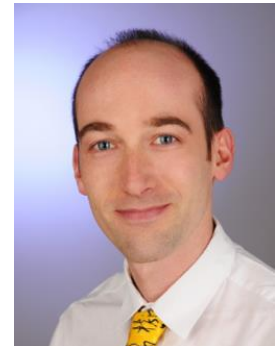


Tokyo, 25th of April, 2018, OPIE Exhibition Talk 15:00 – 15:40

Non-Sequential Optical Modeling with VirtualLab Fusion

Hartwig Crailsheim (LightTrans International UG)



Non-Sequential Extension (NSE)

Since 2018 VirtualLab introduced the so-called

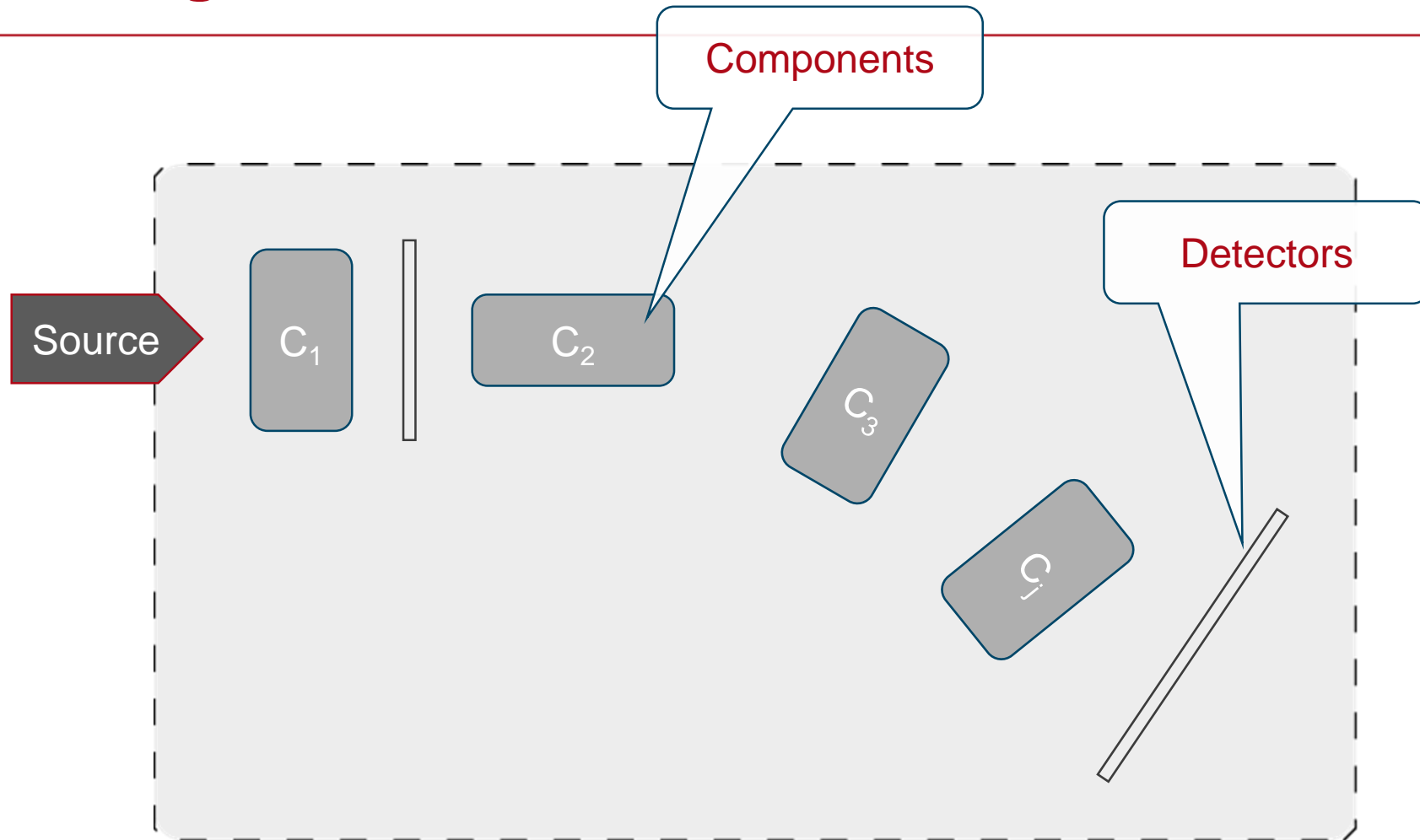
Non-Sequential Extension (NSE).

VirtualLab *without* NSE also allows non-sequential simulations namely by explicit specification of all light paths of interest.

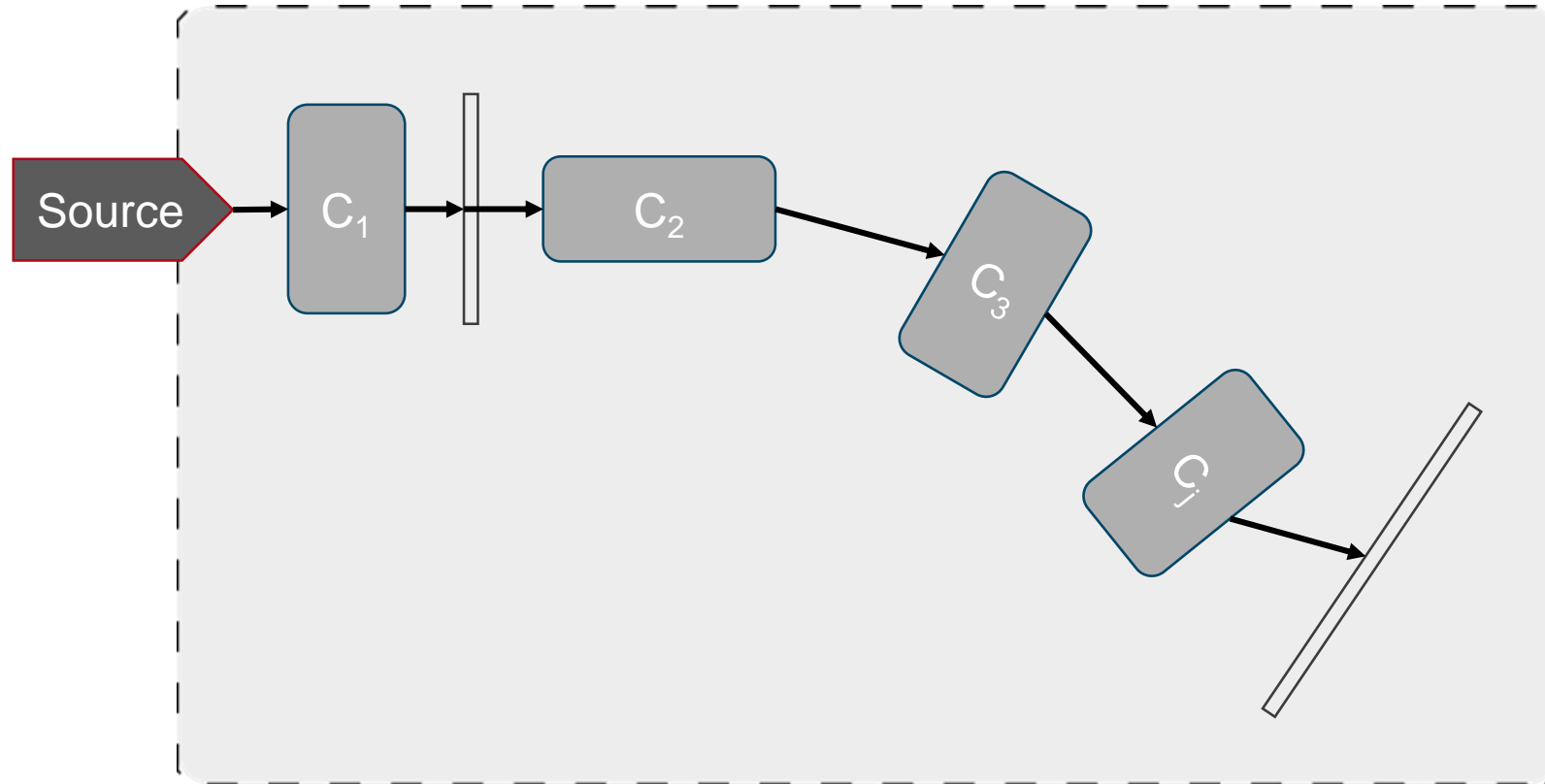
→ *With* the NSE, **setting up systems and analyzing the different light paths** for investigational purposes **become much easier, intuitive and adjustable.**

What is Sequential and Non-Sequential Tracing?

