SPIE Photonics West 2019

Physical-Optics Simulation of Optical Interferometry Systems

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[3] Wyrowski Photonics GmbH, Jena, Germany

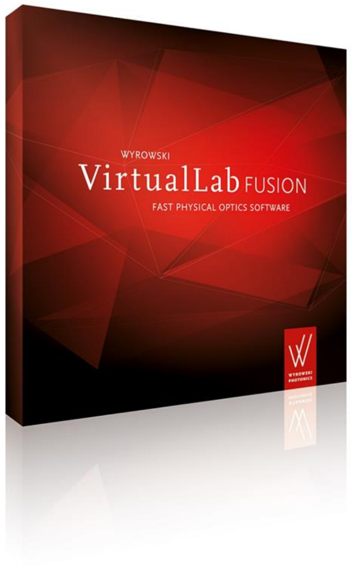
Jena, Germany

University of Jena

Applied Computational Optics Group R&D in optical modeling and design with emphasis on physical optics

Wyrowski Photonics

Wyrowski Photonics
Development of fast physical optics software VirtualLab Fusion

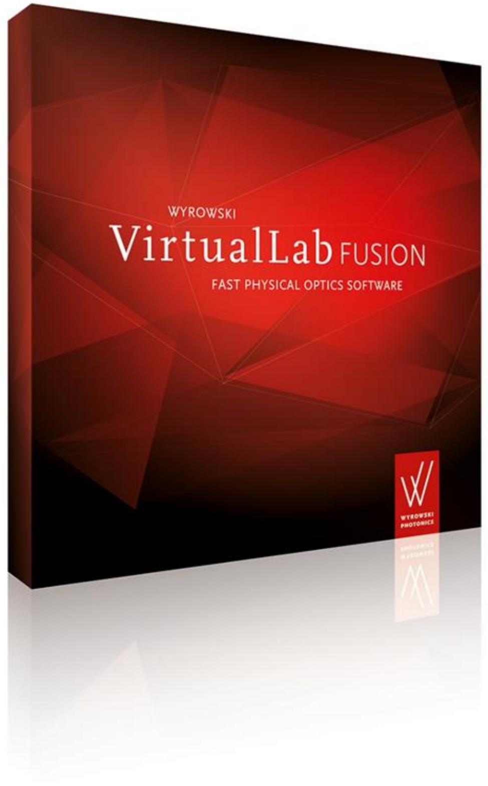


LightTrans International

LightTrans
- Distribution of VirtualLab Fusion, together with distributors worldwide
- Technical support, seminars, and trainings
- Engineering projects

Optical Design Software and Services

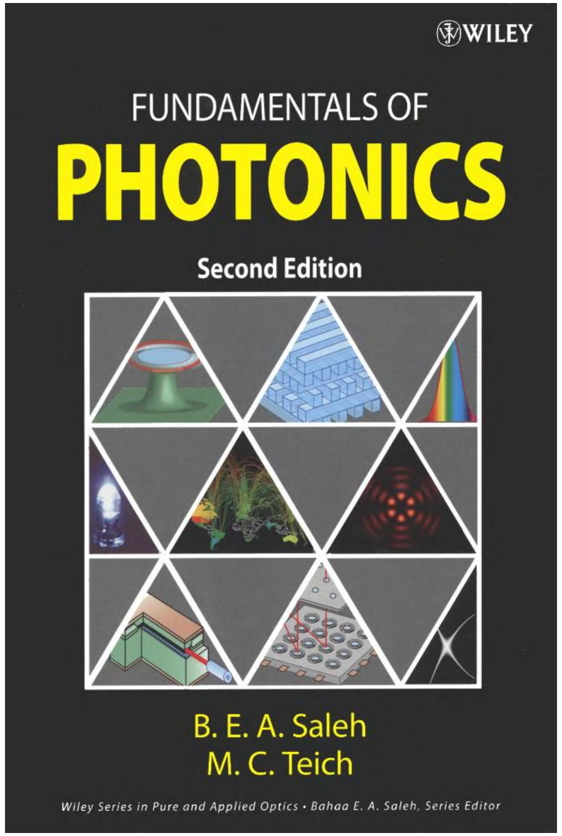
Hall EF (North)
booth 4545-46
German Pavilion

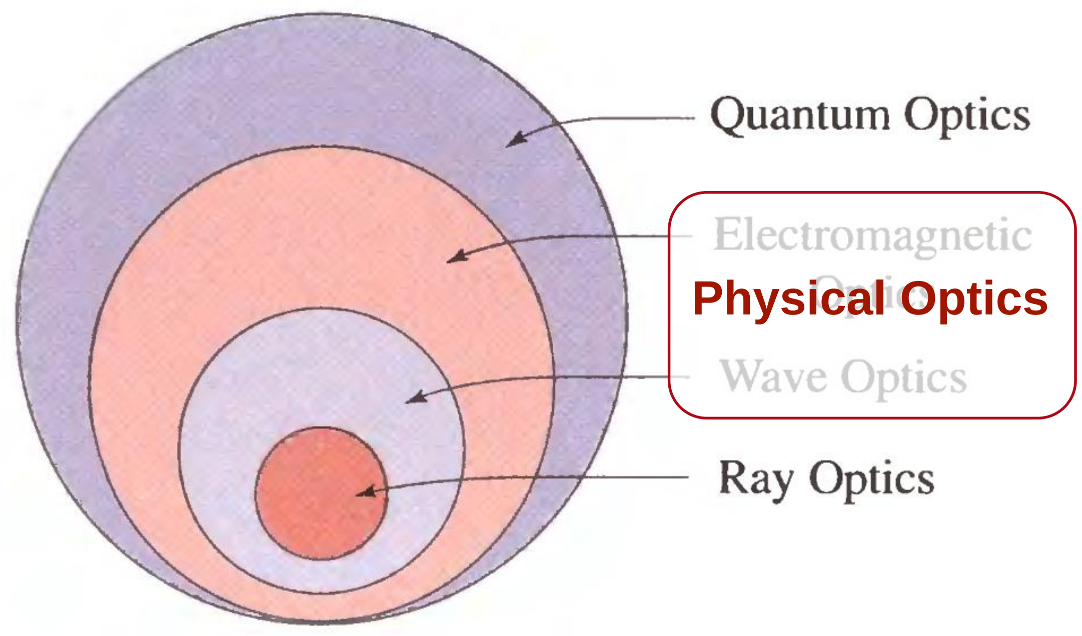


Make physical optics the platform in optical modeling

Paradigm Shift in Optical Modeling Needed

- **Status quo:** Ray optics is currently used as the platform in optical modeling. Physical optics “patches” are added where most needed.





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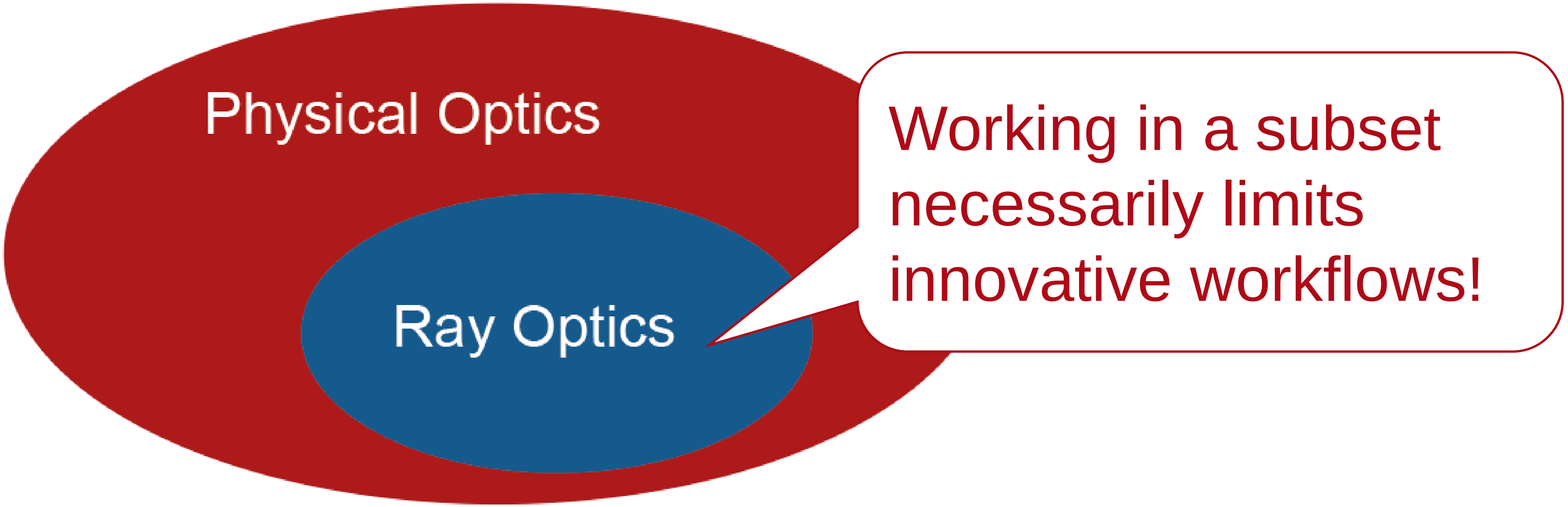

Make Physical Optics the Platform in Optical Modeling

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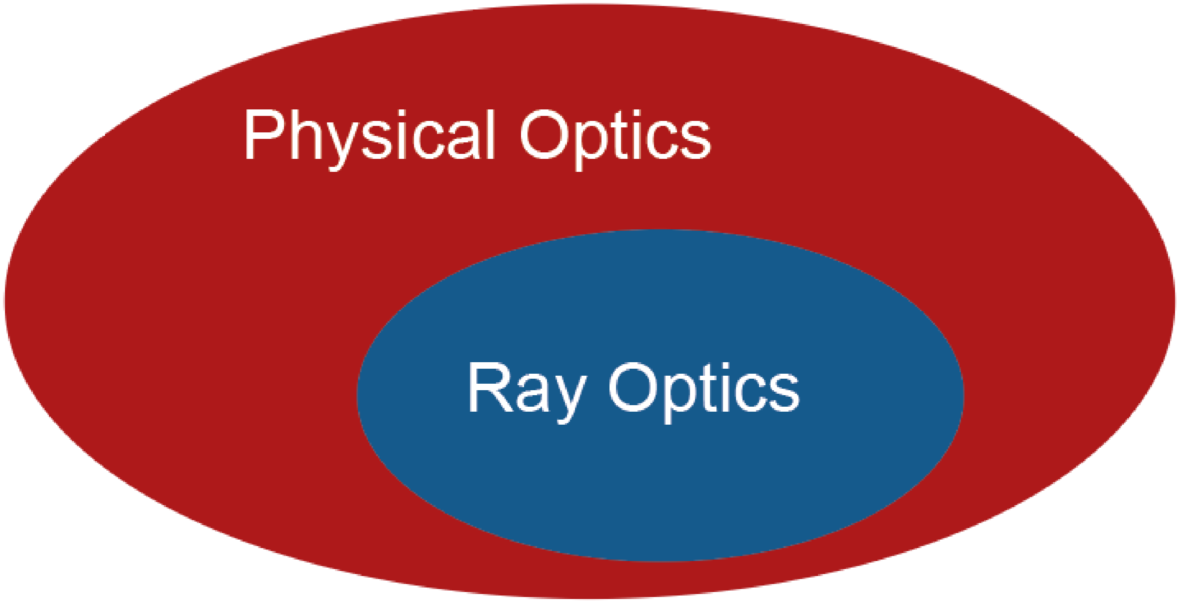
- **Our proposal:** To make physical optics the platform in optical modeling, with ray tracing solidly embedded within.



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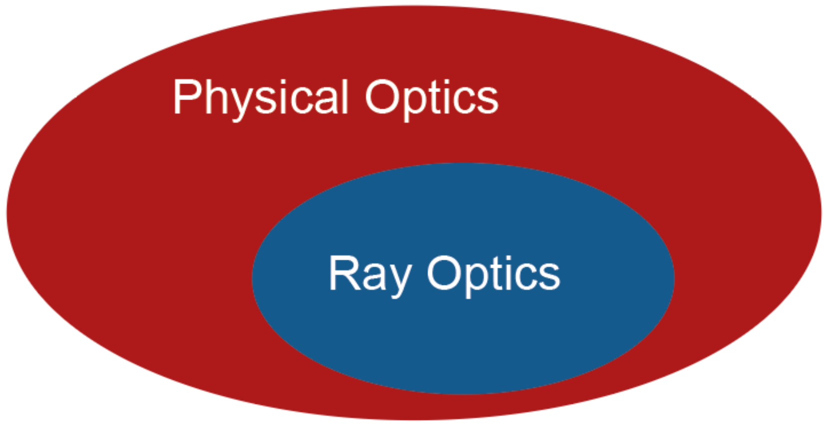
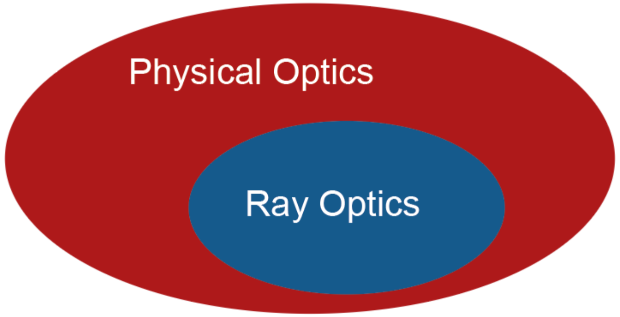
For this paradigm shift physical optics must be **fast** in practice!



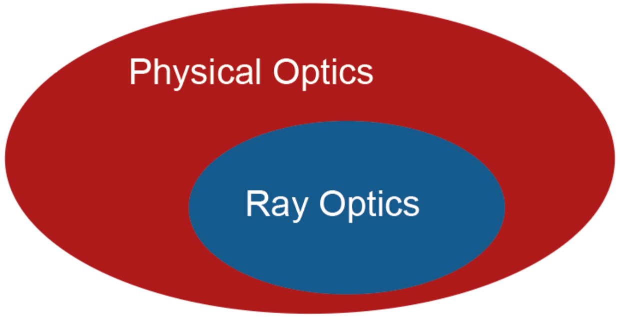
Fast Electromagnetic Modeling Required

- Physical optics modeling must be based on **solutions of Maxwell’s equations**.



Fast Electromagnetic Modeling Required

- Physical optics modeling must be based on **electromagnetic field solvers**.



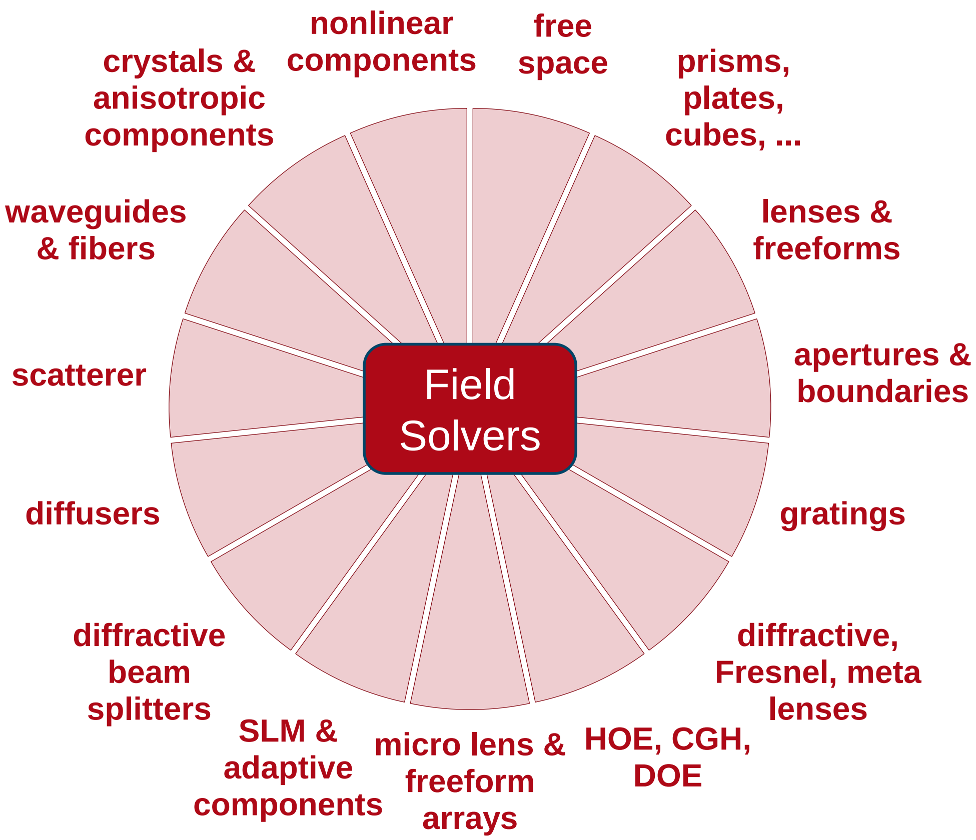
How to realize a fast electromagnetic modeling in optics?

Field tracing enables fast physical optics

Field Tracing Enables Fast Physical Optics

Field Tracing comprises:

- Application of different electromagnetic field solvers in different regions of one system.
- Interconnection of any type of general and specialized field solver.



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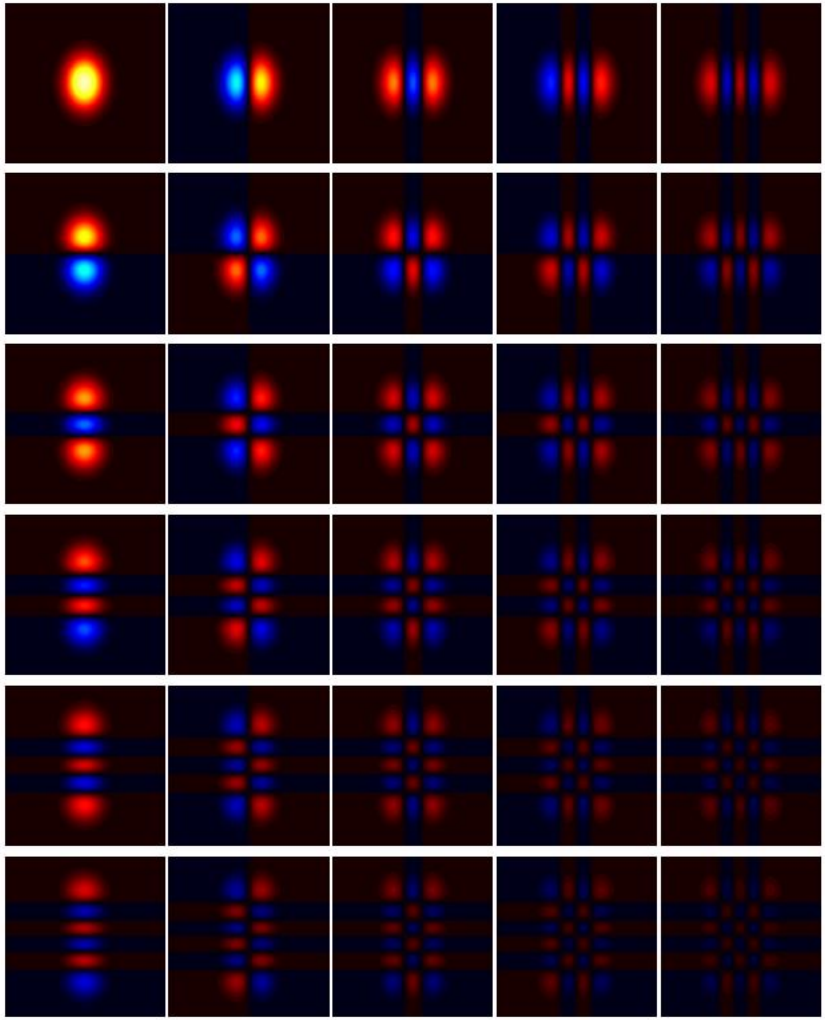
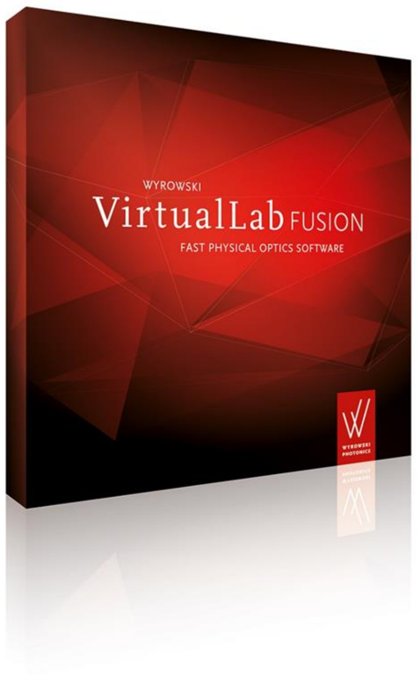
- … and many more techniques



Physical Optics Enables Theoretically Solid Inclusion of ….

