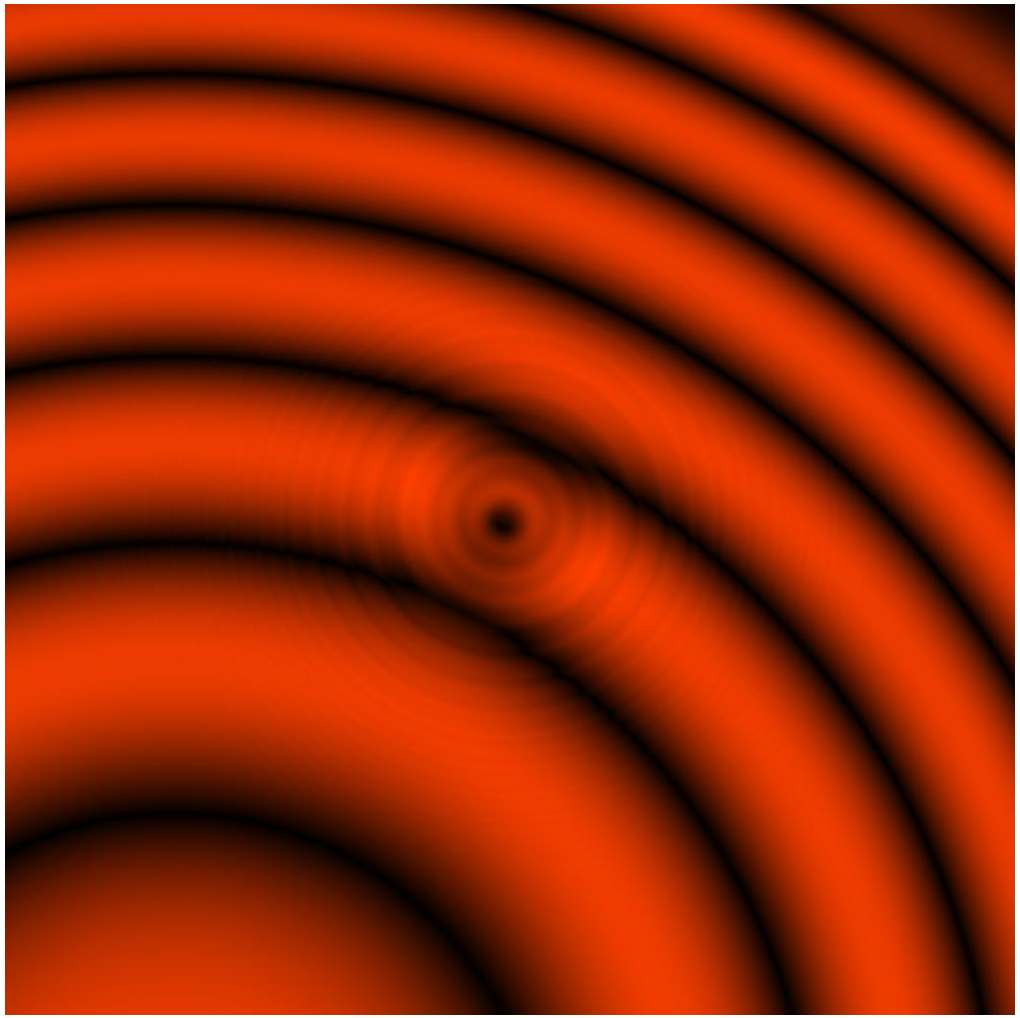
Mach-Zehnder Interferometer with Small Obstruction

Abstract



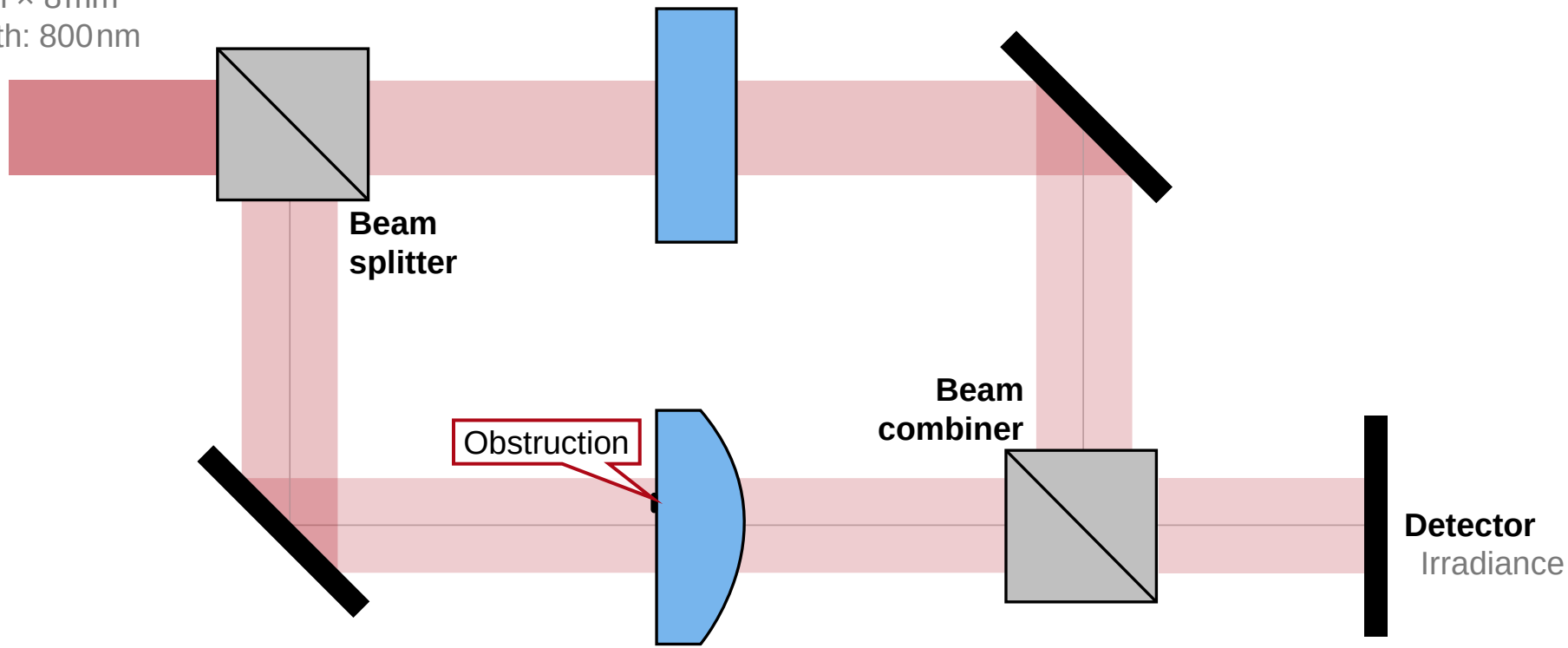
The accurate simulation of light fields that encounter small light-blocking objects during propagation, leading to additional diffraction effects that must be finely sampled, represents a classic multi-scale simulation challenge that is numerically demanding. VirtualLab Fusion enables highly computationally efficient simulations by decomposing light into separate modes. This use case demonstrates the impact of light being blocked at a small point in a Mach-Zehnder interferometer system, such as by an interfering particle on the sample surface.

Application Scenario

Application Scenario: System Specifications

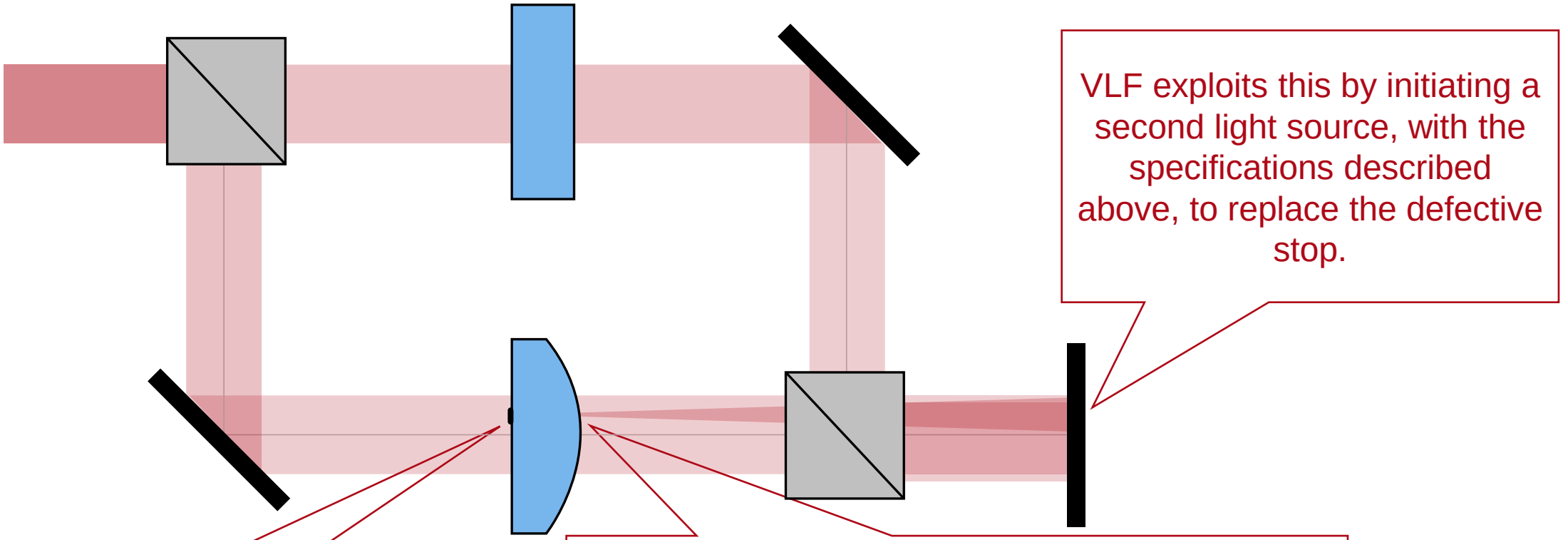
Plane wave source
- Size: 8mm × 8mm
- Wavelength: 800nm