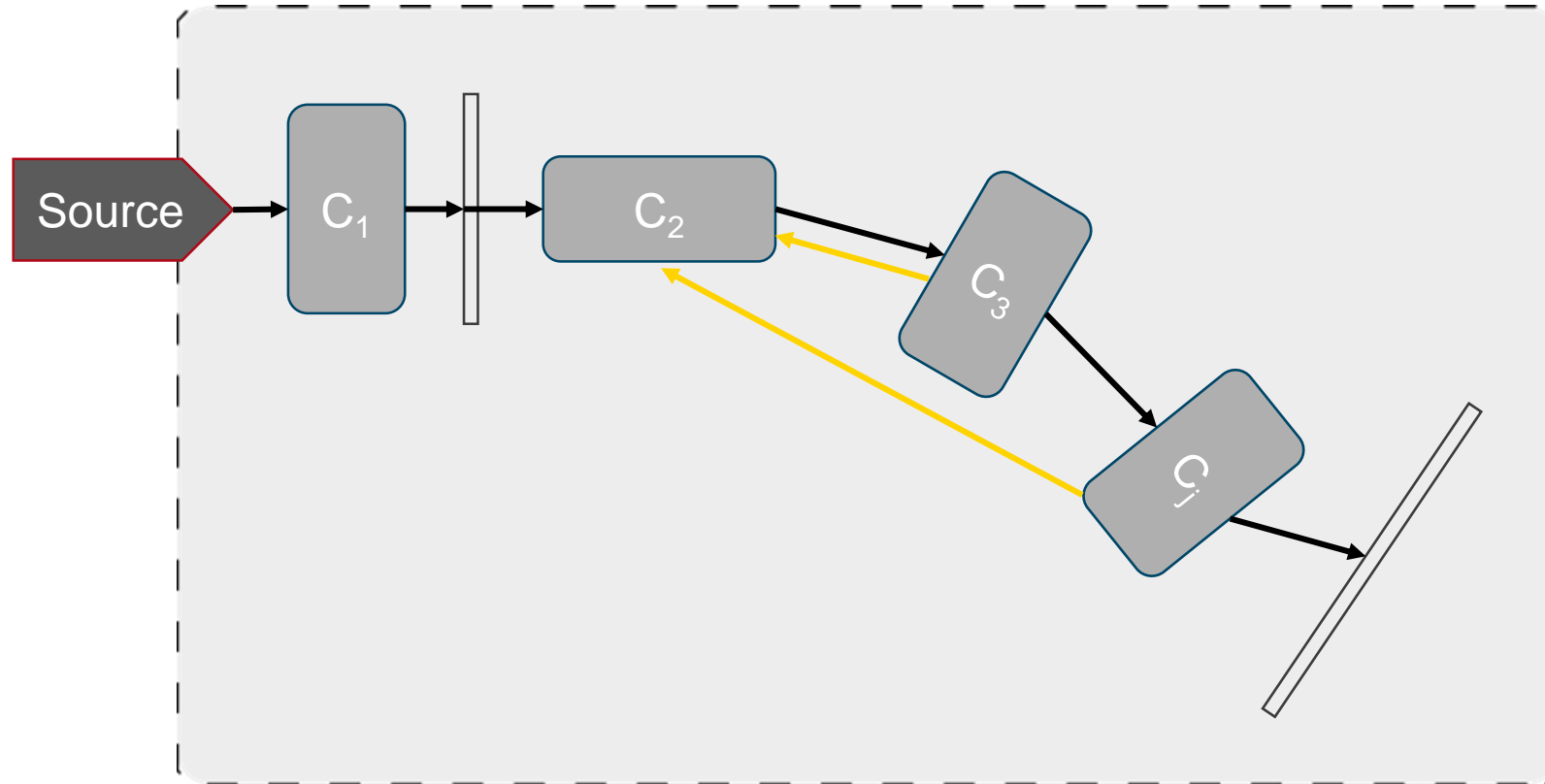
Optical Modeling Task



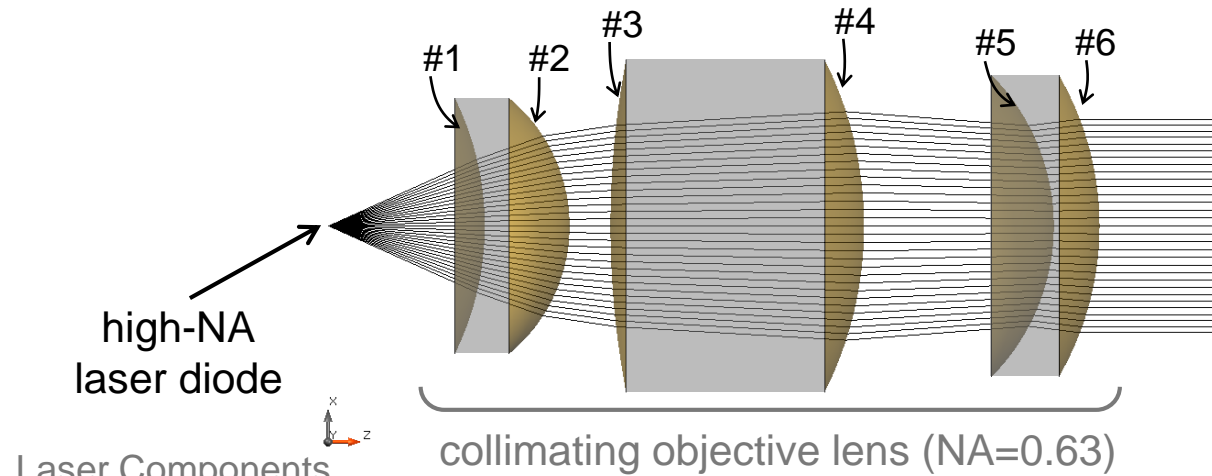
Optical Modeling: Sequential



Optical Modeling: Non-Sequential

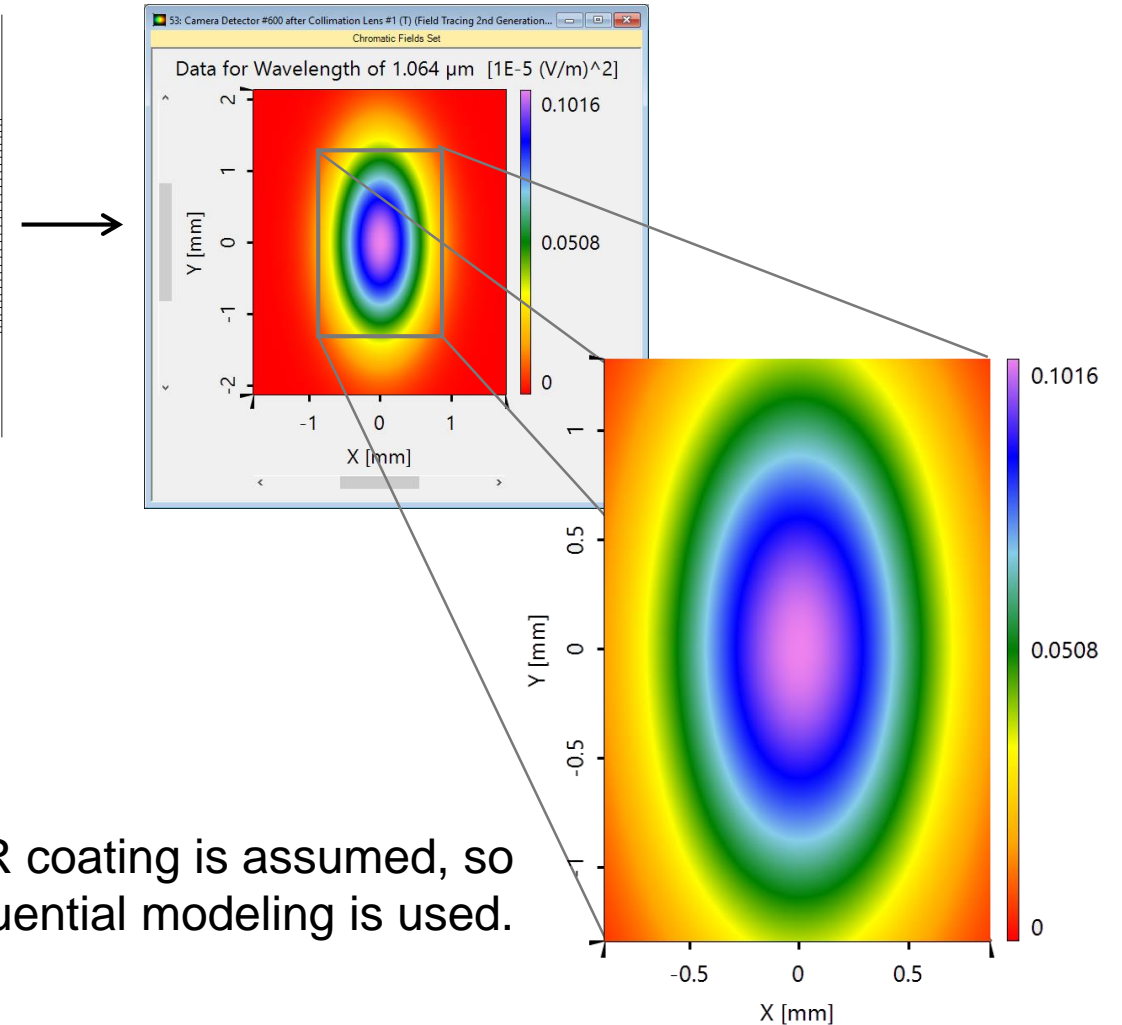


Collimation System: Sequential Simulation



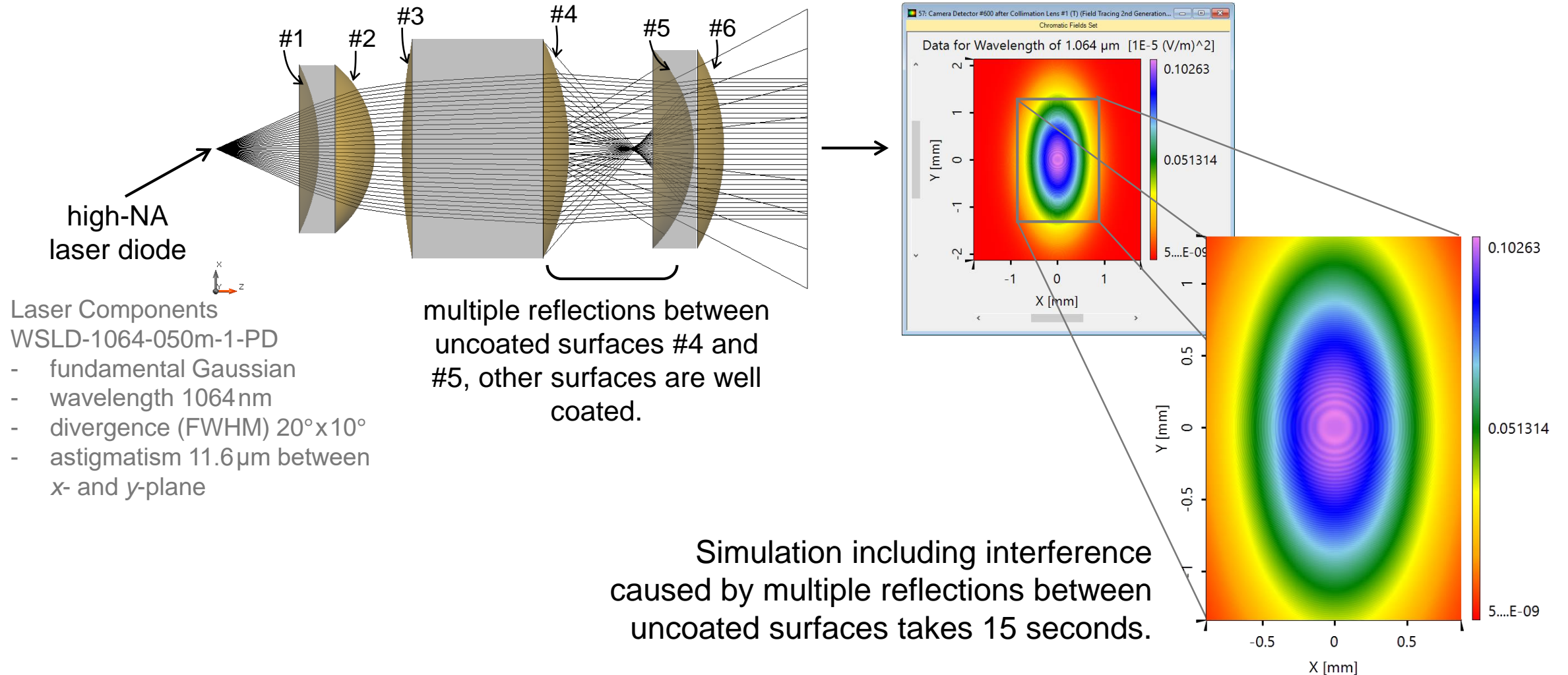
Laser Components
WSLD-1064-050m-1-PD

- fundamental Gaussian
- wavelength 1064 nm
- divergence (FWHM) $20^\circ \times 10^\circ$
- astigmatism $11.6 \mu\text{m}$ between x- and y-plane



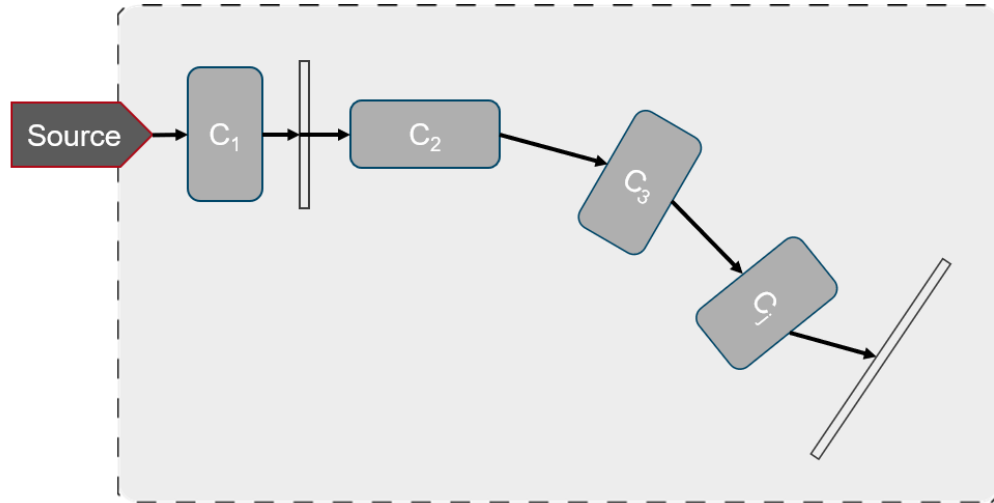
Perfect AR coating is assumed, so sequential modeling is used.

Collimation System: Non-Sequential Simulation

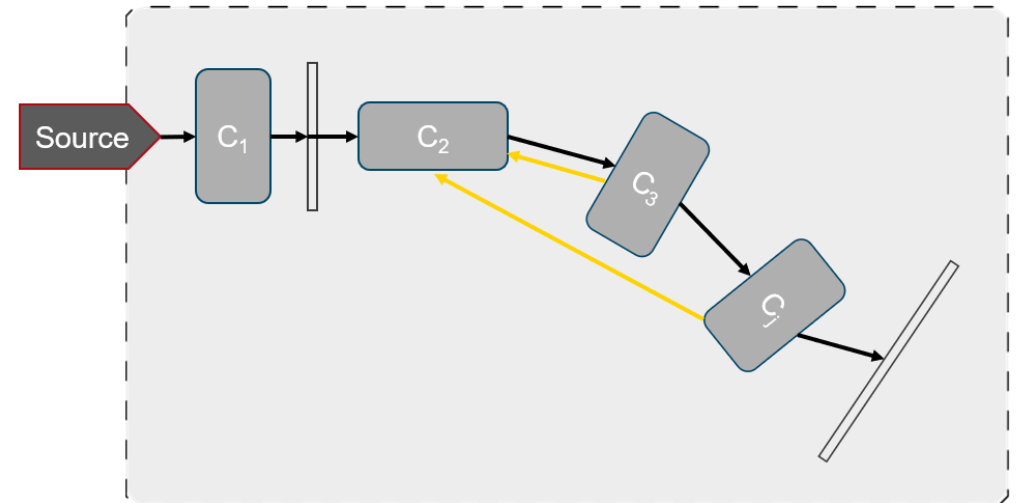


Conclusion of First Question

What is sequential and non-sequential tracing?



- Users predefine the sequence of the components, and light propagation through follows the sequence.
- Light propagates through / reflects from one component just once.



- Light propagation does not follow any sequence.
- Light propagates through / reflects several times from one component.

Note: Linkages are still used, but only for the purpose of referencing (position/orientation).