- Investigation of fields in focal regions
- Diffraction at apertures and of light beams
- Vectorial effects and polarization; no paraxial assumption
- Coherence phenomena and source models
- Ultrashort pulse modeling
- Interference and speckles
- Diffraction at gratings and diffractive optical elements
- Scattering effects
- Crystal and metamaterial modeling
- Nano- and microoptics
- Special effects like Gouy phase shift and Goos Hänchen shift
- Nonlinear optics



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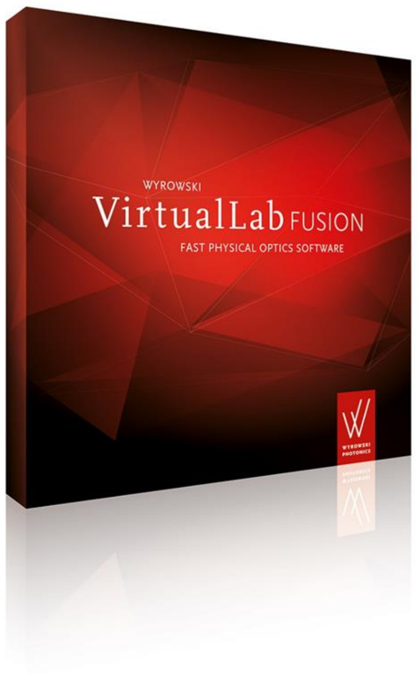

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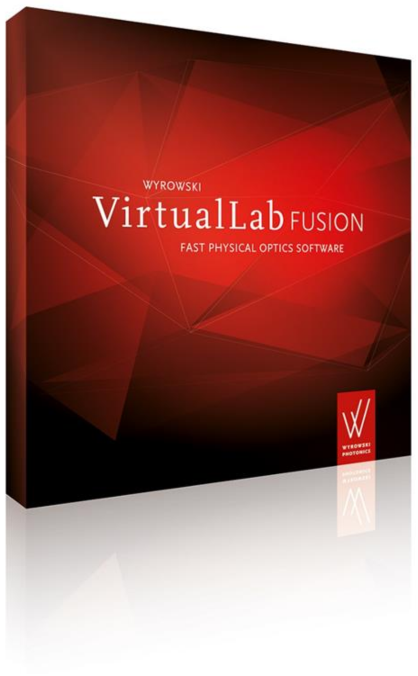

Why Physical Optics?

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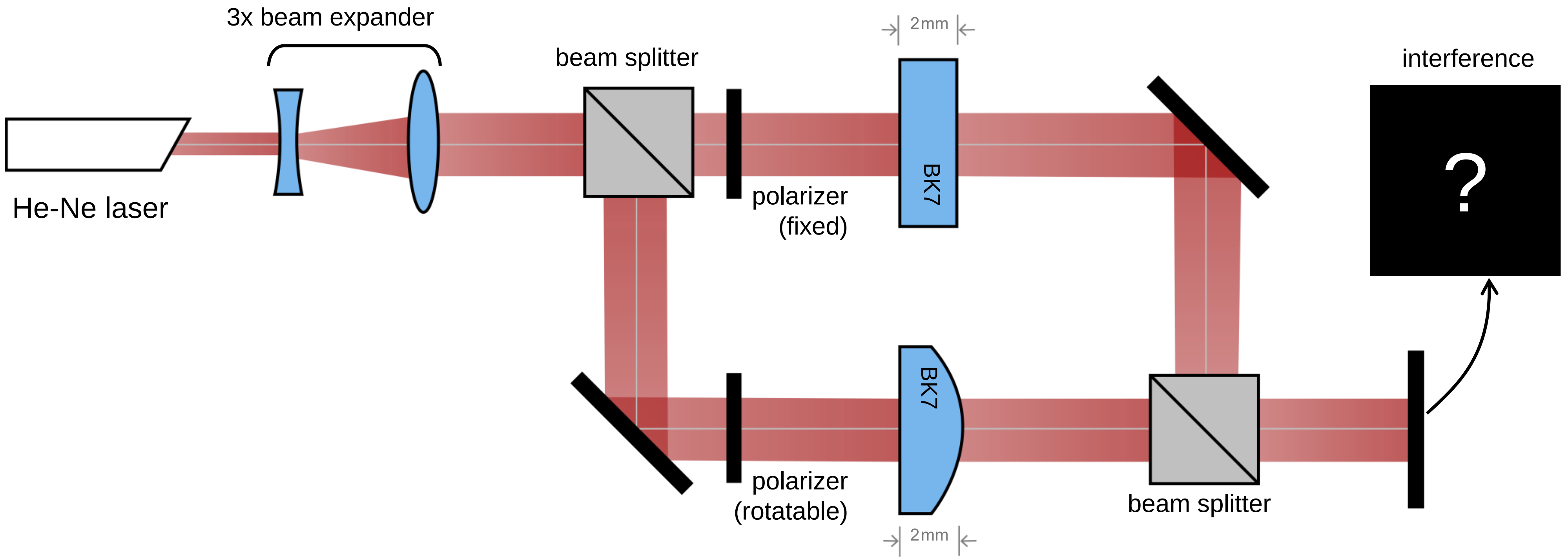

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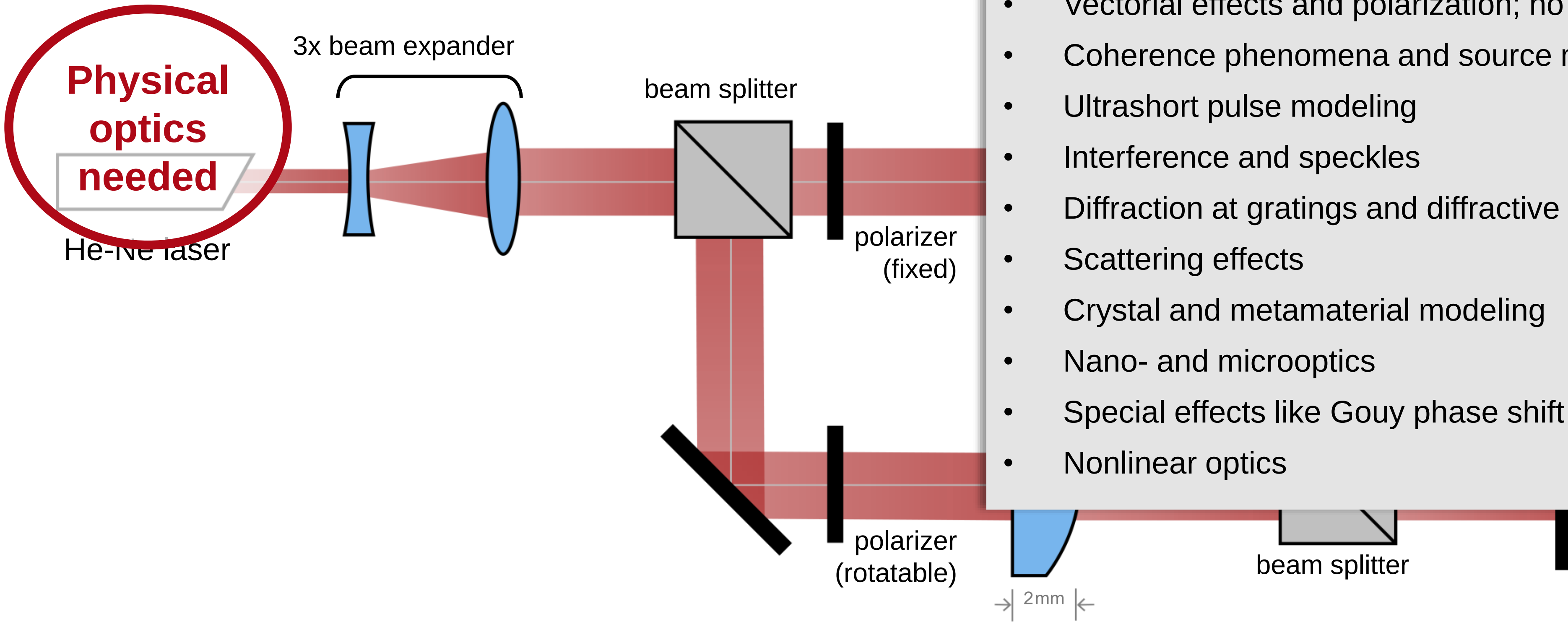

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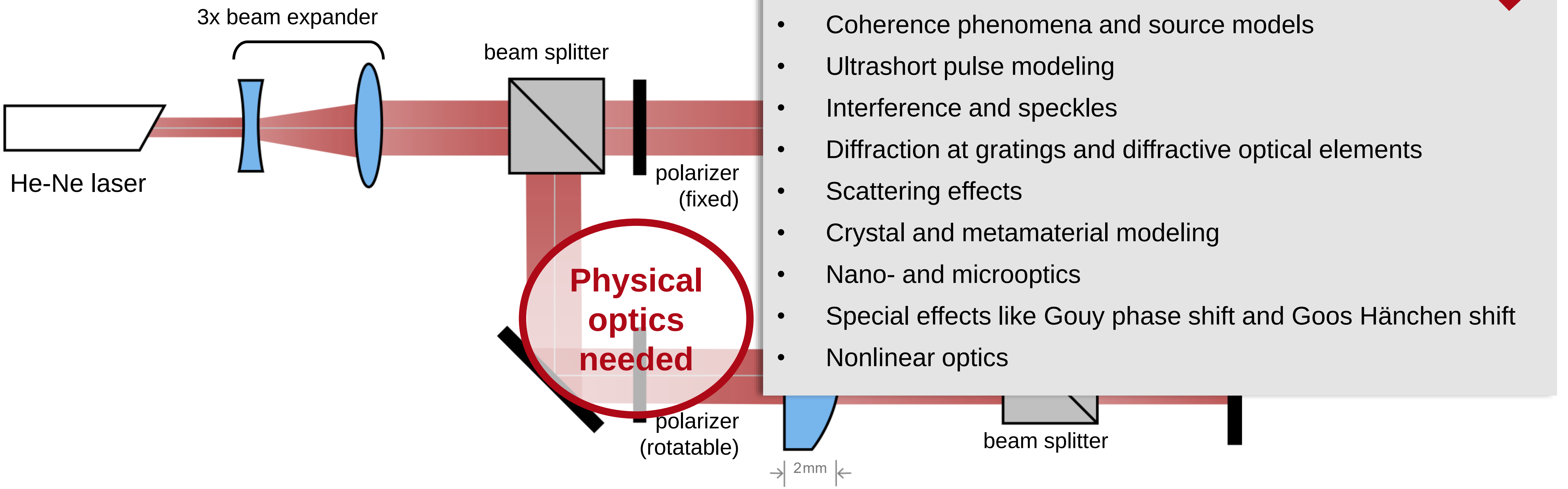

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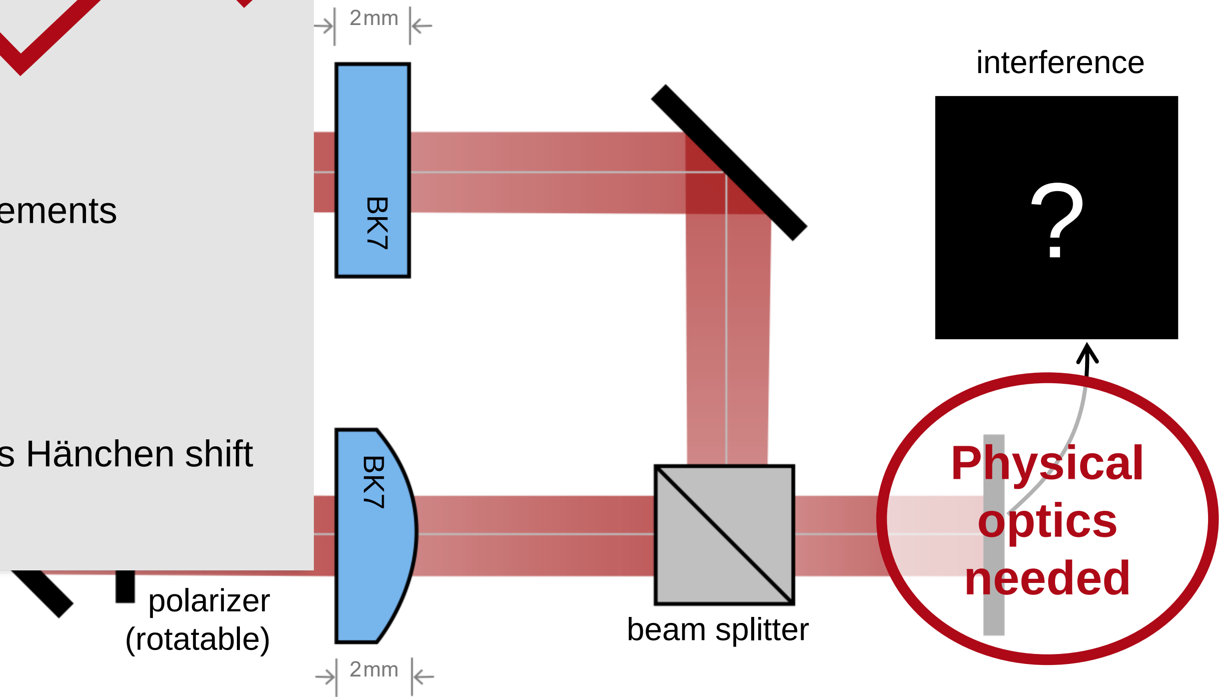
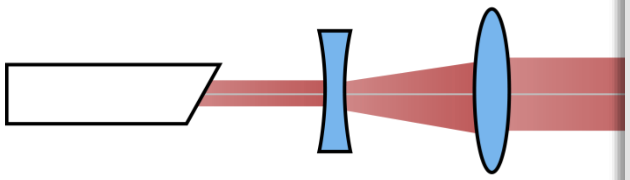


Why Physical Optics?

- Modern interferometers may use …
  - … advanced light sources
  - … innovative optical components
  - … different types of detectors
  - … complex light paths



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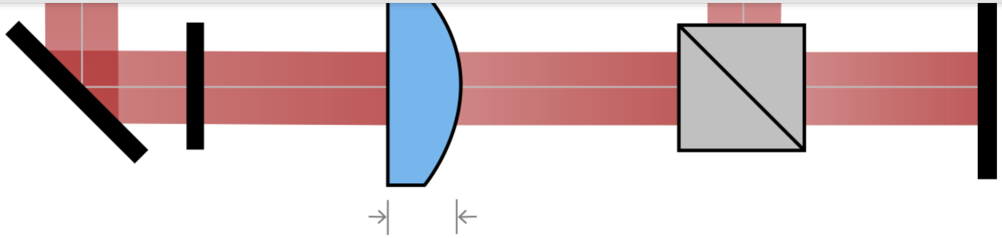