Phase-delaying plate
Thickness: 2mm



Plano-convex lens with defect
- Radius of curvature (convex-part) : 1m
- Center thickness: 2mm
- Size of defect: 50µm - 300µm

Application Scenario: Modeling & Simulation with Defect

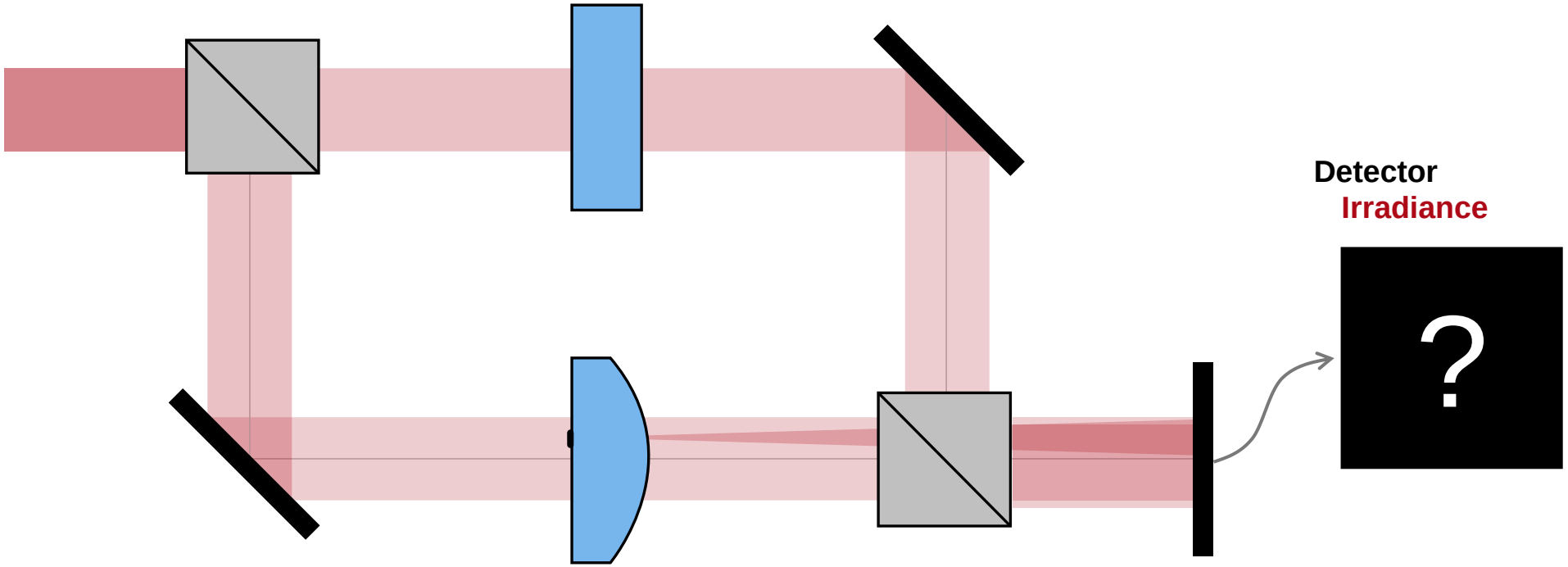


VLF exploits this by initiating a second light source, with the specifications described above, to replace the defective stop.

At the location of the defect, the light is blocked, thus behind it, the amplitude is zero.

This would also be the case if a second light field with the same amplitude but opposite phase values were to occur at this position. VLF exploits this by initiating a second light source, with the specifications described above, to replace the defective stop.

Application Scenario: Task



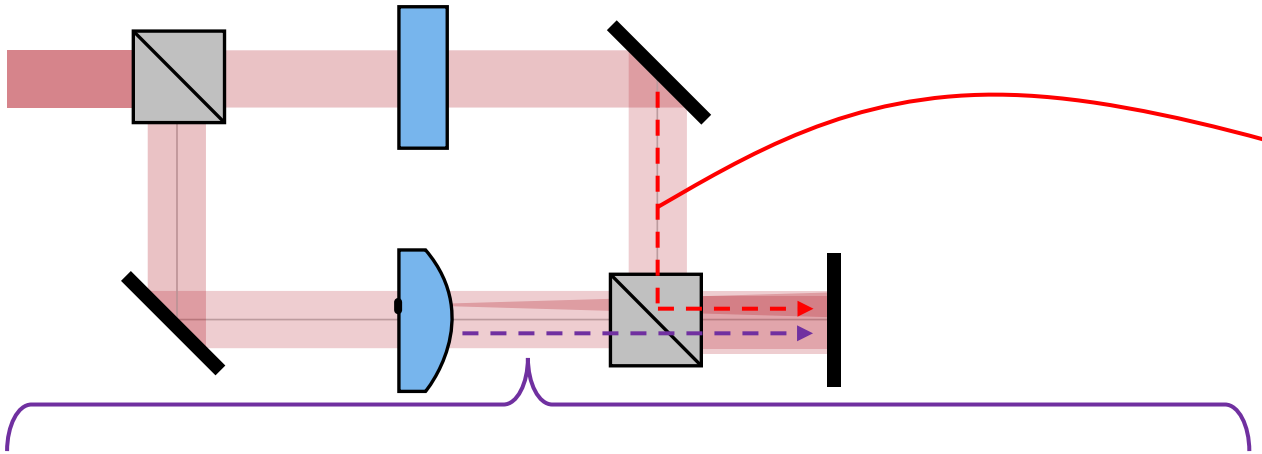
Task 1: Compare the irradiance results of the ideal system
versus a system including a defect with a diameter of 300 µm.

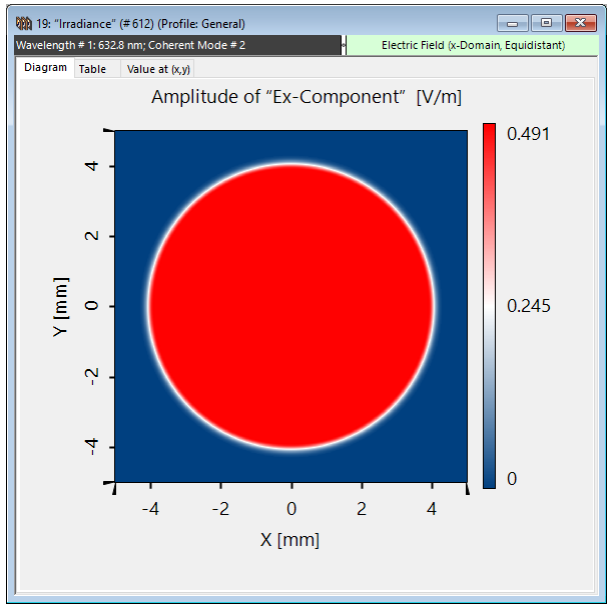
Task 2: Reduce the defect's diameter size to 100 µm and 50 µm
and calculate the irradiance patterns.

