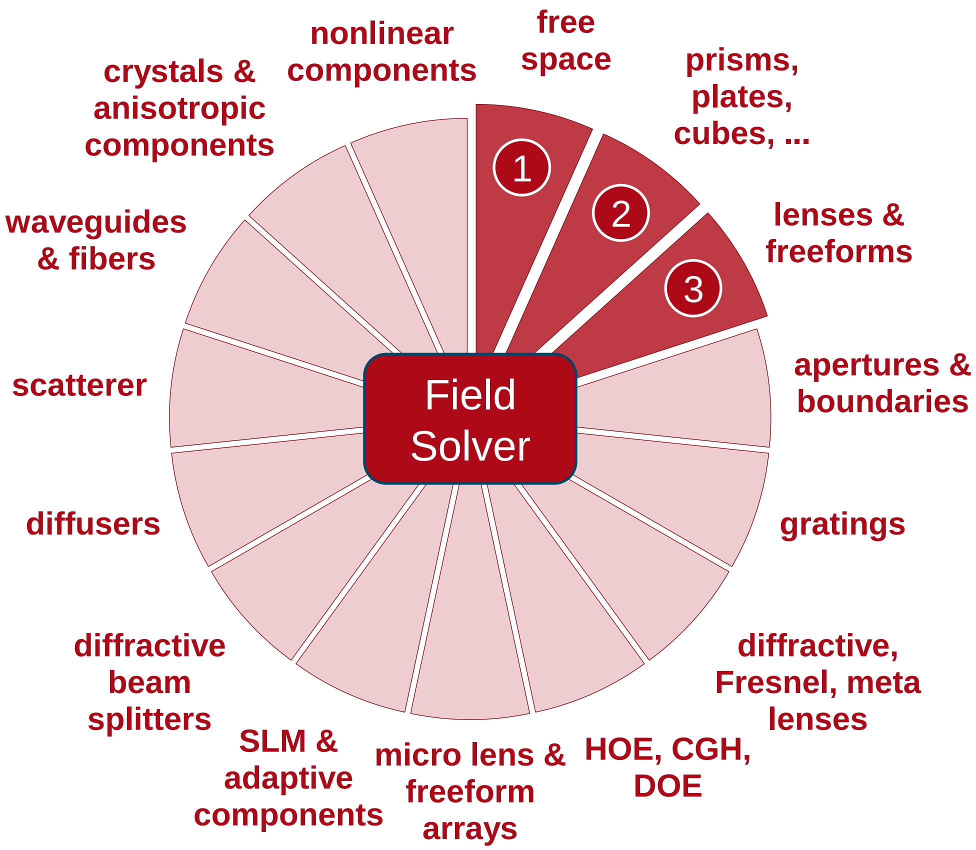
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Import lens systems from Zemax OpticStudio®
  - Import Optical Systems from Zemax [Use Case]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set the non-sequential channels of components
  - Channel Configuration for Surfaces and Grating Regions [Use Case]
- Check influence from selected parameters with Parameter Run
  - Usage of the Parameter Run Document [Use Case]



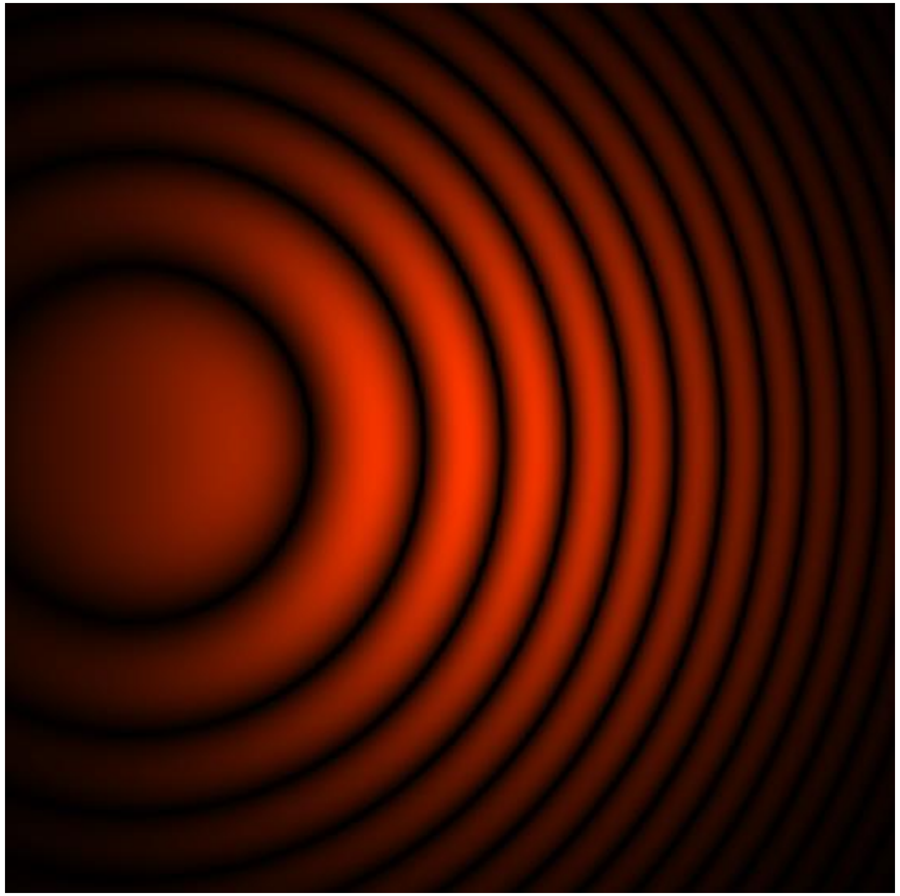
VirtualLab Fusion Technologies





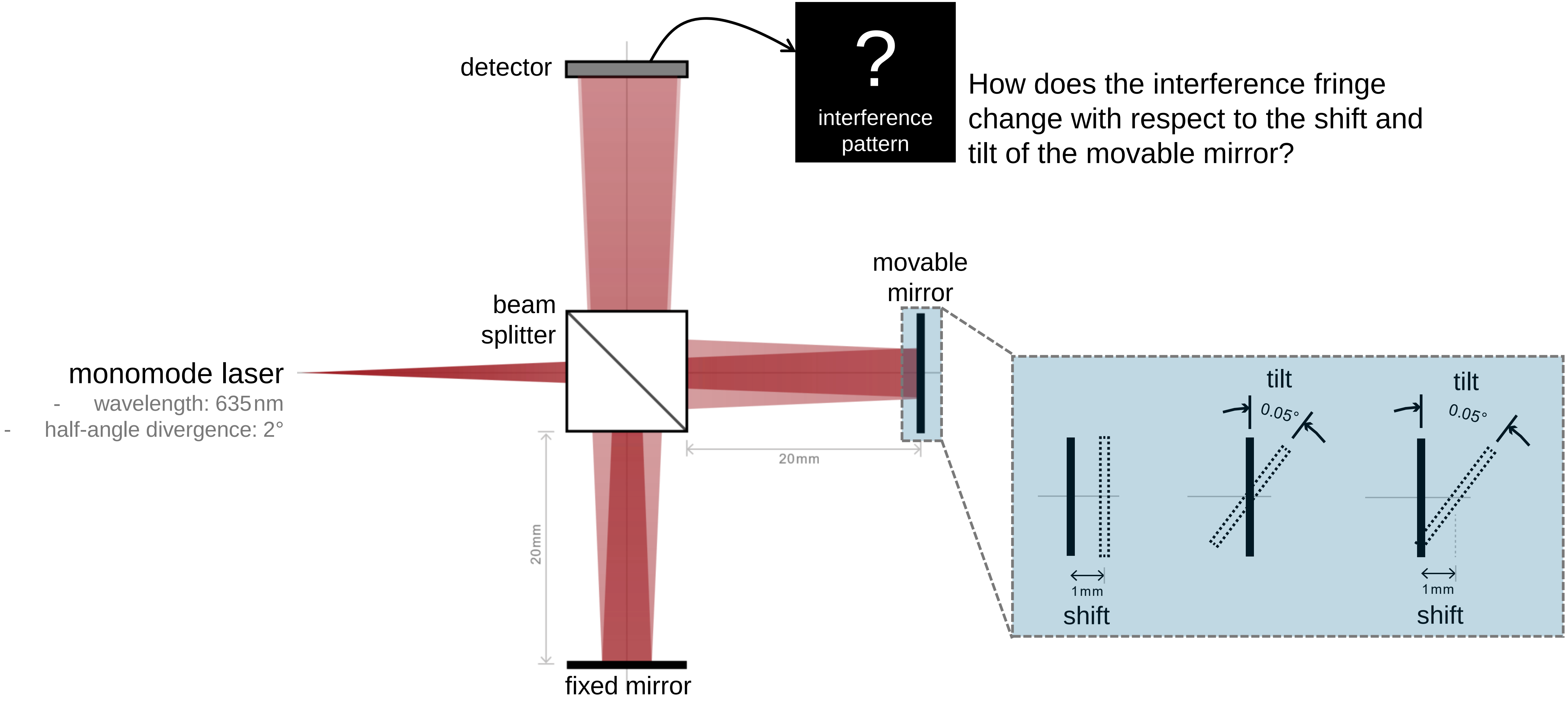
Laser-Based Michelson Interferometer and Interference Fringe Exploration

Abstract



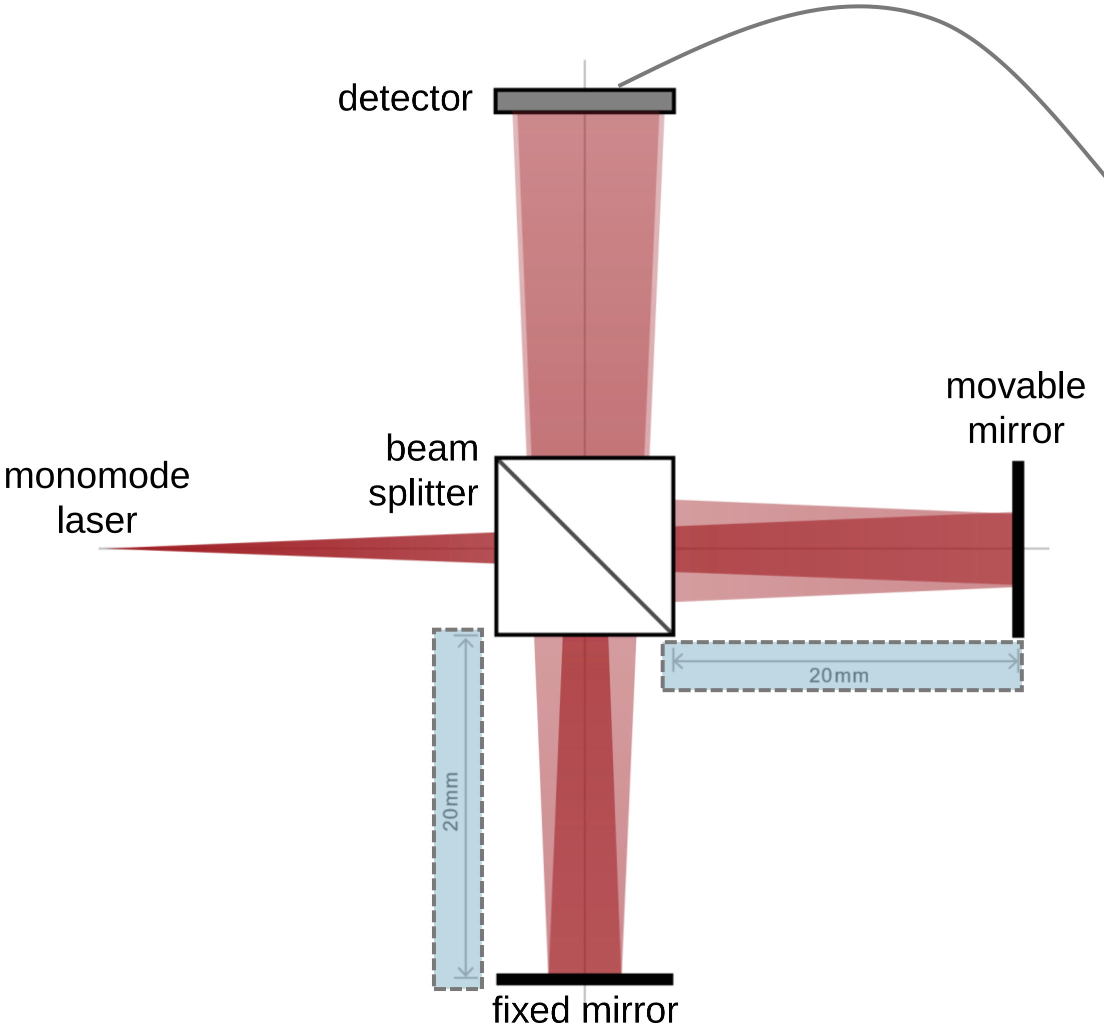
Michelson interferometer is a typical configuration for optical interferometry. Different configurations in the setup may lead to different interference fringes, and therefore it is worth of investigating the relation between them. With the help of non-sequential tracing technology in VirtualLab Fusion, it is easy to set up and to configure a Michelson interferometer, and to visualize the interference fringe in different situations. In this example, several typical situations and the corresponding fringes are demonstrated.

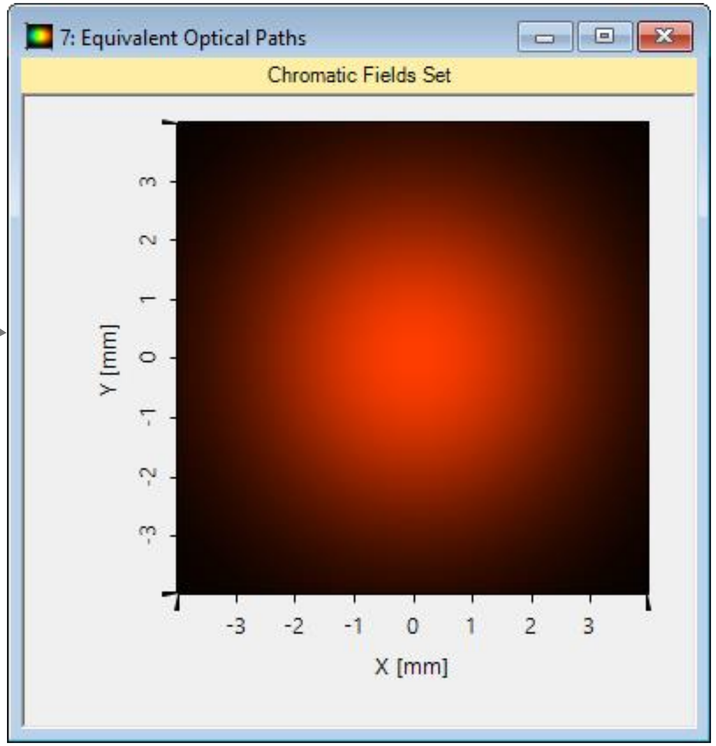
Modeling Task



How does the interference fringe change with respect to the shift and tilt of the movable mirror?

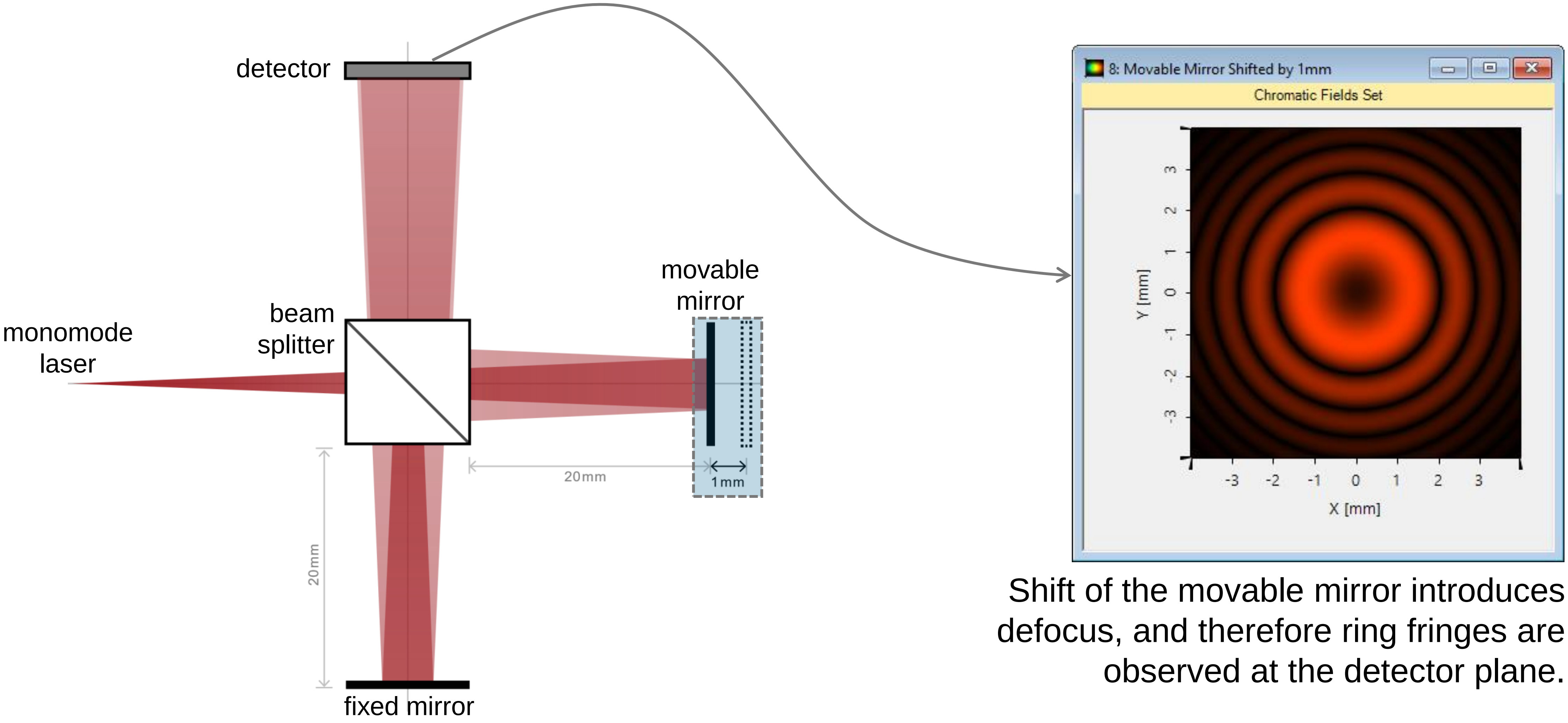
Result with Equivalent Optical Path





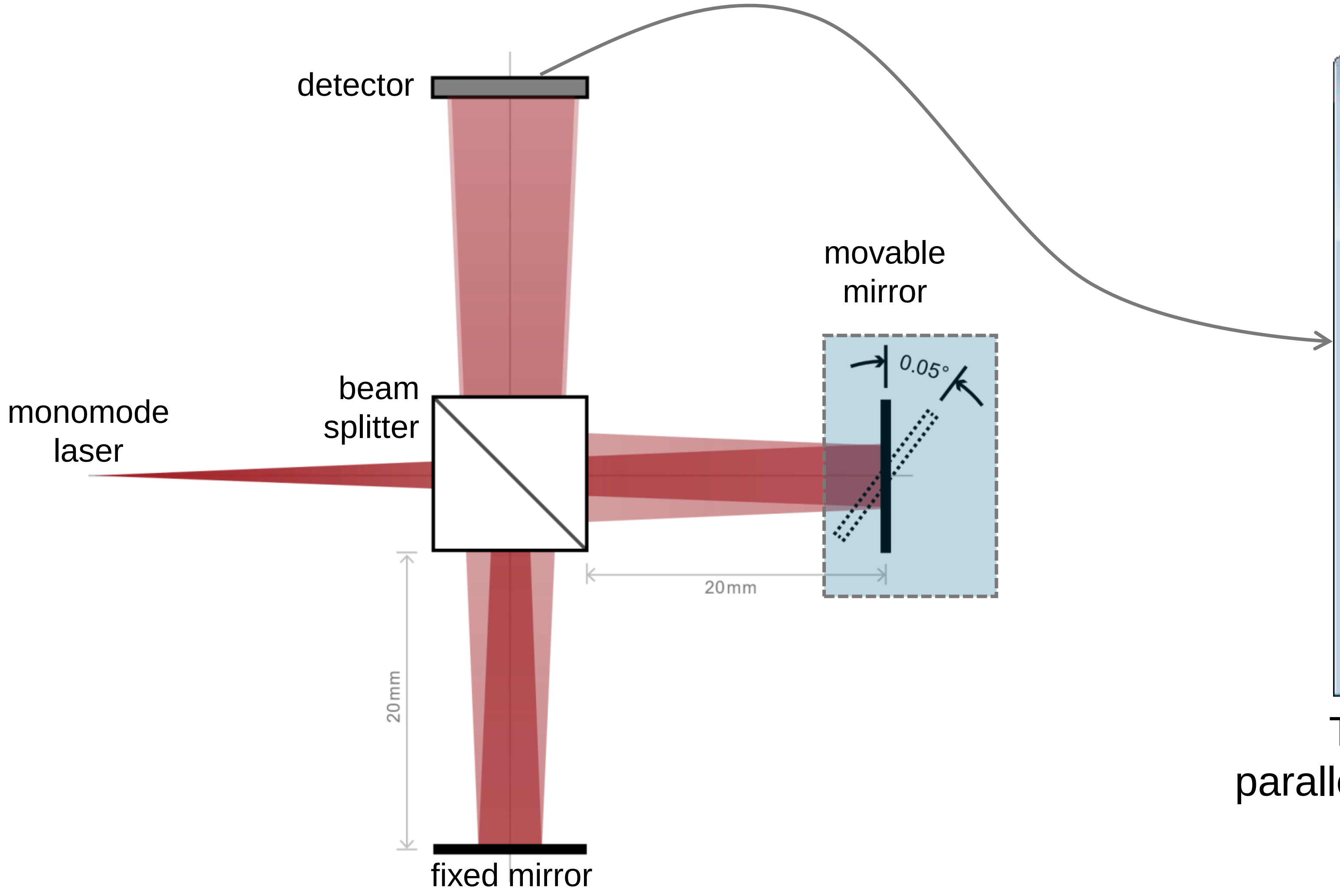
Coherent superposition of two fields reflected from planar mirrors at equivalent-path positions gives no interference fringes.

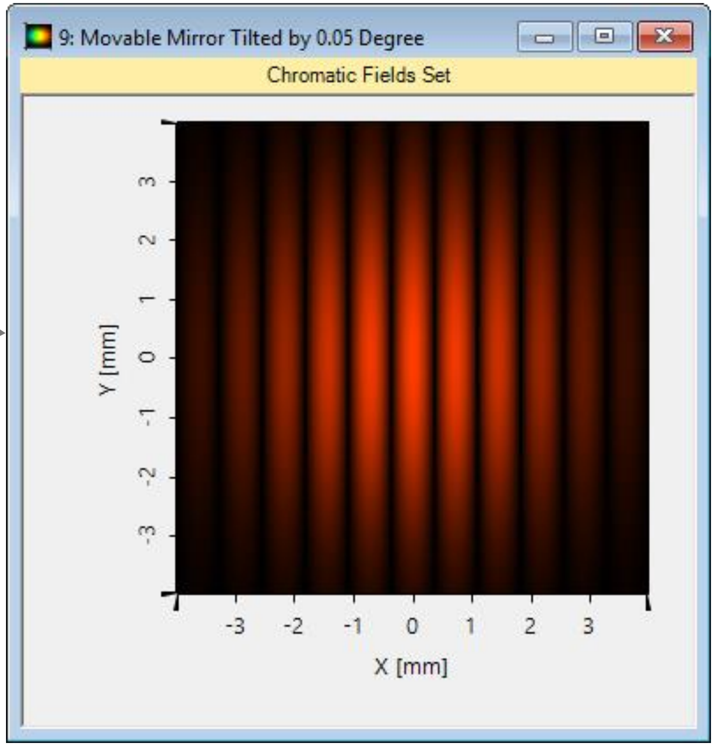
Result with Shifted Movable Mirror



Shift of the movable mirror introduces defocus, and therefore ring fringes are observed at the detector plane.

