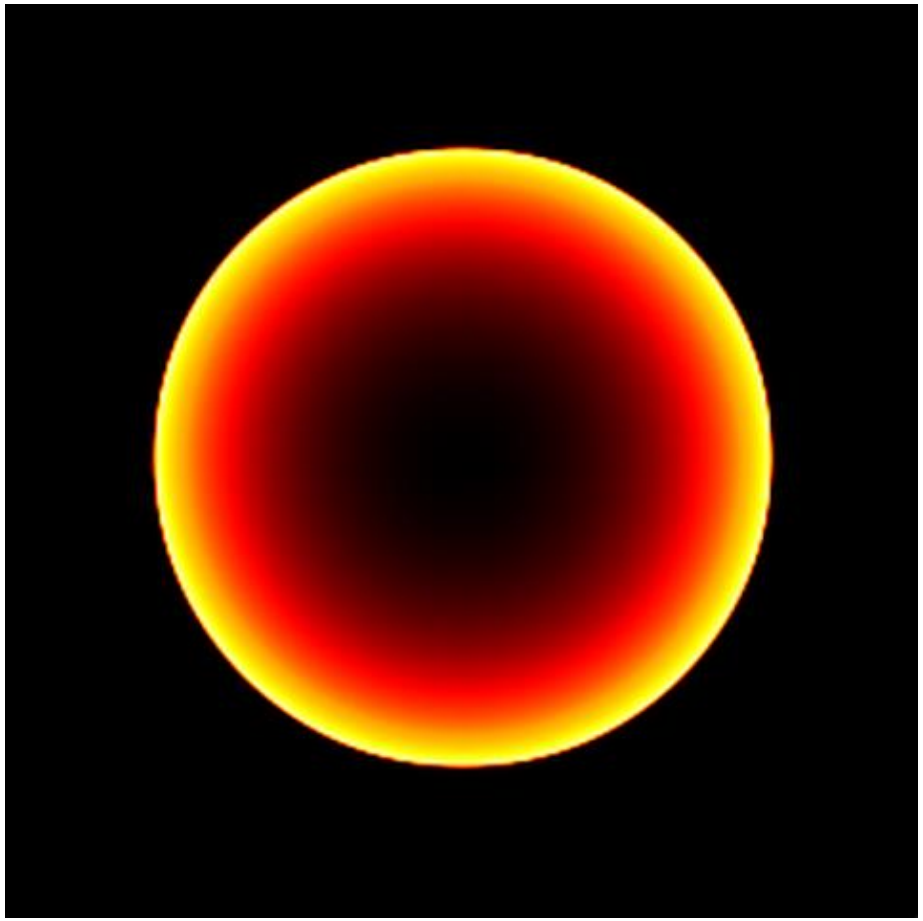
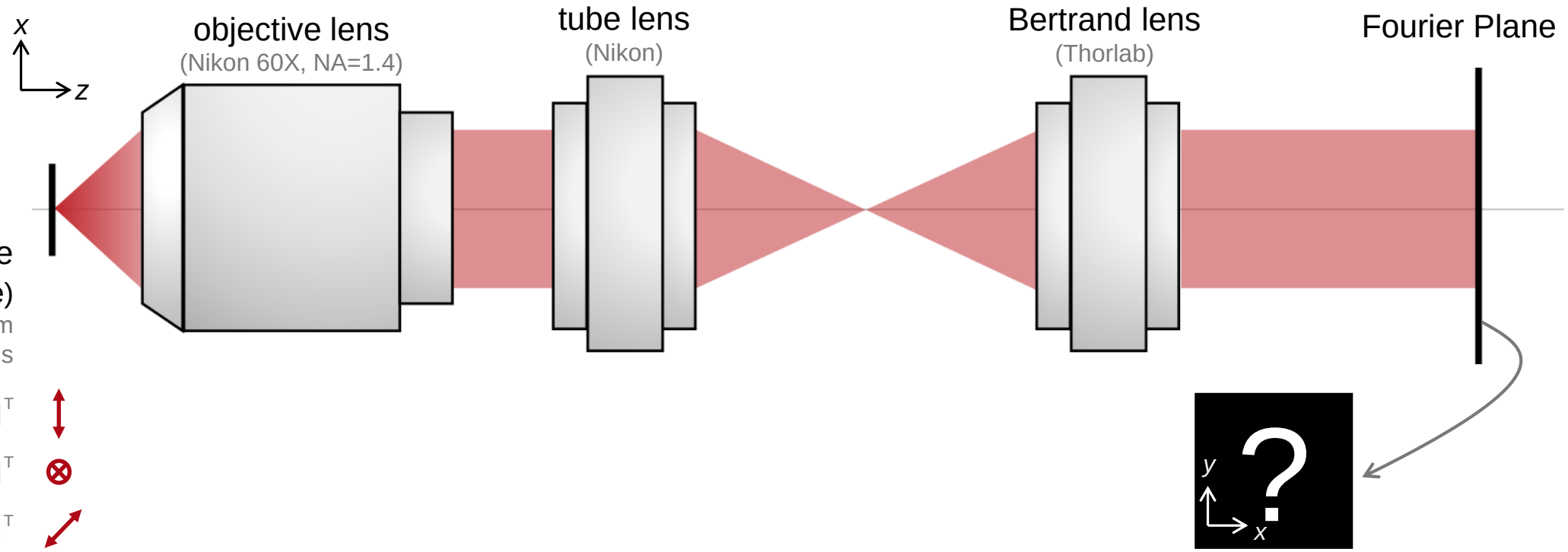
Single Molecule Imaging by High-NA Fourier Microscope

