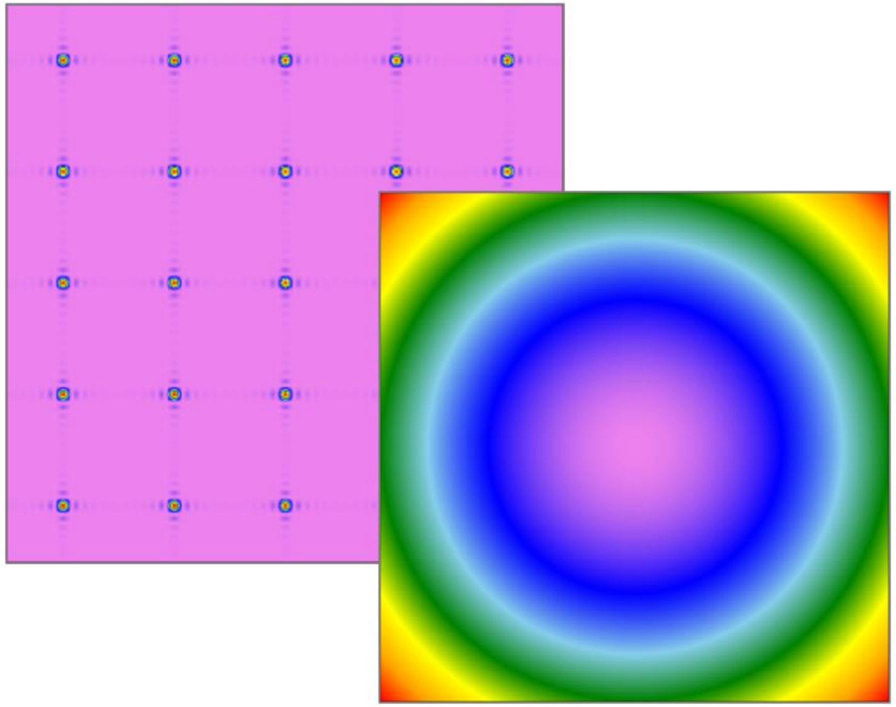
Simulation of a Shack Hartmann Sensor

Abstract



For a full characterization of the electromagnetic field, information about not only the energy density but also the phase are of critical value. While in the simulation we can calculate this information directly from the numerical data, in a real laboratory more sophisticated approaches are necessary. A common tool to measure this information is the Shack-Hartmann sensor, which uses a microlens array (MLA) to reconstruct the wavefront of an incoming field through the displacements of the corresponding spots in the focal plane. For the purpose of investigating this kind of devices we demonstrate the simulation of a Shack-Hartmann sensor, with different wavefronts as input.

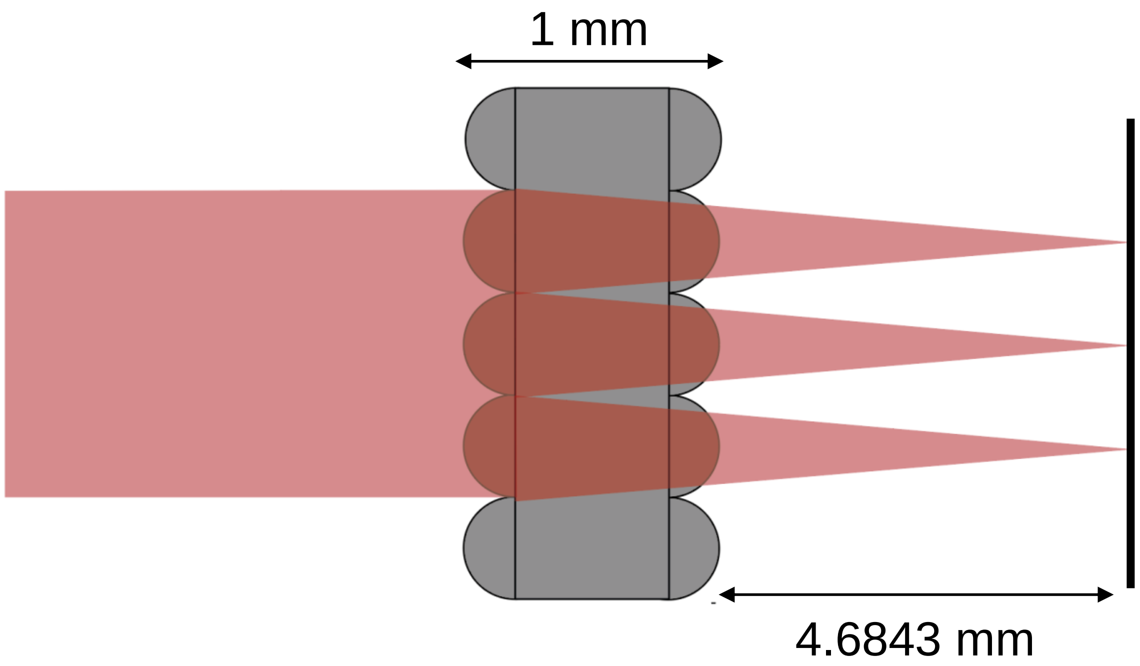
Task Description

a) Plane Wave
- 640 nm wavelength
- Infinite distance to origin
- 2 mm × 2 mm diameter (rectangular)

b) Tilted Plane Wave
- 640 nm wavelength
- 2.5° tilt
- 2 mm × 2 mm diameter (rectangular)

c) Weak Spherical Wave
- 640 nm wavelength
- 100 mm distance to origin
- 2 mm × 2 mm diameter (rectangular)

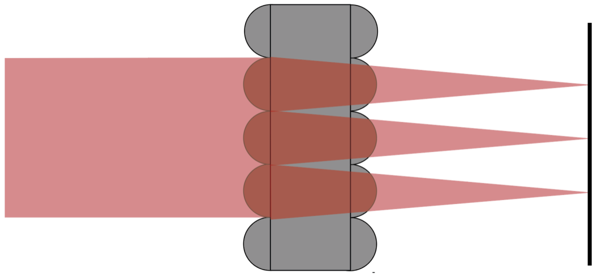
d) Strong Spherical Wave
- 640 nm wavelength
- 40 mm distance to origin
- 2 mm × 2 mm diameter (rectangular)



Microlens Array
- Material: N-BK7
- Convex-Convex doublets
- Radius of Curvature: 5 mm
- 200 µm × 200 µm lens size (rectangular)
- 5 × 5 microlenses

