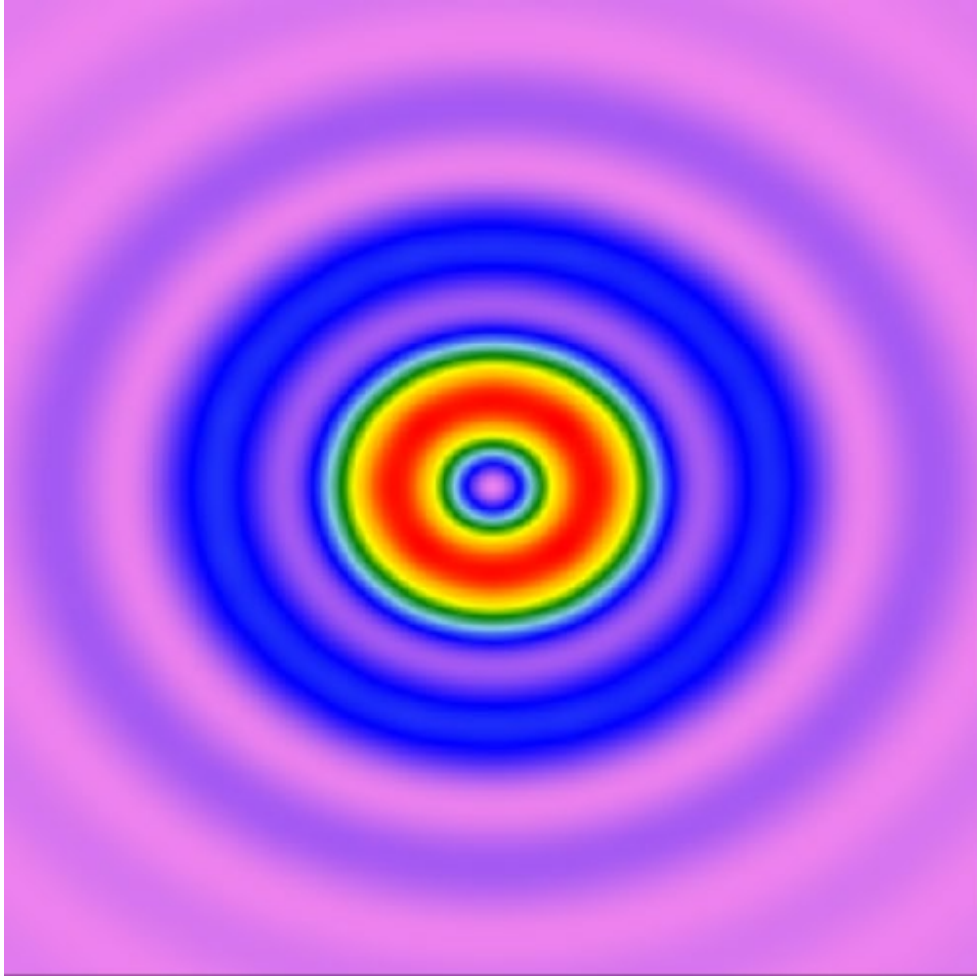


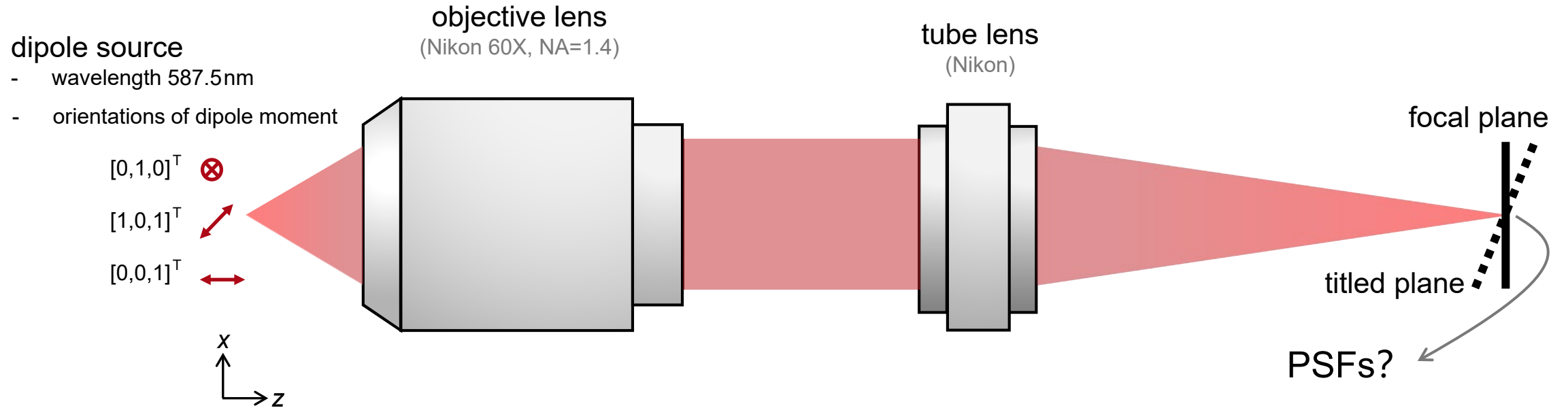
Analysis of PSF of a Dipole Source by a High-NA Microscopy System

Abstract



The emission light of a fluorescent molecule and the scattered light of a nanosphere are well modeled by dipole sources. Therefore, a dipole source is a good model for a point source which considers the vectorial effects in practice. Analysis of the PSF of such point source is important. The dipole source is built in VirtualLab Fusion. By connecting with a complex high-numerical-aperture microscopy system, the PSF is directly calculated in VirtualLab Fusion.

Modeling Task



What are the PSFs of a dipole source with different orientations?
And what are these PSFs on the tilted plane?

Building the System in VirtualLab Fusion

System Building Blocks

The diagram shows an optical system with a light source on the left, three lenses in the middle, and a detector on the right. Three arrows point from the system to three software dialog boxes:

- Edit Combined Light Source**: Shows settings for two light sources. The combination mode is set to "Coherent".
- Edit Lens System Component**: Shows a schematic of the lens system and a table of its components.
- Edit Camera Detector**: Shows settings for the detector window and resolution.

