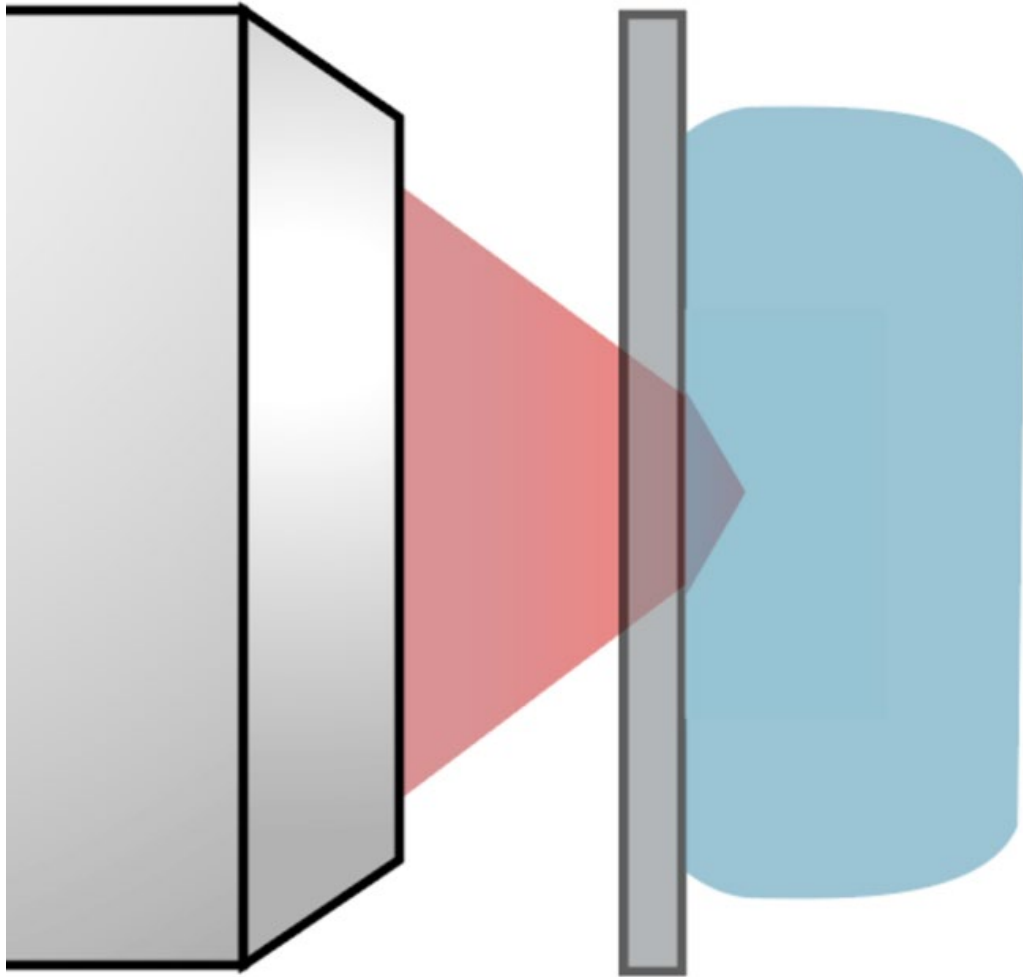


Tight Focusing Through a Stratified Medium

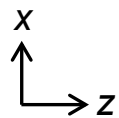
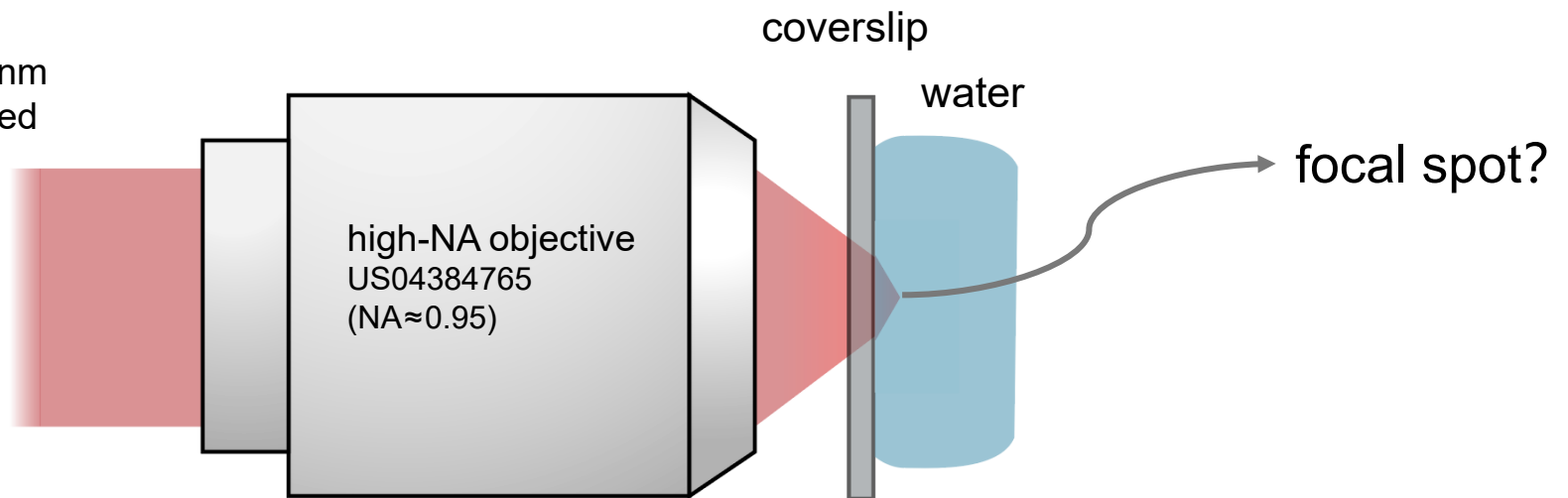
Abstract



In the real-life experiment, a coverslip is very often applied with a microscope for observing biological specimens. The focal spot of the high-NA objective could be influenced by the aberration introduced by the coverslip. In VirtualLab Fusion, the influence of the focal spot by the coverslip can be analyzed straightforwardly with a stratified medium. The aberrated focal spot is demonstrated and analyzed in this use case.

Scenario

- plane wave
- wavelength 532nm
 - circularly polarized



How is the focal spot, defined by the energy density, influenced by the coverslip?

Building the System in VirtualLab Fusion

