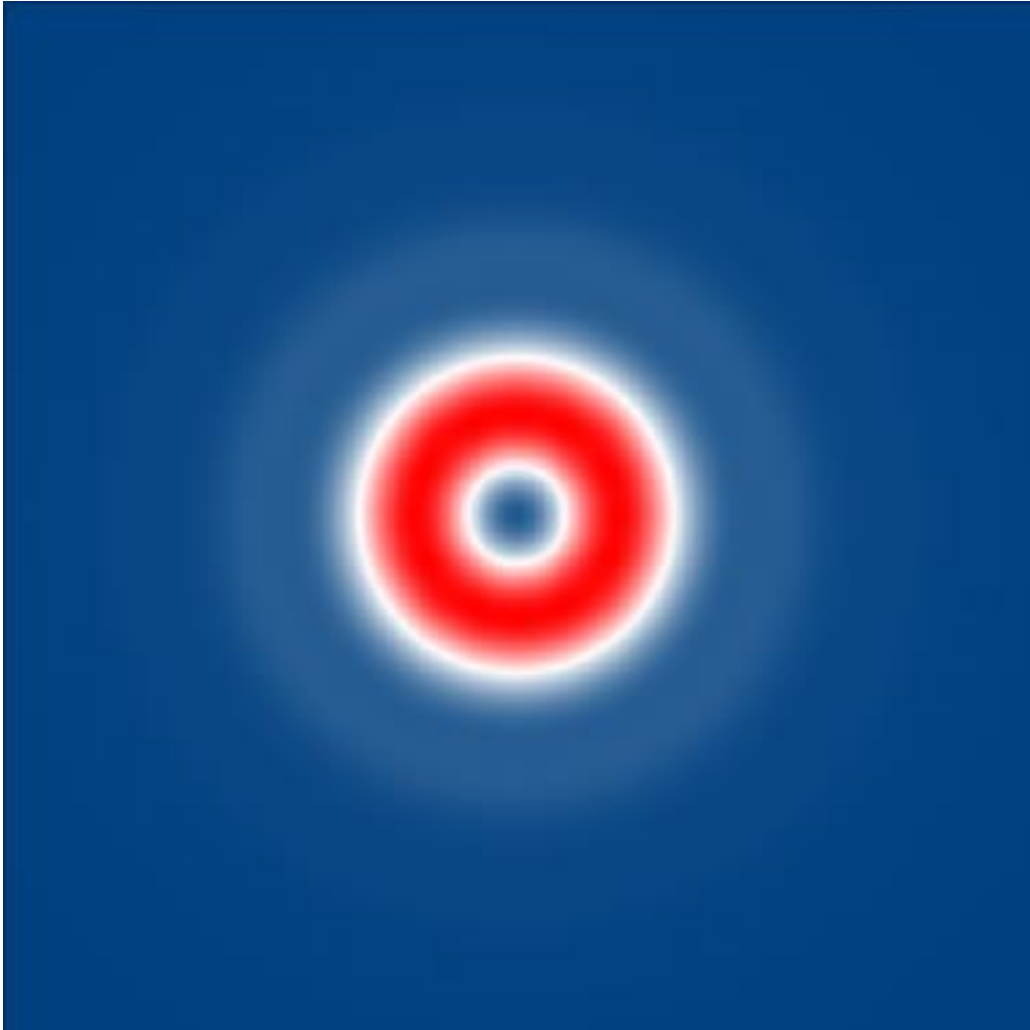


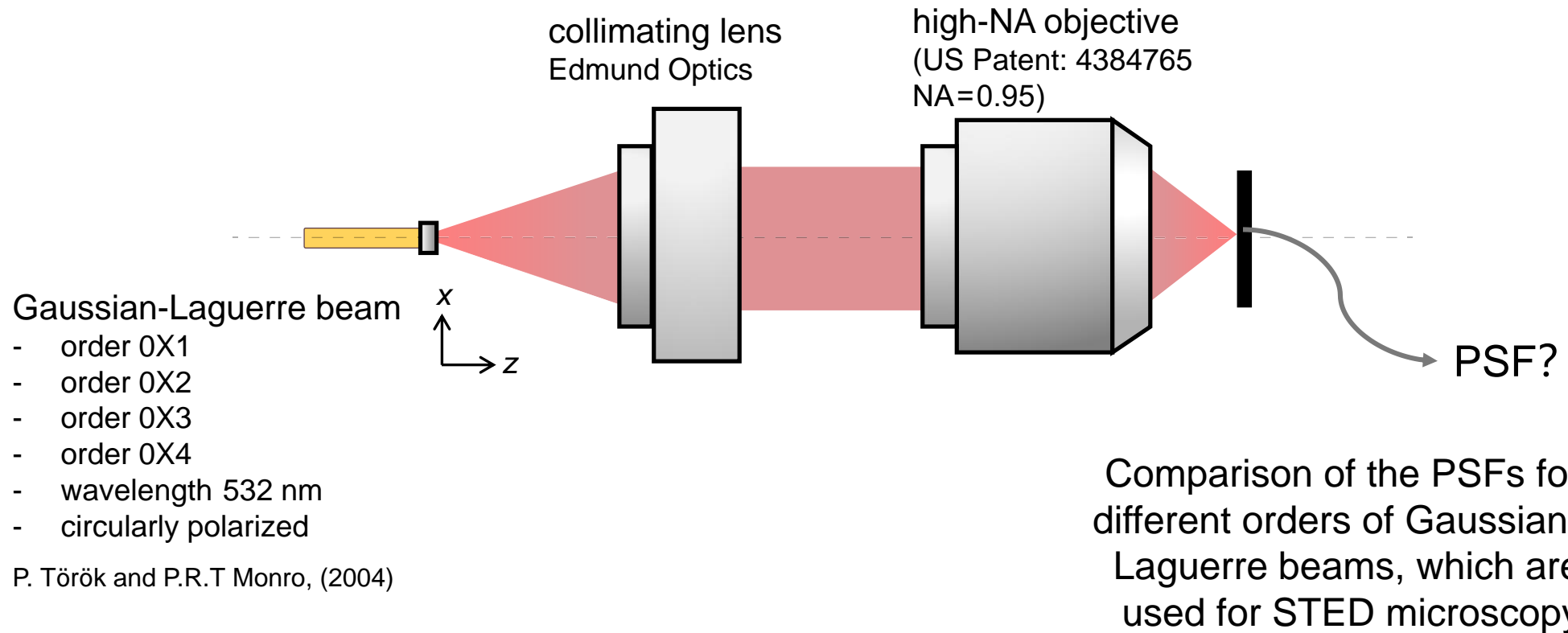
# Focusing of Gaussian-Laguerre Beam for STED Microscopy

# Abstract



STimulated Emission Depletion (STED) microscopy uses a tiny spot in the focal plane to generate super resolution. Two focused beams are needed. One is the excitation beam. The other one is the depletion beam, which can eliminate the emission light. The depletion beam needs to be donut-shaped. In [P. Török and P.R.T. Monroe, (2004)], the authors investigated the donut-shaped PSF can be generated by focusing high order Gaussian-Laguerre beam. In VirtualLab Fusion, the focusing of such high-order Gaussian-Laguerre beam is modeled and analyzed straightforwardly.

# Scenario



P. Török and P.R.T. Monro, (2004)

# **Building the System in VirtualLab Fusion**

# System Building Blocks

The diagram illustrates an optical system with a Gaussian wave source, two lens systems, and a camera detector. Three software windows are shown, each linked to a component in the system:

- Edit Gaussian Wave:** Shows parameters for a Laguerre Gaussian Mode.
 

