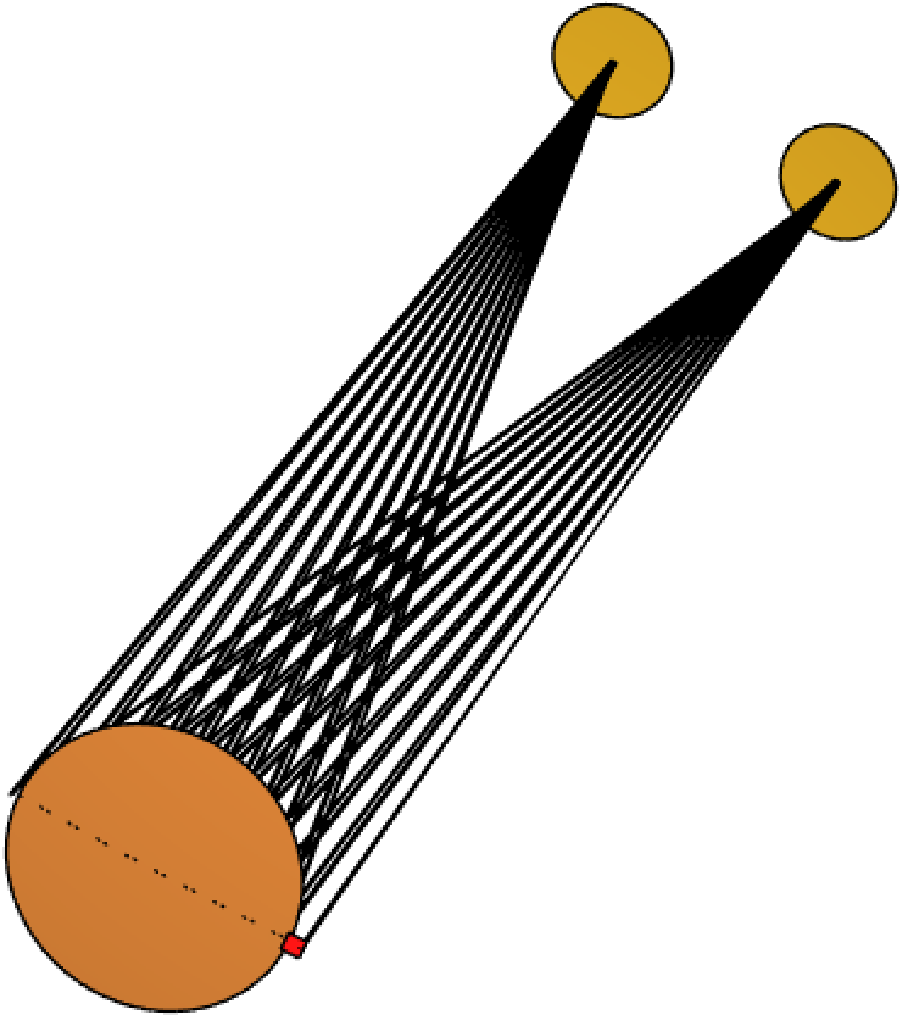
Modeling of Multi-Pass White Cell

Abstract



Multi-pass cells are widely used in gas spectroscopy, offering a compact design that achieves extended optical path lengths through multiple internal reflections. VirtualLab Fusion's non-sequential simulation engine streamlines this process by automatically finding and handling all necessary propagation steps, enabling optical engineers to focus on system design. This Use Case demonstrates this capability in the context of CO_2 absorption measurement.