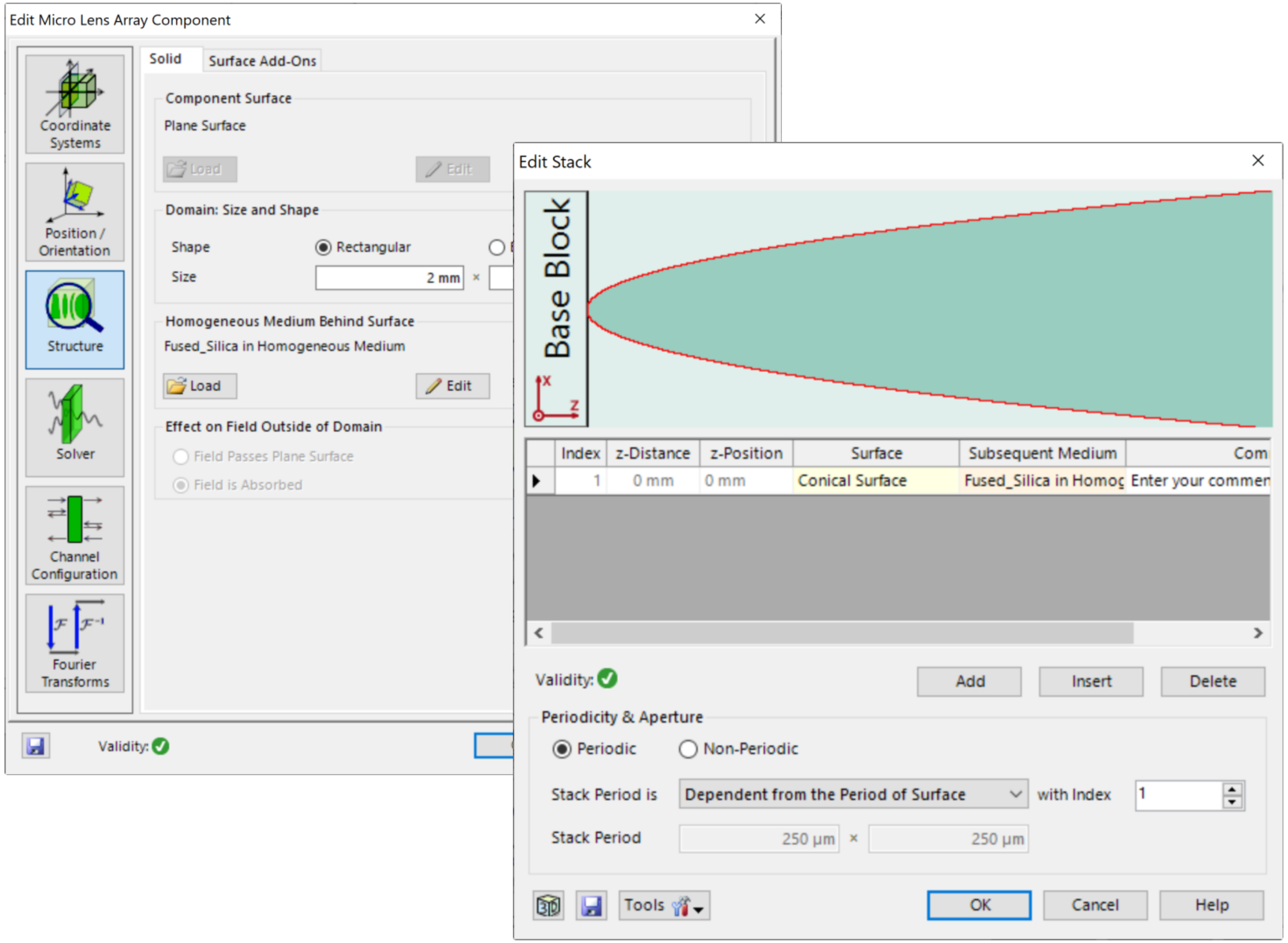
Detectors
- wavefront of input field
- Energy density of the electromagnetic fields in focus plane of ideal plane wave