System Building Blocks

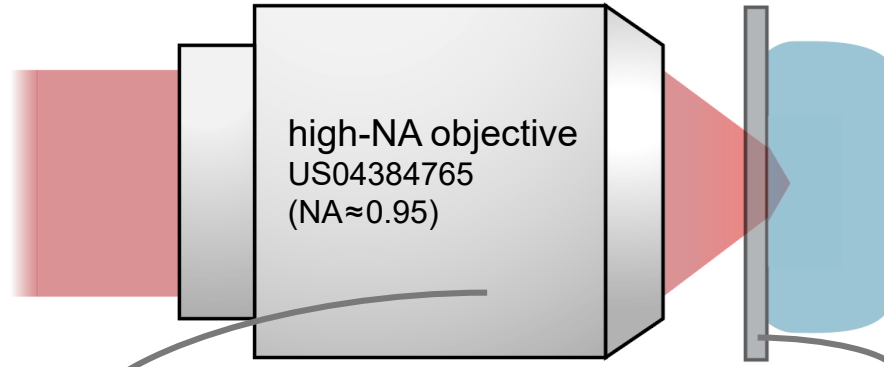
The diagram illustrates the system building blocks for a high-NA objective lens system. A red plane wave enters from the left, passes through a lens, and is focused by a high-NA objective lens (US04384765, NA ≈ 0.95) onto a blue cylindrical component. The system is modeled using Zemax software, with three main interface windows shown:

- Edit Plane Wave:** Shows polarization settings. Global Polarization is selected. Type of Polarization is Circularly Polarized, and Direction of Rotation is Right Circularly Polarized. The Normalized Jones Vector is shown as:

$$\begin{pmatrix} J_x \\ J_y \end{pmatrix} = \begin{pmatrix} 0.70711 \\ i0.70711 \end{pmatrix}$$
- Edit Lens System Component:** Shows a 3D schematic of the lens system and a table of components.

