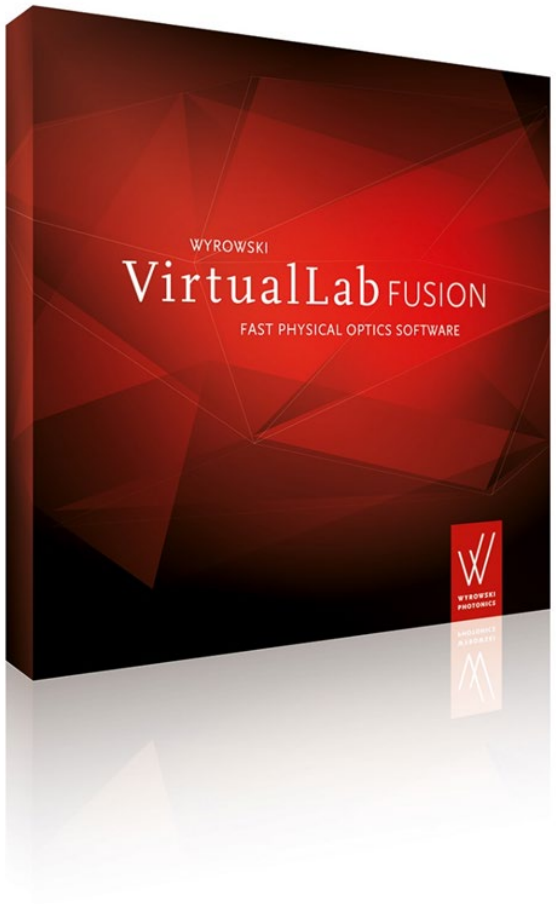
LightTrans

EPIC Online Meeting, 02.11.2021

Seamless transition between ray and physical optics modeling

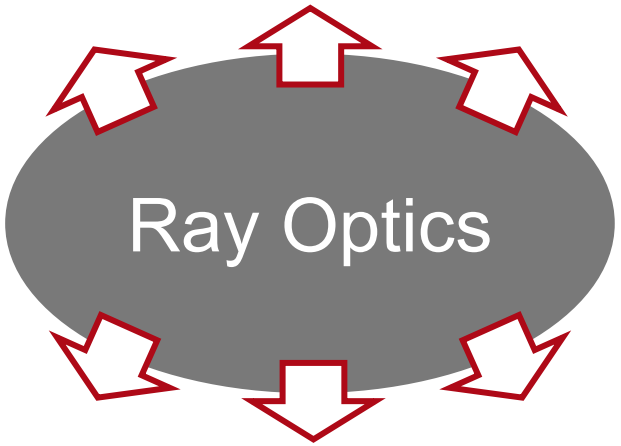
Frank Wyrowski

Fast Physical Optics Modeling with VirtualLab Fusion



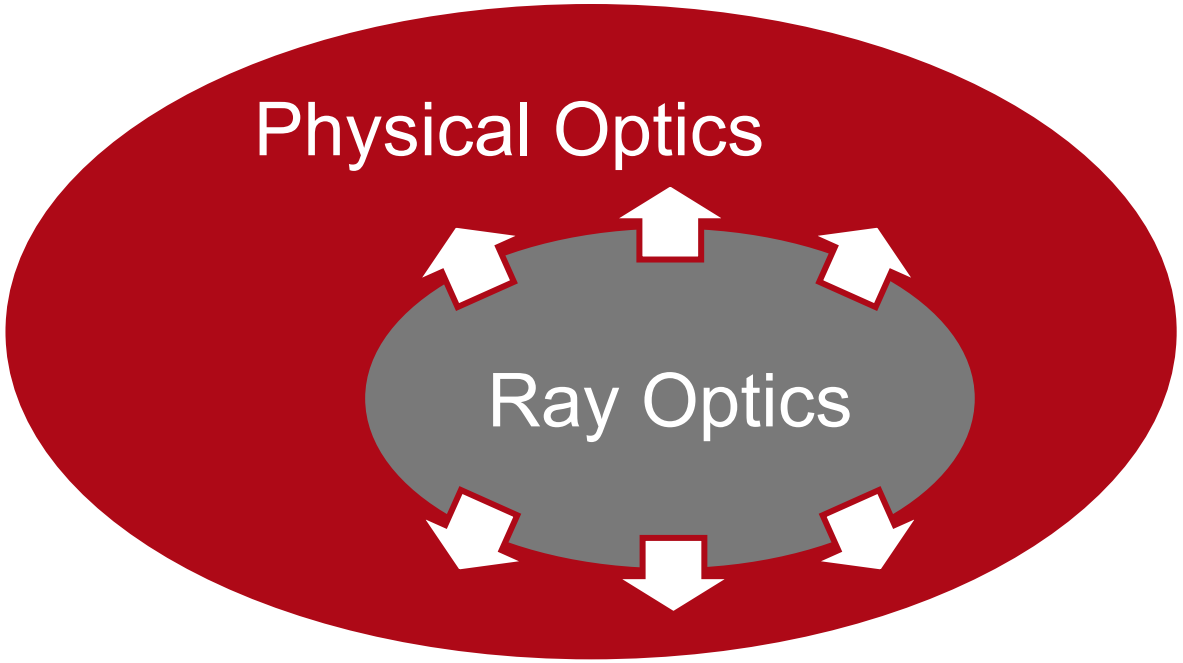
About the breakthrough technology behind VirtualLab Fusion!

Optical Modeling and Design by Ray Optics



- Increasing demand for optical modeling and design in a more general theoretical and algorithm framework.
- Reasons include:
  - Varity of sources
  - Micro/nano-structured surfaces
  - Miniaturization
  - Varity of application scenarios and use cases

Ray Optics Is Subset of Physical Optics



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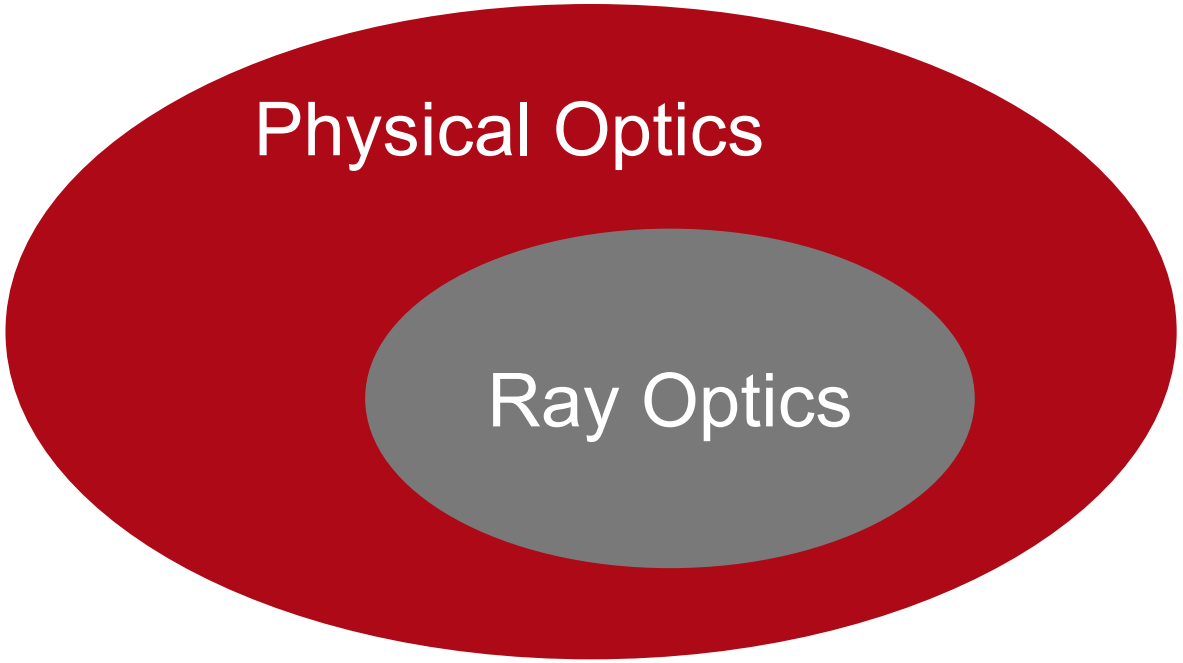


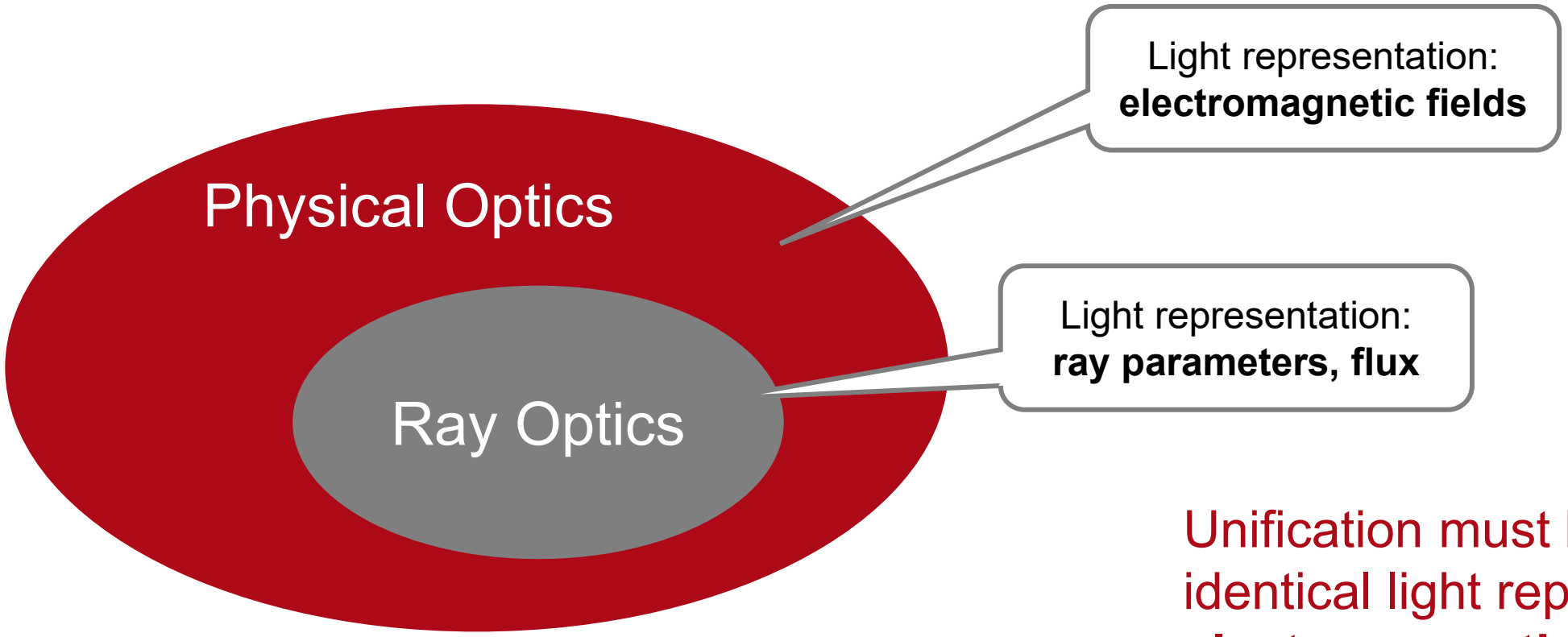
In practice of optical modeling and design **ray and physical optics appear deeply different**!

⇩

Why?

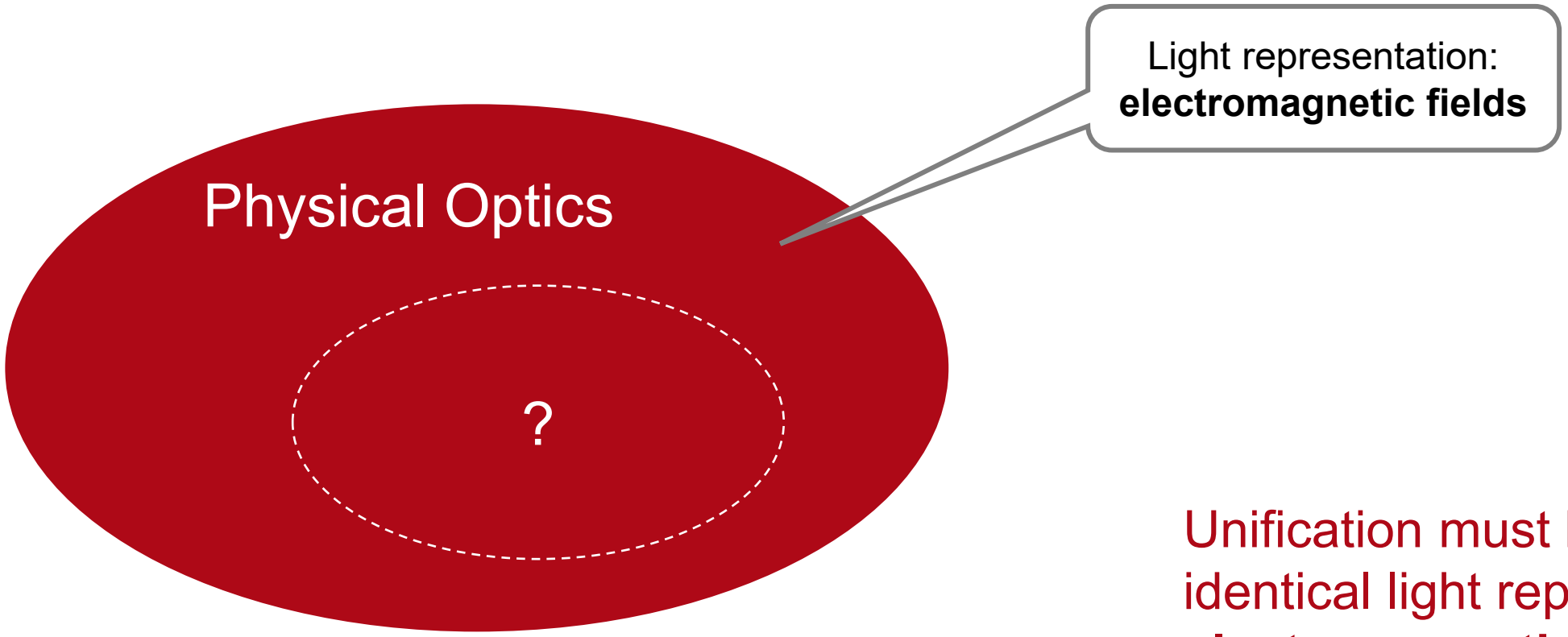
How to overcome that?