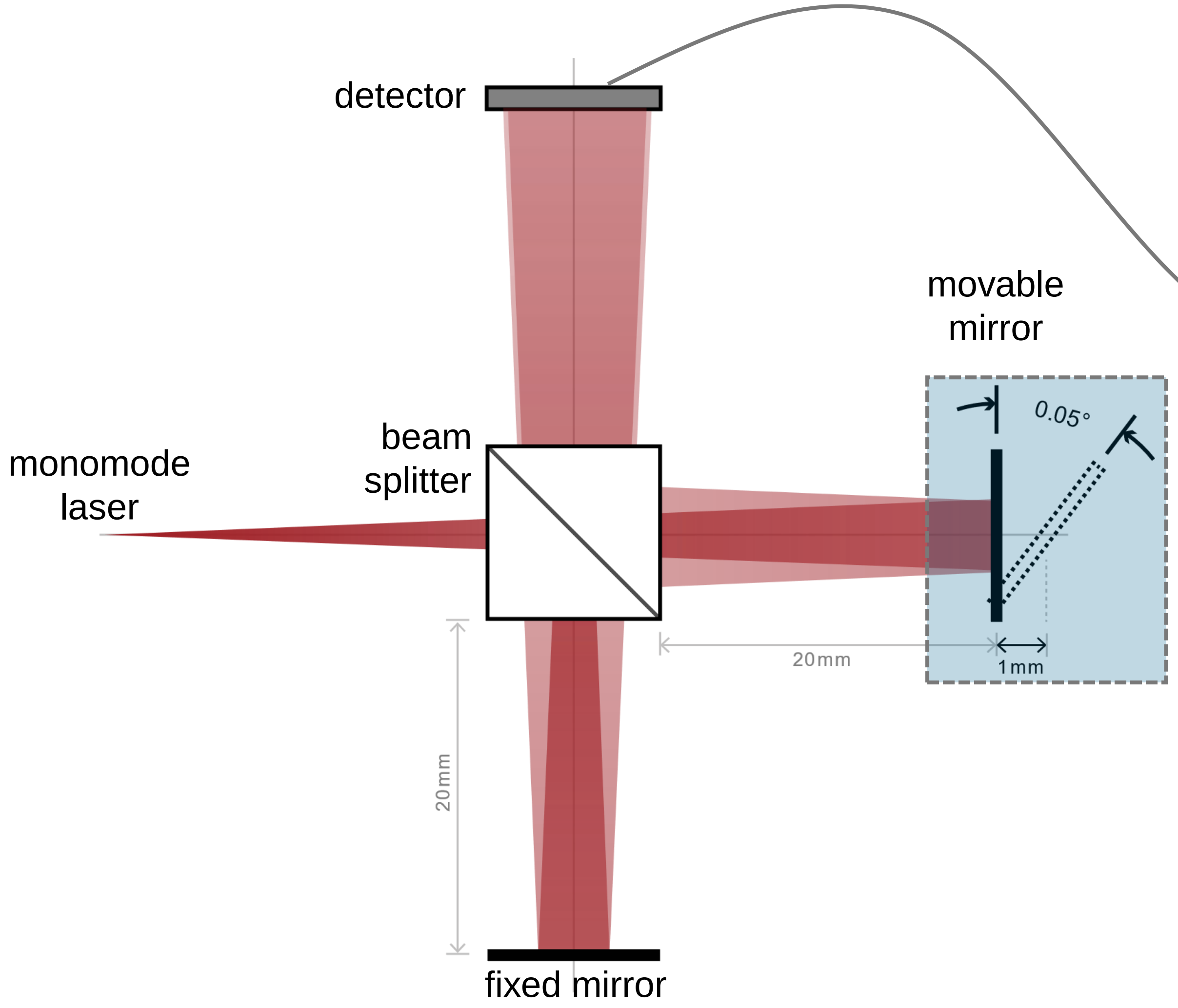
Result with Tilted Movable Mirror

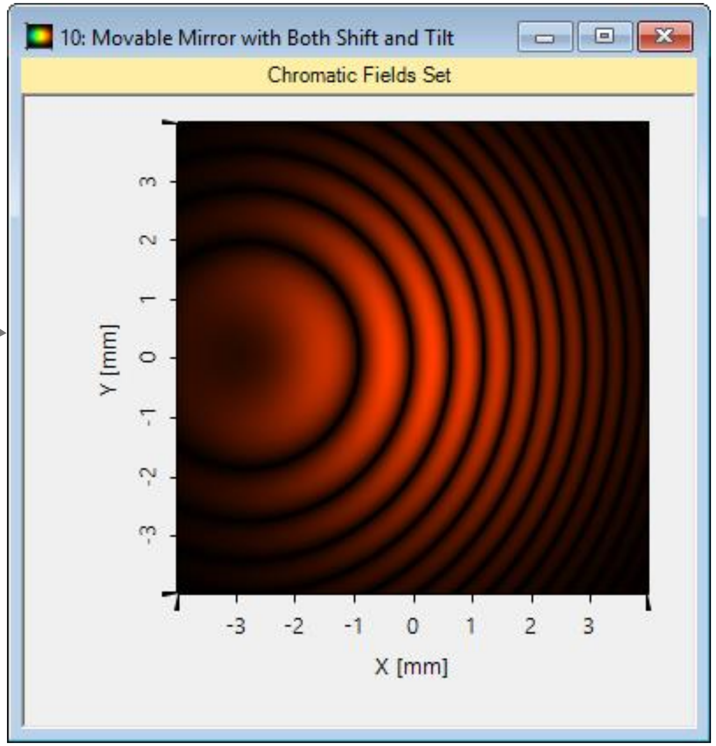




Tilt of the movable mirror leads to parallel striped interference fringes are seen at the detector plane.

Result with Shifted and Tilted Movable Mirror

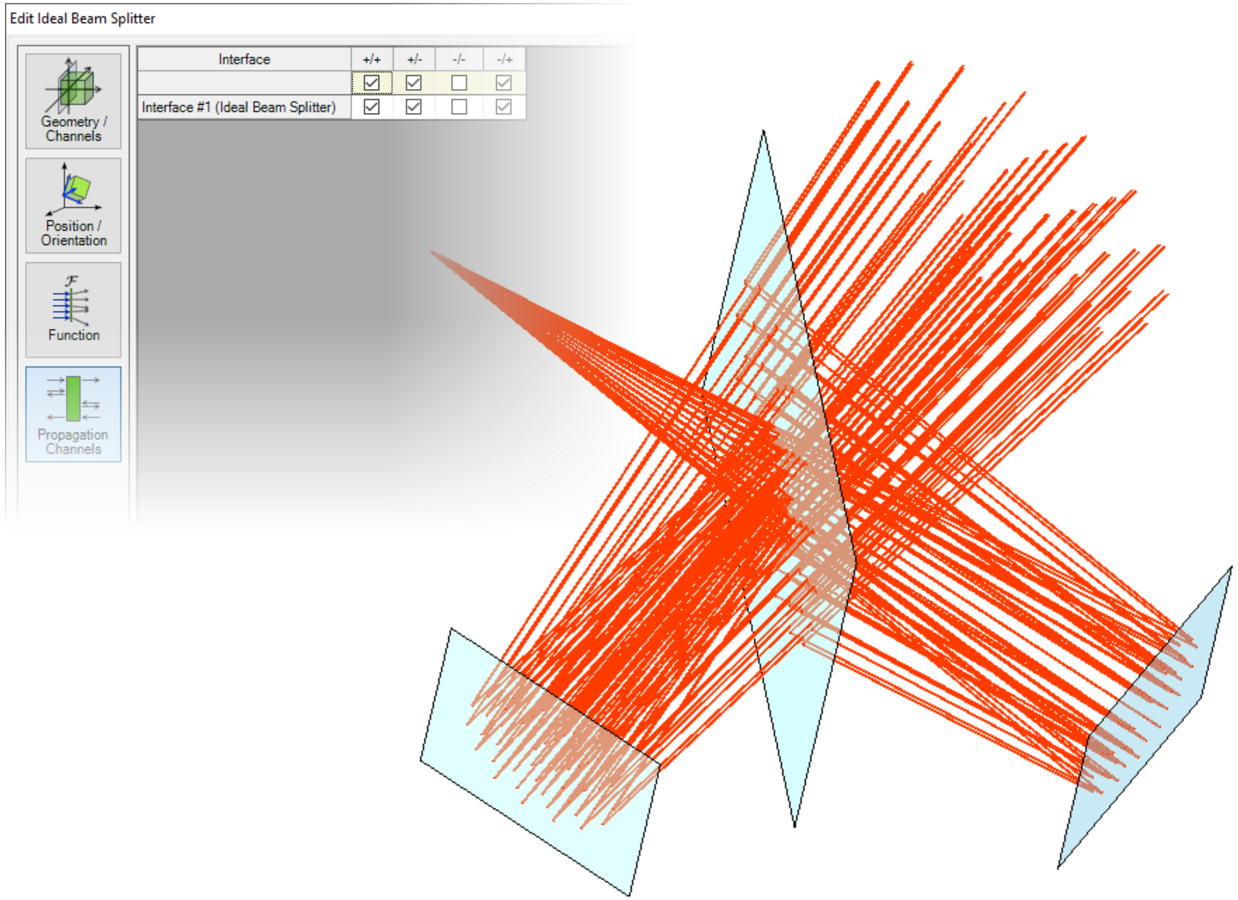


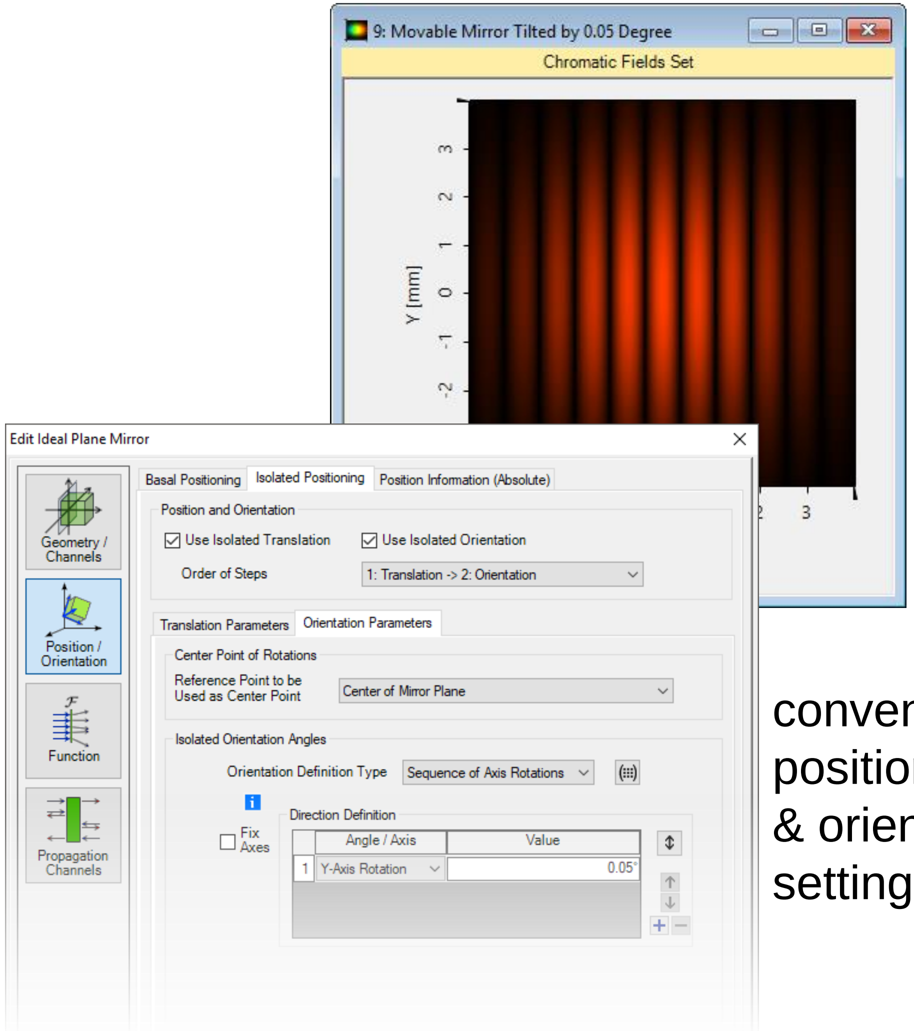


Combination of both shift and tilt of the movable mirror gives rise to shifted ring pattern in the interference fringes.

Peek into VirtualLab Fusion

flexible channel control for non-sequential tracing

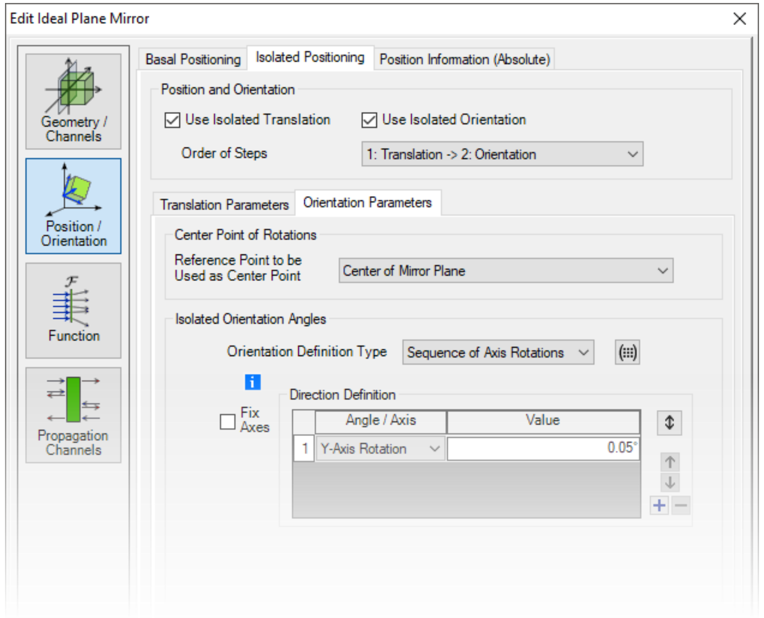




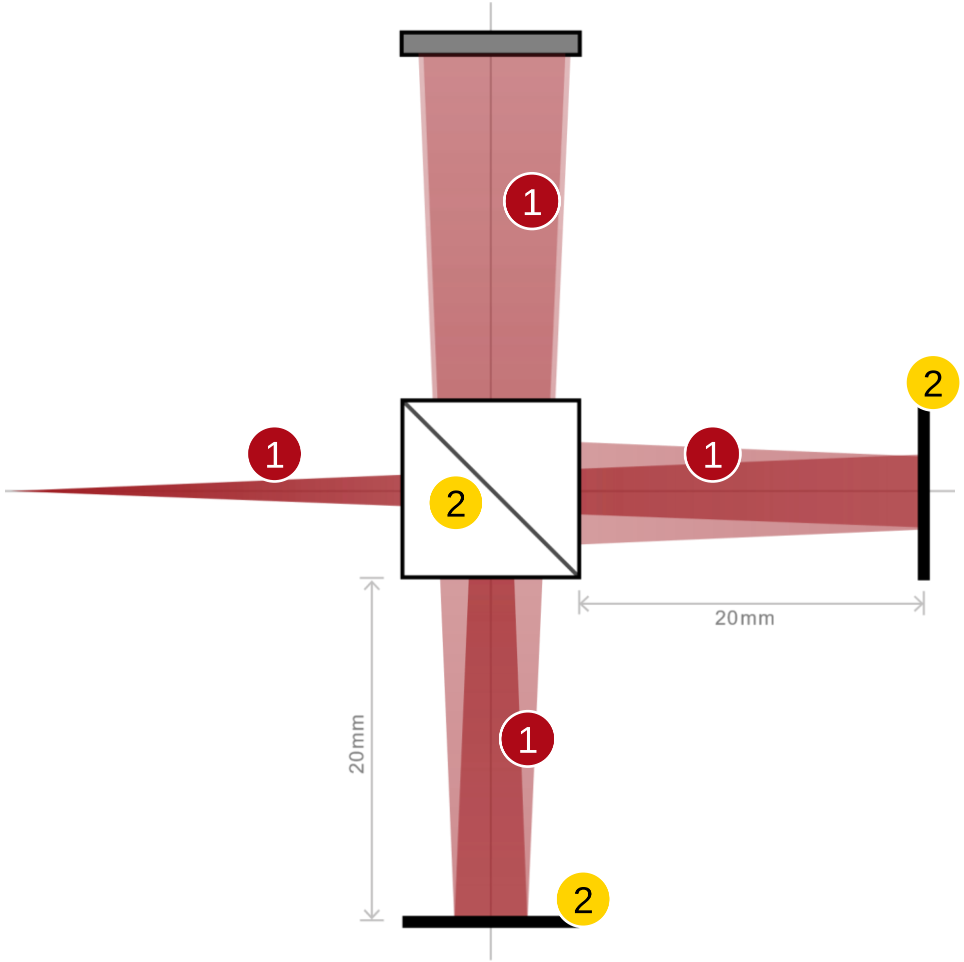
convenient positioning & orientation settings

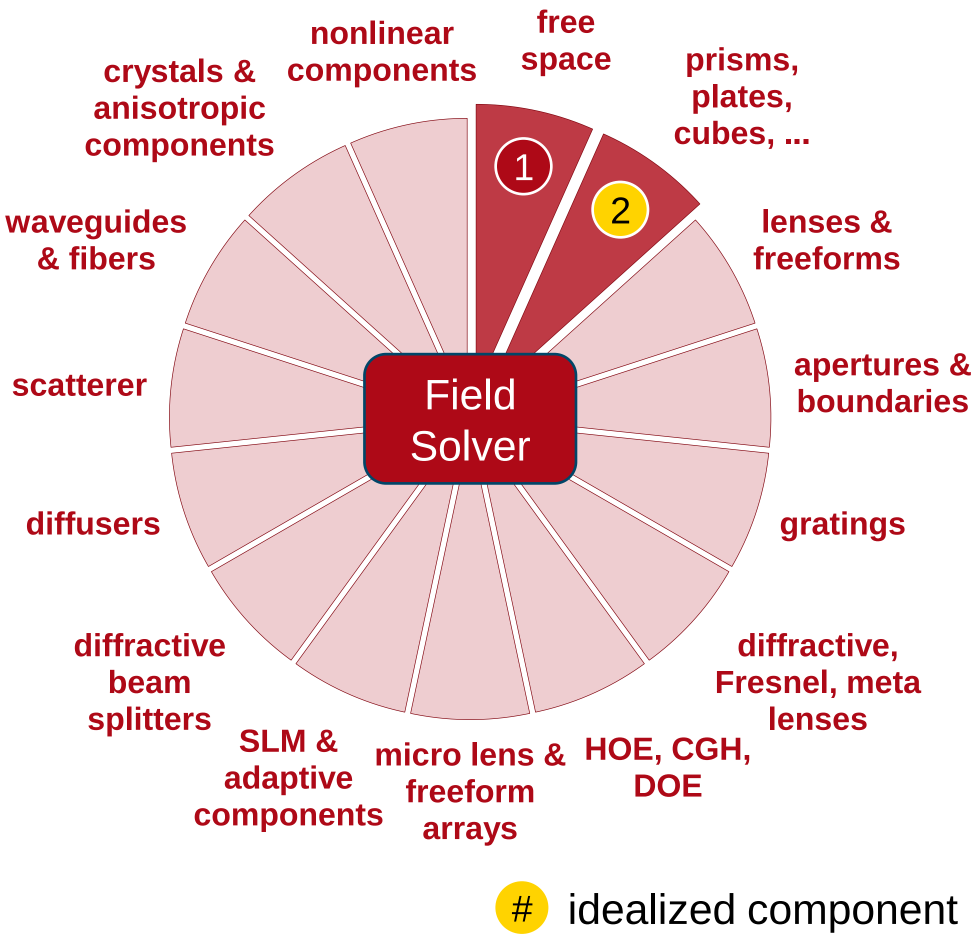
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set the non-sequential channels of components
  - Channel Configuration for Surfaces and Grating Regions [Use Case]
- Use Parameter Run to check influence/changes
  - Usage of the Parameter Run Document [Use Case]



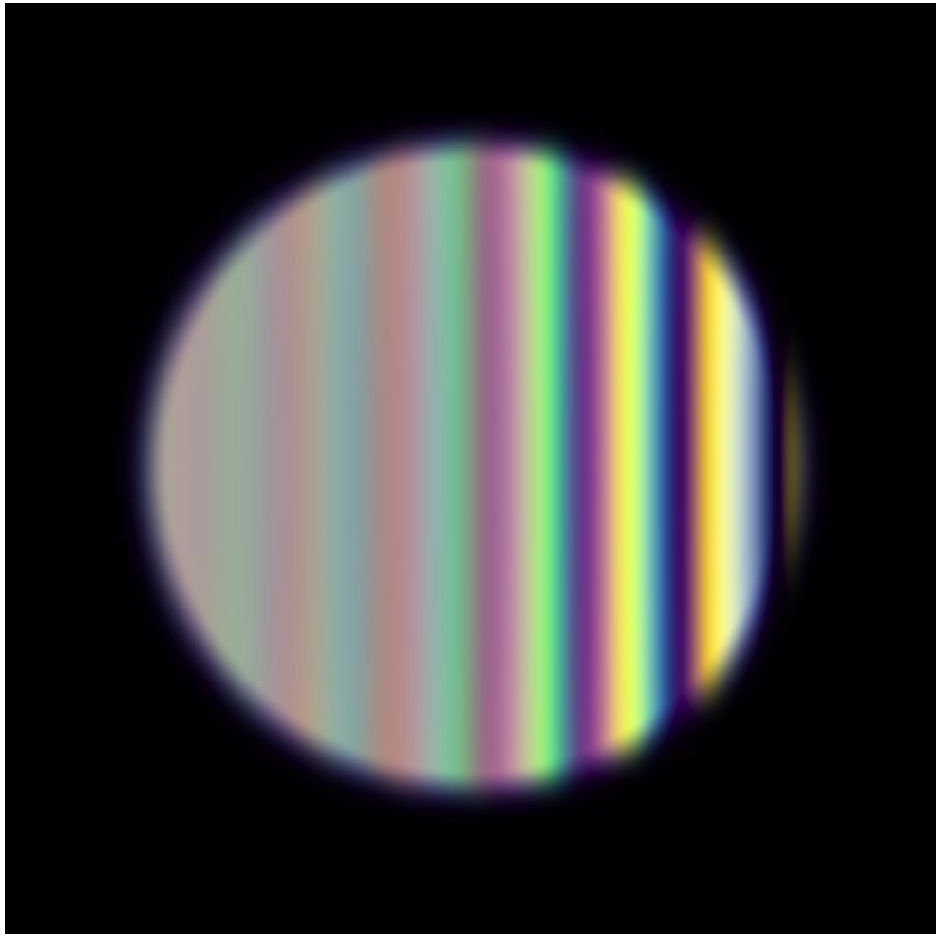
VirtualLab Fusion Technologies





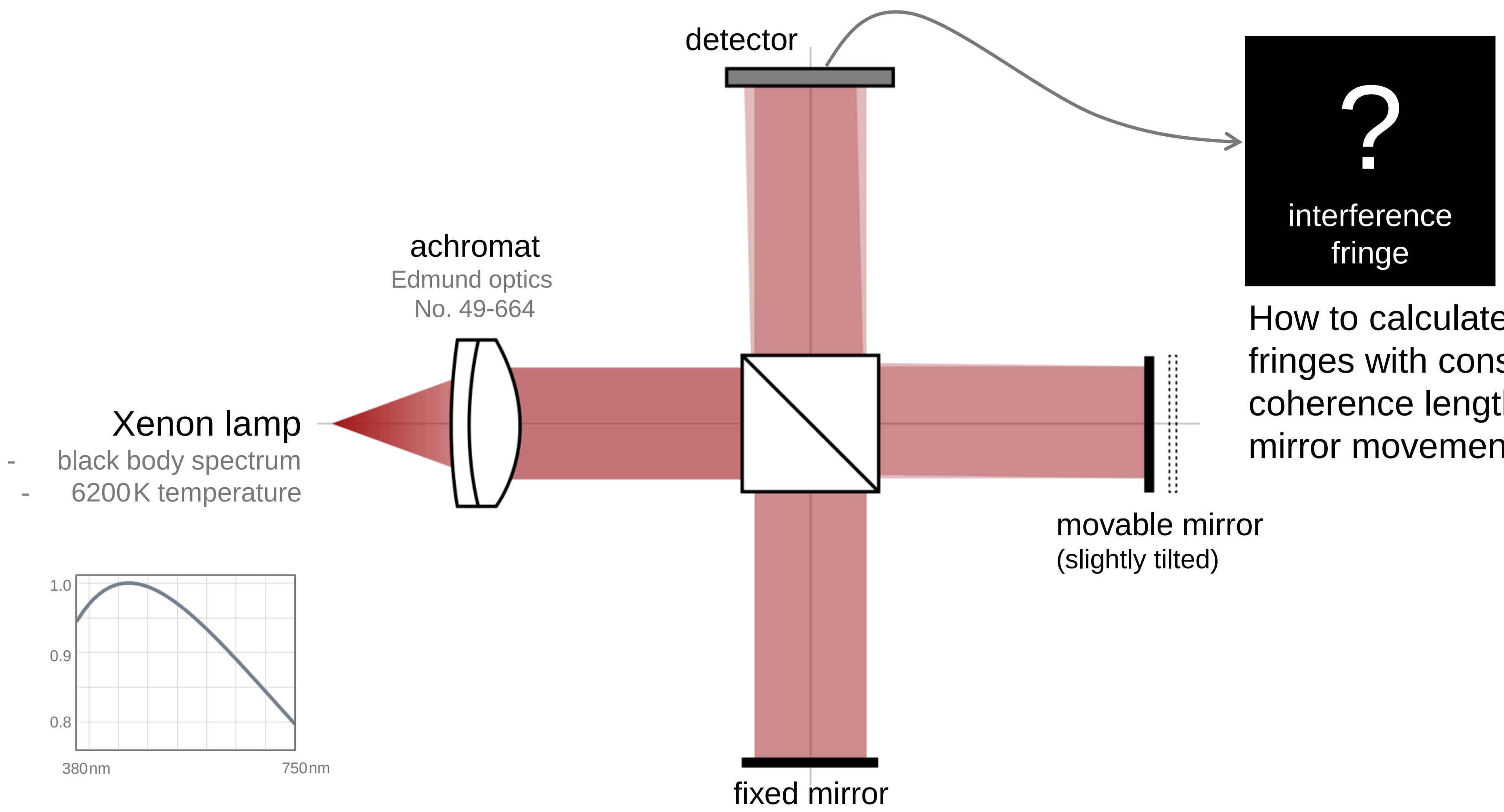
White-Light Michelson Interferometer

Abstract



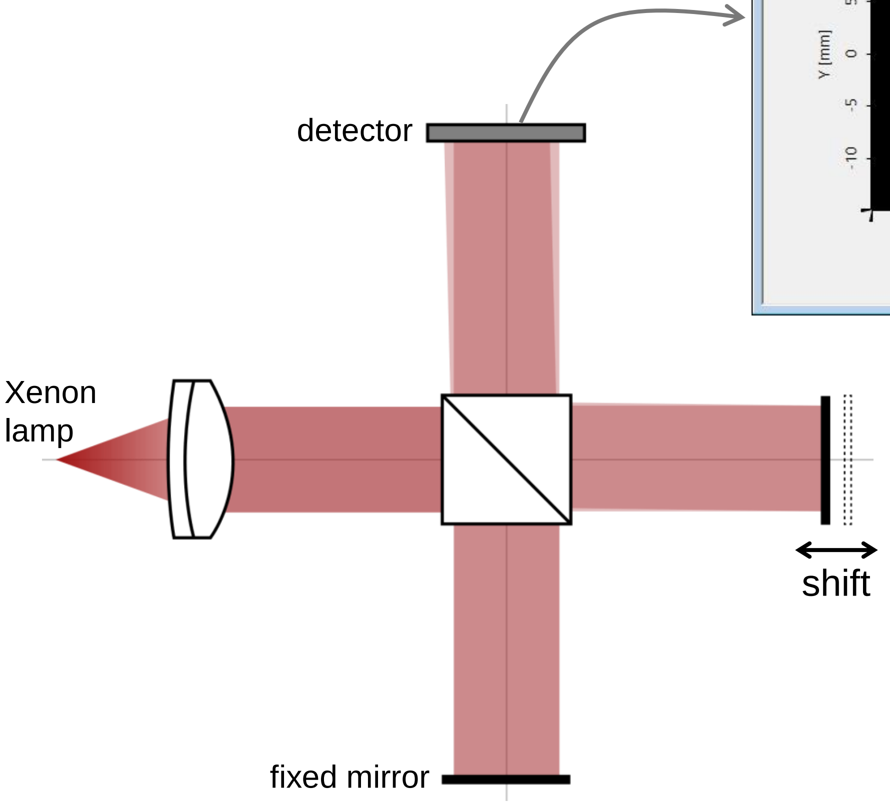
White-light interferometry is a non-contacting technique for precise measurement of e.g. surface profiles and extremely small movements. With a Michelson interferometer setup, and a Xenon lamp source, the white-light interferometry is demonstrated in VirtualLab Fusion. With the spectral property, i.e. limited coherence length, of the source taken into account, it is shown that interference pattern only appears when the path lengths of both arms are almost the same.

