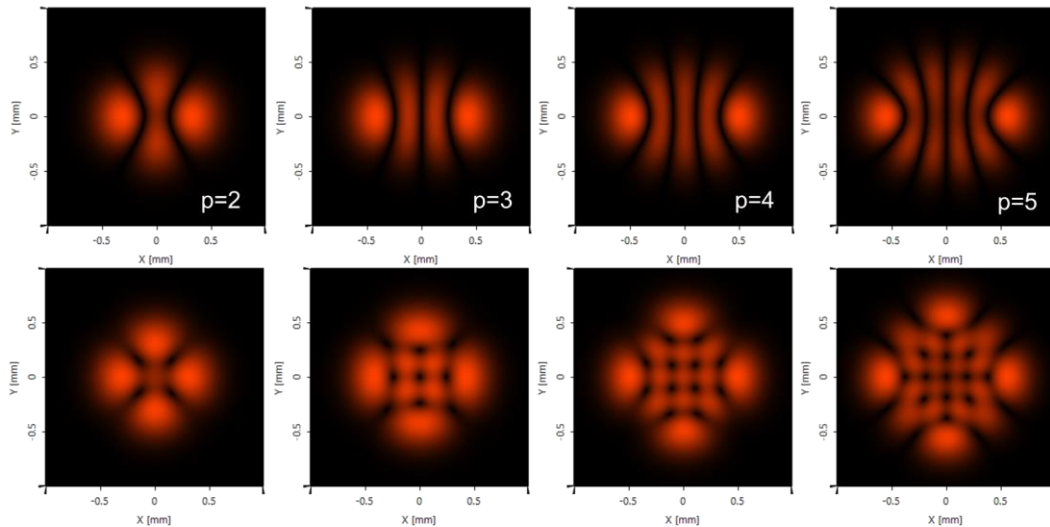


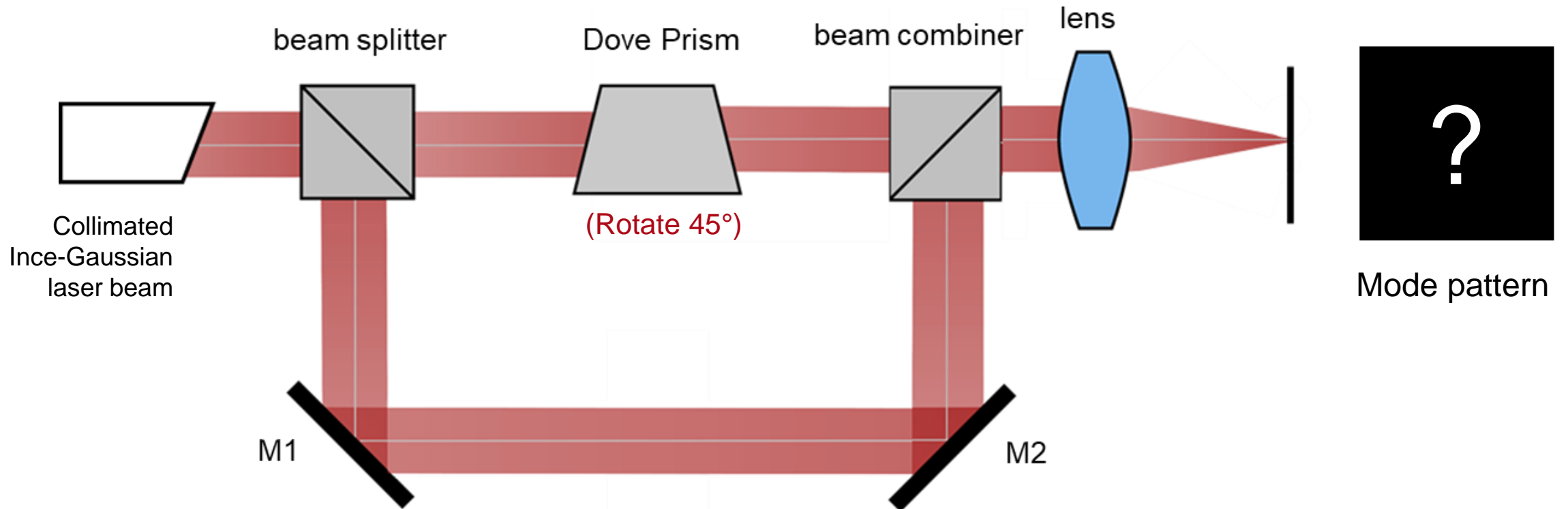
# Observation of Vortex Array Laser Beam Generation from Ince-Gaussian Beam