Edit Combined Light Source Dialog:

Combination Mode: Coherent

Light Source #1: Programmable Light Source

Light Source #2: Programmable Light Source

Buttons: Load, Edit, View

Validity:

Buttons: Ok, Cancel, Help

Edit Lens System Component Dialog:

Index	Distance	Position	Type	Homogeneous Medium	Comment
1	0 mm	0 mm	Plane Interface	Abbe Number V_d Mater	Zemax Interf
2	150 μ m	150 μ m	Plane Interface	S-NSL3_OHARA in Hom	Zemax Interf
3	650 μ m	800 μ m	Conical Interface	LASF35_SCHOTT in Ho	Zemax Interf
4	3.6 mm	4.4 mm	Conical Interface	Air (Zemax) in Homogen	Zemax Interf
5	100 μ m	4.5 mm	Conical Interface	GFK70_SUMITA in Hom	Zemax Interf
6	3.75 mm	8.25 mm	Conical Interface	Air (Zemax) in Homogen	Zemax Interf
7	100 μ m	8.35 mm	Conical Interface	J-F5_HIKARI in Homoge	Zemax Interf
8	1000 μ m	9.35 mm	Conical Interface	GFK70_SUMITA in Hom	Zemax Interf
9	6.8 mm	16.15 mm	Conical Interface	Air (Zemax) in Homogen	Zemax Interf
10	150 μ m	16.3 mm	Conical Interface	J-KZFH1_HIKARI in Hor	Zemax Interf
11	1000 μ m	17.3 mm	Conical Interface	LITHOTEC-CAF2_SCHC	Zemax Interf
12	9.4 mm	26.7 mm	Conical Interface	Air (Zemax) in Homogen	Zemax Interf
13	150 μ m	26.85 mm	Conical Interface	LK7E1_HIKARI in Hor	Zemax Interf

Edit Camera Detector Dialog:

Detector Window and Resolution | Detector Function

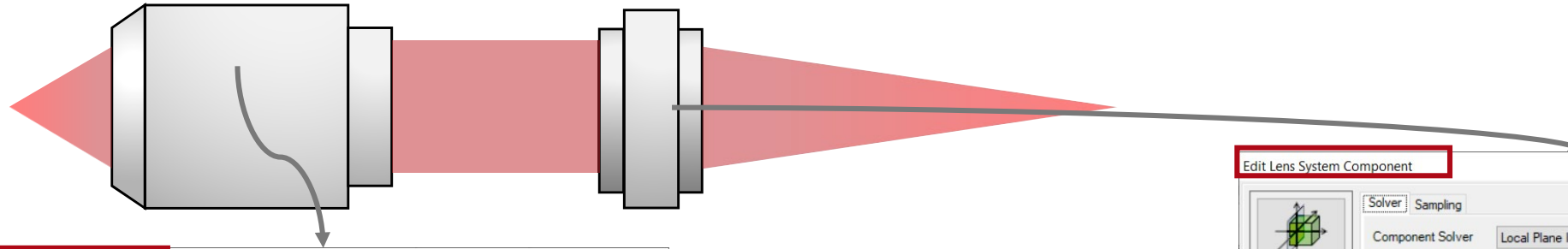
Detector Window

Scale Window Size by Factor

Set Window Size: x

Copy from ... Center Position: x

Solvers for Components



Edit Lens System Component

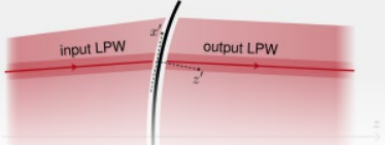
Solver | Sampling






Component Solver: Local Plane Interface Approximation (LPIA) Edit

The LPIA solver works in the spatial domain (**x domain**), locally, in a pointwise manner. The solver follows that

1. the input field on the surface is treated as a composition of local plane waves (LPWs),
2. the part of the surface seen by each LPW is considered a plane interface (locally), and,
3. the interaction of the LPW with the local plane interface can be modeled by the Fresnel (or the layer) matrix.

At an arbitrary location on the curved surface, an approximate local boundary condition is applied, which assumes the interaction of the LPW with the local plane interface. Thus, the Fresnel matrix (or layer matrix for coatings) can be used to connect input and output fields. [Learn more about this solver.](#)



-  Coordinate Systems
-  Position / Orientation
-  Structure
-  Solver
-  Channel Configuration

Edit Lens System Component

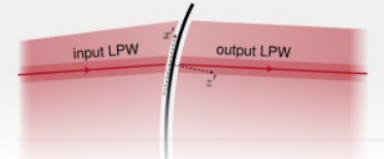
Solver | Sampling






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-  Coordinate Systems
-  Position / Orientation
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-  Solver
-  Channel Configuration