Abstract



Fourier microscopy is widely used for single molecule imaging, surface plasma observation, photonic crystal imaging, etc. It makes the direct observation of the spatial frequency distribution possible. The image quality of single molecule depends on the high-NA Fourier microscopy system, e.g. the angle-dependent Fresnel loss at each optical interfaces in the complex lens systems and the diffraction from the aperture. VirtualLab Fusion can model the entire system with the Fresnel loss and aperture diffraction effects considered. An example is presented in and we compare the simulation results with experimental results from literature.

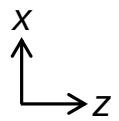
Modeling Task



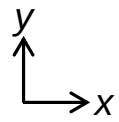
How does the Fourier plane image change with the change of the orientations of the single molecule?

Image at the Fourier Plane

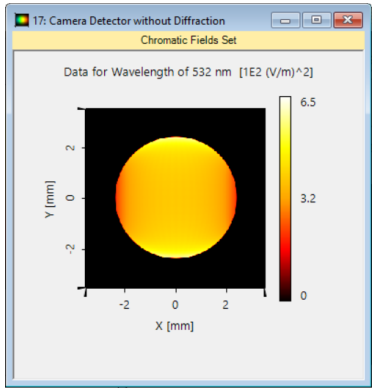
Dipole moment $[p_x, p_y, p_z]^T$

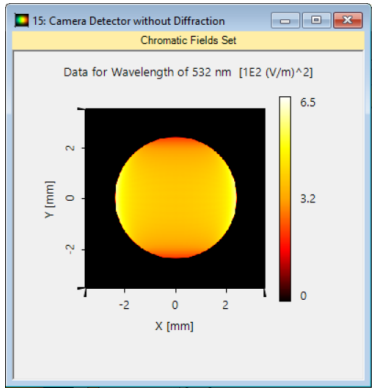


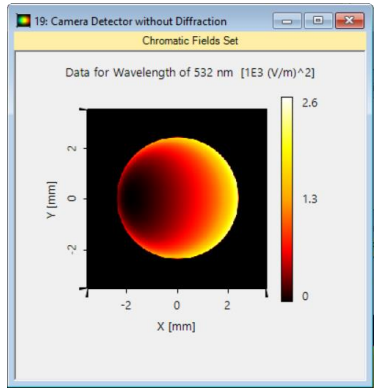
$[1,0,0]^T$ $[0,1,0]^T$ $[1,0,1]^T$ $[0,0,1]^T$