# Abstract

Ince-Gaussian modes are the third complete family of exact and orthogonal solutions of the paraxial wave equation alongside the Hermite-Gaussian and Laguerre-Gaussian modes. Ince-Gaussian modes have a diversiform transverse pattern. In this document, following in the steps of Chu et al. [Opt. Express 16, 19934-19949 (2008)], a Dove prism-embedded unbalanced Mach-Zehnder interferometer is used to simulate the generation of vortex array laser beams based on Ince-Gaussian modes. The resulting vortex array laser beam generated by the proposed interferometric setup maintains its beam profile during propagation, also through a focus. Thus, the proposed vortex array laser beams hold great promise for application in optical tweezers and atom traps in the form of two-dimensional arrays.



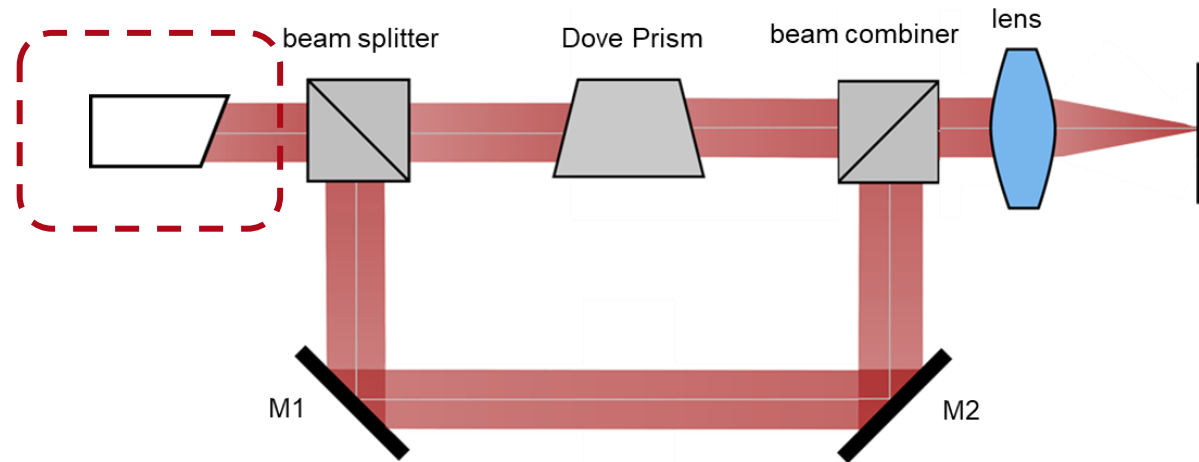
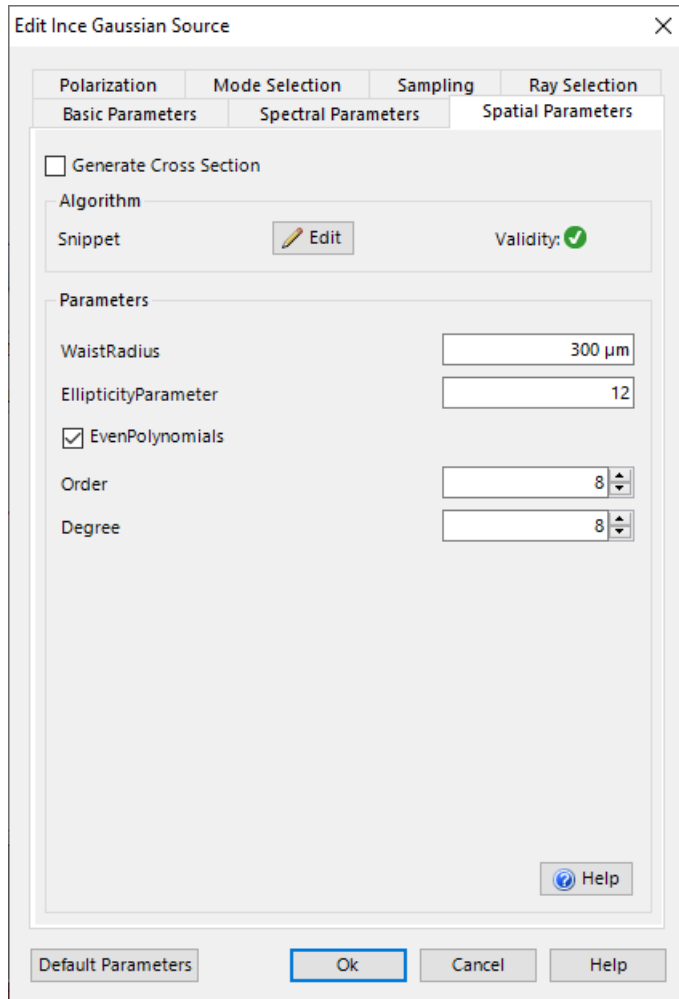
# Task Description



