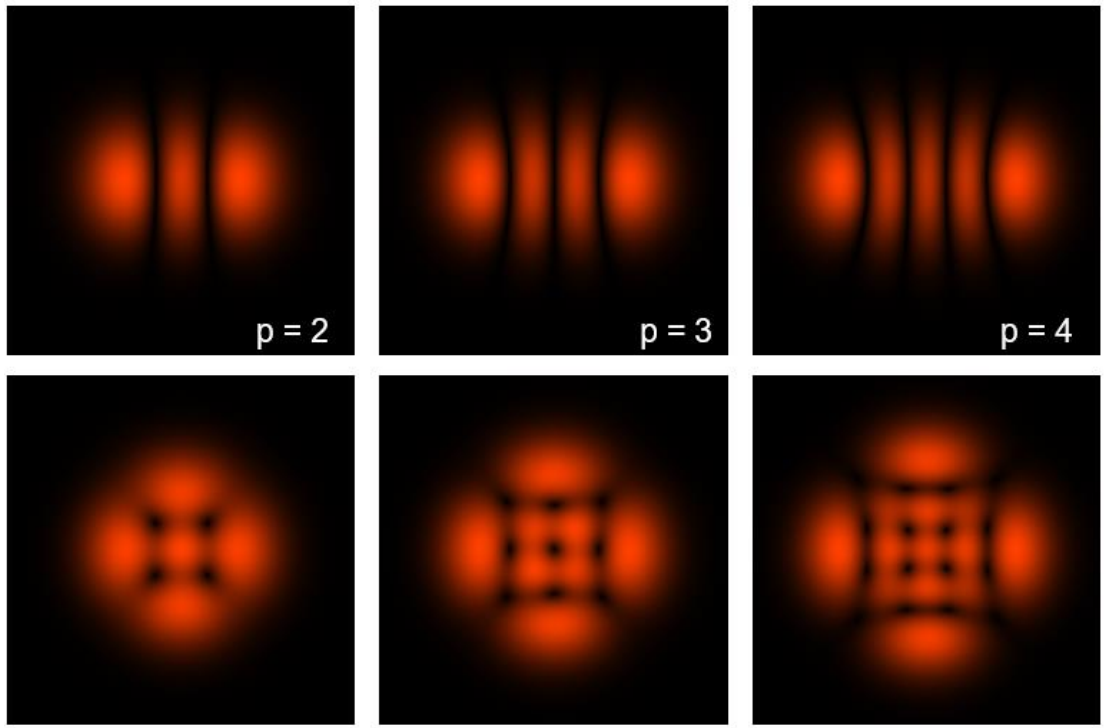
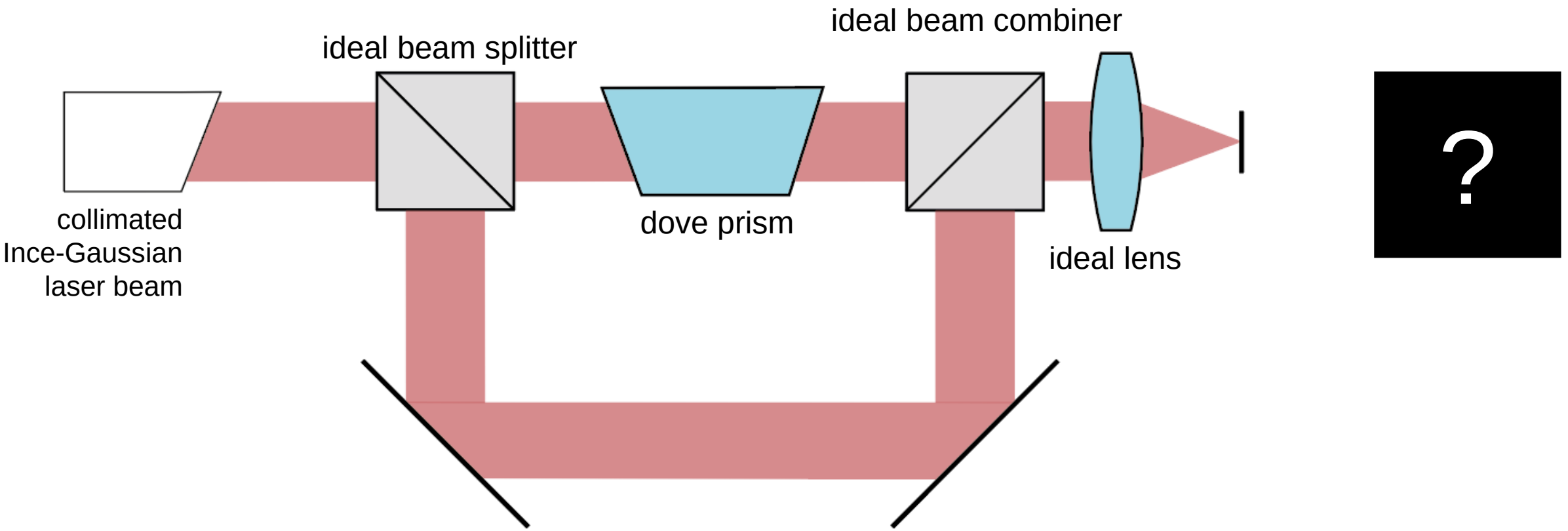
Observation of Vortex-Array Laser-Beam Generation from Ince-Gaussian Beam