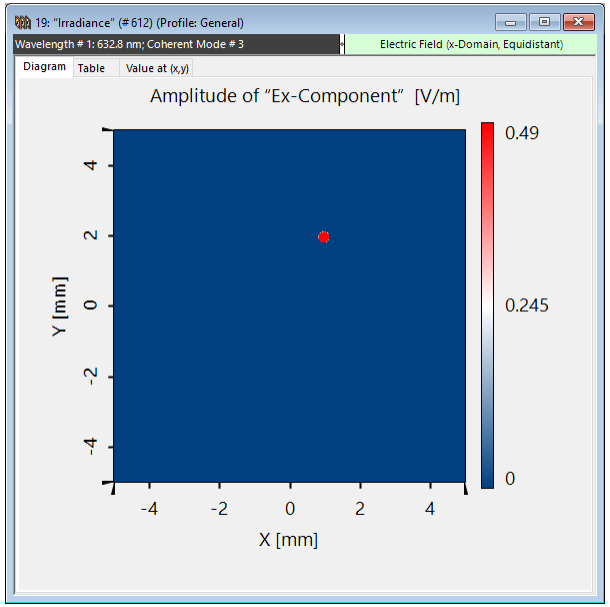
Results

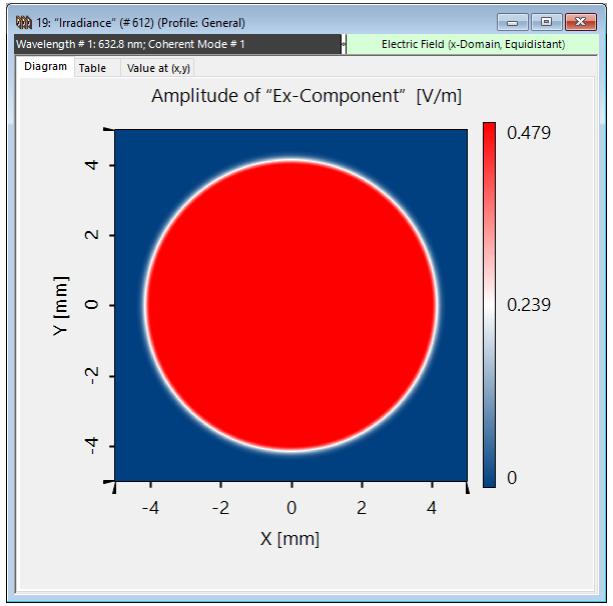
Task 1: Simulation with and without Defect

Separate Field Modes at Detector (without Diffraction)

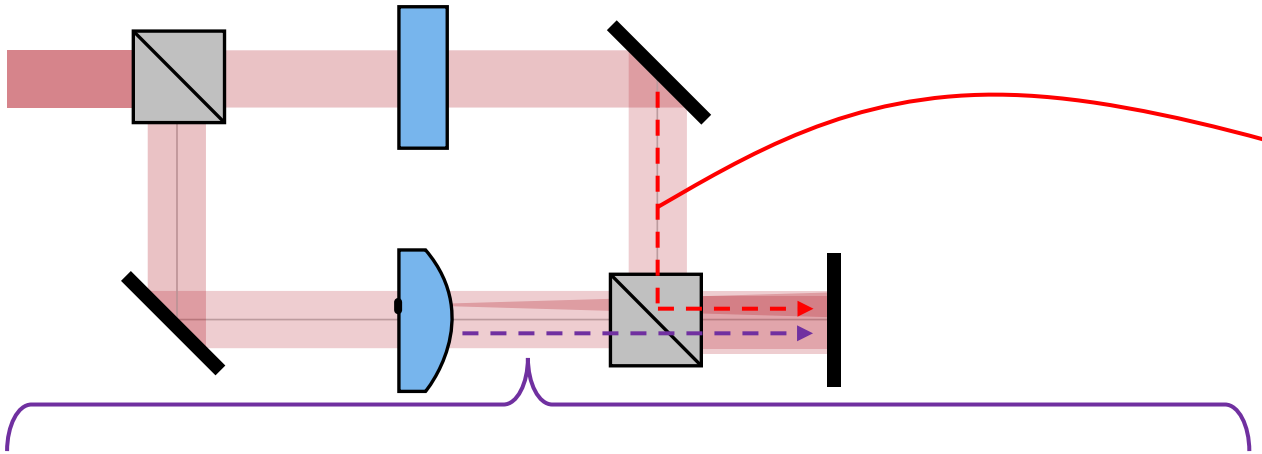


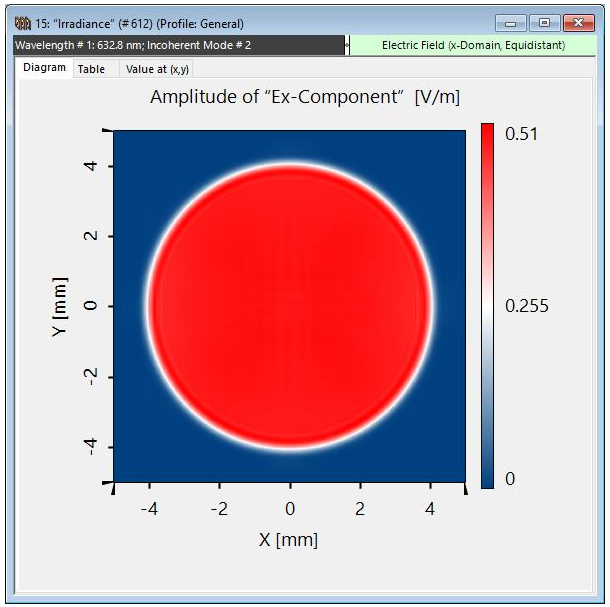


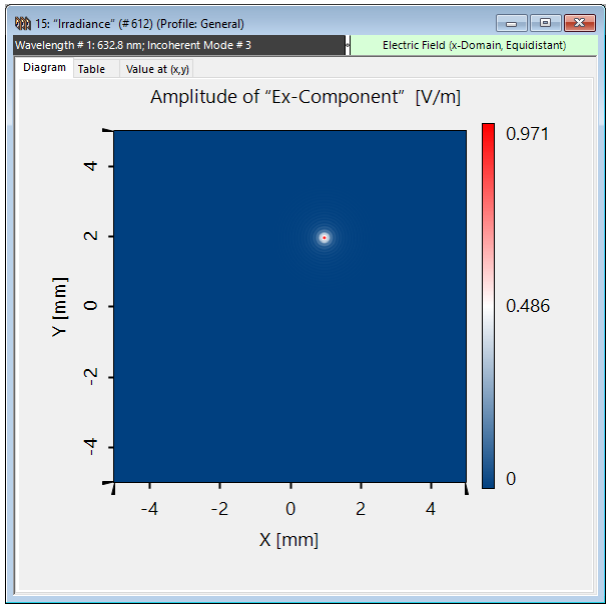


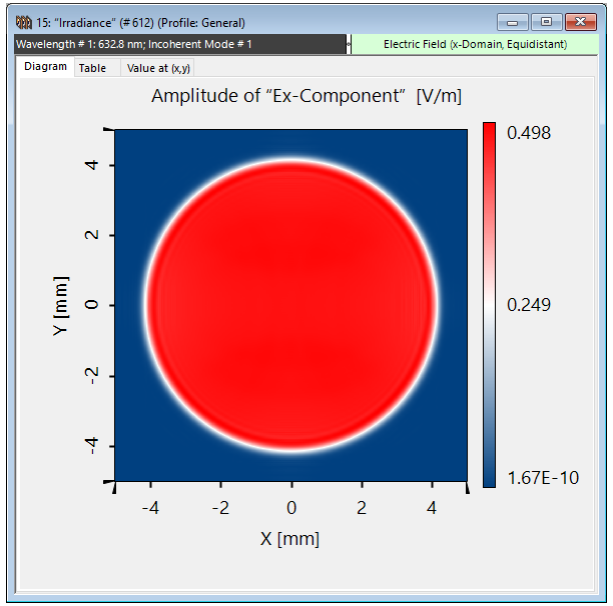


Separate Field Modes at Detector (with Diffraction)