Components

Solvers

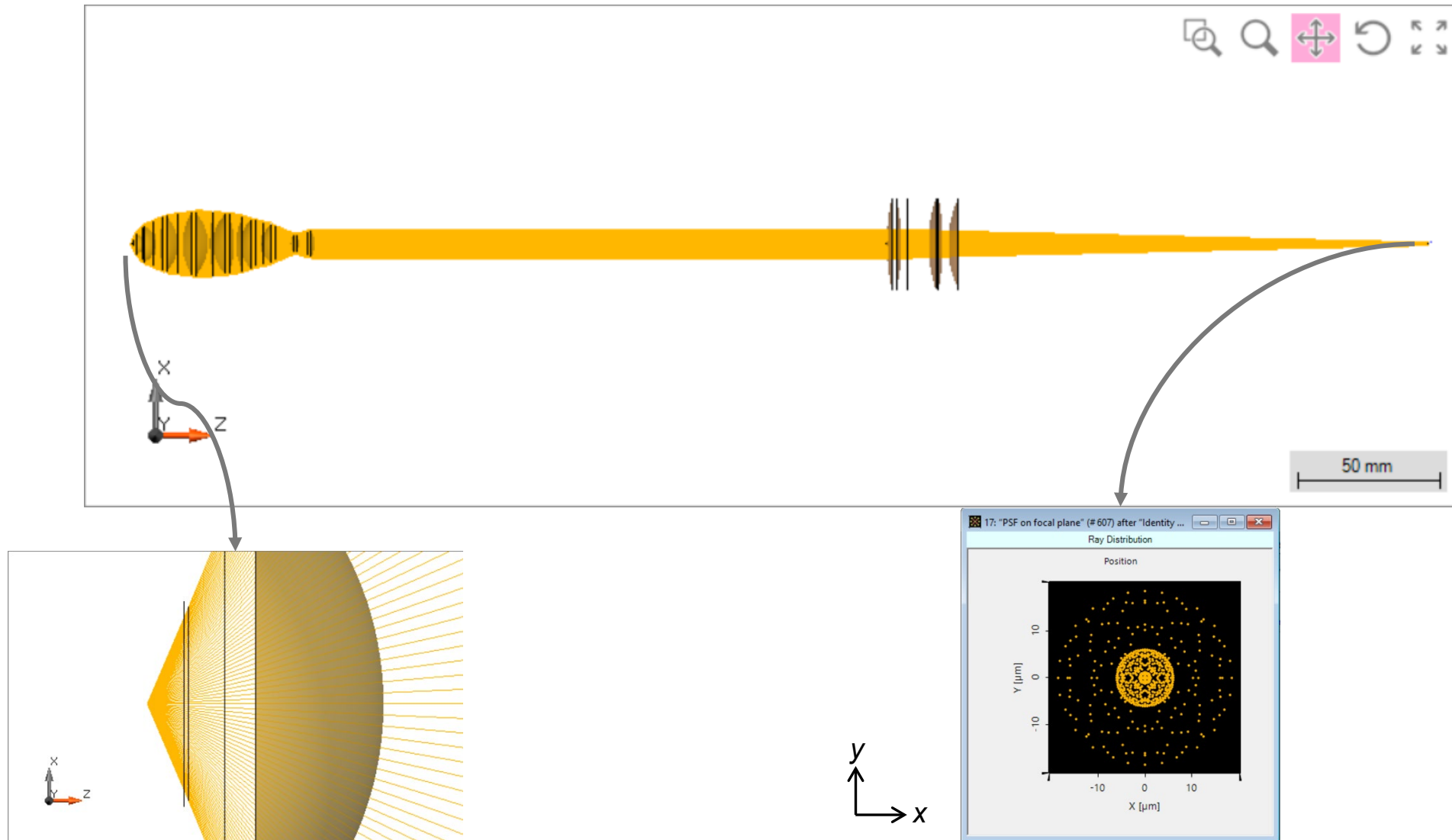
Lens Systems

Local Plane Interface Approximation (LPIA)

Geometric-Optics Simulations

by Ray Tracing

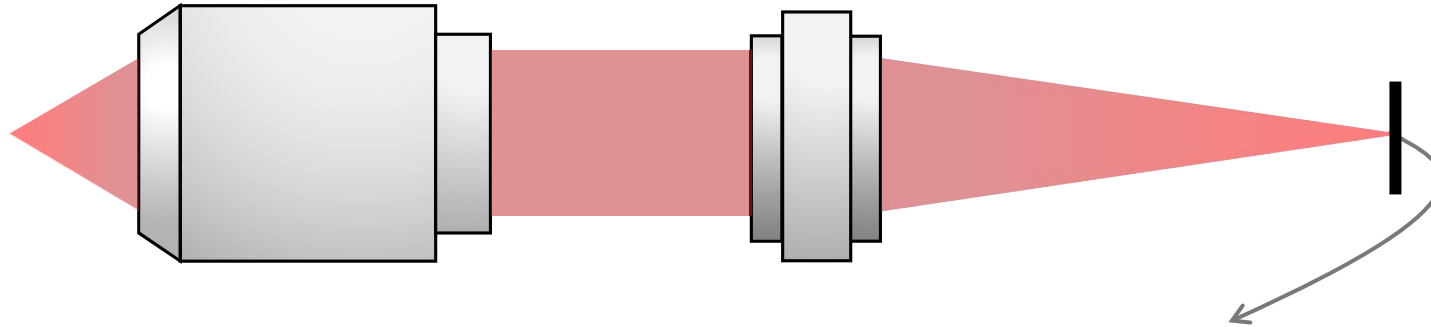
Results: Ray Tracing



Fast Physical-Optics Simulations

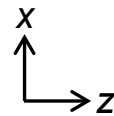
by Field Tracing

PSFs at the Focal Plane



The asymmetry of the PSFs is shown. The donut-shaped PSF is obtained when the orientation of the dipole moment is along z axis.