Abstract



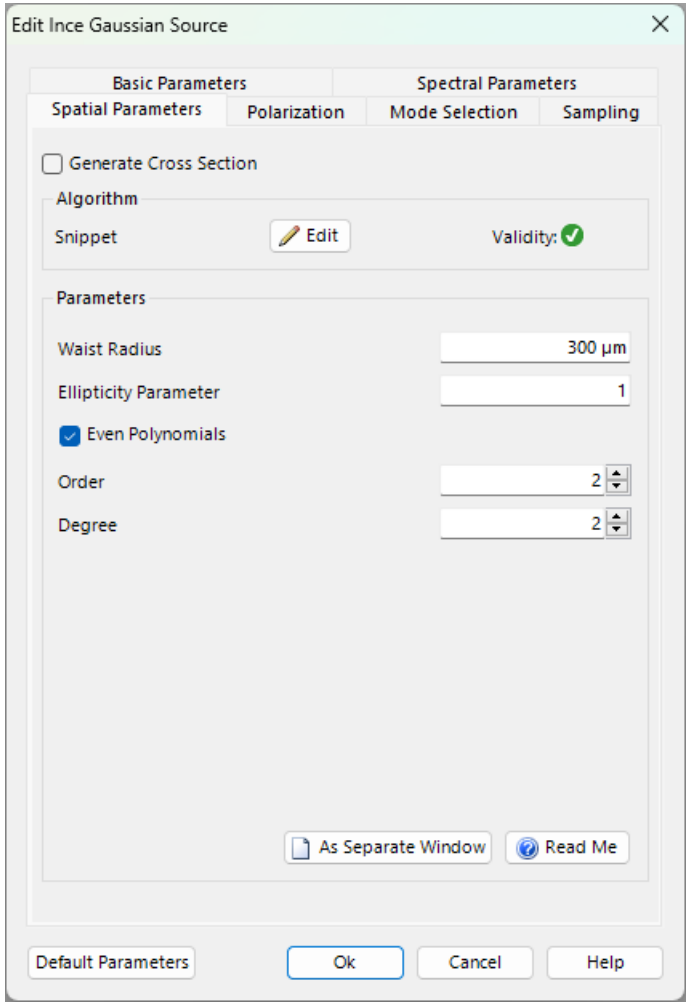
Ince-Gaussian modes are the third complete family of exact and orthogonal solutions of the paraxial wave equation alongside the Hermite-Gaussian and Laguerre-Gaussian modes. Ince-Gaussian modes have a diversiform transverse pattern. In this document, following in the steps of Chu et al. [Opt. Express 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.

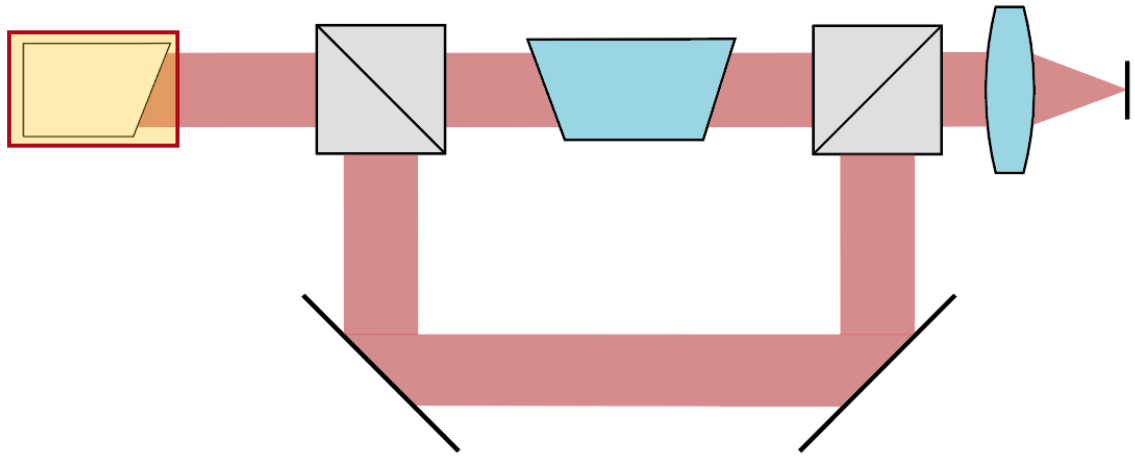
Task Description



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)

Ince Gaussian Mode Source



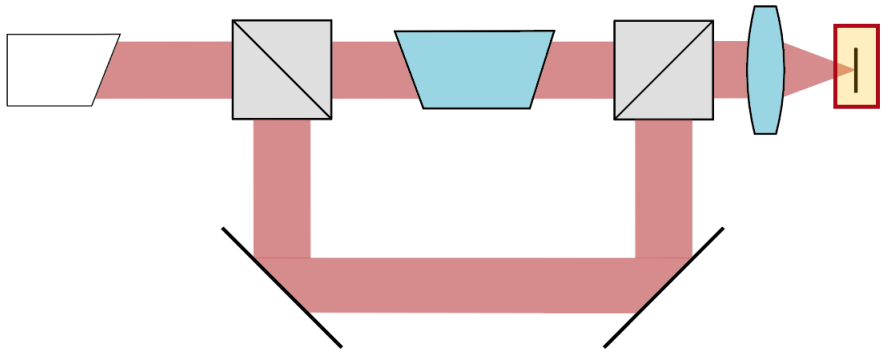


The Ince-Gaussian source can be found in *Light Sources/Basic Source Models*, and offers the following adjustable parameters:

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

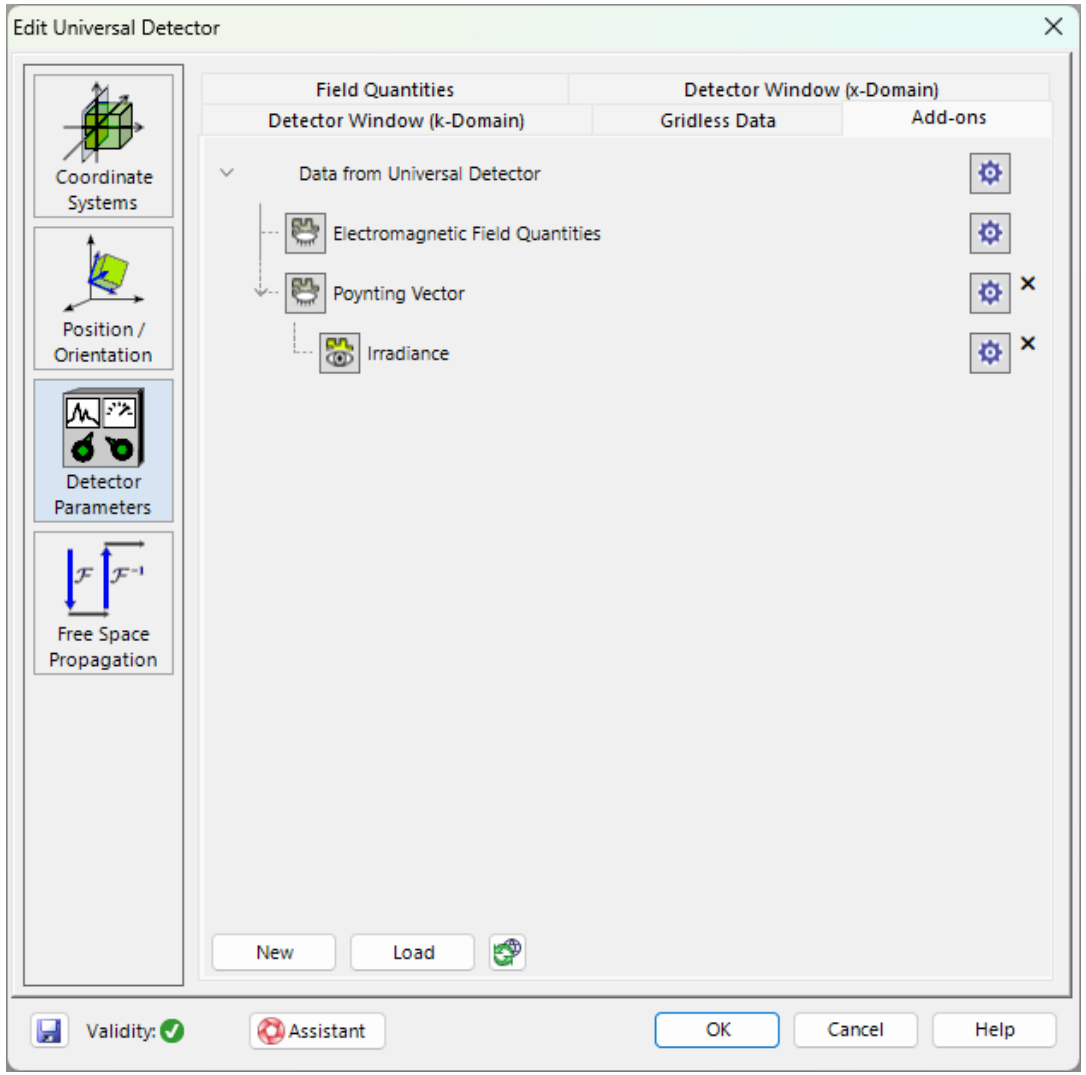
A more detailed explanation of the meaning of the parameters and configuration of the source can be found here: Ince-Gaussian Modes