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 Homogen	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 Homogen	Zemax Interf
6	200 μm	27 mm	Conical Interface	CAF2_MISC in Homogen	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 Homogen	Zemax Interf
9	524.45 μm	32.824 mm	Plane Interface	Air (Zemax) in Homogen	Zemax Interf
10	24.448 μm	32.8 mm	Conical Interface	CAF2_MISC in Homogen	Zemax Interf
11	4.7 mm	37.5 mm	Conical Interface	LASFN16_SUMITA in Hc	Zemax Interf
12	1.45 mm	38.95 mm	Conical Interface	Air (Zemax) in Homogen	Zemax Interf
13	300 μm	38.25 mm	Conical Interface	LAK31_SCHOTT in Hon	Zemax Interf
- Edit Camera Detector:** Shows detector parameters. Summation Type is Coherent Summation. Components to Integrate are Ex-Component, Ey-Component, and Ez-Component. View Settings of Result are set to False Color with a Reverse Rainbow color map.
- Edit Stratified Media Component:** Shows a 5 mm x 5 mm component size. Reference Surface is Plane Surface. Aperture is No. Coating Name is BBCoat02_470-710nm. Coating Orientation is Front Side Application. Homogeneous Medium Behind Surface is Water in Homogeneous Medium.

Solvers for Components



Edit Lens System Component

Solver: Sampling
Component Solver: **Local Plane Interface Approximation (LPIA)**

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](#).

Edit Stratified Media Component

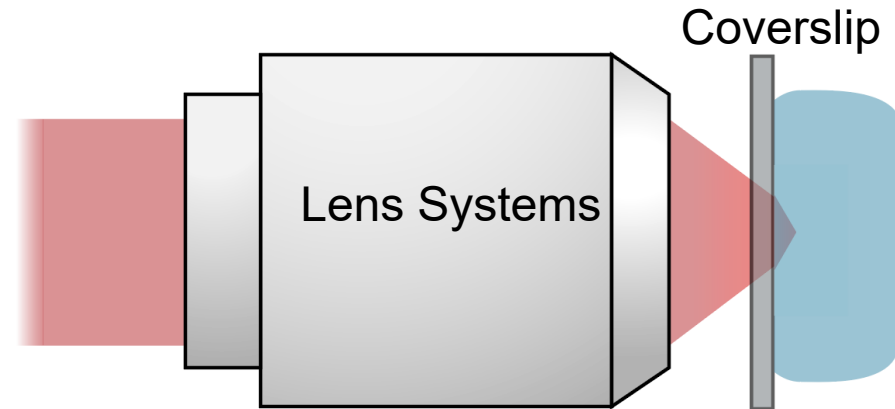
Solver: Sampling
Component Solver: **Layer Matrix [S-Matrix]**

The layer matrix solver works in the spatial frequency domain (**k domain**). It consists of

1. an eigenmode solver for each homogeneous layer and
2. an S-matrix for matching the boundary conditions at all surfaces.

The eigenmode solver computes the field solution in the k domain for the homogeneous medium in each layer. The S-matrix algorithm calculates the response of the whole layer system by matching the boundary conditions in a recursive manner. It is well-known for its unconditional numerical stability since, unlike the traditional transfer matrix, it avoids the exponentially growing functions in the calculation steps. [Learn more about this solver](#).