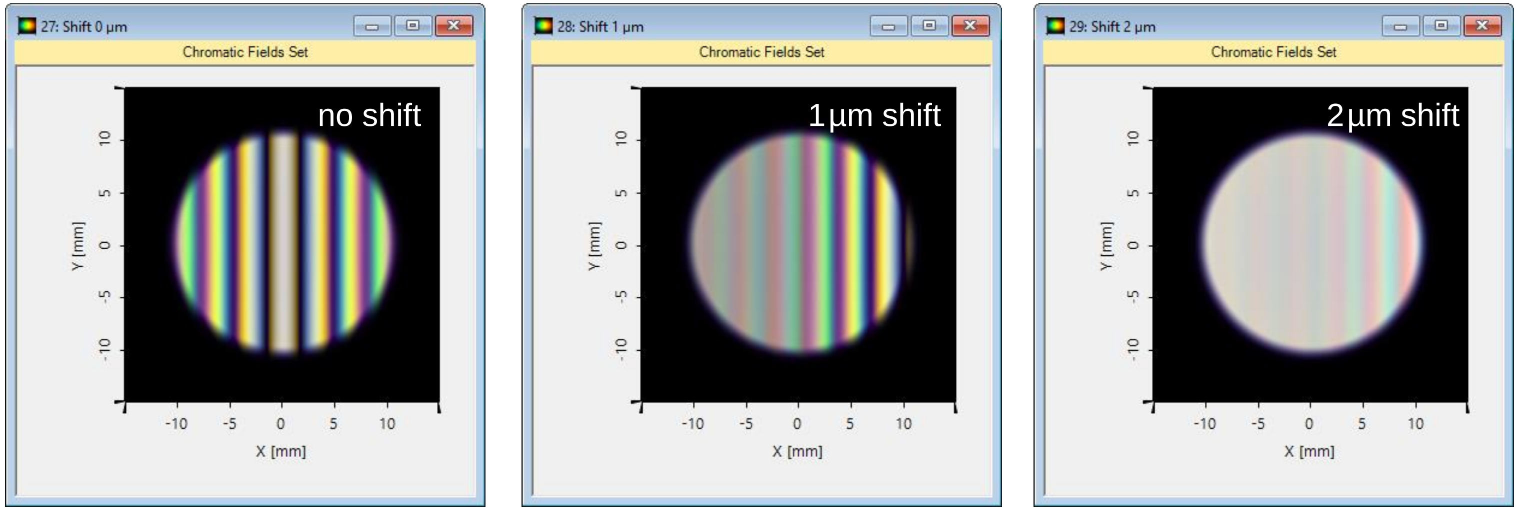
Modeling Task



How to calculate the interference fringes with consideration of the finite coherence length of the source and the mirror movement?

Change in Interference Fringes



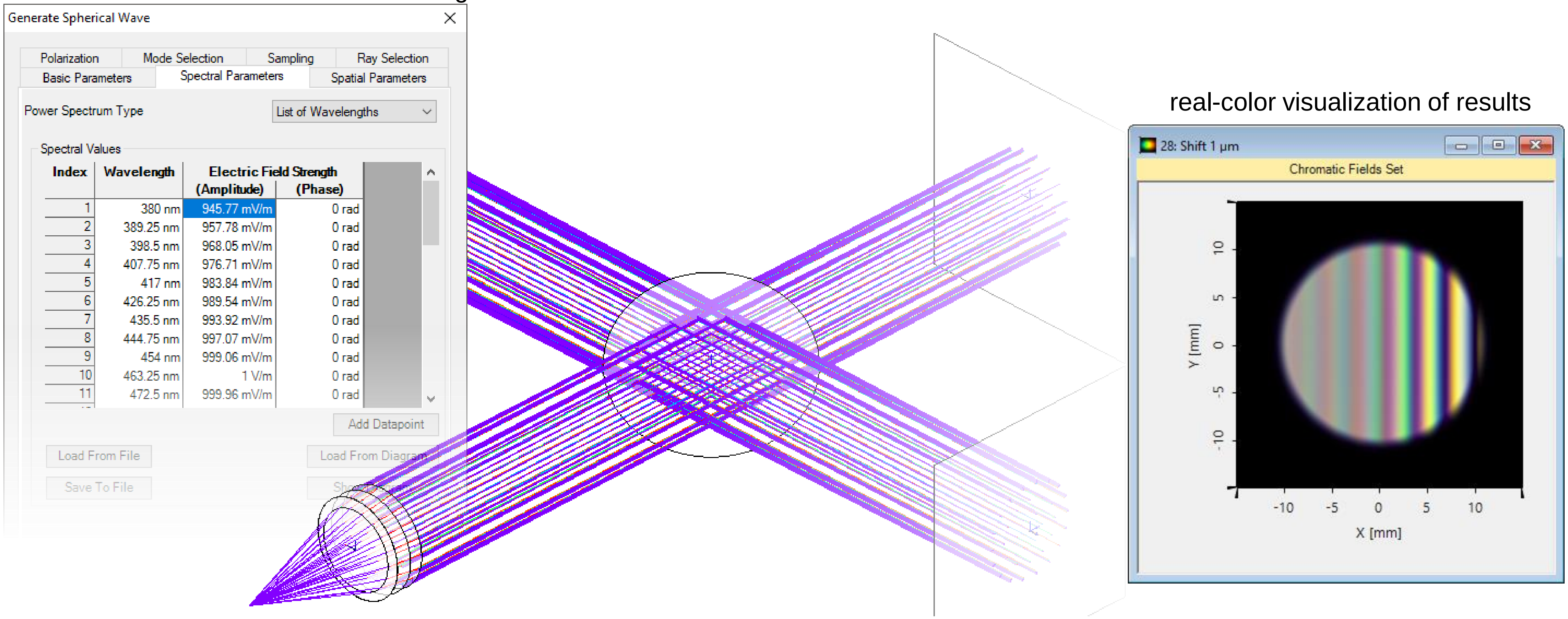


When the movable mirror moves from 0 µm to 2 µm, the contrast of interference pattern decreases, due to limited coherence length of the light source.

Peek into VirtualLab Fusion

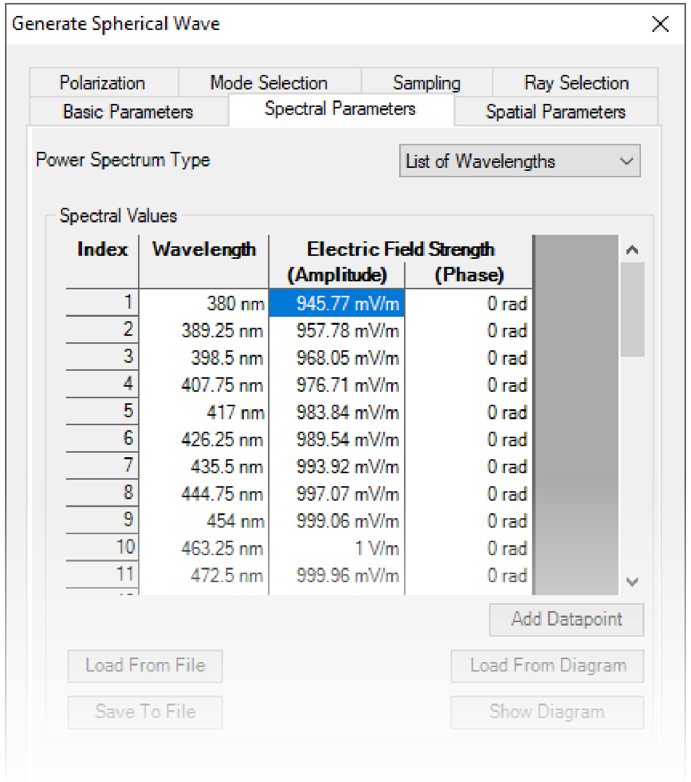
customizable power spectrum
for source modeling

real-color visualization of results

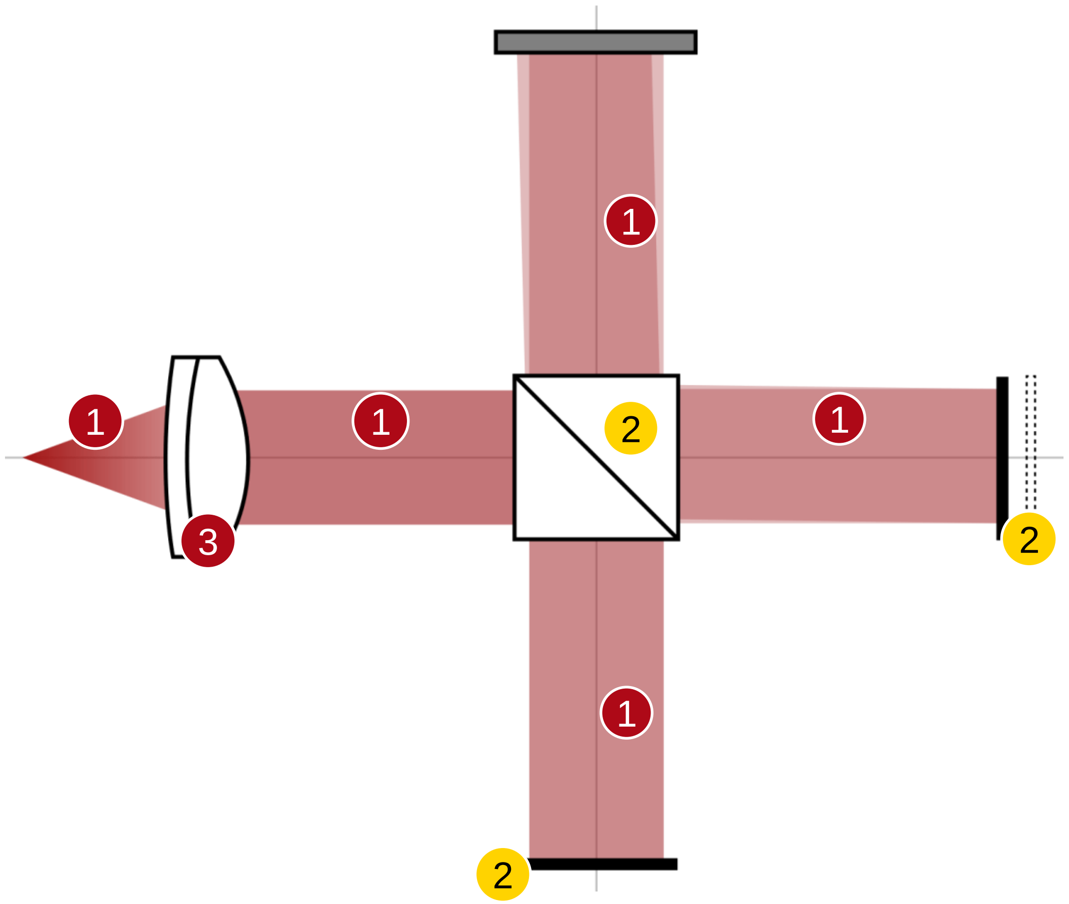


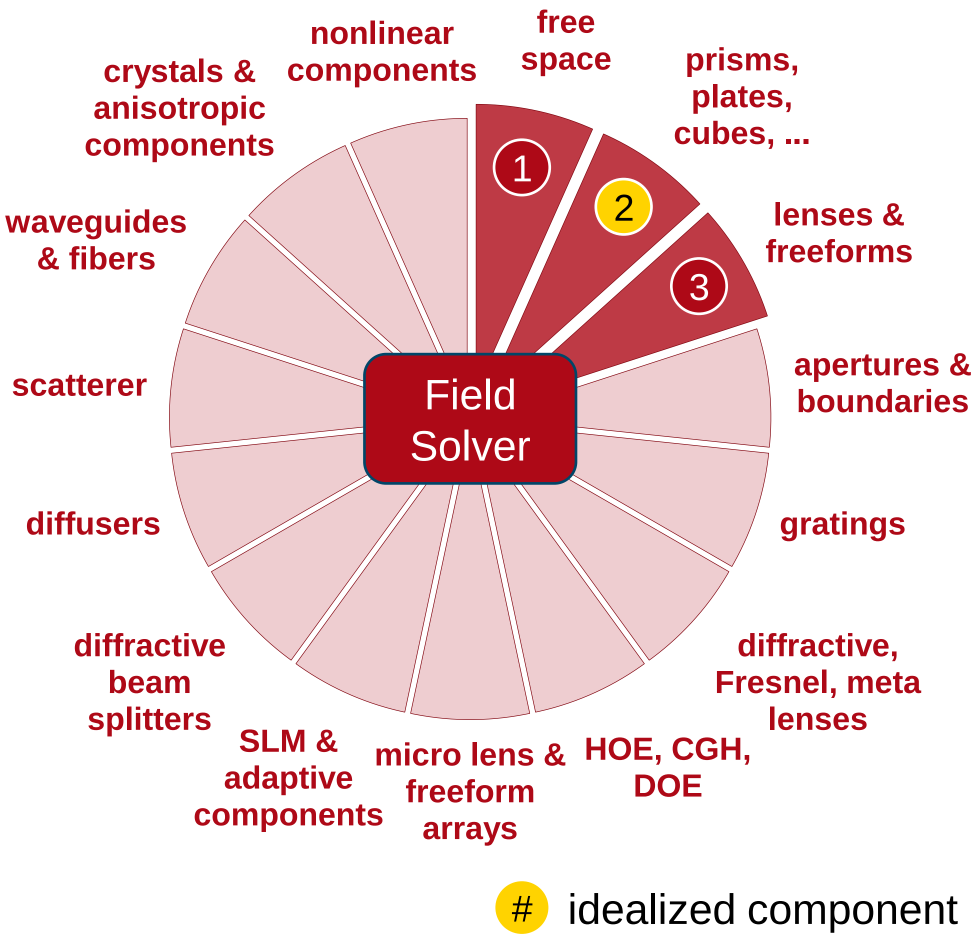
Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set channels properly for non-sequential tracing
  - Channel Setting for Non-Sequential Tracing [Use Case]
- Use Parameter Run to check influence/changes
  - Usage of the Parameter Run Document [Use Case]



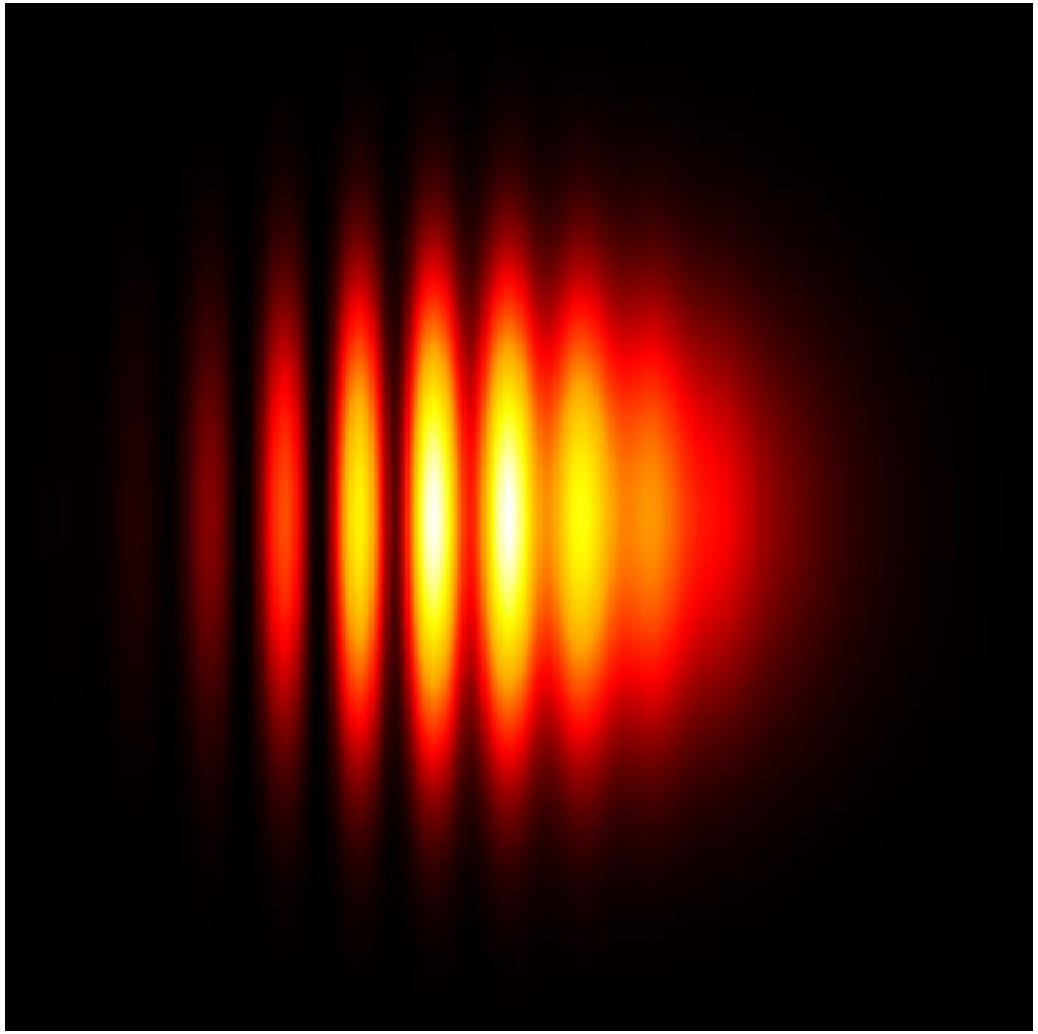
VirtualLab Fusion Technologies





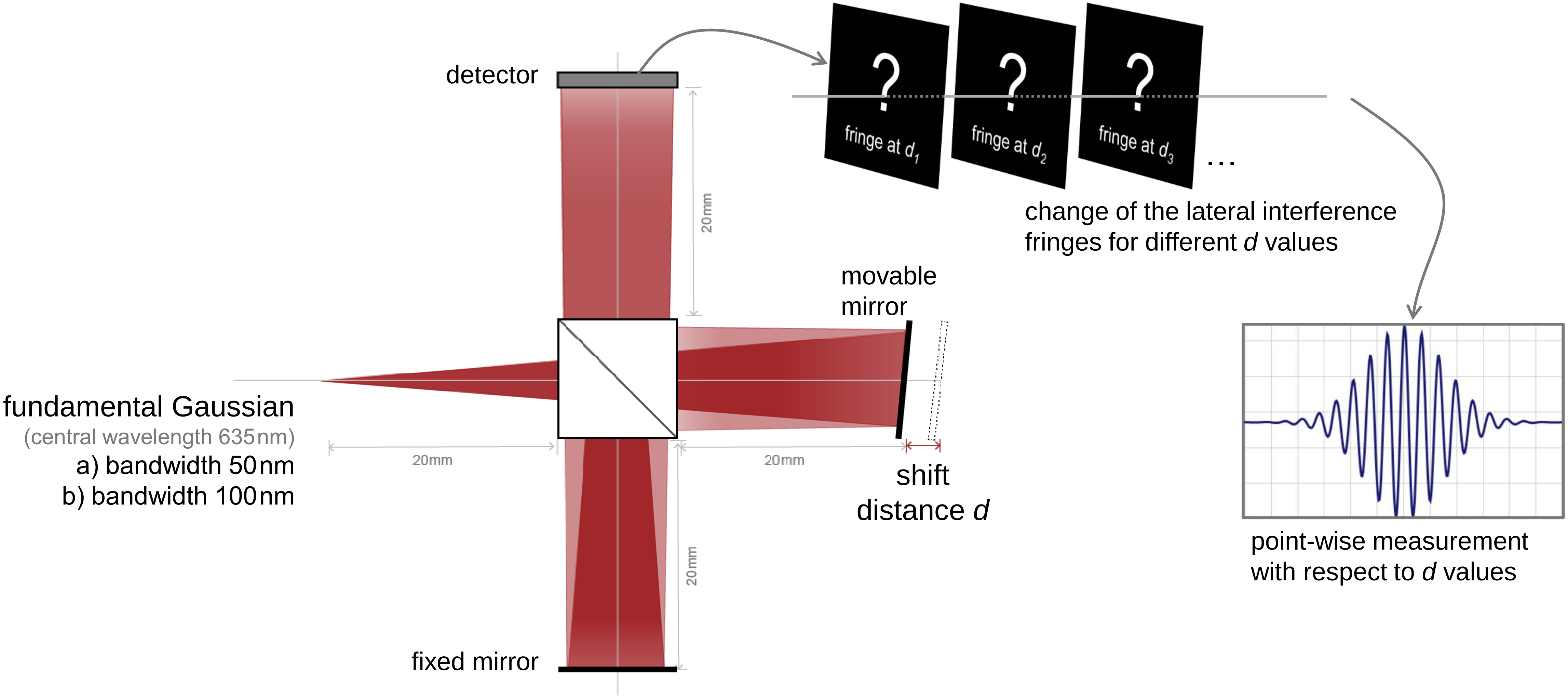
Coherence Measurement Using Michelson Interferometer and Fourier Transform Spectroscopy

Abstract

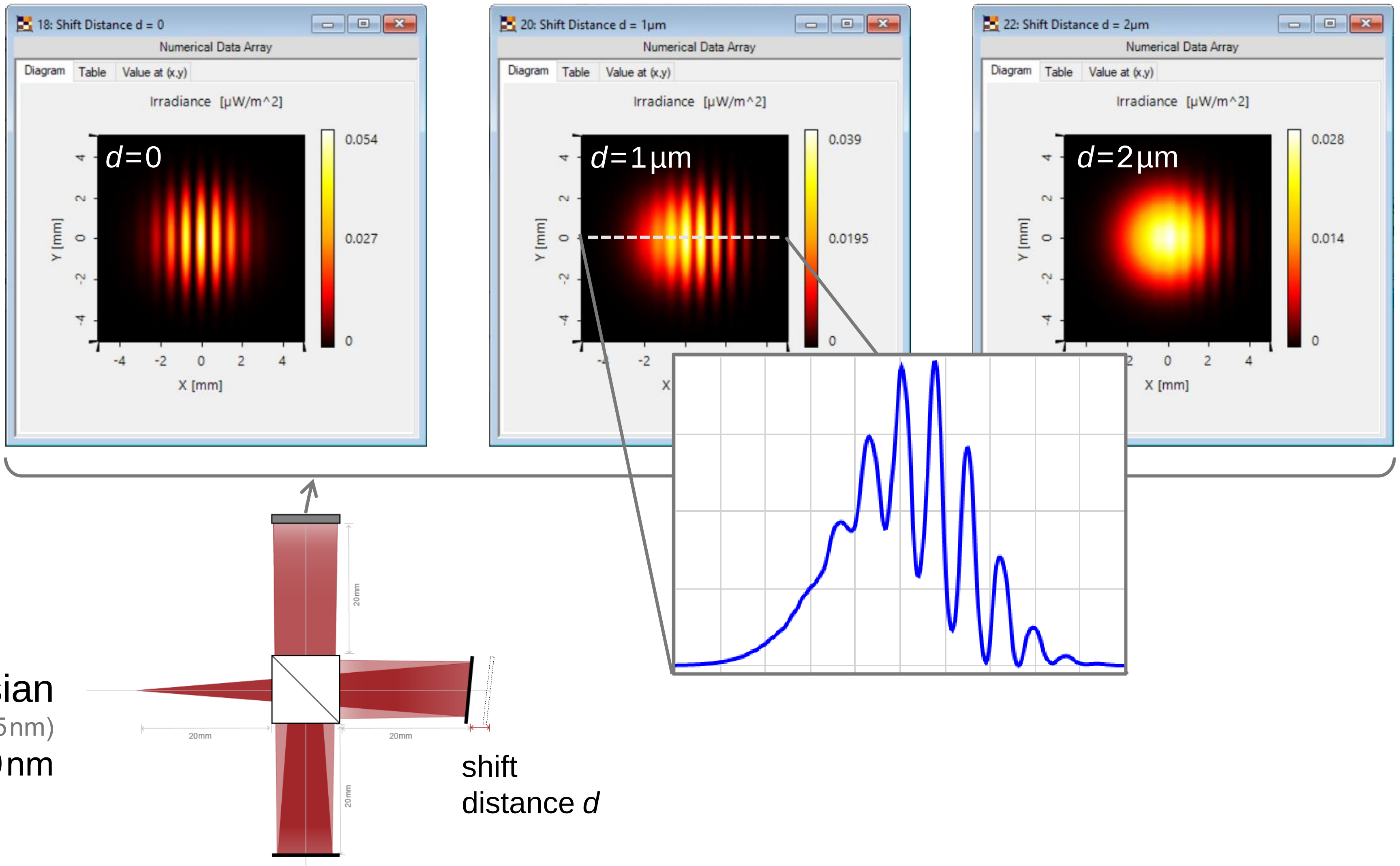


It is known that in an interferometer the fringe contrast may depend on the coherent property of light sources. For example, in a Michelson interferometer with a source of certain bandwidth, the interference fringe contrast varies with different the optical path difference. By measuring the interferogram contrast at different positions of the movable mirror, the coherence length of the source can be concluded. Typical Fourier-transform spectroscopy is usually based on such type of optical setup.