Detector Add-On

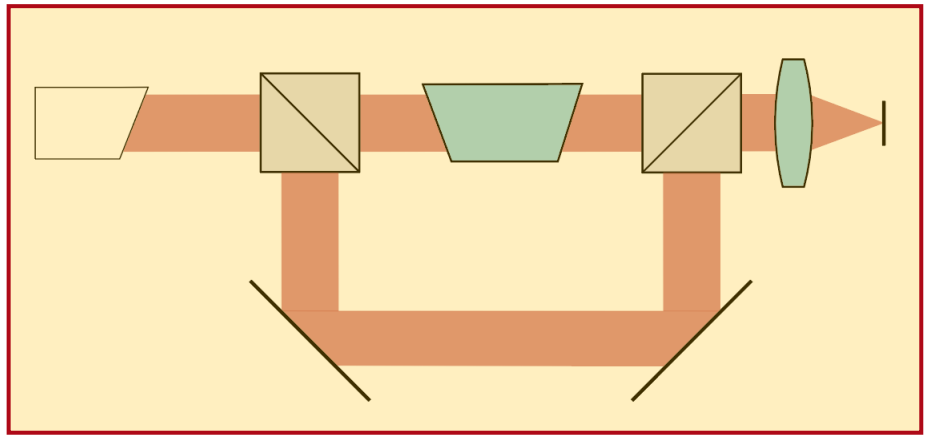


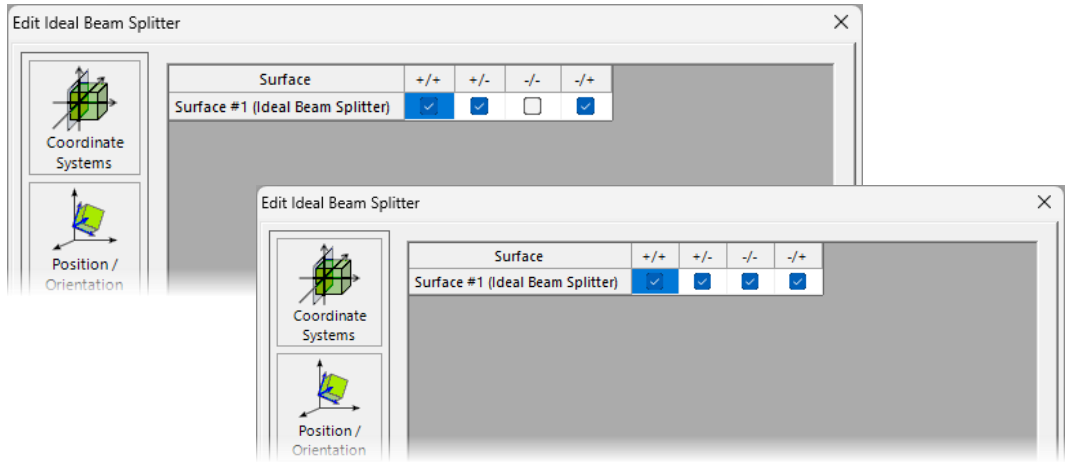
The *Universal Detector* enables the evaluation of the impinging field and the calculation of various physical quantities through so-called *Add-Ons*. As an example, they can calculate the *Irradiance*. For more information, see:

Universal Detector

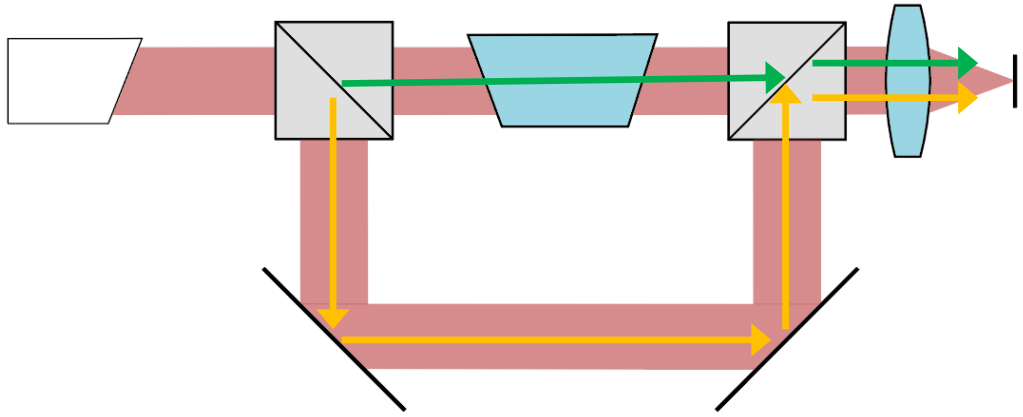


Non-Sequential Tracing



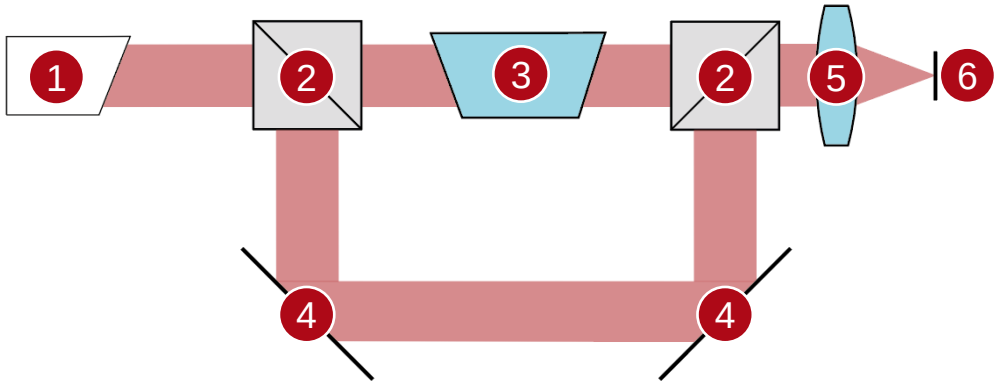


With the channel configuration mode toggle set to *Manual Configuration*, the user can specify, for each surface in the system, which channels to open for the simulation. When the simulation is run, a preliminary analysis of the active light paths will be performed (by the so-called *Light Path Finder*). The field will then be traced along these light paths by the engine, to the detectors present in the system.