Ref: Shu-Chun Chu, Chao-Shun Yang, and Kenju Otsuka, "Vortex array laser beam generation from a Dove prism-embedded unbalanced Mach-Zehnder interferometer," *Opt. Express* 16, 19934-19949 (2008)

# **Building the System in VirtualLab Fusion**

# System Building Blocks – Source



The Ince-Gaussian source can be found in *Light Sources* -> *Basic Source Models*, and offers the following adjustable parameters

- Waist radius
- Ellipticity parameter
- Order of mode polynomial
- Degree of mode polynomial

A more detailed explanation of the meaning of the parameters and configuration of the source can be found here: [Ince-Gaussian Modes](#)

# System Building Blocks – Components and Detector

Filter by...

- Light Sources
- Components
  - Component from Catalog
  - Functional Single Surface
  - Index Modulated
  - Multiple Surfaces
    - 1 Lens System
    - Light Guide
    - Spherical Lens
  - Single Surface & Coating
    - Curved Surface
    - 2 Off-Axis Parabolic Mirror (Wedge Type)
    - Plane Surface
    - Stratified Media
  - Single Surface & Stack
  - Programmable Component
  - Subsystem
- Ideal Components
  - Programmable Function
  - Stored Function
  - Apertures and Lenses
  - 3 Beam Splitters
    - Ideal Beam Splitter
    - Polarization Beam Splitter
  - Diffusers
  - Grating Transmissions
  - Jones Matrices
  - Manipulators
  - 4 Mirrors
    - Ideal Plane Mirror
    - Ideal Spherical Mirror
  - Miscellaneous Functions
  - Special Components
- Detectors
  - Analyzers
  - Coordinate Break
  - Camera Detector
  - Electromagnetic Field Detector

Edit Plane Surface Component

Basal Positioning | Isolated Positioning | Position Information (Absolute)

Position and Orientation

Use Isolated Translation  Use Isolated Orientation

Orientation Parameters

Center Point of Rotations

Reference Point to be Used as Center Point: Center of Plane

Isolated Orientation Angles

Orientation Definition Type: Spherical Angles

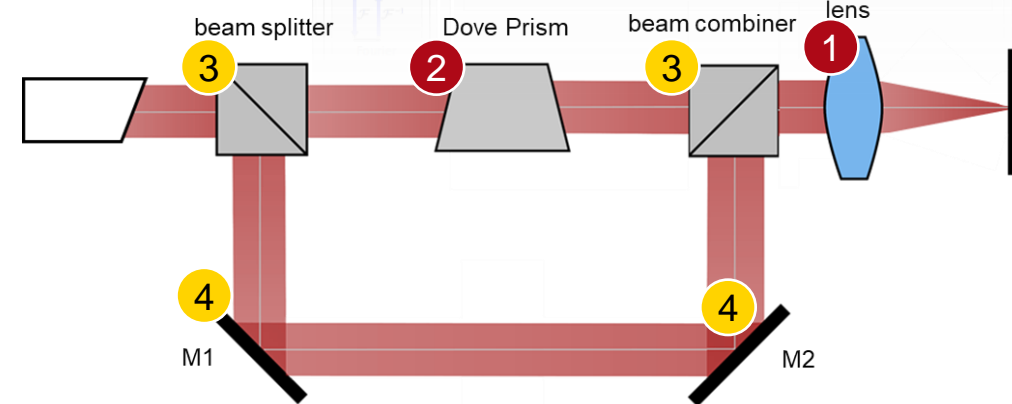
Angle / Axis	Value
Theta (Spherical)	90°
Phi (Spherical)	180°

Z-Axis Direction Definition

Rotation About Z-Axis: Z-Axis Rotation Angle: 0°

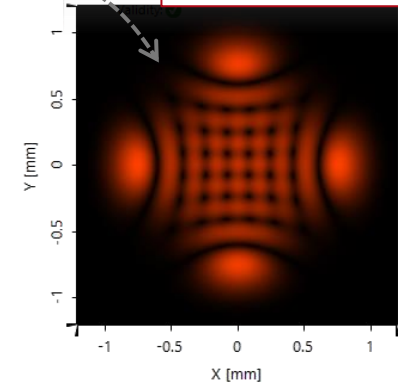
Edit Ideal Beam Splitter

Surface	+/+	+/-	-/-	-/+
Surface #1 (Beam combiner (ideal))	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>