Different Needs for Non-Sequentiality

A) for evaluation of undesired (detrimental) reflections

- ghost images effects
- stray light orders in waveguides
- ... (any back reflections between different surfaces in a system)

B) for simulation of intended (necessary) reflections

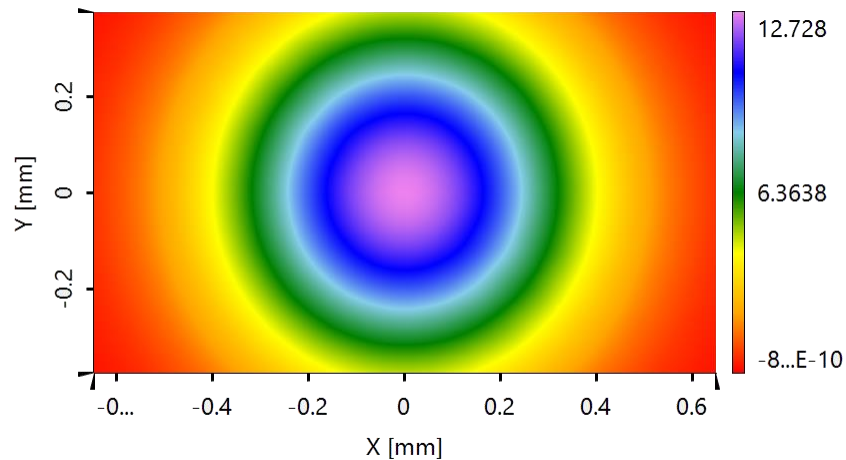
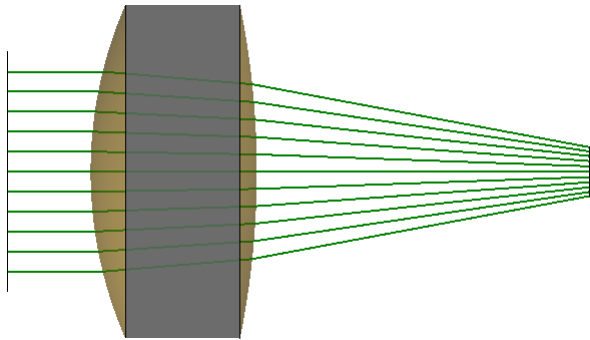
- systems with splitted light paths (e.g. any interferometer setup)
 - systems with folded light paths (e.g. diverse telescope setups)
 - etalons
 - ... (whatever system makes use of multiple or reflected light paths)
-

Unwanted Multiple Reflections / Light Paths

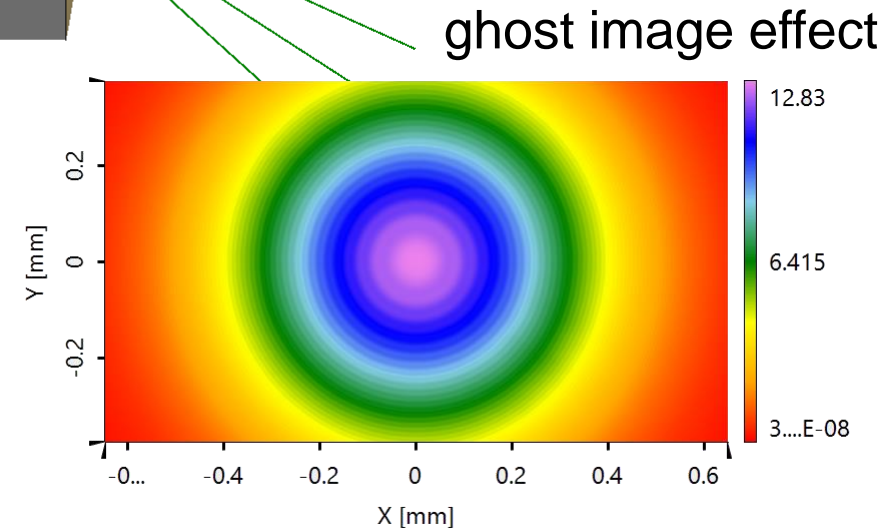
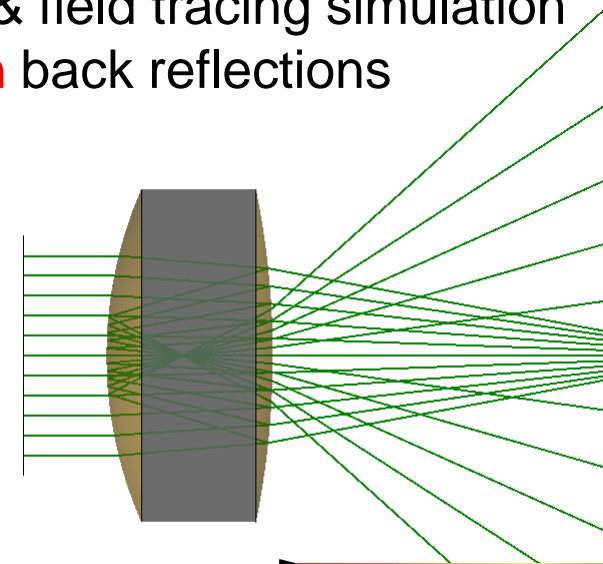
Setup with & without Non-Sequential Extension (NSE)

Back Reflection in Bi-Convex Lens

ray & field tracing simulation
without back reflections

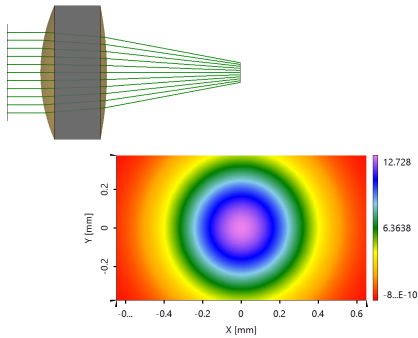


ray & field tracing simulation
with back reflections

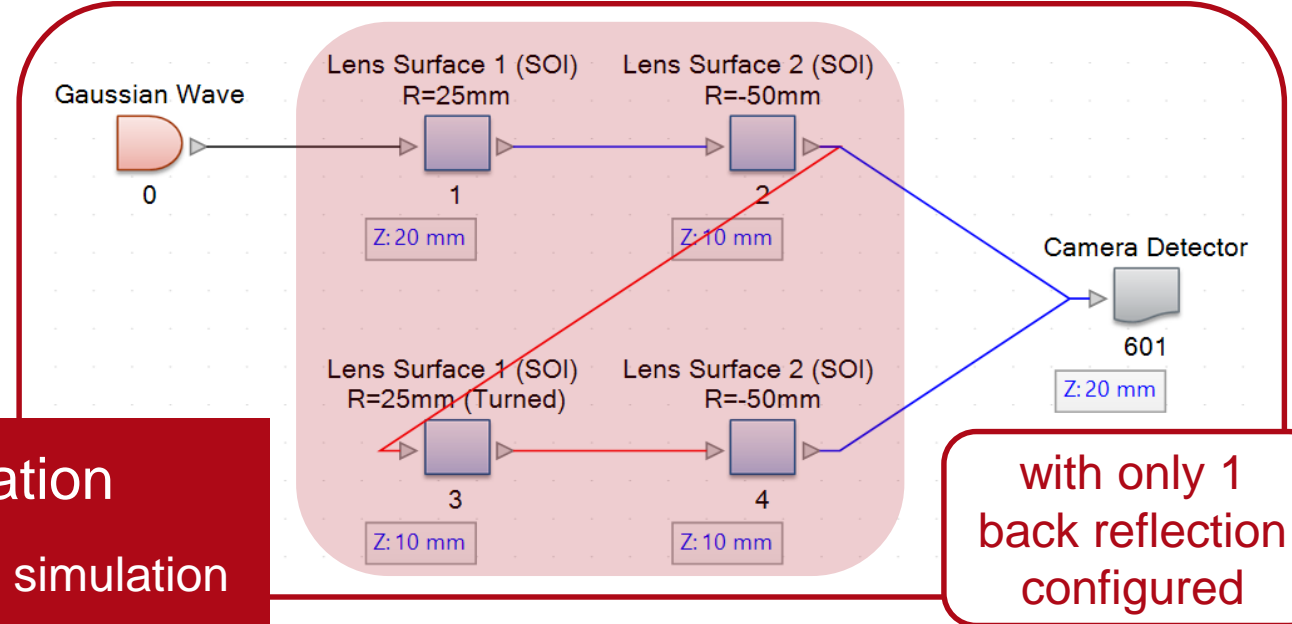
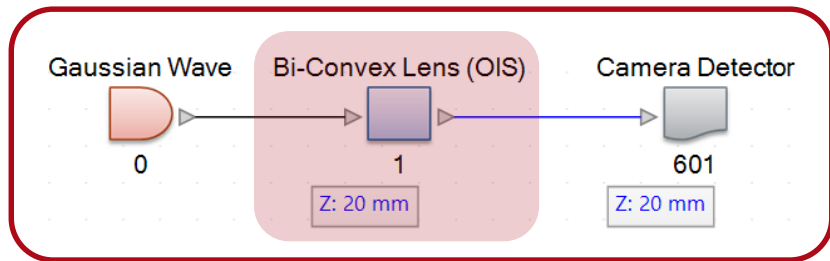
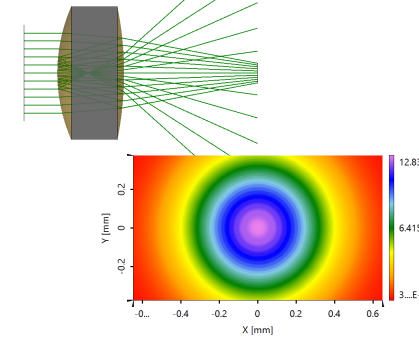


Setup in VirtualLab **Exclusive** Non-Sequential Extension (NSE)

without reflections



with reflections

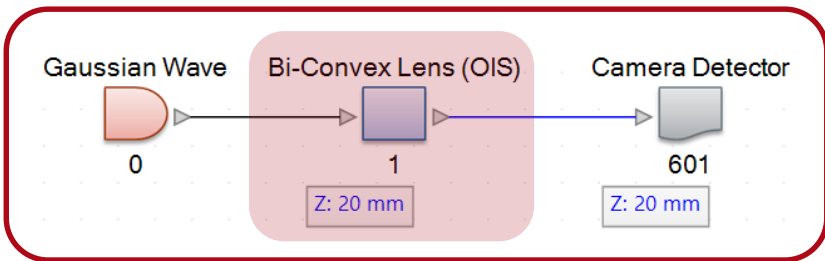
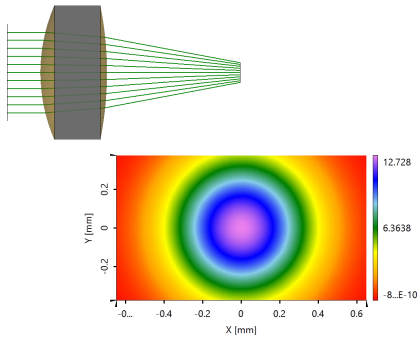


sequential setup \nRightarrow sequential simulation
complex setup WAS necessary for non-sequential simulation

with only 1
back reflection
configured

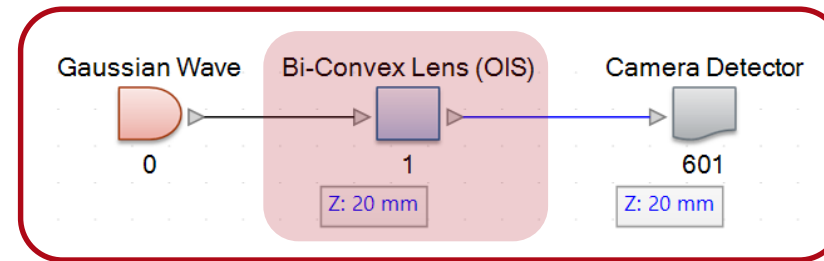
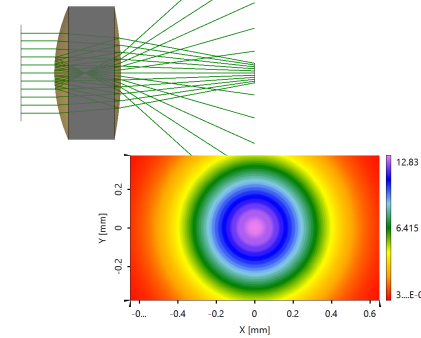
Setup in VirtualLab **Inclusive** Non-Sequential Extension (NSE)

without reflections



Flag: Non-Sequential Tracing = False

with reflections



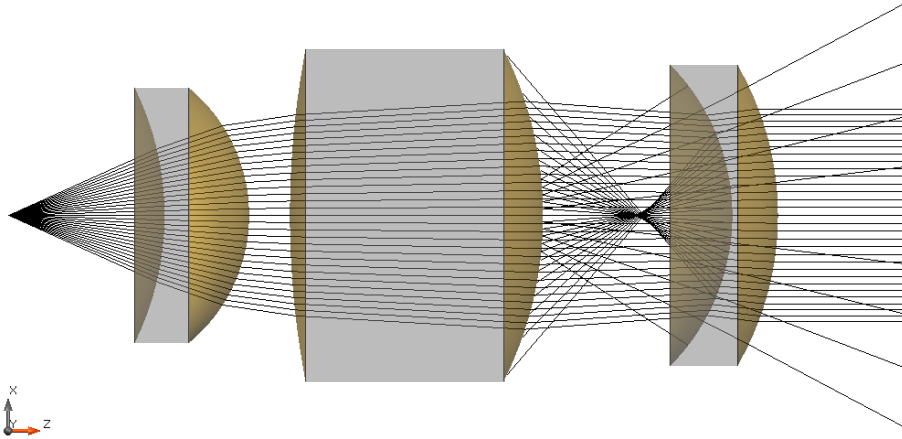
Flag: Non-Sequential Tracing = True

difference for setup = 1 Double CLICK !