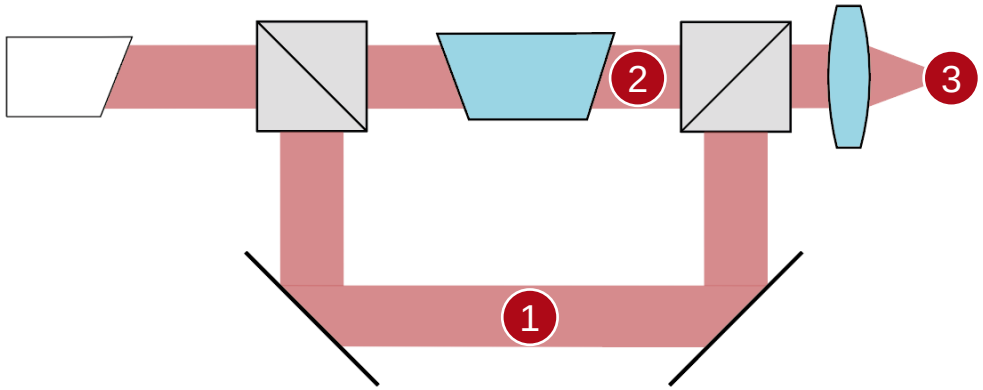
Channel Setting for Non-Sequential Tracing

Summary – Components...

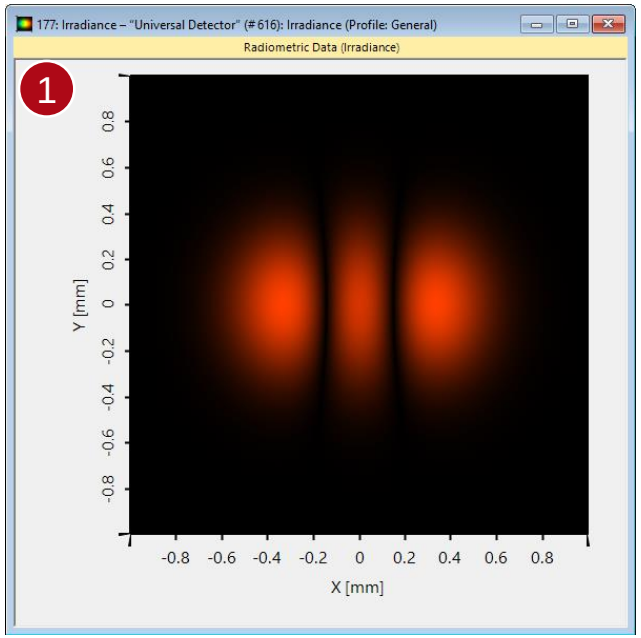


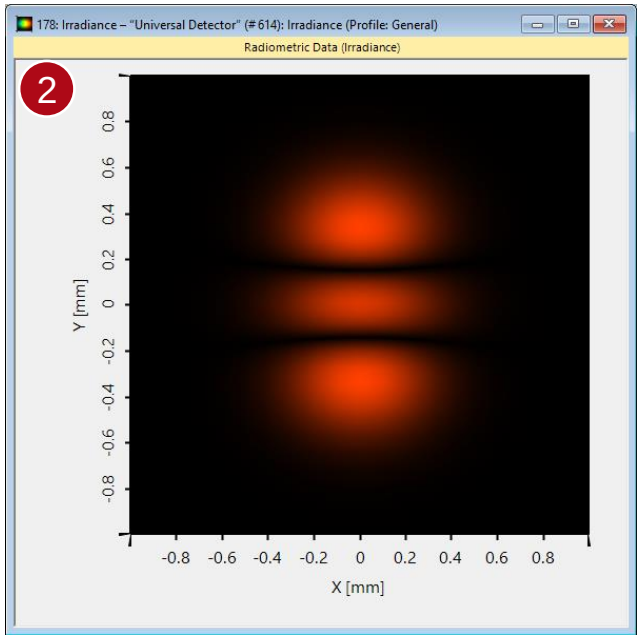
… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. source	*Ince Gaussian Source*	Ince-Gaussian mode calculation
2. beam splitter	*Ideal Beam Splitter*	transmission function
3. Dove prism	*Plane Interfaces*	Fresnel Matrix
4. mirror	*Ideal Mirror*	Local Plane Interface Approximation
5. lens	*Ideal Lens*	transmission function
6. detector	*Universal Detector*	irradiance

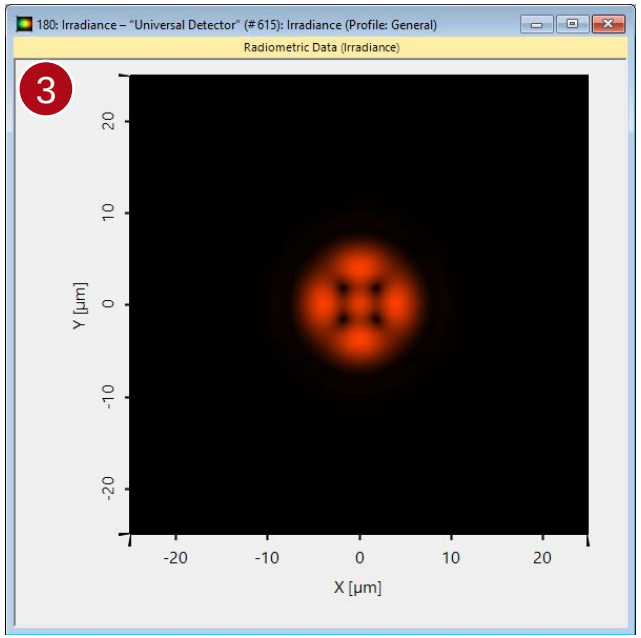
Simulation of Vortex-Array Laser-Beam Generation