Unified Modeling and Design: Light Representation



Unification must be based on identical light representation:
electromagnetic fields

Unified Modeling and Design: Light Representation



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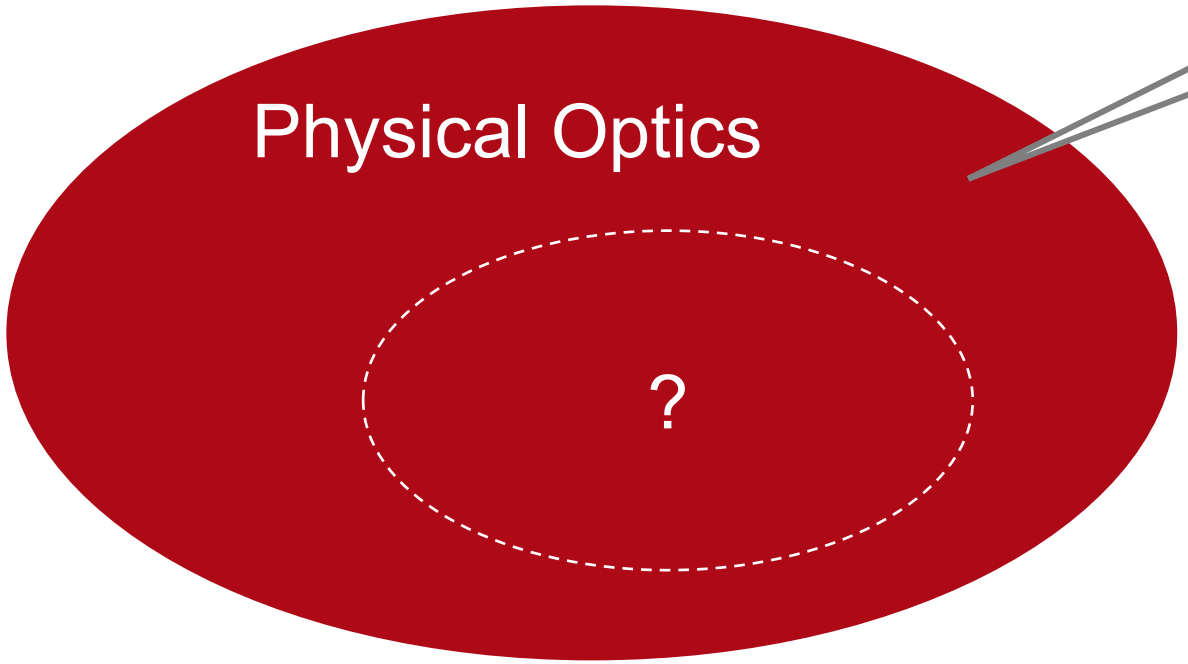
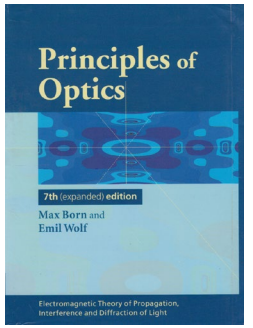
Unified Modeling and Design: Light Representation



Light representation:
electromagnetic fields

We need to identify that part of physical optics, which deals with "***geometrical laws relating to the propagation of the 'amplitude vectors' E and H.***"

We follow a suggestion of Max Born and Emil Wolf!

Citation from 

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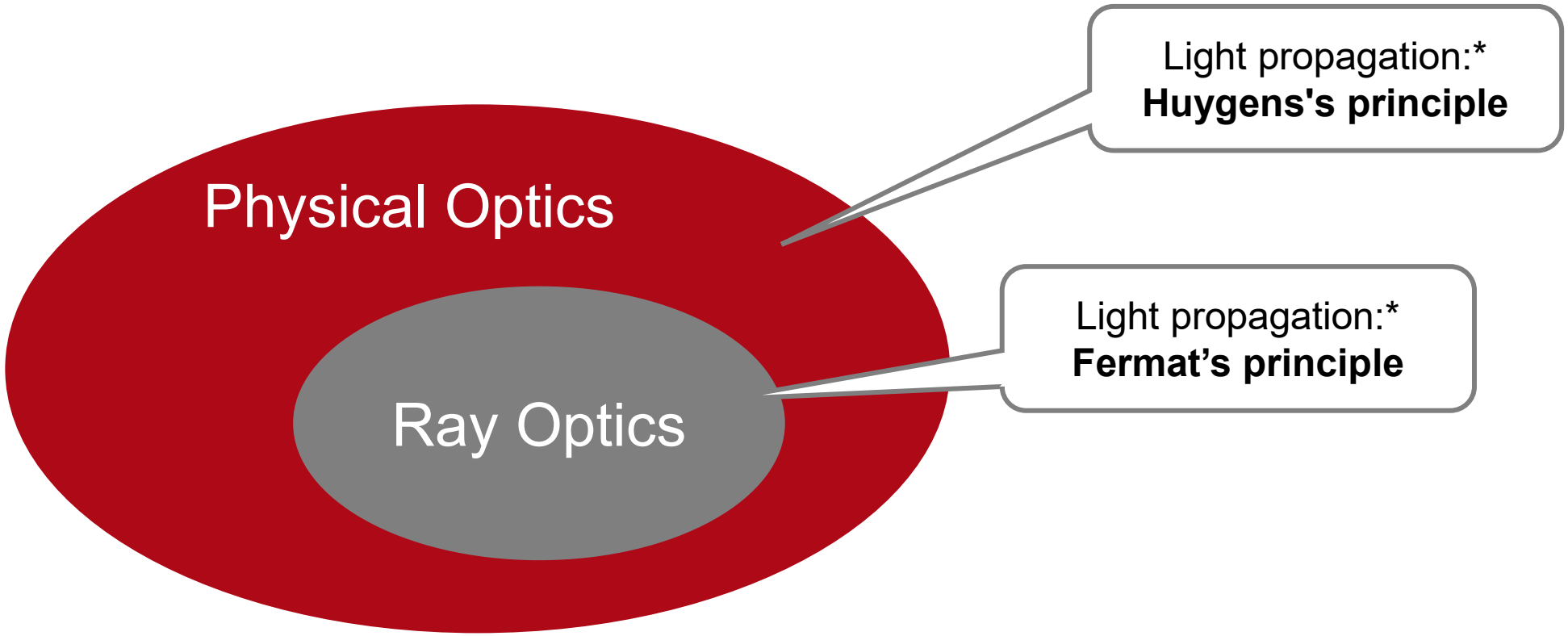
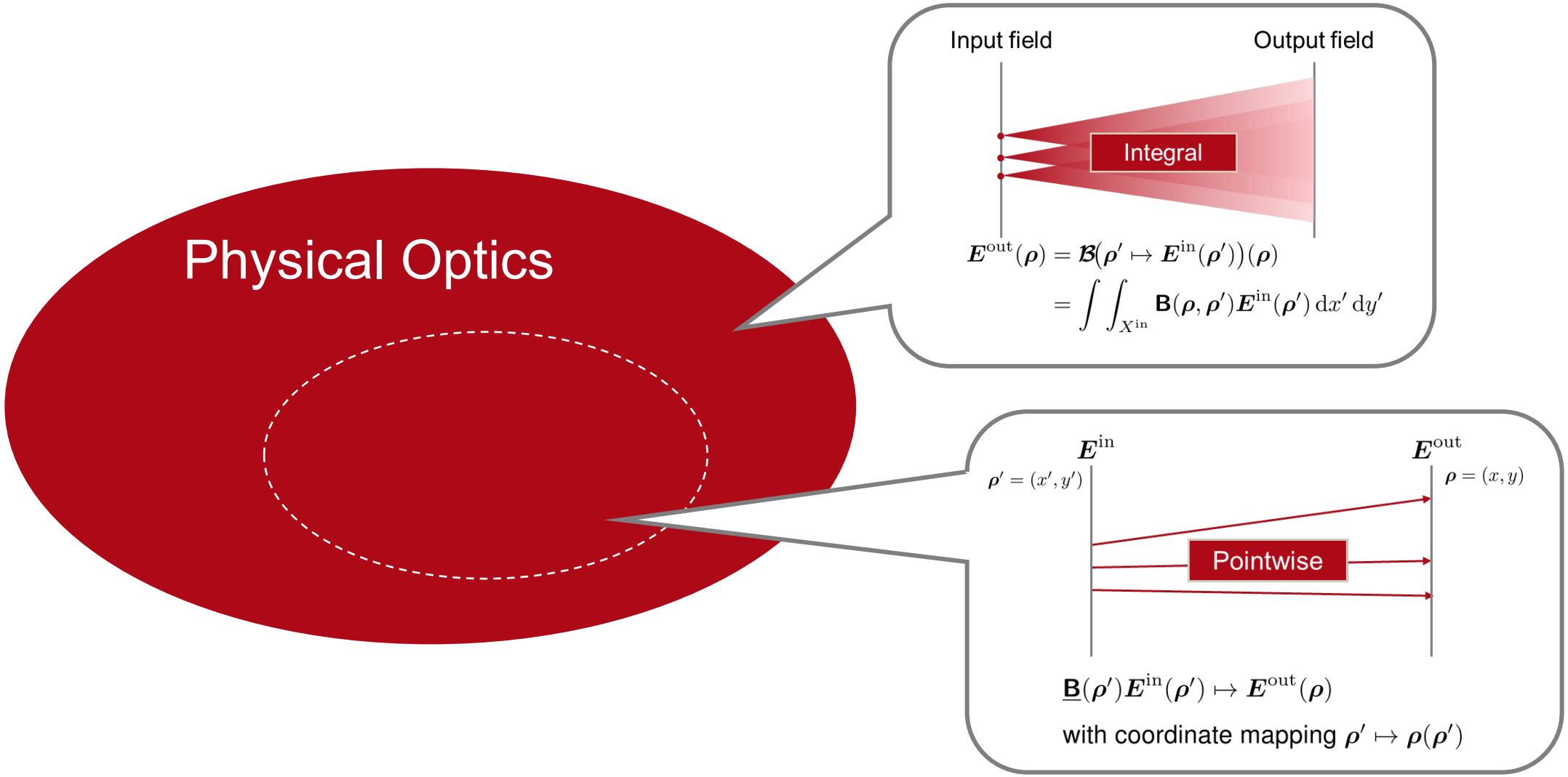
Unified Modeling and Design: Light Propagation

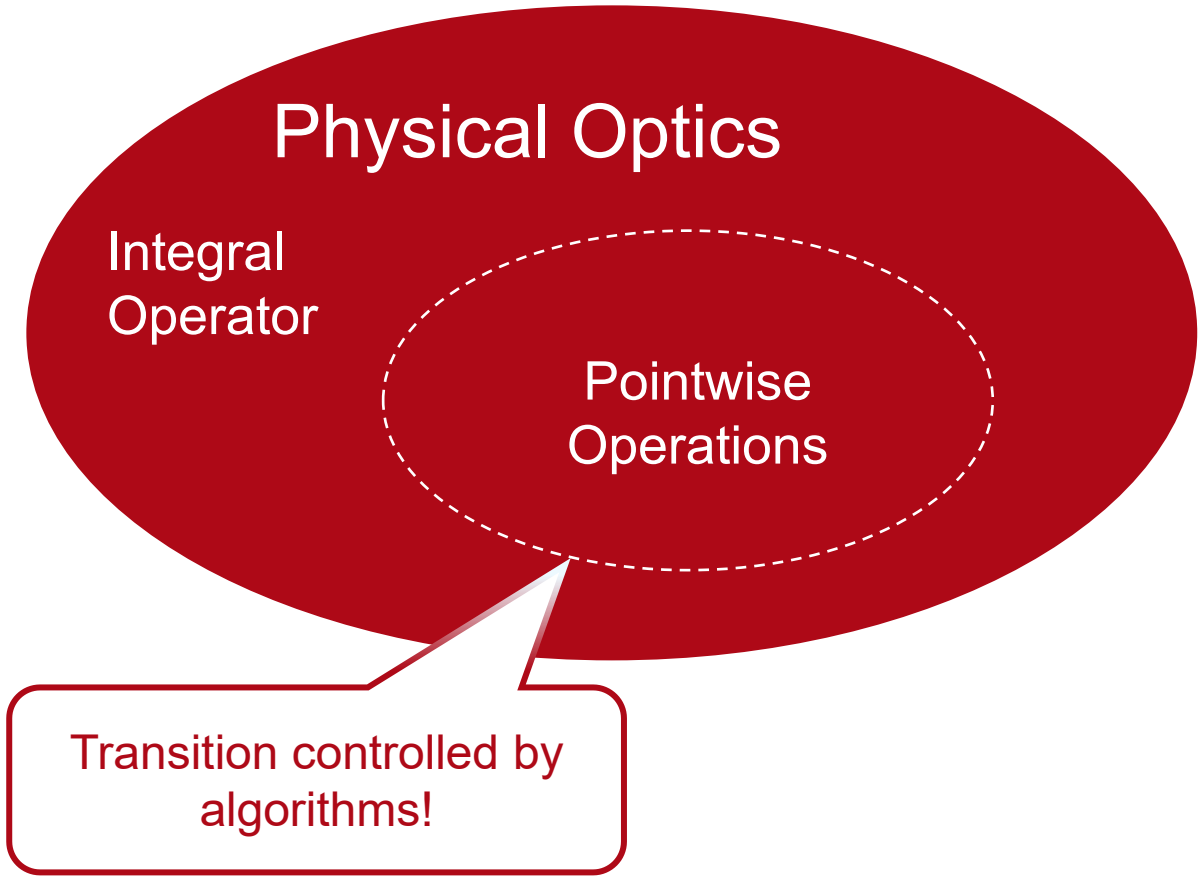


*Here: Propagation in homogeneous media

Unified Modeling and Design: Light Propagation



Unified Modeling and Design



Integral

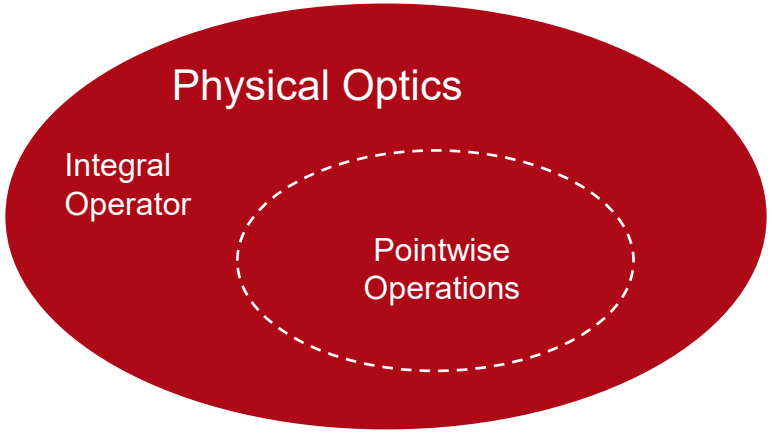
$$\boldsymbol{E}^{\mathrm{out}}(\boldsymbol{\rho}) = \mathcal{B}\big(\boldsymbol{\rho}' \mapsto \boldsymbol{E}^{\mathrm{in}}(\boldsymbol{\rho}')\big)(\boldsymbol{\rho}) = \int\int_{X^{\mathrm{in}}} \mathsf{B}(\boldsymbol{\rho}, \boldsymbol{\rho}')\boldsymbol{E}^{\mathrm{in}}(\boldsymbol{\rho}')\,\mathrm{d}x'\,\mathrm{d}y'$$