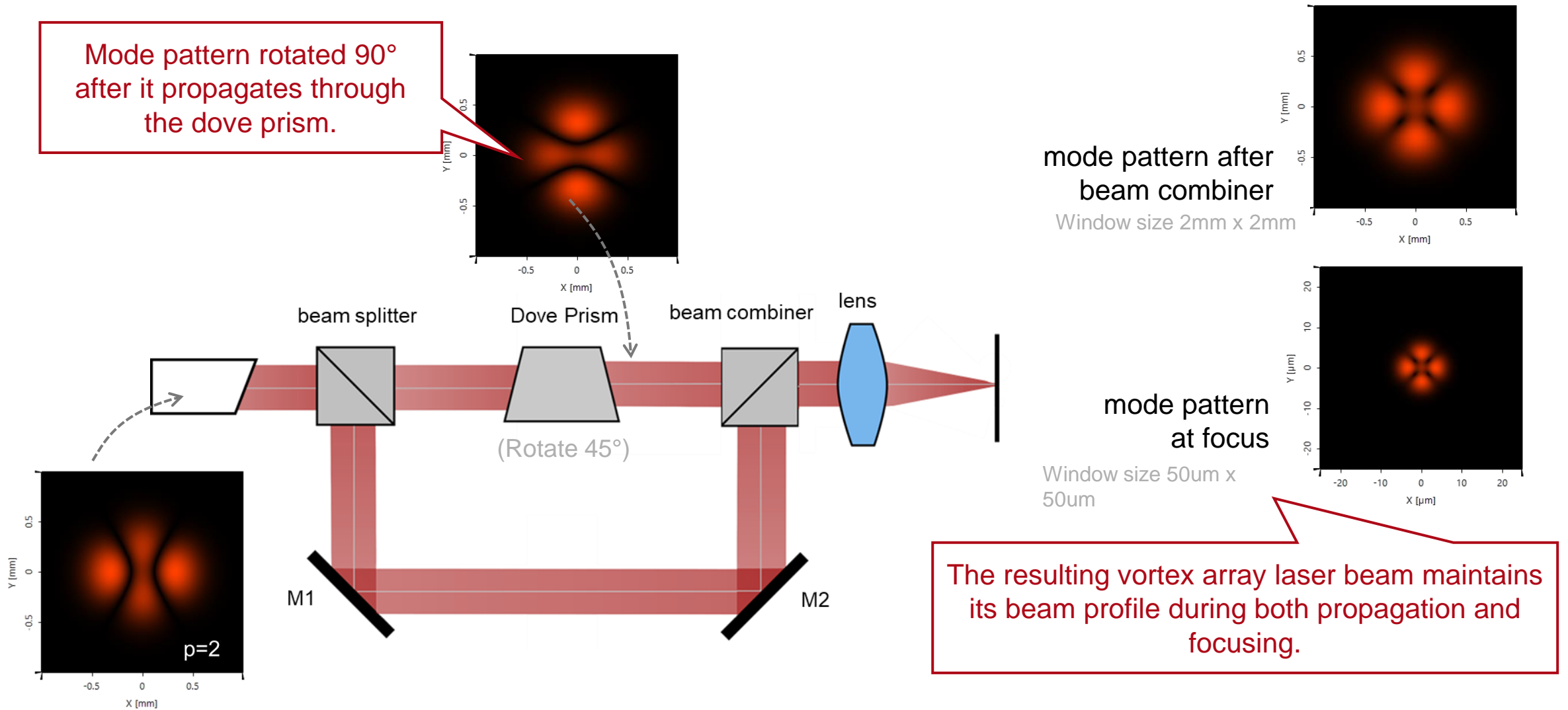
# idealized component

flexible position and orientation settings and a flexible channel configuration for non-sequential simulations makes the construction of the system a simple and intuitive process.