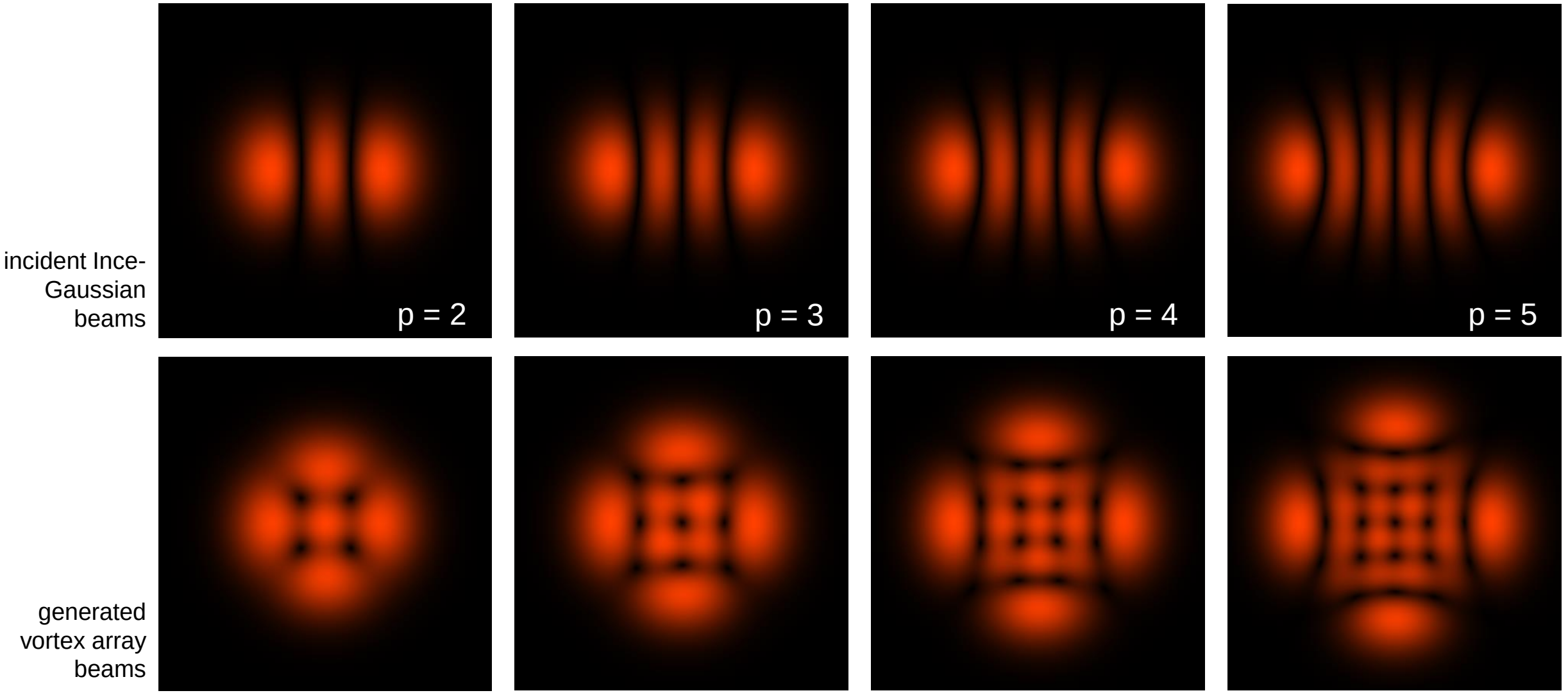
The Dove prism will rotate the Ince Gaussian beam by 90°. Interfering the rotated beam with the original will create a pattern that remains stable through the focusing process and can be used for e.g. atom trap applications.