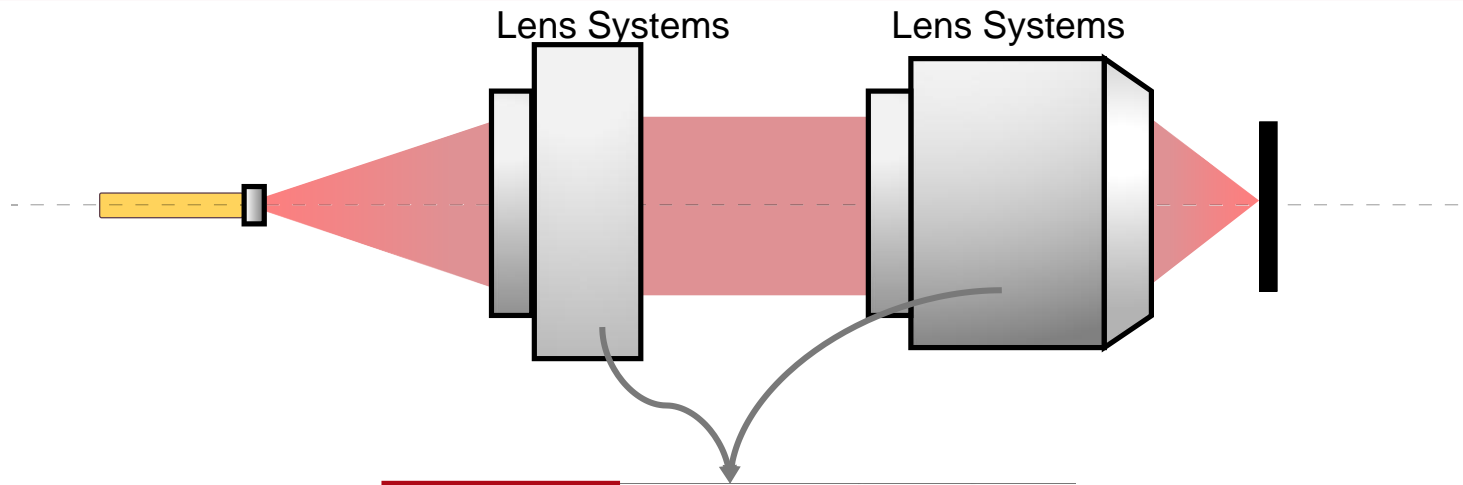
Order	M <sup>2</sup> Parameter	Reference Wavelength (Vacuum)
0	3	532 nm
- Edit Lens System Component (Left):** Shows a 5-element lens system.
 

Index	Distance	Position	Type	Homogeneous Medium	Comment
1	0 mm	0 mm	Plane Interface	Air in Homogeneous Me	Enter your comr
2	0 mm	0 mm	Conical Interface	S-BSM14_OHARA in Ho	Zemax Interface
3	9 mm	9 mm	Conical Interface	S-TIH53_OHARA in Ho	Zemax Interface
4	2.5 mm	11.5 mm	Conical Interface	Abbe Number V_d Mater	Zemax Interface
5	80 μm	11.58 mm	Aspherical Interface	Air in Homogeneous Me	Zemax Interface
- Edit Lens System Component (Right):** Shows a 13-element lens system.
 

Index	Distance	Position	Type	Homogeneous Medium	Comment
1	0 mm	0 mm	Conical Interface	BAF52_SCHOTT in Hon	Zemax Interf
2	4 mm	4 mm	Conical Interface	Air (Zemax) in Homog	Zemax Interf
3	8 mm	12 mm	Plane Interface	N-SK11_SCHOTT in Ho	Zemax Interf
4	11.3 mm	23.3 mm	Conical Interface	E-FD1_HOYA in Homog	Zemax Interf
5	3.5 mm	26.8 mm	Conical Interface	Air (Zemax) in Homog	Zemax Interf
6	200 μm	27 mm	Conical Interface	CAF2_MISC in Homog	Zemax Interf
7	4 mm	31 mm	Conical Interface	N-SF56_SCHOTT in Ho	Zemax Interf
8	1.3 mm	32.3 mm	Conical Interface	Air (Zemax) in Homog	Zemax Interf
9	524.45 μm	32.824 mm	Plane Interface	Air (Zemax) in Homog	Zemax Interf
10	24.448 μm	32.8 mm	Conical Interface	CAF2_MISC in Homog	Zemax Interf
11	4.7 mm	37.5 mm	Conical Interface	LASFN16_SUMITA in H	Zemax Interf
12	1.45 mm	38.95 mm	Conical Interface	Air (Zemax) in Homog	Zemax Interf
13	300 μm	39.25 mm	Conical Interface	LAK11_SCHOTT in Ho	Zemax Interf
- Edit Camera Detector:** Shows detector window and resolution settings.
 

Summation Type	Components to Integrate	View Settings of Result
Coherent Summation	<input checked="" type="checkbox"/> Ex-Component, <input checked="" type="checkbox"/> Ey-Component, <input checked="" type="checkbox"/> Ez-Component	<input checked="" type="radio"/> False Color, <input type="radio"/> Tricolor