Energy Consideration

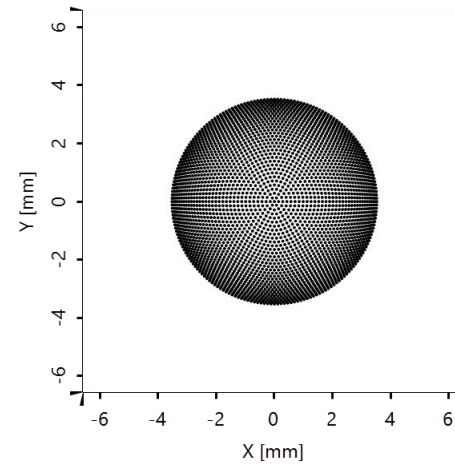
- collimation objective lens example
- near-eye display (NED) waveguide example

Accurate Representation of Resulting Light

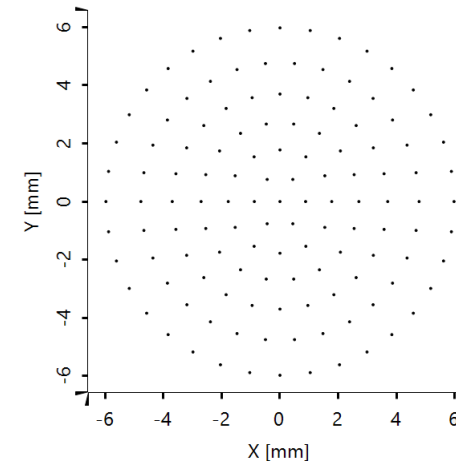


- Non-sequential simulations require the accurate consideration of energy conservation.
- It is of paramount importance to know how much energy the different deflected light portions carry.

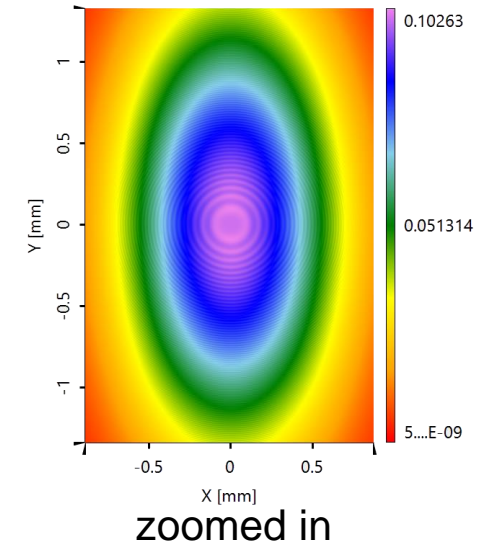
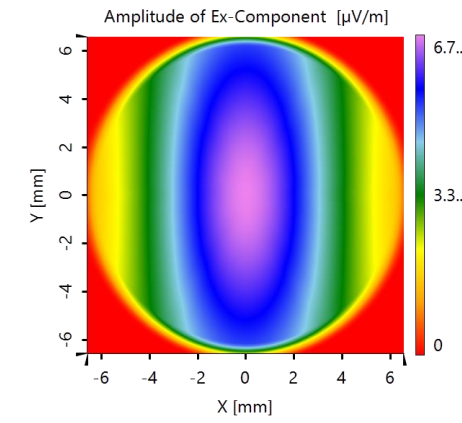
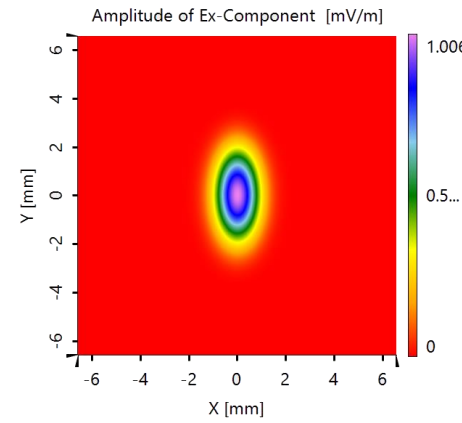
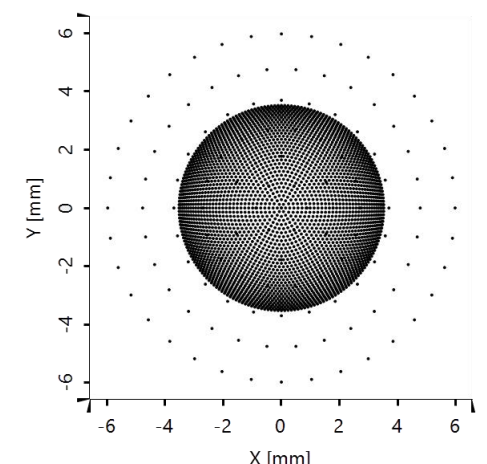
coherent mode #1



coherent mode #2



both coherent modes

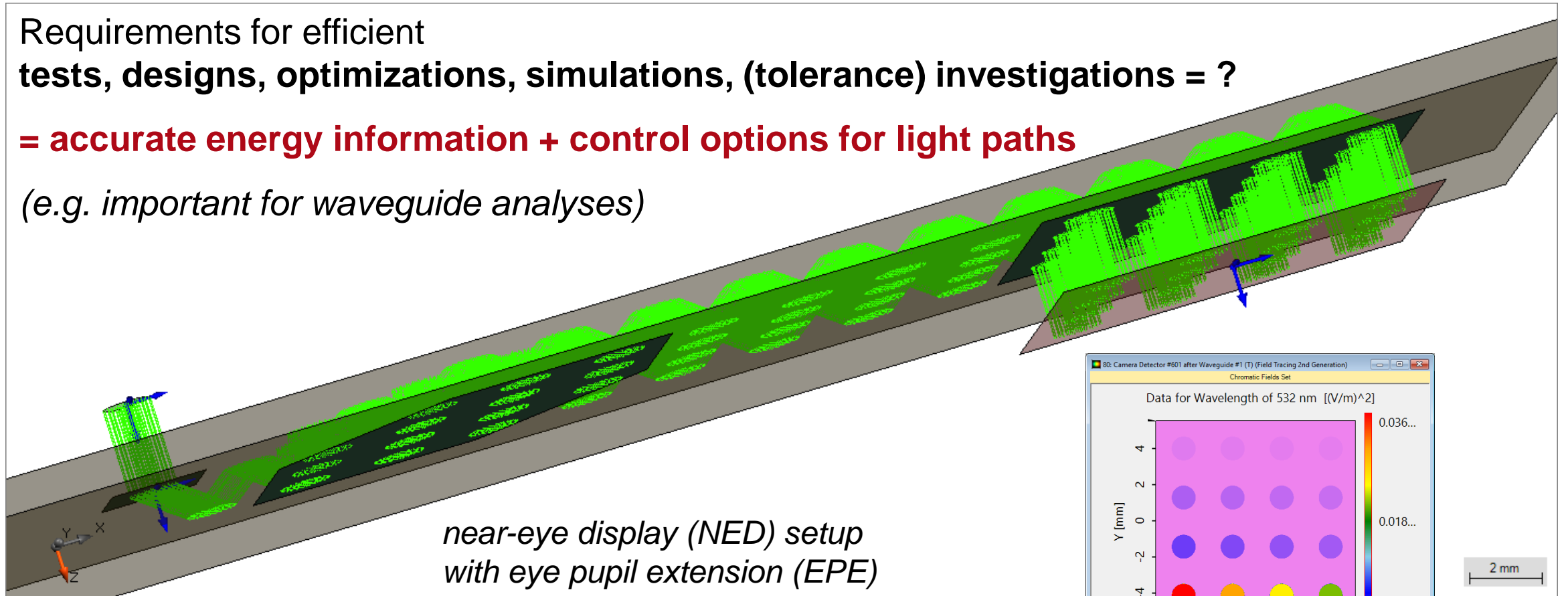


Knowing Which Light Paths Are of Significance

Requirements for efficient tests, designs, optimizations, simulations, (tolerance) investigations = ?

= accurate energy information + control options for light paths

(e.g. important for waveguide analyses)

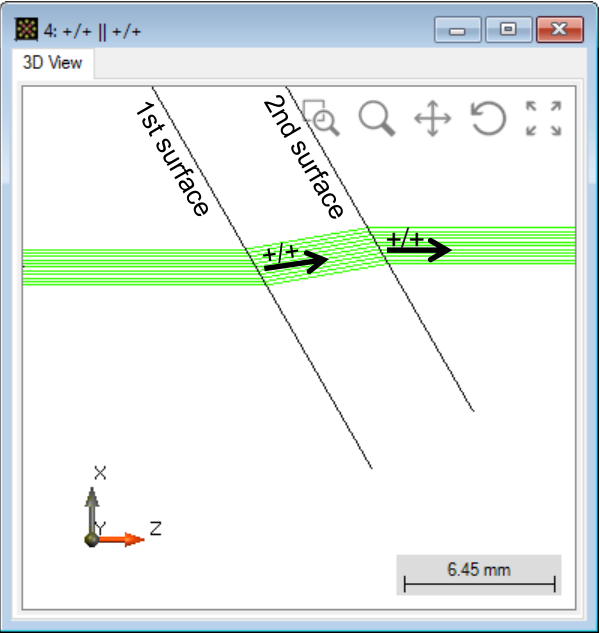


How to Enable Sequential and Non-Sequential Tracing?