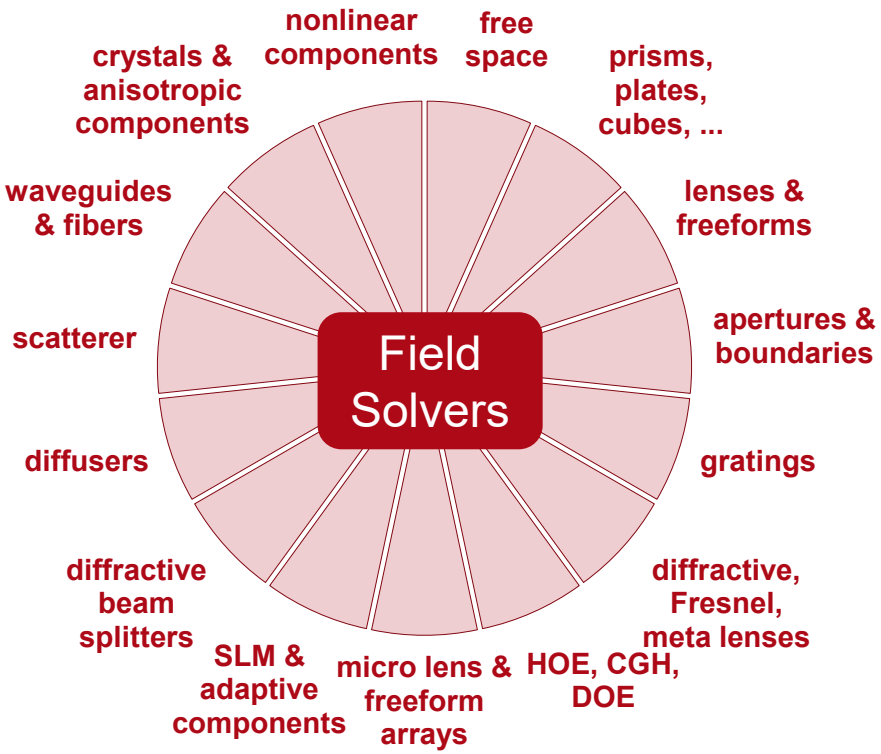
Pointwise

$$\underline{\mathsf{B}}(\boldsymbol{\rho}')\boldsymbol{E}^{\mathrm{in}}(\boldsymbol{\rho}') \mapsto \boldsymbol{E}^{\mathrm{out}}(\boldsymbol{\rho})$$

with coordinate mapping $\boldsymbol{\rho}' \mapsto \boldsymbol{\rho}(\boldsymbol{\rho}')$

Connecting Solvers: Components





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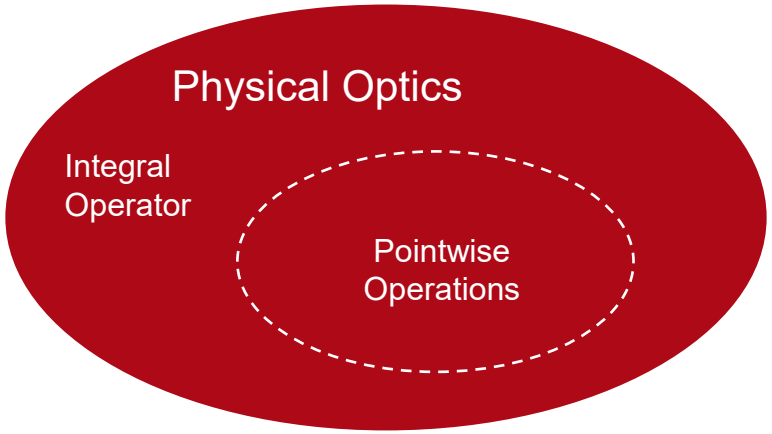
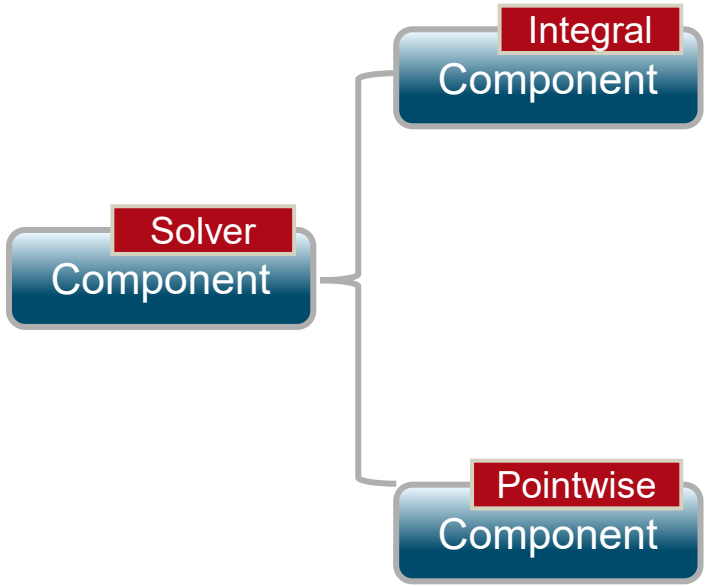


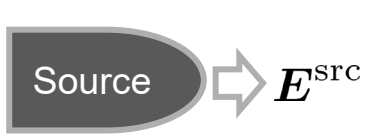


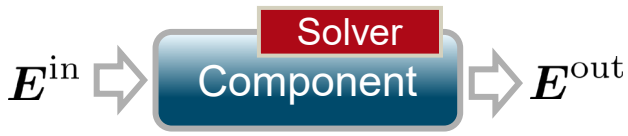
Includes

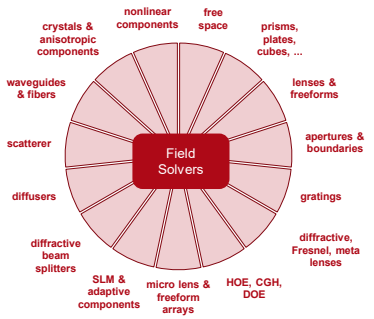
- Fourier Modal Method (FMM)
- Rigorous Coupled Wave (RCWA)
- Beam Propagation Method (BPM)
- LP Solver
- Mie Solver
- Runge Kutta Solver
- BSDF data

Includes

- Stratified media S matrix
- Coating matrix
- FMM per order
- Local elementary solvers
  - Thin Element Approximation (TEA)
  - Local Stratified Media Approximation (LSMA)
  - Local Grating Approximation (LGA)







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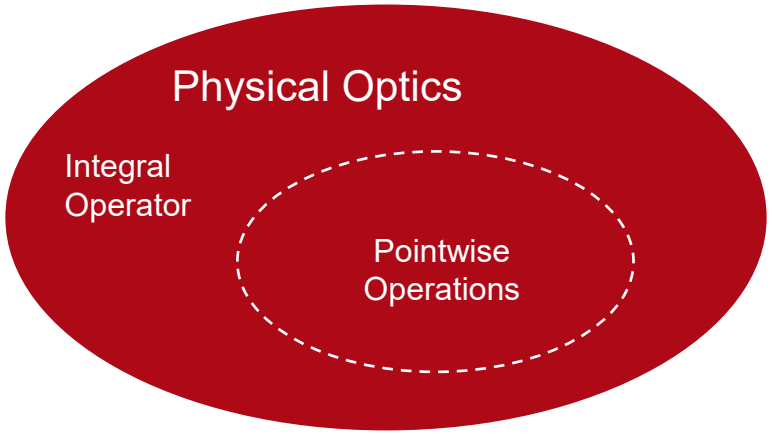
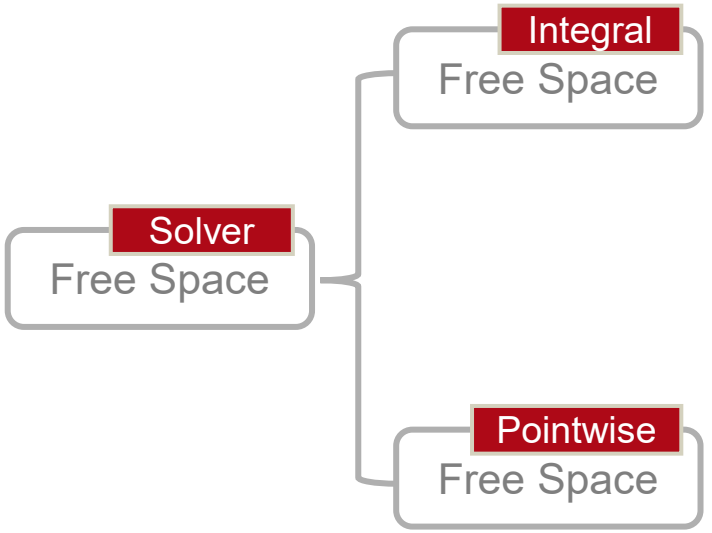
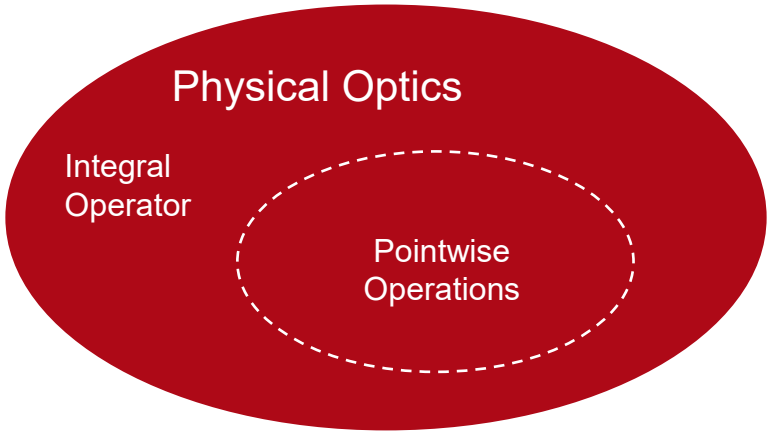


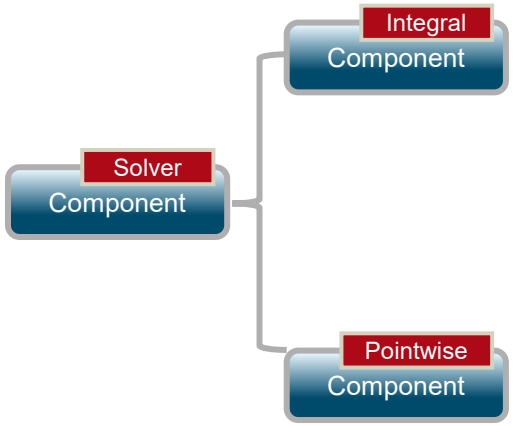


Includes and extends

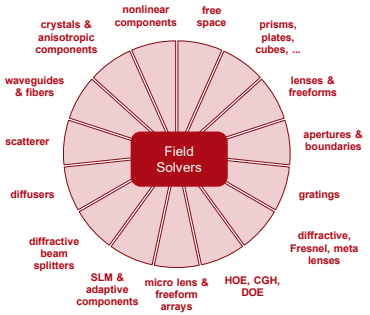
- SPW integral
- Rayleigh-Sommerfeld integral
- Huygens' integral
- Far-field integral
- Debye integral
- Fresnel integral
- Fraunhofer integral

Connecting Solvers

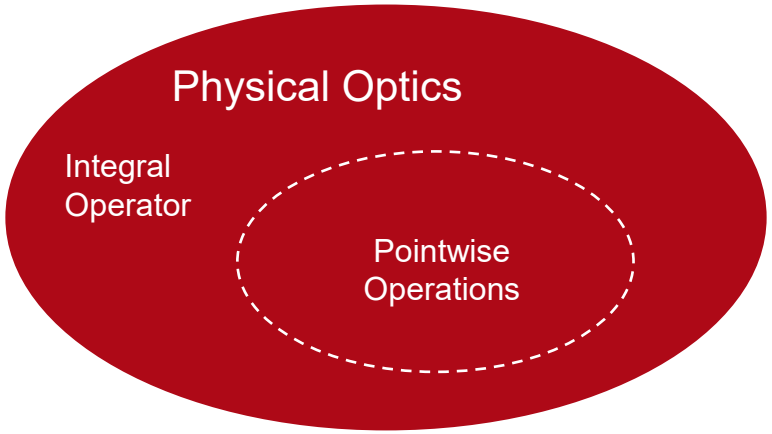


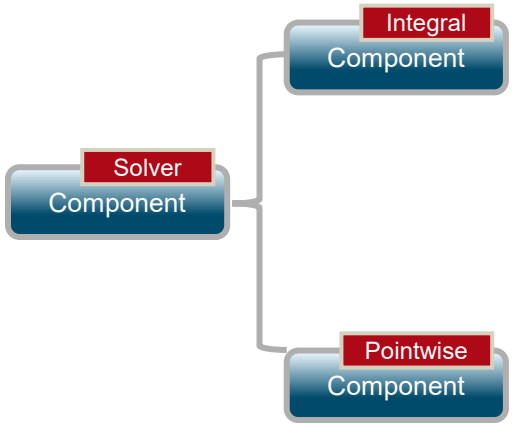


Component solver selected with component!