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



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



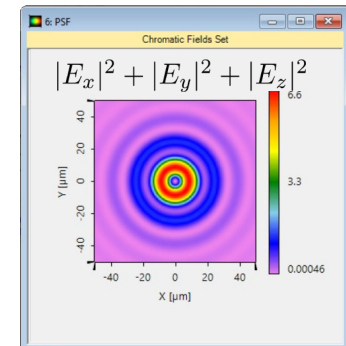
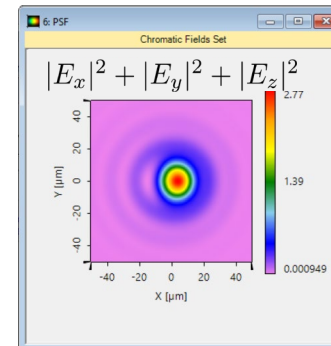
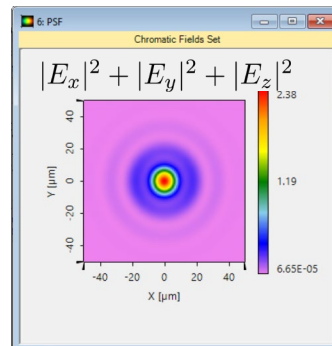
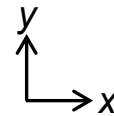
$$[1, 0, 1]^T$$



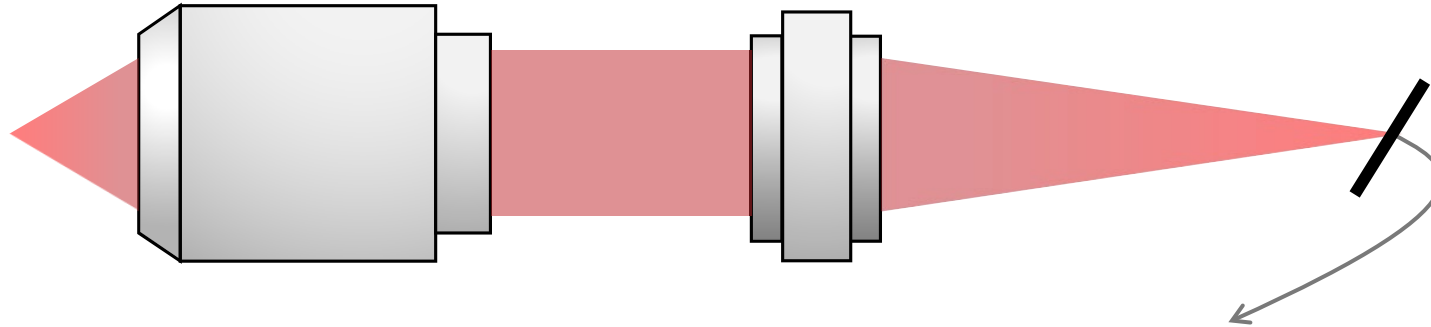
$$[0, 0, 1]^T$$



PSFs on focal plane

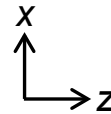


PSFs at the Tilted Plane with 30° in x Direction



The PSFs is elongated in x direction when the detector is tilted.