System Building Blocks – Components

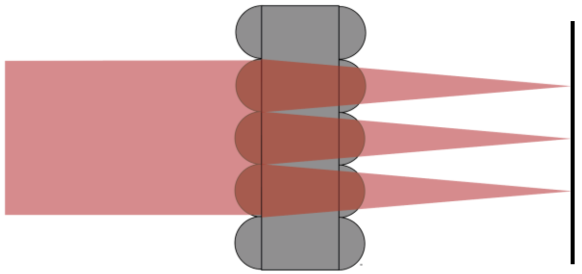


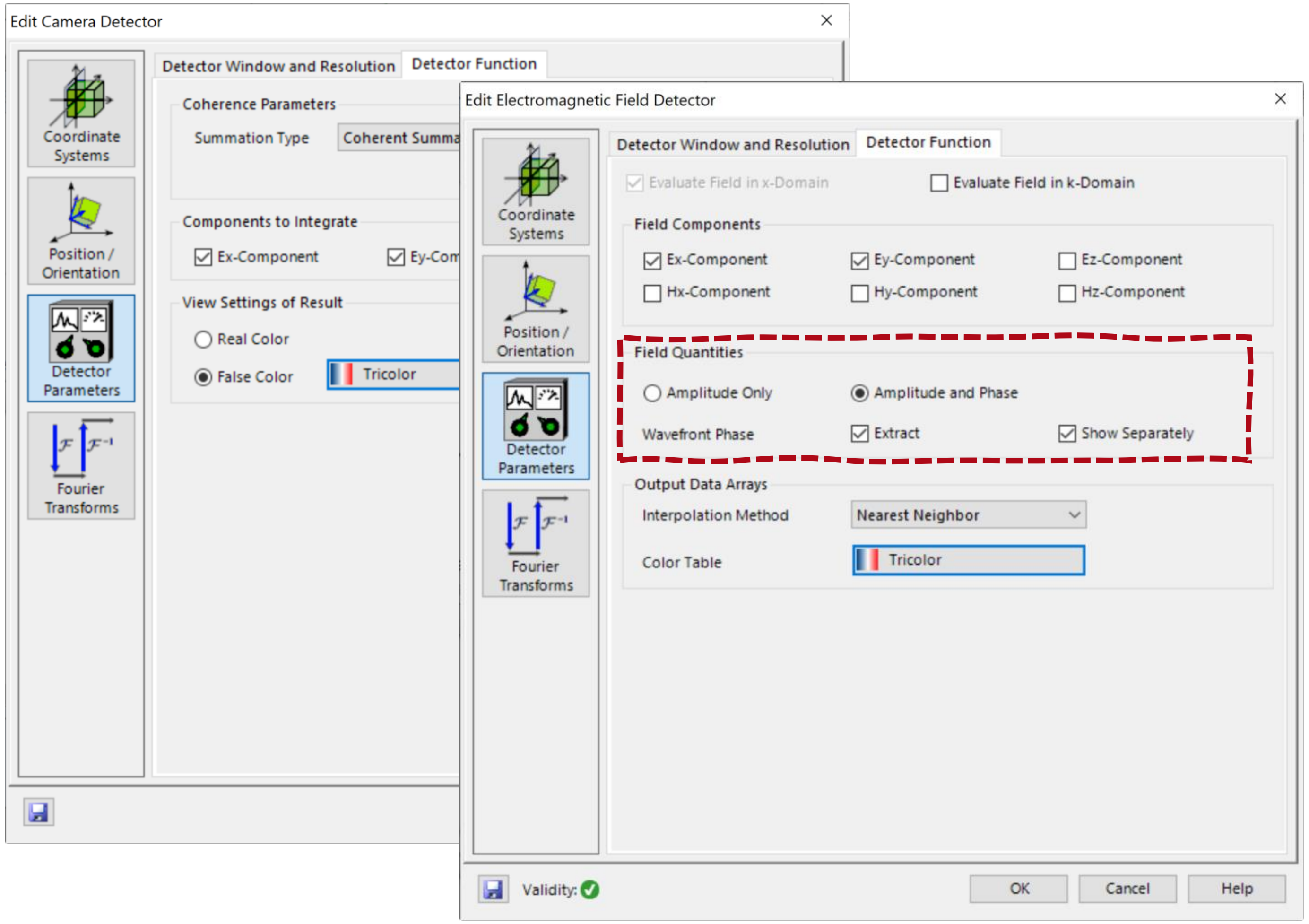
The *Microlens Array* component allows an easy definition of an arbitrarily shaped microlens array. The material and size are defined via the *Solid* tab, while the microlens surface shape is configured using the stack concept, and is accessible via the separate *Surface Add-Ons* tab.

The component enables the simulation through the entire structure or through an individual microlens.



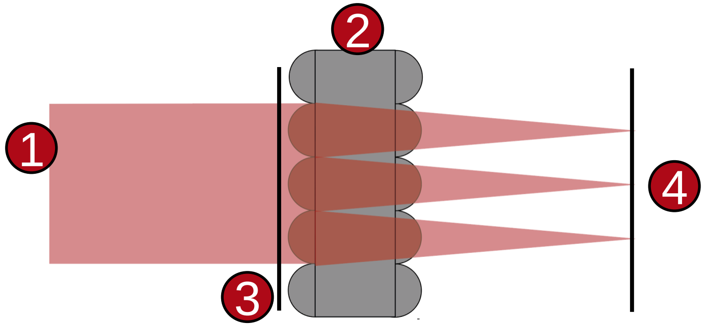
System Building Blocks – Detectors





The *Camera Detector* is able to calculate the energy density of the electromagnetic field at any point of the system. The *Electromagnetic Field* Detector calculates the pure, complex-valued field data. It can also calculate and extract the wavefront of said field if the user wishes to see this information.

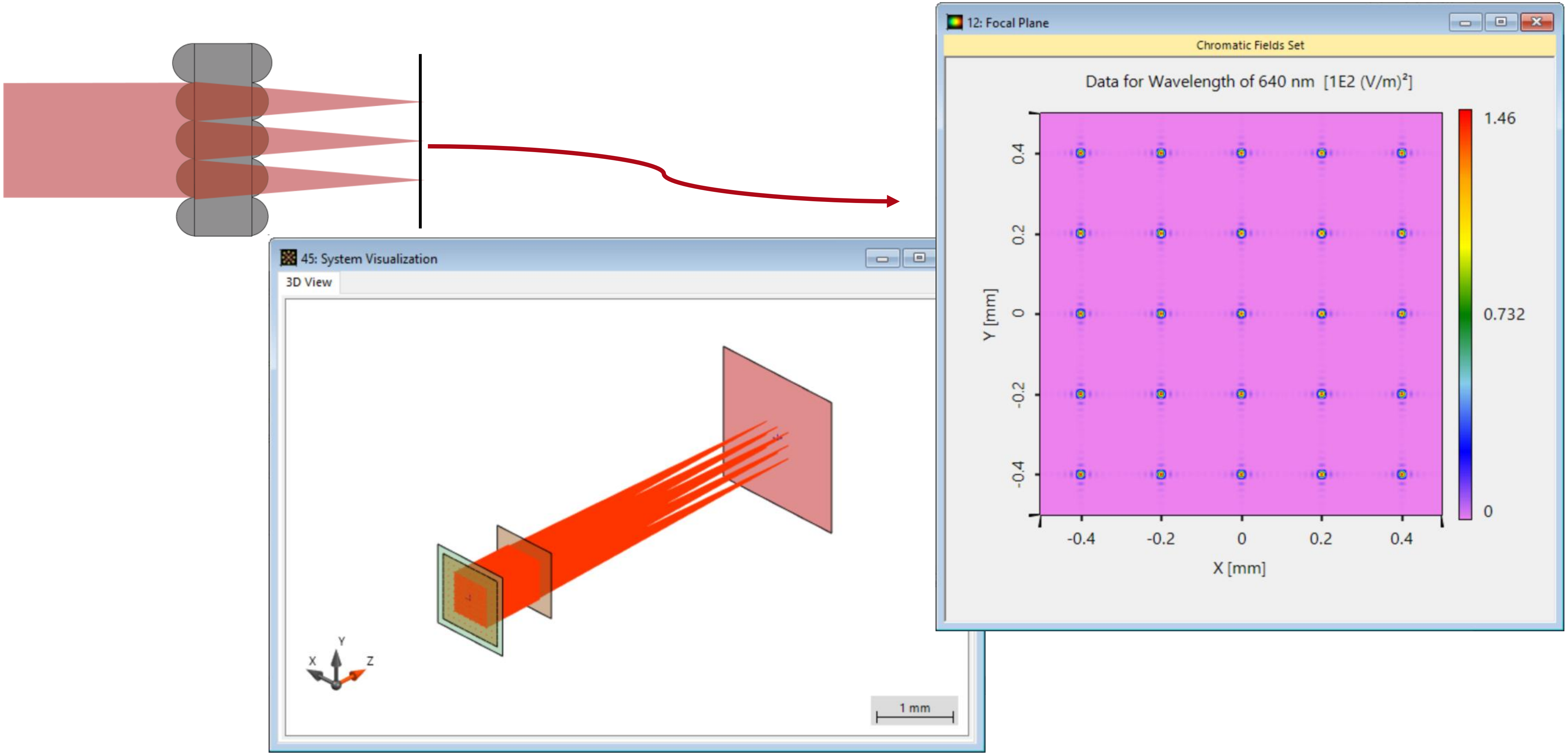
Summary – Components...