Connecting Solvers: Example Configuration





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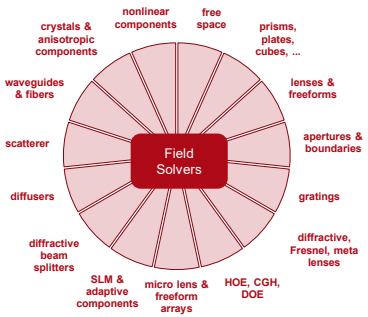

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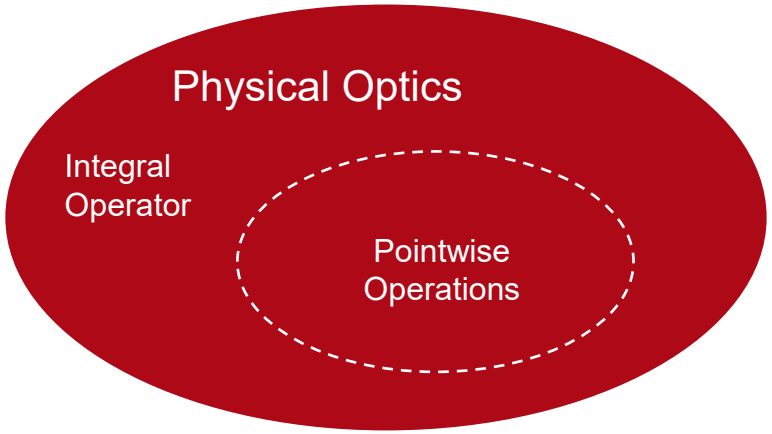
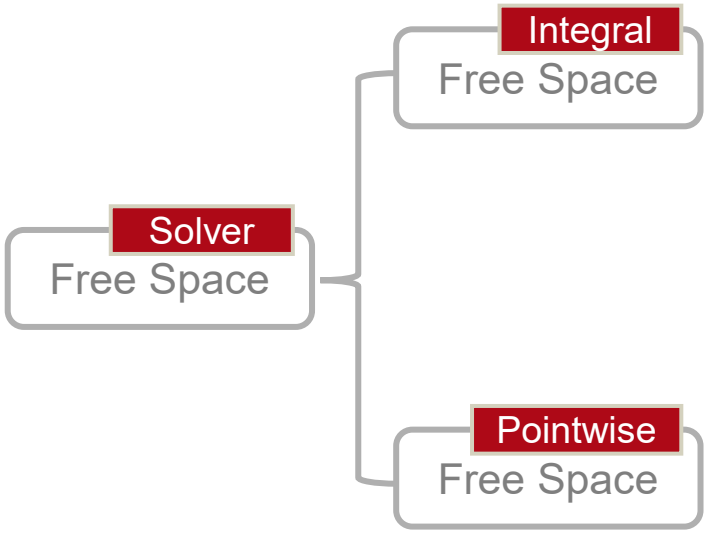
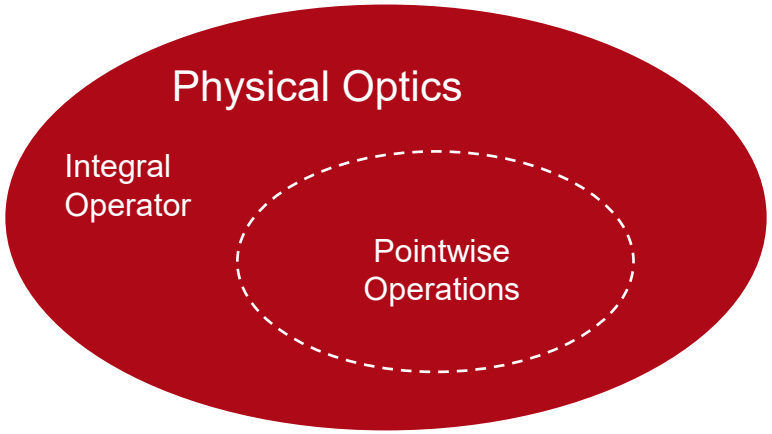


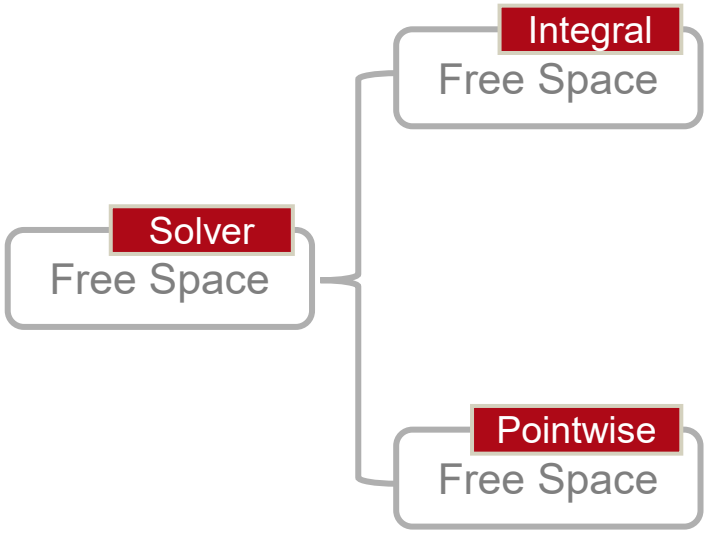


Selection of free-space propagation

- Preconfigured
- Automatic
- Customized

Connecting Solvers: Example Configuration





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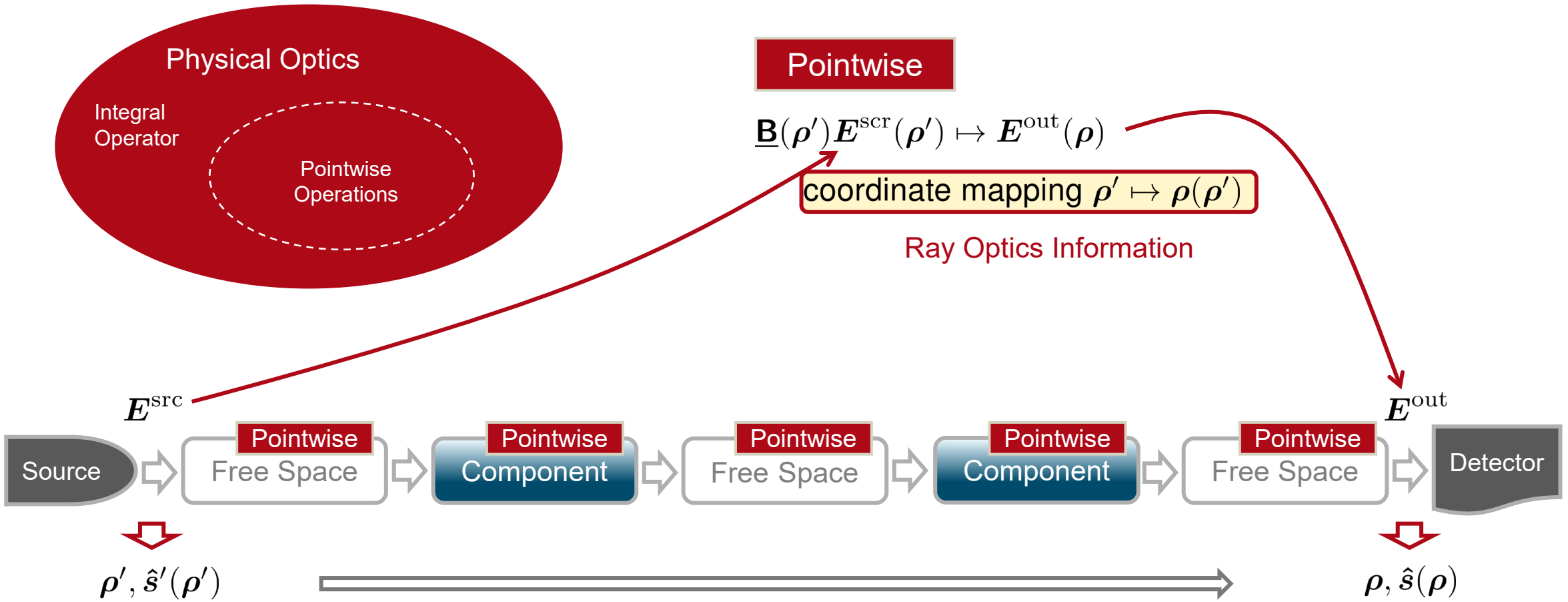
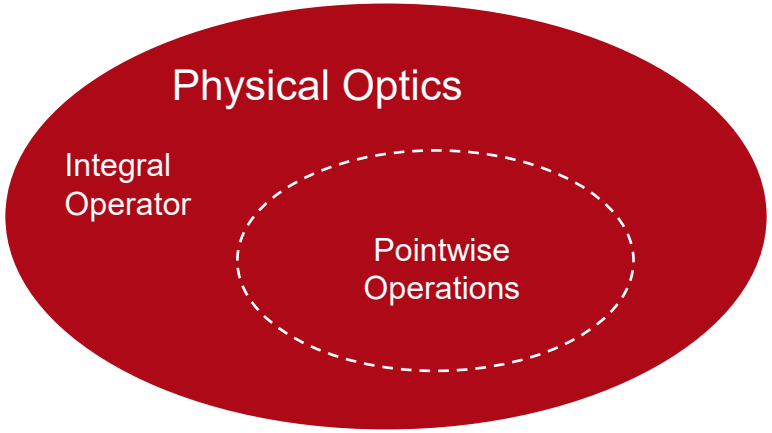
Connecting Solvers: Example Configuration II



Connecting Solvers: From Pointwise to Ray Optics

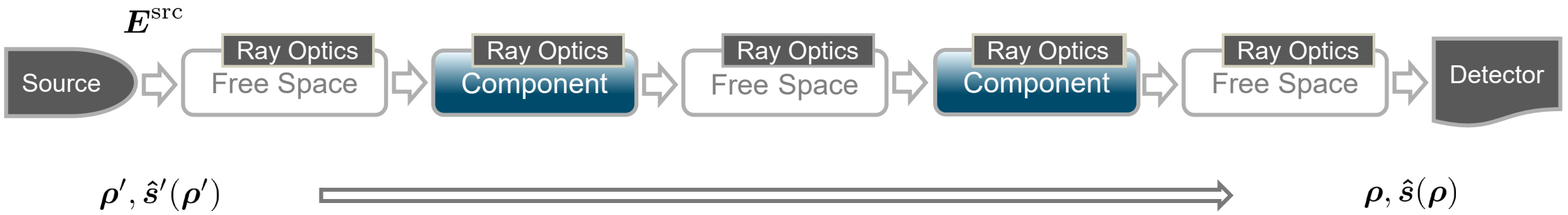


Pointwise

$$\underline{\mathbf{B}}(\boldsymbol{\rho}')\boldsymbol{E}^{\mathrm{scr}}(\boldsymbol{\rho}') \mapsto \boldsymbol{E}^{\mathrm{out}}(\boldsymbol{\rho})$$

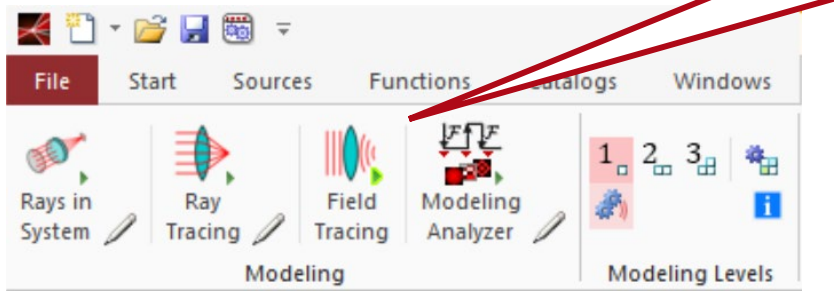
coordinate mapping $\boldsymbol{\rho}' \mapsto \boldsymbol{\rho}(\boldsymbol{\rho}')$

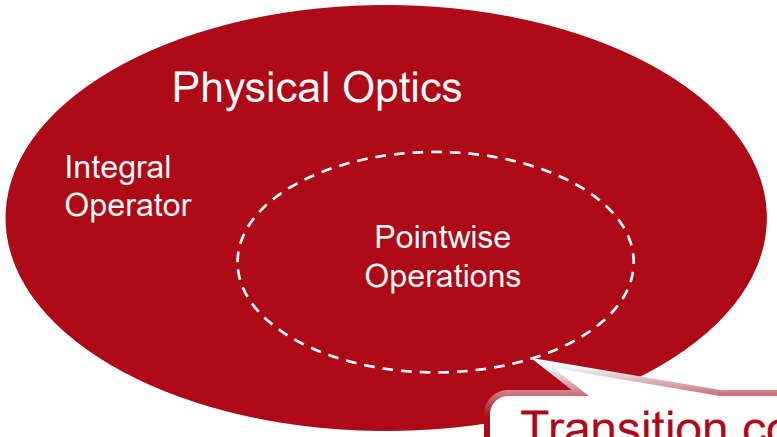
Ray Optics Information



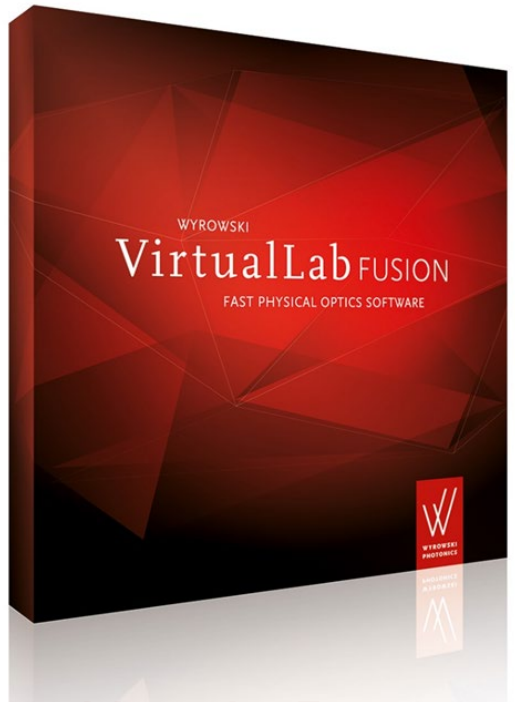
Modeling Control Panel

Field Tracing: Physical-optics system modeling technology





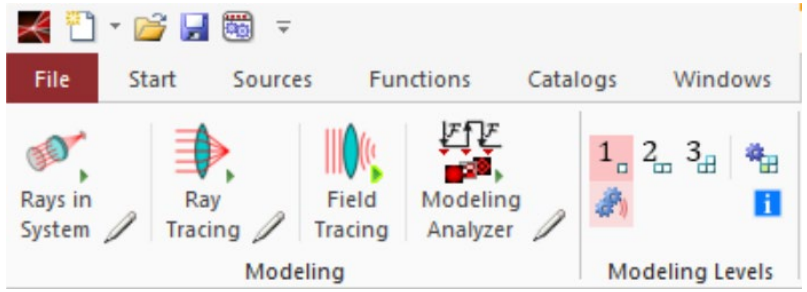
Transition controlled by algorithms!