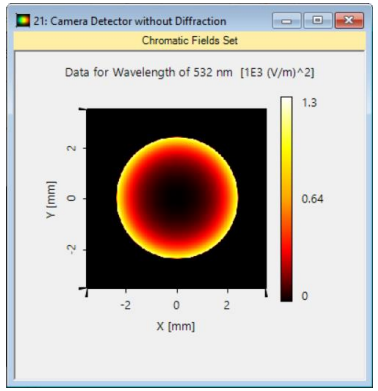


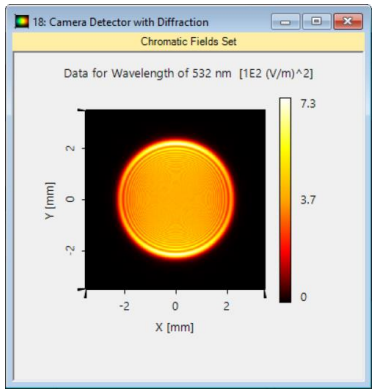
- without diffraction from aperture
- with diffraction from aperture

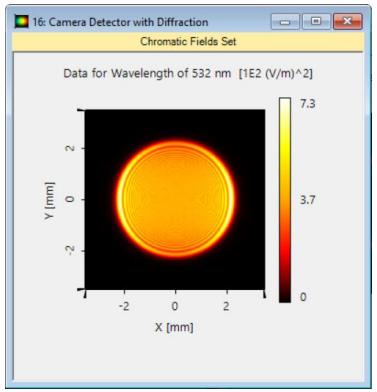


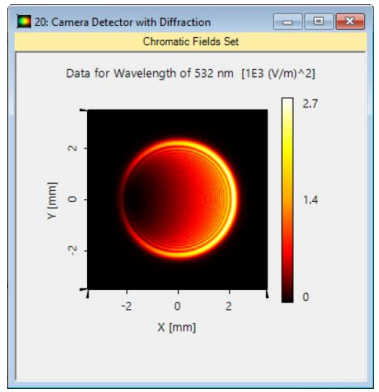












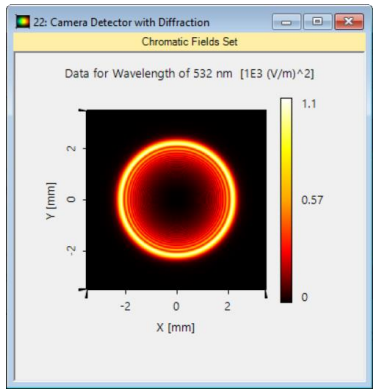
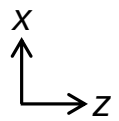
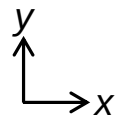


Image at the Fourier Plane

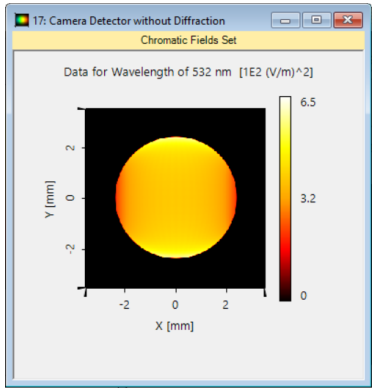
Dipole moment $[p_x, p_y, p_z]^T$

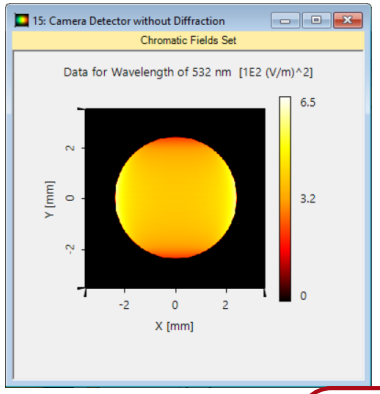


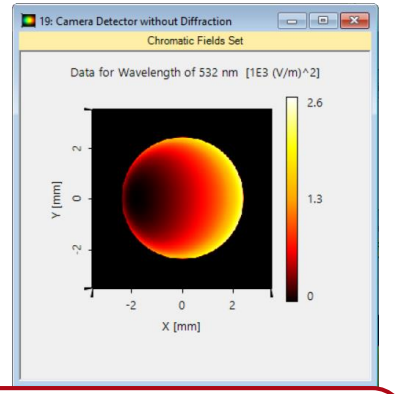
$[1,0,0]^T$ $[0,1,0]^T$ $[1,0,1]^T$ $[0,0,1]^T$