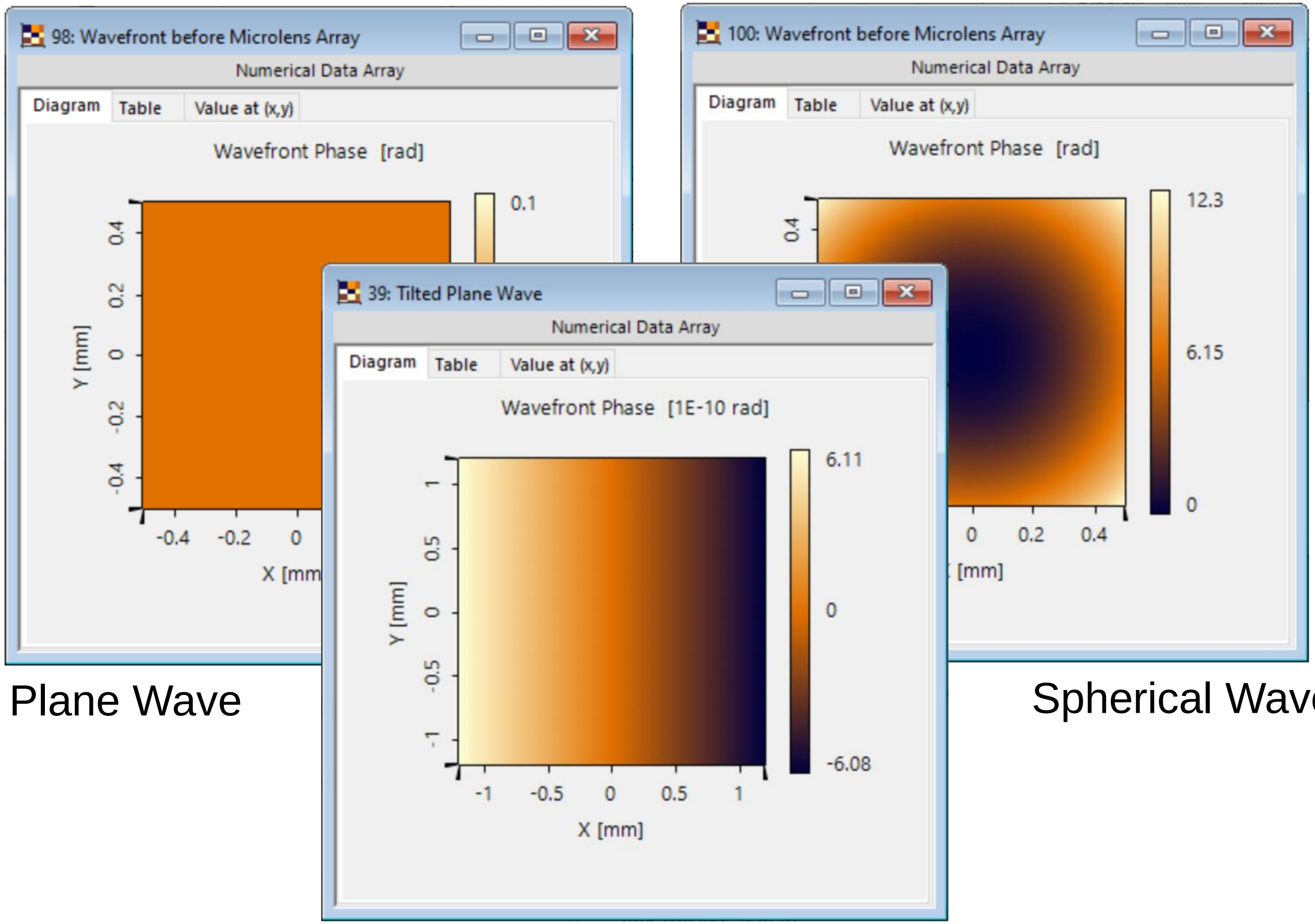
… of Optical System	**… in VirtualLab Fusion**	**Model/Solver**
1. Source	*Plane Wave* Source	Truncated Ideal Plane Wave
2. Microlens Array	*Microlens Array* Component	Local Plane Interface Approximation
3. Detector before MLA	*Electromagnetic Field Detector*	Field Components with optional Extraction of Wavefront
4. Detector in Focal Plane	*Camera Detector*	Energy density