- New in Release 2021.1
- Further developed in 2021.2

... and coming releases 2022

Modeling Control Panel: Example Mach-Zehnder Interferometer

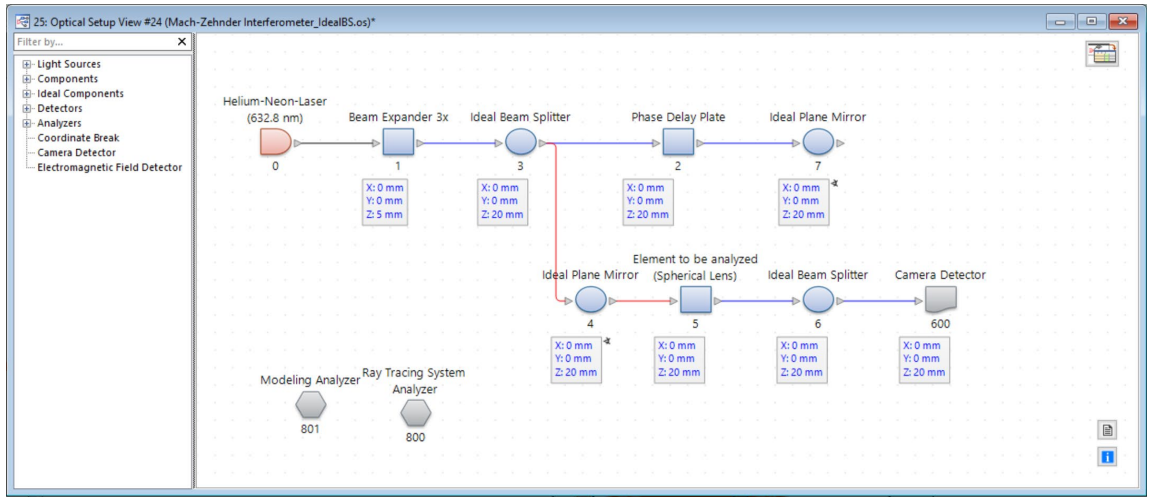


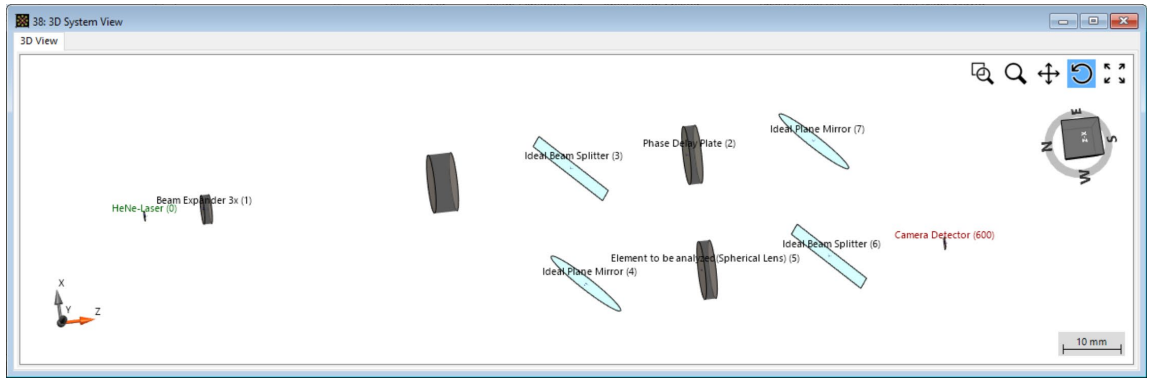
Physical Optics

Integral Operator

Pointwise Operations

Transition controlled by algorithms!





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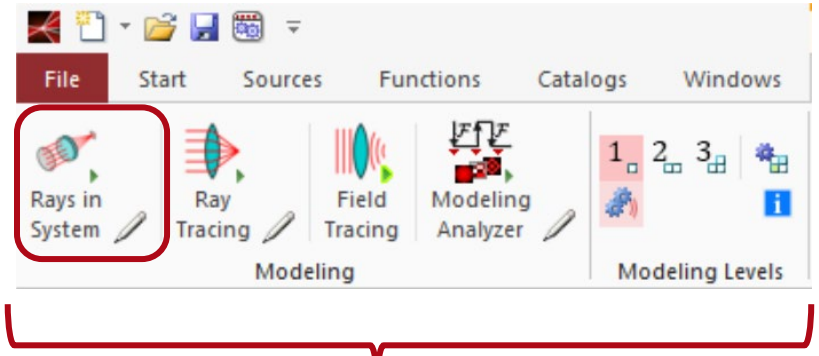

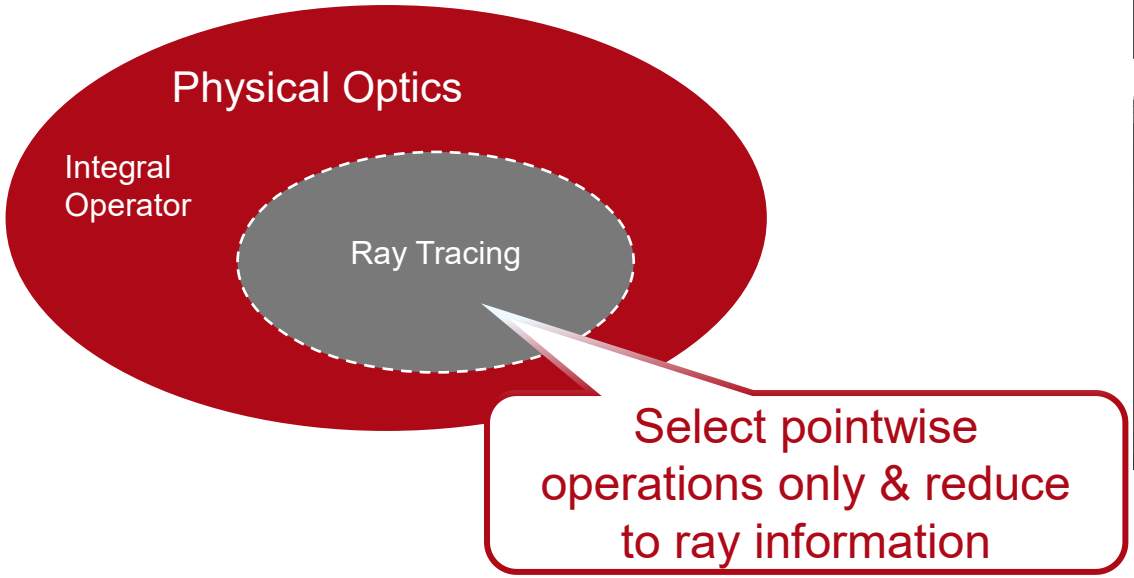

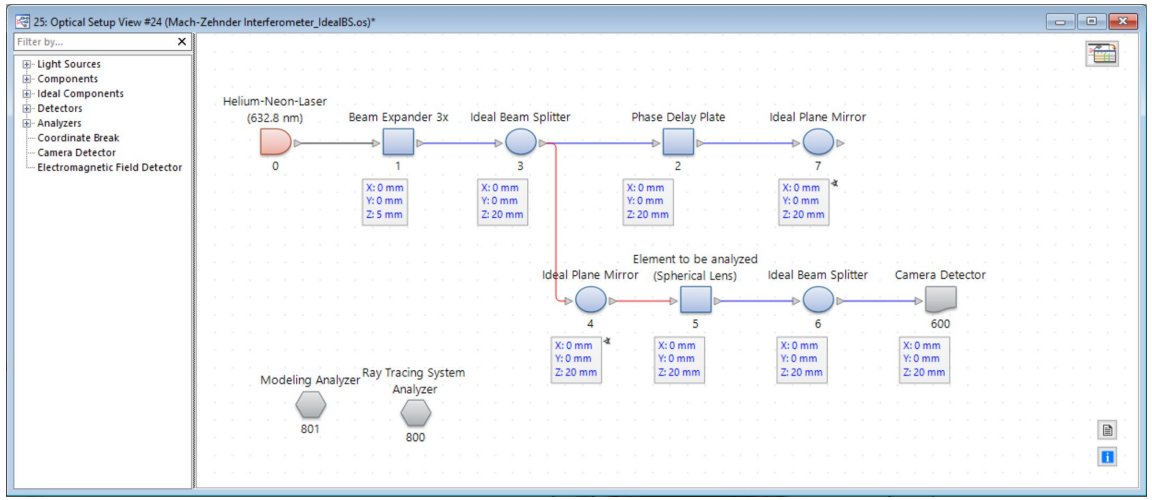

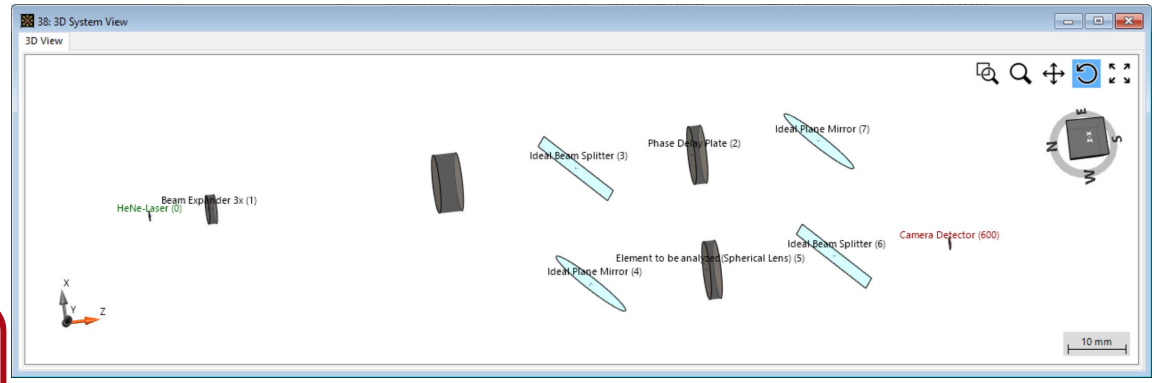

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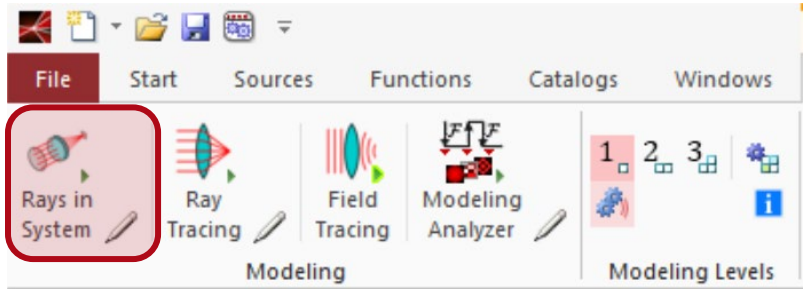

