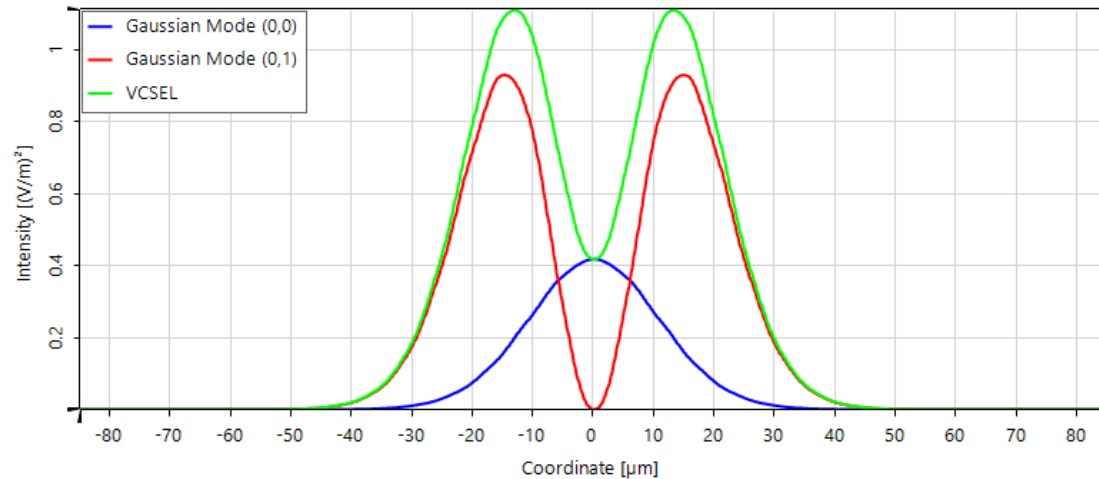


Modeling of VCSEL Source by Two Uncorrelated Laguerre-Gaussian Modes

Abstract



Vertical cavity surface emitting laser (VCSEL) diodes are of interest for numerous applications, such as optical sensors and pattern generators. In order to be able to investigate these kinds of setups in VirtualLab Fusion, an appropriate source model is required. In this use case, we demonstrated how to achieve the desired intensity distribution of a specific VCSEL source via parametric optimization of two uncorrelated Gaussian modes with the help of the multiple light source.

Simulation Task



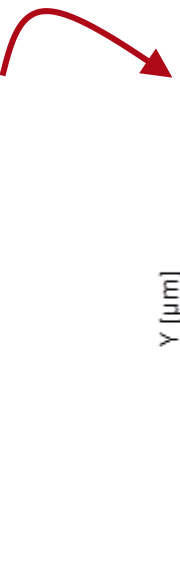
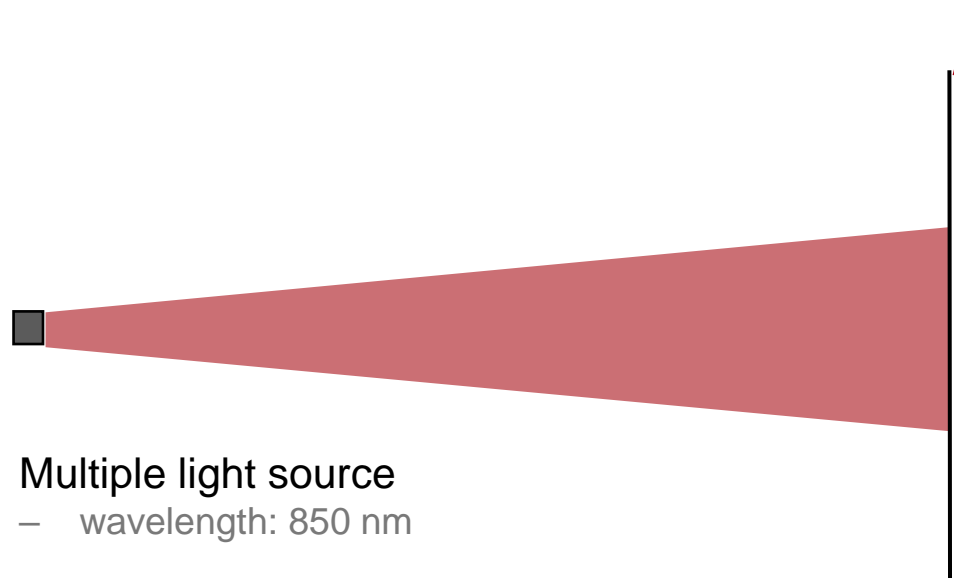
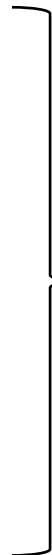
Mode (0,0)