→ Channel Concept

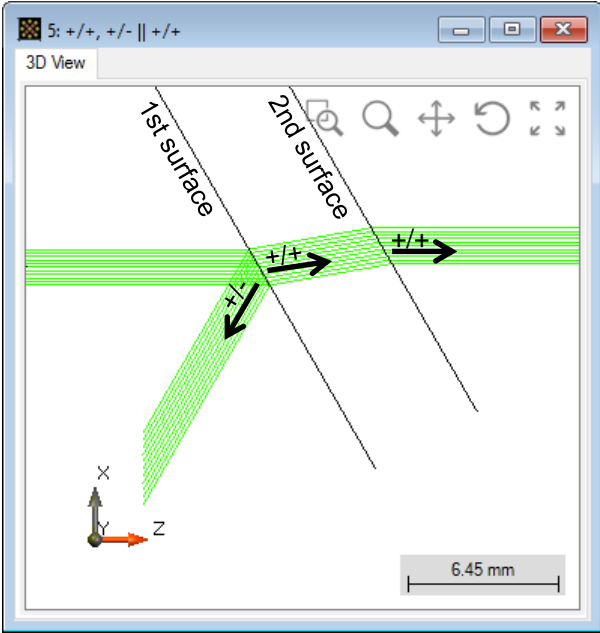
Surface Channels

- Setting A



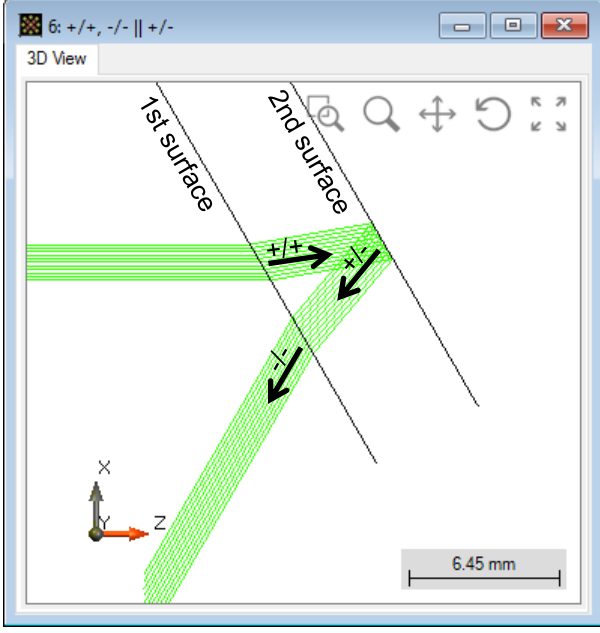
Surface	+/+	+/-	-/-	-/+
1st	×			
2nd	×			

- Setting B



Surface	+/+	+/-	-/-	-/+
1st	×	×		
2nd	×			

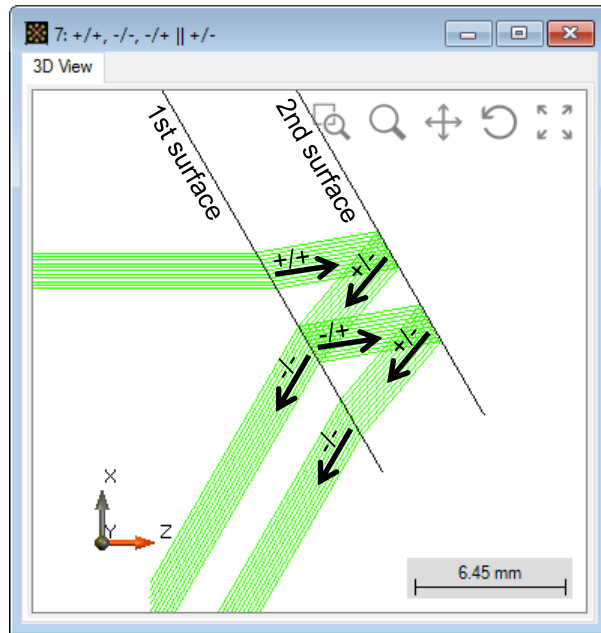
- Setting C



Surface	+/+	+/-	-/-	-/+
1st	×		×	
2nd		×		

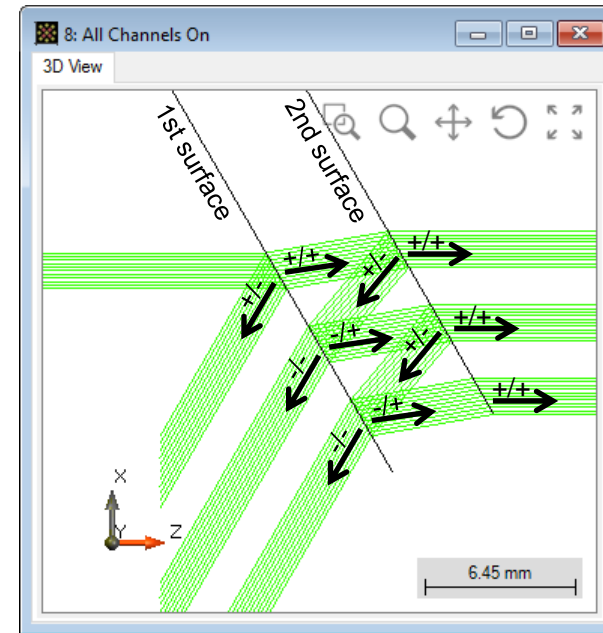
Surface Channels

- Setting D



Surface	+/+	+/-	-/-	-/+
1st	×		×	×
2nd		×		

- Setting E



Surface	+/+	+/-	-/-	-/+
1st	×	×	×	×
2nd	×	×	×	×

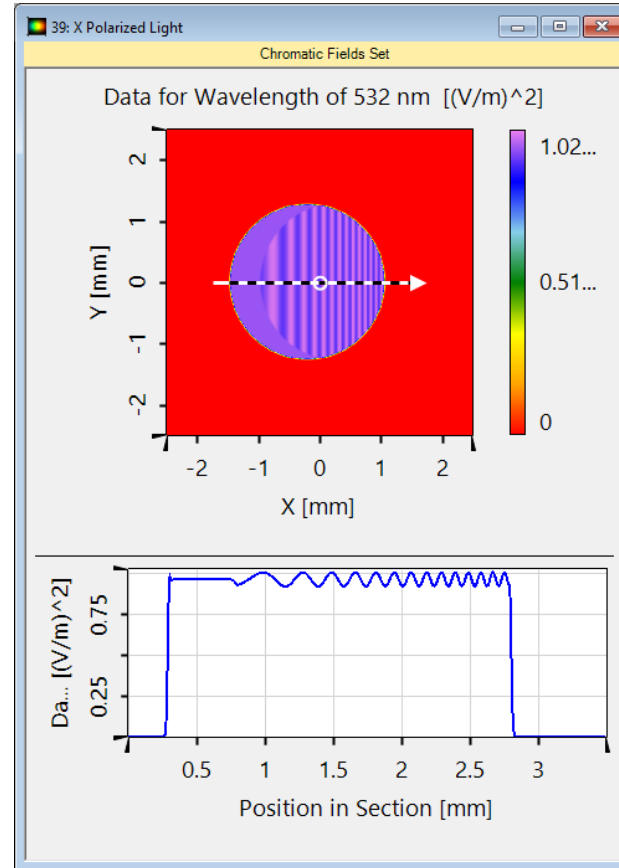
Etalon Example

with regard of polarization of incident light

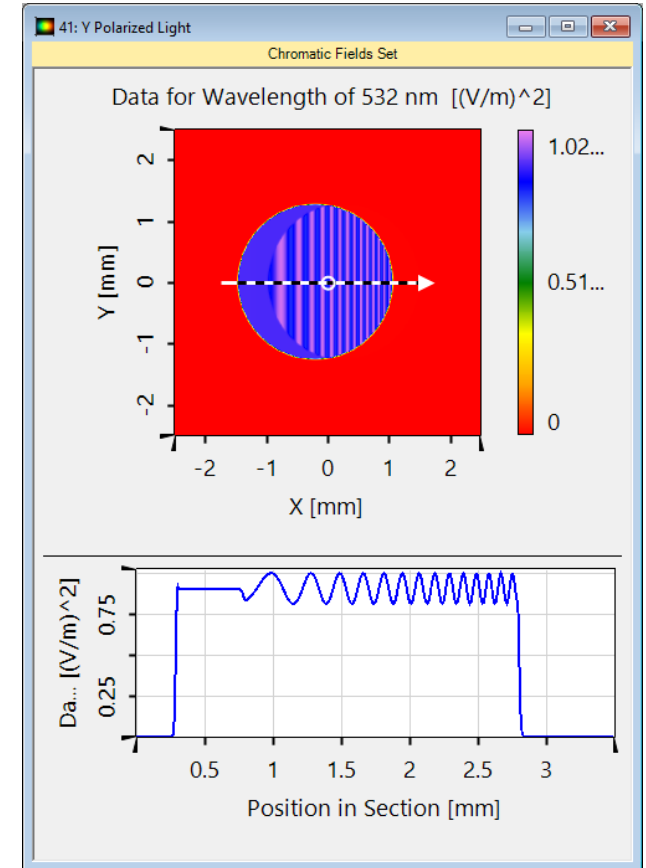
Optical Etalon

- Configuration of input field
 - plane wave
 - Polarization (try both)
 - E_x -polarized
 - E_y -polarized
- Configuration of etalon
 - cylindrical-planar
 - center thickness $700\mu\text{m}$
 - cylindrical surface radius 1 m

related sample file: 01_Etalon.lpd



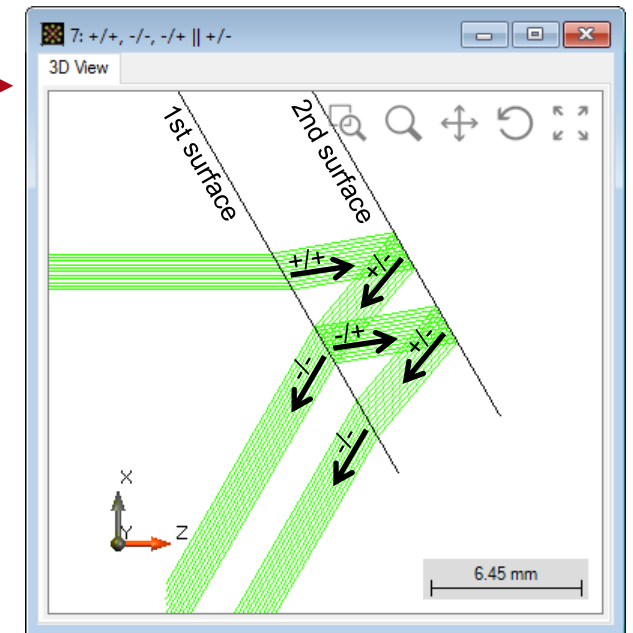
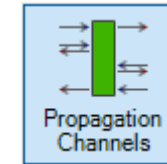
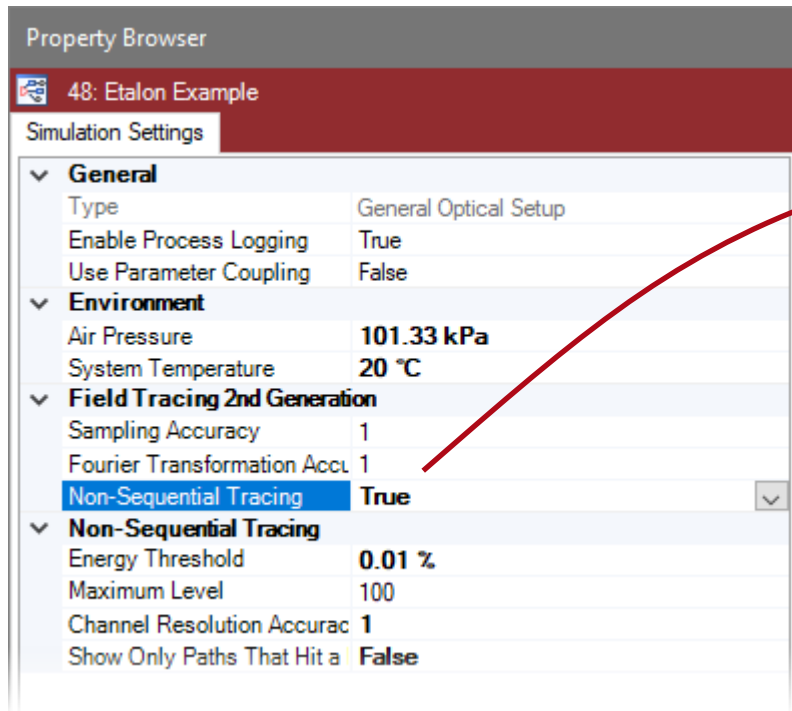
x polarized light



y polarized light

Conclusion of Second Question

How to enable sequential and non-sequential tracing?



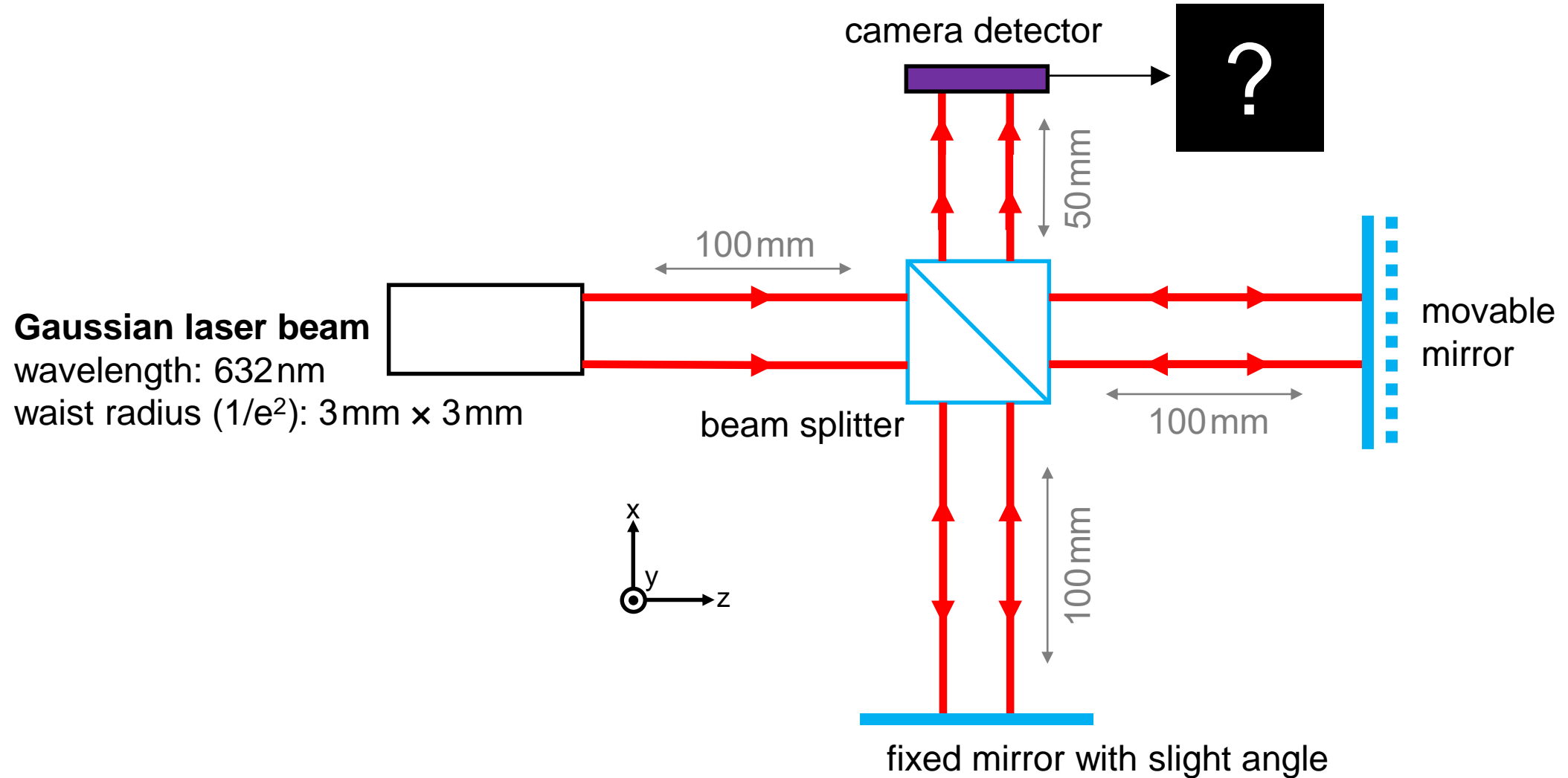
- For each Optical Setup, enable the term *Non-Sequential Tracing*
- Four channels can be chosen in each surface/component (+/+, +/-, -/-, -/+)