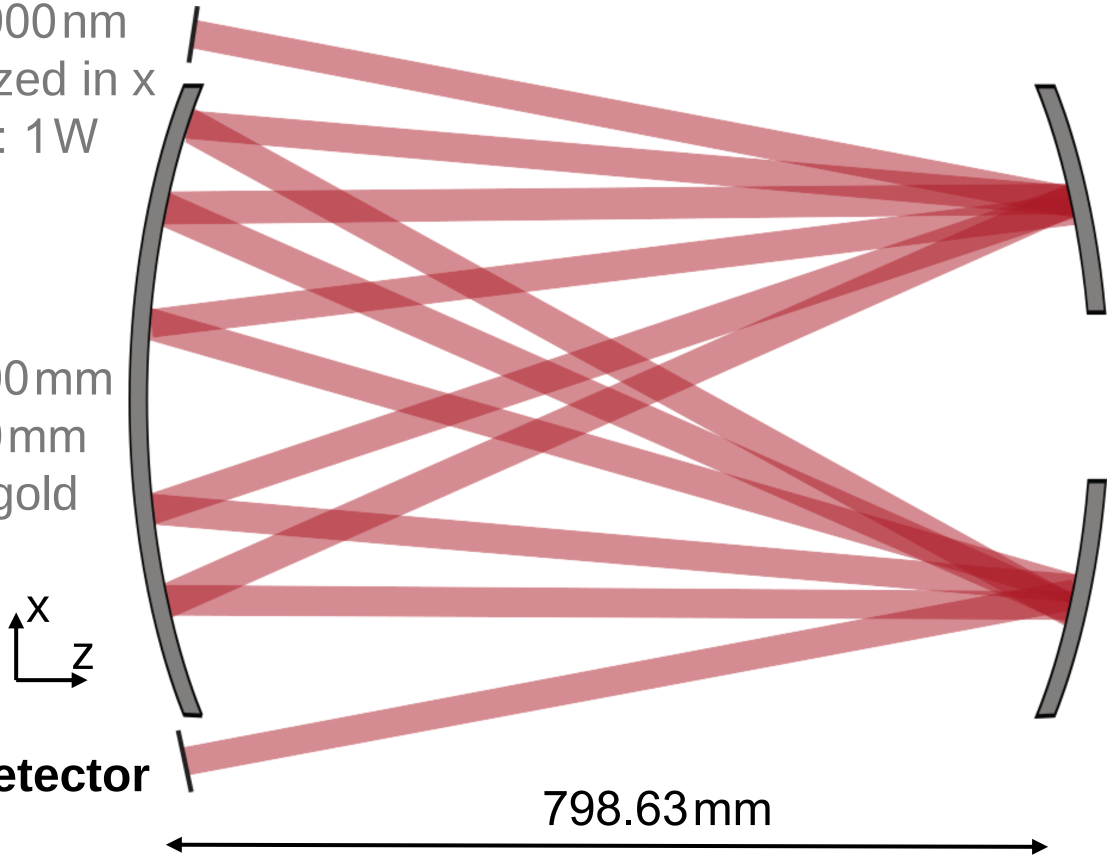
Modeling Scenario

plane wave

- wavelength: 900 nm
- linearly polarized in x
- source power: 1 W

spherical mirror #2

- radius of curvature: -800 mm
- diameter: 120 mm × 120 mm
- coating: HR protected gold



detector

spherical mirror #1

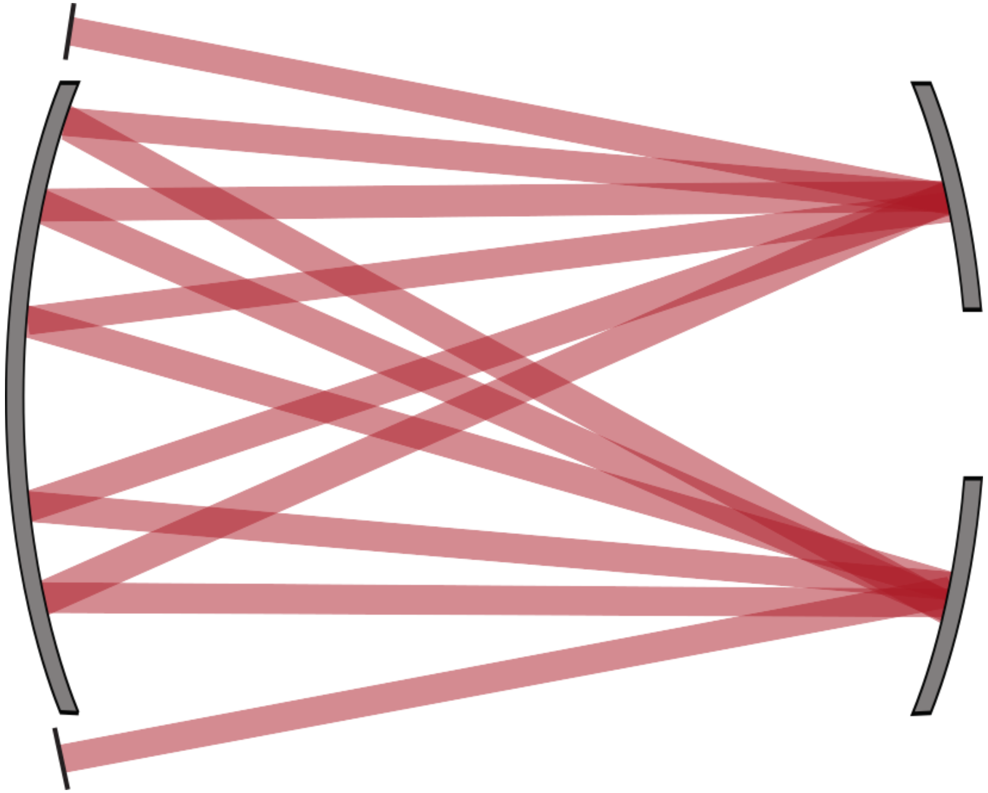
- radius of curvature: -800 mm
- diameter: 47.5 mm × 47.5 mm
- coating: protected gold

spherical mirror #3

- radius of curvature: -800 mm
- diameter: 47.5 mm × 47.5 mm
- coating: HR protected gold

system parameters: *Yin Guo and Liqun Sun, "Biconic White multipass cell design based on a skew ray-tracing model," Appl. Opt.* ***56****, 7586-7595 (2017).*