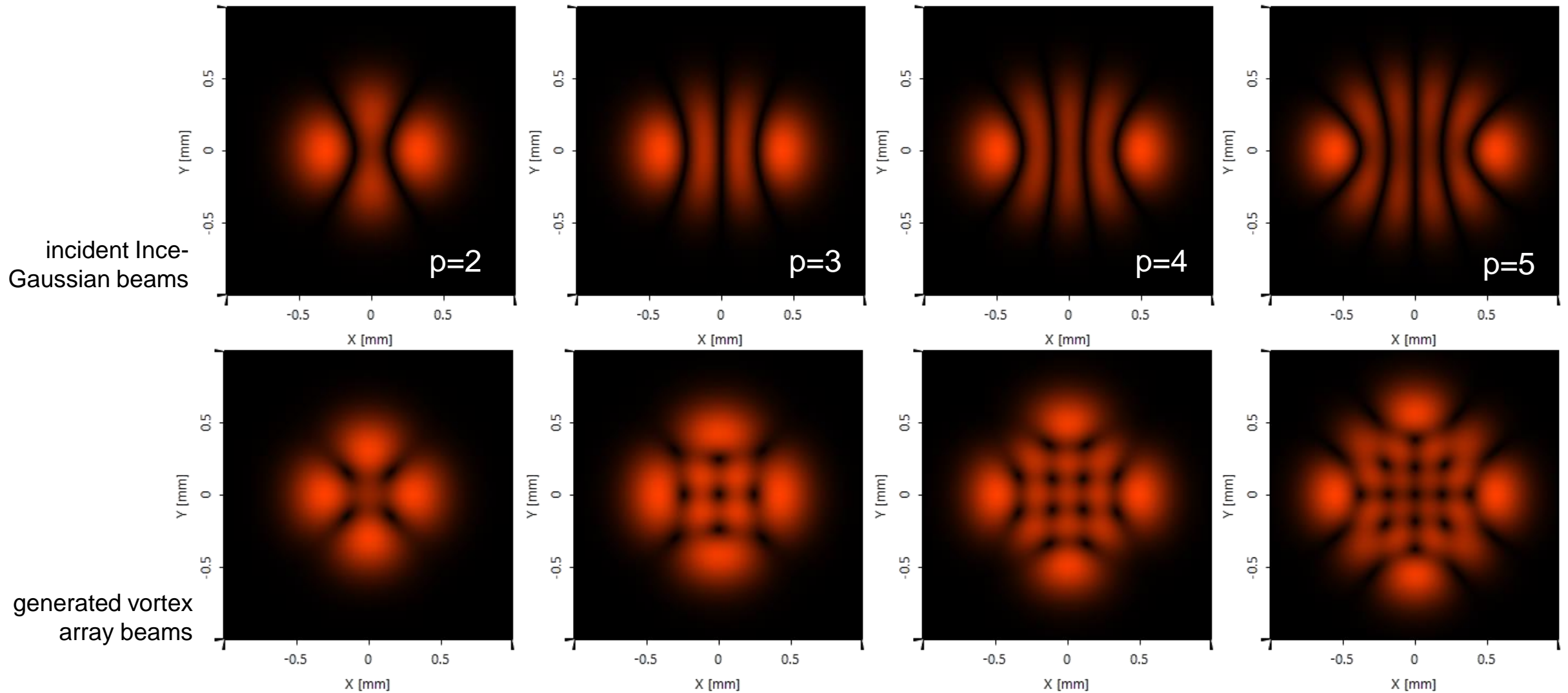


Direct observation of the mode pattern

# Simulation of Vortex Array Laser Beam Generation

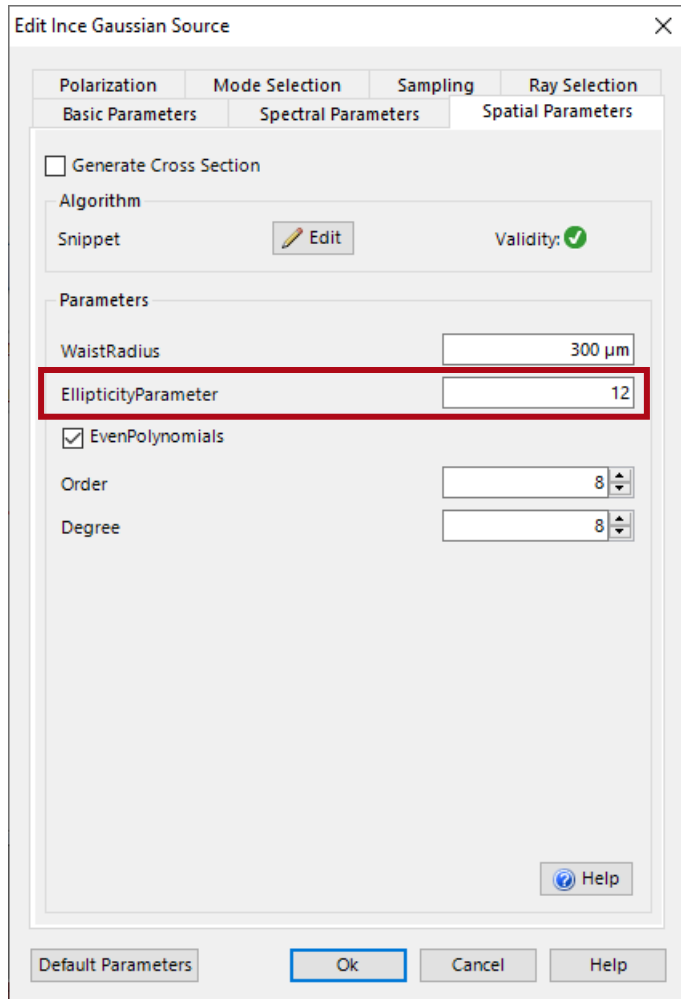


# Generated Vortex Array Using Different Mode Orders in Source



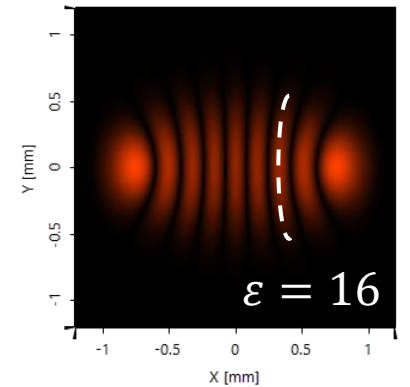
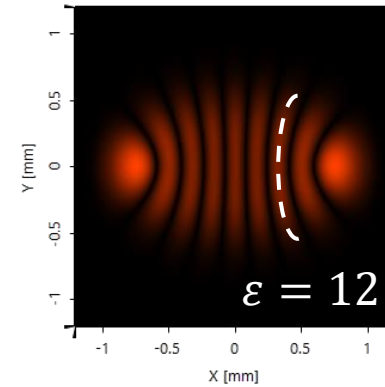
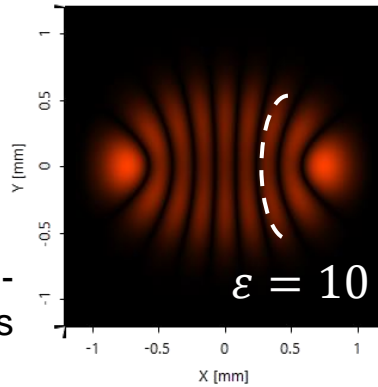