Modeling Task

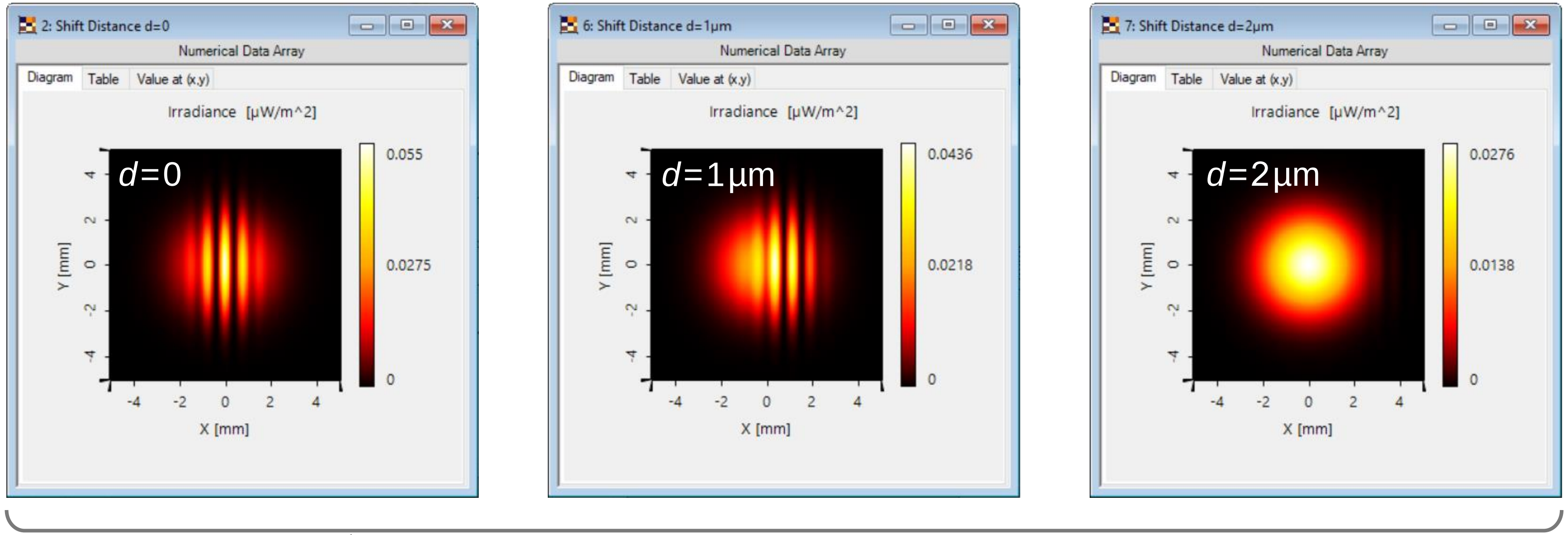


Lateral Interference Fringes – 50 nm Bandwidth



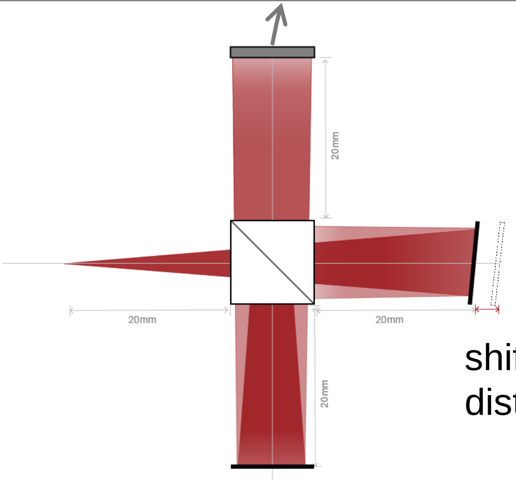
fundamental Gaussian
(central wavelength 635 nm)
a) bandwidth 50 nm

Lateral Interference Fringes – 100 nm Bandwidth



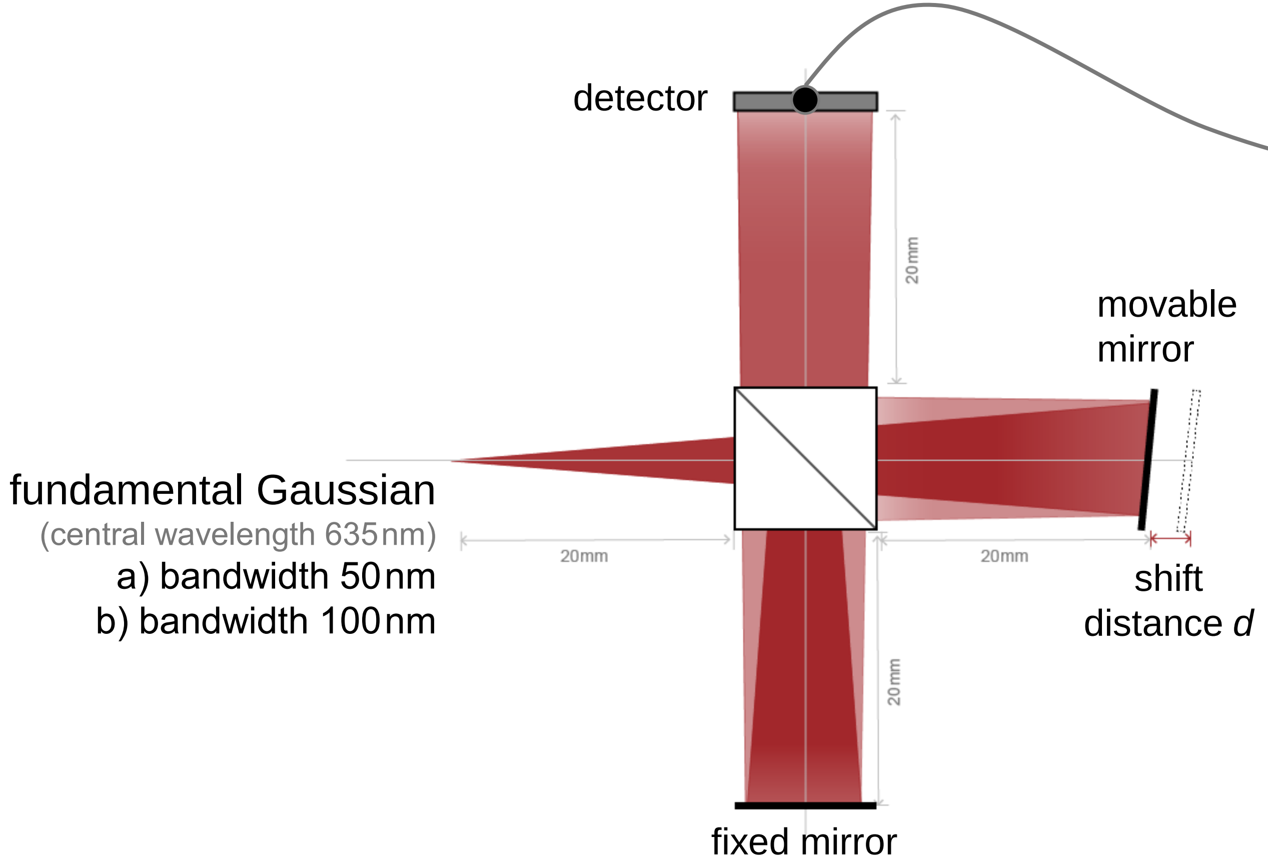
Broader spectral bandwidth leads to shorter coherent length; and therefore the interference fringe starts to vanish sooner in comparison to the case with narrower bandwidth.

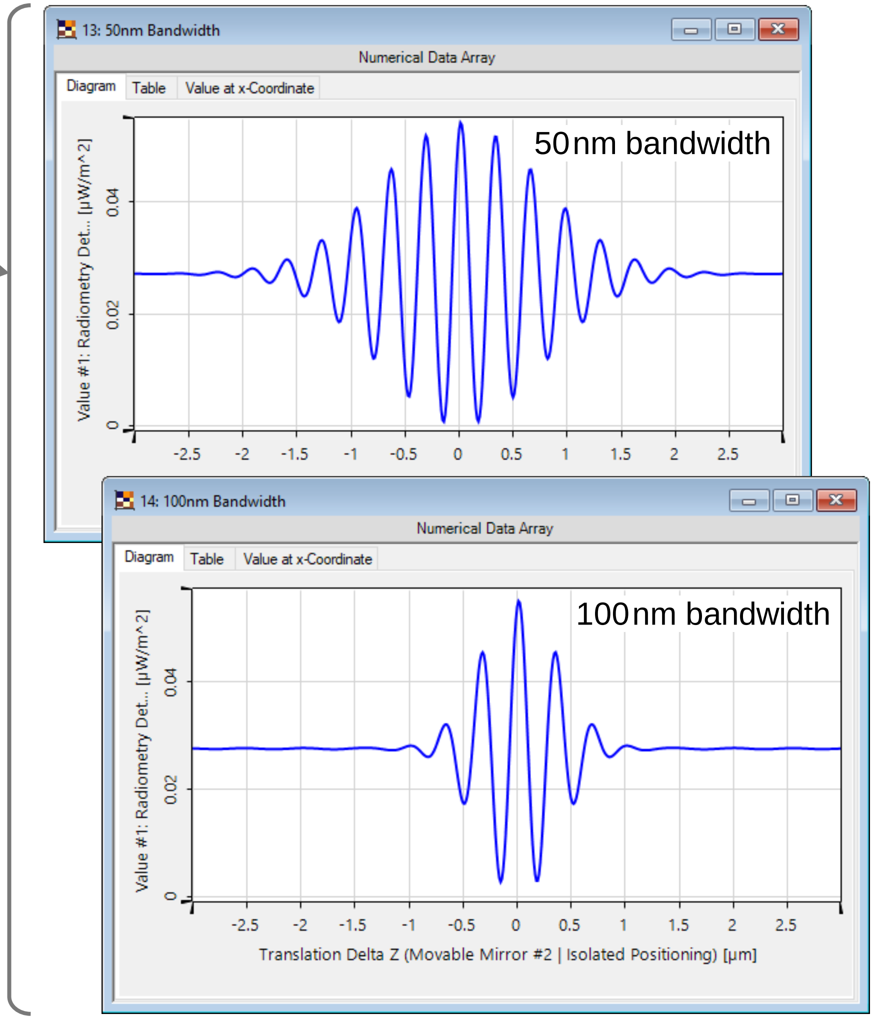
fundamental Gaussian
(central wavelength 635 nm)
b) bandwidth: 100 nm



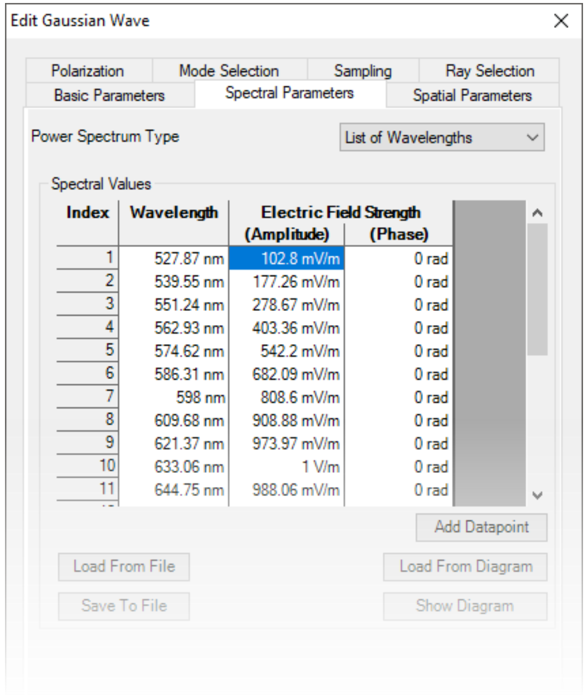
shift
distance *d*

Pointwise Measurement

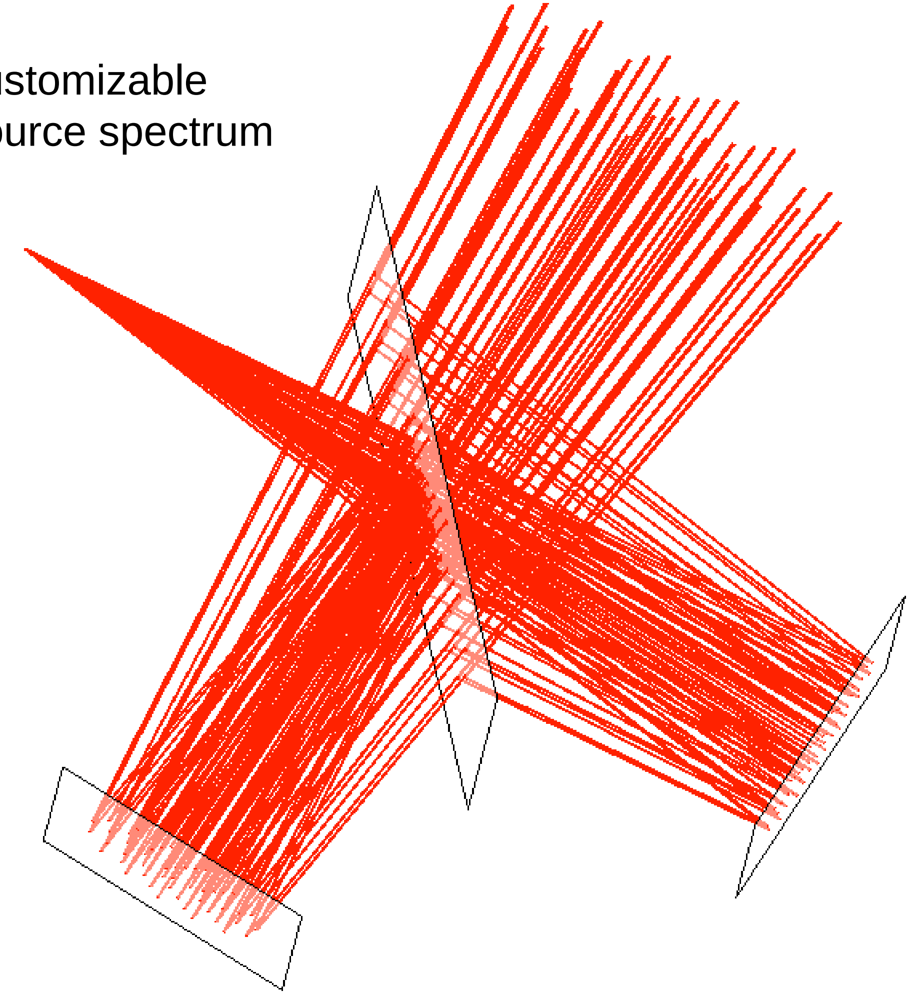


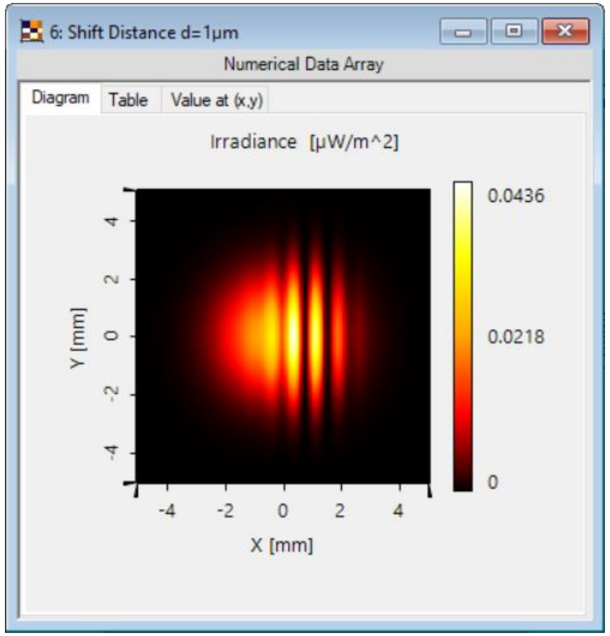


Peek into VirtualLab Fusion



customizable
source spectrum

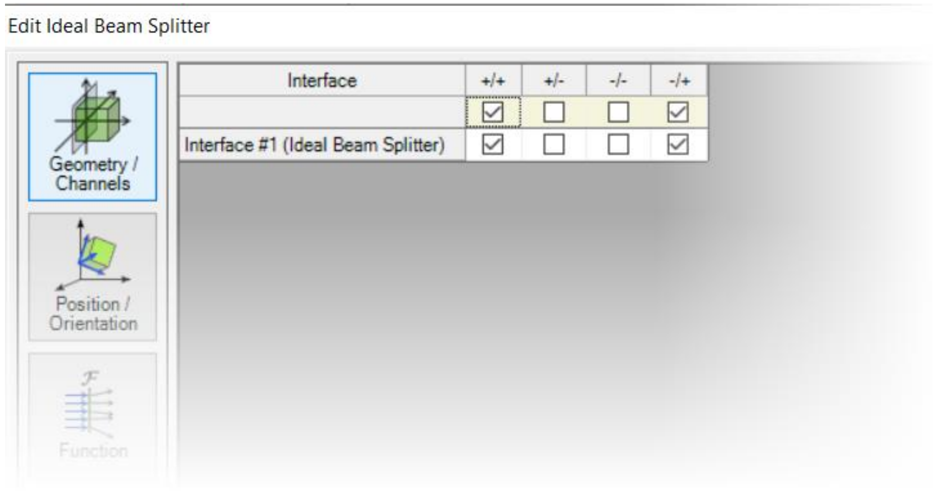




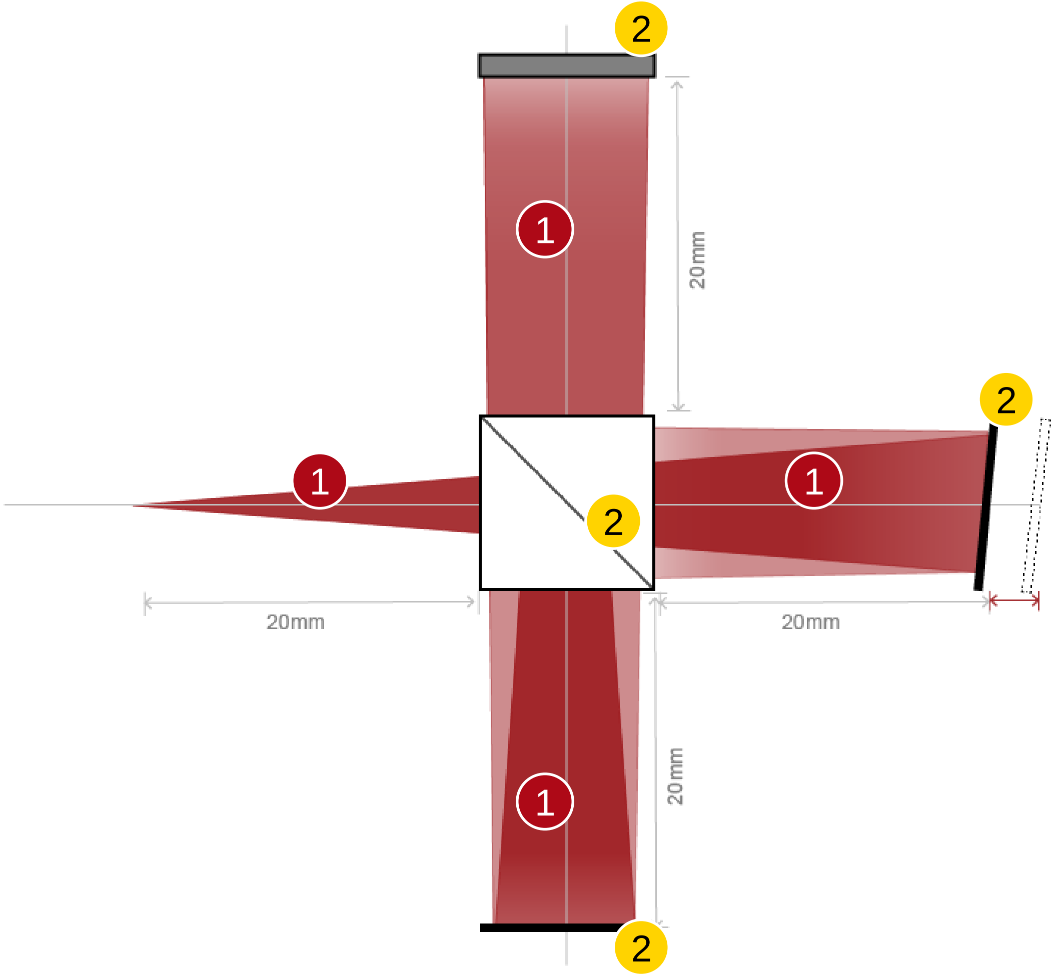
detector with coherence
property taken into account

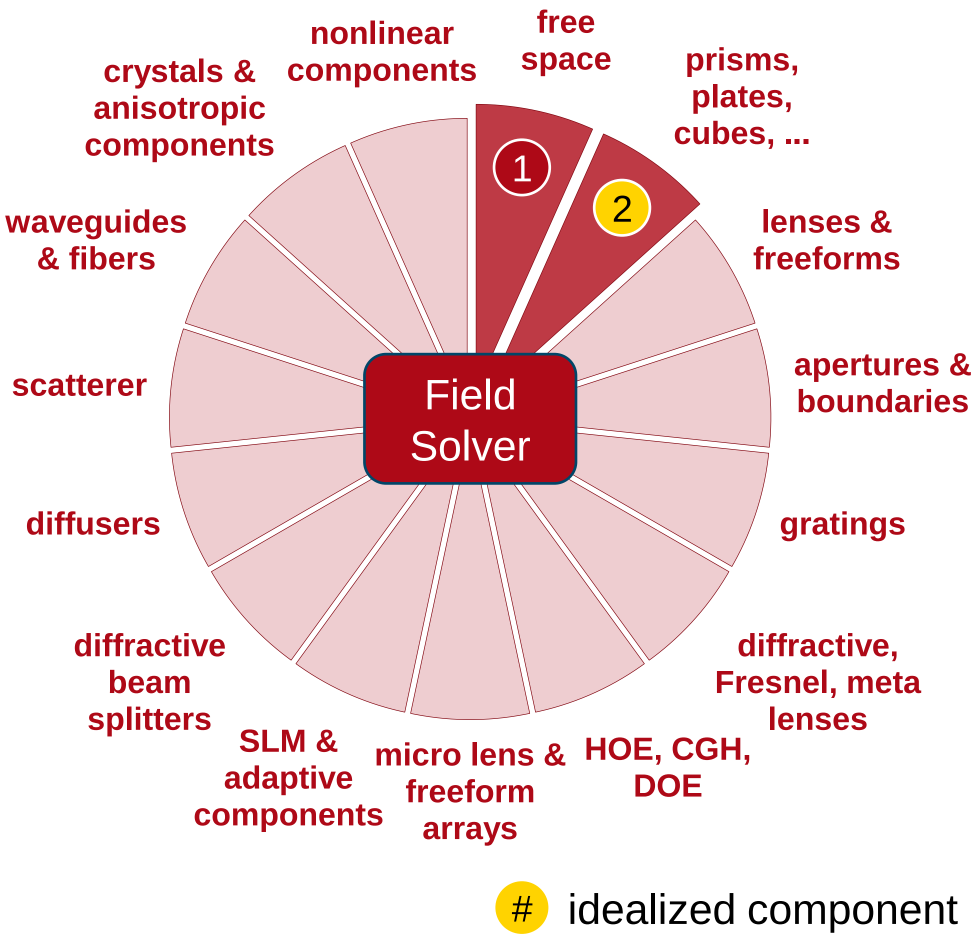
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Video Tutorial]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Video Tutorial]
- Set the non-sequential channels of components
  - Channel Setting for Non-Sequential Tracing [Use Case]
- Use Parameter Run to check influence/changes
  - Usage of the Parameter Run Document [Use Case]



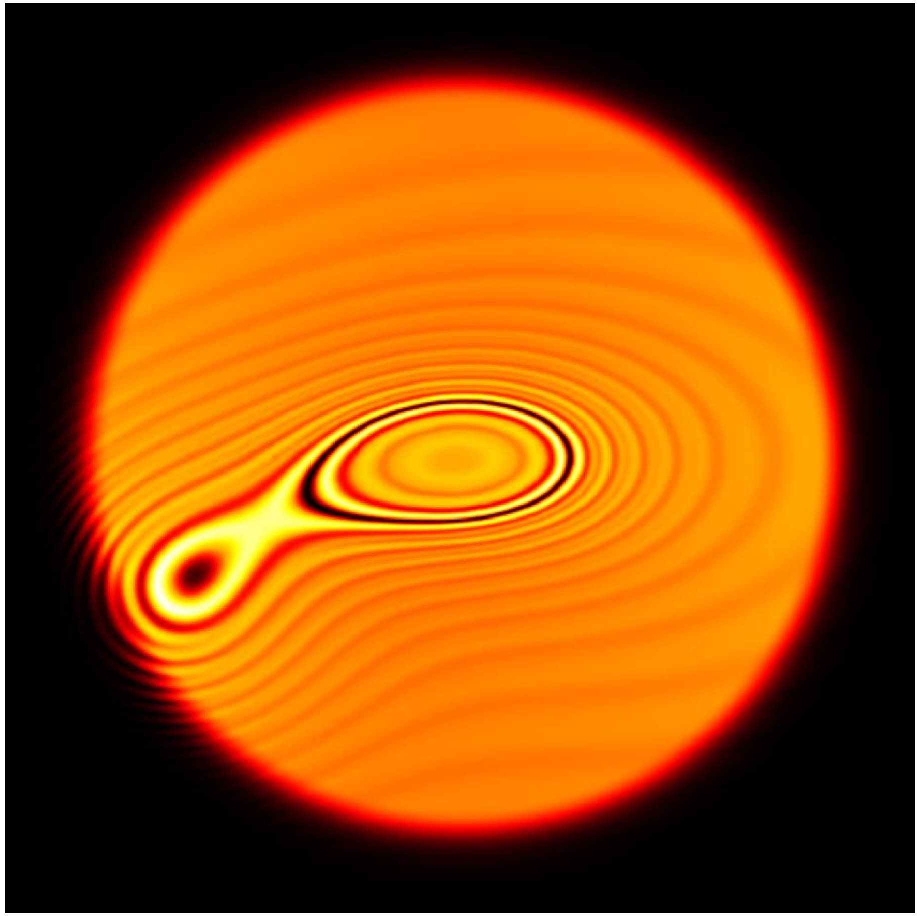
VirtualLab Fusion Technologies





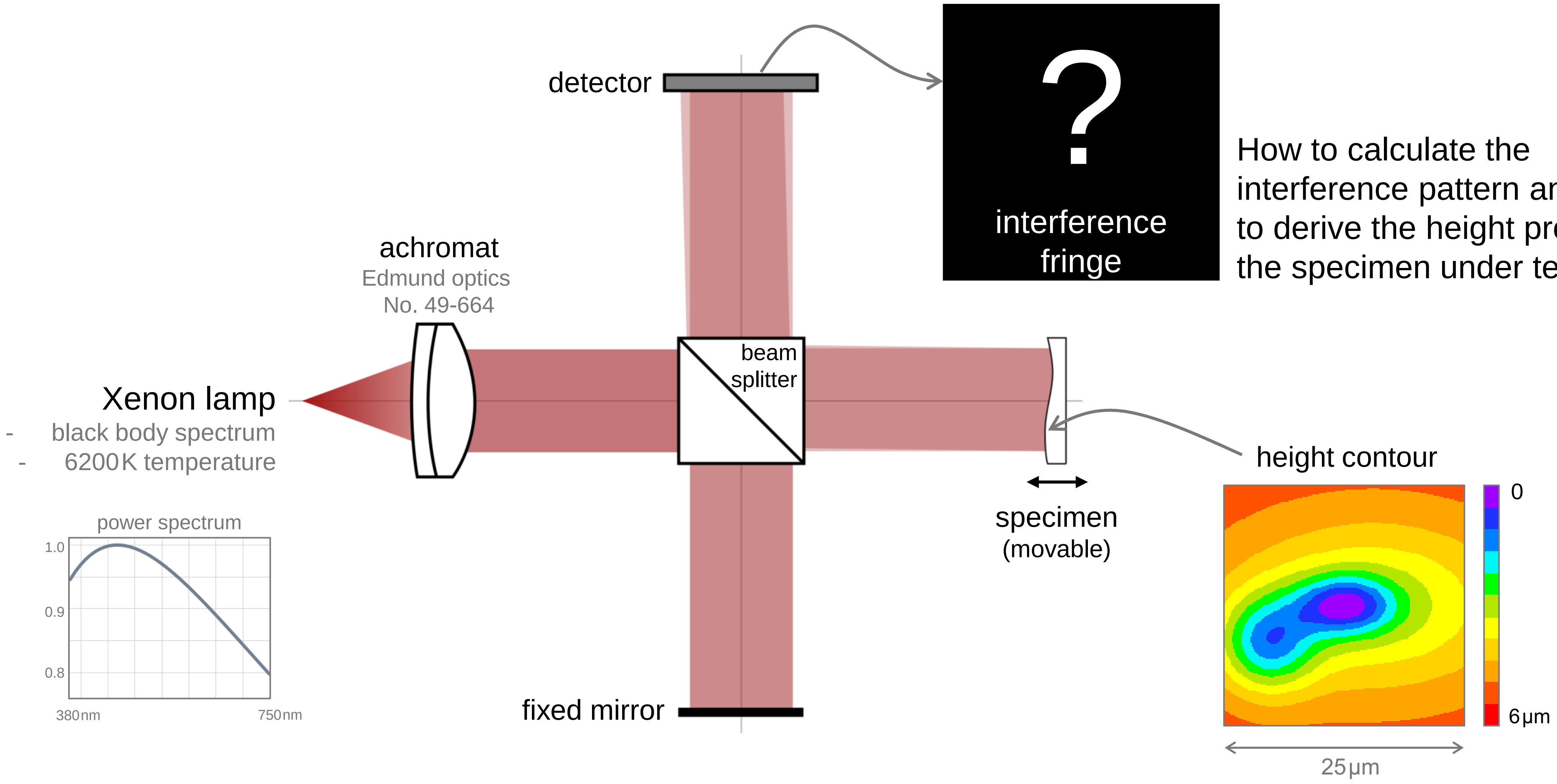
Full-Field Optical Coherence Scanning Interferometry