Summary

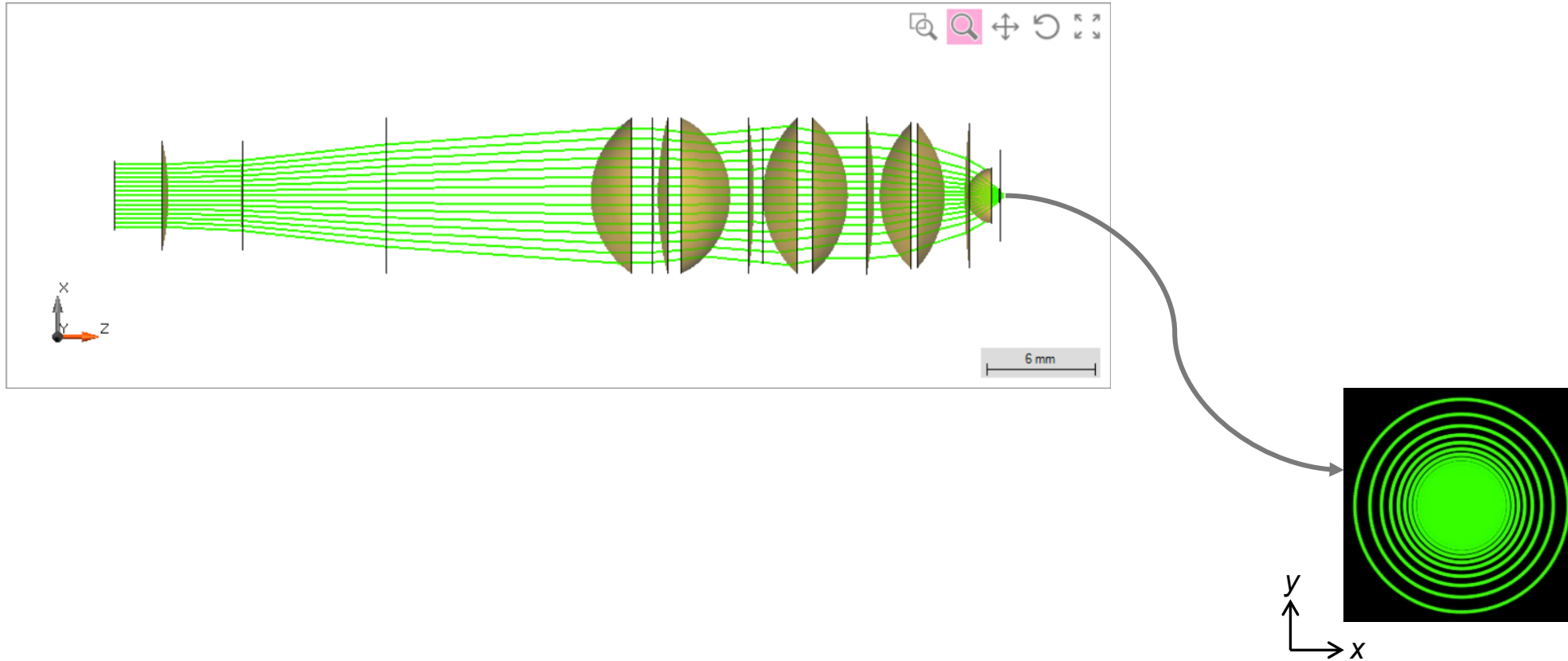


Components	Solvers
Lens Systems	Local Plane Interface Approximation (LPIA)
Coverslip	S-matrix for stratified medium