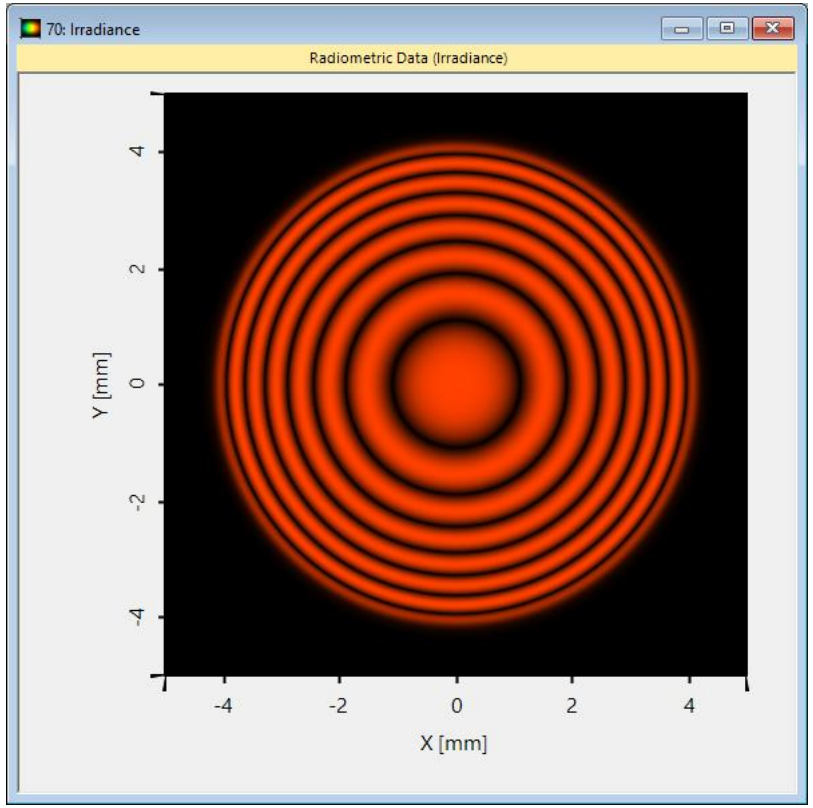




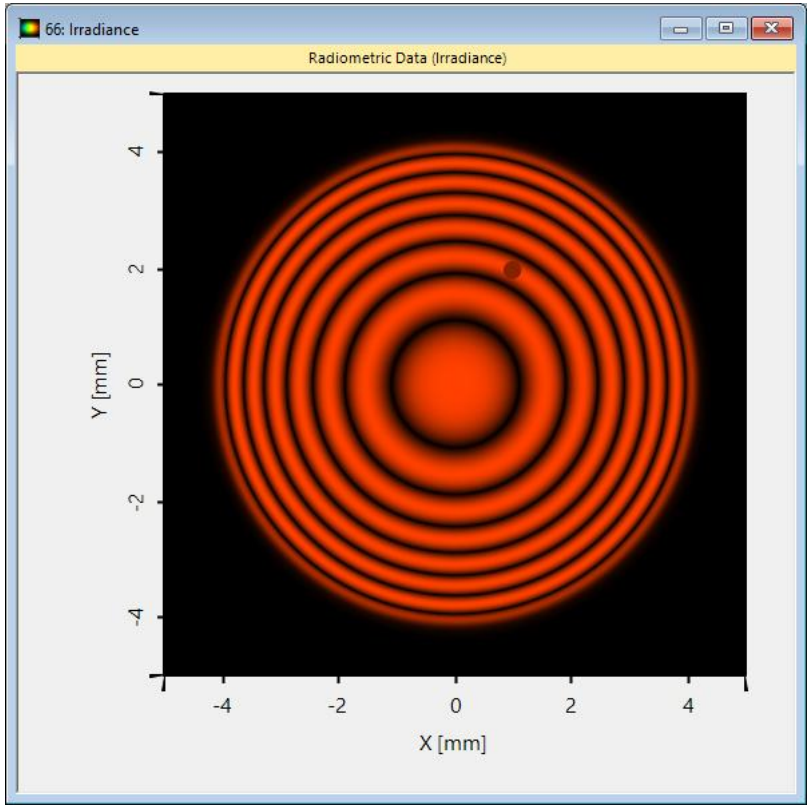




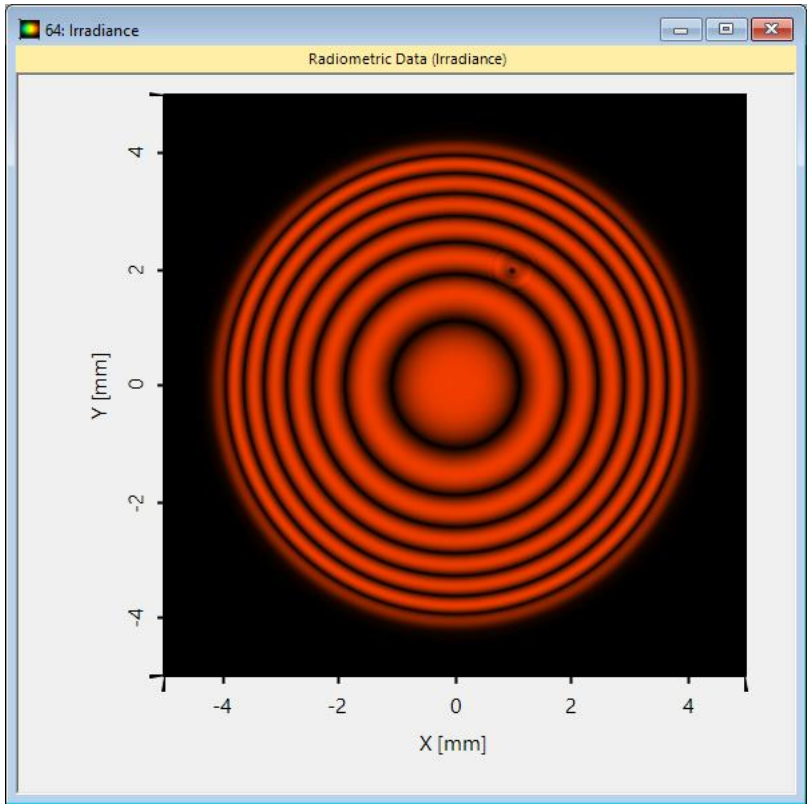
Comparison



Irradiance of the unobstructed field

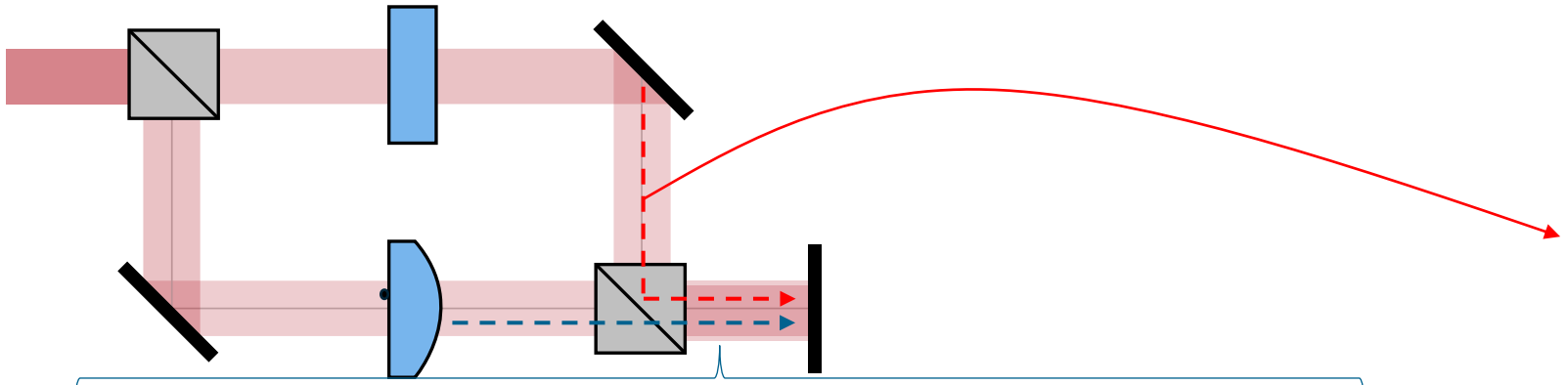


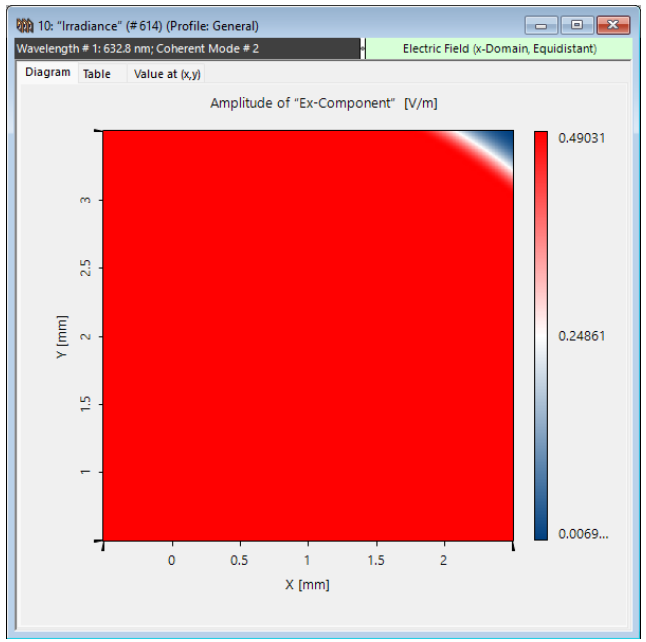
Irradiance of obstructed field without diffraction effects