Abstract



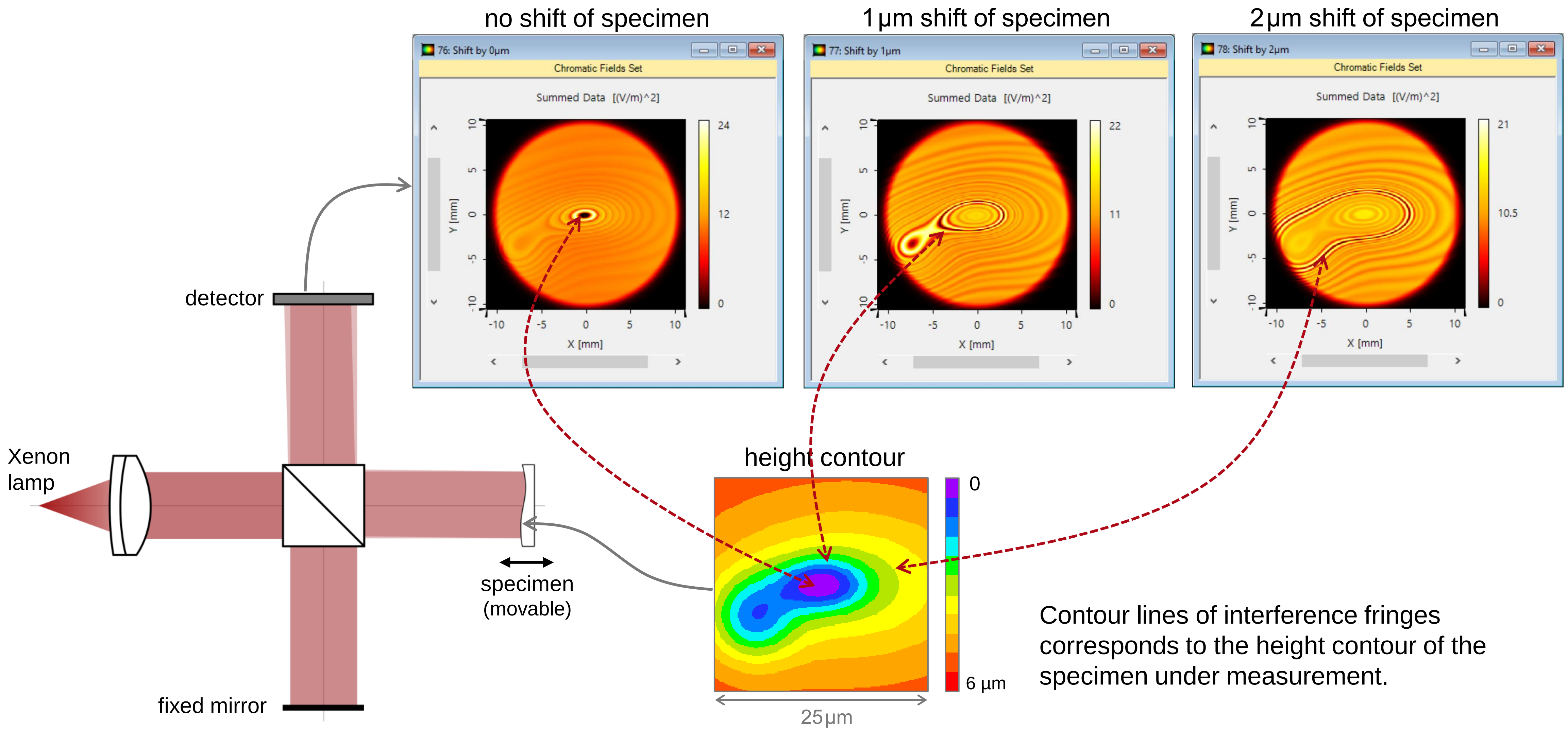
Scanning interferometry is the technique for performing surface height measurement. By exploiting the low coherence of white light source, interference pattern appears only when the path length difference is within the coherent length. Therefore, it enables precise microscopic measurement. Together with a Xenon lamp, a Michelson interferometer is built up and used to measure a specimen with smoothly varying front surface.

Modeling Task



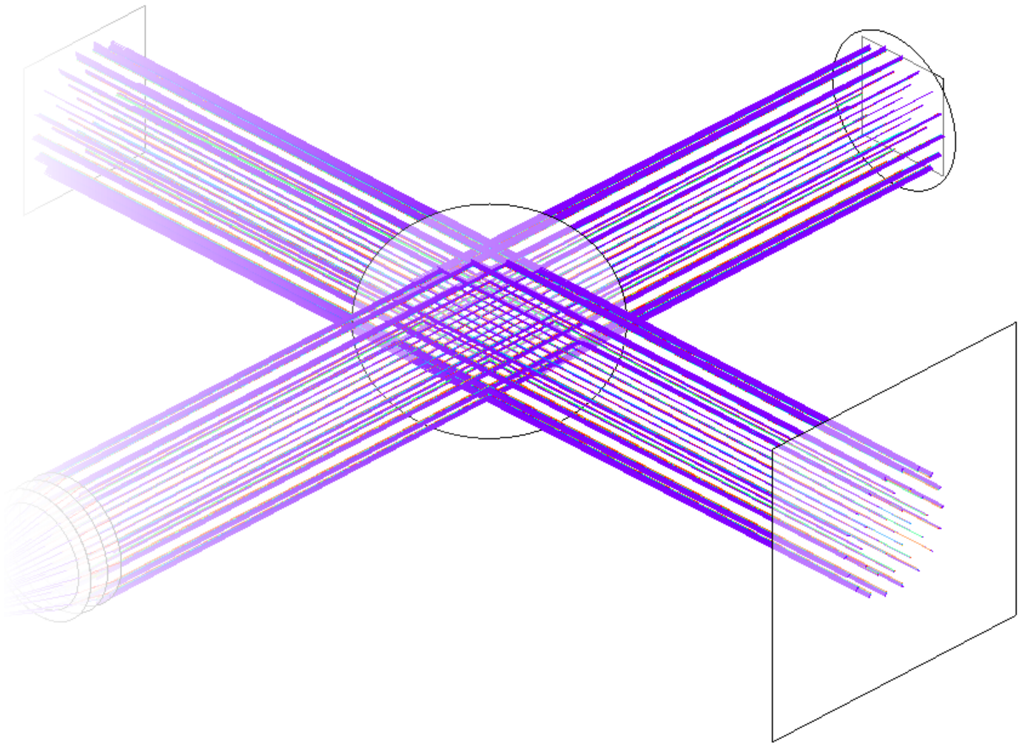
How to calculate the interference pattern and even to derive the height profile of the specimen under test?

Simulated Interference Fringes

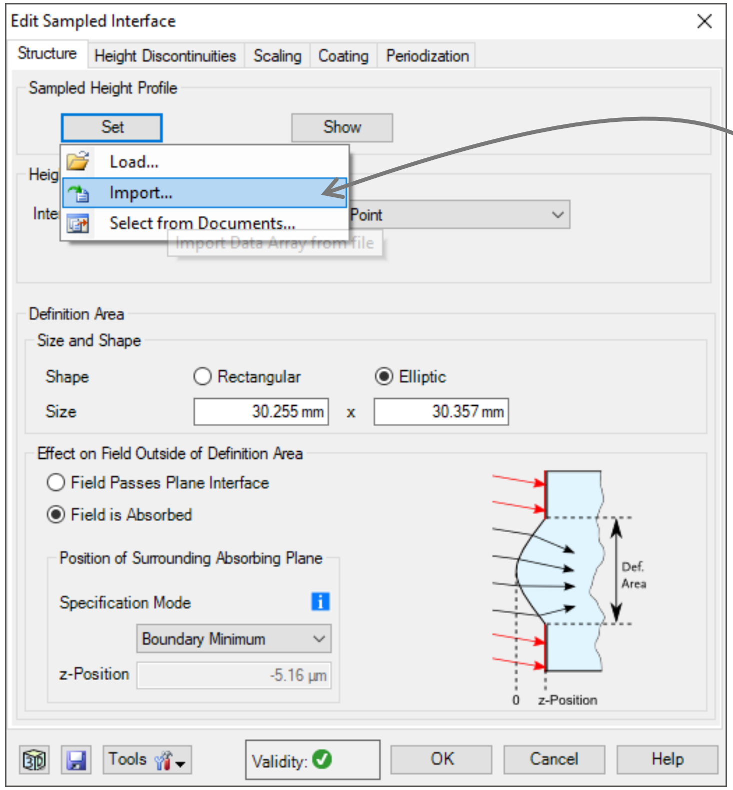


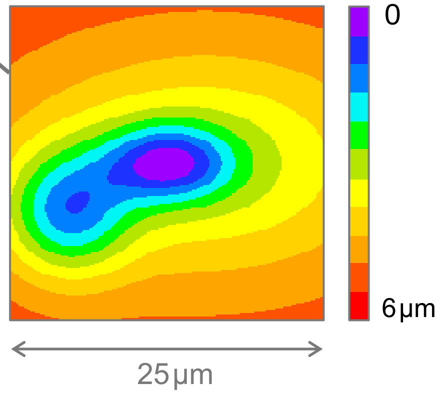
Contour lines of interference fringes corresponds to the height contour of the specimen under measurement.

Peek into VirtualLab Fusion



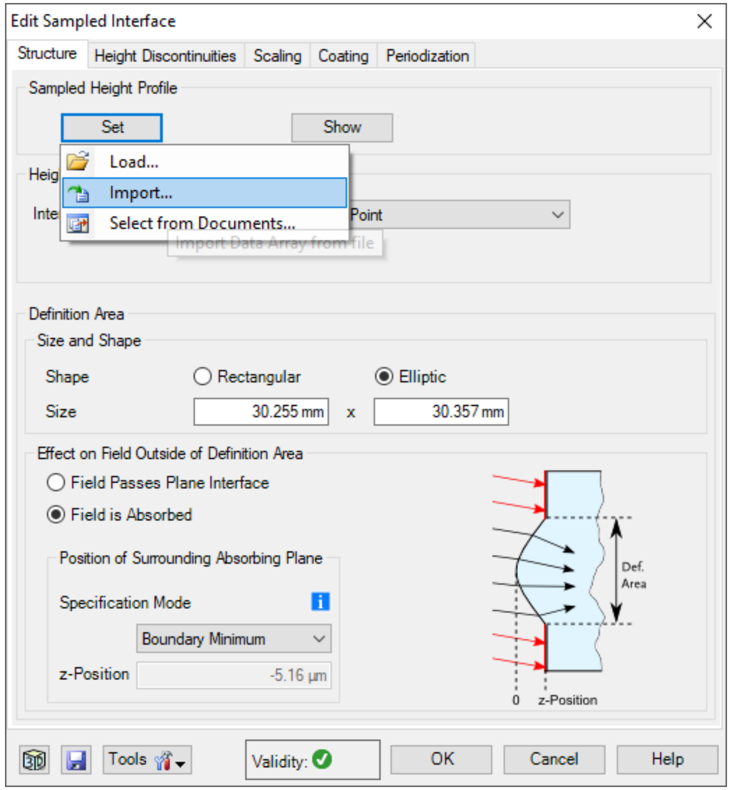
customizable surface definition via import



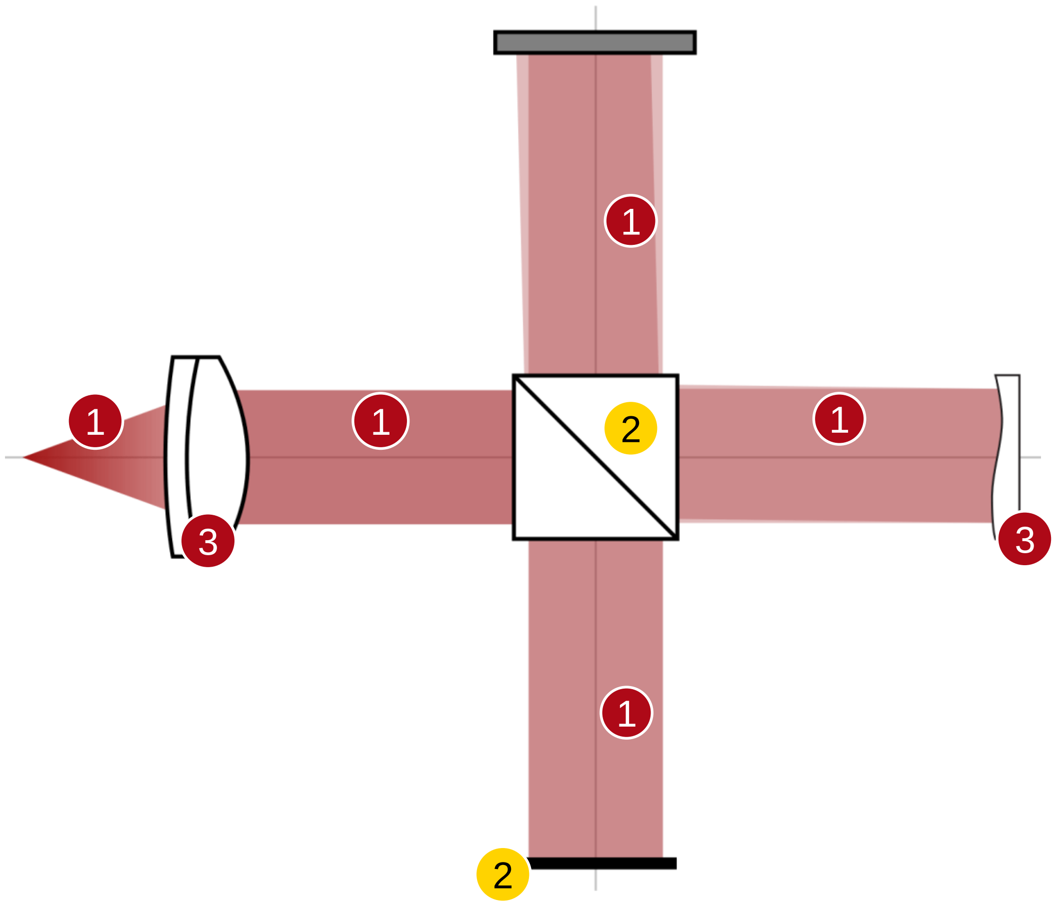


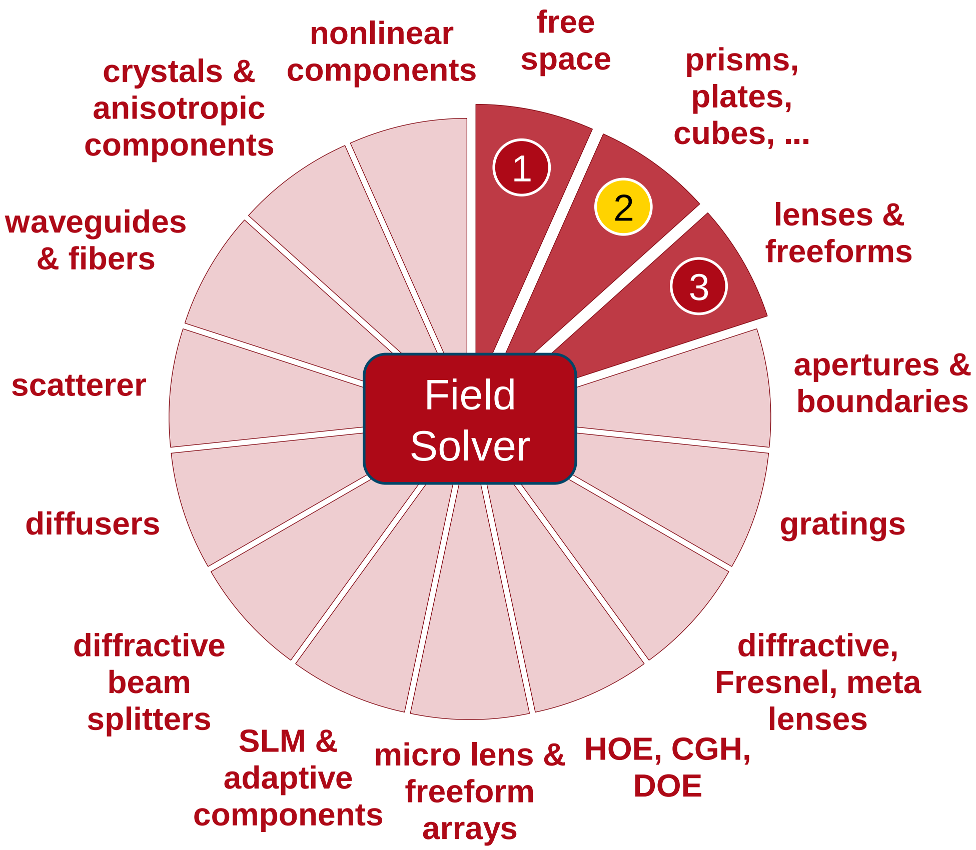
Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Customize surface profile using imported data
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set channels properly for non-sequential tracing
  - Channel Configuration for Surfaces and Grating Regions [Use Case]
- Use Parameter Run to check influence/changes
  - Usage of the Parameter Run Document [Use Case]



VirtualLab Fusion Technologies

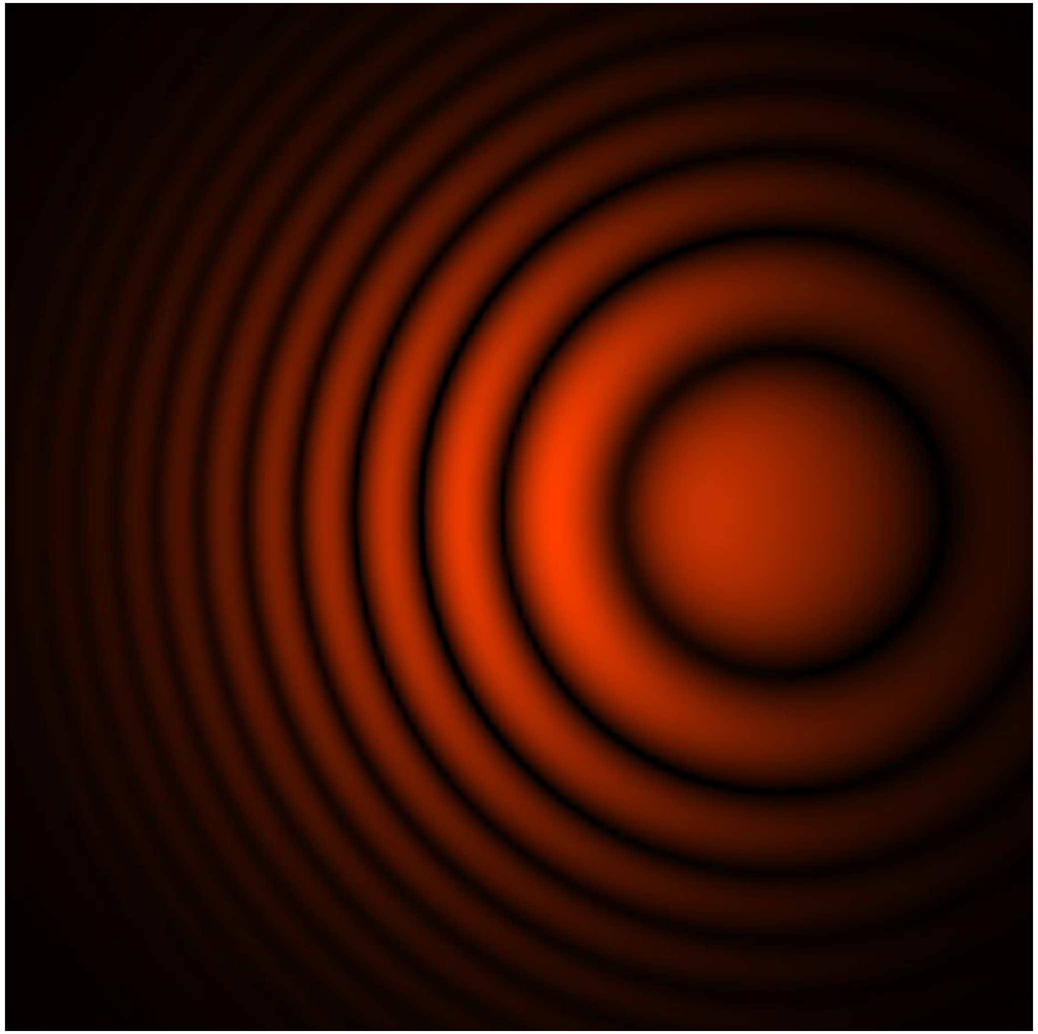




idealized component

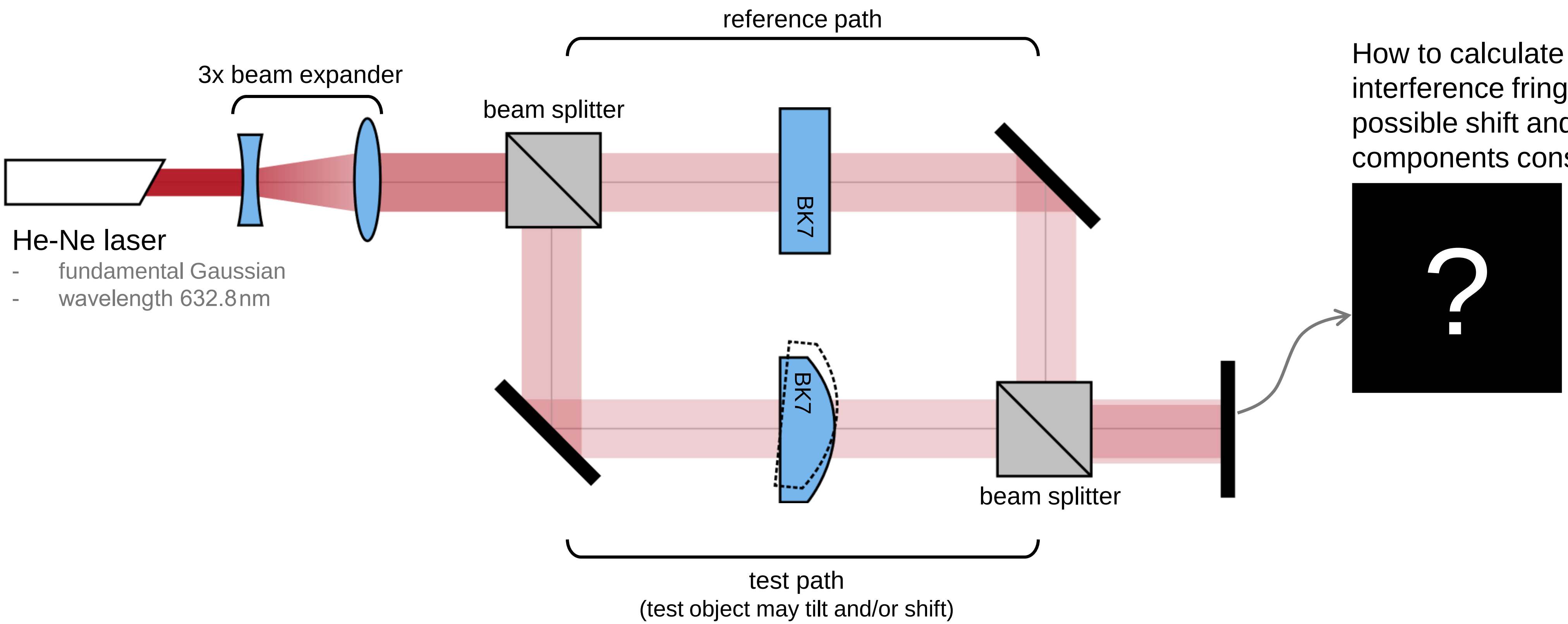
Mach-Zehnder Interferometer

Abstract



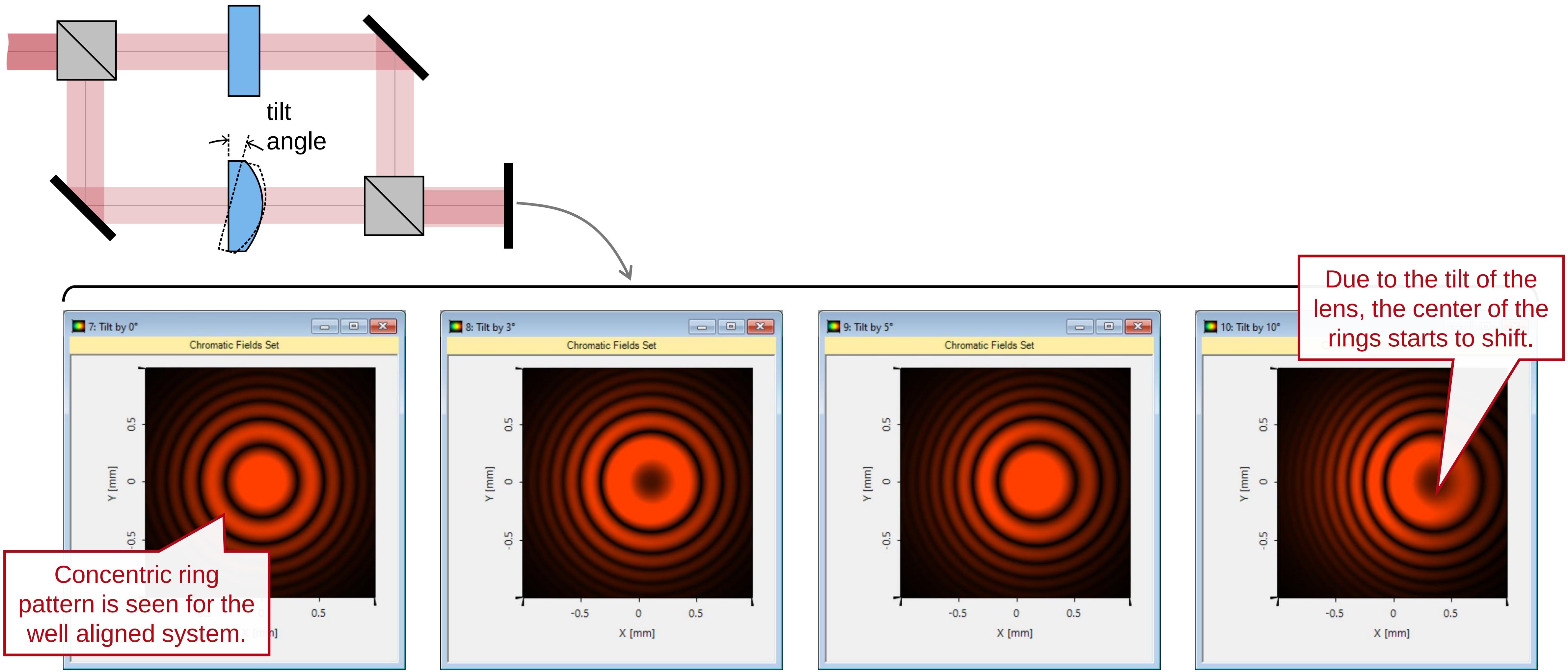
Interferometry is an important technology for optical metrology. It is widely used for the measurements of e.g. surface profile, defects, mechanical and thermal distortion with high precision. As a typical example, a Mach-Zehnder interferometer with coherent laser source is build up in VirtualLab Fusion, with the help of non-sequential field tracing. It is demonstrated that how the tilt and shift of an optical elements may affect the interference fringe pattern.