Modeling Tasks



detector

- optical path length
- irradiance
- radiant flux

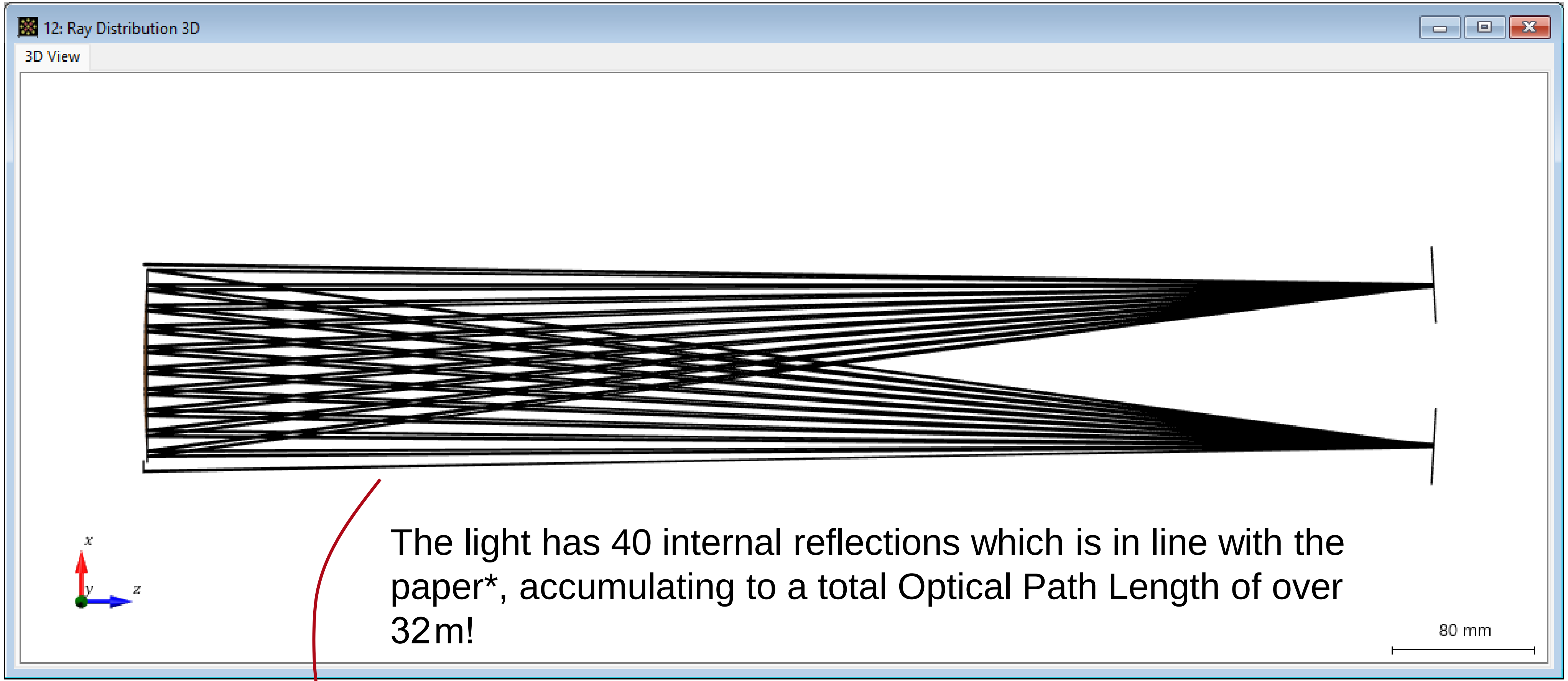
Tasks:

- calculate the total beam path
- calculate irradiance and radiant flux when the cell is filled with:
  - air
  - CO_2* (n=1.00044, absorption coefficient 0.11/m)

* **Values from:** *Old, J. G., K. L. Gentili, and E. R. Peck. "Dispersion of carbon dioxide." JOSA 61.1 (1971): 89-90.*

Simulation Results

System Overview – OPL Detection

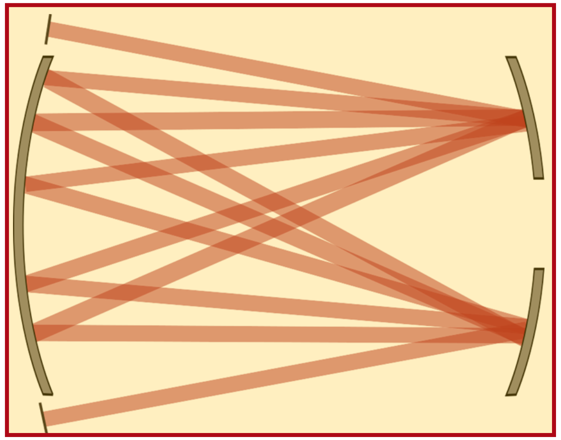


The light has 40 internal reflections which is in line with the paper*, accumulating to a total Optical Path Length of over 32 m!

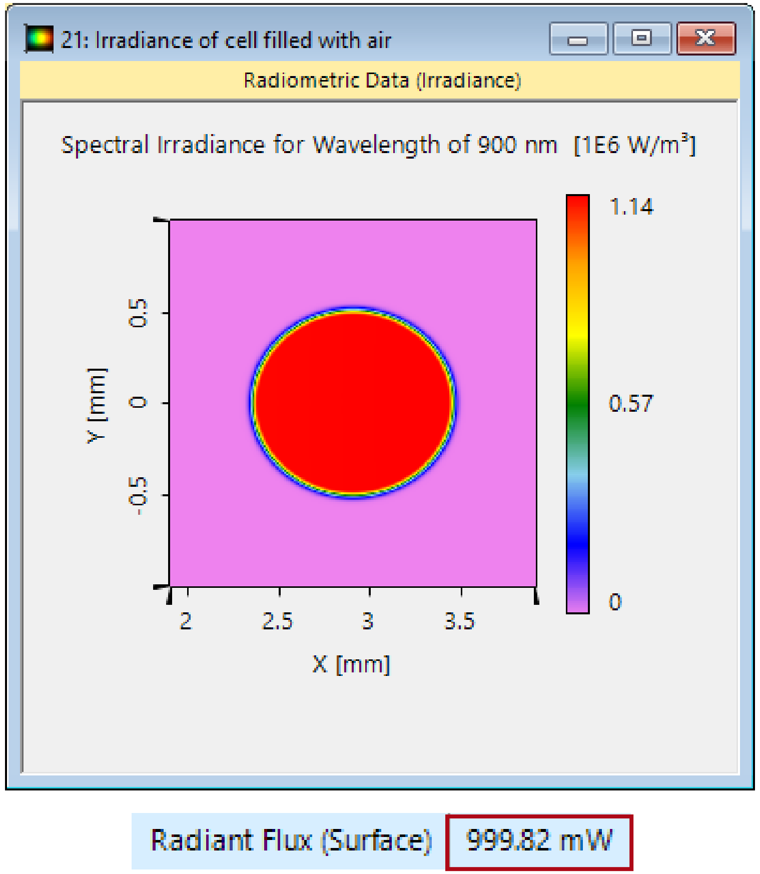
Detector	Sub - Detector	Result
"Universal Detector" (# 600): Optical Path Length (Profile: General)	OPL value @(2.8 mm; 0 mm) of Mode #1	32.013 m