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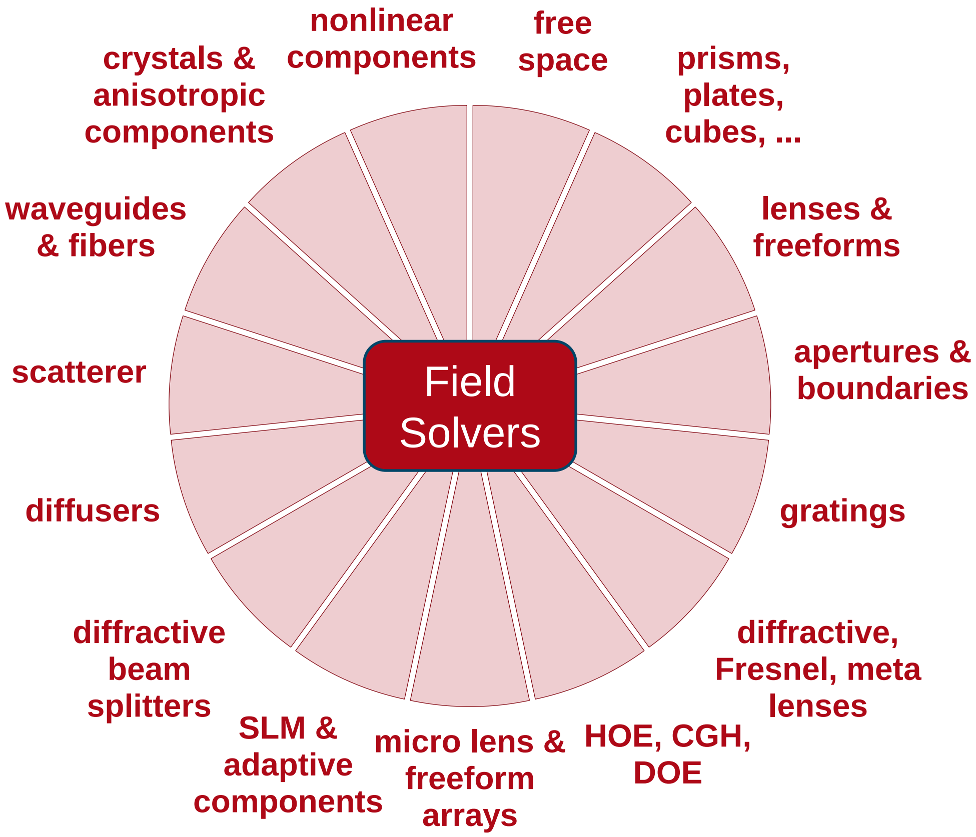
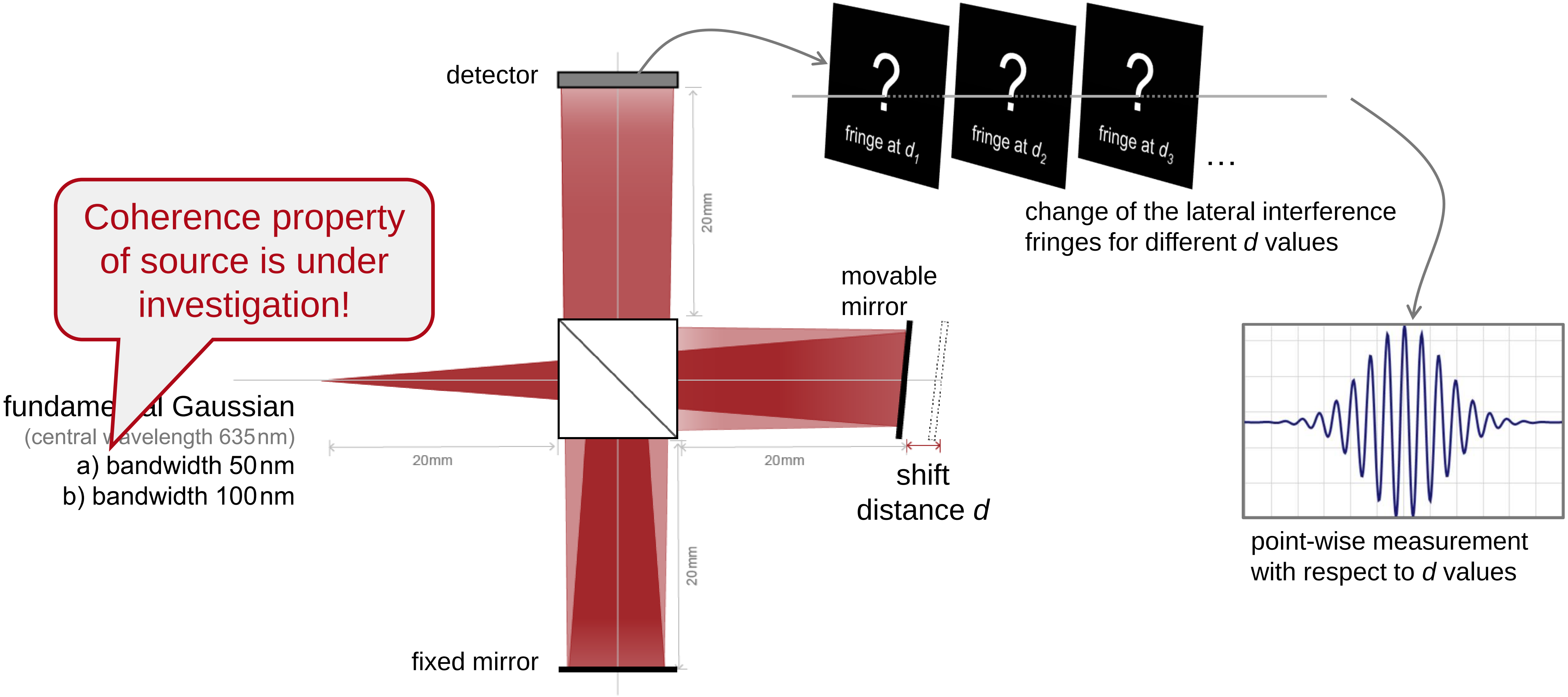
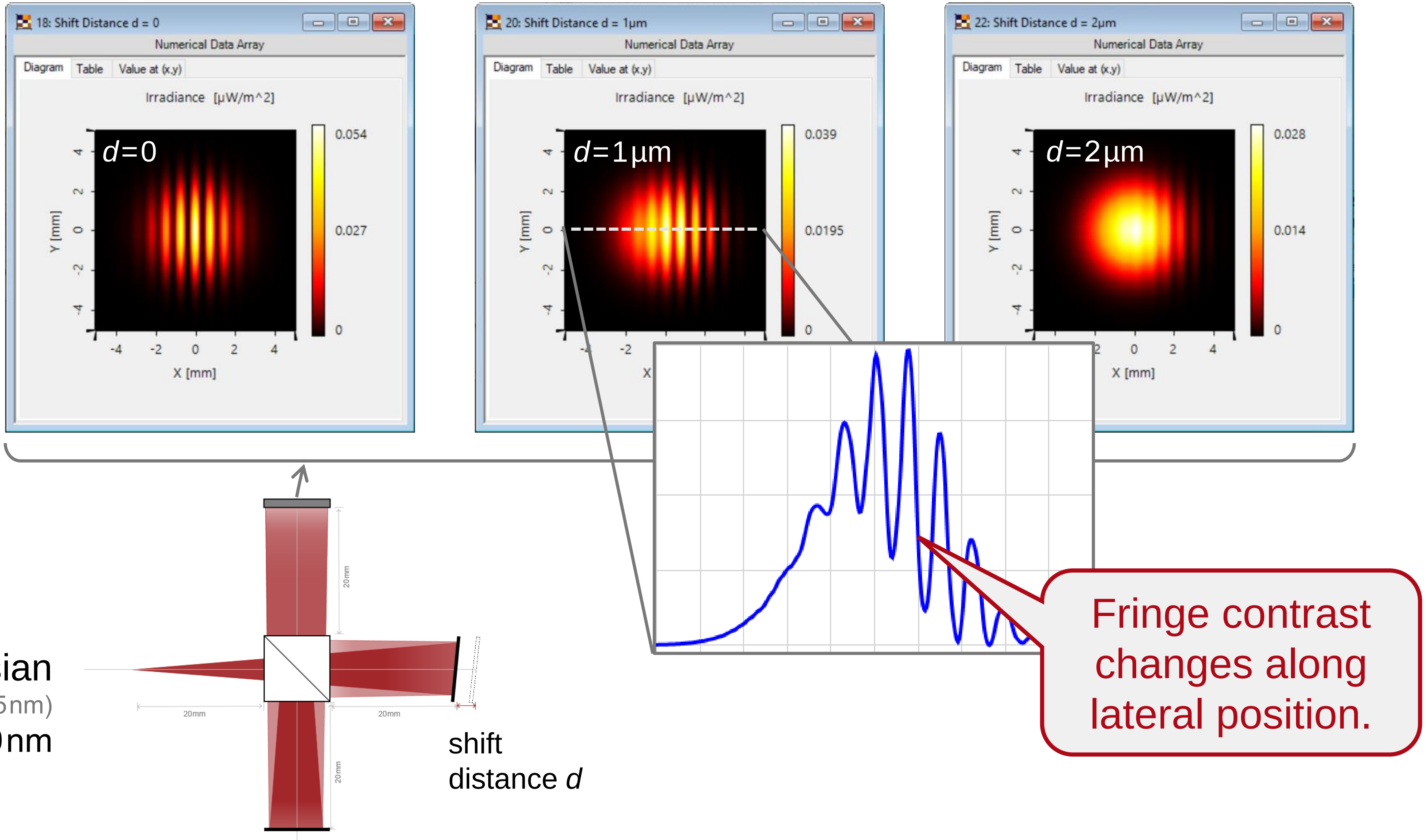


Coherence Measurement Using Michelson Interferometer and Fourier Transform Spectroscopy

Modeling Task

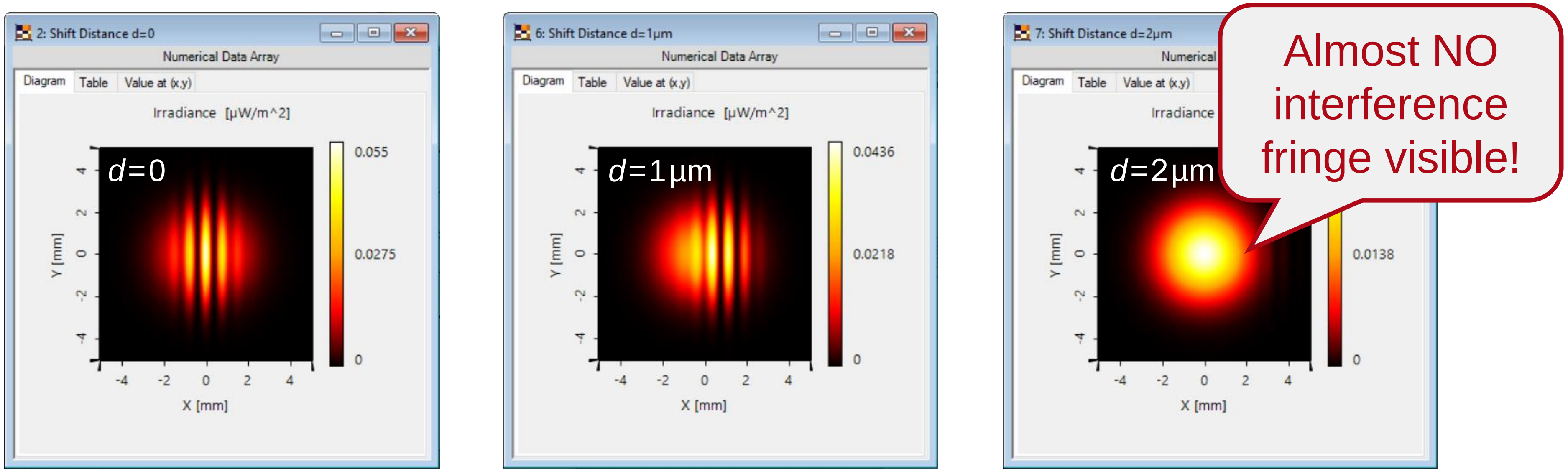


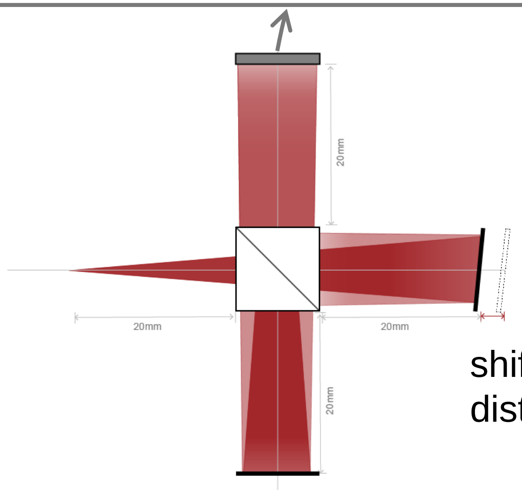
Lateral Interference Fringes – 50 nm Bandwidth



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

Lateral Interference Fringes – 100 nm Bandwidth



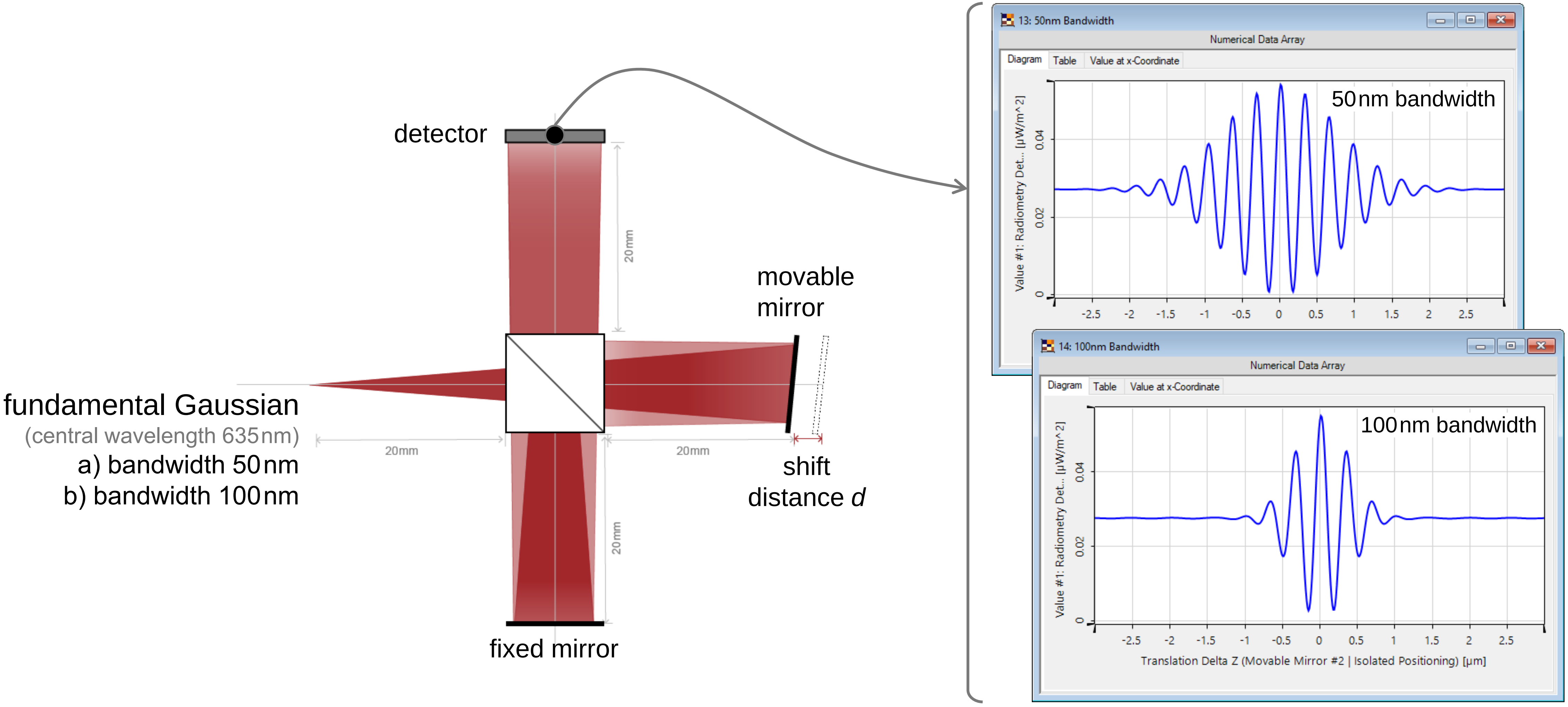


fundamental Gaussian
(central wavelength 635 nm)
b) bandwidth: 100 nm

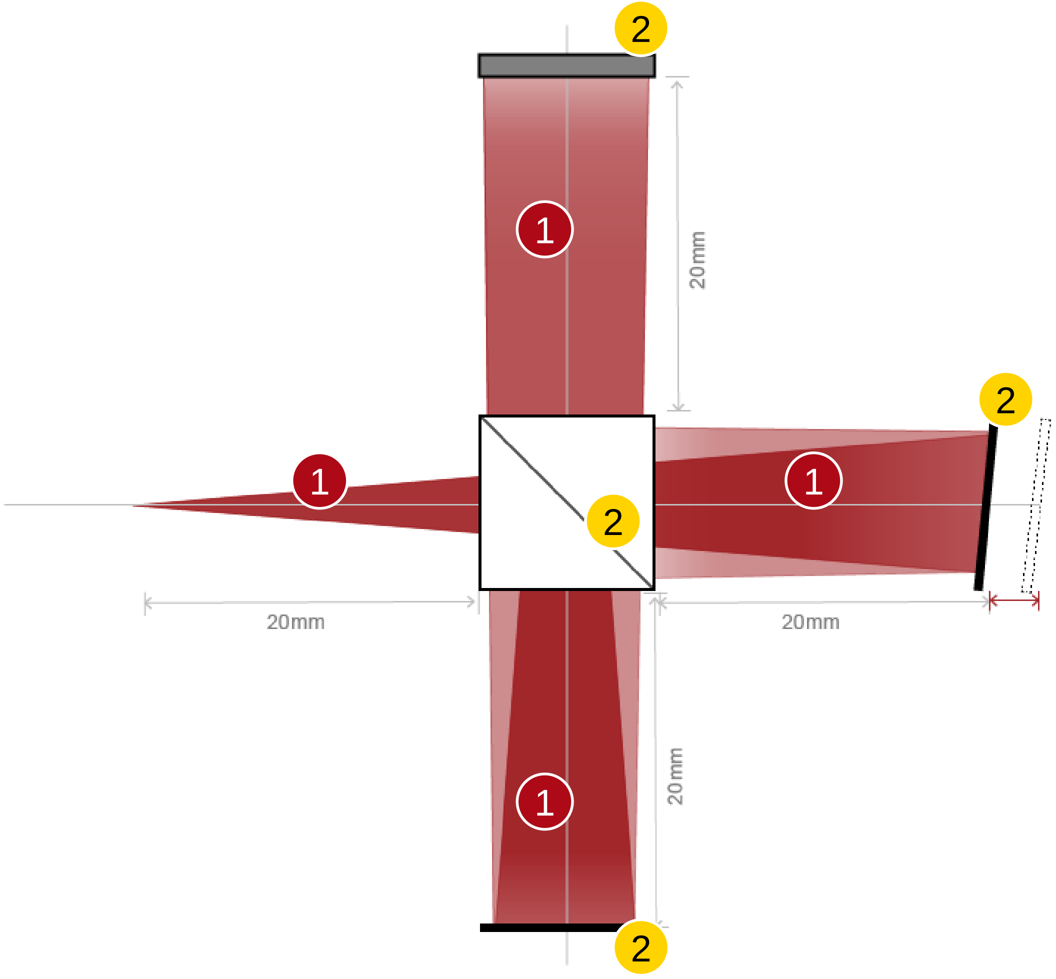
shift distance *d*

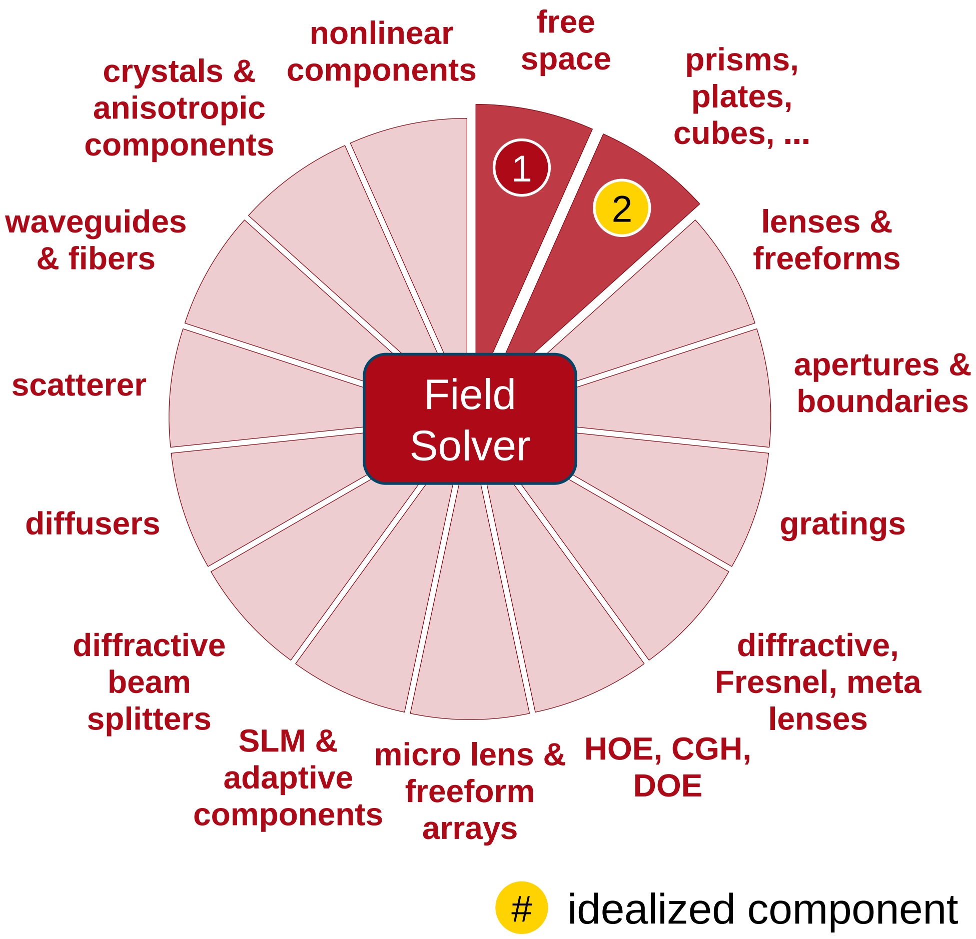
Broader spectral bandwidth leads to shorter coherent length; and therefore the interference fringe starts to vanish sooner in comparison to the case with narrower bandwidth.