Modeling Task

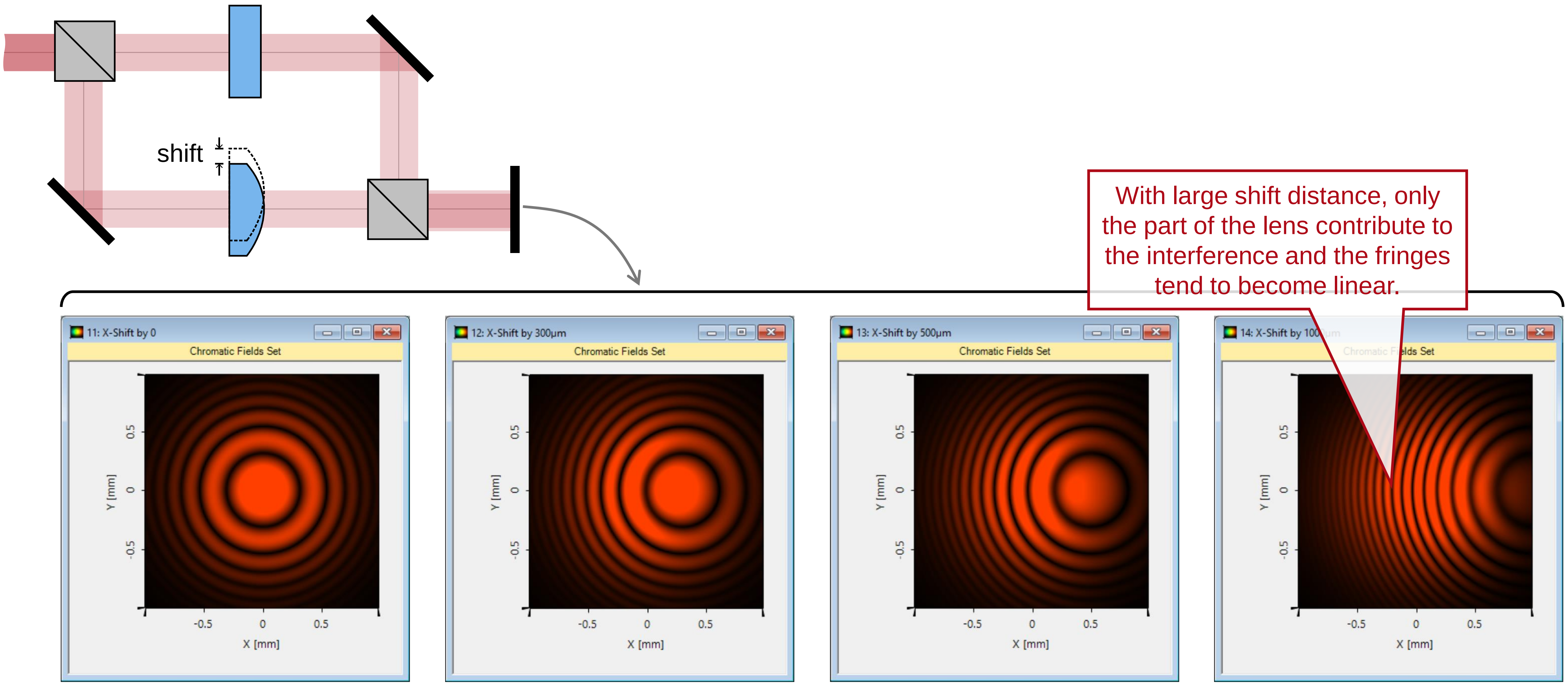


How to calculate interference fringe with the possible shift and tilt of components considered?

Interference Fringe Due to Component Tilt



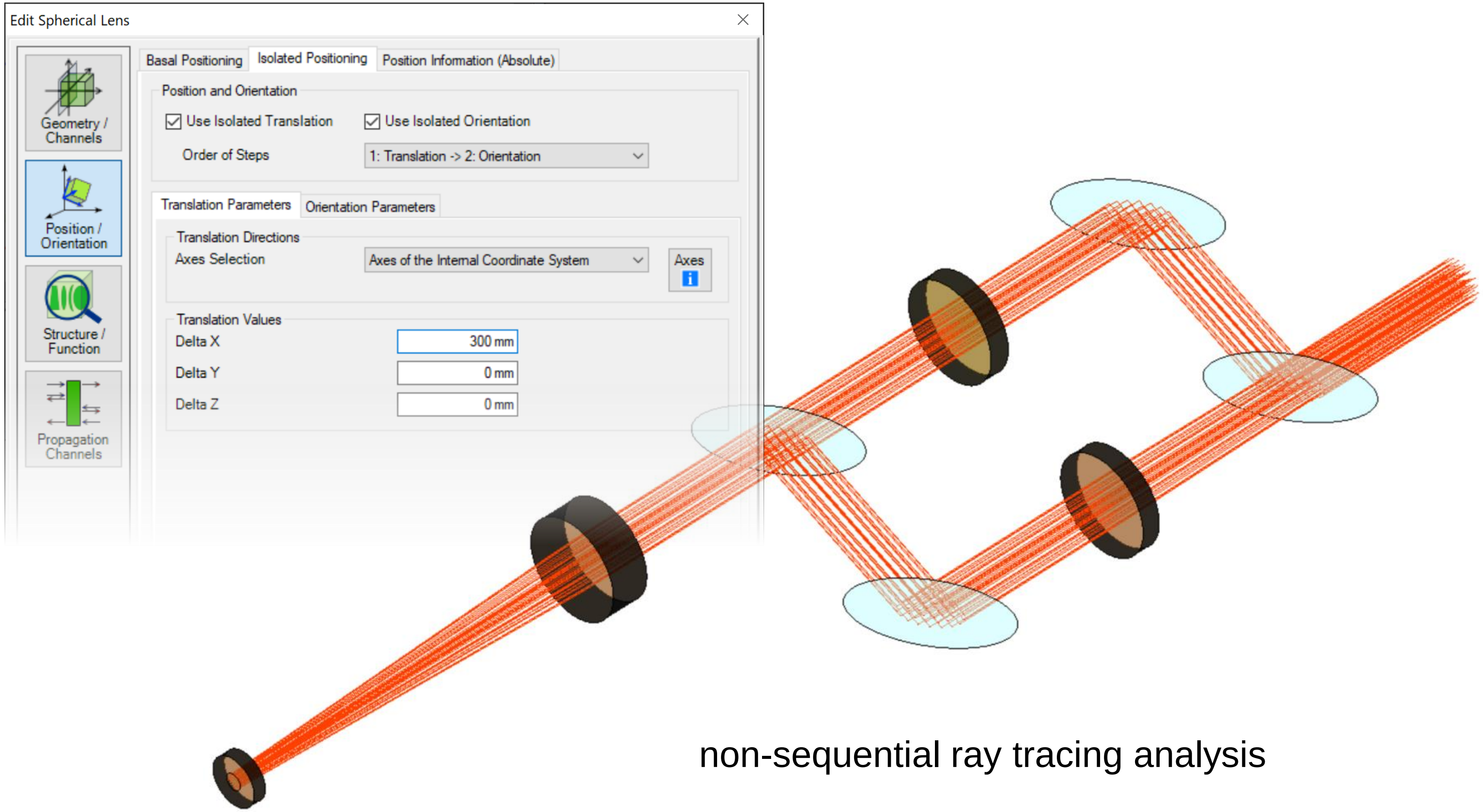
Interference Fringe Due to Component Shift



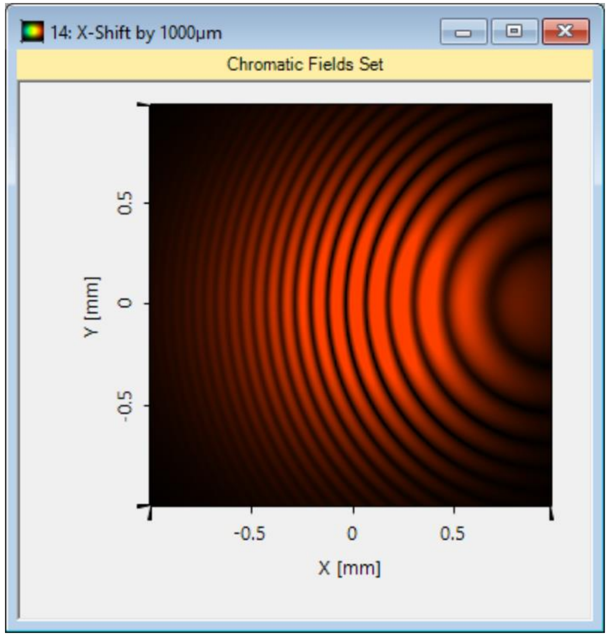
With large shift distance, only the part of the lens contribute to the interference and the fringes tend to become linear.

Peek into VirtualLab Fusion

flexible position and orientation settings



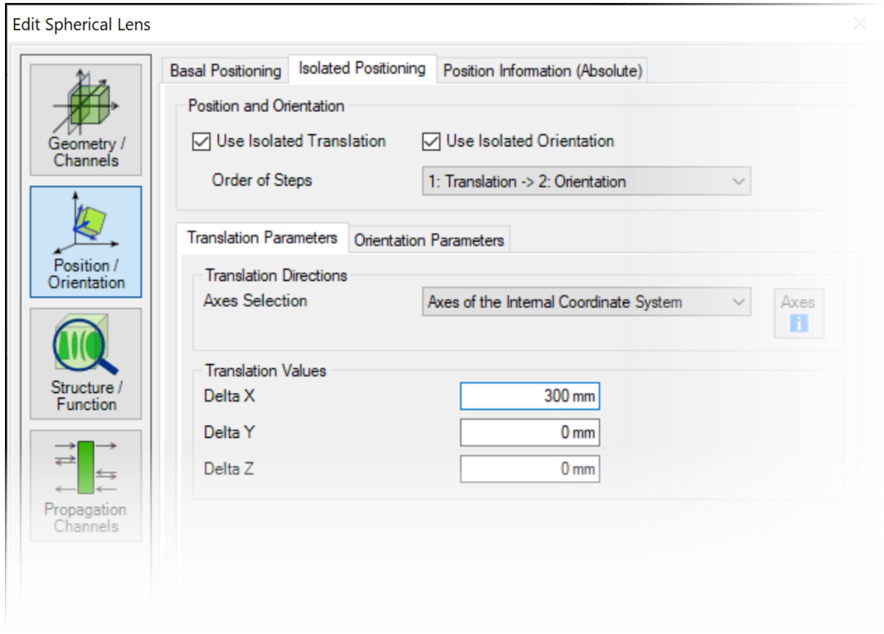
non-sequential ray tracing analysis



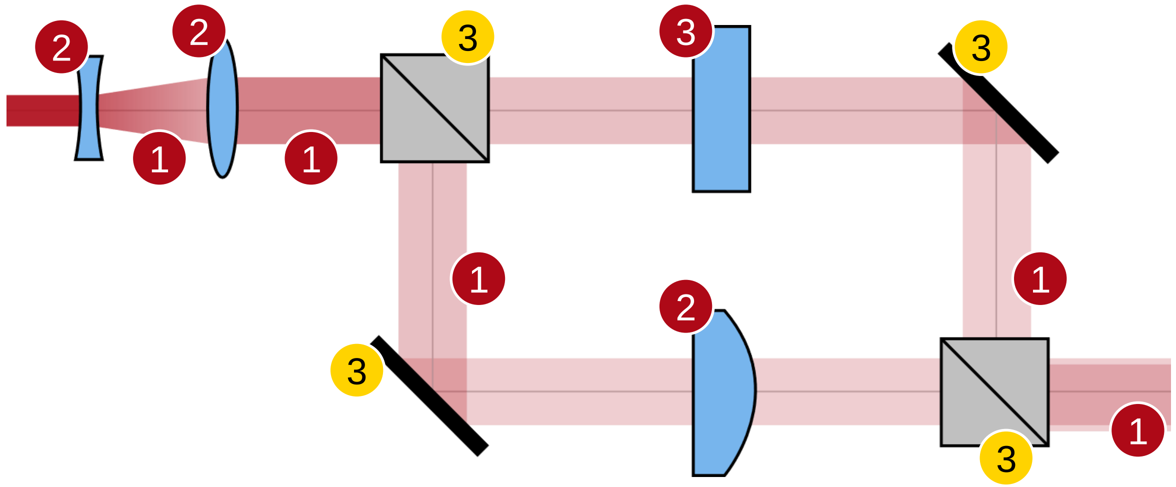
direct observation of interference fringes

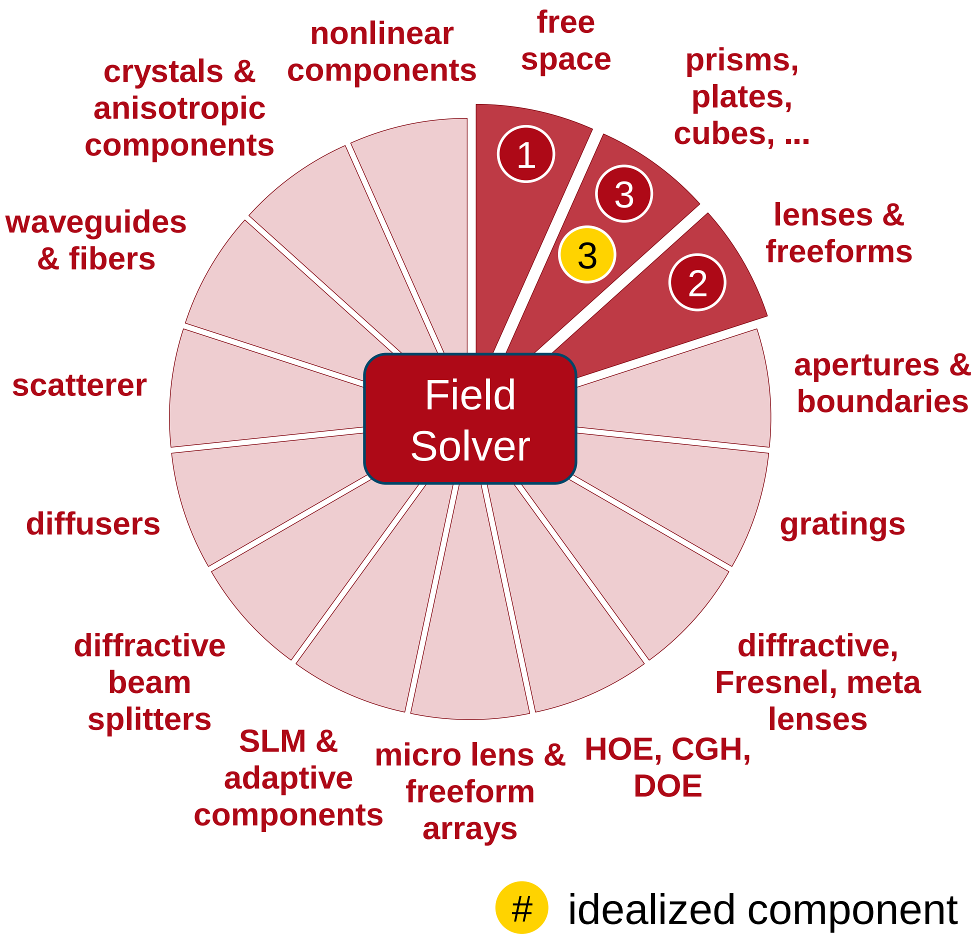
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Configure the surface channels of components
  - Channel Configuration for Surfaces and Grating Regions [Use Case]



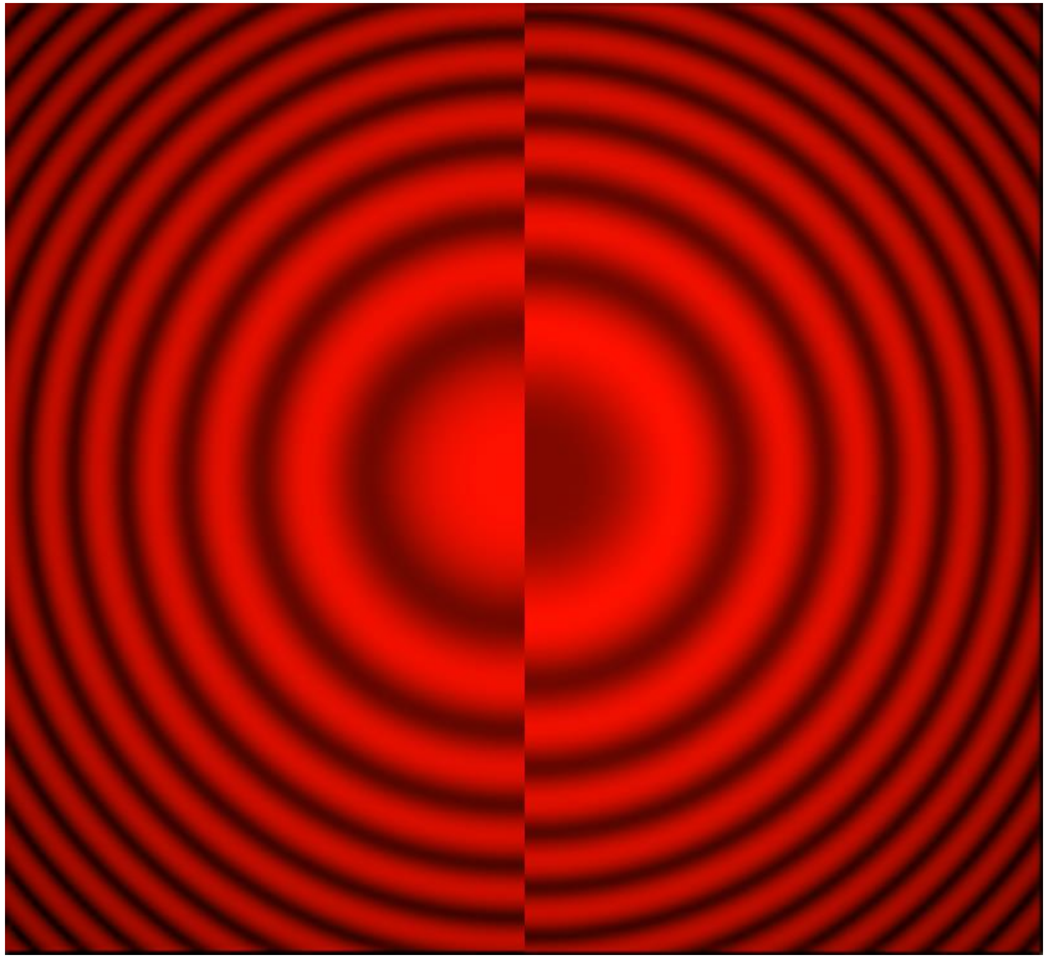
VirtualLab Fusion Technologies





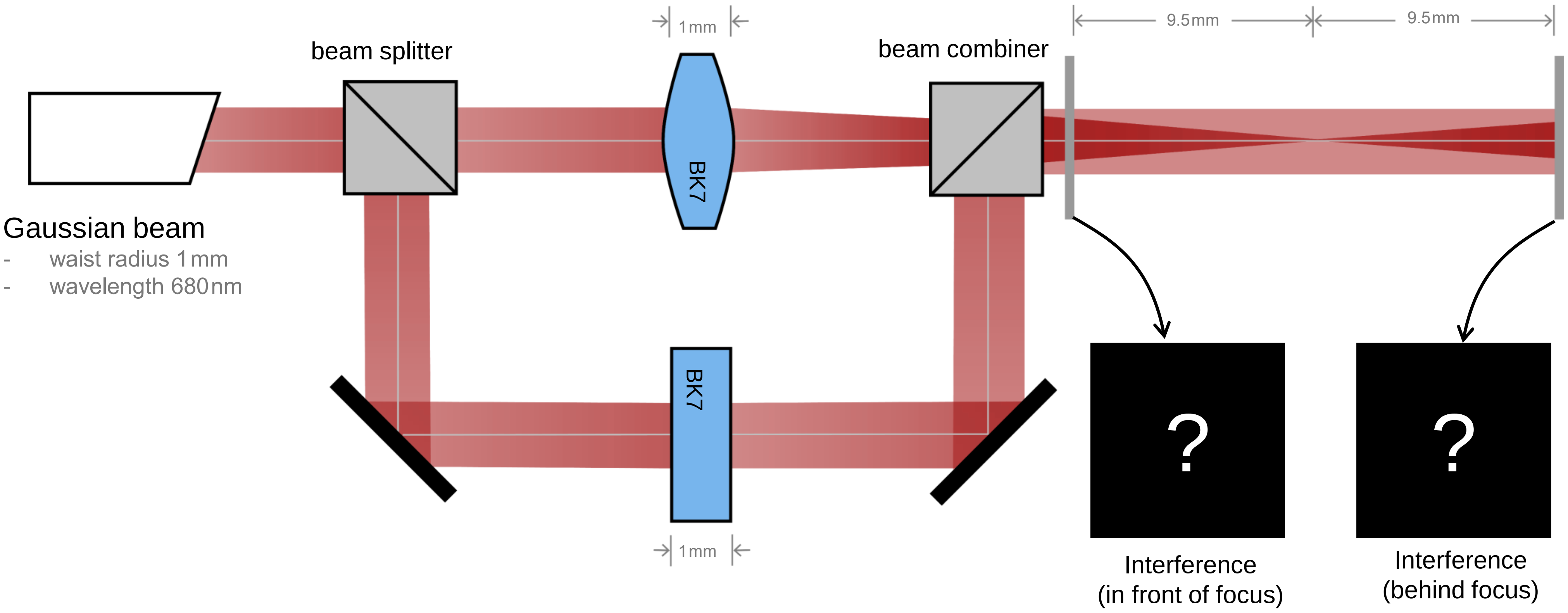
Observation of Gouy Phase Shift in a Mach-Zehnder Interferometer

Abstract

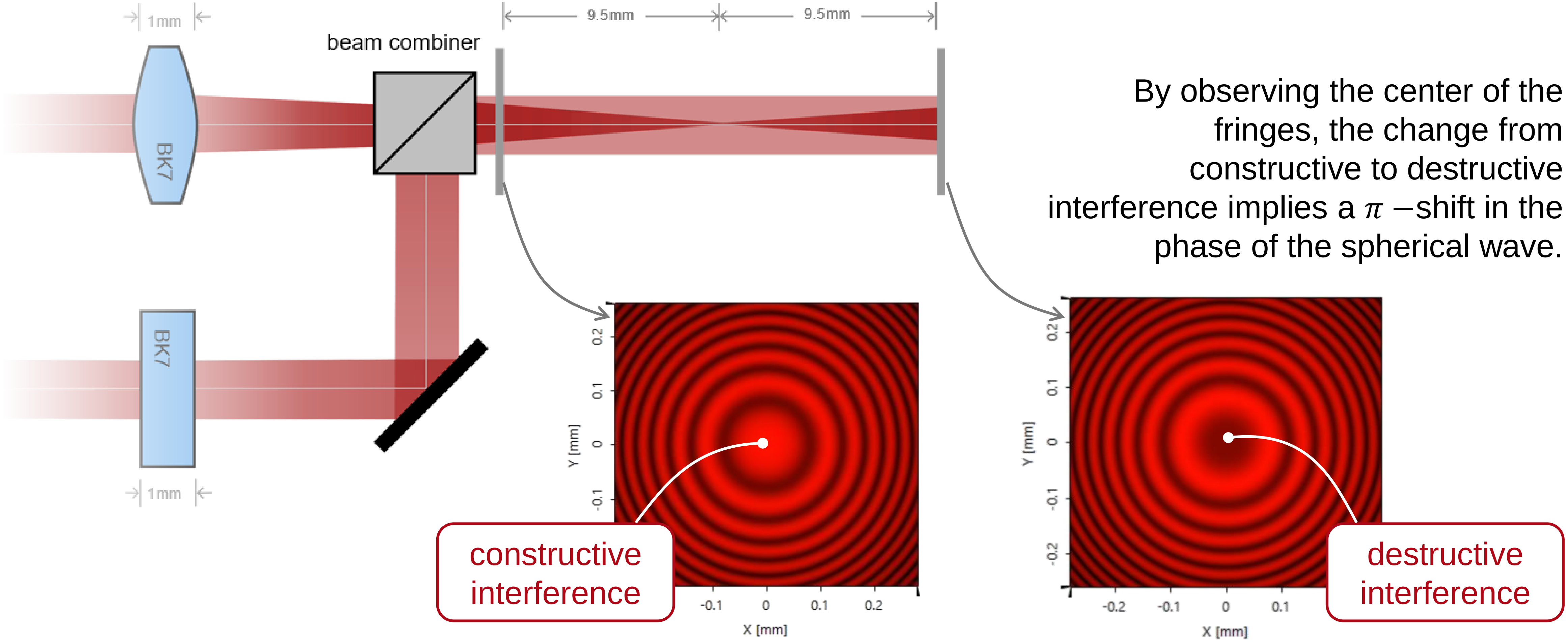


Convergent beams travelling through their focus from minus infinity to plus infinity not only experience the accumulation of the phase corresponding to the traversed optical path length, but also accrue a constant π phase term, known as the Gouy phase shift, discovered by the scientist of the same name at the end of the nineteenth century. When such a beam interferes with a collimated one, the Gouy phase shift is revealed when the interference patterns generated on both sides of the focus are compared: the ring patterns are negatives of each other. This can be observed in a Mach-Zehnder.