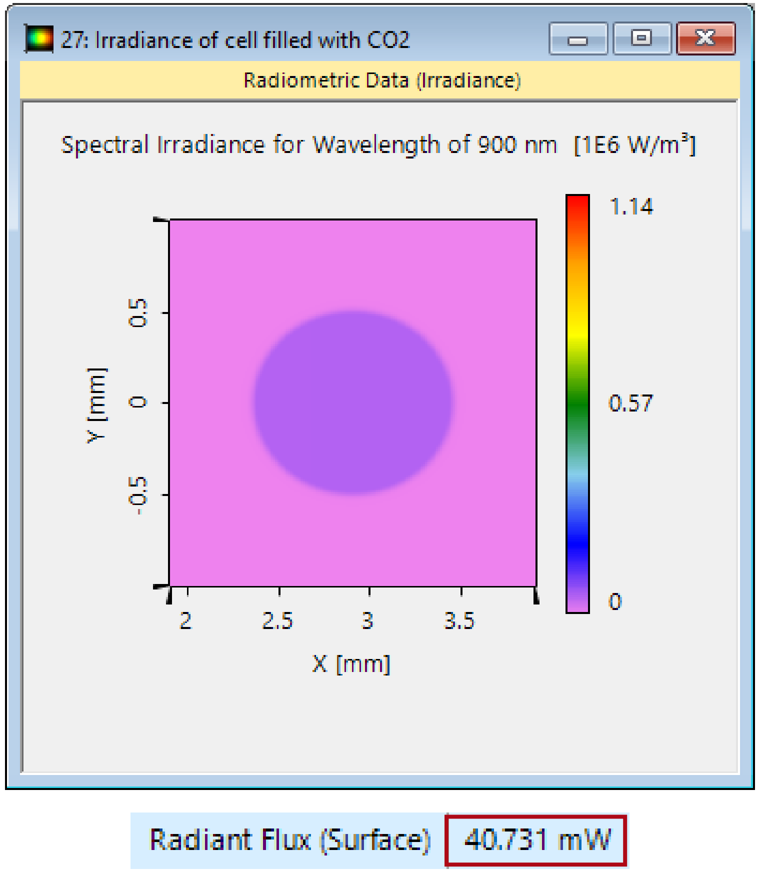
 * *Yin Guo and Liqun Sun, "Biconic White multipass cell design based on a skew ray-tracing model," Appl. Opt.* ***56****, 7586-7595 (2017).*

Physical Optics Results – Irradiance & Radiant Flux



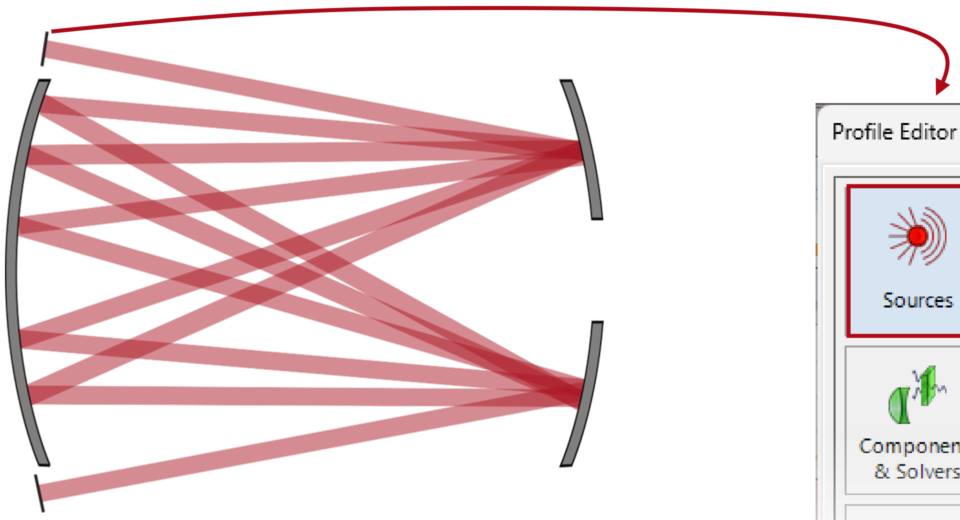
When the White cell is filled with an absorptive gas (such as carbon dioxide for a beam with wavelength of 900 nm) the decrease in energy can be measured after the resonator. Due to the high number of passes over a long distance in such configuration, the loss of radiant flux over 32.021 m is noticeable, as can be observed from the figures on the right.