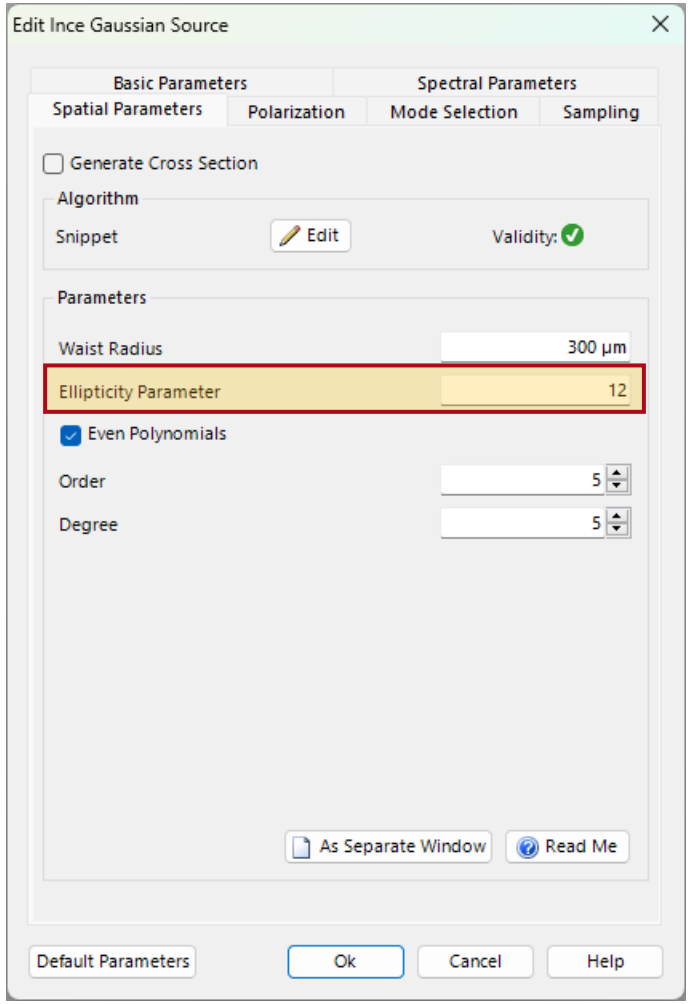




Generated Vortex Array Using Different Mode Orders in Source



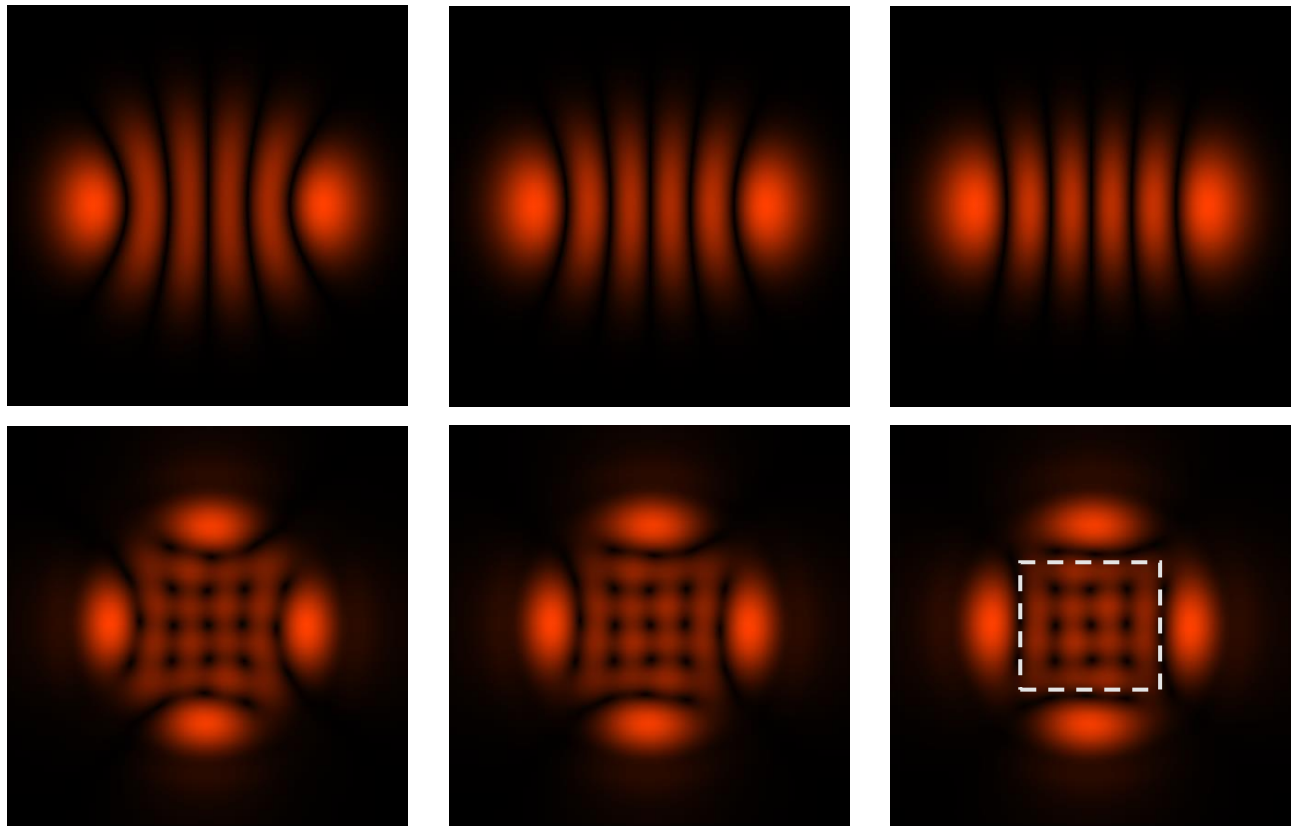
Effect of Ellipticity Parameter on Vortex Array Pattern