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



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



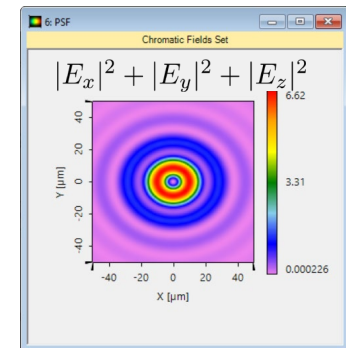
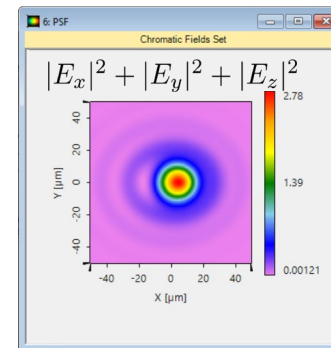
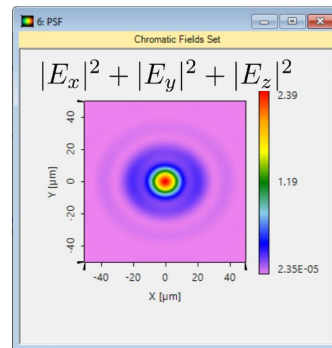
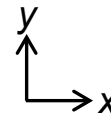
$$[1, 0, 1]^T$$



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

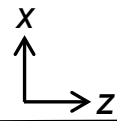


PSFs on titled plane
 at focal position with
 30° in x direction



Summary

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



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



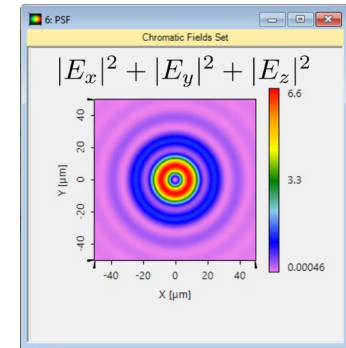
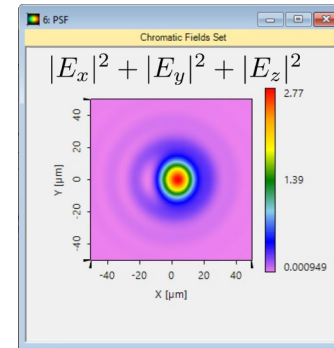
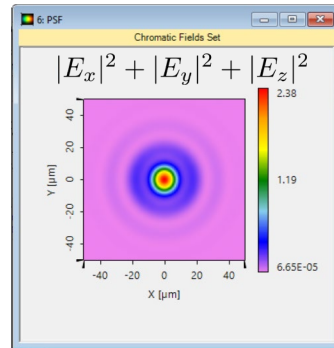
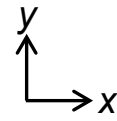
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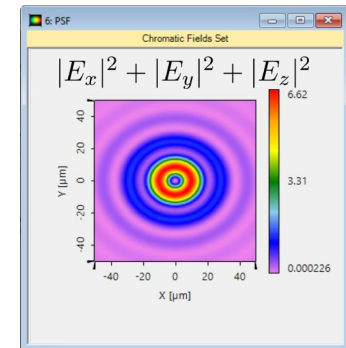
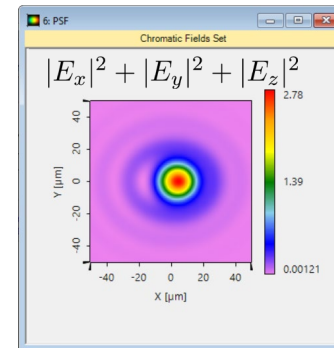
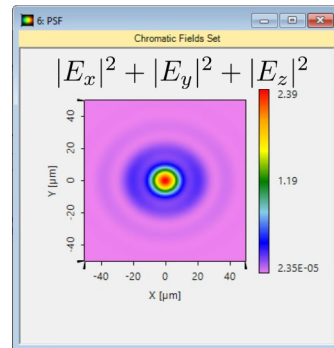
$$[0, 0, 1]^T$$



PSFs on focal plane



PSFs on titled plane
 at focal position with
 30° in x direction



Document Information

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software version	2020.2 (Build 1.116)
category	Application Use Case
further reading	<ul style="list-style-type: none">- <u>Analyzing High-NA Objective Lens</u>- <u>Resolution Investigation for Microscope Objective Lenses by Rayleigh Criterion</u>- <u>Single Molecule Imaging by High-NA Fourier Microscope</u>