# Effect of Ellipticity Parameter on Vortex Array Pattern

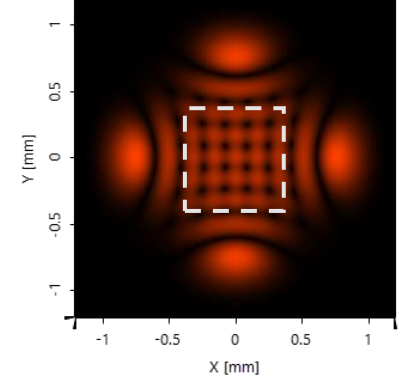
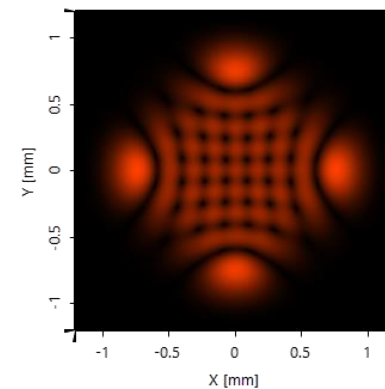
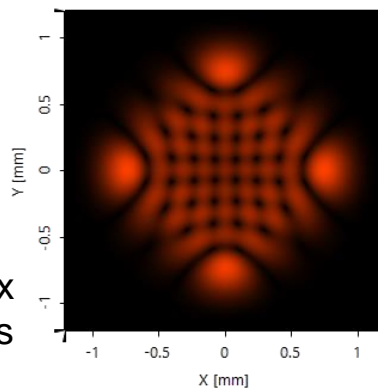


A larger value of the ellipticity parameter  $\varepsilon$  of the incident Ince-Gaussian laser beam reduces the curvature of the mode parabola, with the result that the generated vortices form a less distorted (squarer) array.