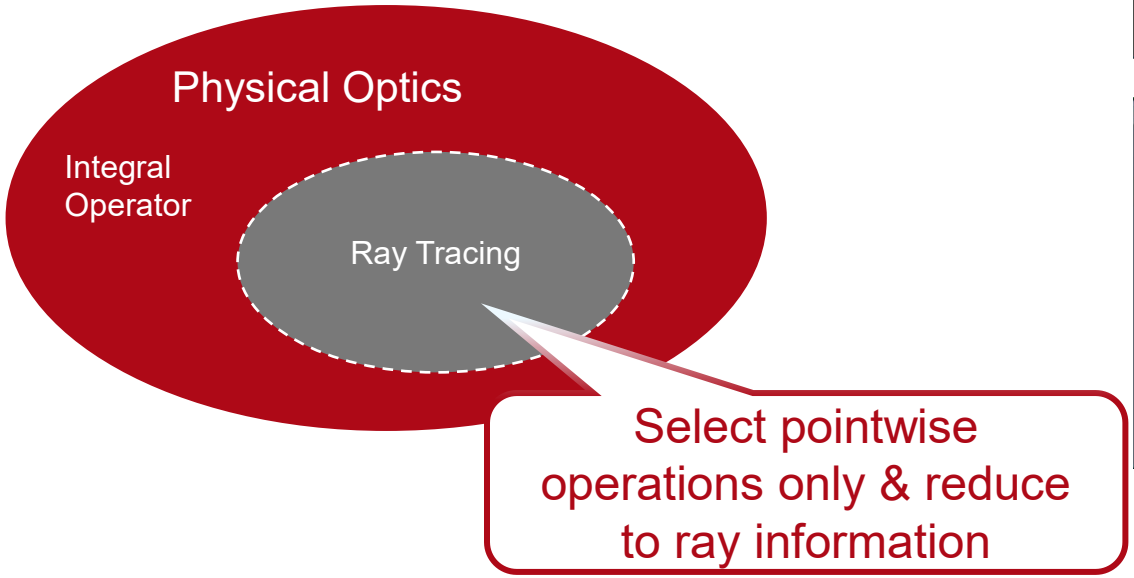

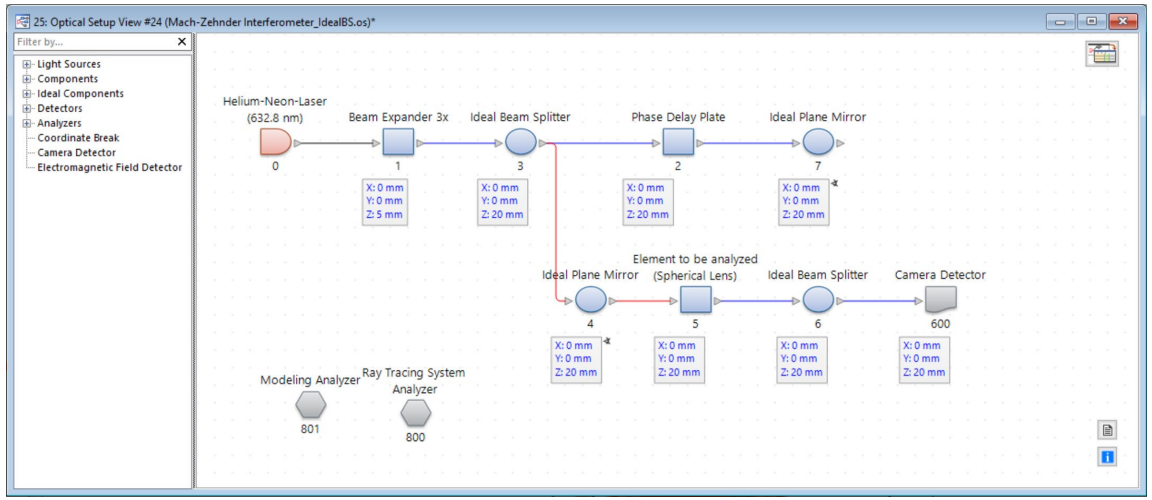

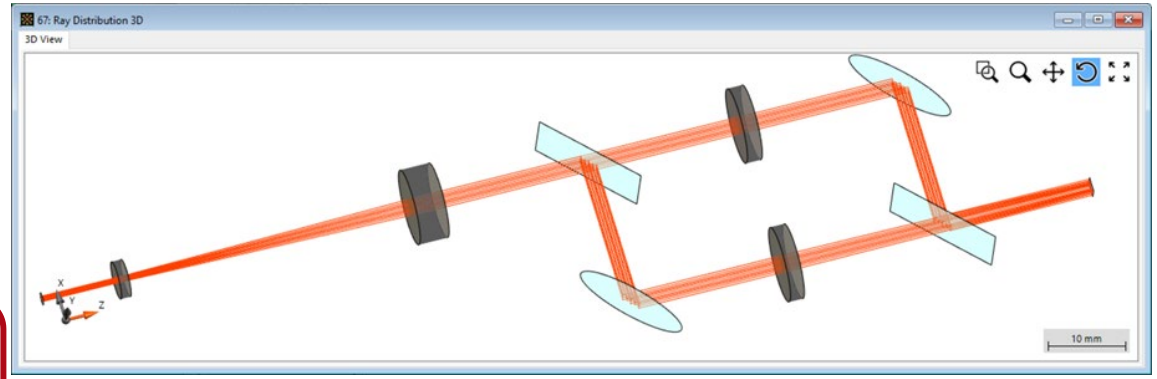

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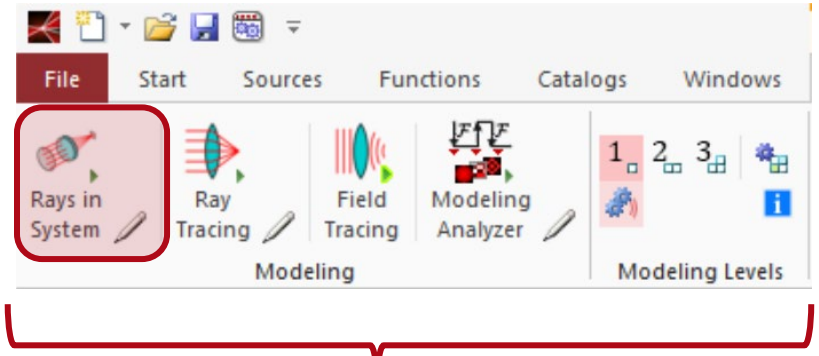
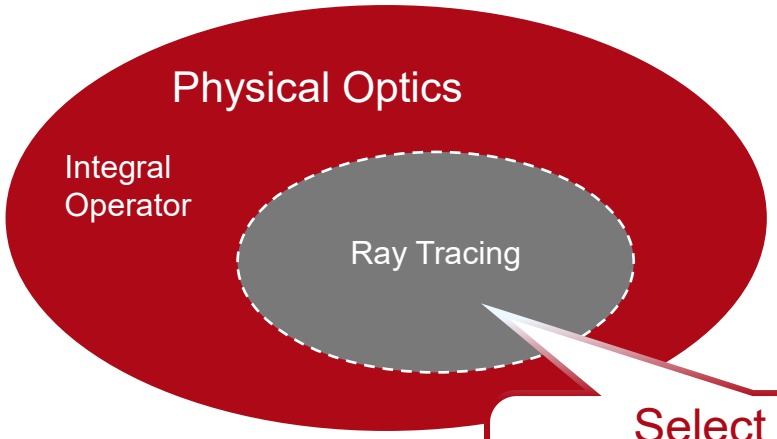
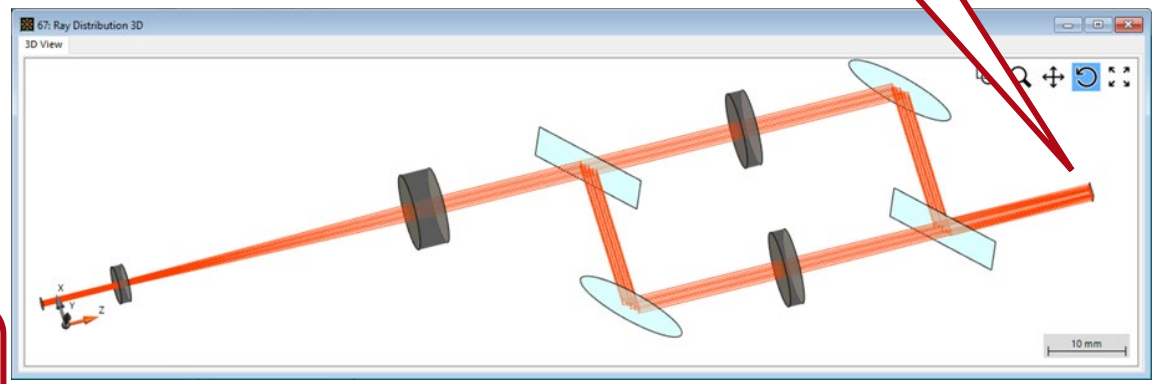




Select pointwise operations only & reduce to ray information

Dot Diagram?



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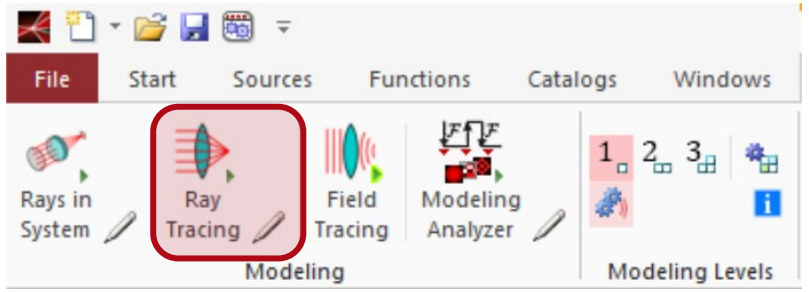

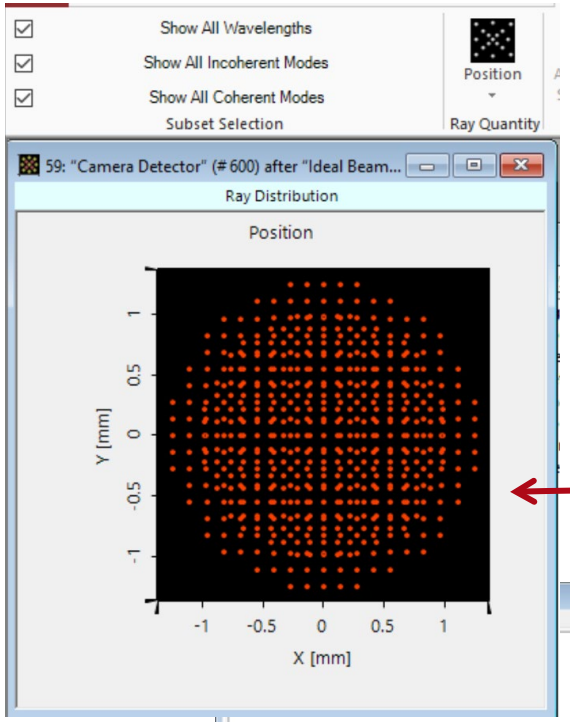

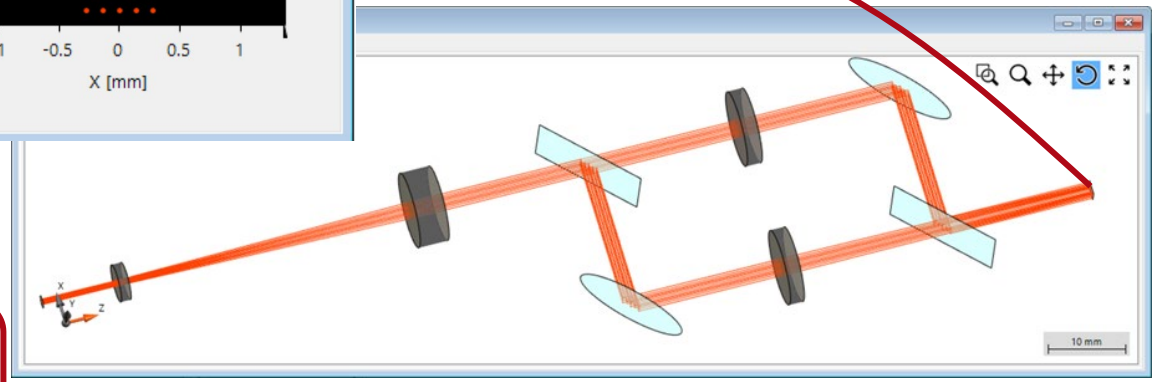

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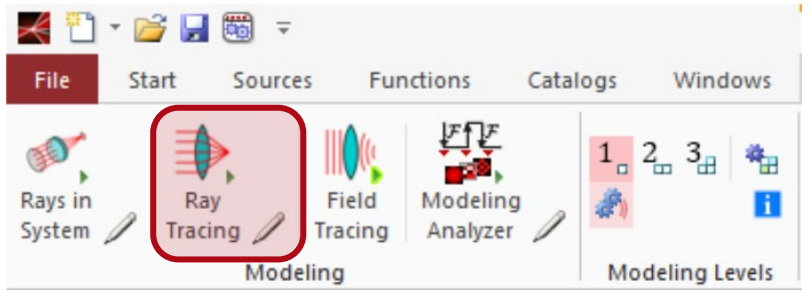
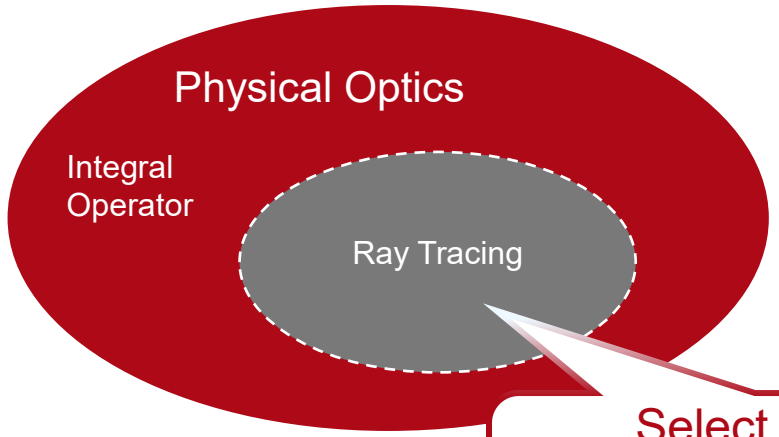
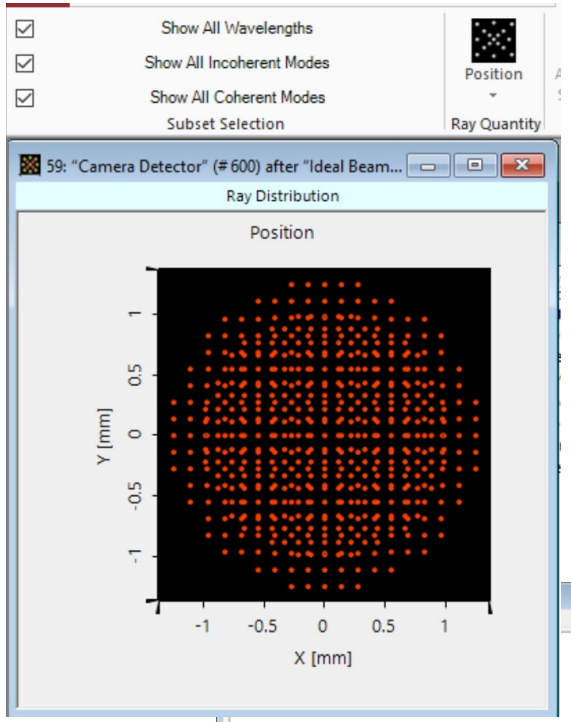
Select pointwise operations only & reduce to ray information

Modeling Control Panel: Example Mach-Zehnder Interferometer





Select pointwise operations only & reduce to ray information



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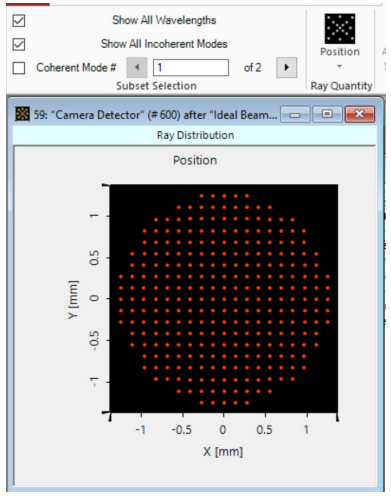

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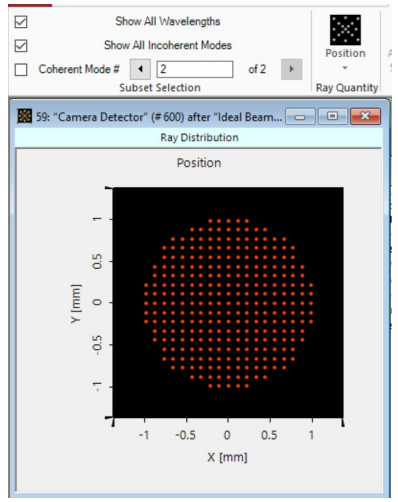
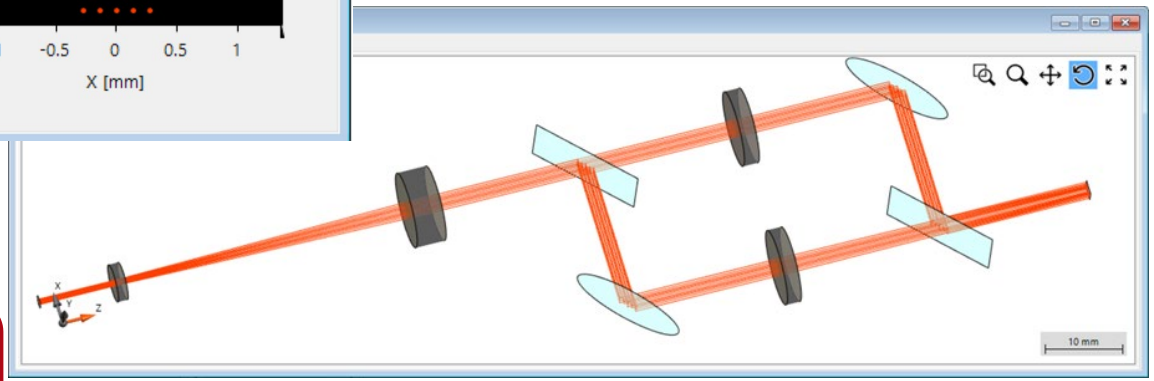
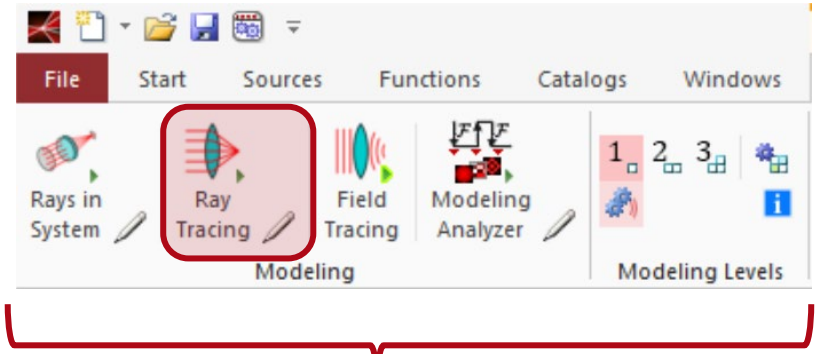
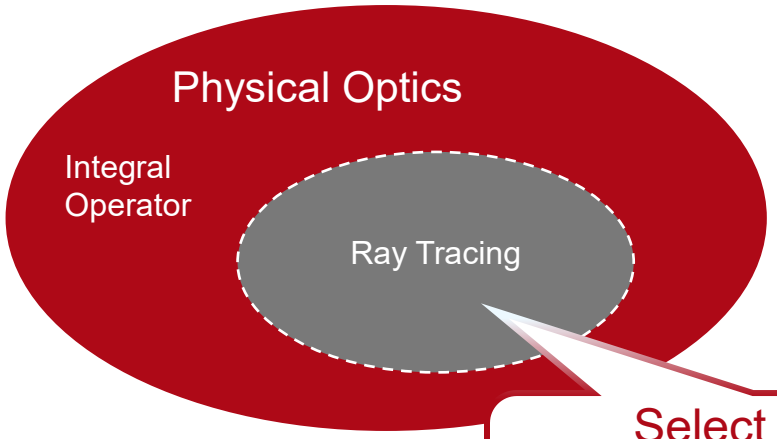