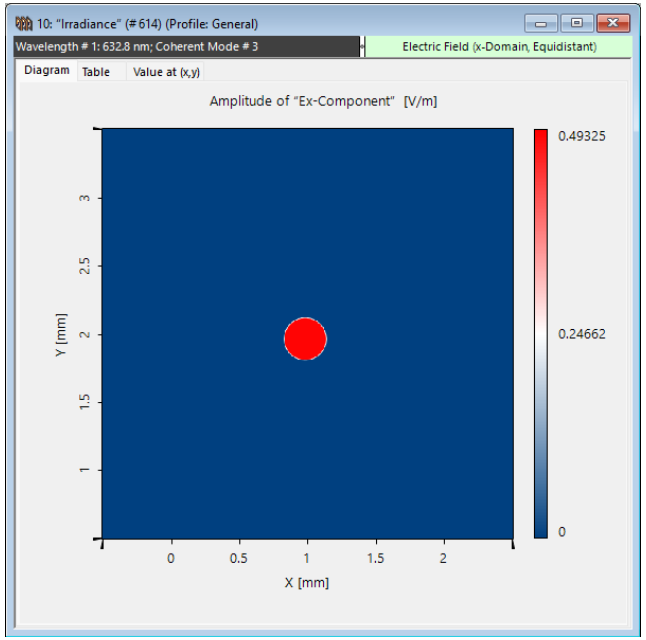


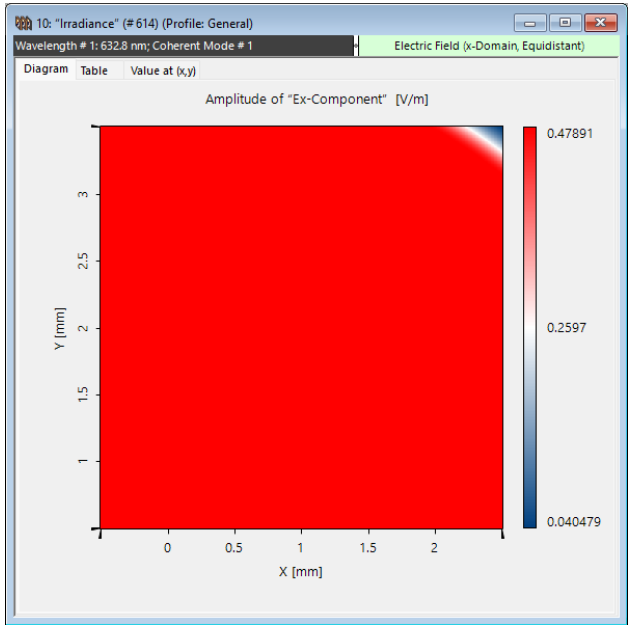
Irradiance of obstructed field with diffraction effects