Pointwise Measurement



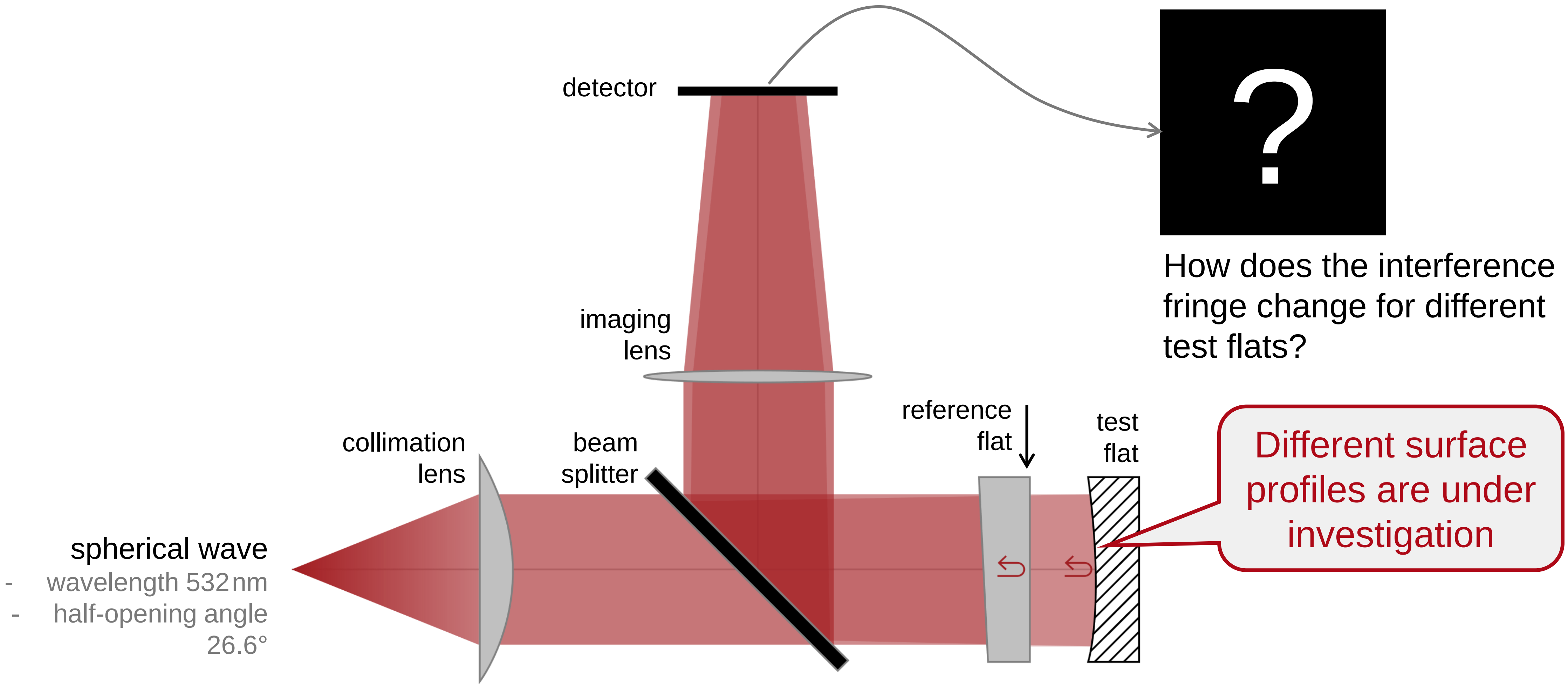
VirtualLab Fusion Technologies





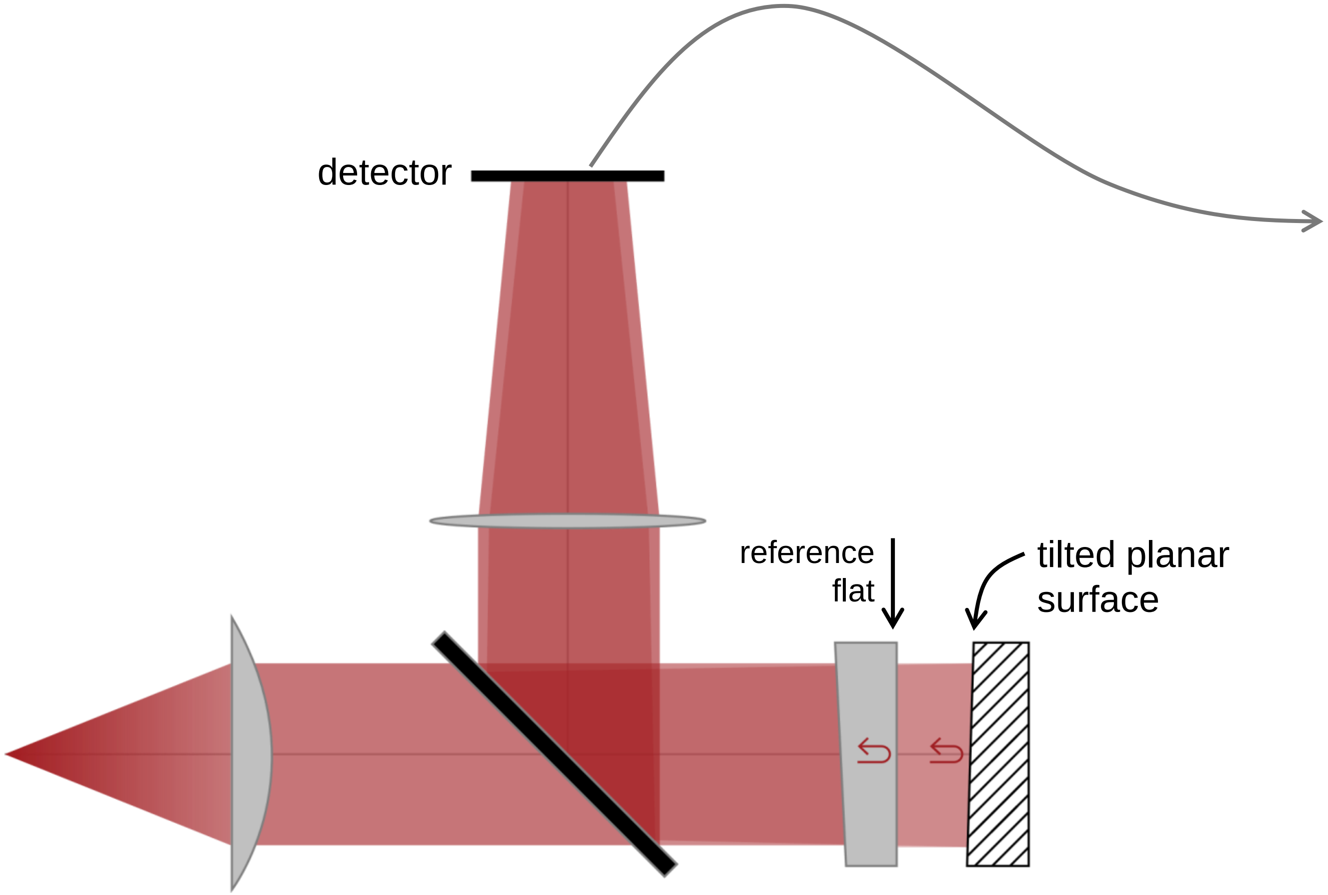
Fizeau Interferometer for Optical Testing

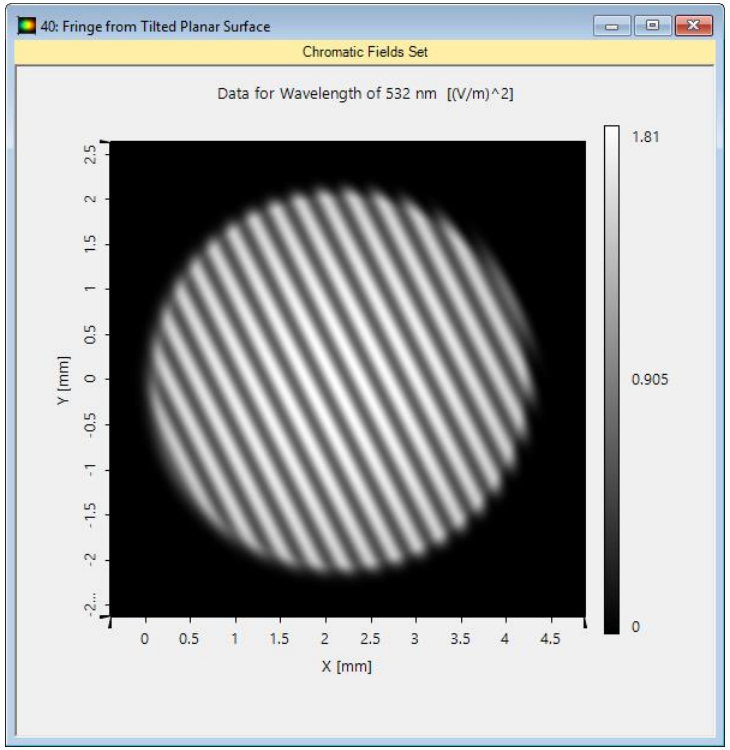
Modeling Task



How does the interference fringe change for different test flats?

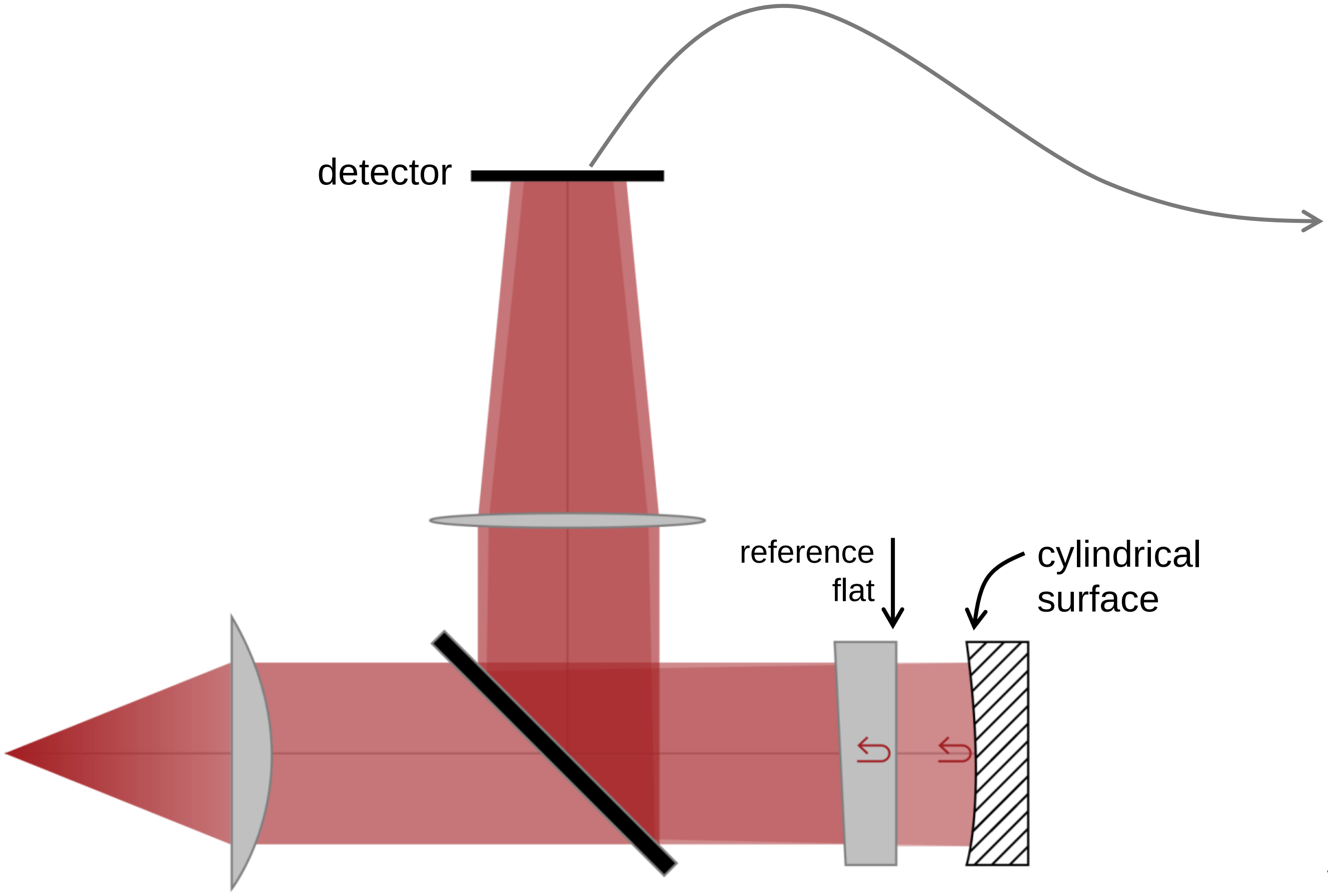
Tilted Planar Surface under Observation

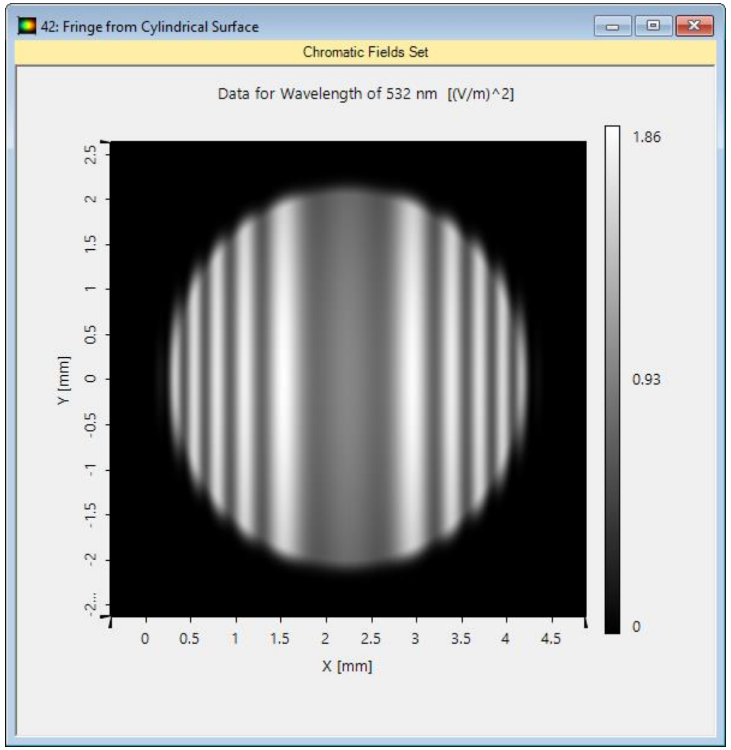




Reflection from the test planar surface remain as plane waves, but only with slightly different direction, and therefore leading to parallel striped fringes.

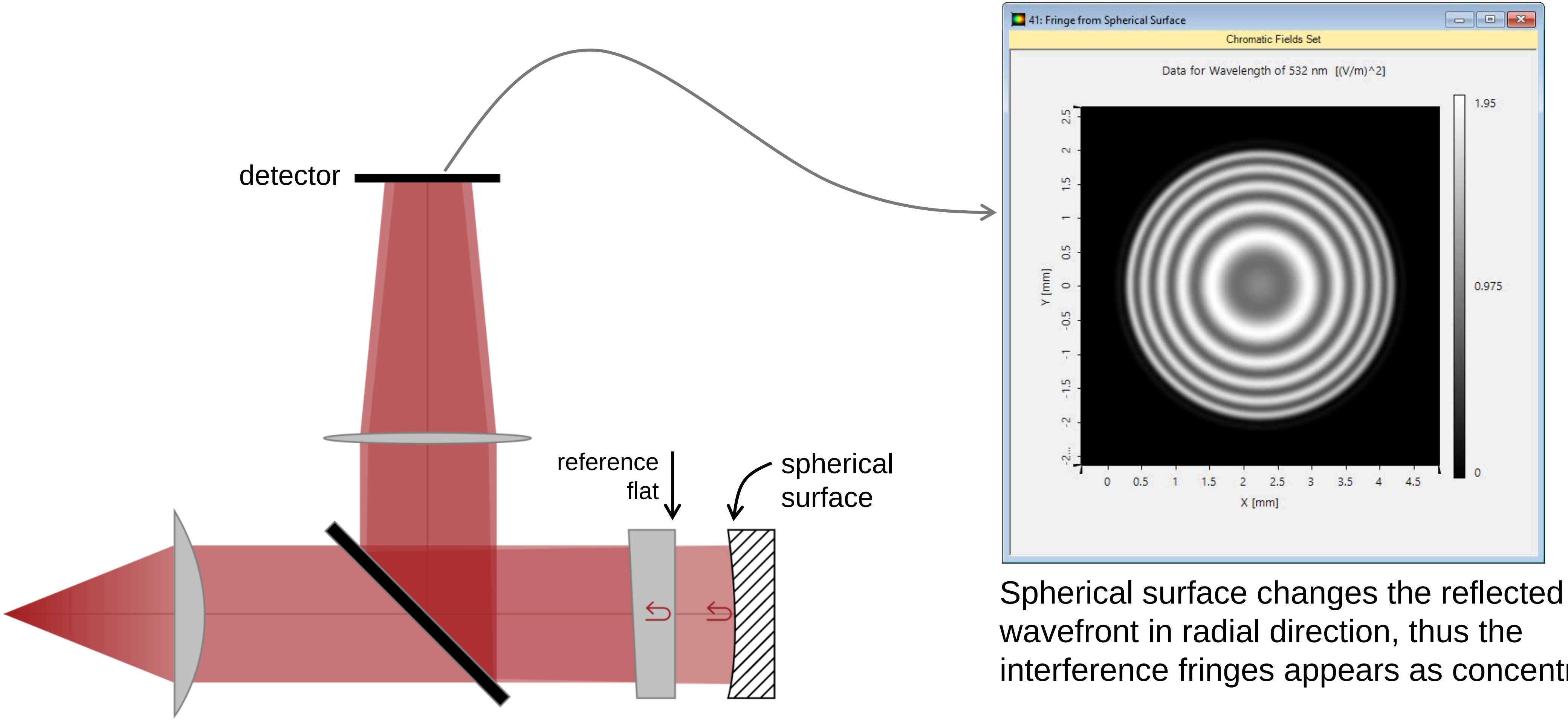
Cylindrical Surface under Observation





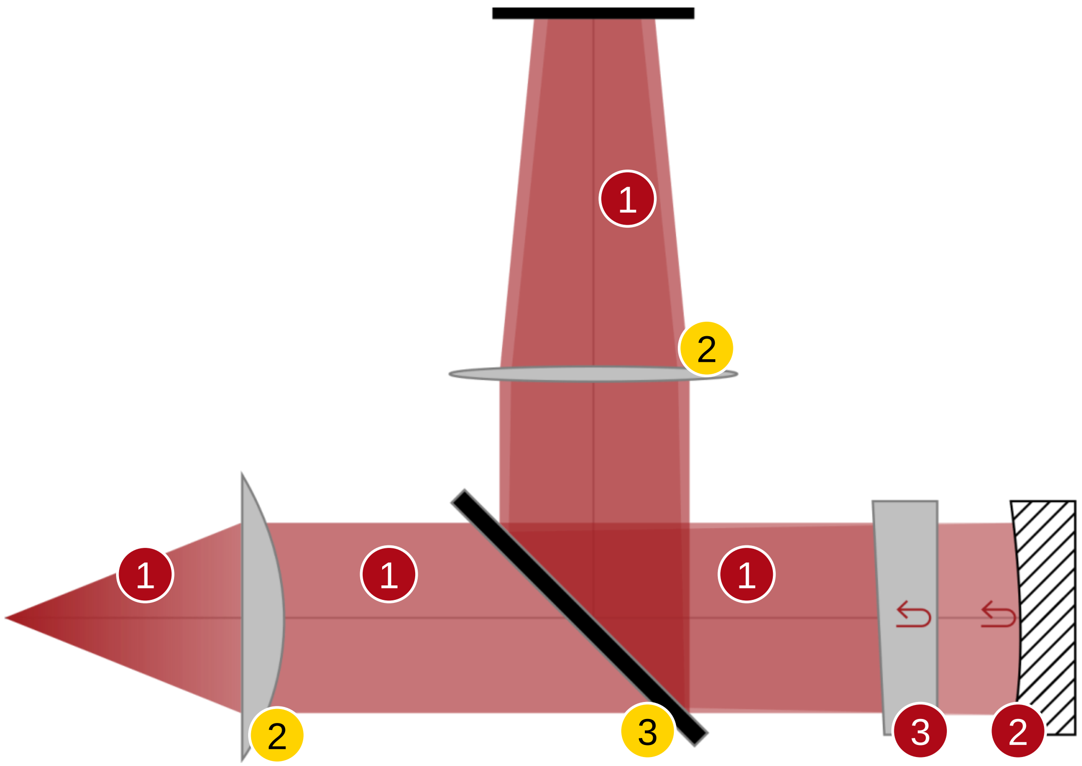
Reflected wavefront from the test cylindrical surface gets curved in one direction, therefore leading to parallel striped fringes but with varying pitch.