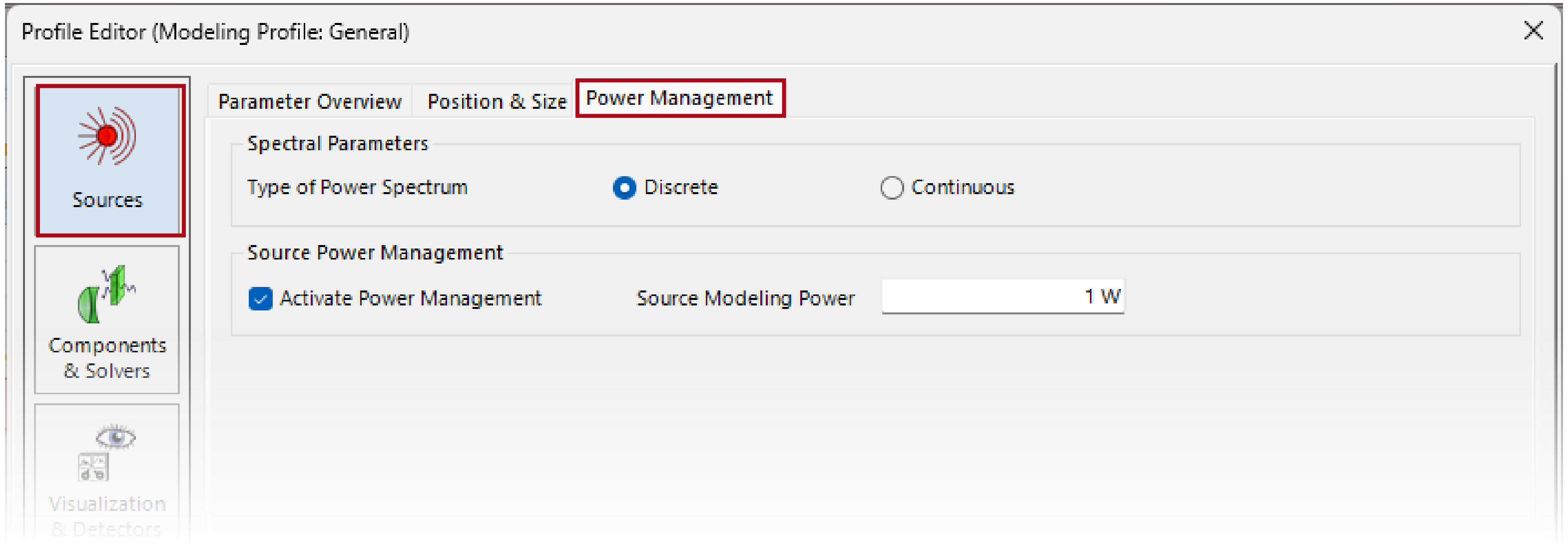




Workflows

Power Management

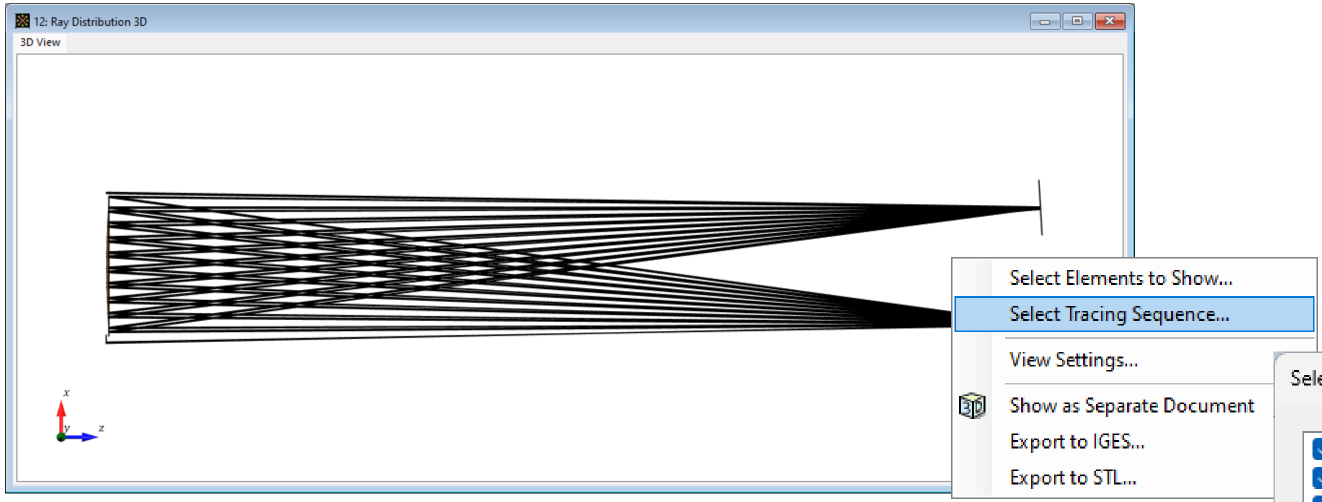


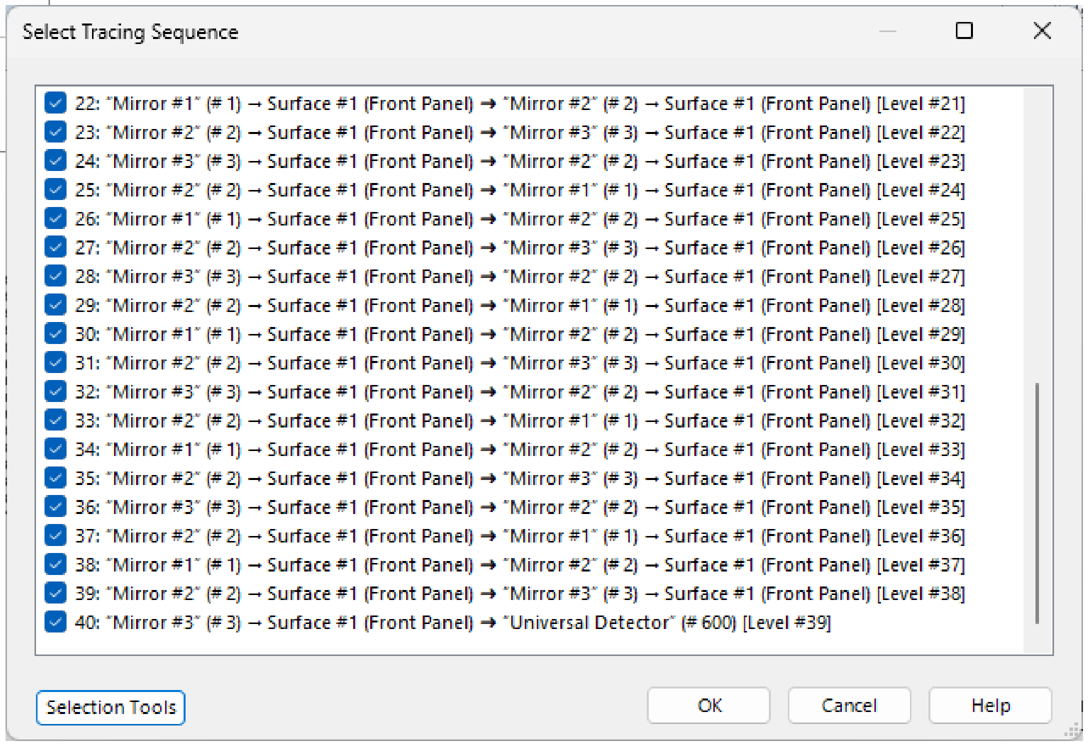


In VirtualLab Fusion, it is possible to define the power of the source. This can be done via the Power Management in Profile Editor. For more information:

[Profile Editor]

Non-Sequential Tracing



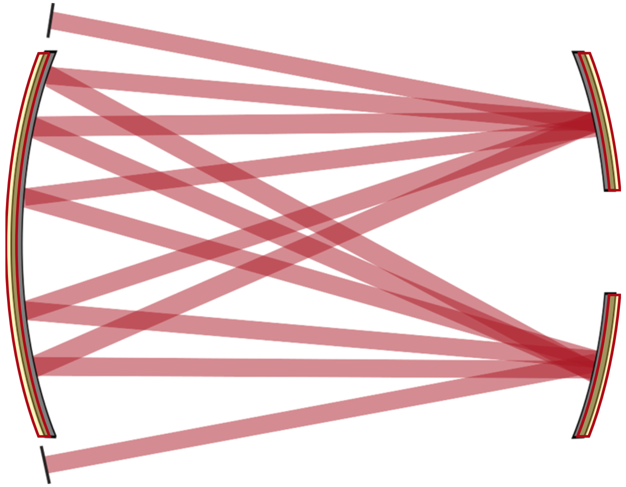


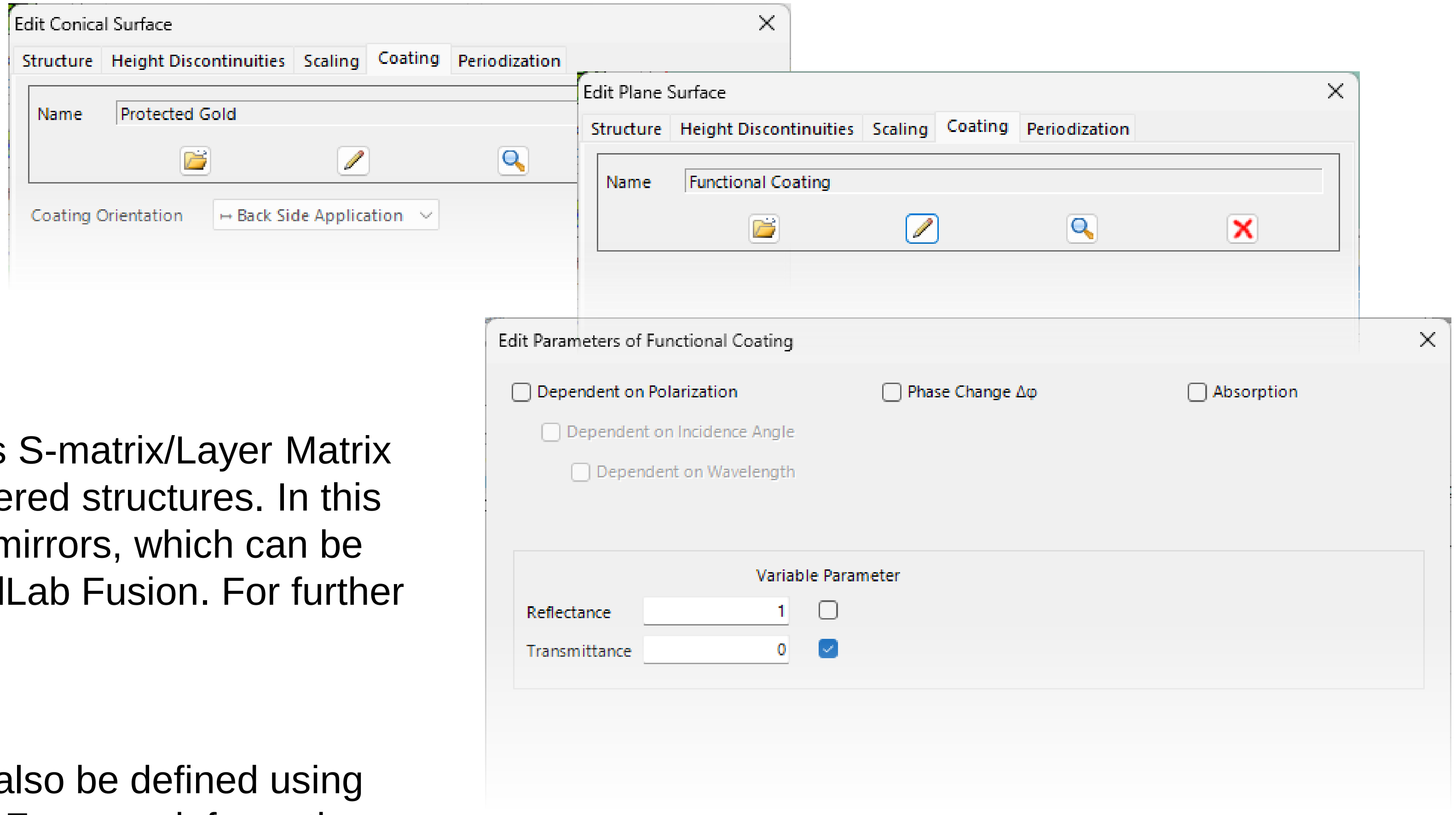
With the non-sequential approach in VirtualLab Fusion, it is possible to follow the multiple-passes the light will make until it reaches the detector. This can be seen via the “*Select Tracing Sequence*“ by right-clicking on the *System 3D Result*.