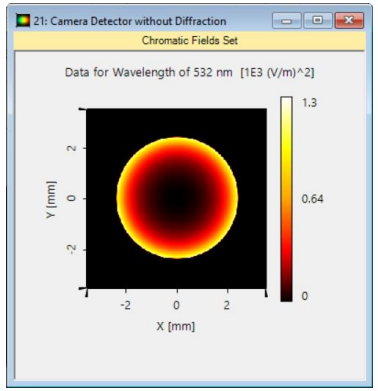


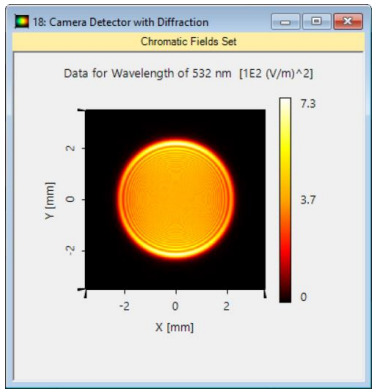
- without diffraction from aperture
- with diffraction from aperture

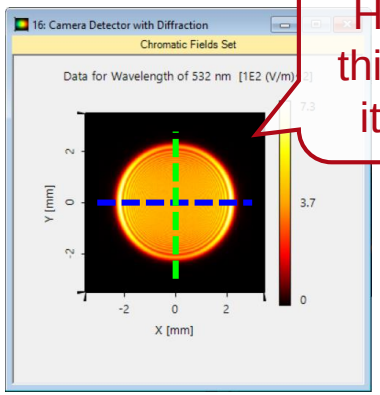


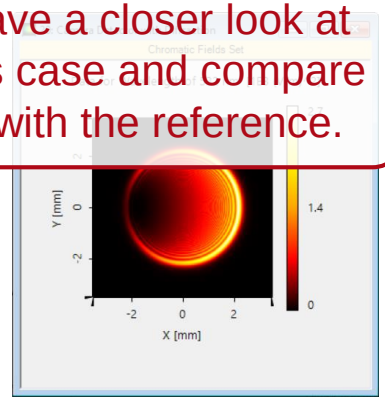


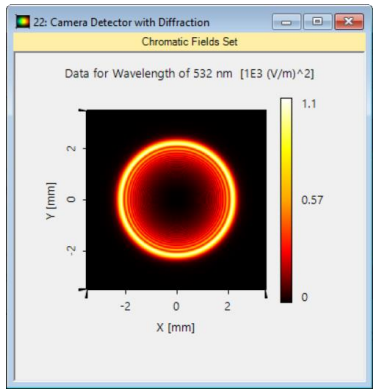






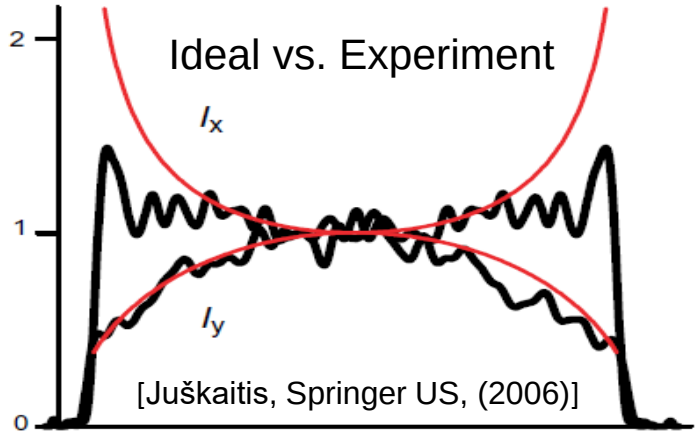


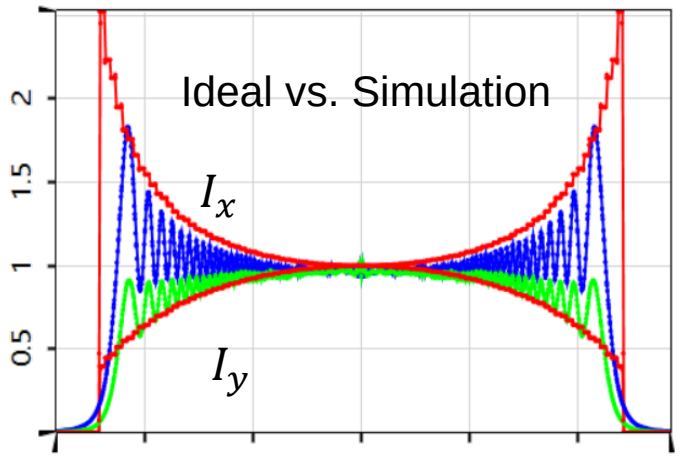




Have a closer look at this case and compare it with the reference.