Simulation Results

First Impressions of Ray and Field Simulation



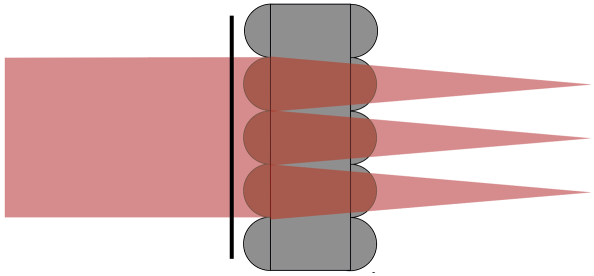
Wavefront before MLA



Plane Wave

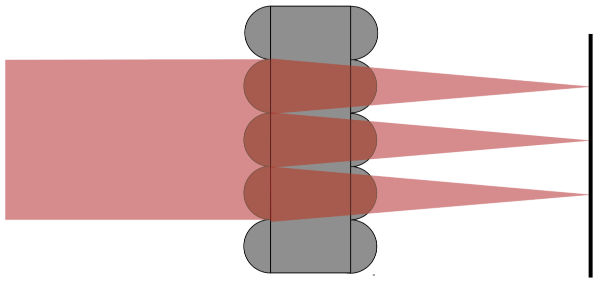
Spherical Wave

Tilted Plane Wave

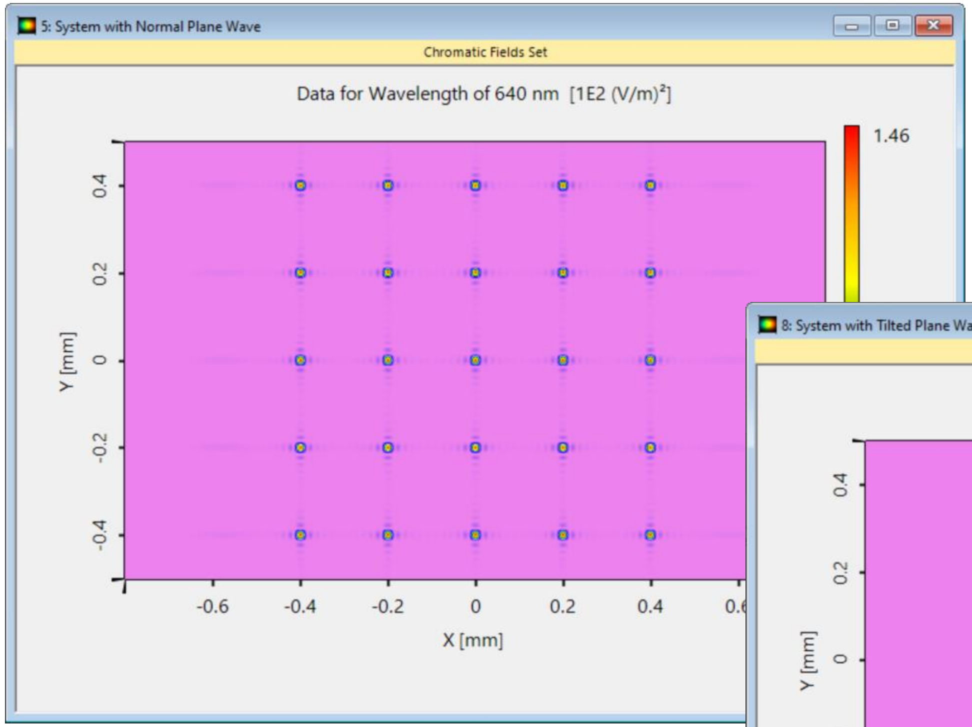


In a simulation, the wavefront of the field can be detected before entering the Shack-Hartmann sensor. For a well-collimated beam, since it does not possess a significantly deformed wavefront, we expect the spots in the focal plane to form an equidistant grid. In the case of the spherical wave, however, the off-center spots will experience a shift in their position, depending on the strength of the spherical wavefront.

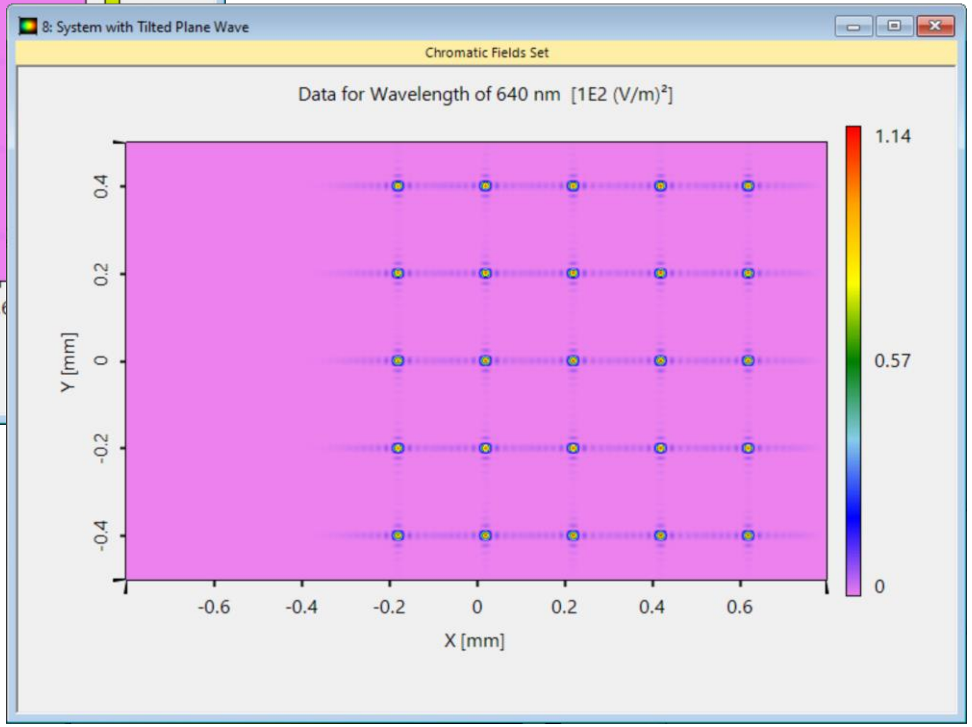
Normal vs Tilted Plane Wave



Normal Plane Wave



Tilted Plane Wave



- A non-perpendicularly impinging plane wave leads to a shift of the entire pattern to the corresponding side.

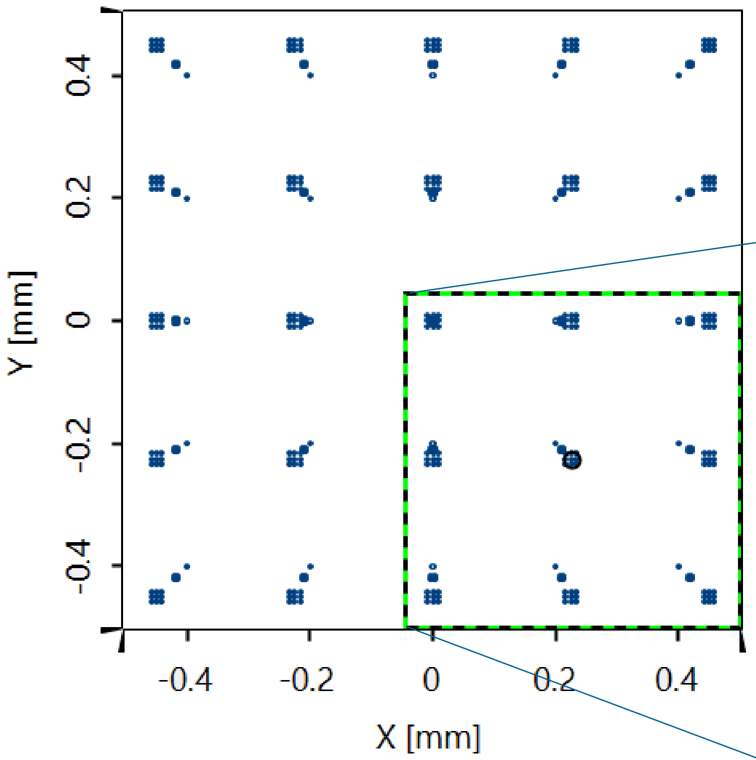
- More complex wavefront phases lead to an inhomogeneous distribution of the spot shifts.