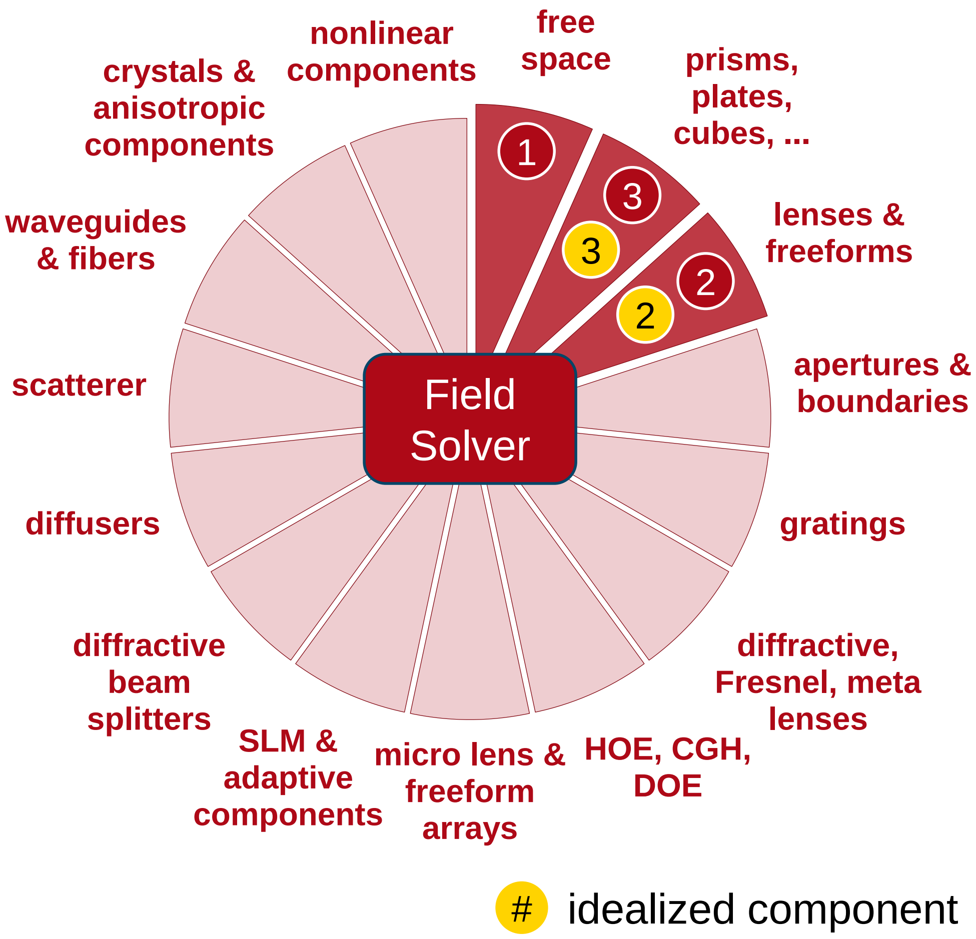
Spherical Surface under Observation



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

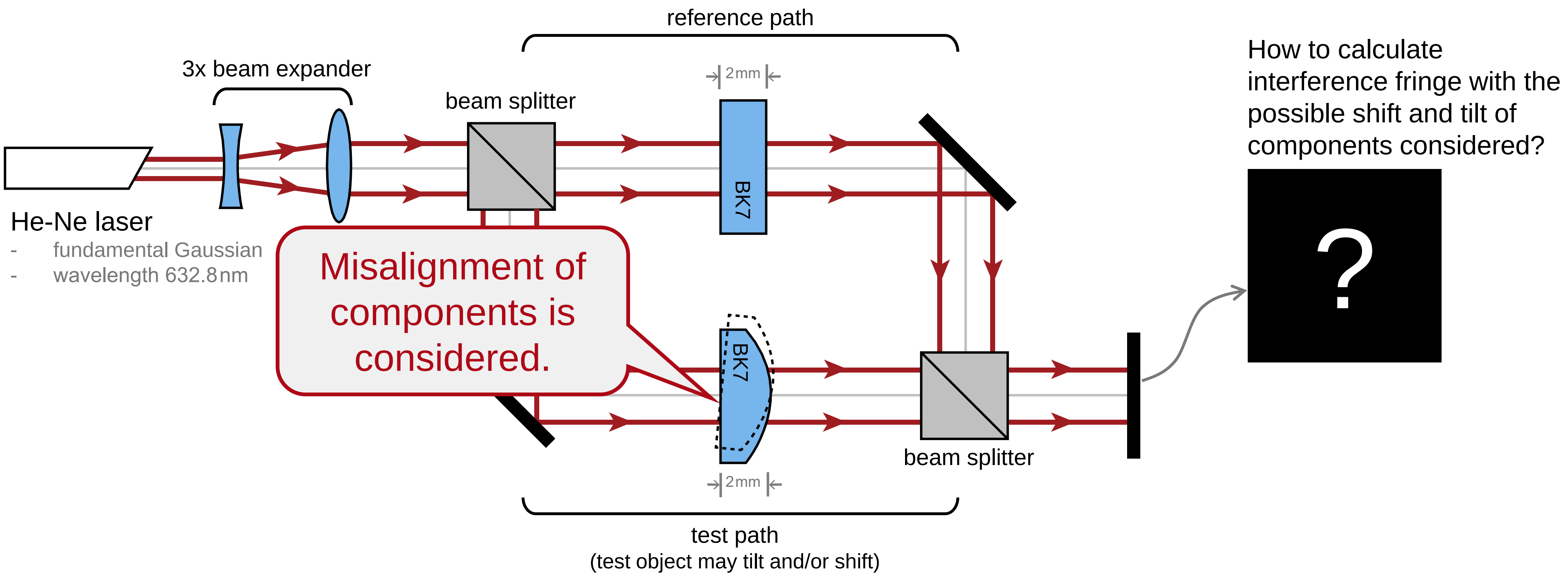
VirtualLab Fusion Technologies



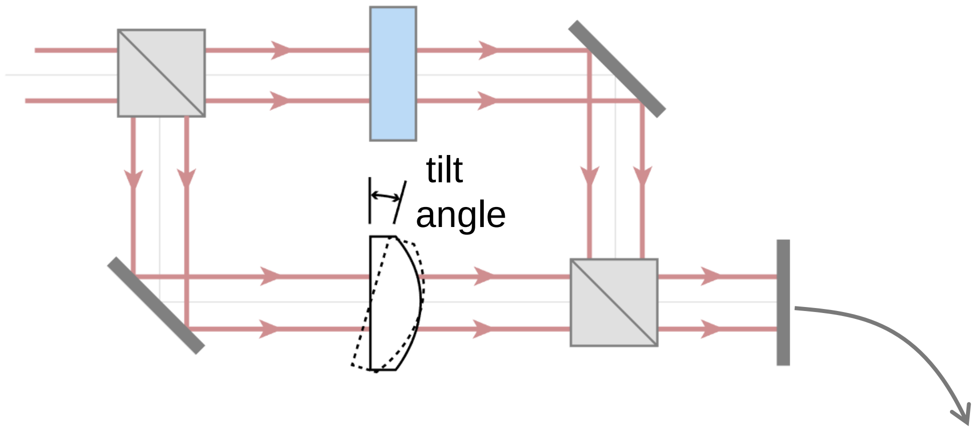


Mach-Zehnder Interferometer

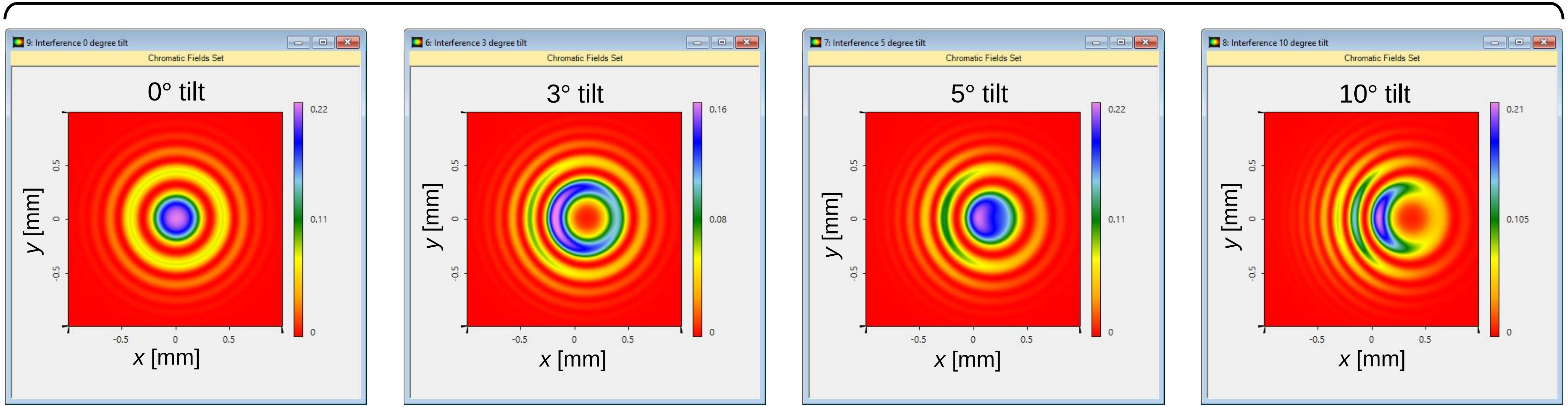
Modeling Task



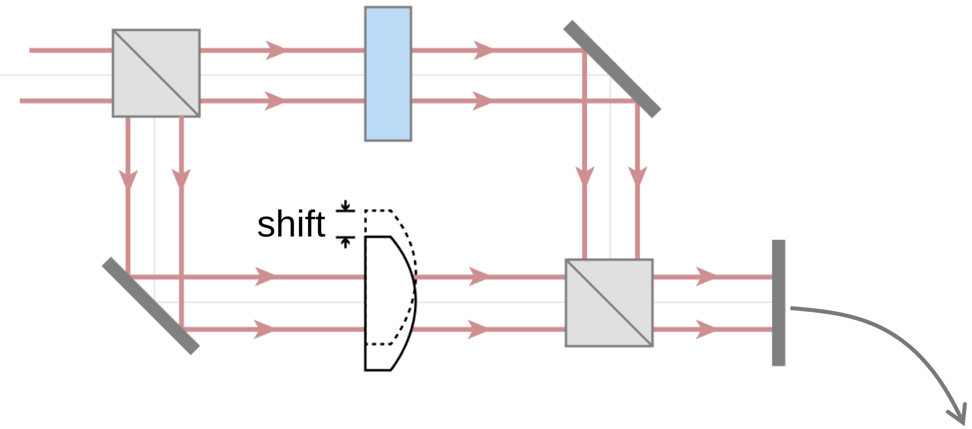
Interference Fringe Due to Component Tilt



Calculation of interference pattern including element tilt takes less than 2 seconds!



Interference Fringe Due to Component Shift



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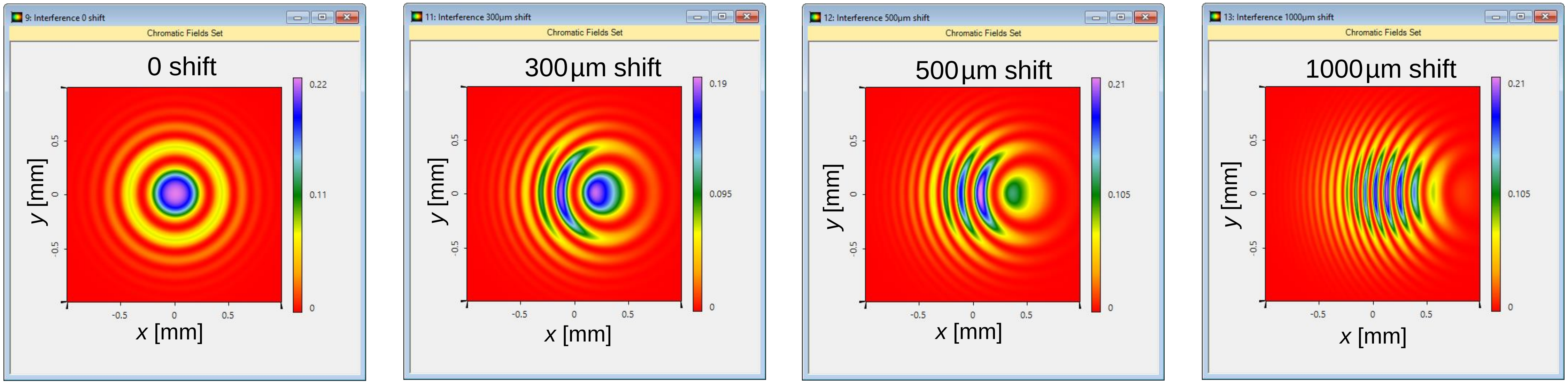
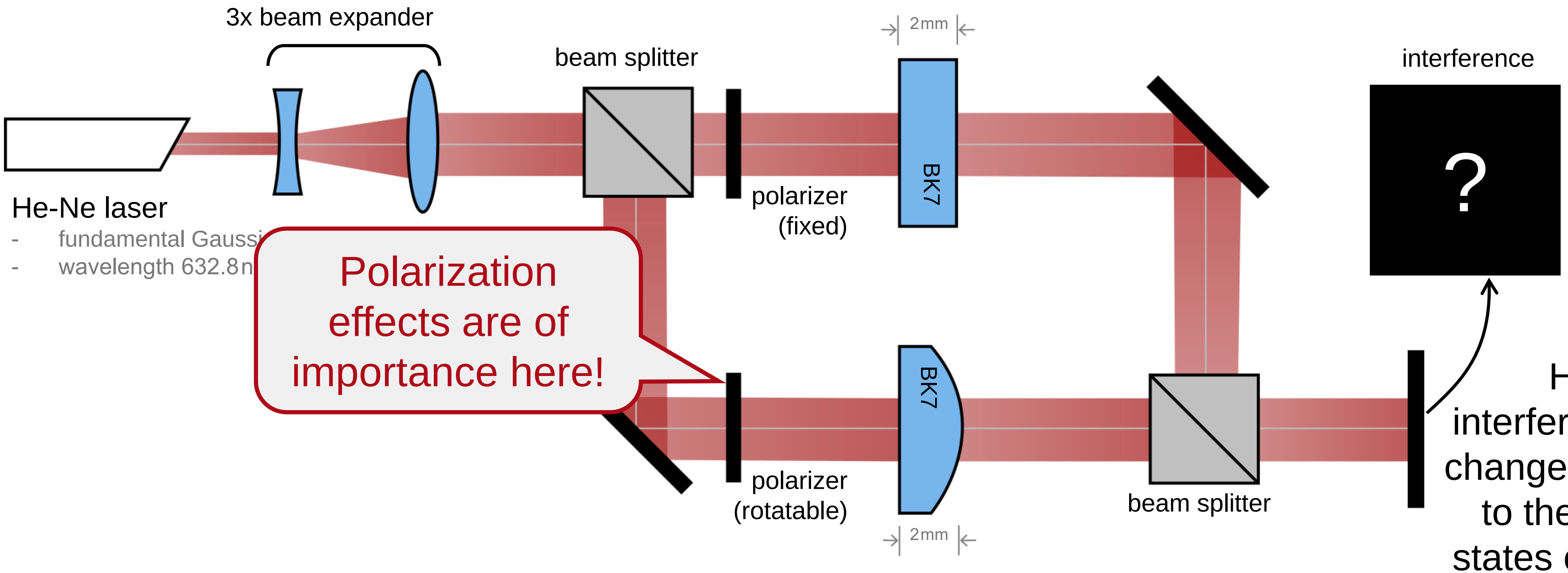