Ideal vs. Experiment & Ideal vs. Simulation for Orientation [0,1,0]



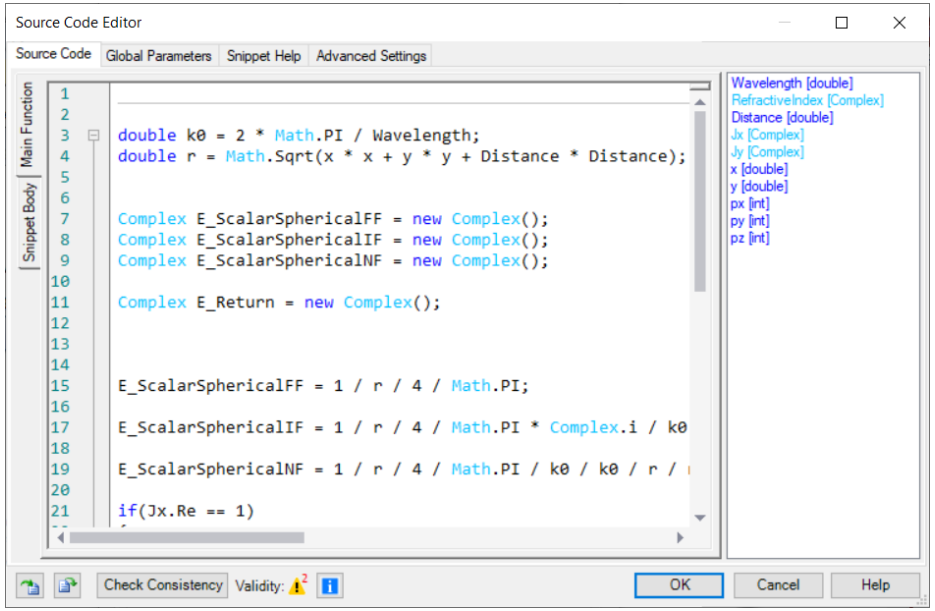


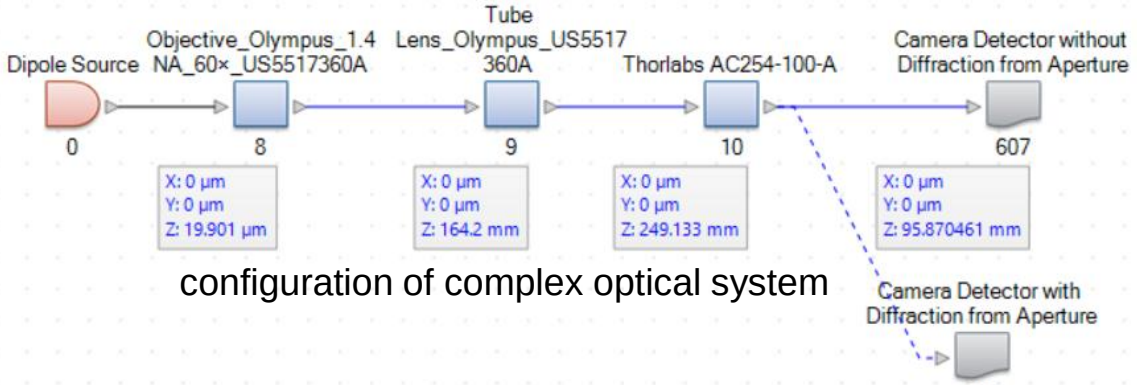
The red curves are from the ideal system. The black curves are from experiment. The blue and green curves are profiles from the simulation extracted from previous slide in corresponding colors.

- Ideal: It is calculated by $I_x = \cos\theta$, $I_y = \sec\theta$. [Juškaitis, Springer US, (2006)]
- Experiment: The diffraction from aperture generates ripples of energy density at Fourier plane. The differences between ideal model (red curves) and experiment (black curves) are two-fold: Fresnel losses and diffraction.
- Simulation: Physical-optics considering Fresnel losses and diffraction from the aperture of the objective lens results in ripples at Fourier plane, which is in good correspondence with the experiment.