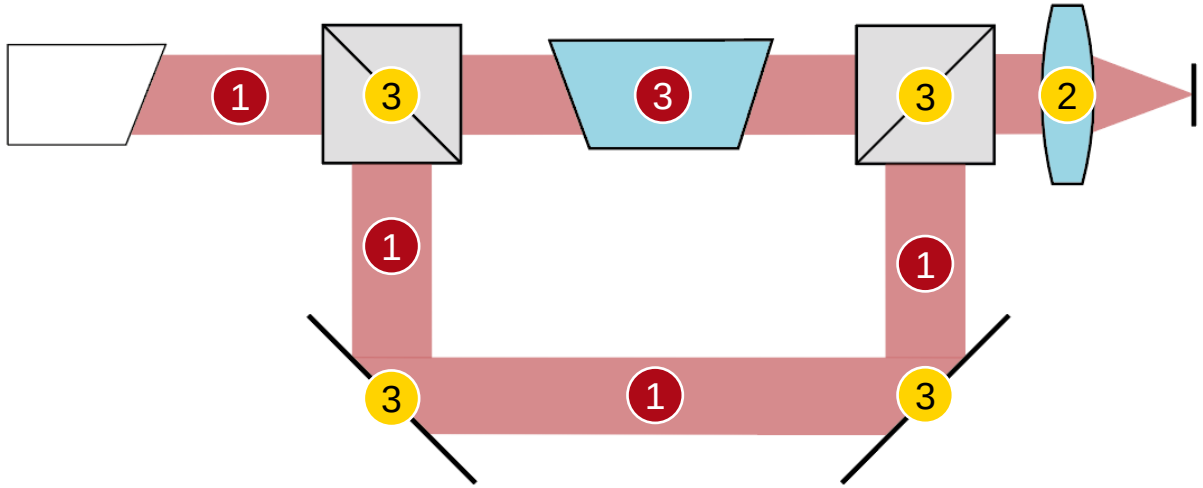
A higher value of the ellipticity parameter ε of the incident Ince-Gaussian laser beam reduces the curvature of the mode parabola, resulting in the generated vortices forming a less distorted (squarer) array.

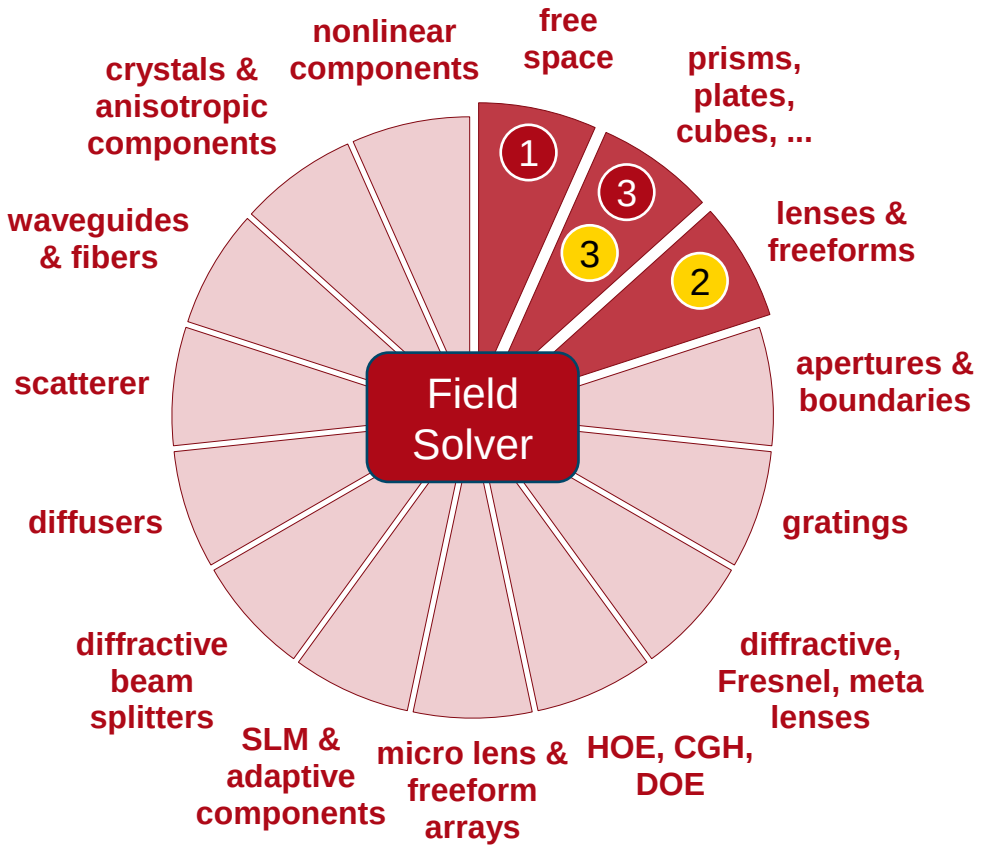
incident Ince-Gaussian beams

generated vortex array beams



VirtualLab Fusion Technologies





Document Information

title	Observation of Vortex-Array Laser-Beam Generation from Ince-Gaussian Beam
document code	SRC.0003
version	1.1
edition	VirtualLab Fusion Basic
software version	2023.1 (Build 1.556)
category	Application Use Case
further reading	• Mach-Zehnder Interferometer • Ince-Gaussian Modes

Marketing Picture

incident Ince-Gaussian beams

generated vortex array beams