# Solvers for Components



**Edit Lens System Component** [X]

**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.](#)

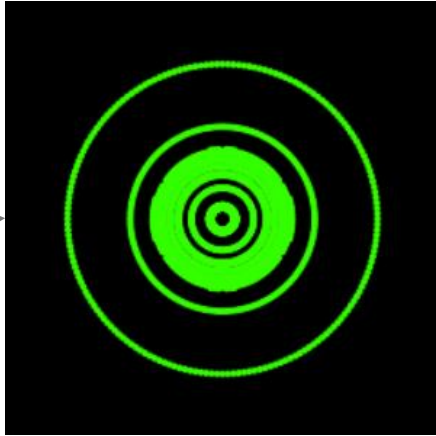
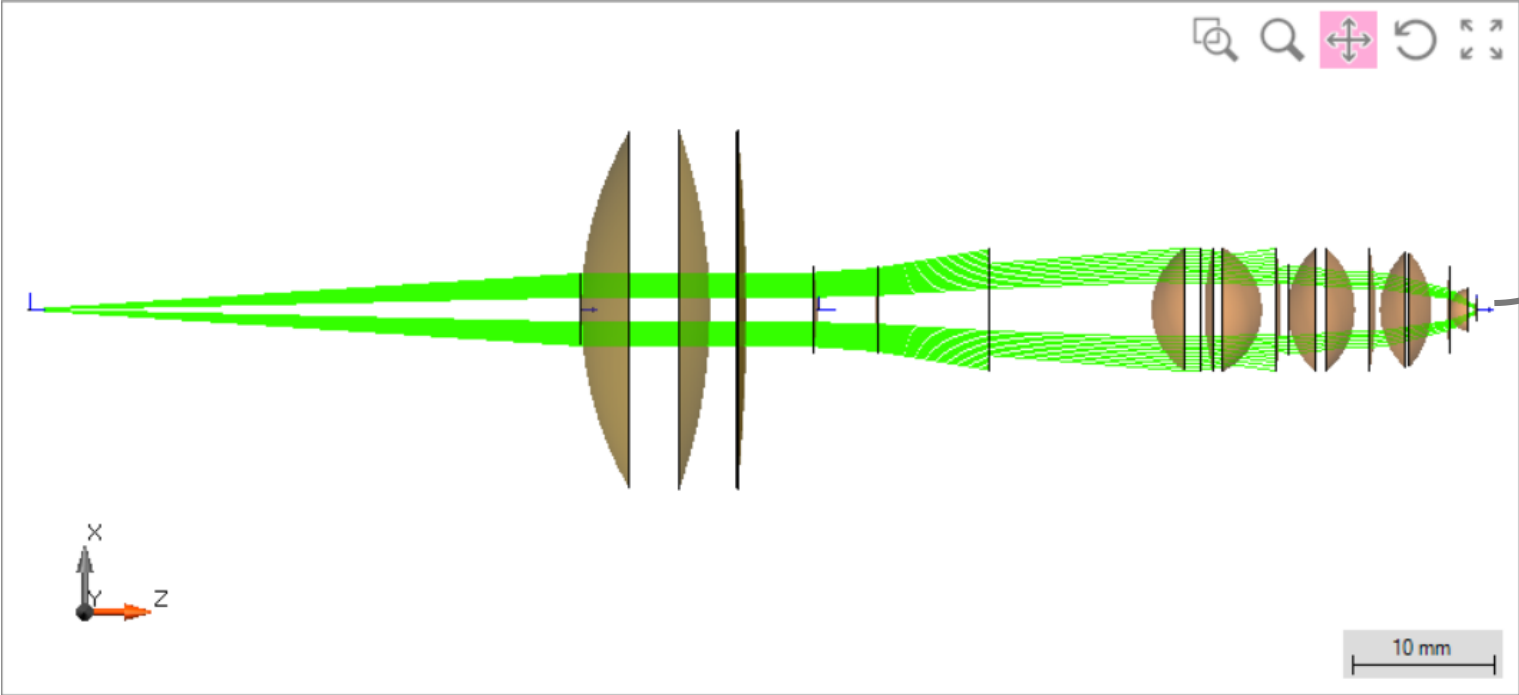
The diagram shows a curved surface with an 'input LPW' plane and an 'output LPW' plane. The surface is divided into 'front' and 'behind' regions relative to the planes. The coordinate system shows  $x$  and  $z$  axes.