Modeling Task



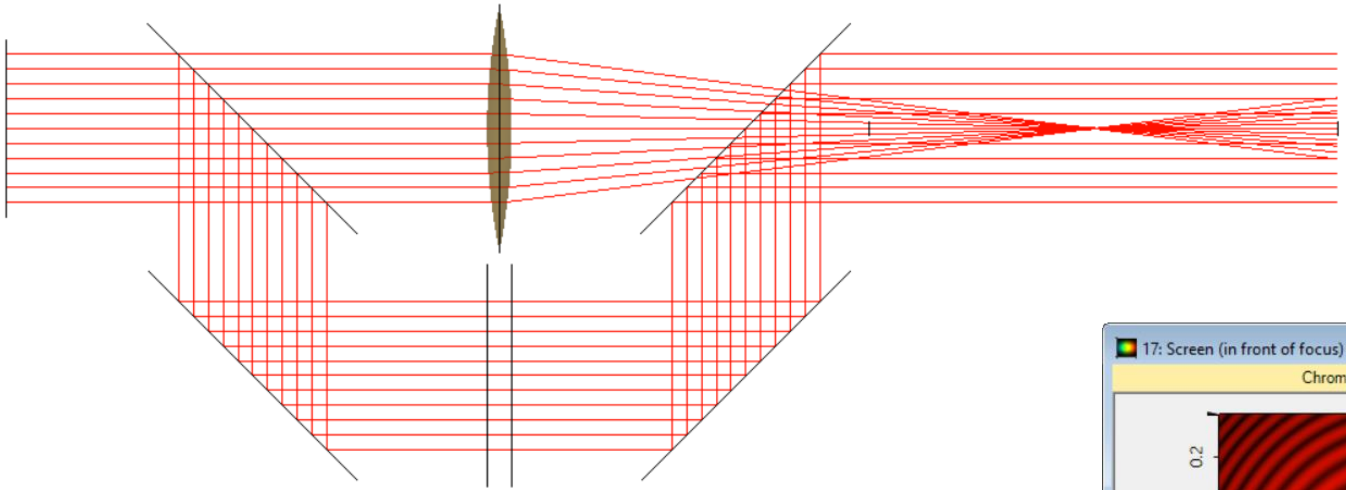
Interference Pattern

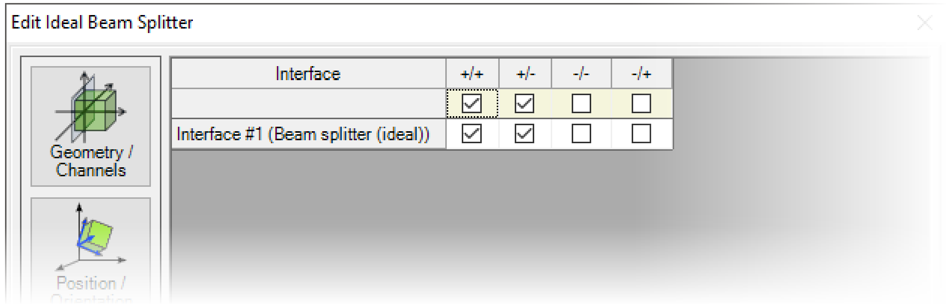


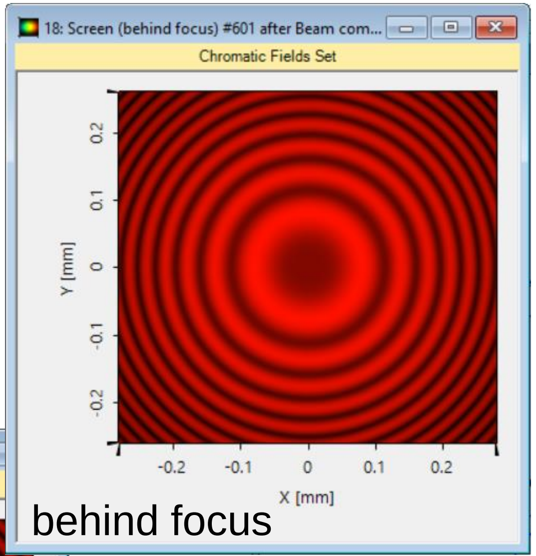
By observing the center of the fringes, the change from constructive to destructive interference implies a π –shift in the phase of the spherical wave.

Peek into VirtualLab Fusion

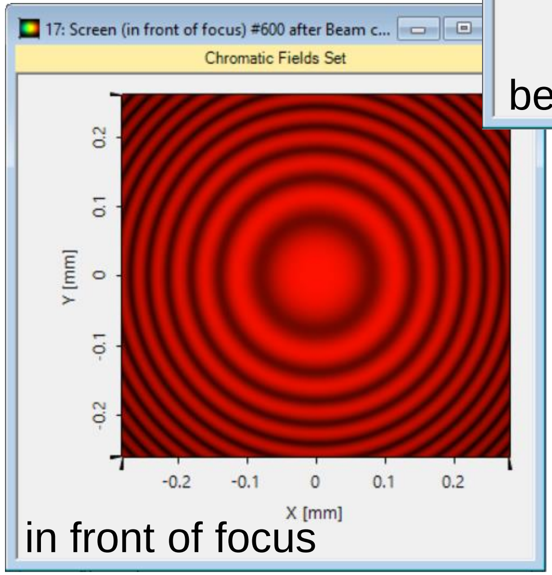
ray tracing through Mach-Zehnder interferometer







behind focus

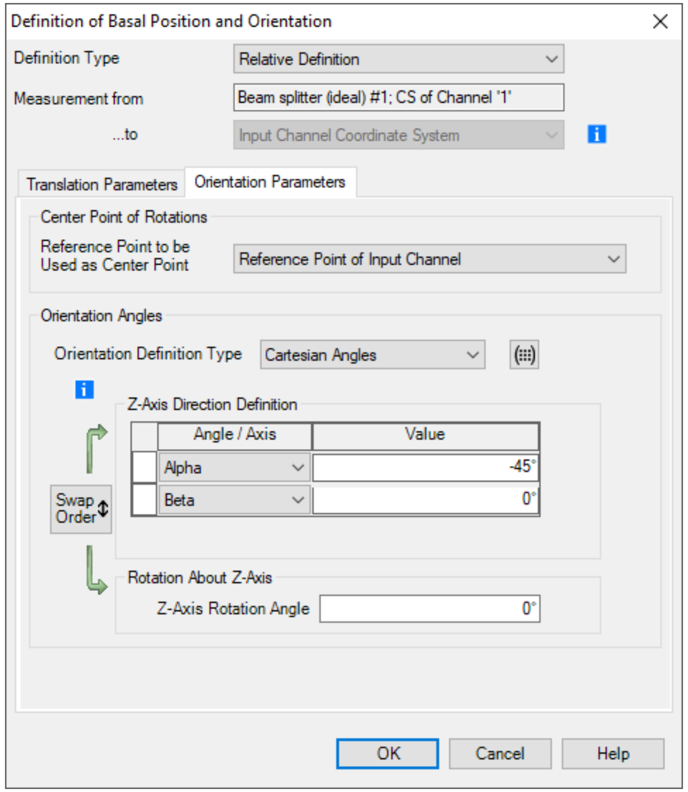


in front of focus

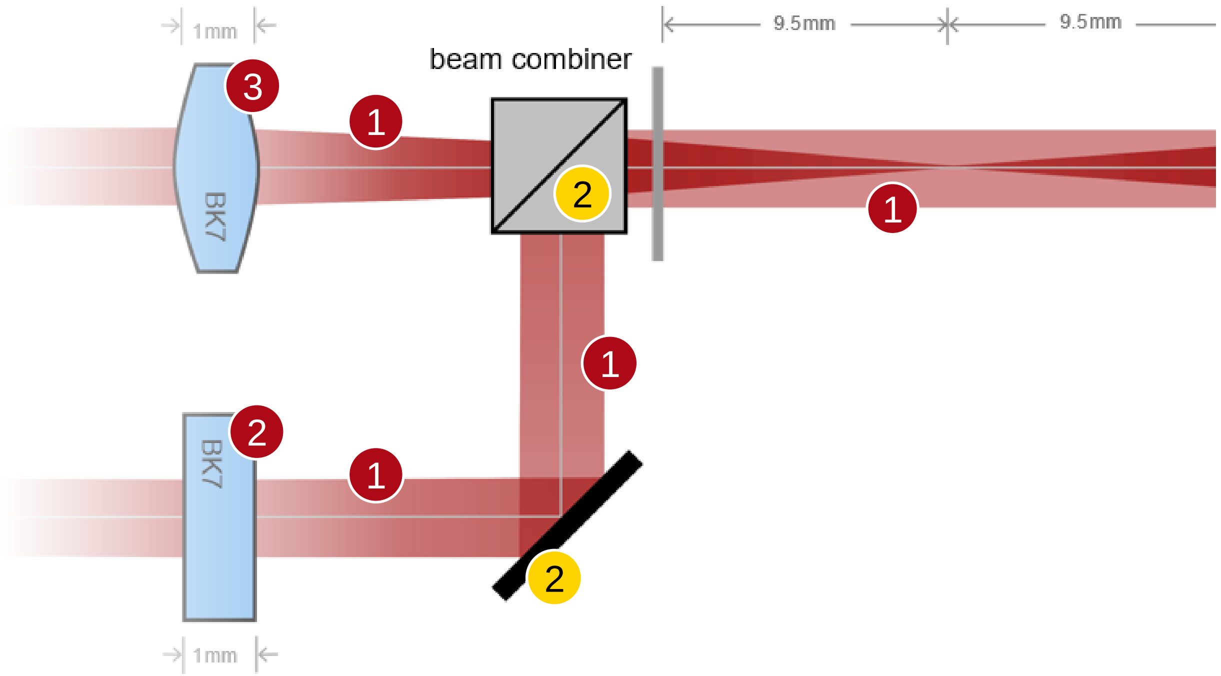
visualization of interference fringes at selected planes

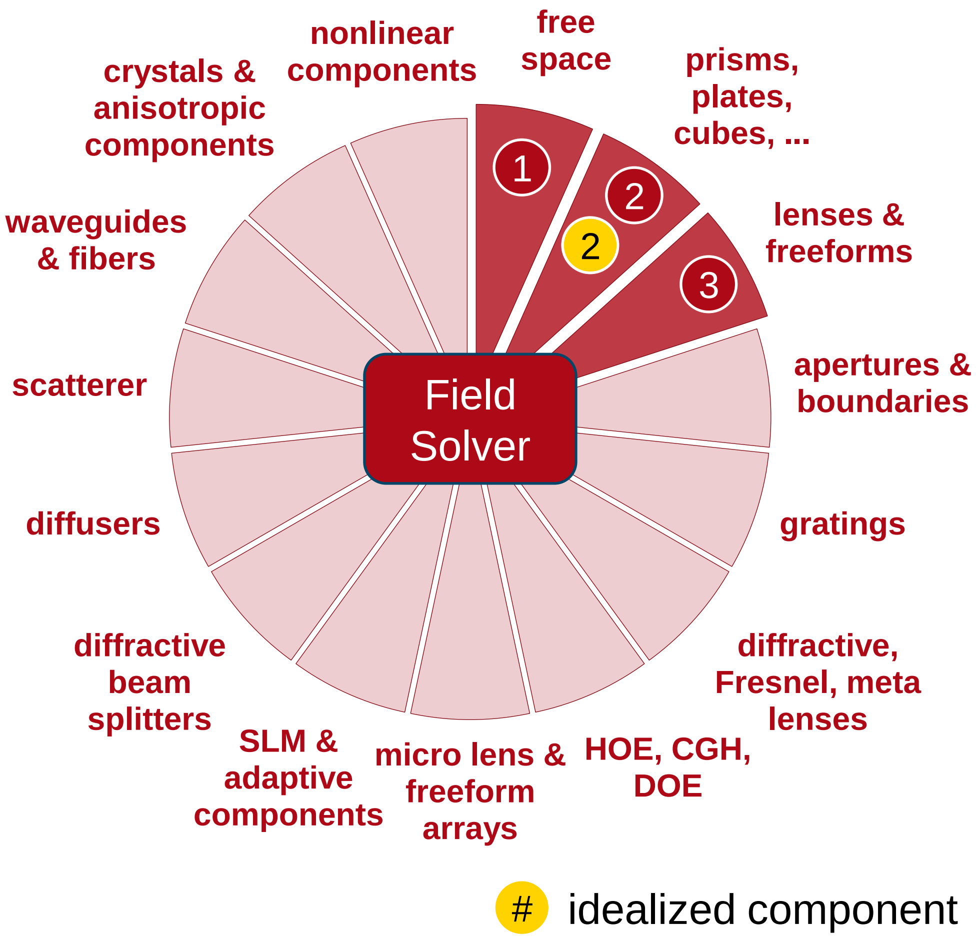
Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Construct real components using surfaces
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Set channels properly for non-sequential tracing
  - Channel Setting for Non-Sequential Tracing [Use Case]



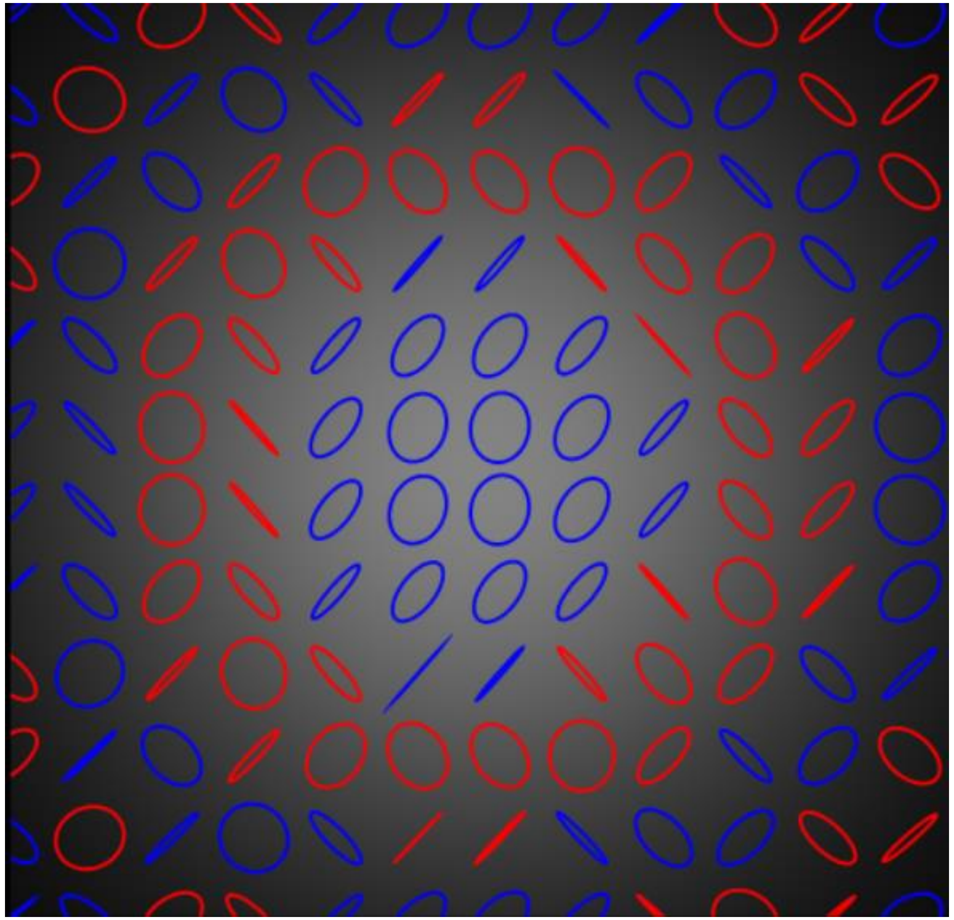
VirtualLab Fusion Technologies





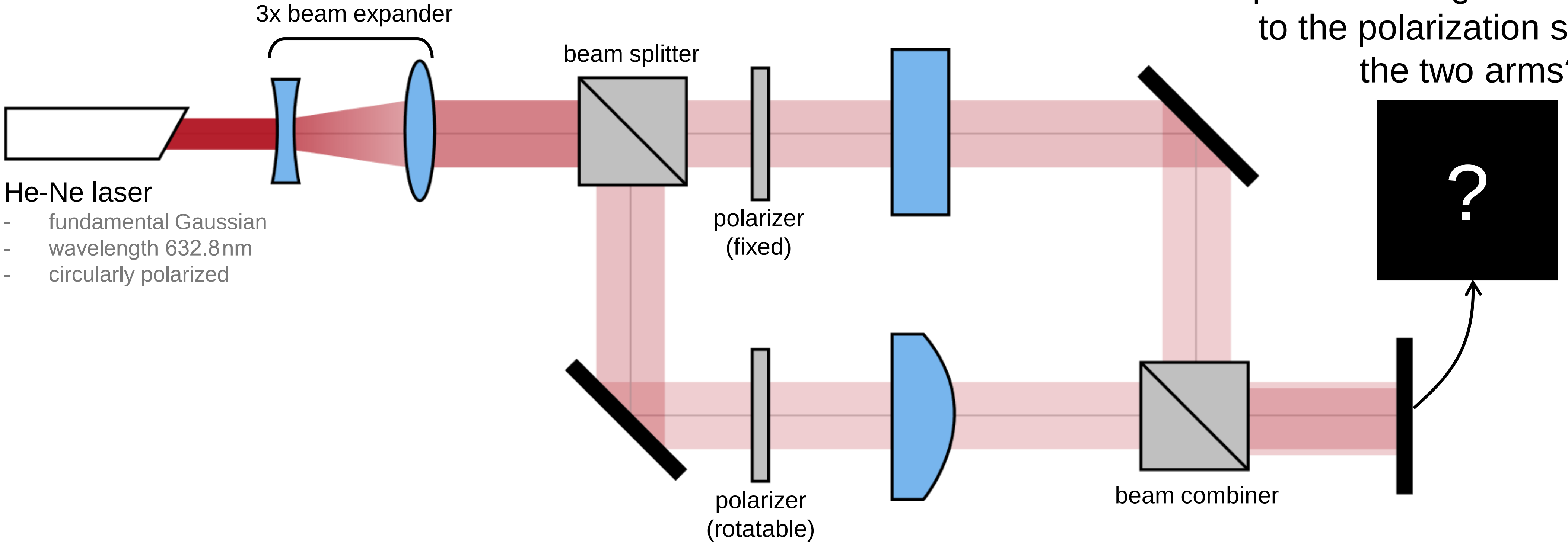
Generation of Spatially Varying Polarization by Interference with Polarized Light

Abstract



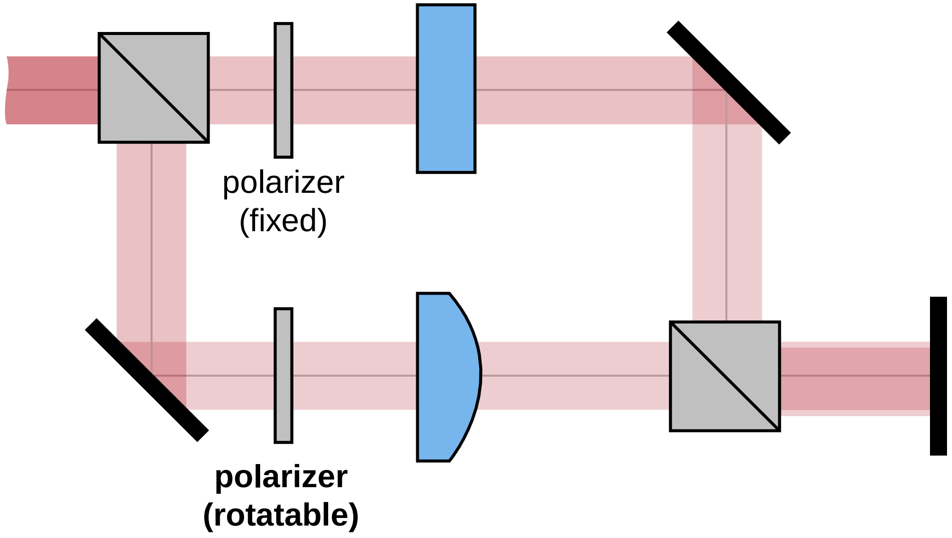
Interferometry is an important technique for optical metrology. As an example, a Mach-Zehnder interferometer with coherent laser source is build up in VirtualLab Fusion. Particularly in this example, two polarizers are inserted to control the polarization states of the two interfering beams. By rotating one polarizer, the changes in the interference pattern is visualized, and as a result, spatially varying polarization is generated.

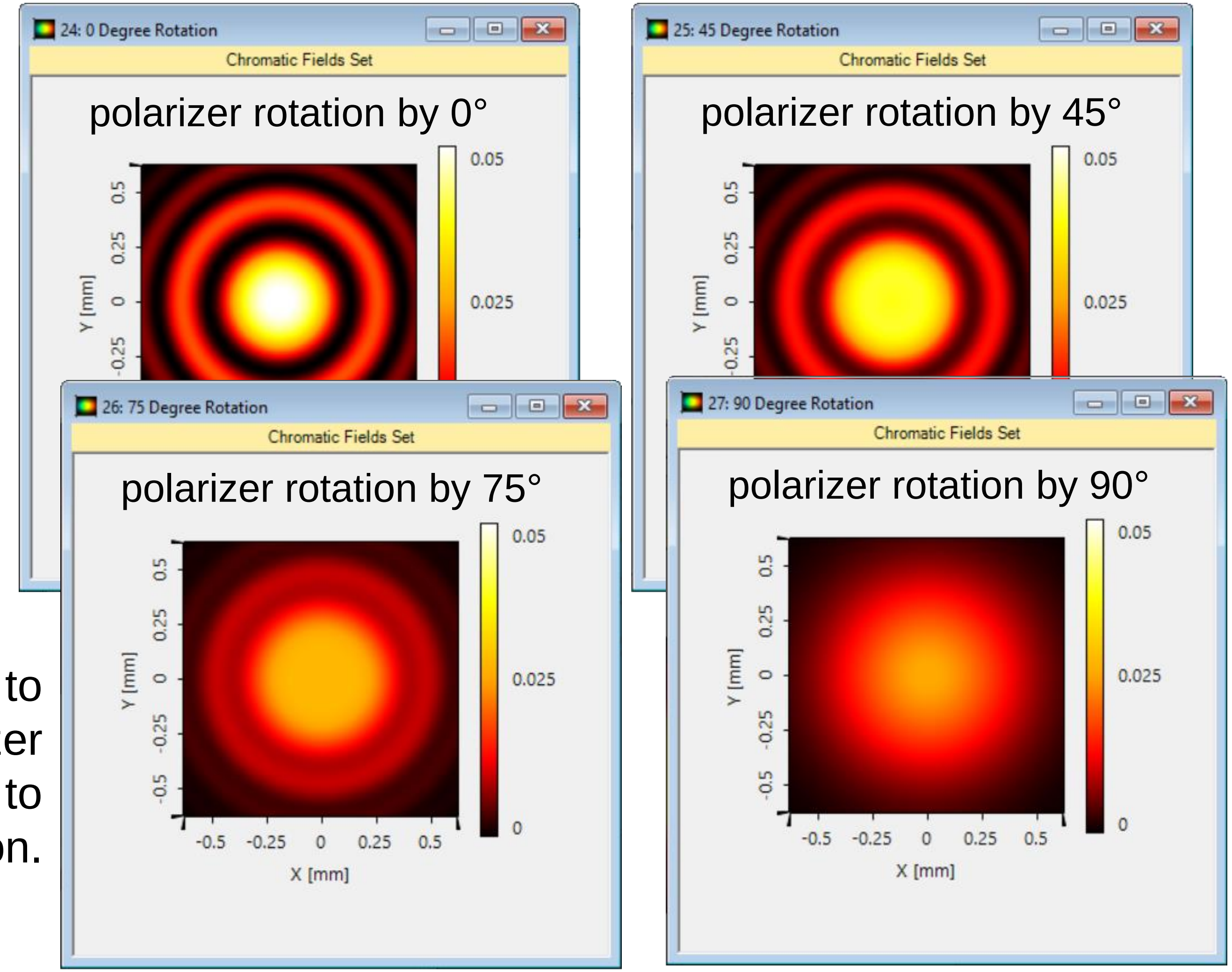
Modeling Task



How does the interference pattern change with respect to the polarization states of the two arms?