Field per Mode at Detector (without Diffraction) - Zoom

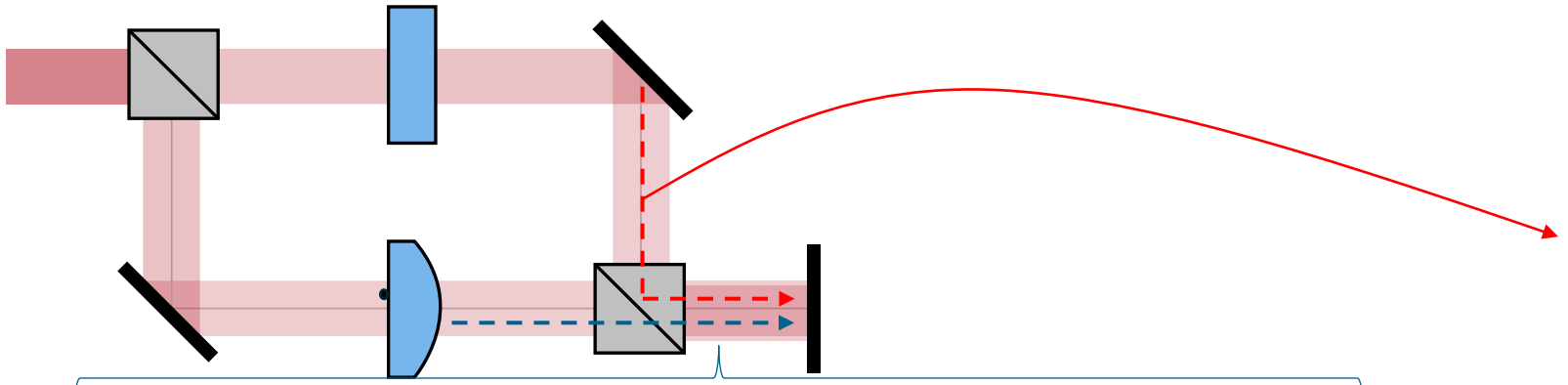


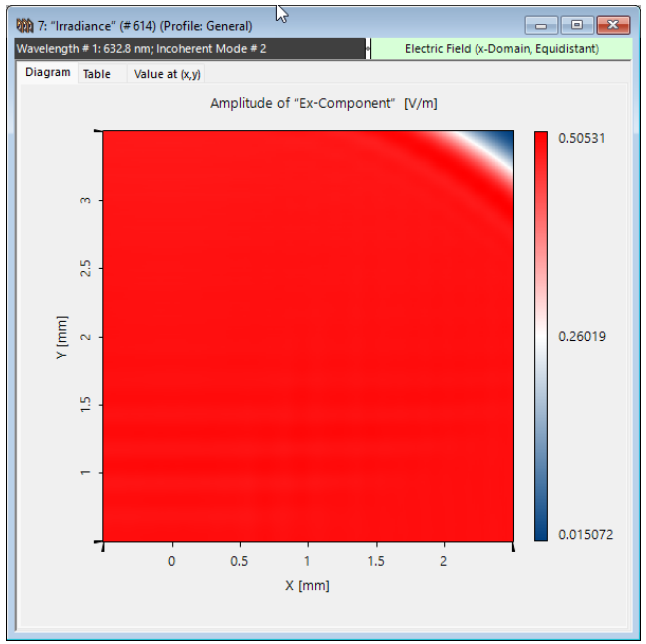


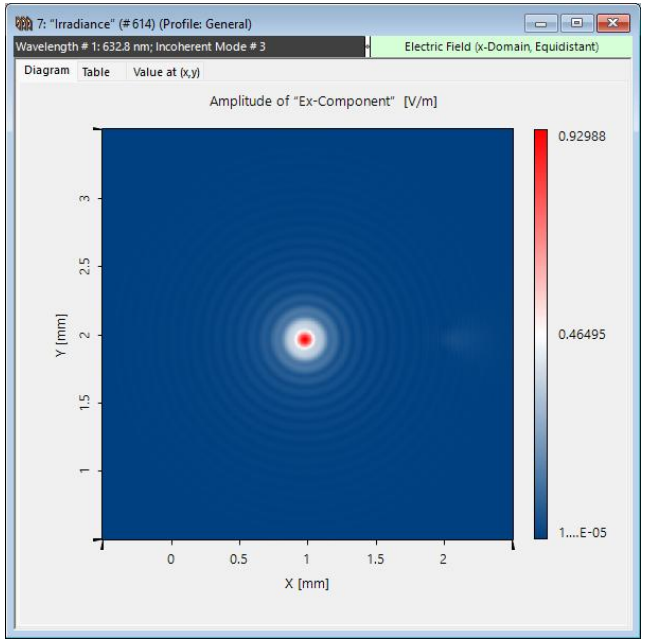


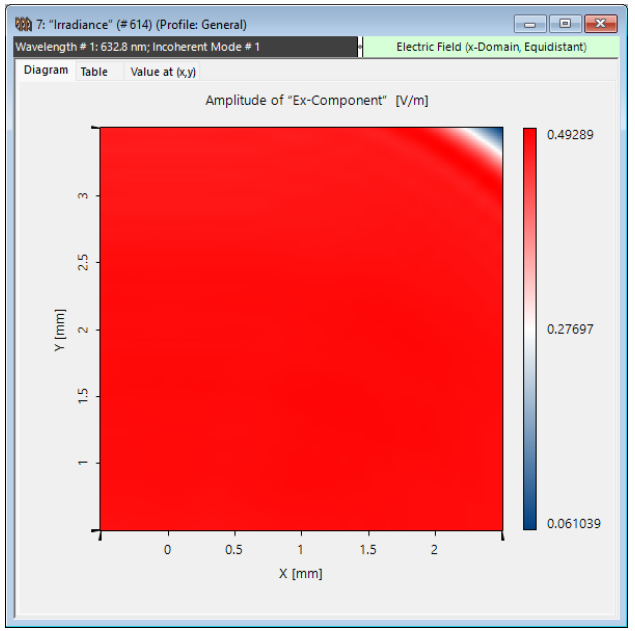


Field per Mode at Detector (with Diffraction)- Zoom

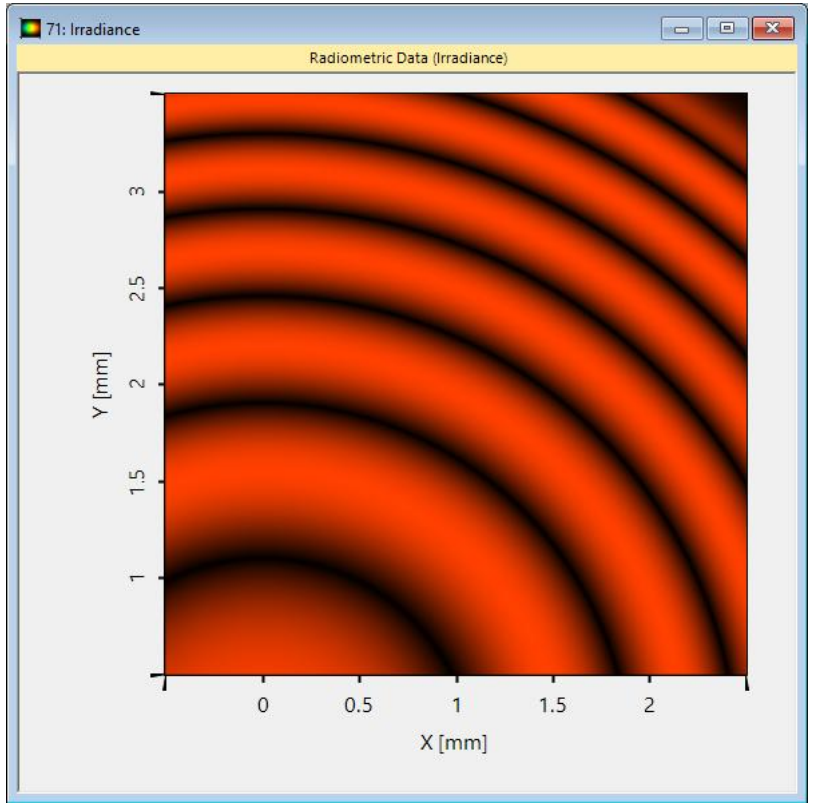




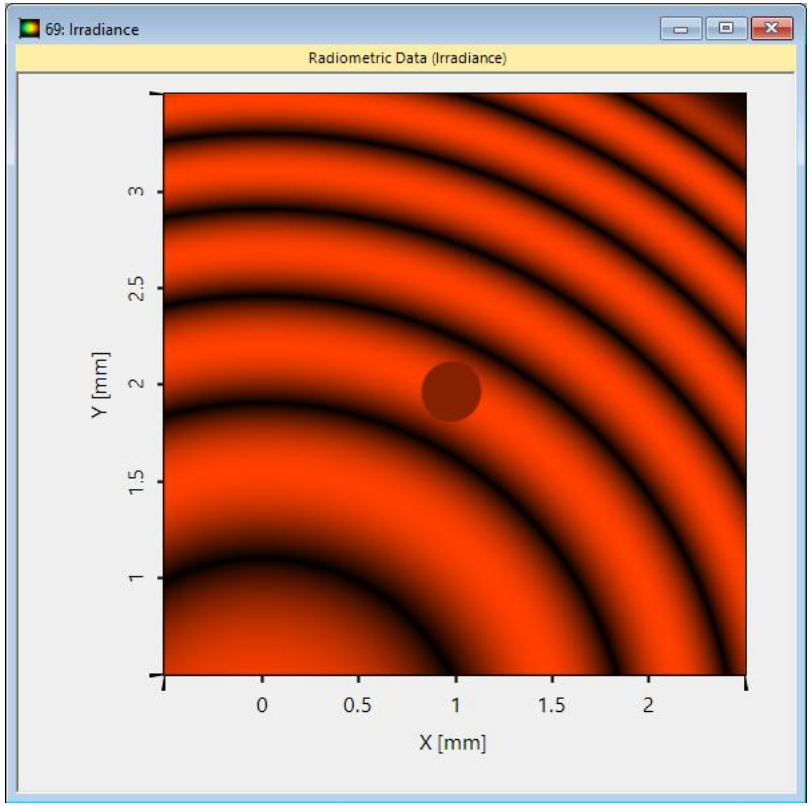




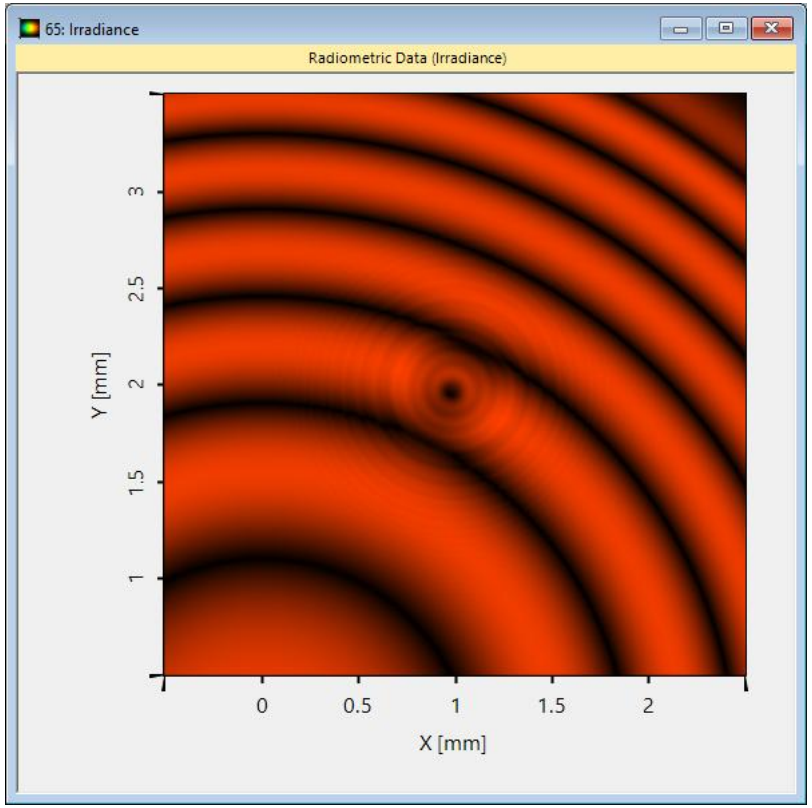
Comparison - Zoom



Irradiance of the unobstructed field



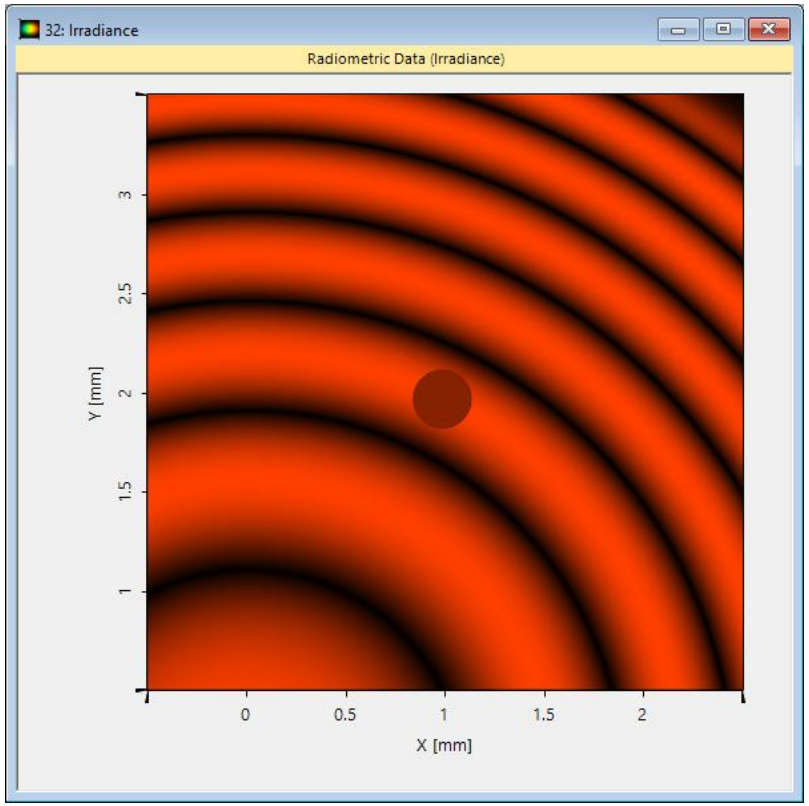
Irradiance of obstructed field without diffraction effects



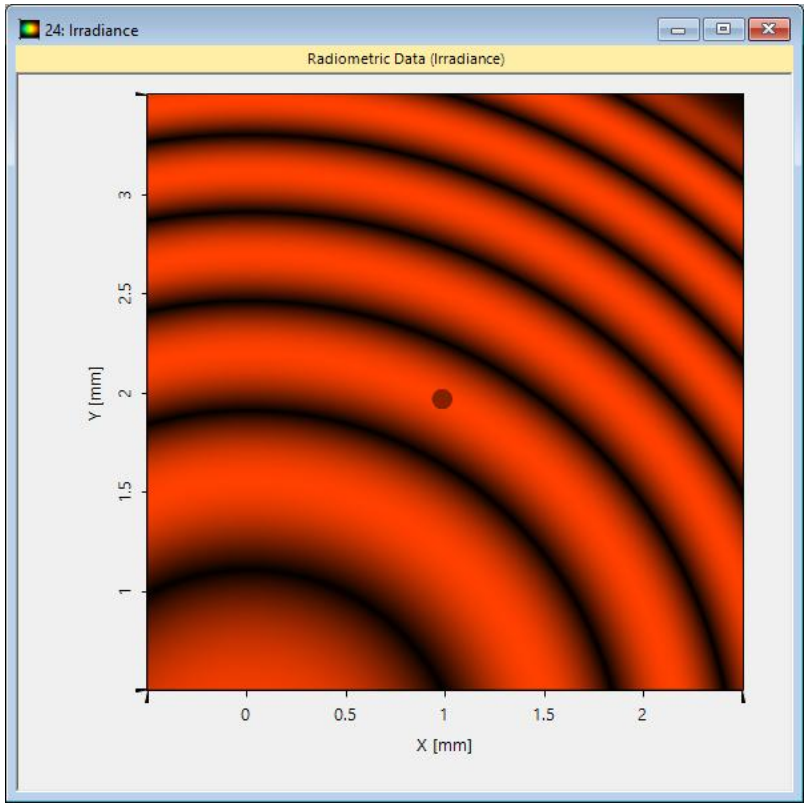
Irradiance of obstructed field with diffraction effects