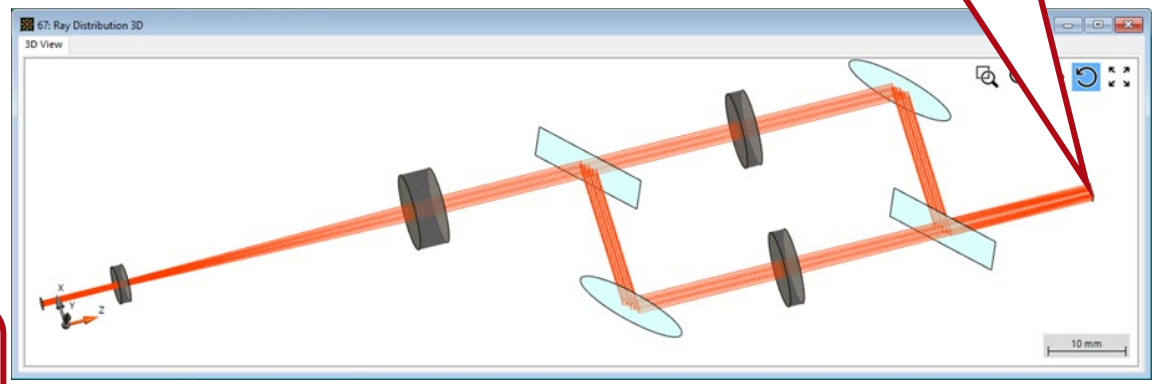
Modeling Control Panel: Example Mach-Zehnder Interferometer



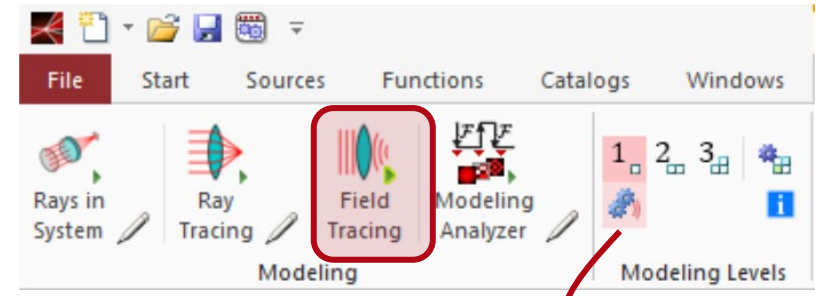


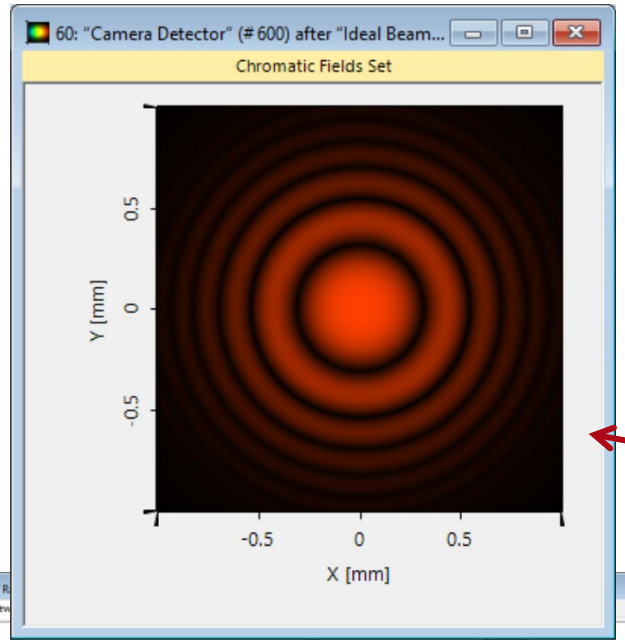
Select pointwise operations only & reduce to ray information

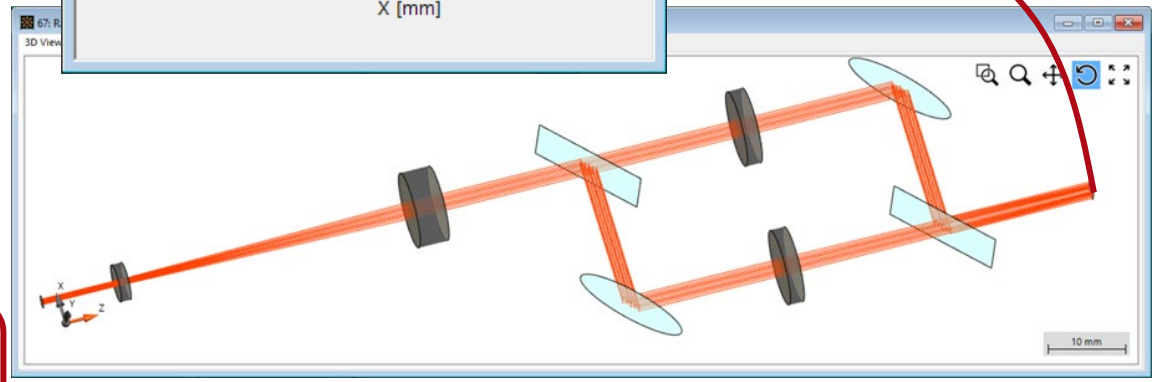
Physical optics result: Interferogram?



Modeling Control Panel: Example Mach-Zehnder Interferometer







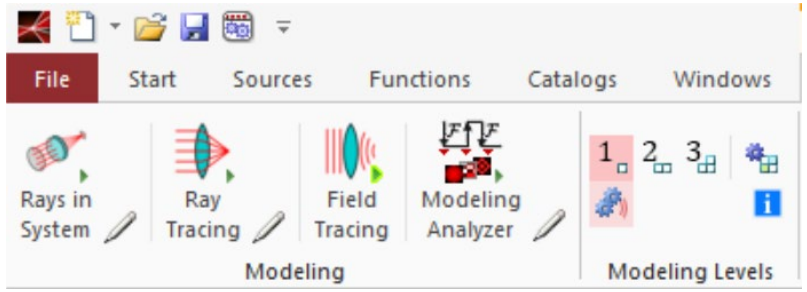
Physical Optics

Integral Operator

Pointwise Operations

Select pointwise operations only; full electromagnetic fields

Modeling Control Panel: Example Mach-Zehnder Interferometer

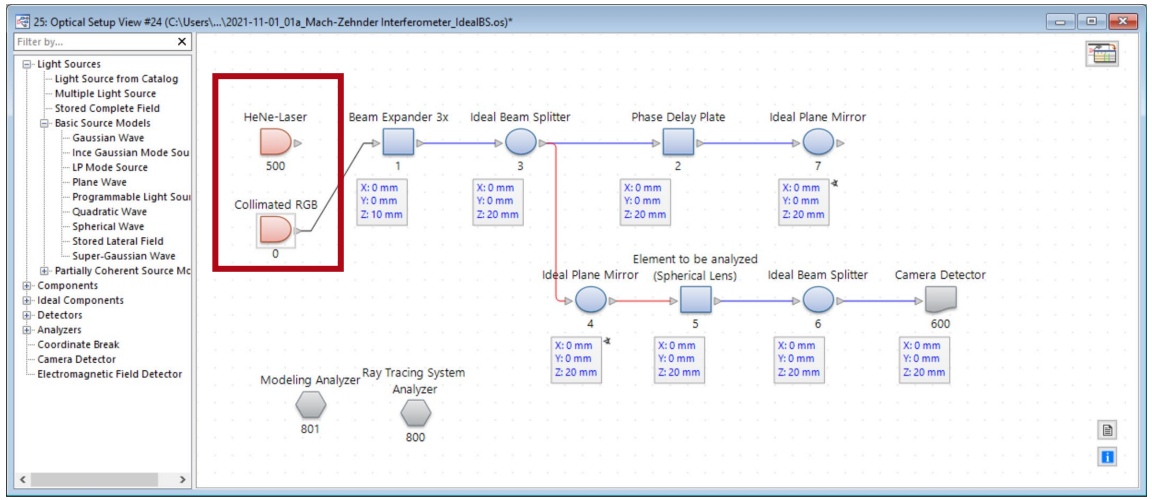


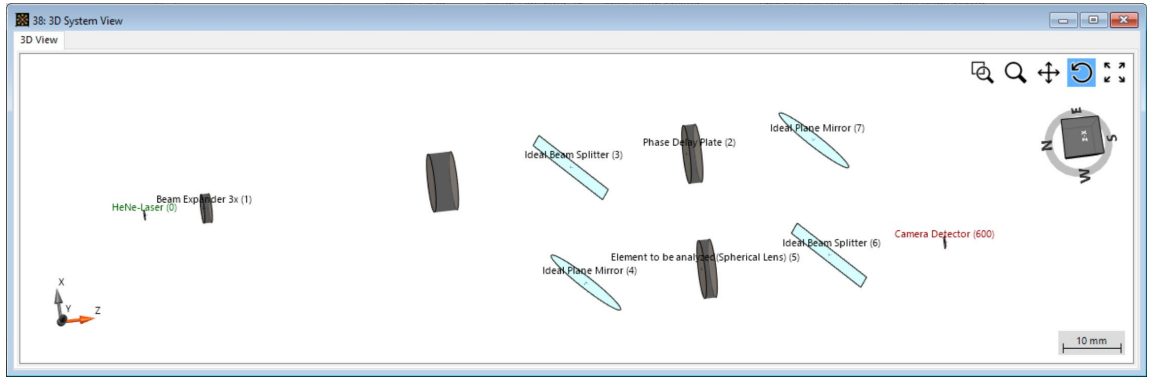
Physical Optics

Integral Operator

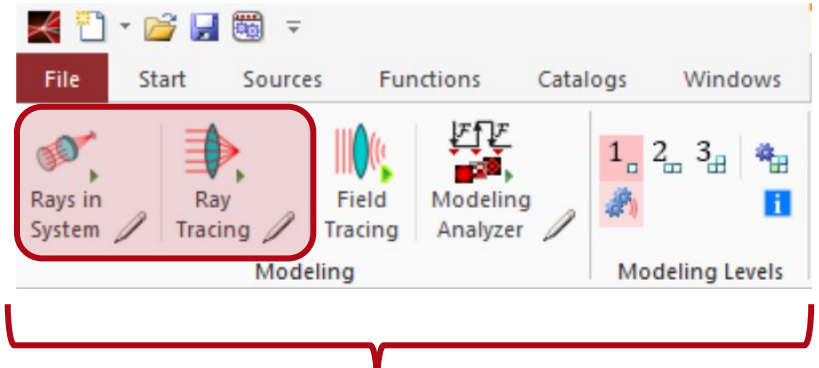
Pointwise Operations

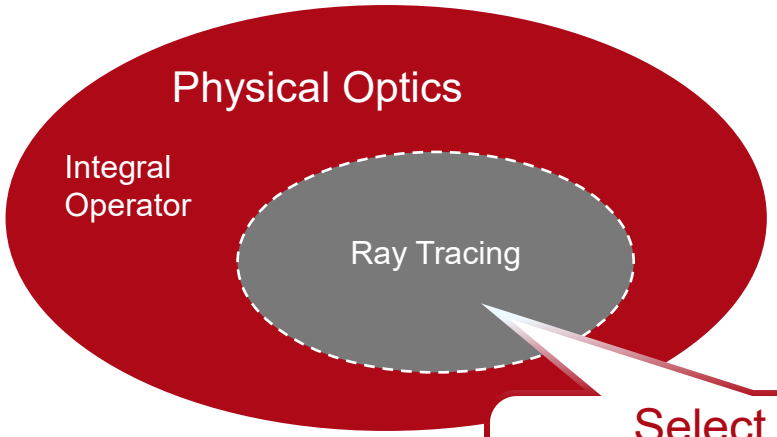
Transition controlled by algorithms!