Surface	+/+	+/-	-/-	-/+
1st	×		×	×
2nd		×		

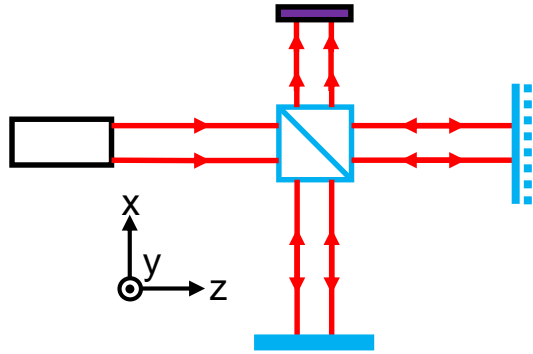
Interferometer Example

Michelson type

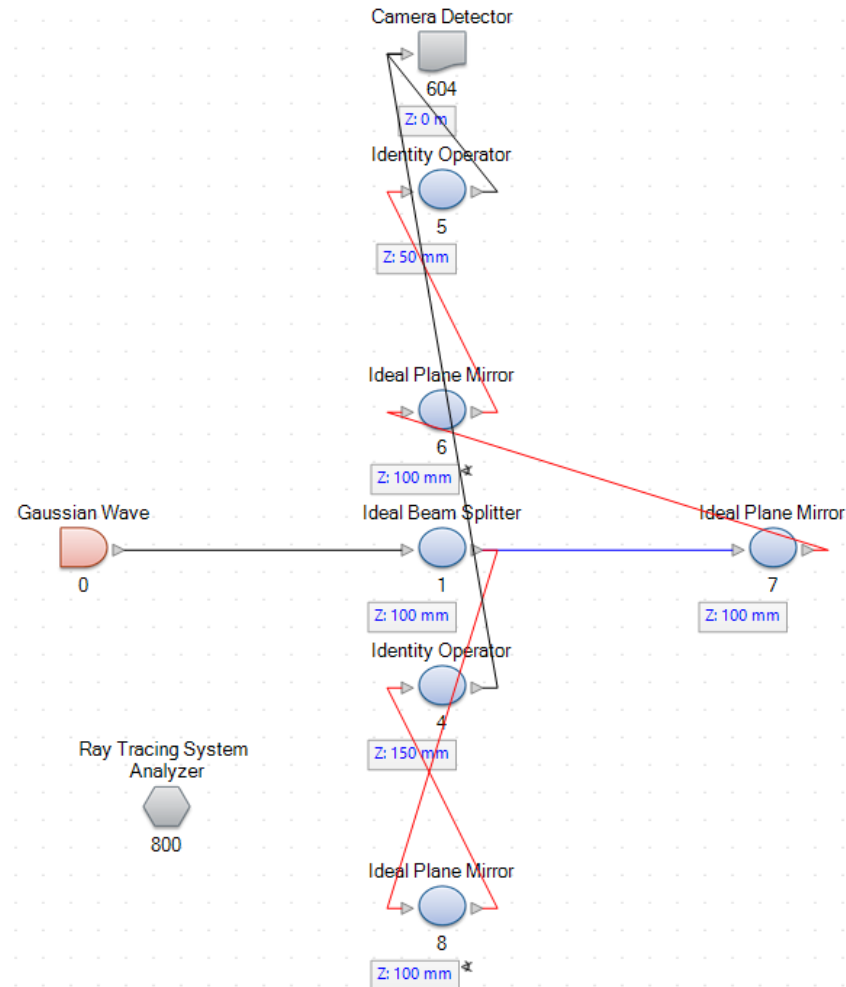
Michelson Interferometer Specification



Michelson Interferometer Setup

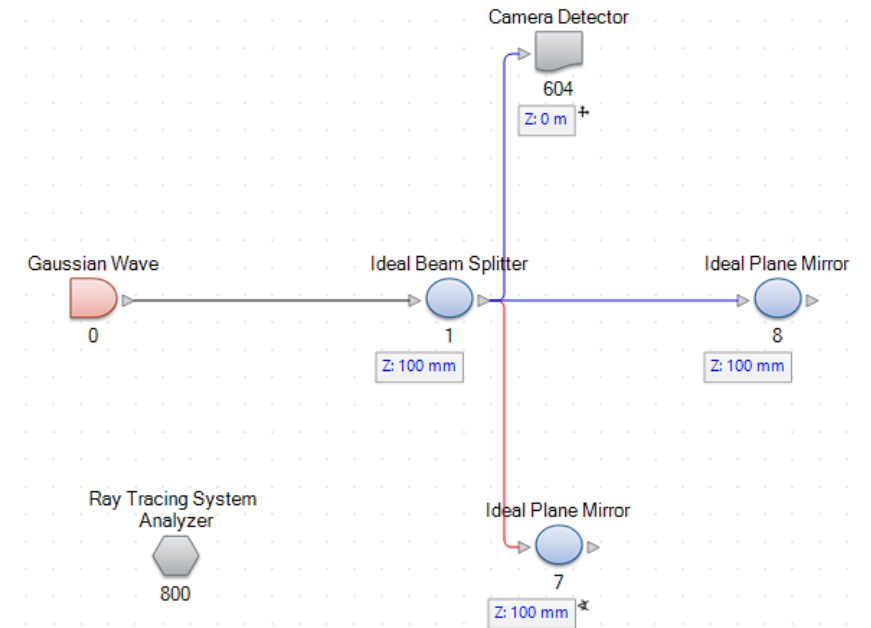


setup without NSE

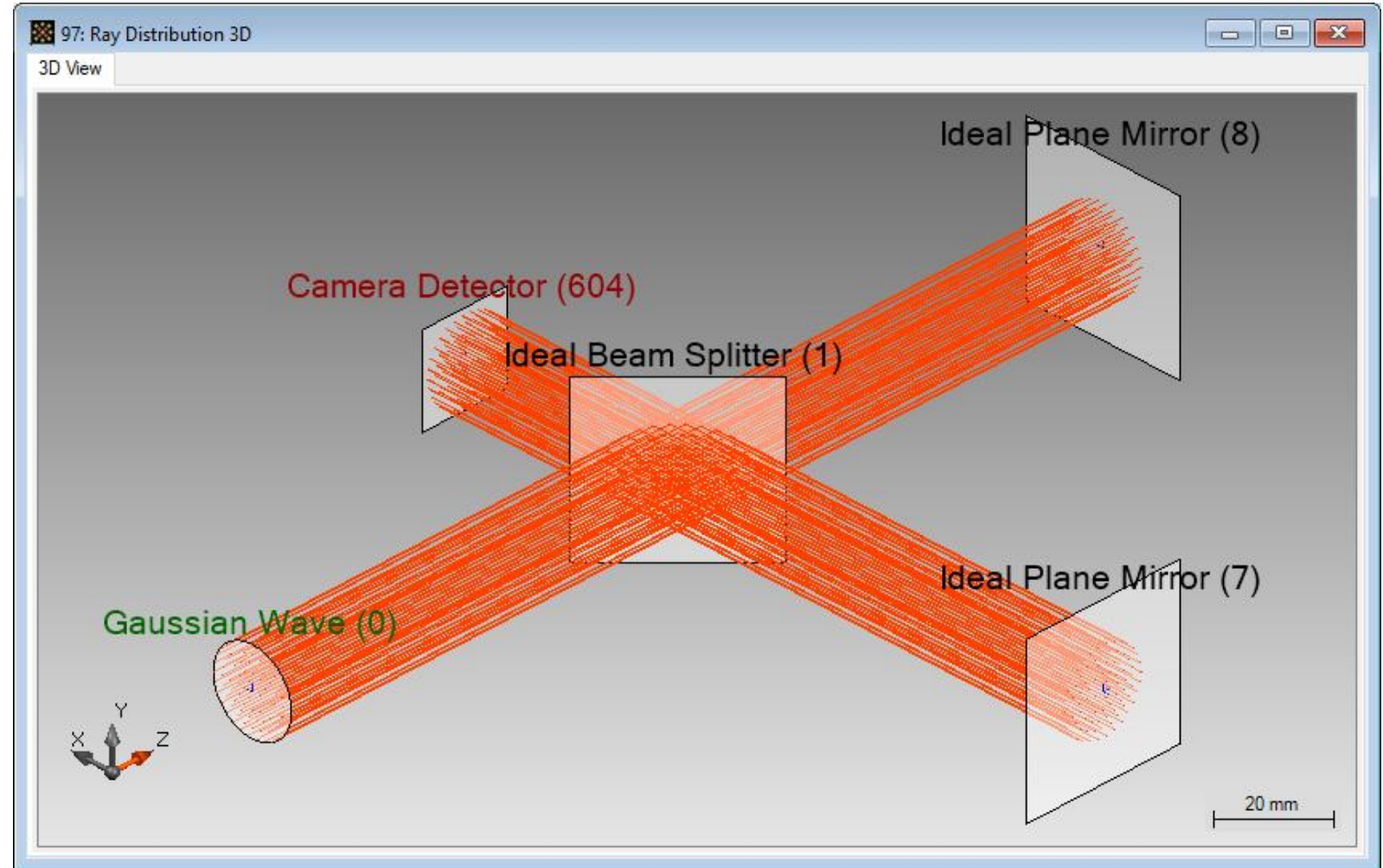
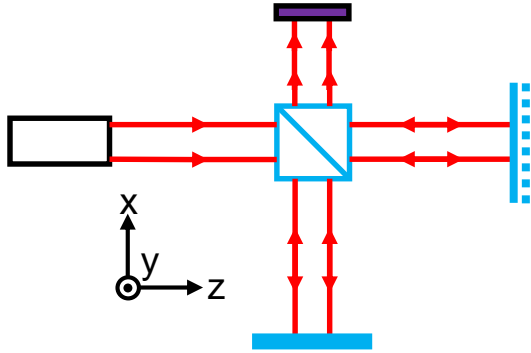


setup with NSE (*)

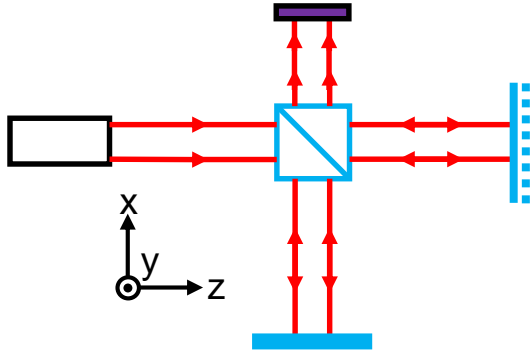
(*) if system is based on non-sequential effect, and system is build with NSE, simulation does not make sense with deactivated NSE.