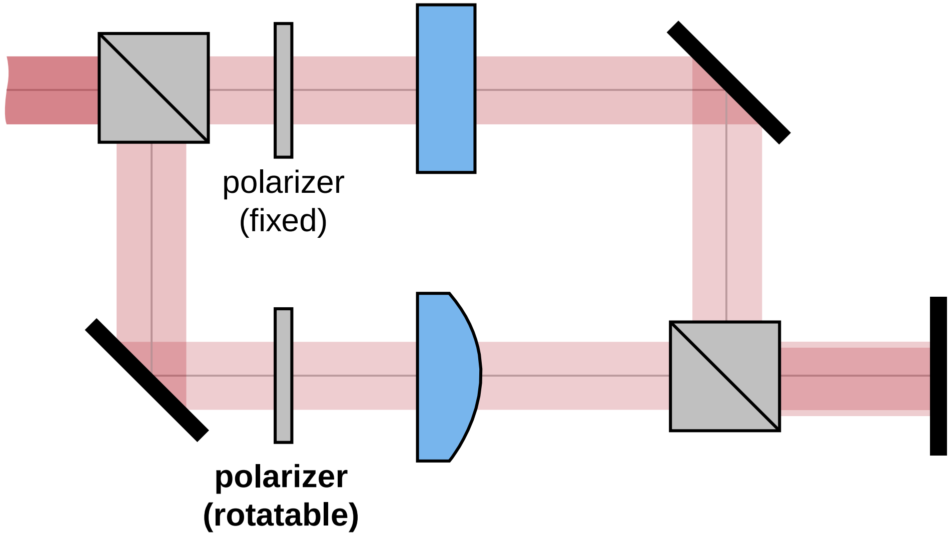
Interference Pattern Changes with Polarizer Rotation



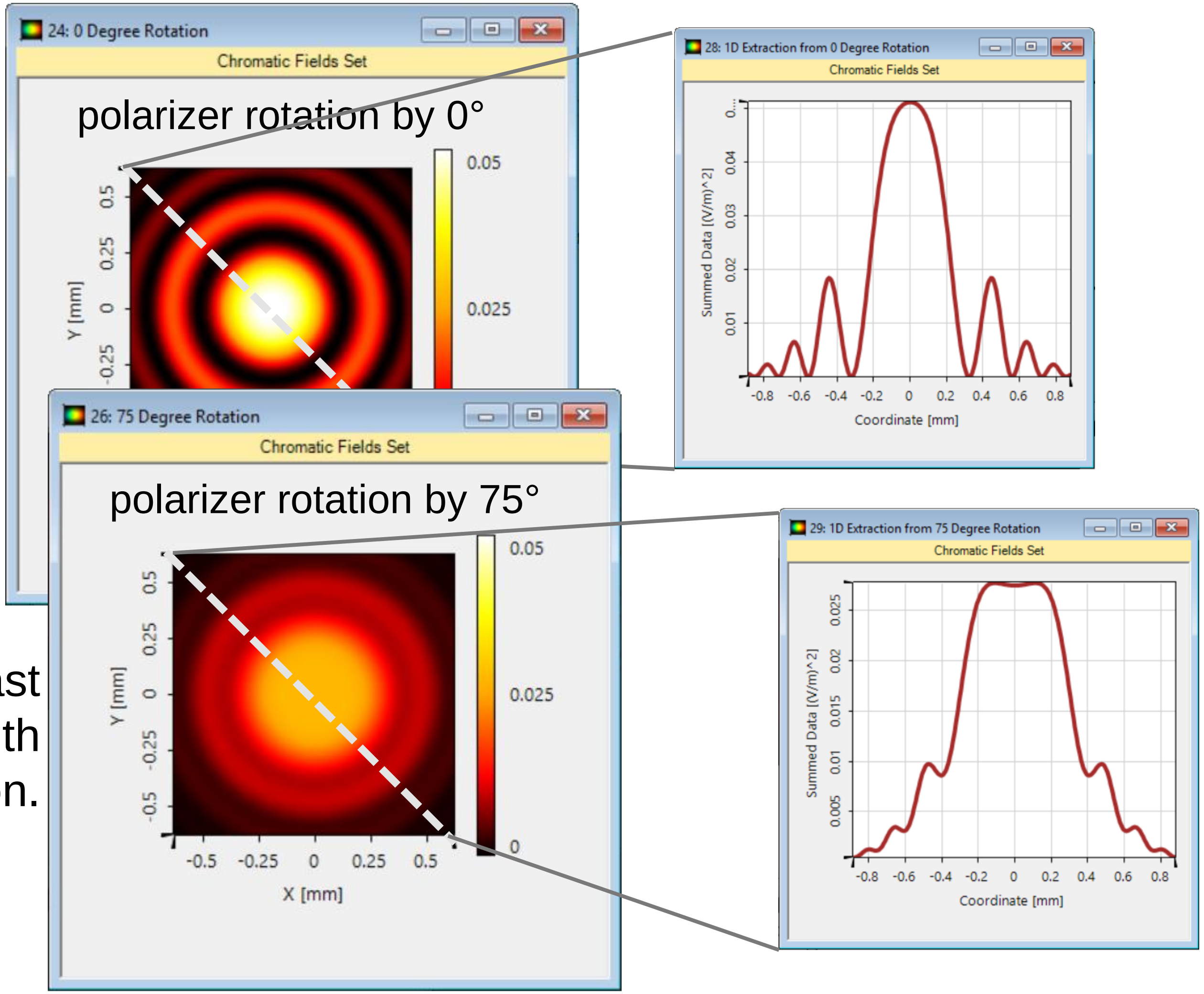


Interference fringes start to disappear, when polarizer rotates from parallel to orthogonal orientation.

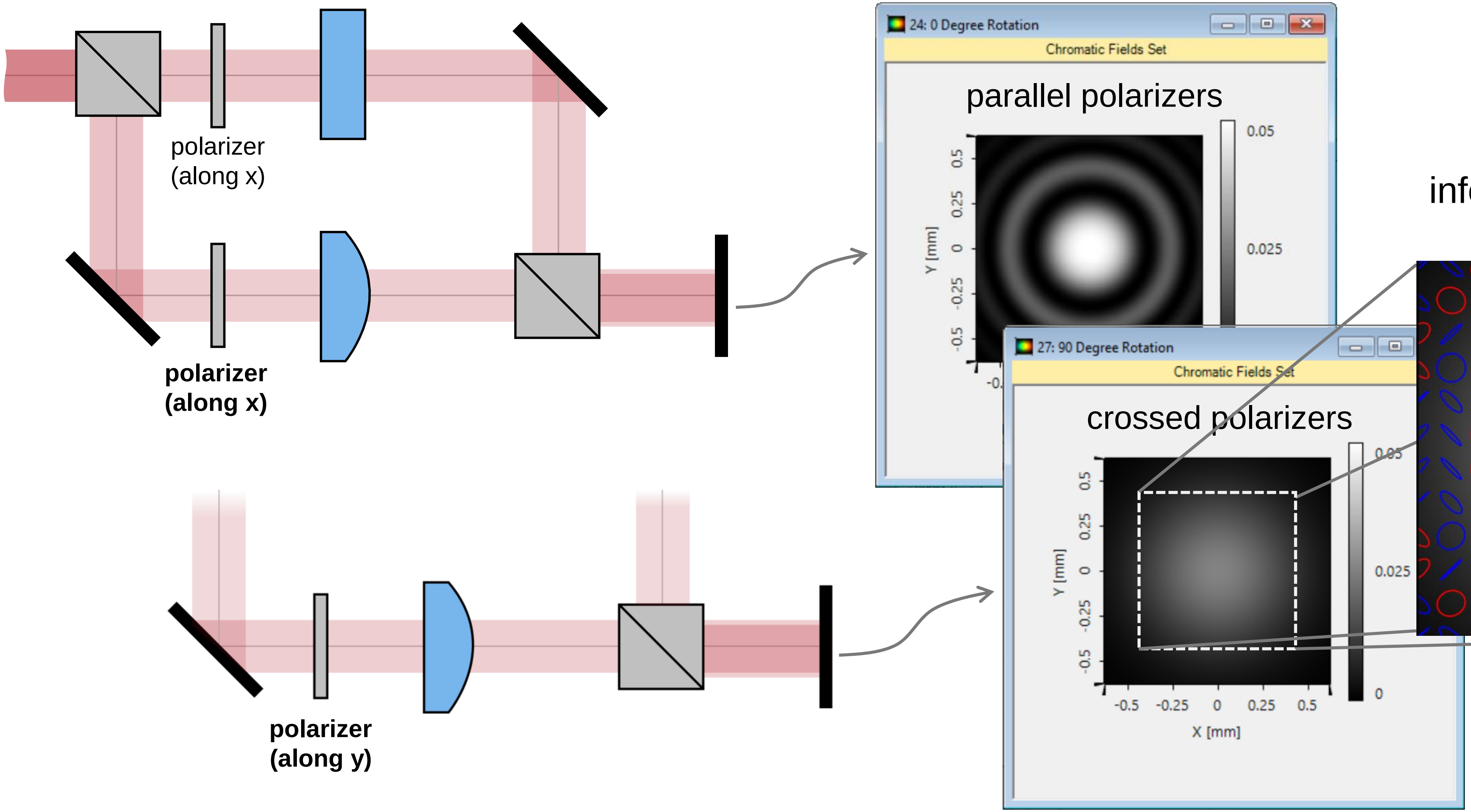
Interference Pattern Changes with Polarizer Rotation



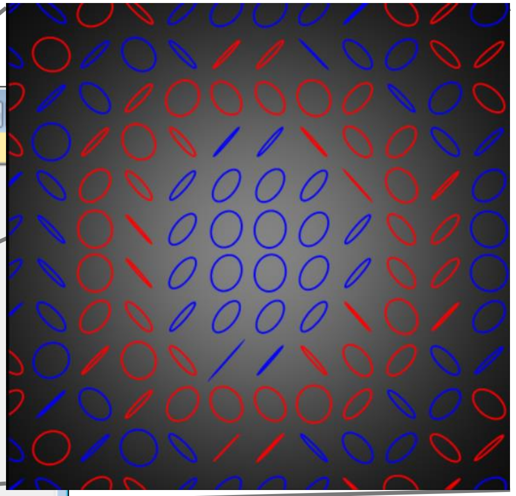
Fringe contrast changes with polarizer rotation.



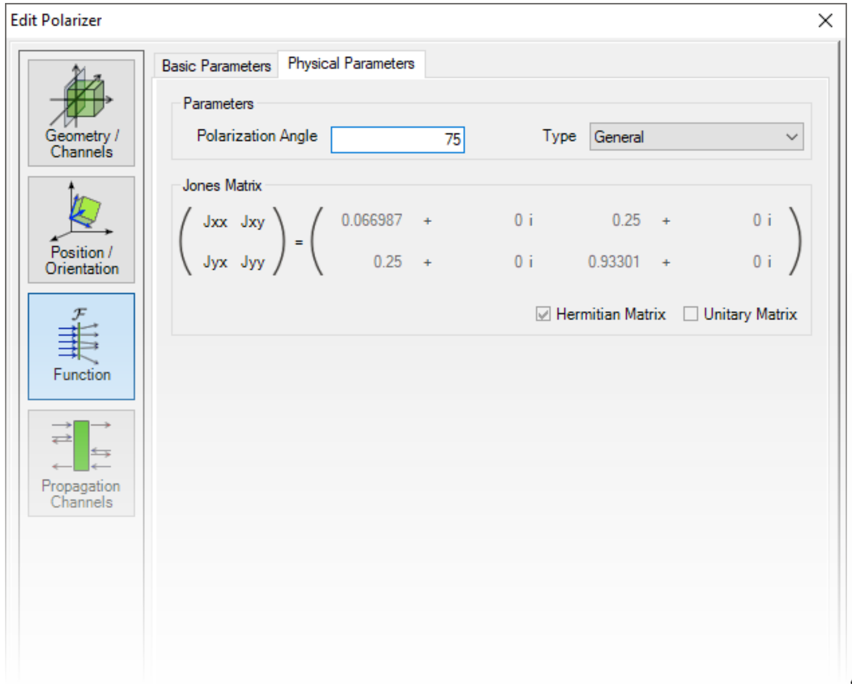
Interference Pattern



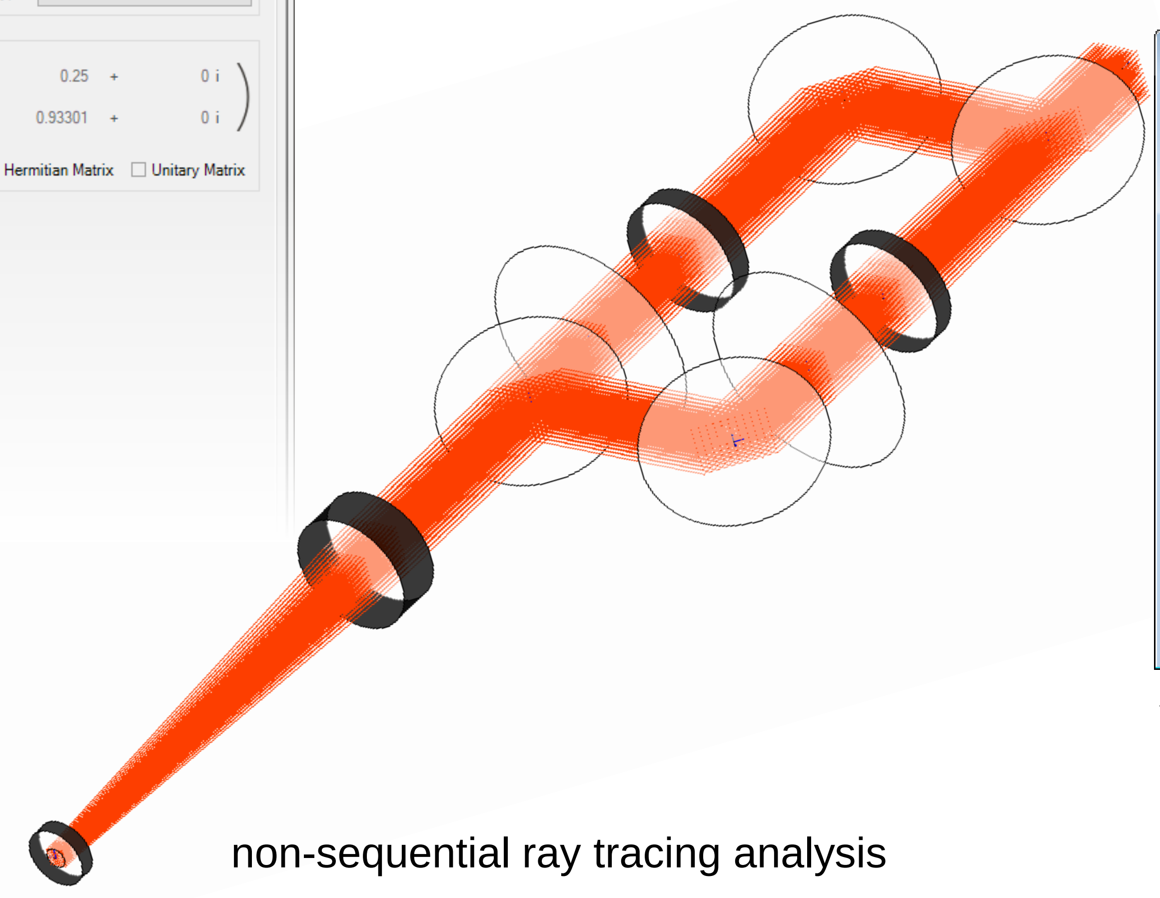
Interference information is encoded in polarization state.



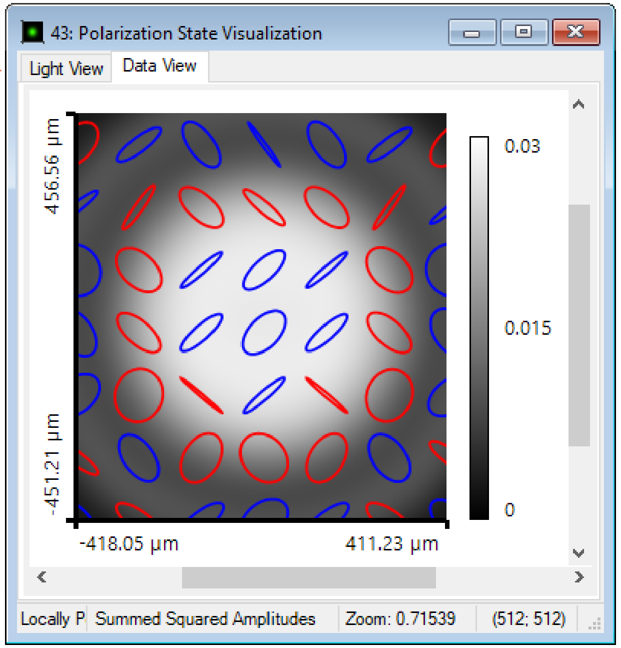
Peek into VirtualLab Fusion



setting of polarization angle



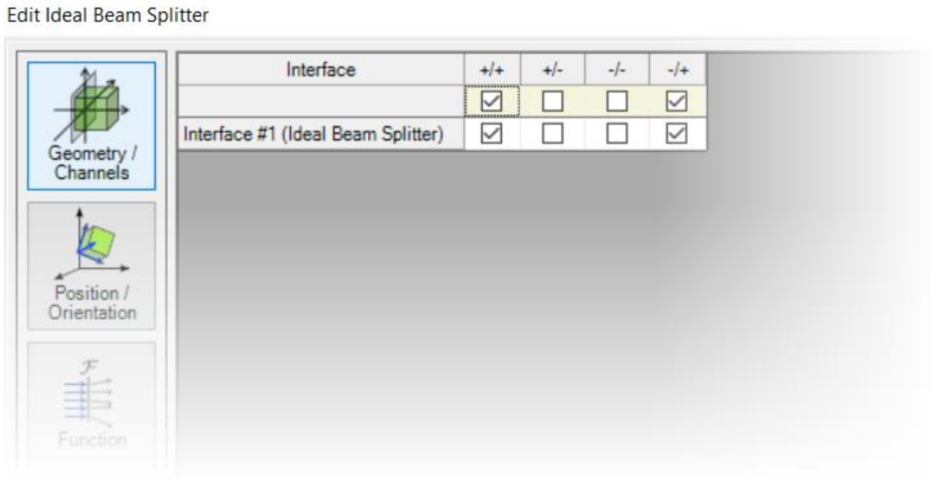
non-sequential ray tracing analysis



visualization of polarization state

Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Set the position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]
- Configure the surface channels of components
  - Channel Configuration for Surfaces and Grating Regions [Use Case]



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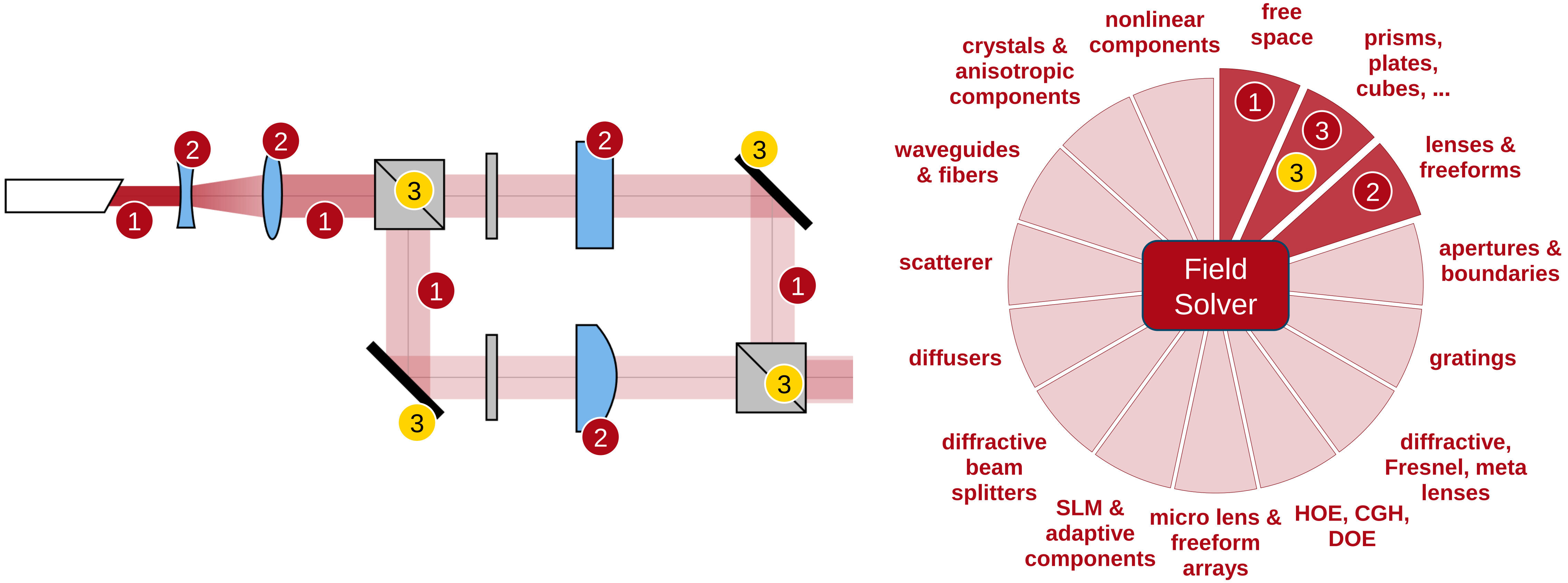
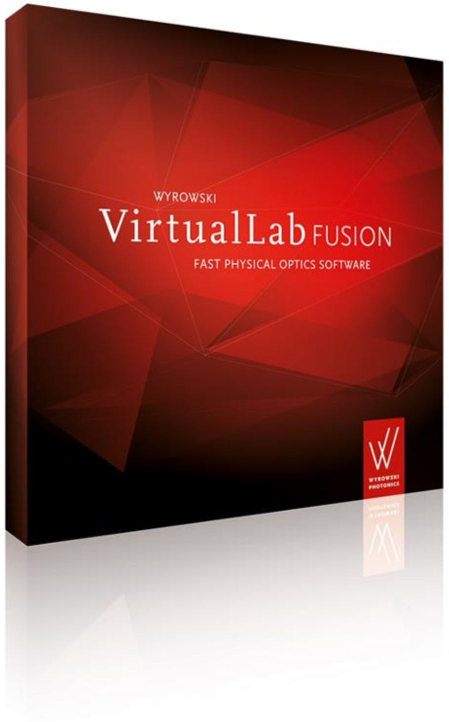


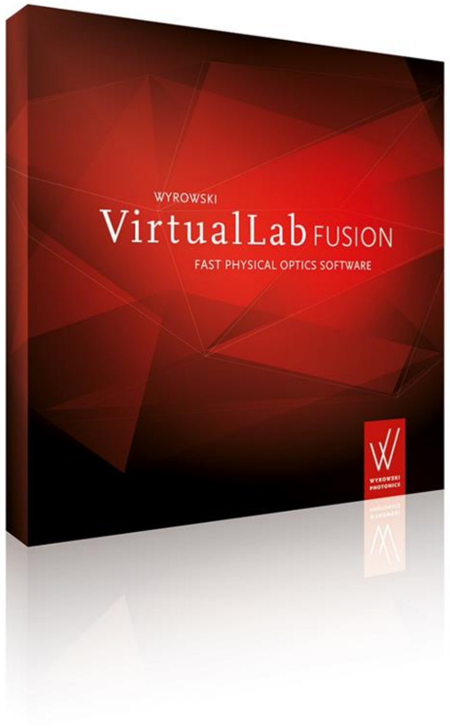
\# idealized component

Links of Interest

- LightTrans International website: www.lighttrans.com/
- VirtualLab Fusion product information: www.lighttrans.com/products-services/virtuallab-fusion.html
- Subscribe to our newsletters: www.lighttrans.com/newsletter.html
- Connect with us on LinkedIn: www.linkedin.com/company/lighttrans/
- Follow us on Twitter: twitter.com/LightTrans
- Request your trial version: www.lighttrans.com/resources/trial-software.html
- Our distributors around the world: www.lighttrans.com/company/distributors.html
- Email us your questions: info@lighttrans.com



List of Use Cases



1. Modeling of Etalon with Planar or Curved Surfaces: www.lighttrans.com/use-cases/application-use-cases/modeling-of-etalon-with-planar-or-curved-surfaces.html

2. Examination of Sodium D Lines with Fabry-Pérot Etalon: www.lighttrans.com/use-cases/application-use-cases/examination-of-sodium-d-lines-with-etalon.html

3. Fizeau Interferometer for Optical Testing: www.lighttrans.com/use-cases/application-use-cases/fizeau-interferometer-for-optical-testing.html

4. Collimation Testing with Shearing Interferometry: www.lighttrans.com/use-cases/application-use-cases/collimation-testing-with-shearing-interferometry.html

5. Laser-Based Michelson Interferometer: www.lighttrans.com/use-cases/application-use-cases/laser-based-michelson-interferometer-and-interference-fringe-exploration.html

6. White-Light Michelson Interferometer: www.lighttrans.com/use-cases/application-use-cases/white-light-michelson-interferometer.html

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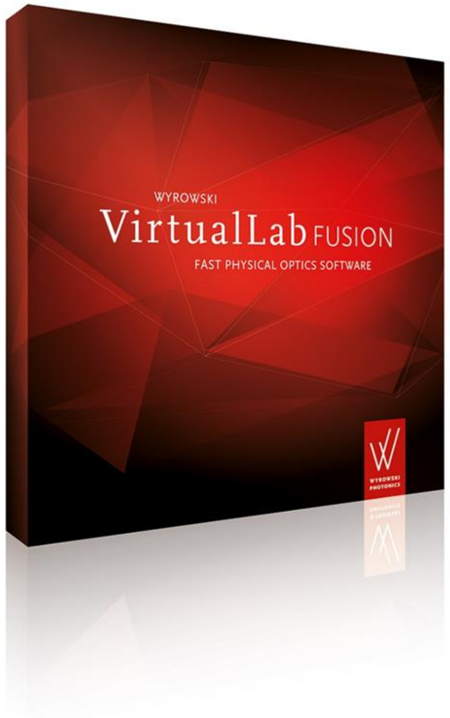

7. Coherence Measurement Using Michelson Interferometer and Fourier Transform Spectroscopy: www.lighttrans.com/use-cases/application-use-cases/coherence-measurement-using-michelson-interferometer-and-fourier-transform-spectroscopy.html

8. Full-Field Optical Coherence Scanning Interferometry: www.lighttrans.com/use-cases/application-use-cases/full-field-optical-coherence-scanning-interferometry.html

9. Mach-Zehnder Interferometer: www.lighttrans.com/use-cases/application-use-cases/mach-zehnder-interferometer.html

10. Observation of Gouy Phase Shift in a Mach-Zehnder Interferometer: www.lighttrans.com/use-cases/application-use-cases/observation-of-gouy-phase-shift-in-a-mach-zehnder-interferometer.html

11. Generation of Spatially Varying Polarization by Interference with Polarized Light: www.lighttrans.com/use-cases/application-use-cases/generation-of-spatially-varying-polarization-by-interference-with-polarized-light.html