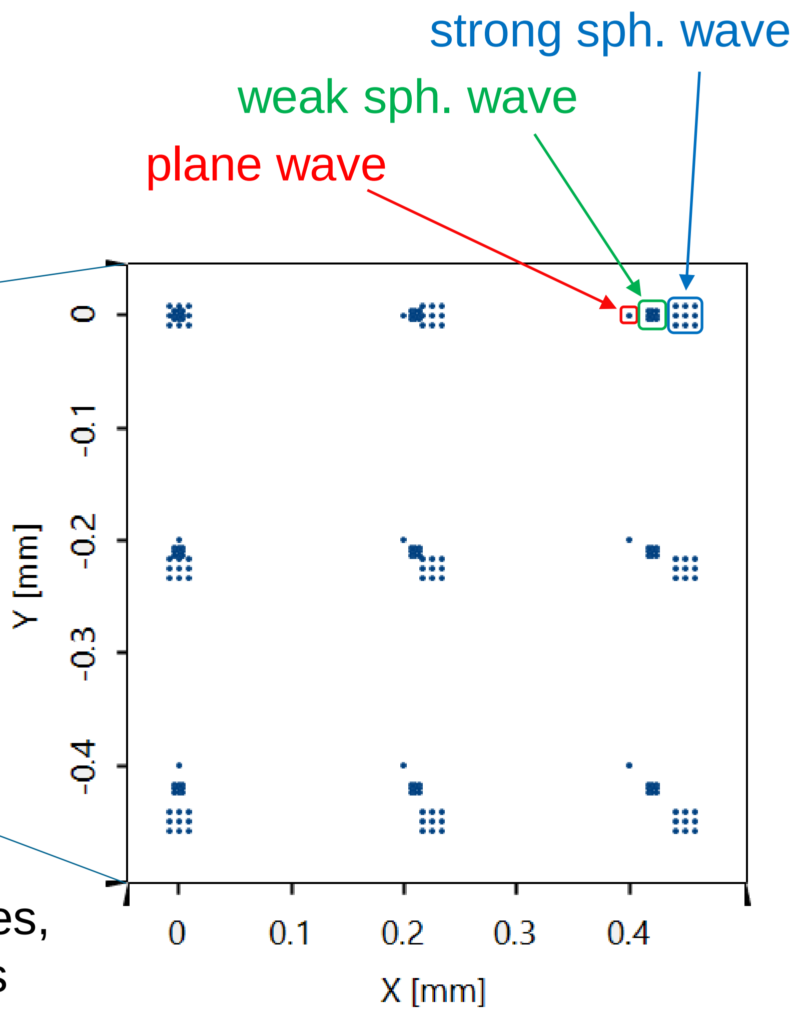
Ray Tracing Result from Plane & Two Spherical Waves

The adjacent figures show the ray tracing results from the

- plane wave
- weak divergent spherical wave
- strong divergent spherical wave

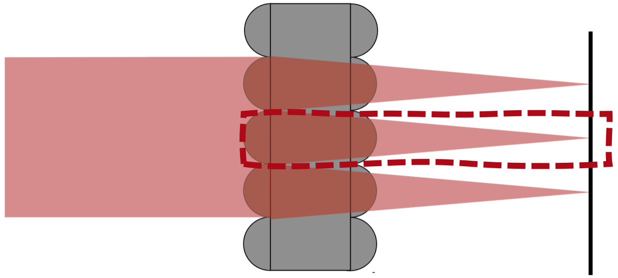
together in one plot simulated via the Multiple Light Source.



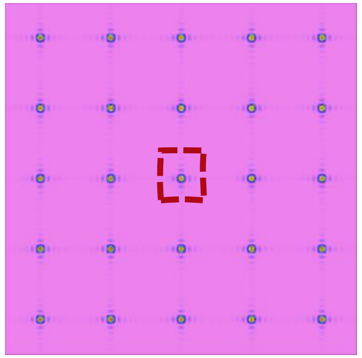


The center spots are at the same position, but with different spot appearances, and the further away from the center, the spots derived from spherical waves exhibit an additional outwards shift according to their divergence.