Components	Solvers
Lens Systems	Local Plane Interface Approximation (LPIA)

# **Geometric-Optics Simulations**

by Ray Tracing

# Results: Ray Tracing

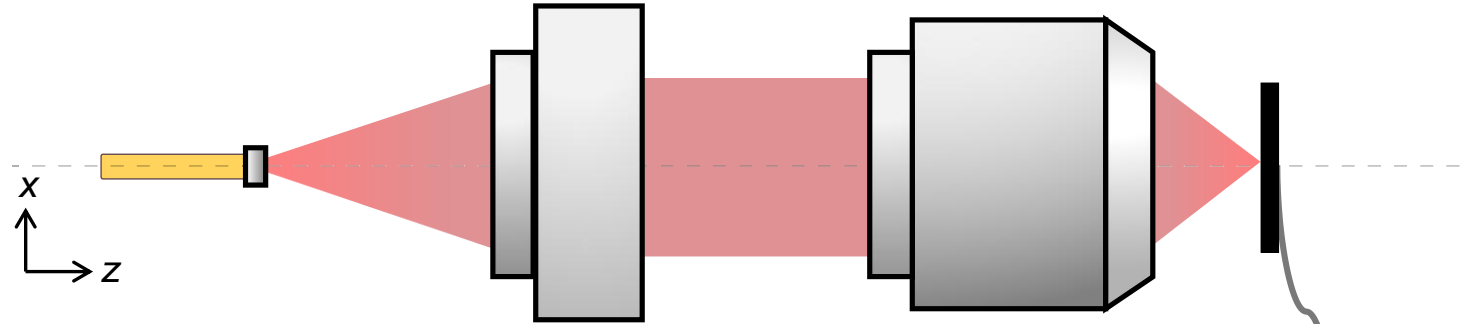




# **Fast Physical-Optics Simulations**

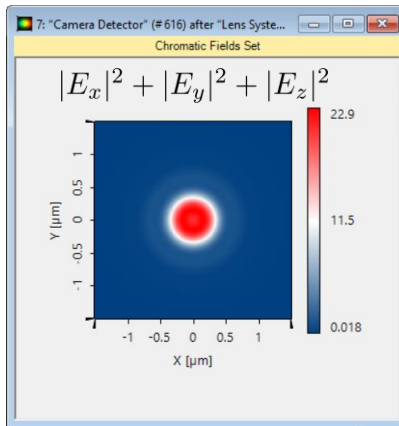
by Field Tracing

# Focusing of Gaussian-Laguerre Beams

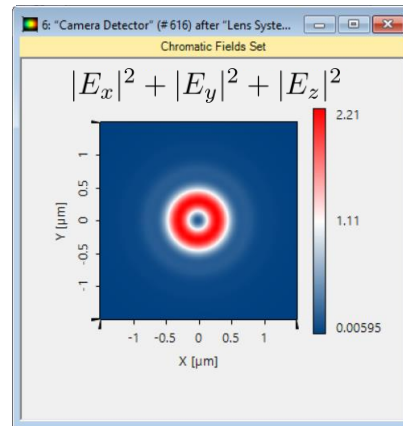


Focusing of higher orders of the Gaussian-Laguerre beam generates the donut-shaped PSFs, which are applied in the STED microscopy.

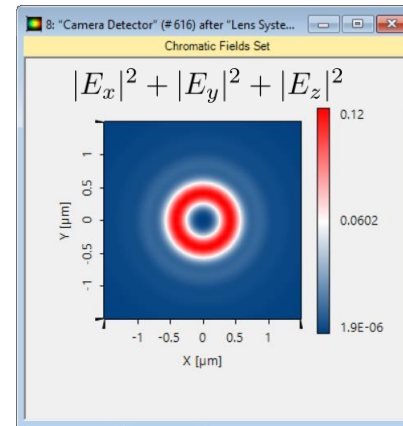
order 0X1



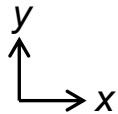
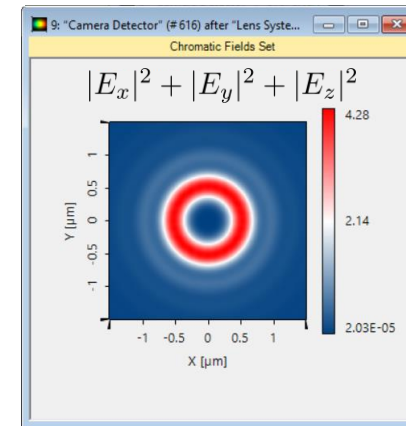
order 0X2



order 0X3



order 0X4



# Document Information

title	Focusing of Gaussian-Laguerre Beam for STED Microscopy
document code	MIC.0014
version	1.0
edition	VirtualLab Fusion Basic
software version	2020.2 (Build 1.116)
category	Application Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#"><u>Debye-Wolf Integral Calculator</u></a></li><li>- <a href="#"><u>Analyzing High-NA Objective Lens</u></a></li><li>- <a href="#"><u>Resolution Investigation for Microscope Objective Lenses by Rayleigh Criterion</u></a></li></ul>