Michelson Interferometer Simulation → Result (3D Ray Tracing)

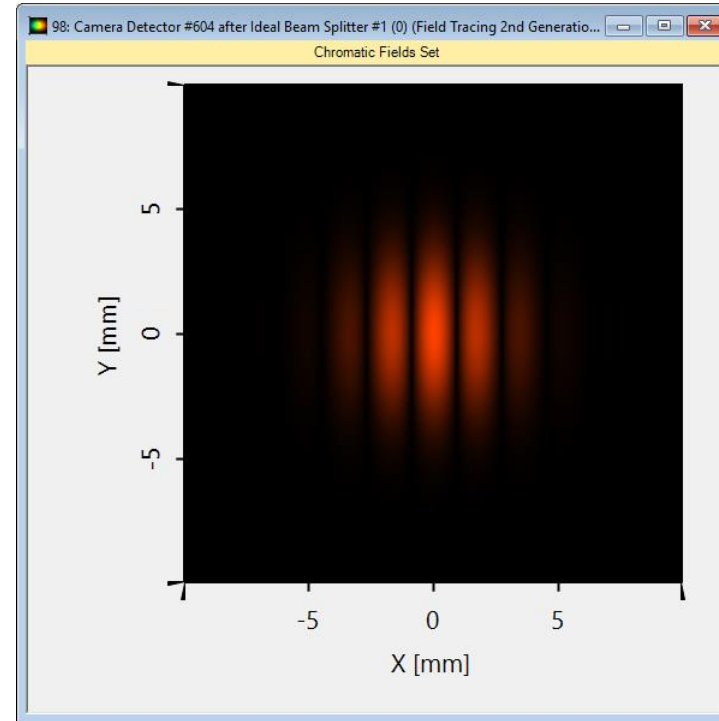


Michelson Interferometer Simulation → Results (Field Tracing) 1

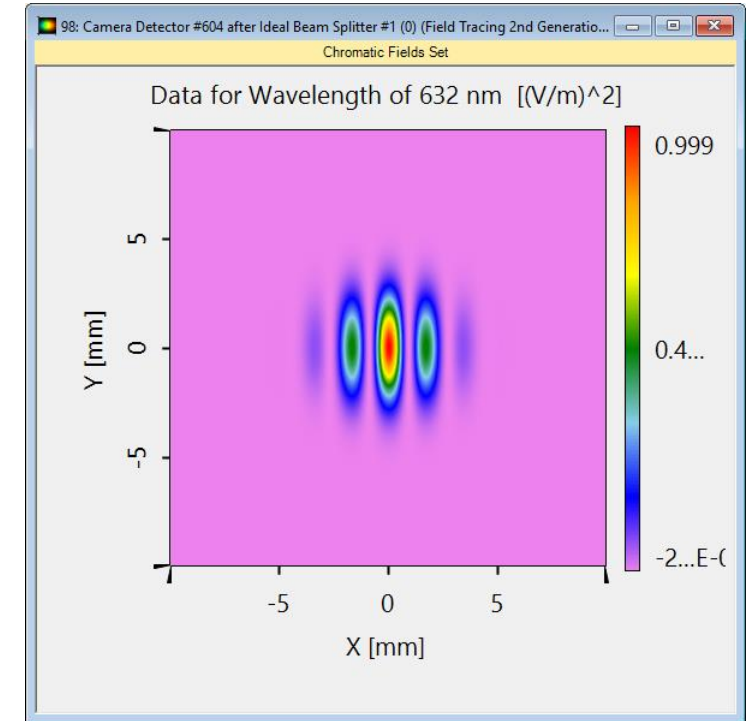


simulation time without NSE: ~3s

simulation time with NSE: ~ 2s

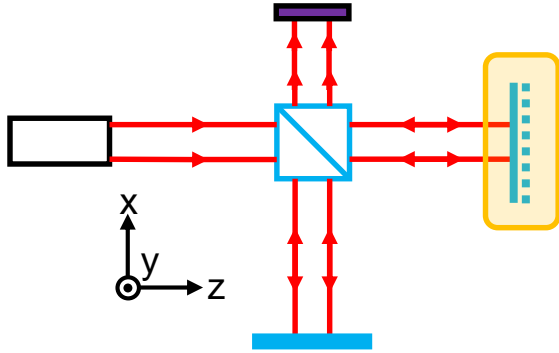


real color



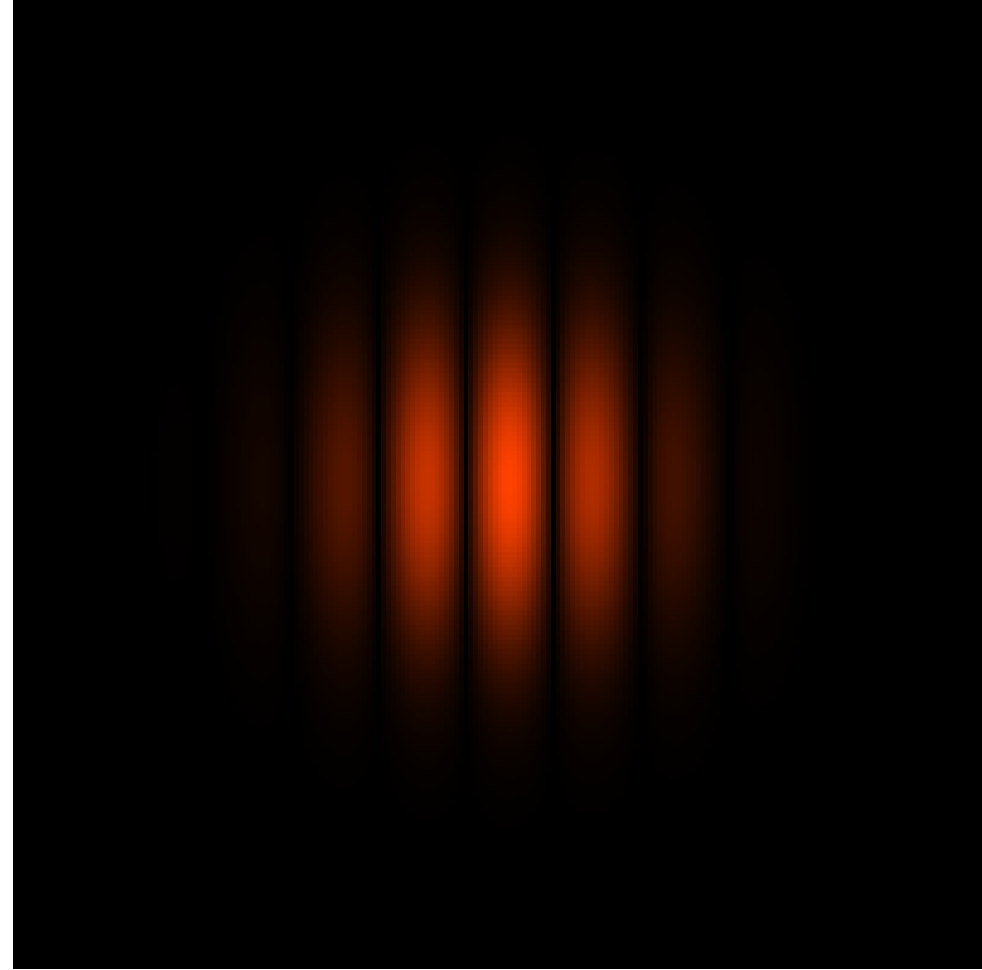
inverse rainbow colors

Michelson Interferometer Simulation → Results (Field Tracing) 2

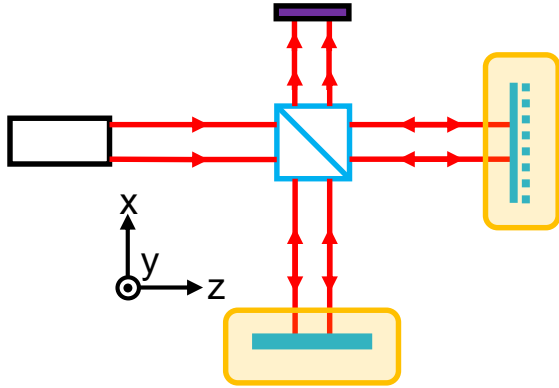


simulation with

- varying distances of movable mirror (from $-600\mu\text{m}$ to $+600\mu\text{m}$)

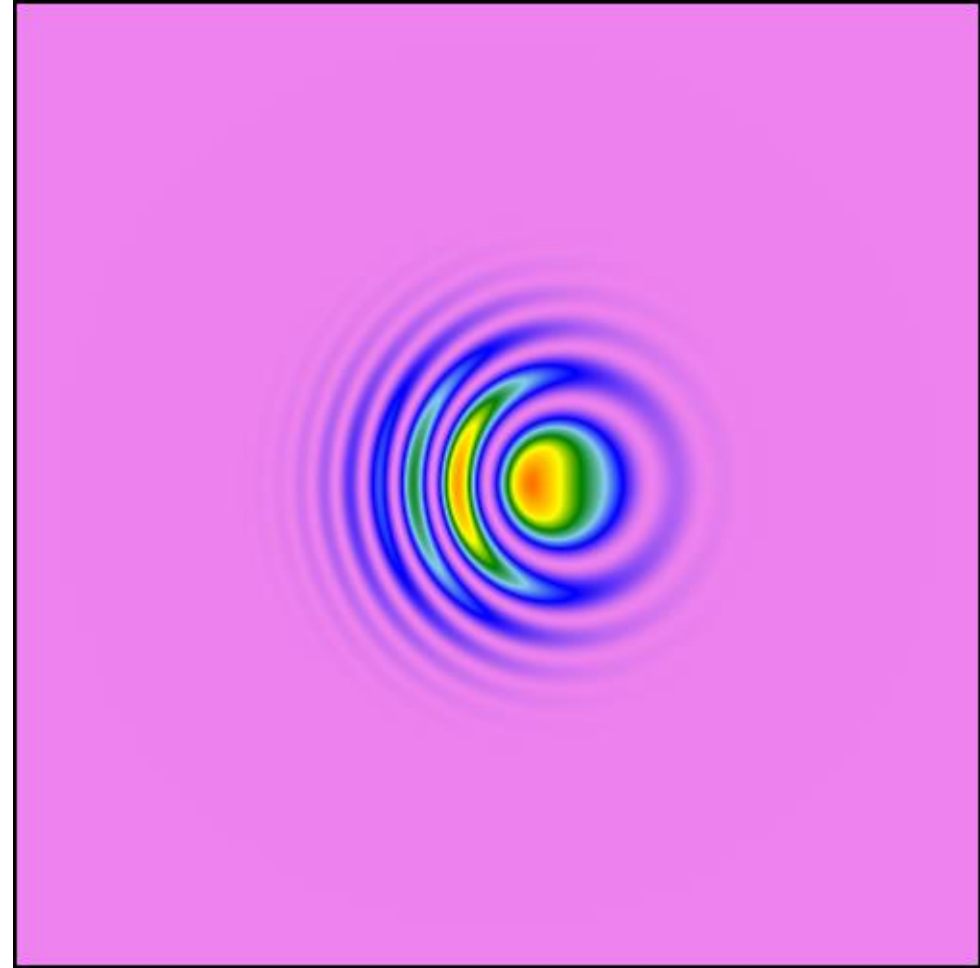


Michelson Interferometer Simulation → Results (Field Tracing) 3



simulation with

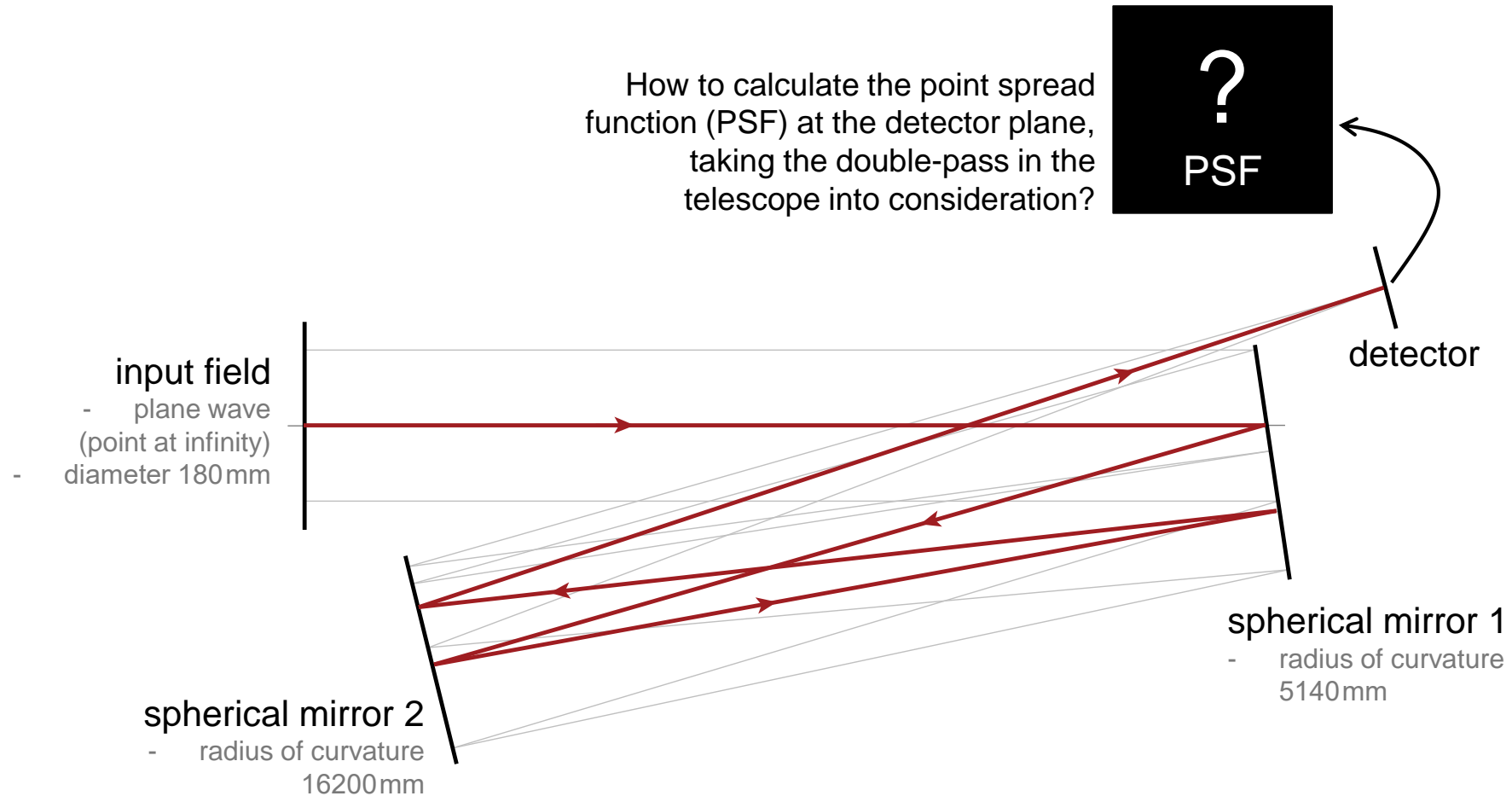
- varying distances of movable mirror (from $-600\mu\text{m}$ to $+600\mu\text{m}$)
- and fixed mirror with slight curvature (10m radius)