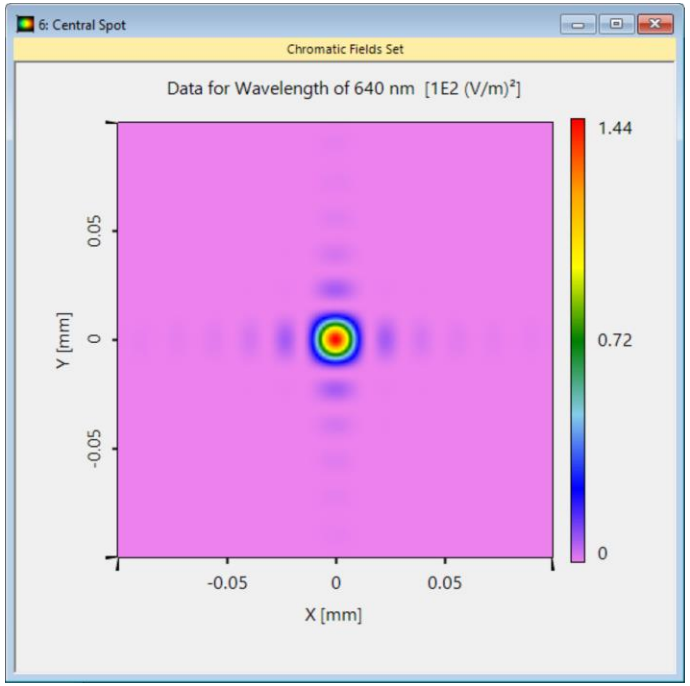
Spherical Wavefront – Central Spot



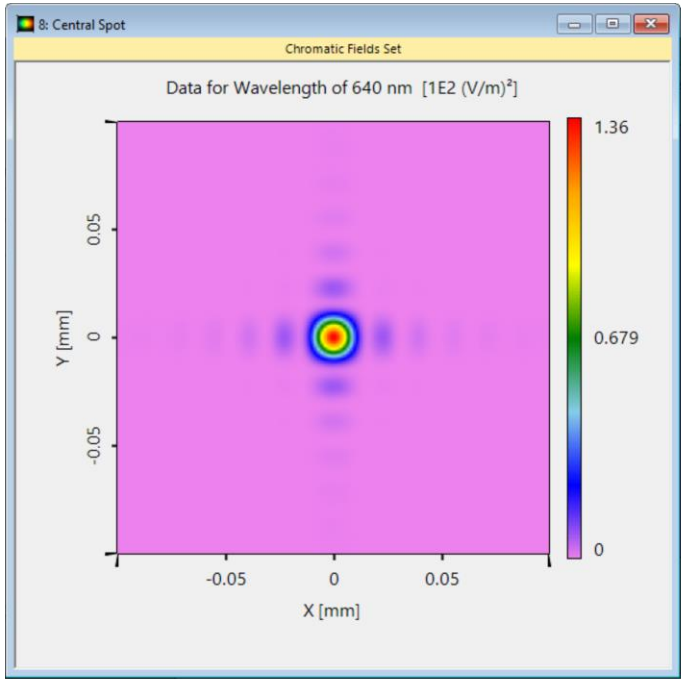
For the central spots the positioning is the same as the wavefront on the optical axis is also the same for all three cases.



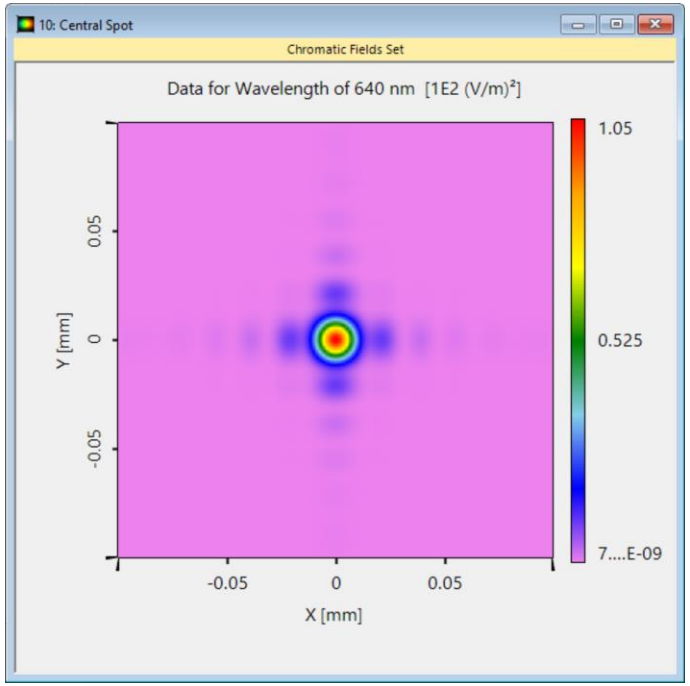
Plane Wave



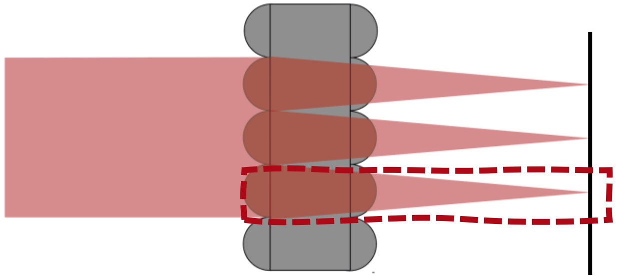
Weak Spherical Wave



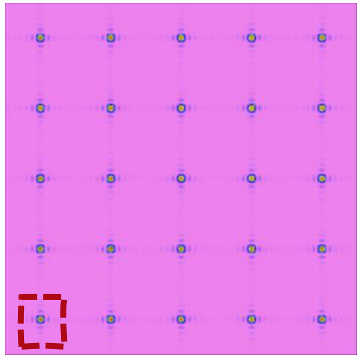
Strong Spherical Wave



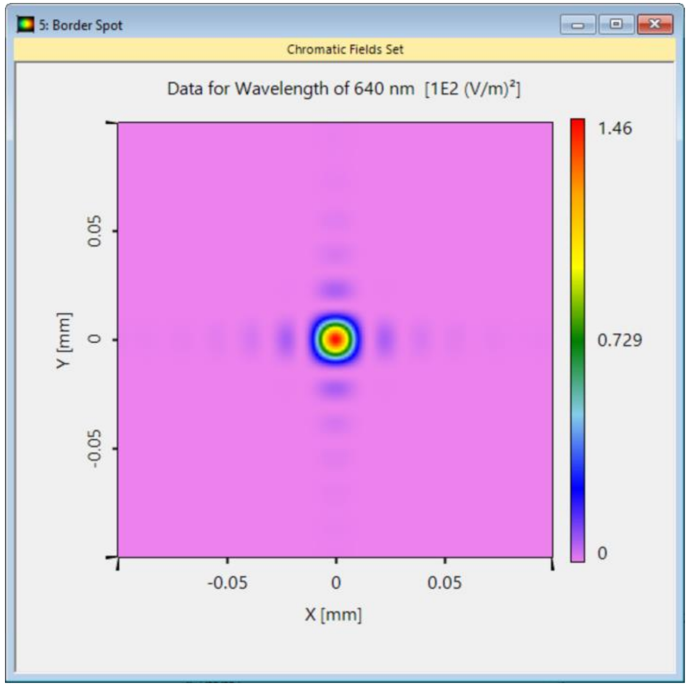
Spherical Wavefront – Corner Spot



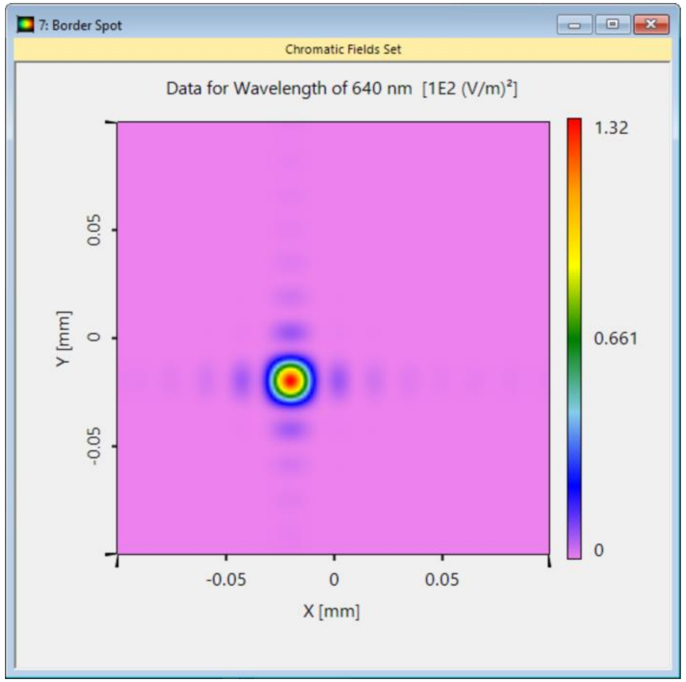
For the off-axis spots, however, the position of the spot shifts depending on the strength of the incoming wavefront.