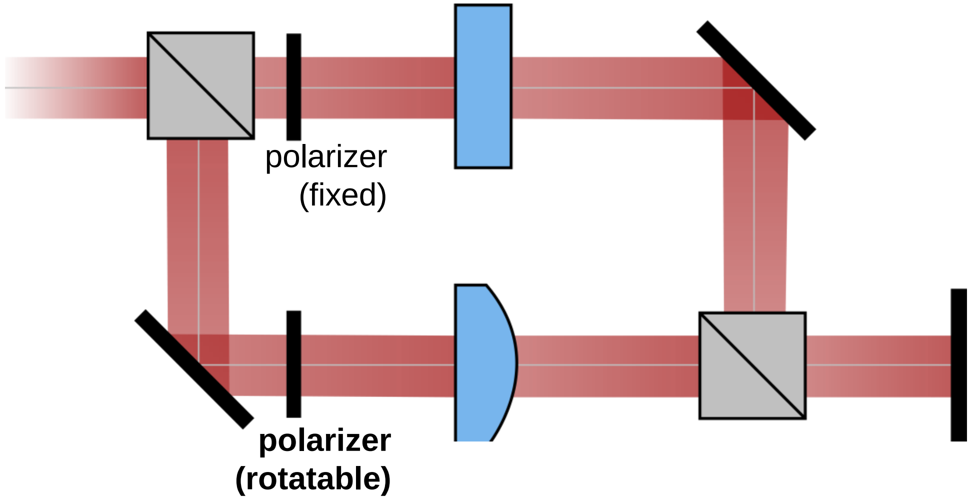
Polarization Interference

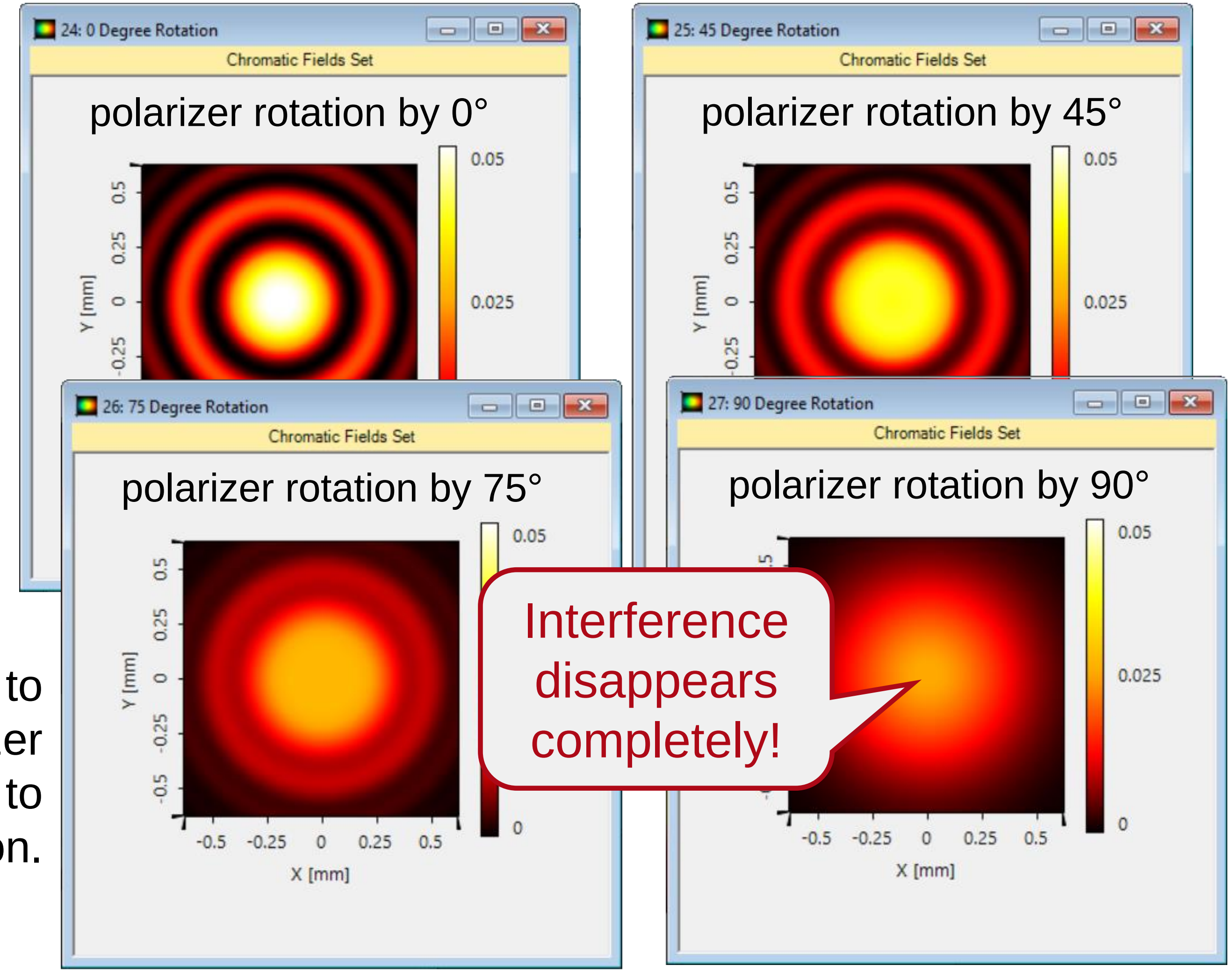
Modeling Task



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

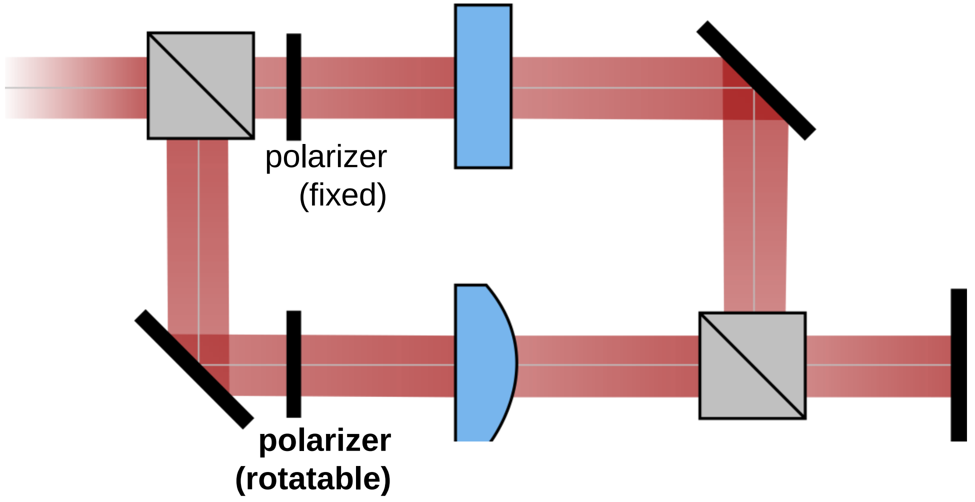
Interference Pattern Changes with Polarizer Rotation

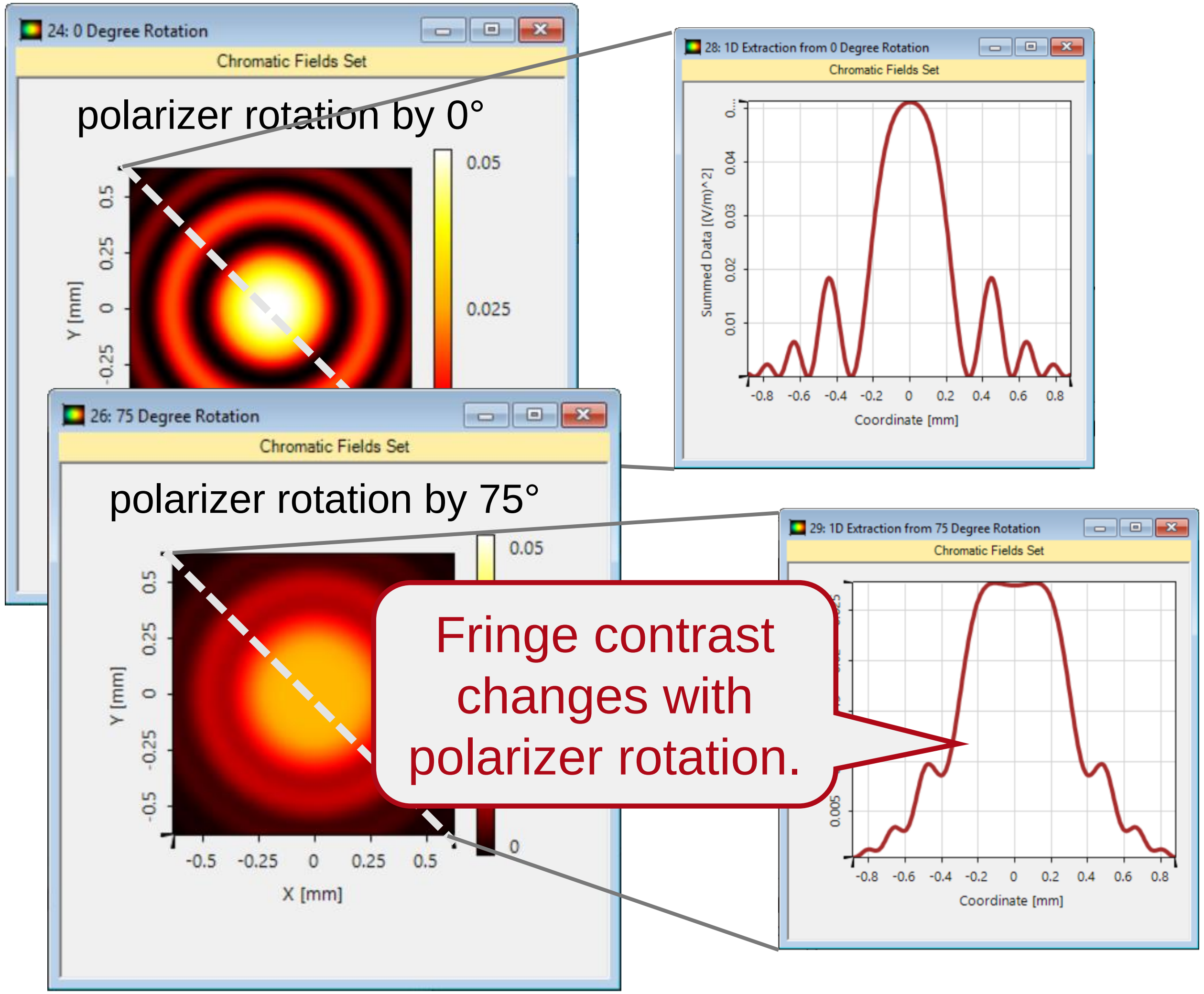




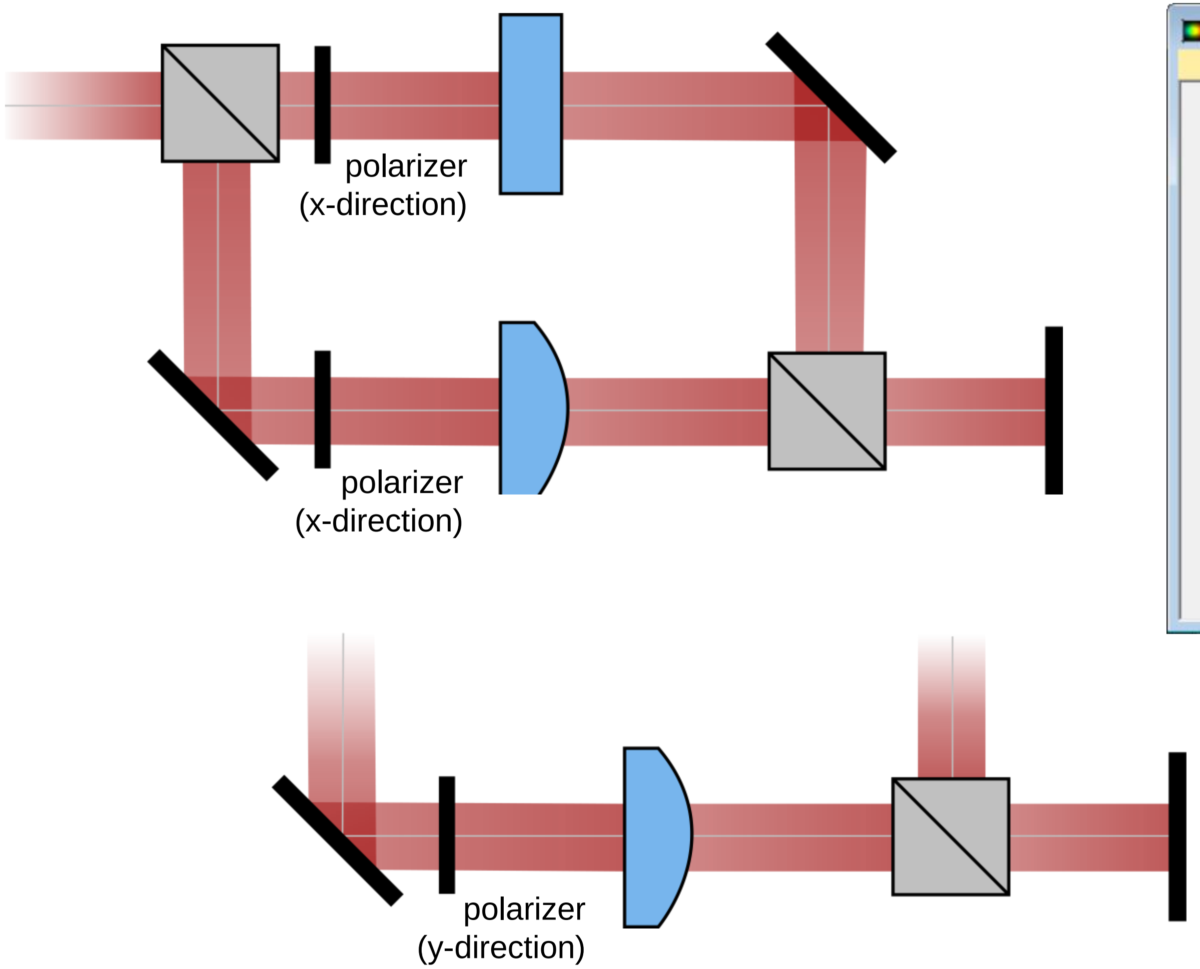
Interference fringes start to disappear, when polarizer rotates from parallel to orthogonal orientation.

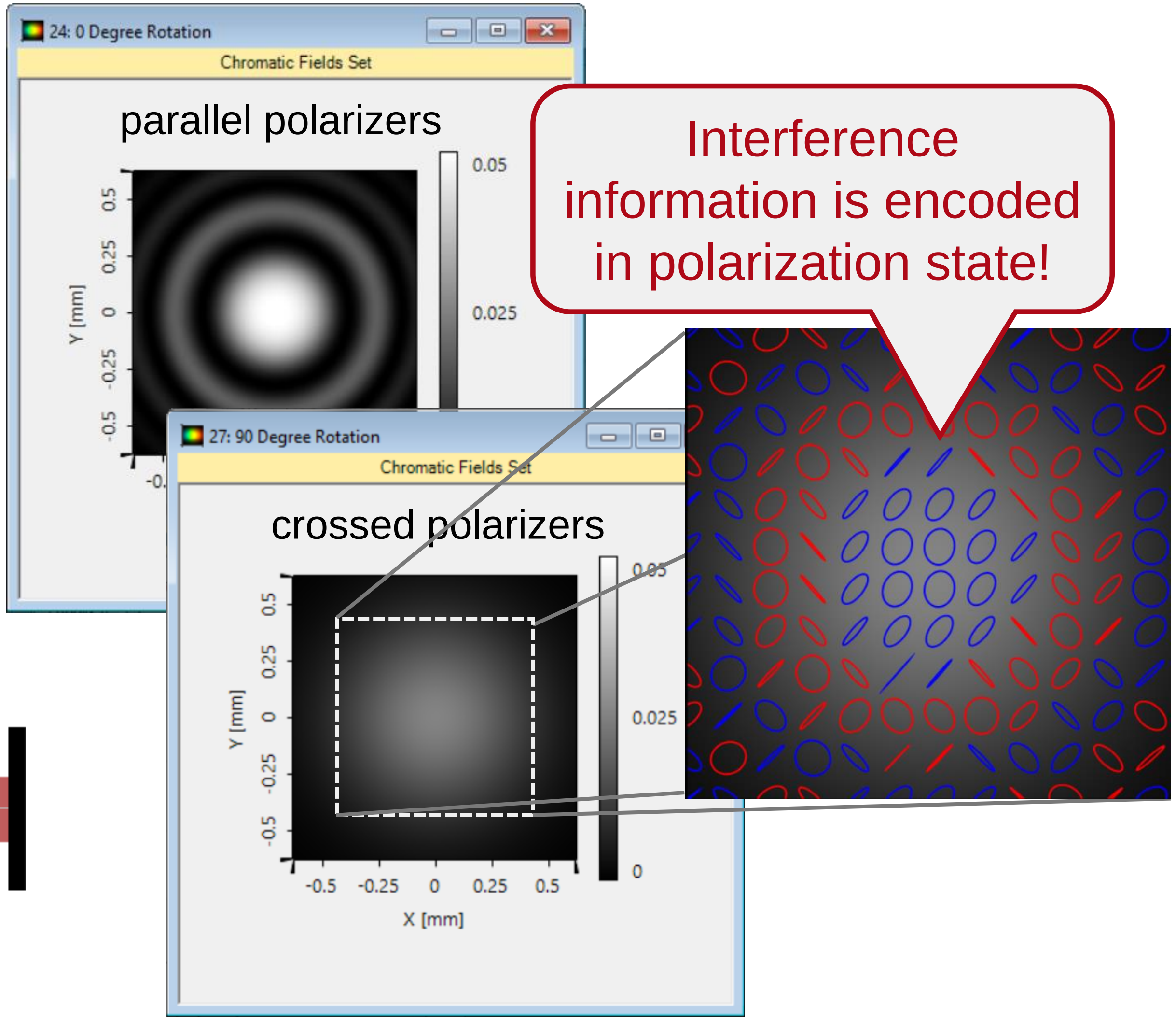
Interference Pattern Changes with Polarizer Rotation