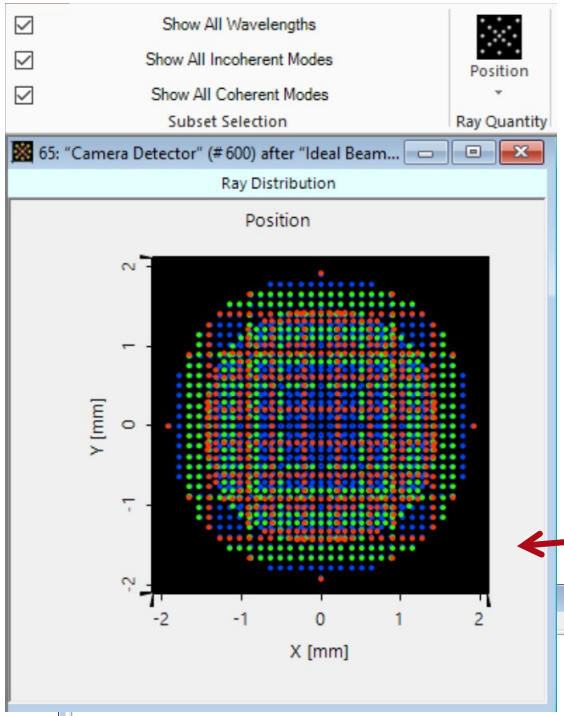


Modeling Control Panel: Example Mach-Zehnder Interferometer

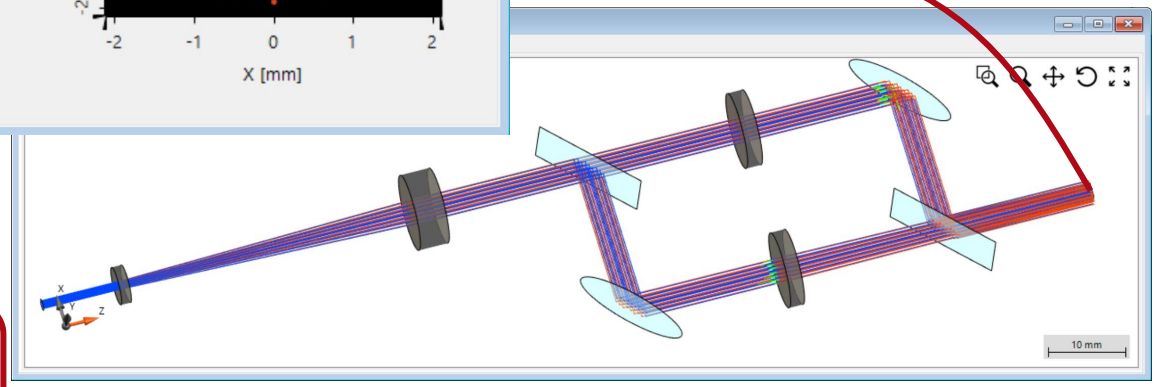




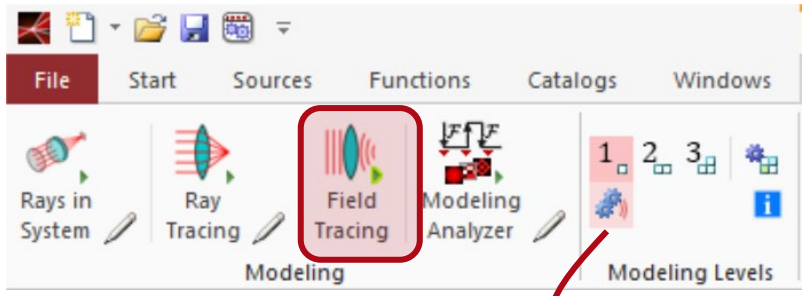
Select pointwise operations only & reduce to ray information

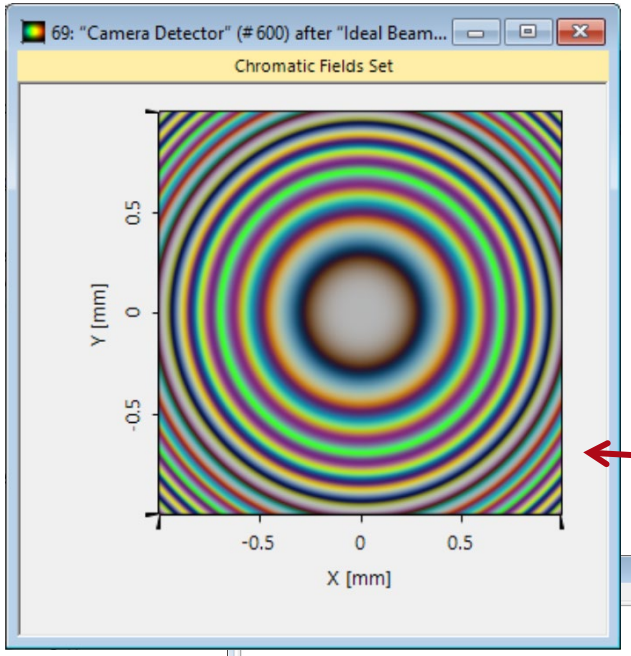


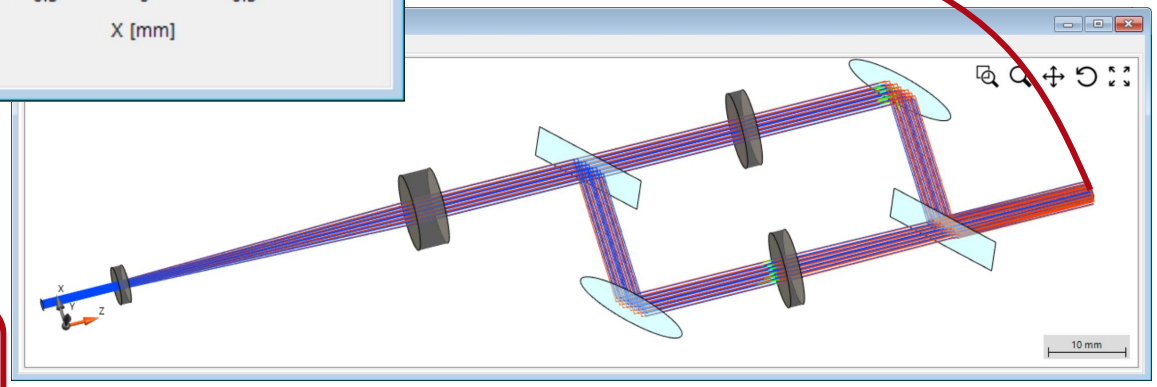
Six dot diagrams superimposed



Modeling Control Panel: Example Mach-Zehnder Interferometer







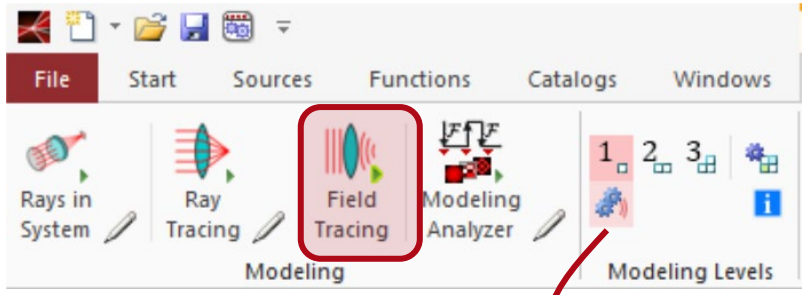
Physical Optics

Integral Operator

Pointwise Operations

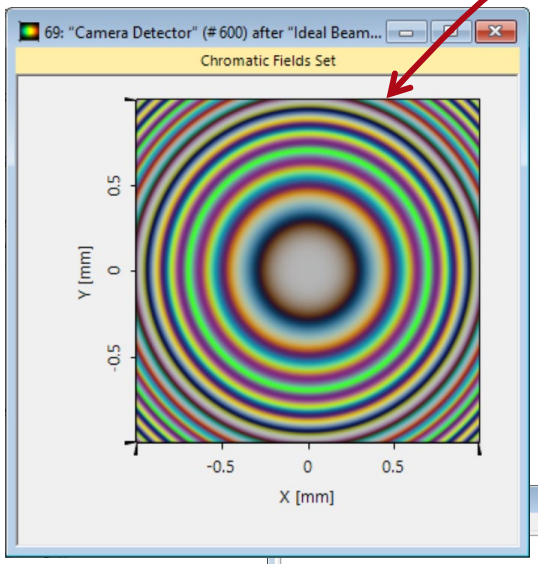
Select pointwise operations only; full electromagnetic fields

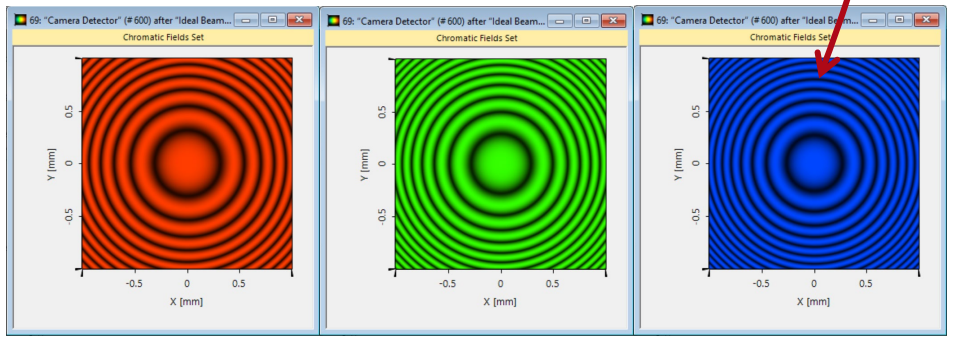
Modeling Control Panel: Example Mach-Zehnder Interferometer

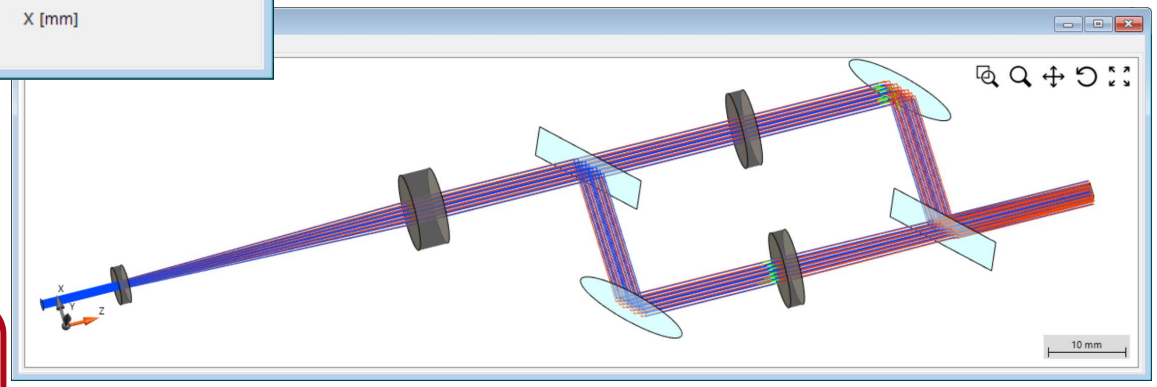


Coherent sum per wavelength

Incoherent sum of wavelengths







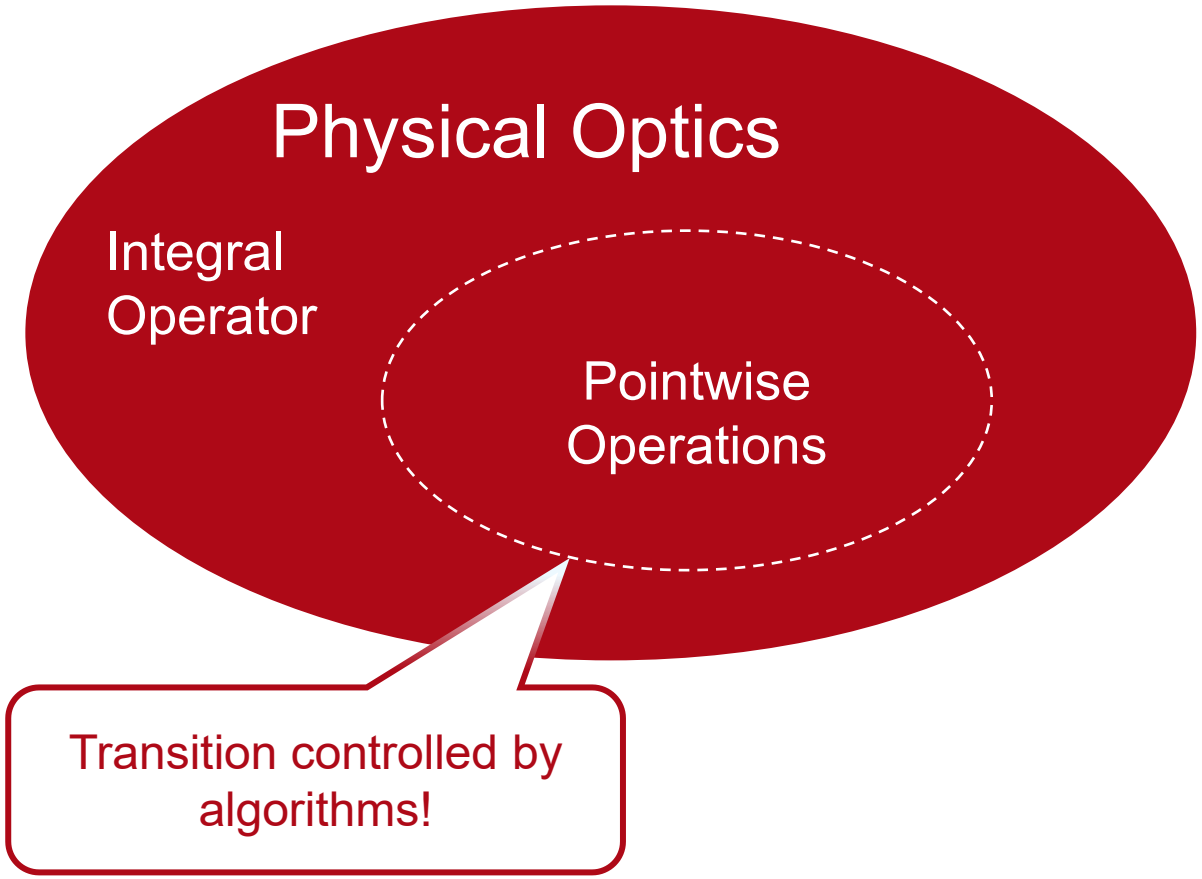
Physical Optics

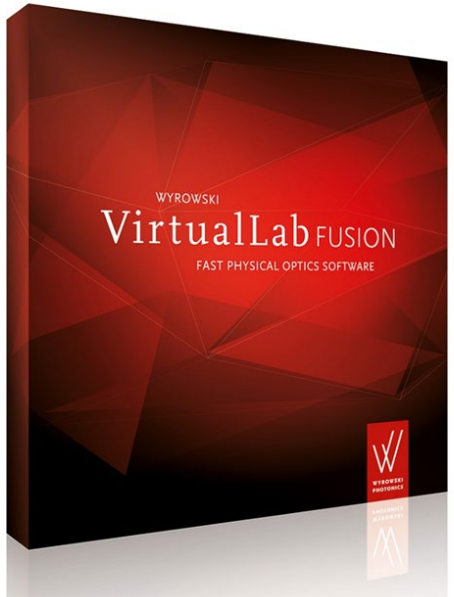
Integral Operator

Pointwise Operations

Select pointwise operations only; full electromagnetic fields

Fast Physical Optics by VirtualLab Fusion





- Connecting field solvers
- Seamless transition between pointwise and integral operations
- Includes ray optics
- Enables fast physical optics modeling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