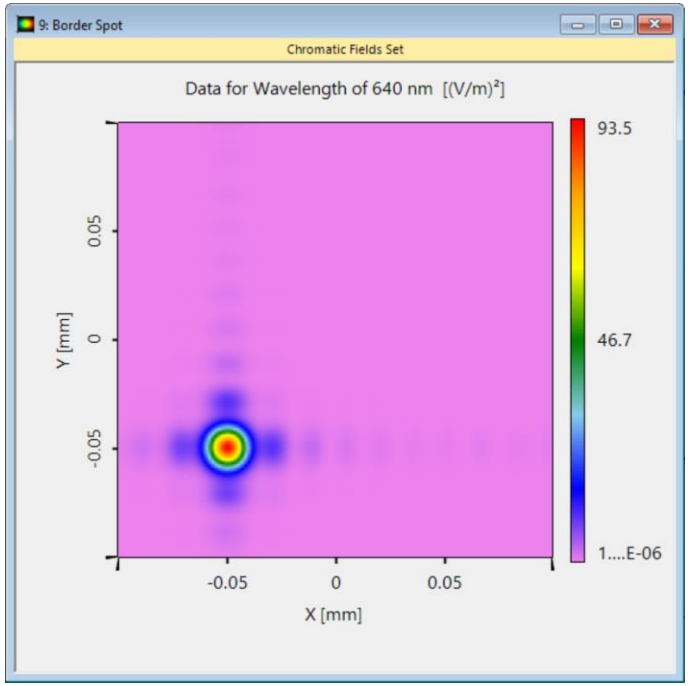
Plane Wave



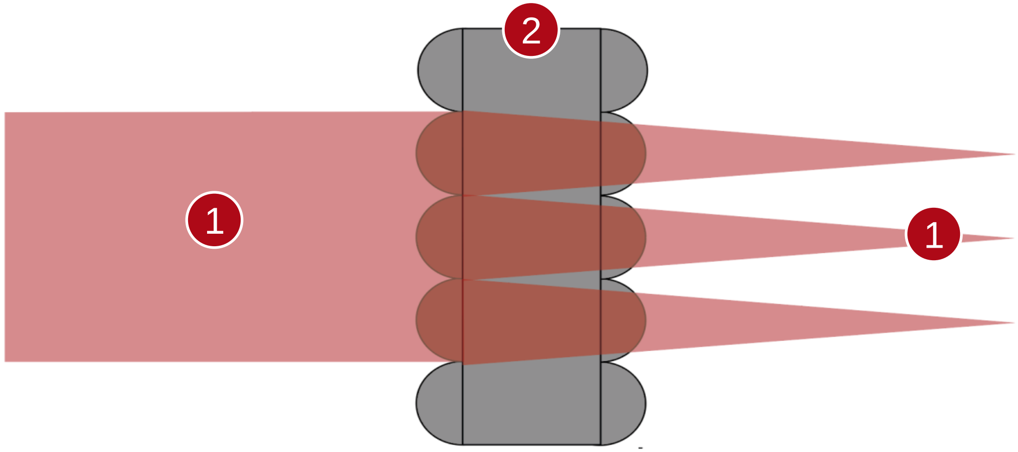
Weak Spherical Wave

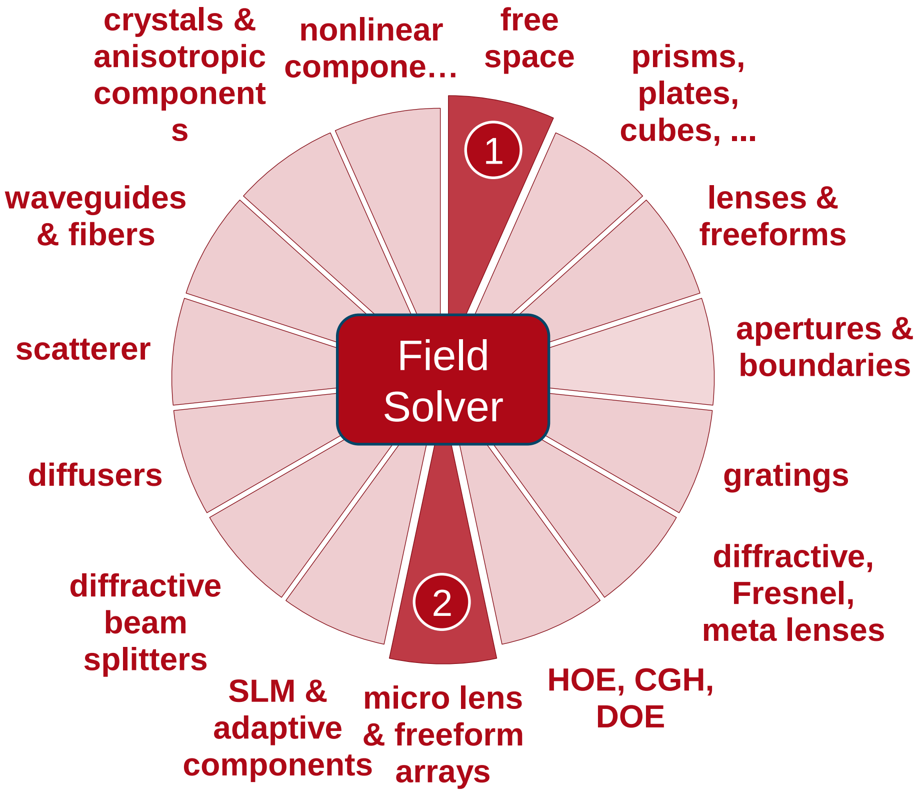


Strong Spherical Wave



VirtualLab Fusion Technologies





Document Information

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