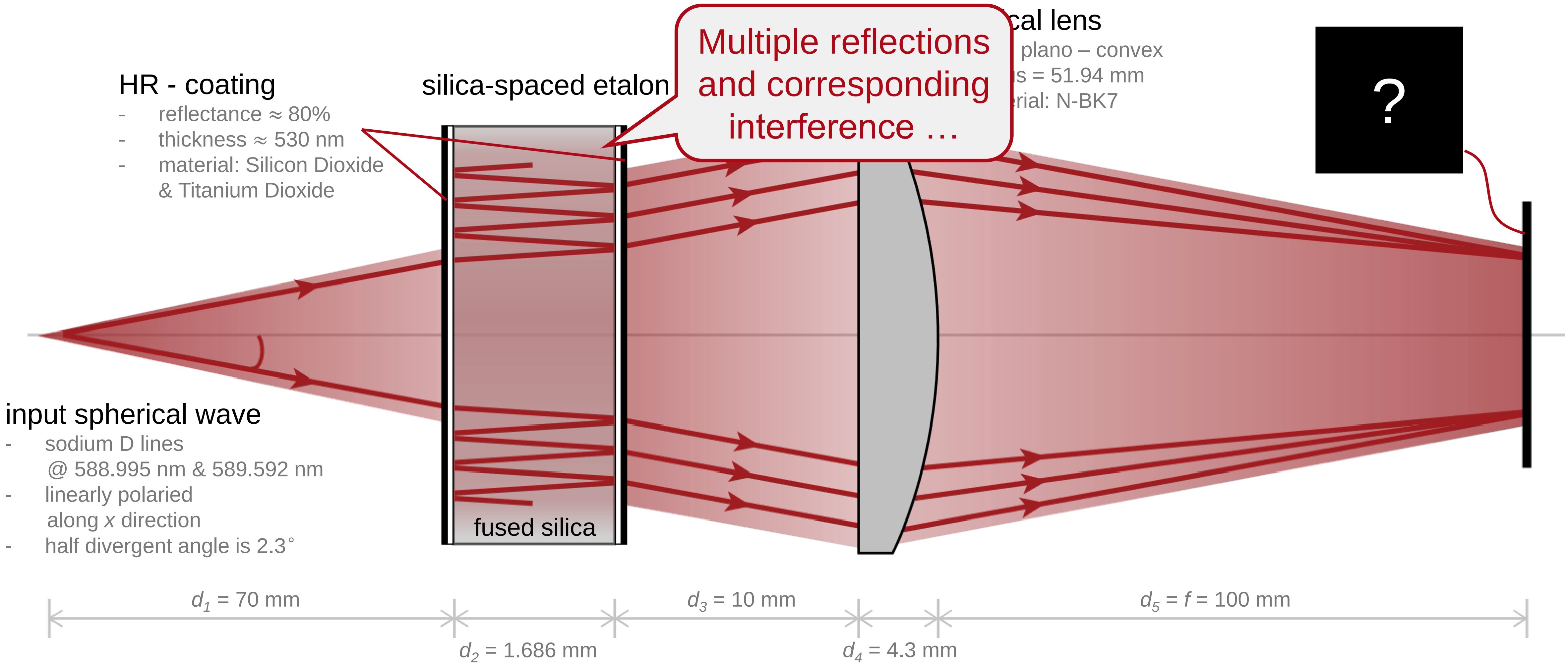
Interference Pattern



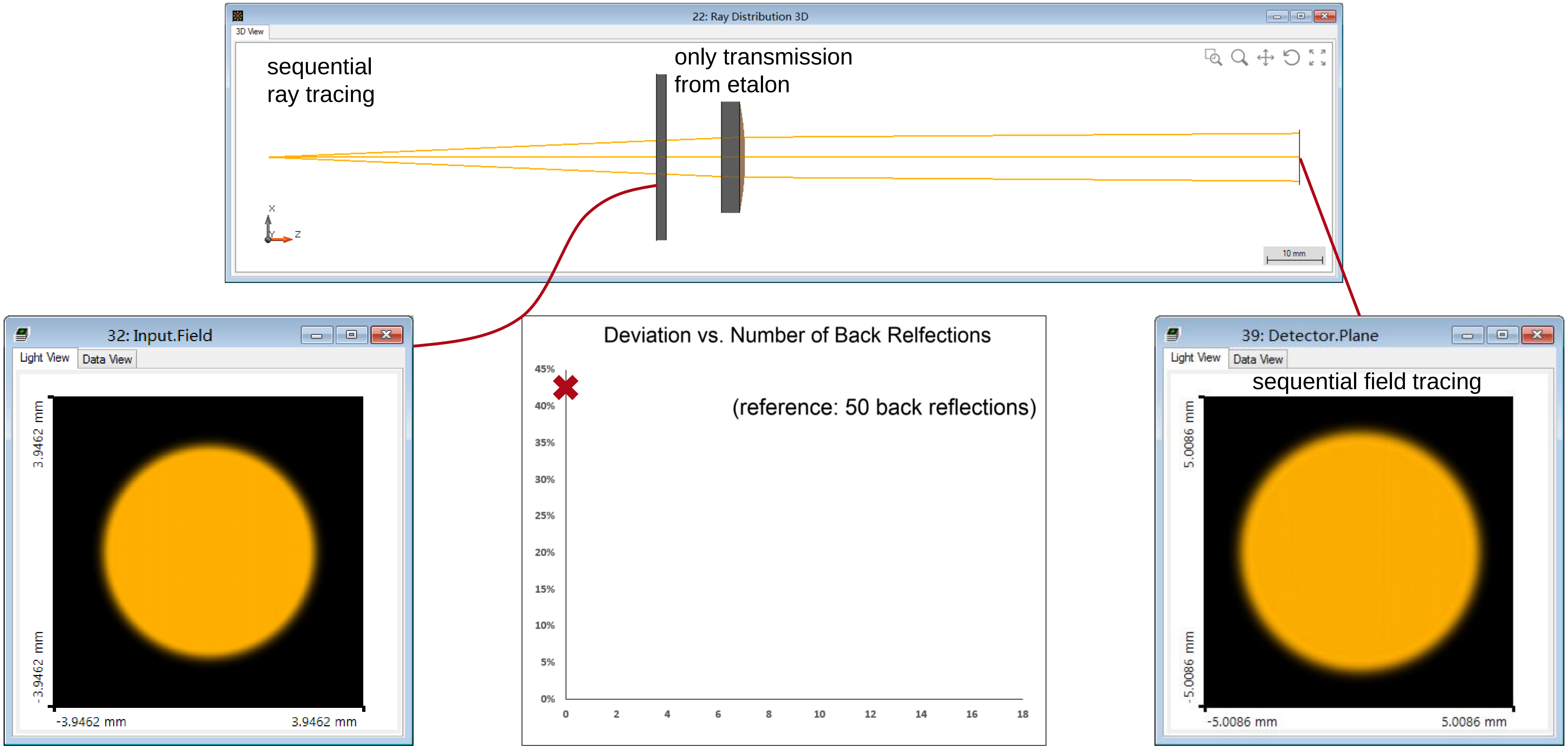


Examination of Sodium D Lines with Etalon

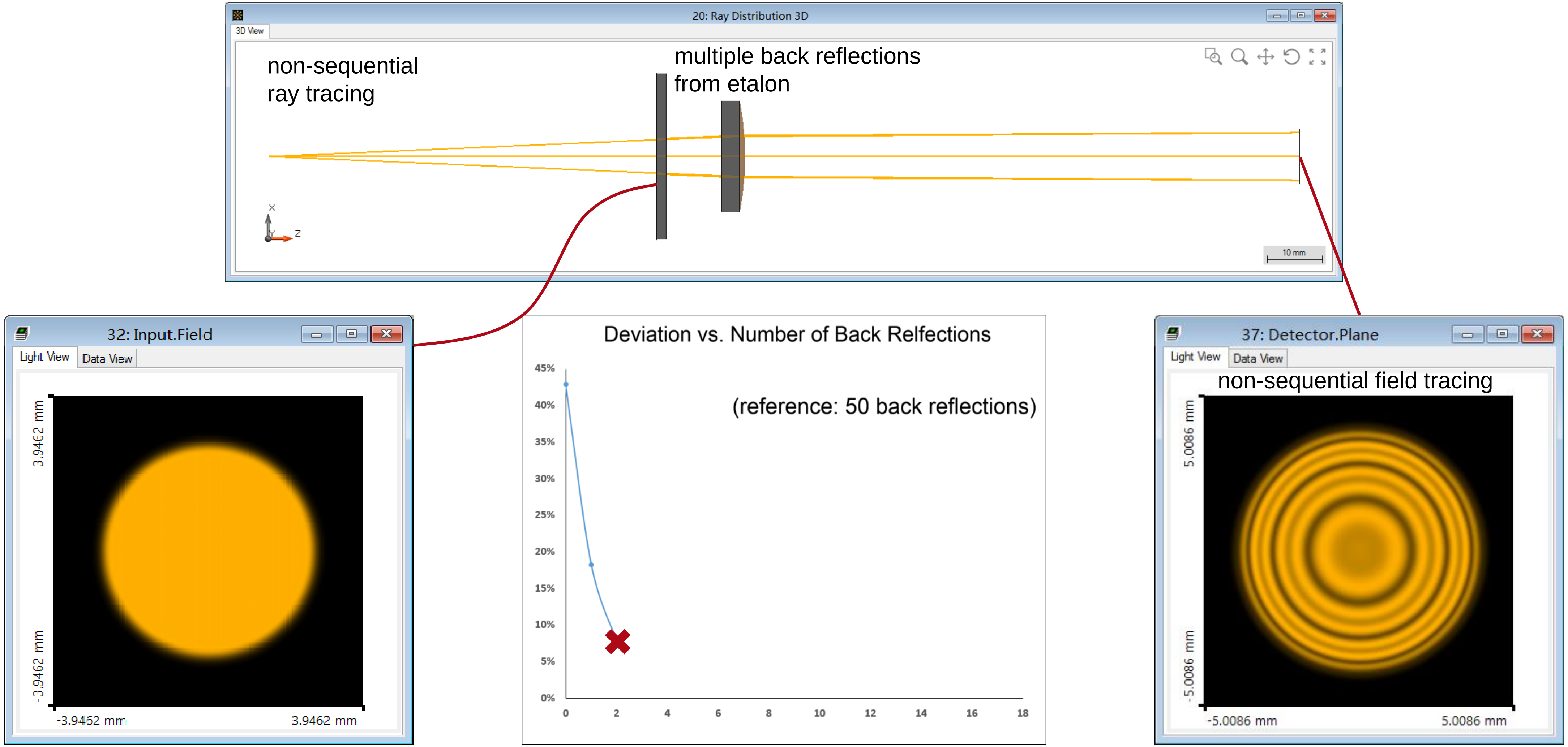
Modeling Task



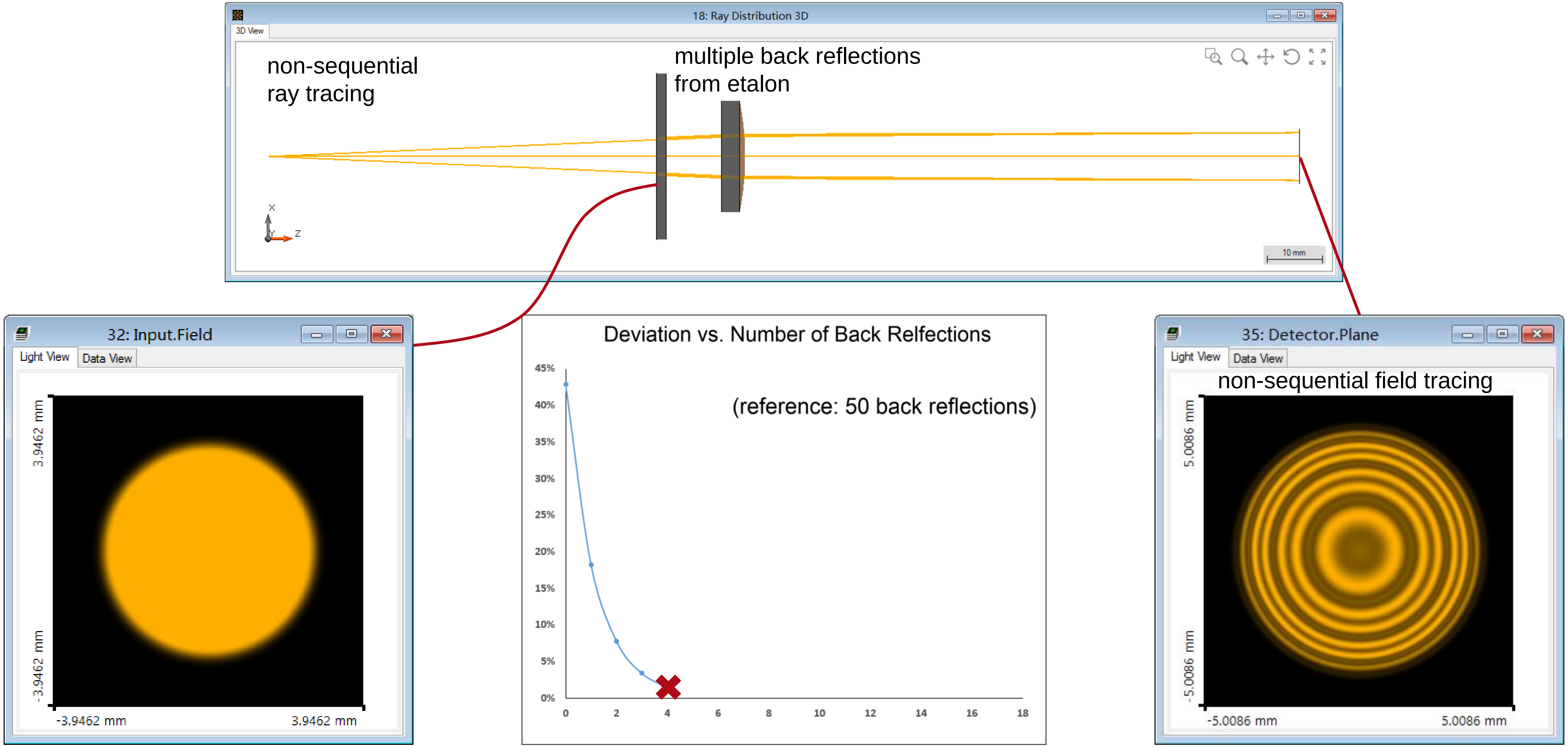
Result: only Transmitted Field



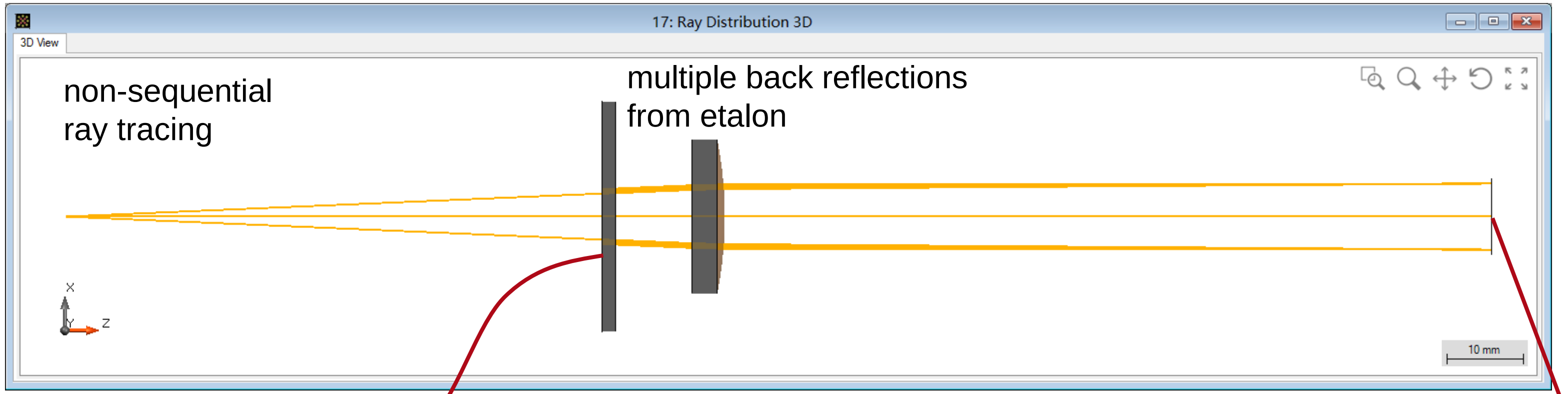
Result: Transmitted Field + 2 Back Reflections

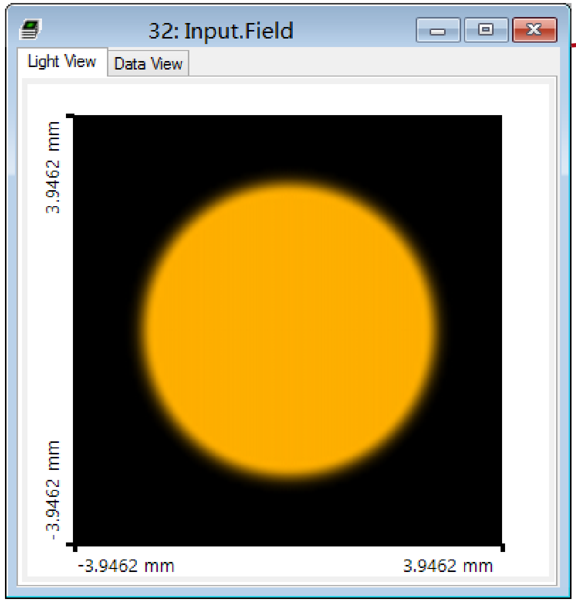


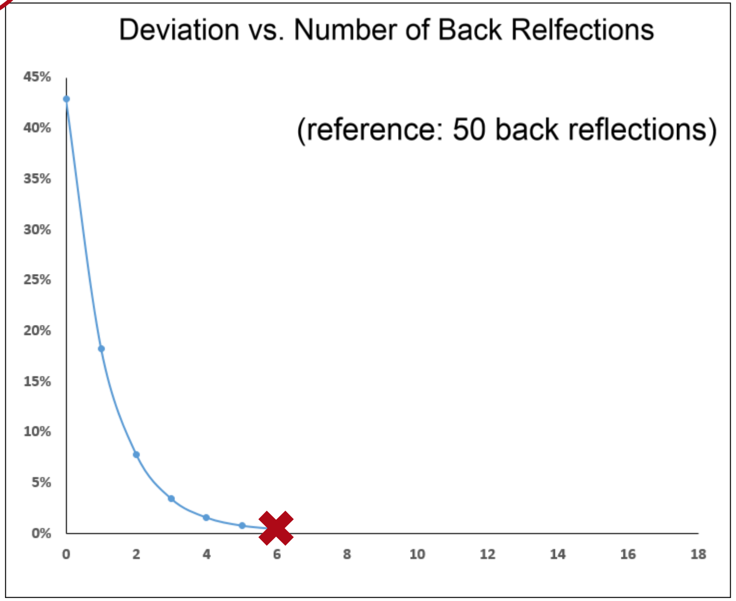
Result: Transmitted Field + 4 Back Reflections