Geometric-Optics Simulations

by Ray Tracing

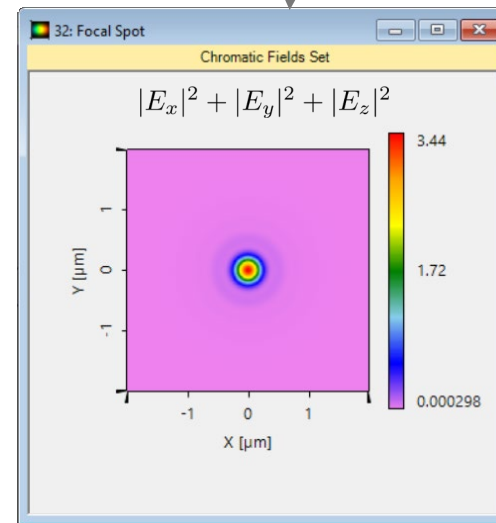
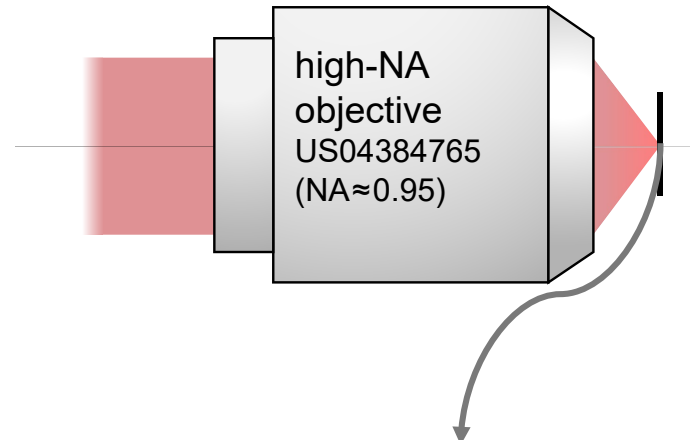
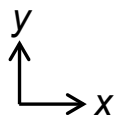
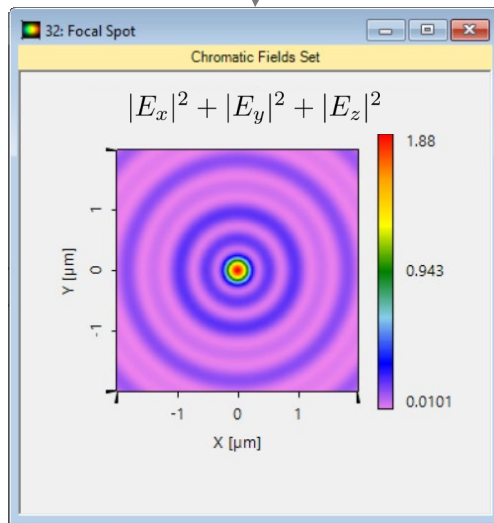
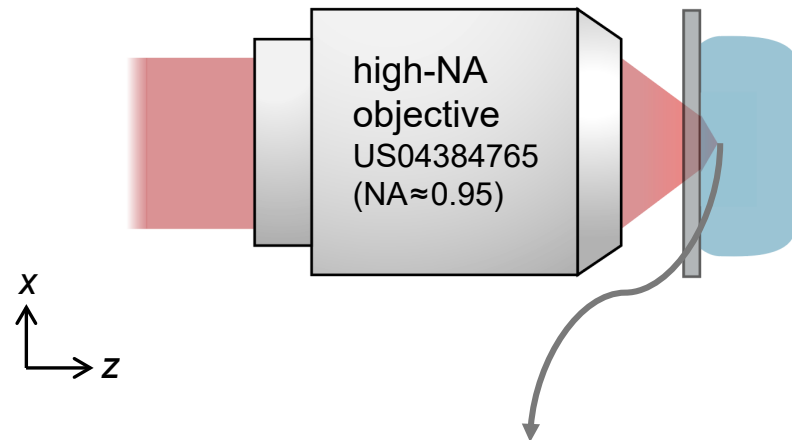
Results: Ray Tracing



Fast Physical-Optics Simulations

by Field Tracing

Focusing through the Coverslip into the Medium



original focal spot in air

By comparing the original focal spot in air, the focal spot influenced by the aberration is clearly demonstrated.

Document Information

title	Tight Focusing Through a Stratified Medium
document code	MIC.0012
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">- <u>Debye-Wolf Integral Calculator</u>- <u>Analyzing High-NA Objective Lens</u>- <u>Resolution Investigation for Microscope Objective Lenses by Rayleigh Criterion</u>