Telescope Example

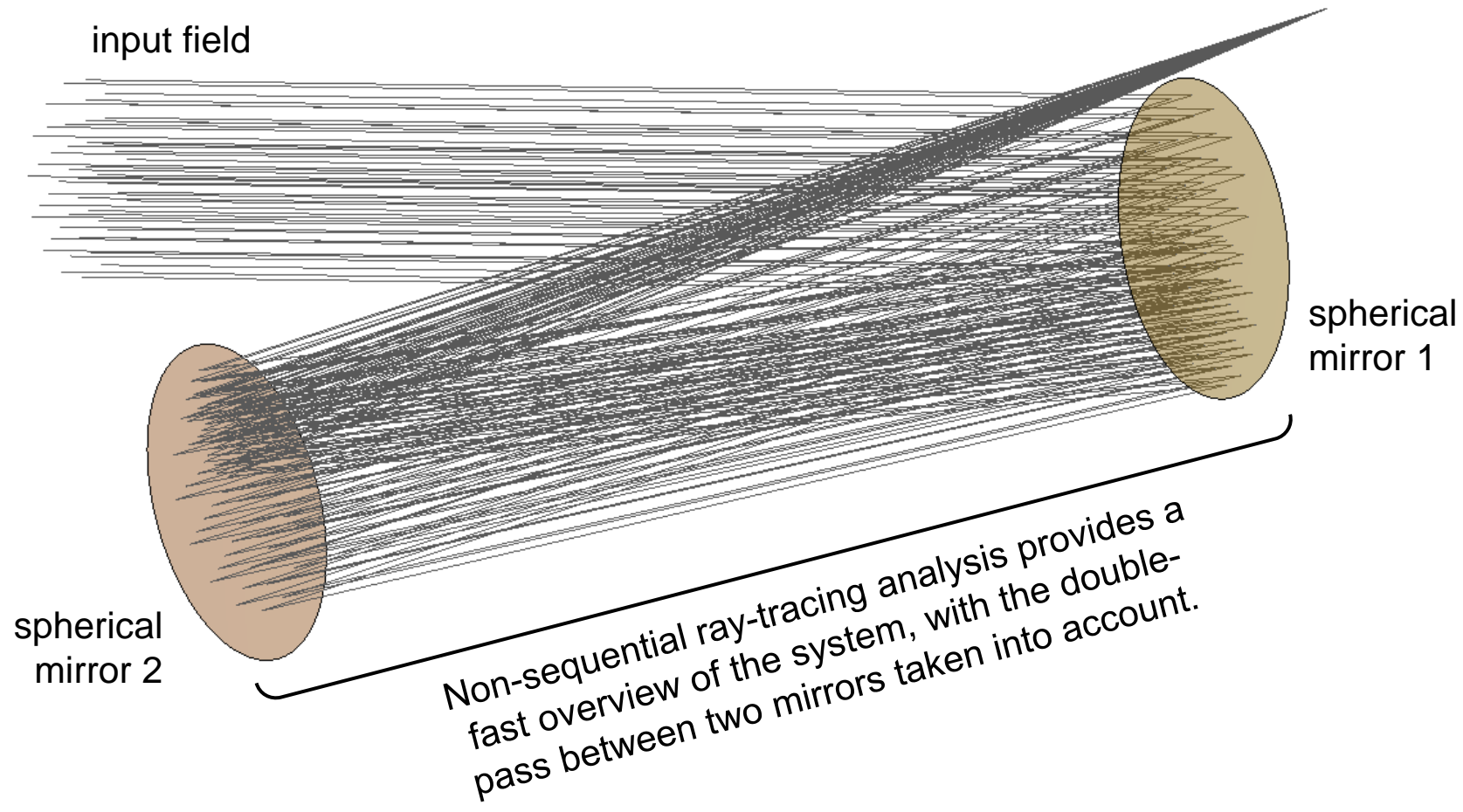
Herrig Schiefspiegler type

Modeling Task



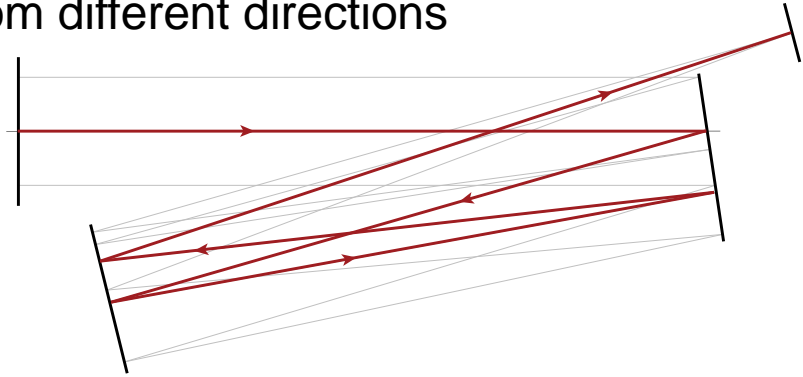
related sample file: 03_Herrig Schiefspiegler Telescope.lpd

Ray Tracing System Analyzer Result



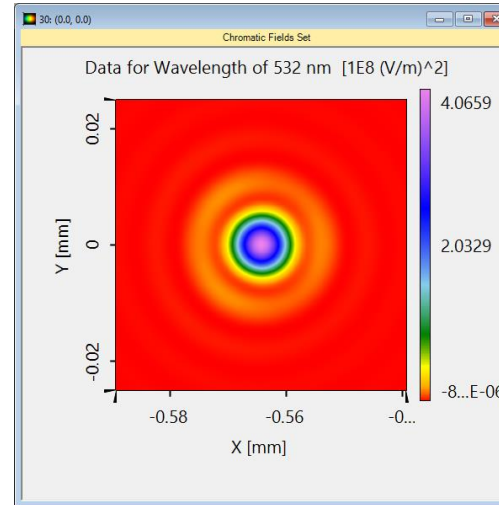
Field Tracing Results (PSFs) with Different Incident Angles

input field
from different directions

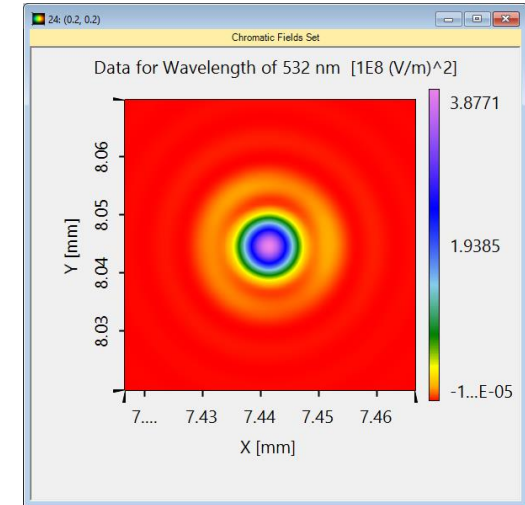


Non-sequential field tracing
for the PSF calculation,
including double-pass between two mirrors,
takes less than 10 seconds

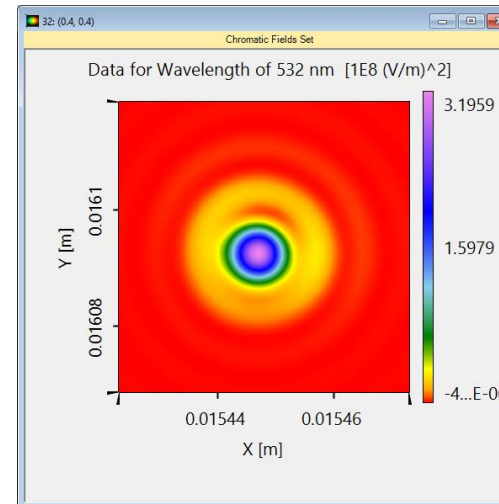
(0°, 0°)



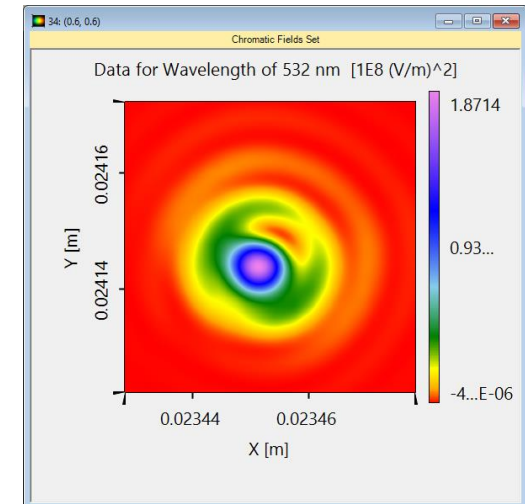
(0.2°, 0.2°)



(0.4°, 0.4°)

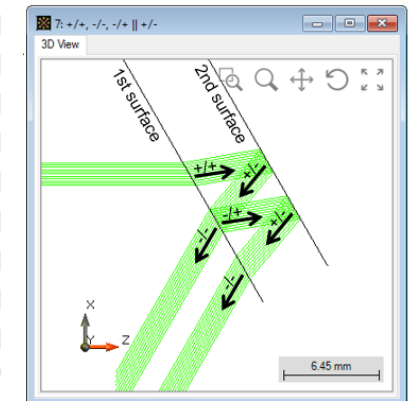
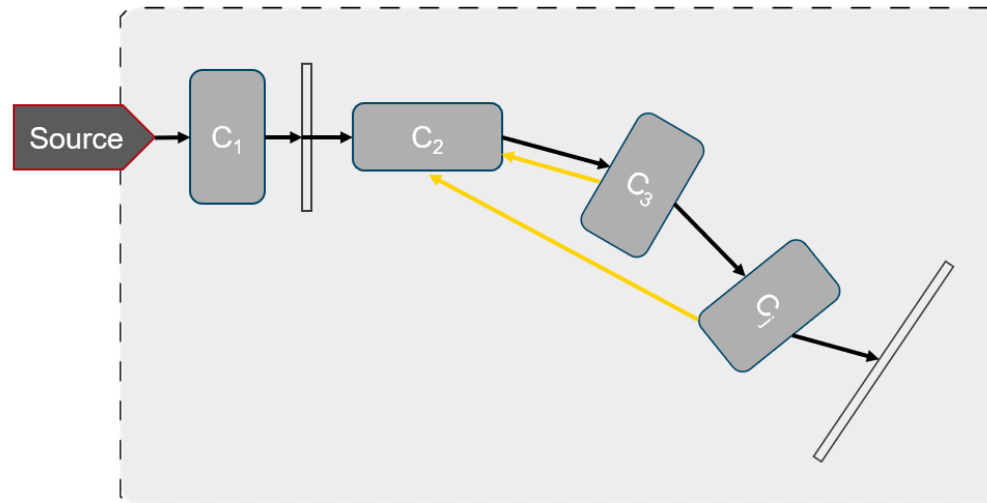
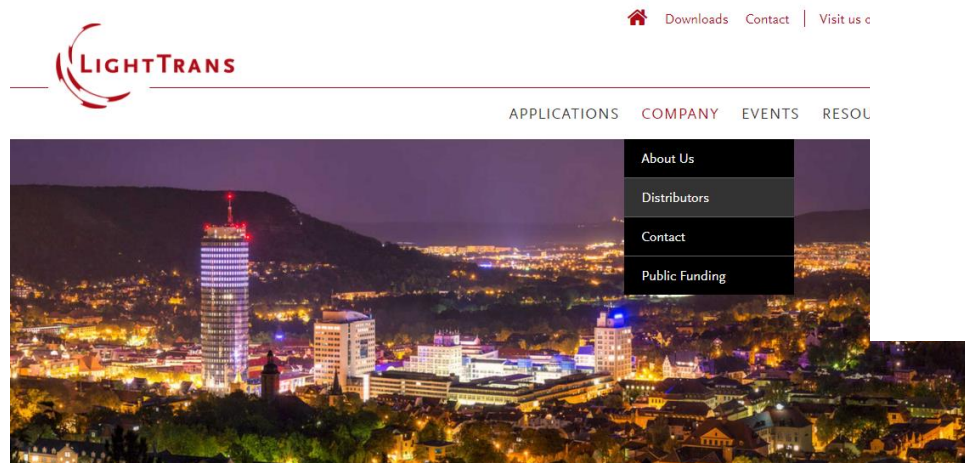


(0.6°, 0.6°)



Conclusion

- VirtualLab Fusion offers both, sequential and non-sequential ray & field tracing!
 - with total control of investigations of relevant light paths (energy consideration)
- Modeling of a lot of applications take advantages of non-sequential tracing.
- Further information
→ www.lighttrans.com



Surface	+/+	+/-	-/-	-/+
1st	x		x	x
2nd		x		