For more information regarding the non-sequential configuration in VirtualLab Fusion:

[Channel Setting for Non-Sequential Tracing]

Coatings

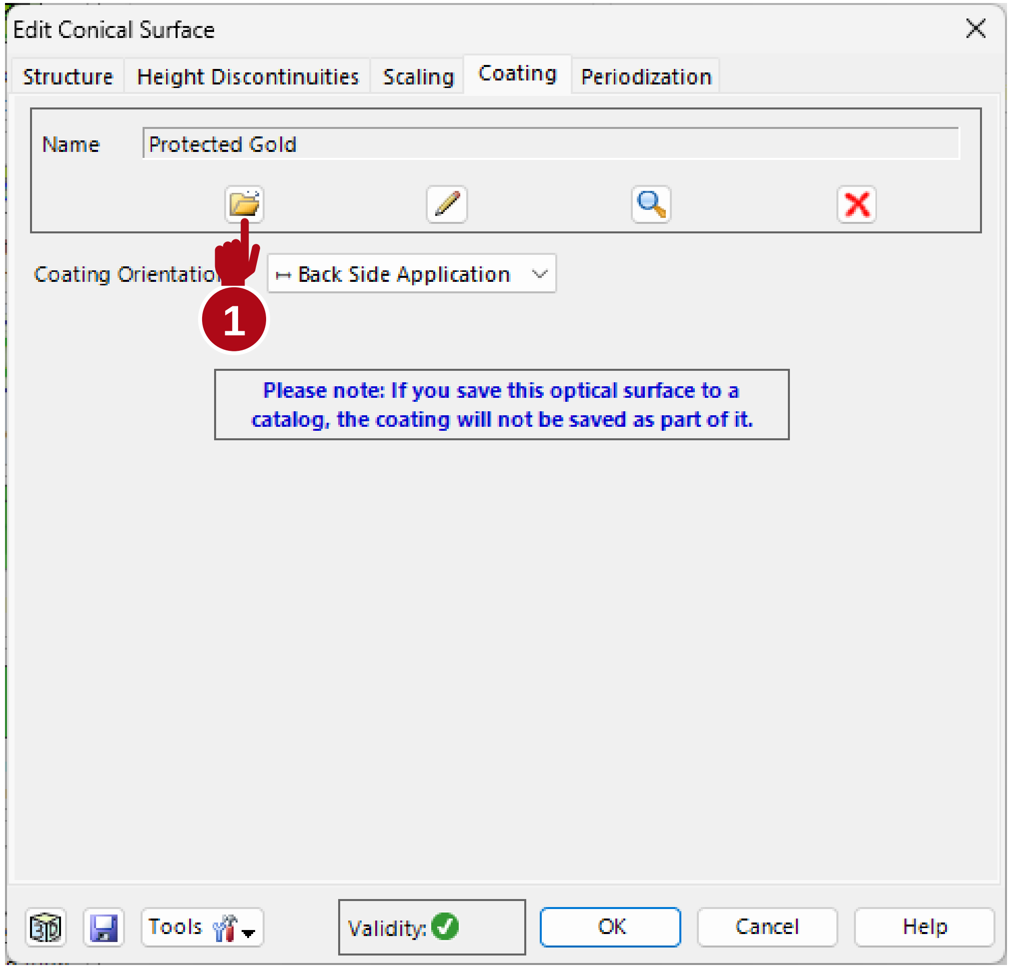


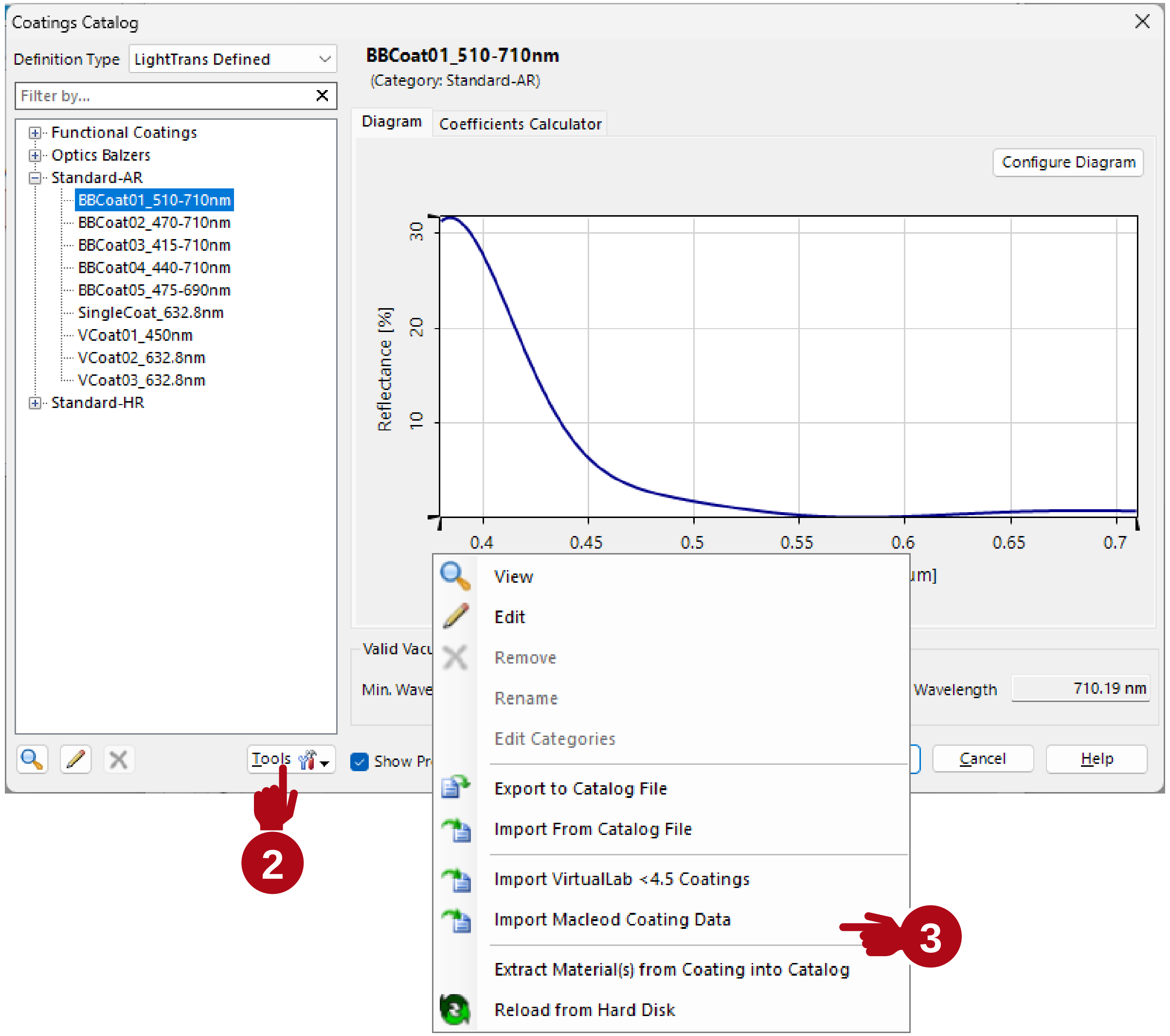


Coatings are modeled using the rigorous S-matrix/Layer Matrix algorithm, optimized for x,y-invariant layered structures. In this case, actual coatings were used on the mirrors, which can be built from scratch or imported into VirtualLab Fusion. For further information:
[Import Coating into VirtualLab Fusion]

Alternatively, coating functionalities can also be defined using Functional Coatings within the software. For more information:
[Functional Coatings]

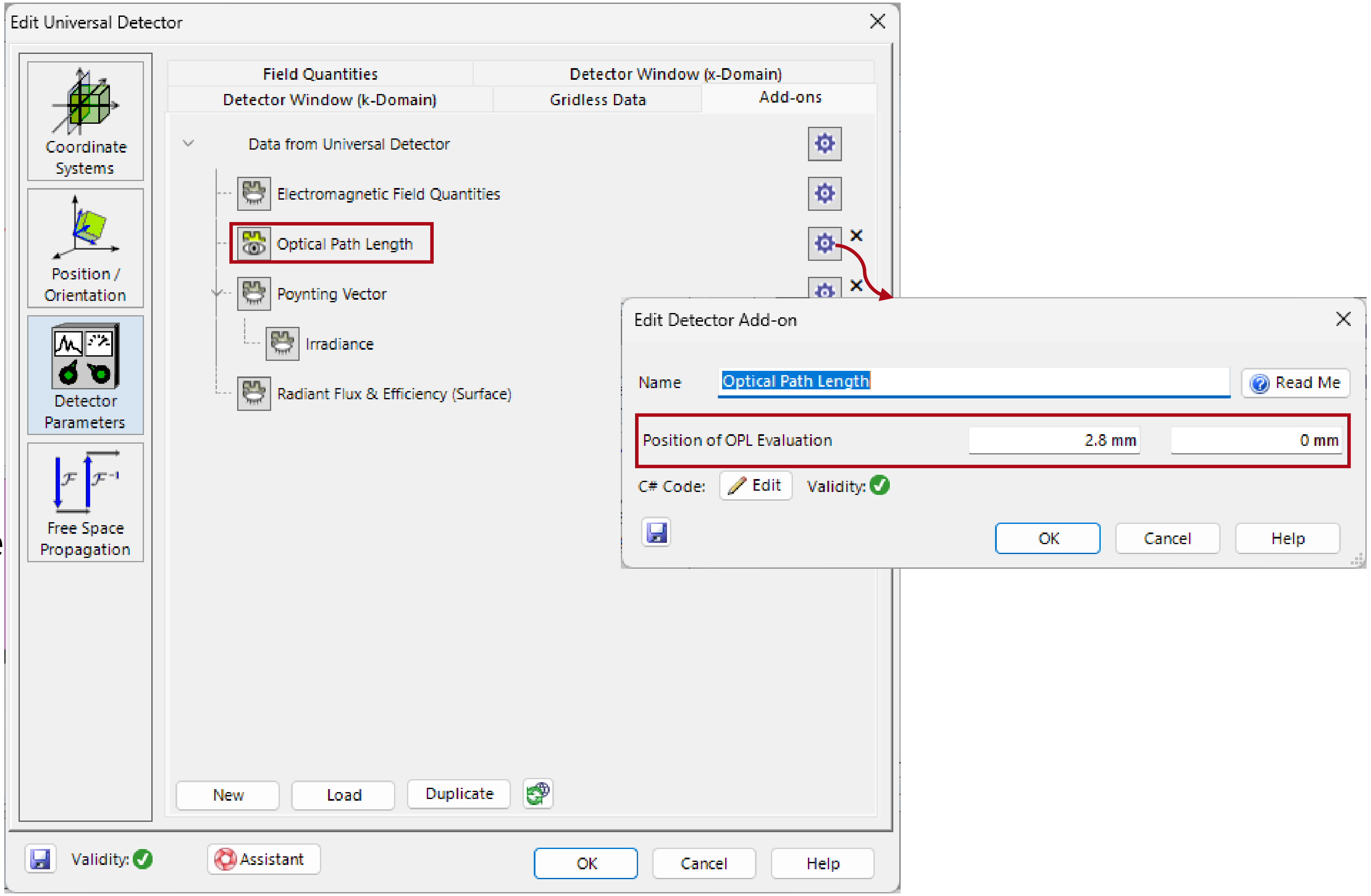
Import Coatings into VirtualLab Fusion





Universal Detector – Optical Path Length Add-on

The total Optical Path Length (OPL) information can be extracted from the smooth wavefront phase per source mode and position in the *Universal Detector*. More information under: Universal Detector



Document Information

title	Modeling and Evaluation of Multi-Pass White Cell
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document version	1.0
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software version	2024.1 (Build 1.132)
category	Use Case
further reading	• Modeling of a Herriot-Cell • Functional Coatings • Universal Detector • Programming Detector Add-ons in VirtualLab Fusion