Peek into VirtualLab Fusion

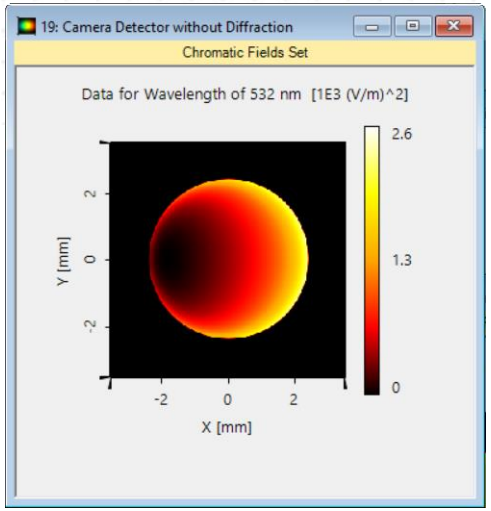
flexible and customizable definition
for various types of sources

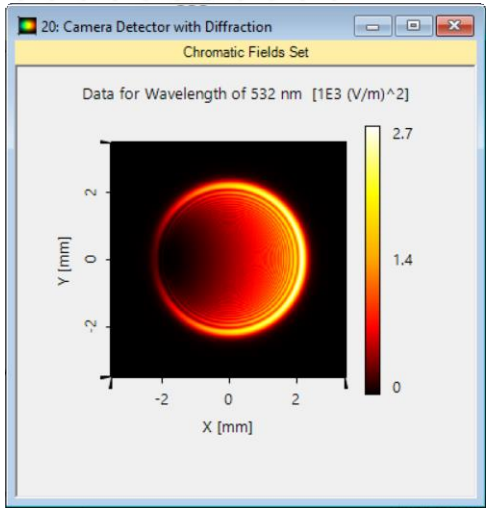




configuration of complex optical system

visualization of
physical-optics
simulation results

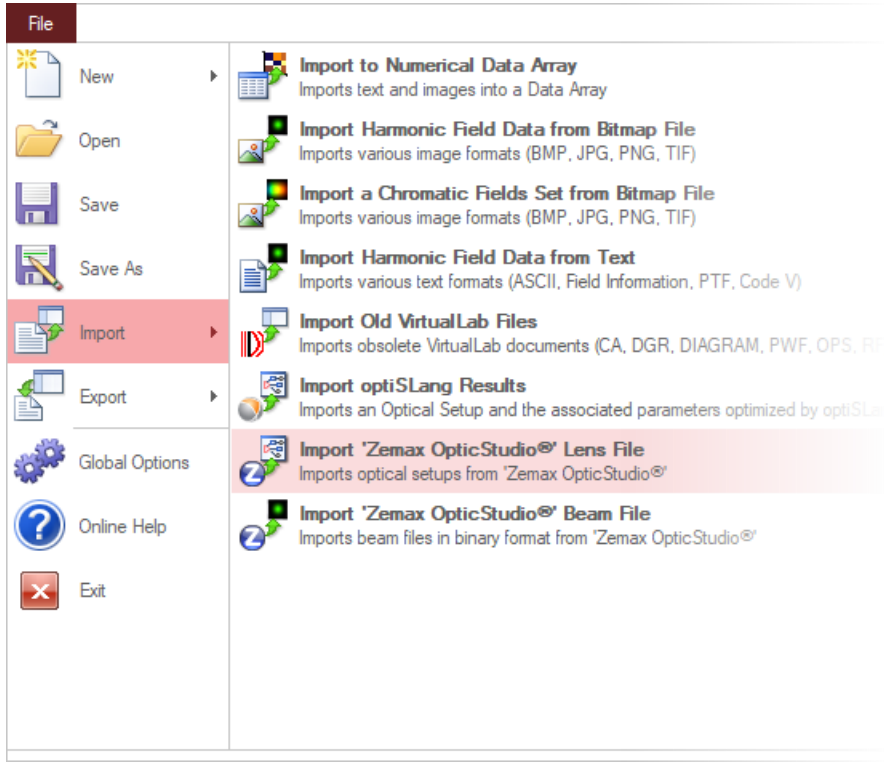




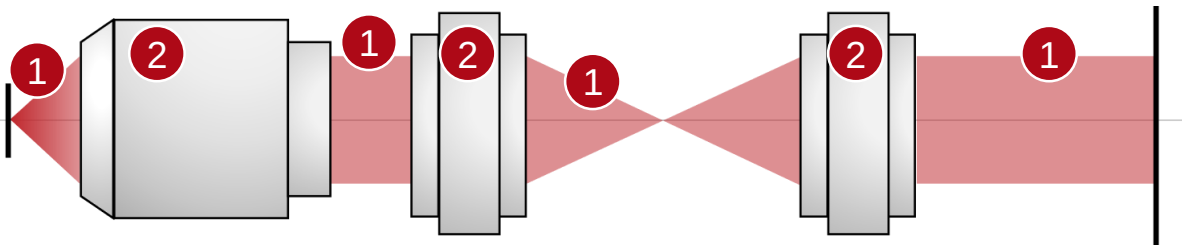
Workflow in VirtualLab Fusion

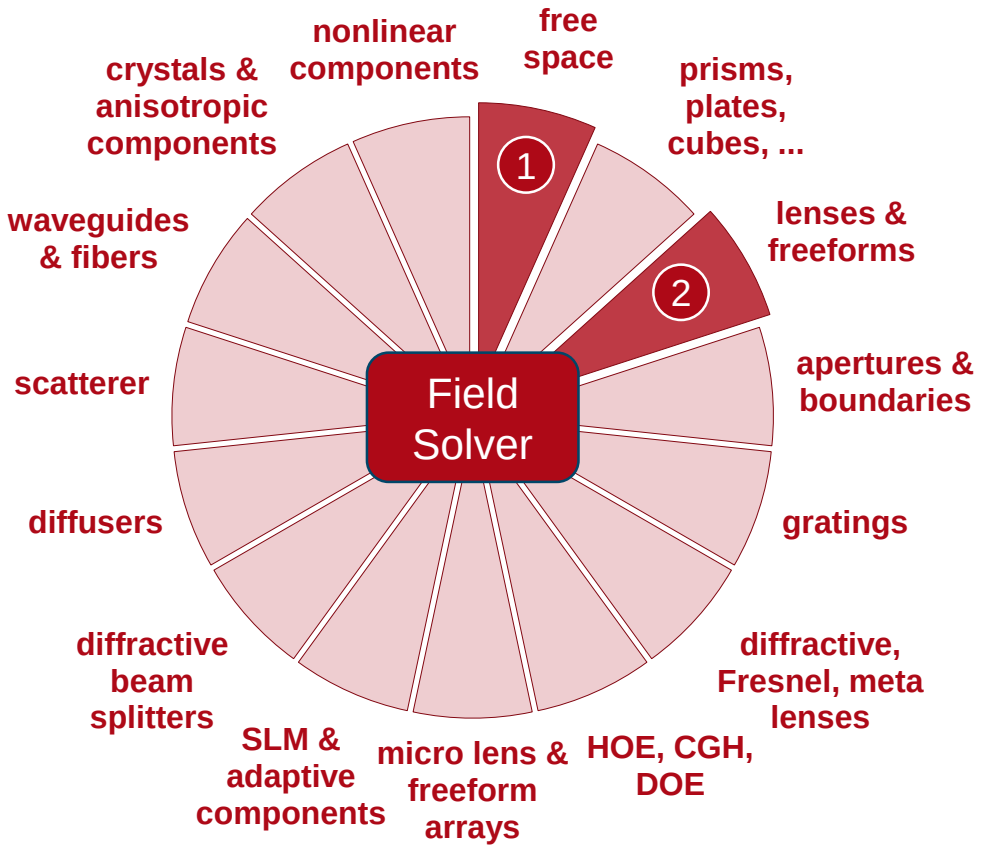
- Import lens systems from Zemax OpticStudio®
  - Import Optical Systems from Zemax [Use Case]

- Analyze imaging performance of real lens system
  - Analyzing High-NA Objective Lens Focusing [Use Case]



VirtualLab Fusion Technologies





Document Information

title	Single Molecule Imaging by High-NA Fourier Microscope
document code	MIC.0008
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toolbox(es)	Starter Toolbox
VL version used for simulations	VirtualLab Fusion 2019 Summer Release (7.6.1.18)
category	Application Use Case
further reading	- Analyzing High-NA Objective Lens Focusing - Resolution Investigation for Microscope Objective Lenses by Rayleigh Criterion