Task 2: Different Stop Sizes

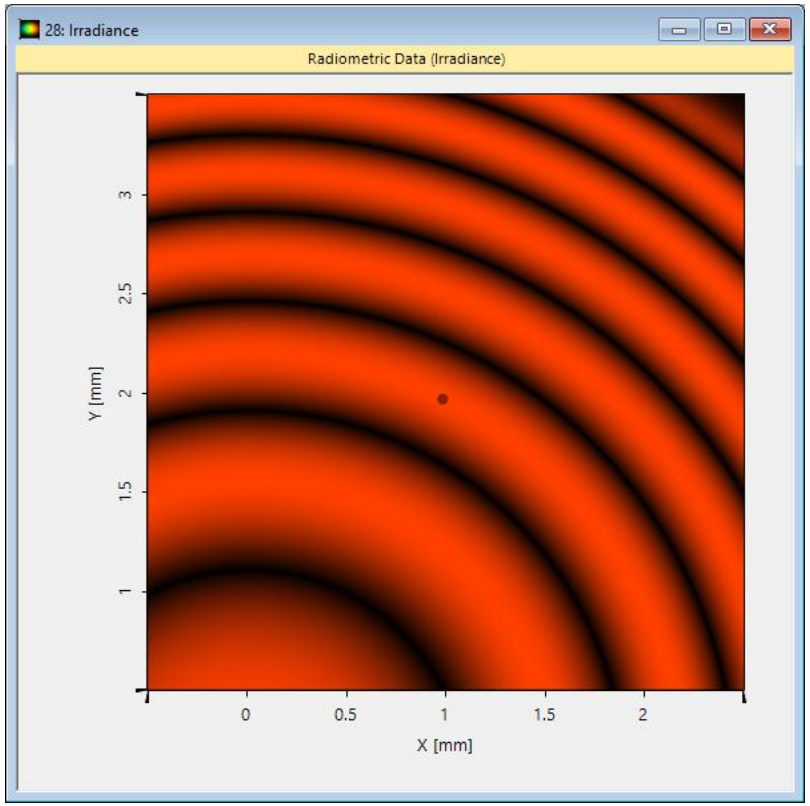
Variation of Defect Size without Considering Diffraction



300 µm defect size

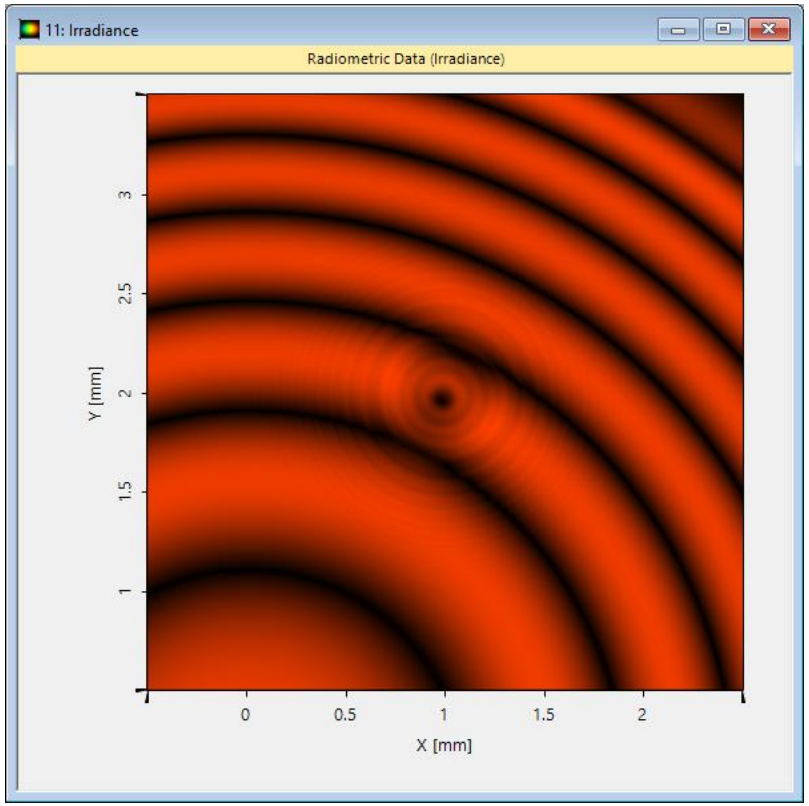


100 µm defect size

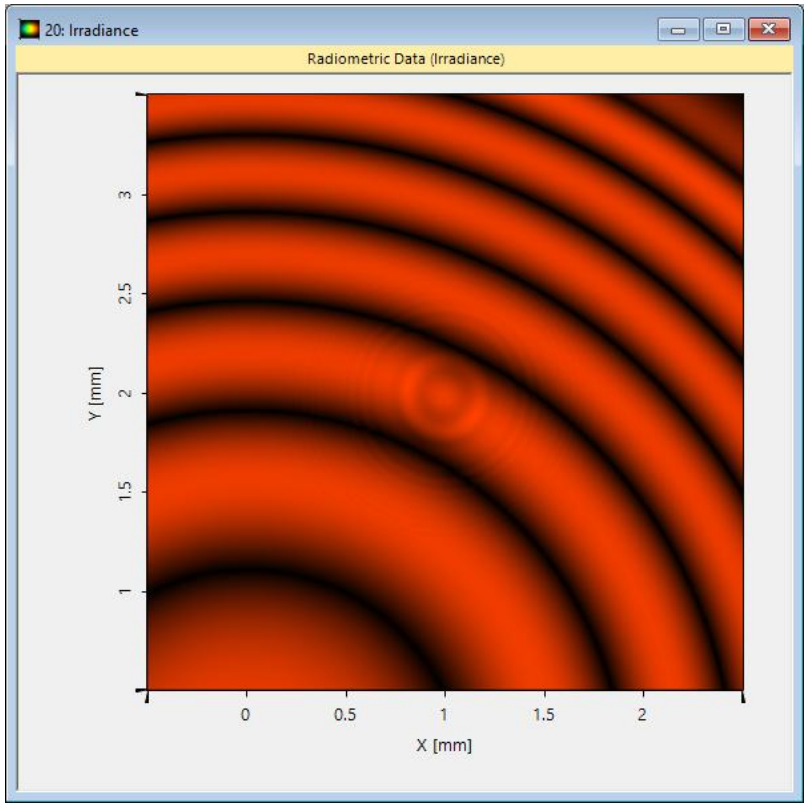


50 µm defect size

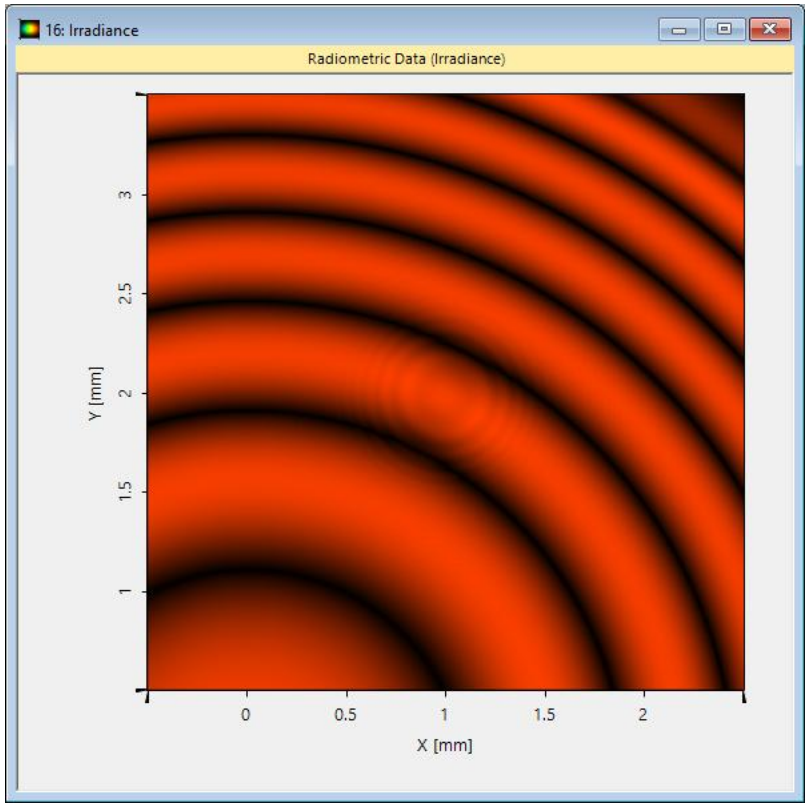
Variation of Defect Size with Considering Diffraction