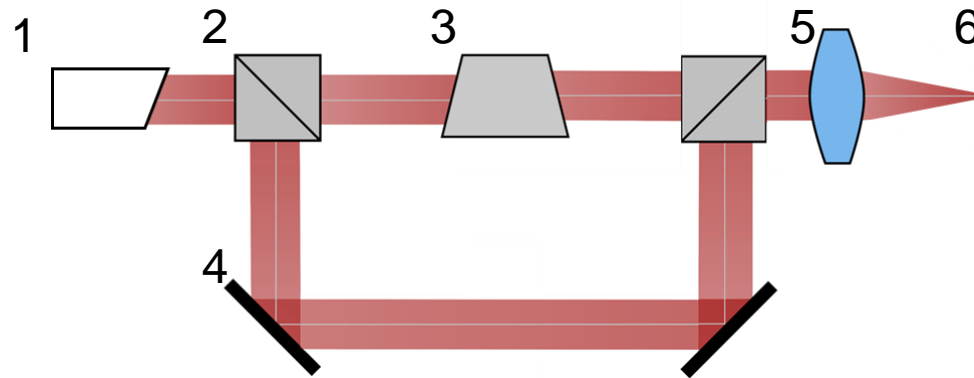
incident Ince-Gaussian beams



generated vortex array beams



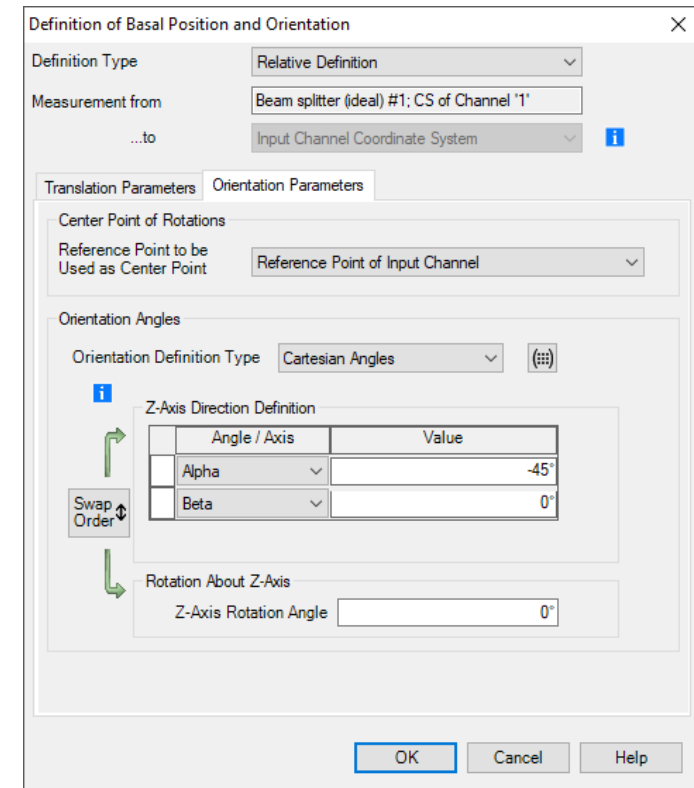
# Summary – System Building Blocks...