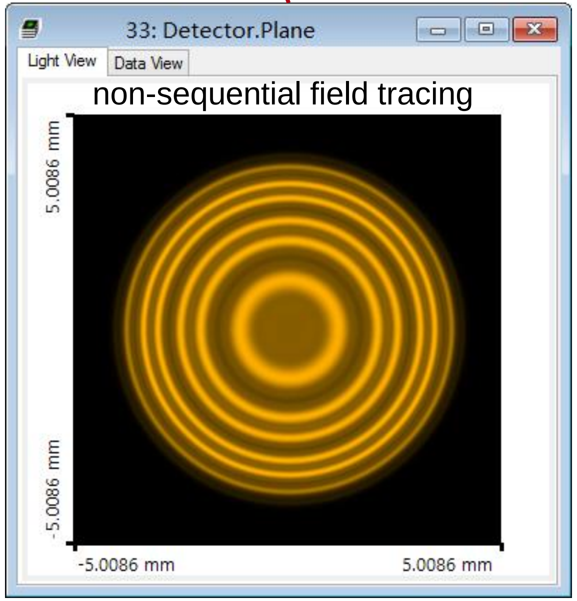


Result: Transmitted Field + 6 Back Reflections

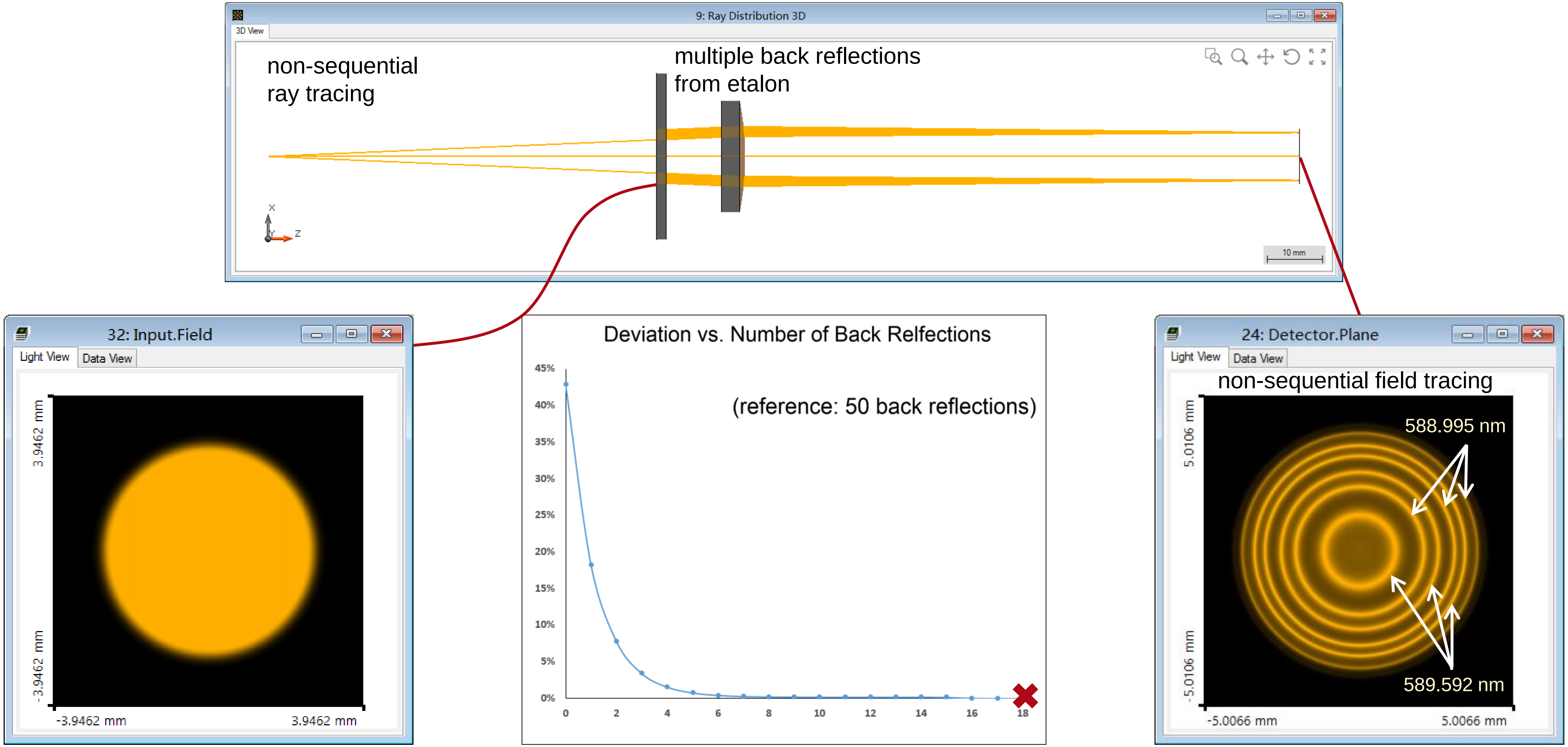






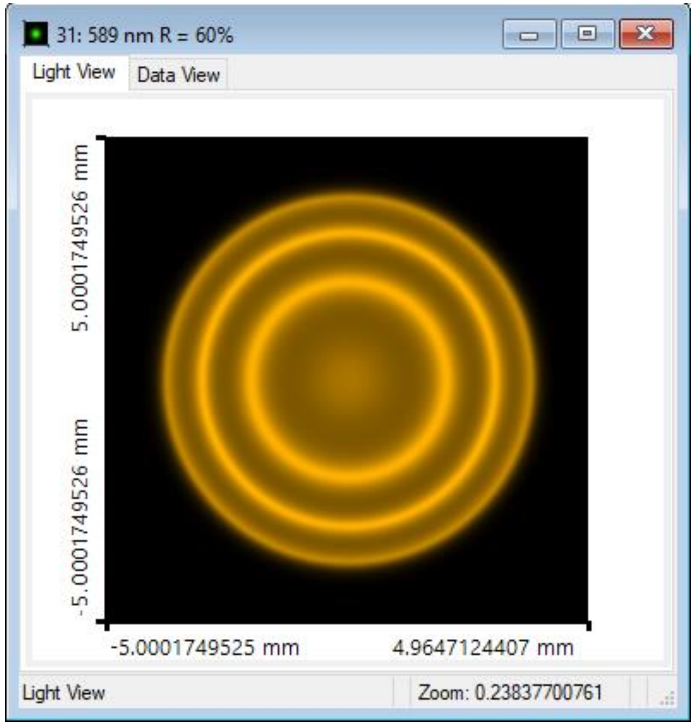


Result: Transmitted Field + 18 Back Reflections

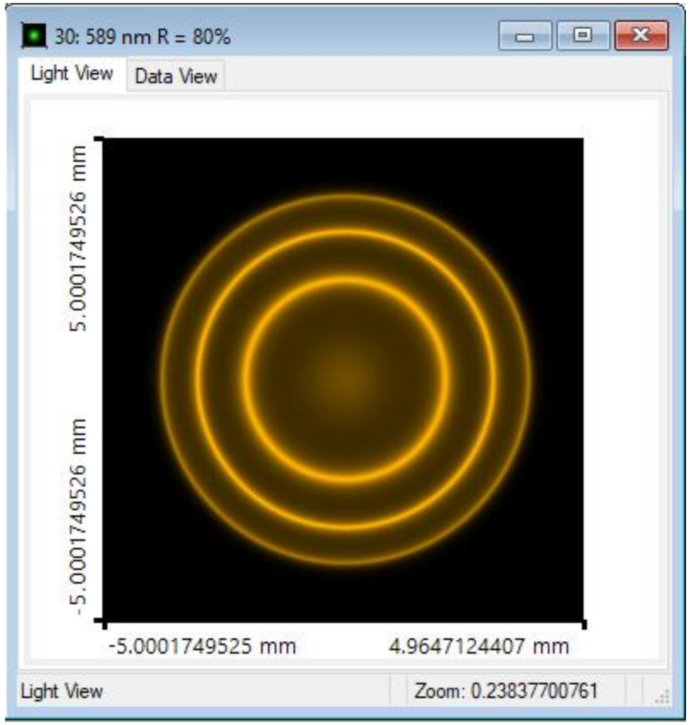


Result: HR-Coating Reflectance vs. Finesse

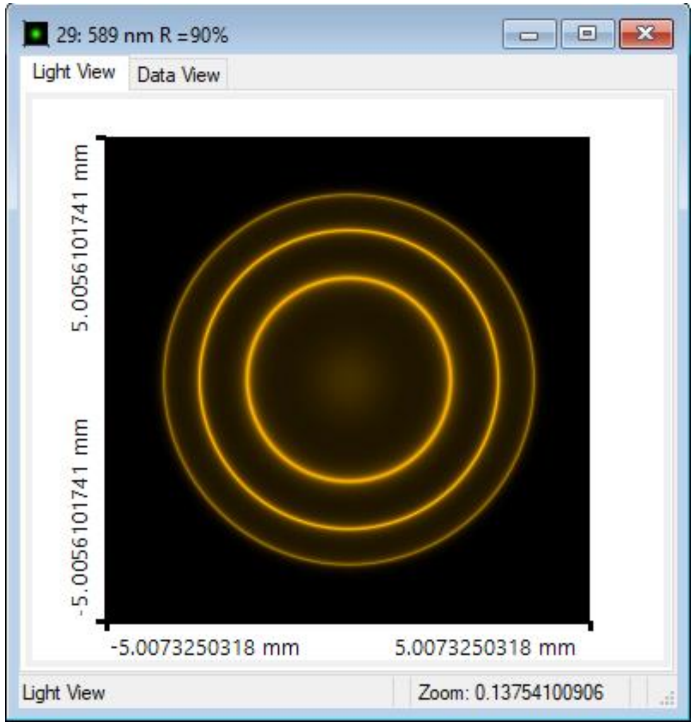
Coating **R = 60%** @ 589nm



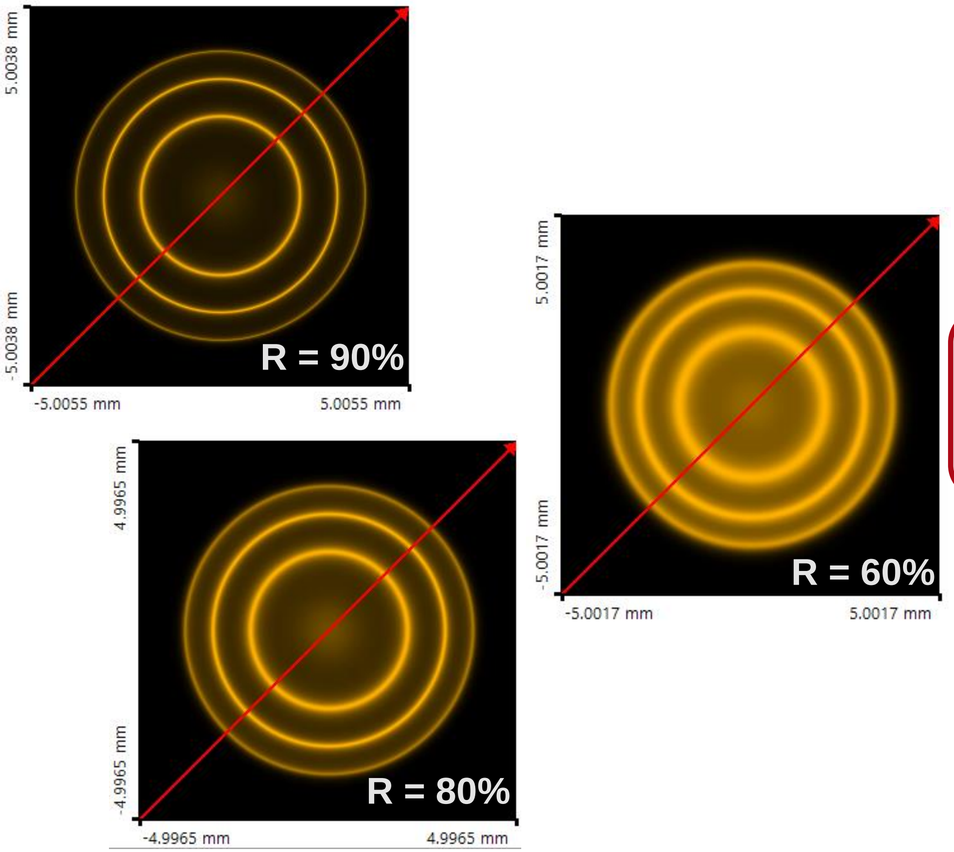
Coating **R = 80%** @ 589nm



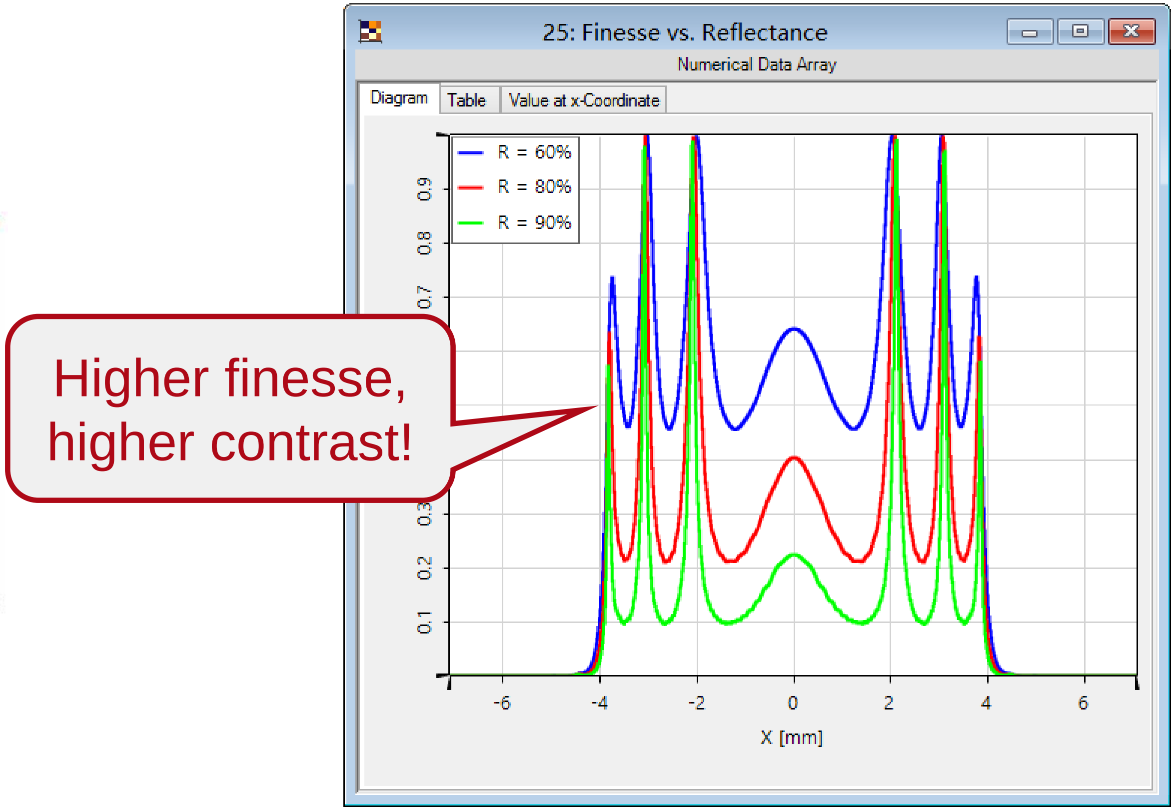
Coating **R = 90%** @ 589nm



Result: HR-Coating Reflectance vs. Finesse

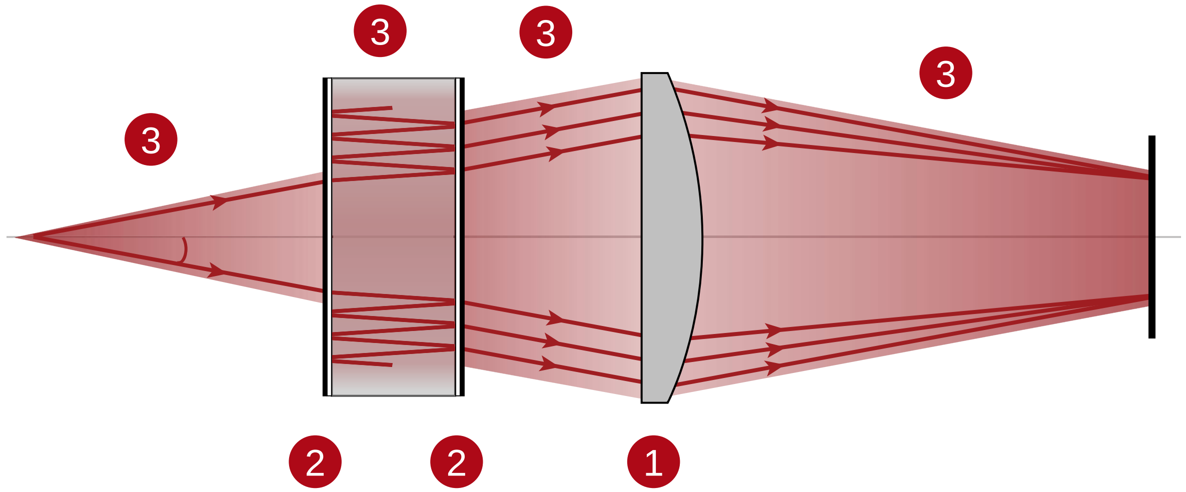


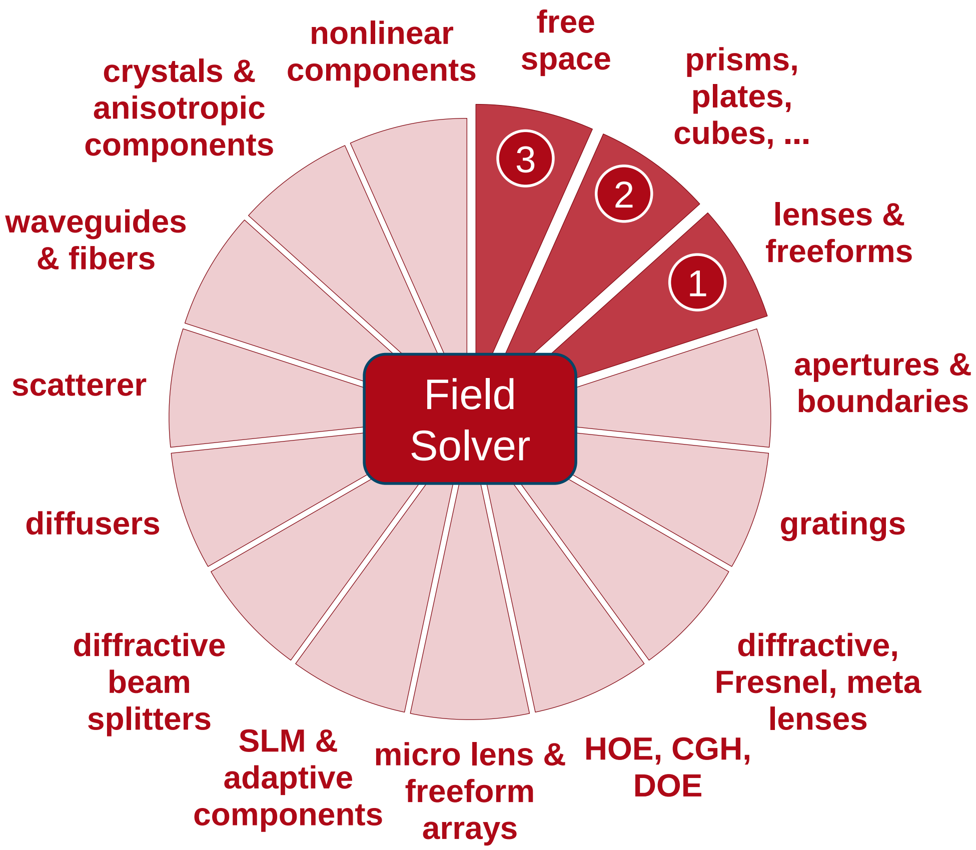
Extract 1D data along the diagonal line



The higher reflectance, the sharper interference stripe

VirtualLab Technologies





Related Talks and Poster Presentations

- **Talk**: How the design concepts of high-NA beam splitters and diffusers, as well as of beam shapers by freeform surfaces are related
  Time & Location: Wednesday, 6 February | 16:30 – 16:50, Room 210
- **Talk**: Physical-optics modeling of diffractive/meta-lenses and their design
  Time & Location: Wednesday, 6 February 2019 | 17:10 – 17:30, Room 210

- **Poster**: Design of single-mode fiber coupling lenses and tolerance analysis
  Time & Location: Tuesday, 5 February 2019 | 18:00 – 20:00, Golden Gate Ballroom
- **Poster**: Design and optimization strategy of incoupling gratings for near-eye displays
  Time & Location: Wednesday, 6 February 2019 | 18:00 – 20:00, Golden Gate Ballroom

Workshops and Seminars

- SPIE Industry Workshop in cooperation with ZEMAX/OpticStudio®
  Modeling and design of diffractive and meta-lenses with VirtualLab Fusion
  Time & Location: Wednesday, 6 February 2019 | 15:30 – 17:00, Room 12

- Free VirtualLab Fusion Seminar Thursday
  VirtualLab Fusion Technology and Applications:
  Interferometry, Microscopy and Fiber Coupling
  Time & Location: Thursday, 7 February 2019 | 09:00 – 13:00, 49 Geary Street

- Free VirtualLab Fusion Seminar Friday
  Beyond Ray Tracing: Innovative Optical Design with Fast Physical Optics
  Time & Location: Friday, 8 February 2019 | 09:00 – 16:00, 49 Geary Street