300 µm defect size



100 µm defect size



50 µm defect size

Workflows

LP Mode Source

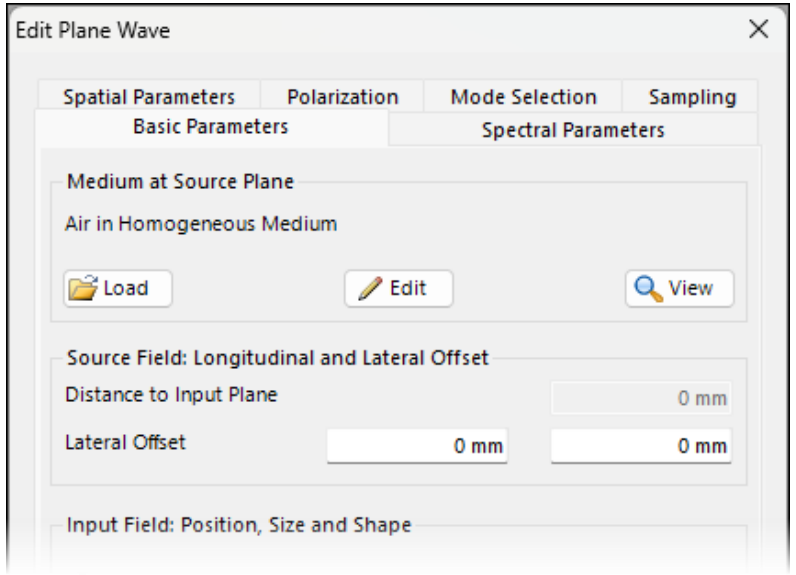
Source selection

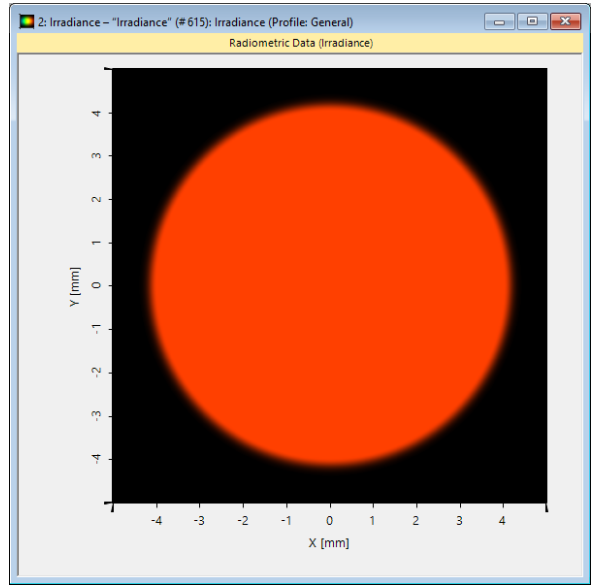
System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Plane Wave





System Setup

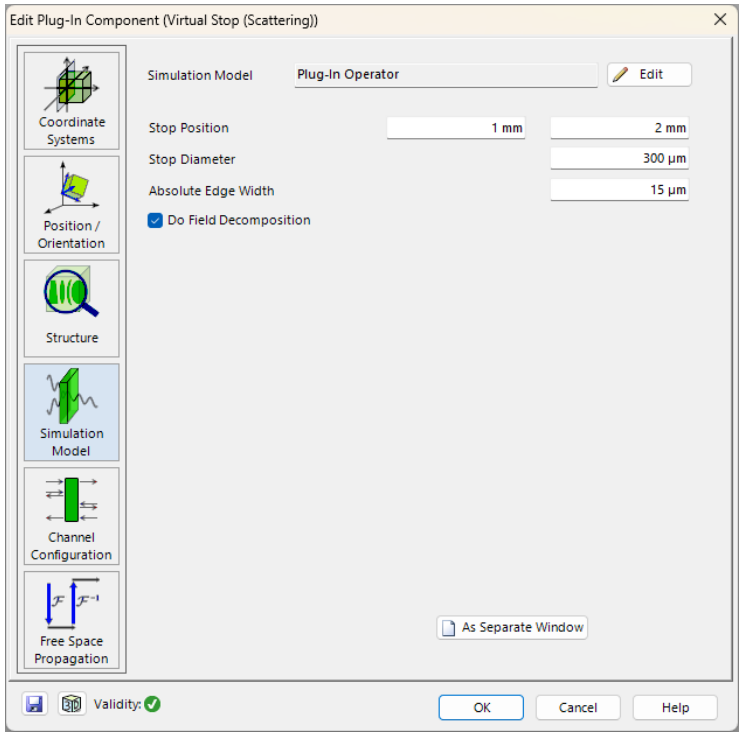
Source selection

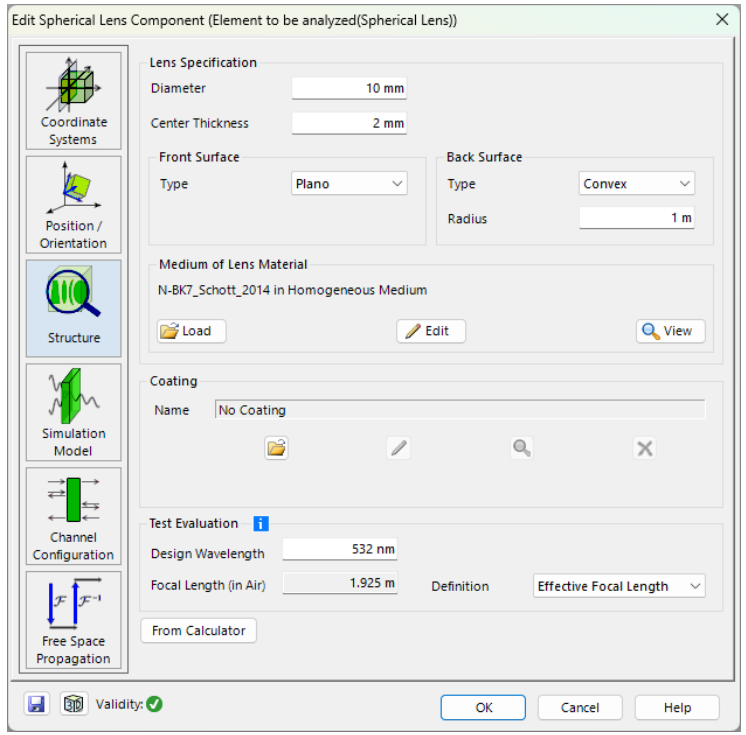
System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Model lens by Spherical Lens component
- Include defect by Virtual Stop component





Detector Selection

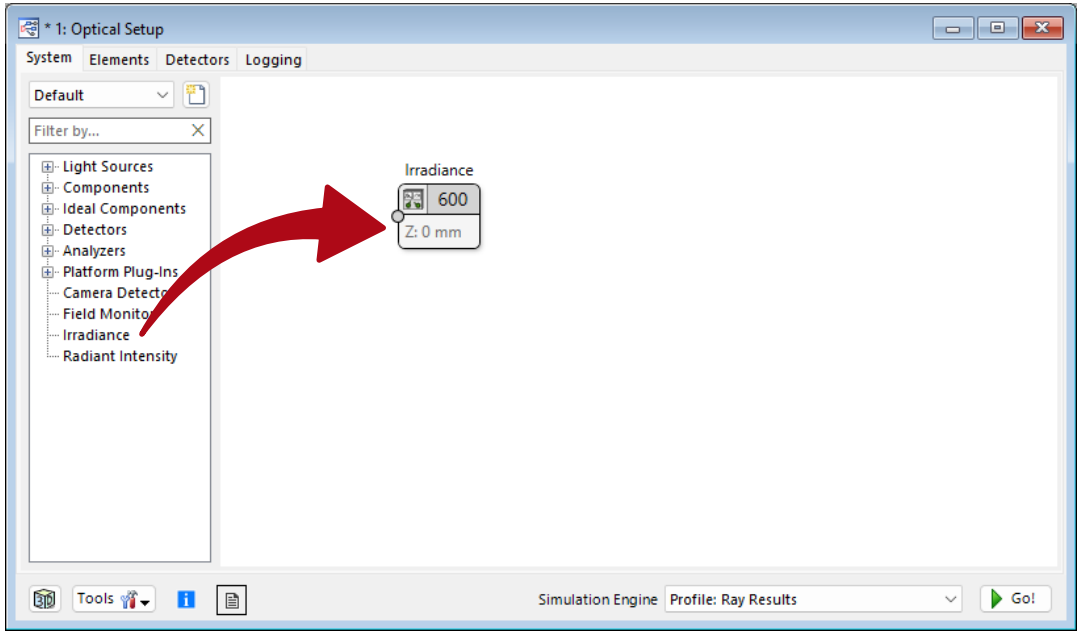
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Add Irradiance detector to your system.



Document Information

Title	Mach-Zehnder Interferometer with Small Obstructions
Document code	USC.0464
Publication date	05.09.2025
Required packages	-
Software version	2025.2 (Build 1.118)*
Category	Use Case
Further reading	- Laser-Based Michelson Interferometer and Interference Fringe Exploration - Fizeau Interferometer for Optical Testing

* *The files attached to this document require the specific version or later.*