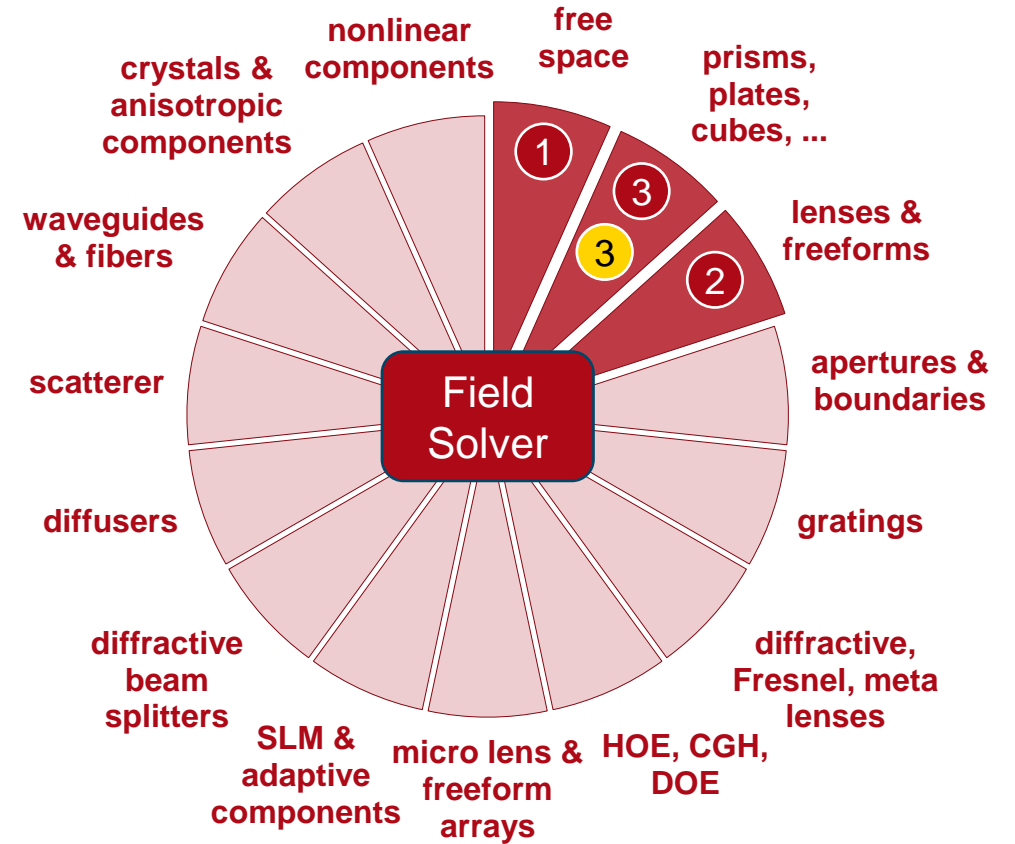
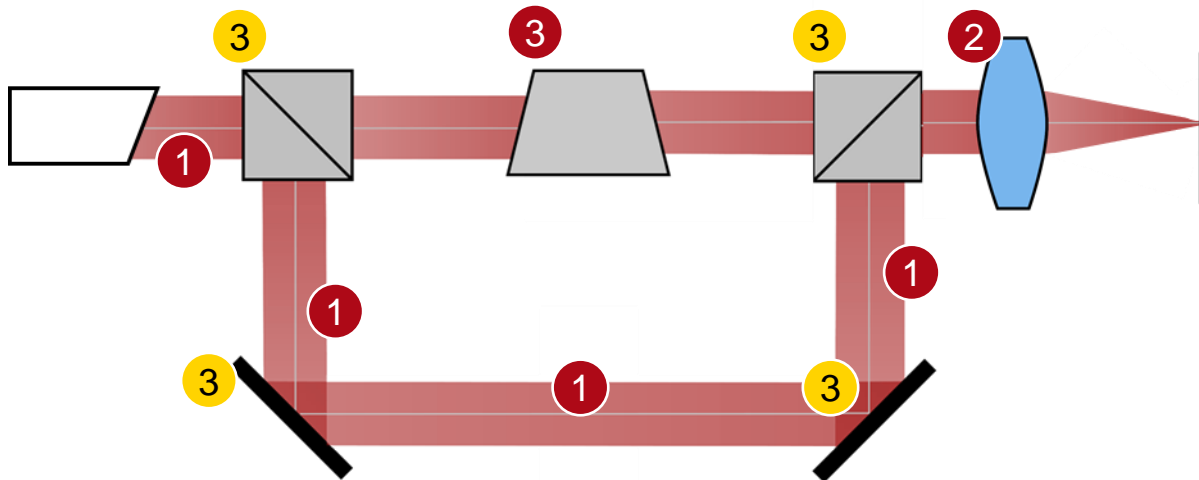
... of Optical System	... in VirtualLab Fusion	Source Model/Component Solver
1. Source	Ince Gaussian Source	Ince-Gaussian mode calculation
2. Beam Splitter	Ideal Beam Splitter	-
3. Dove Prism	Plane Interfaces	Fresnel Matrix
4. Mirror	Ideal Mirror	Local Plane Interface Approximation
5. Lens	Ideal Lens	-
6. Detector	Camera Detector	-

# Workflow in VirtualLab Fusion

- Set up input field
  - [Basic Source Models](#) [Tutorial Video]
  - [Ince-Gaussian Modes](#) [Use Case]
- Construct real components using surfaces
- Define position and orientation of components
  - [LPD II: Position and Orientation](#) [Tutorial Video]
- Set channels properly for non-sequential tracing
  - [Channel Setting for Non-Sequential Tracing](#) [Use Case]



# VirtualLab Fusion Technologies



# idealized component

# Document Information

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title	Observation of Vortex Array Laser Beam Generation from Ince-Gaussian Beam
document code	SRC.0003
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.176)
category	Application Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#">Mach-Zehnder Interferometer</a></li><li>- <a href="#">Ince-Gaussian Modes</a></li></ul>