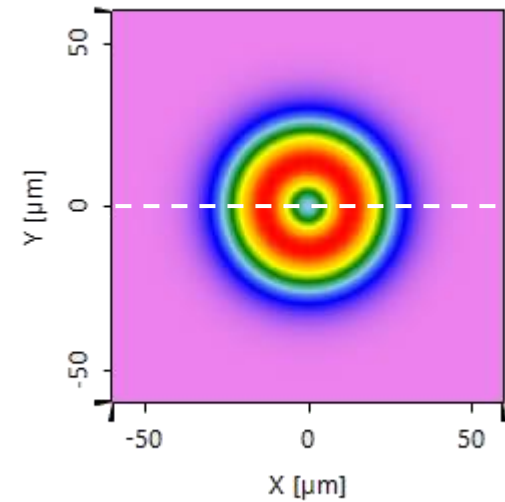
Mode (0,1)



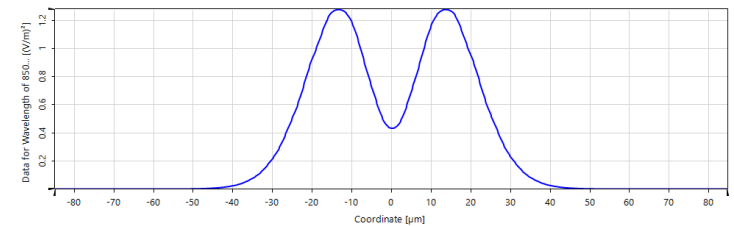
Multiple light source
– wavelength: 850 nm



far-field
energy density



How to determine the parameters of both modes to achieve the desired far-field energy density?



Laguerre-Gaussian Modes for VCSEL Source Modeling

Two Laguerre-Gaussian modes (0,0) and (0,1) are used to model the VCSEL source.

Use the Multiple Light Source to model the VCSEL source

Combination Mode: Incoherent

Light Source Name	Light Source	Use
Light Source 1	Gaussian Wave	<input checked="" type="checkbox"/>
Light Source 2	Gaussian Wave	<input checked="" type="checkbox"/>

Use the Multiple Light Source to model the VCSEL source

Mode 0,0

Order: 0, 0
M² Parameter: 1

Reference Wavelength (Vacuum): 850 nm

Select Achromatic Parameter:
 Waist Radius (1/e²) 1 μm
 Half-Angle Divergence (1/e²) 15.13575805°
 Rayleigh Length 3.696989526 μm

Astigmatism
Offset between y- and x-Plane: 0 mm

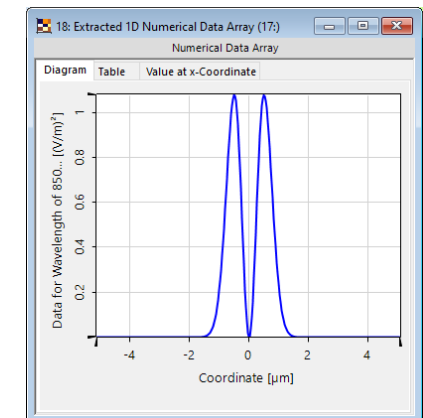
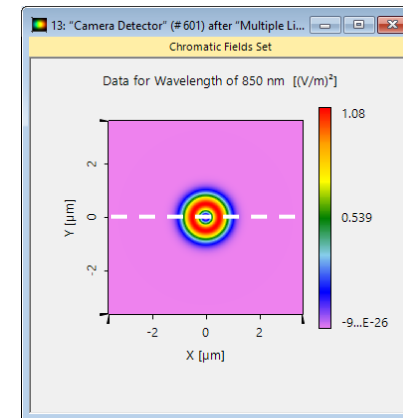
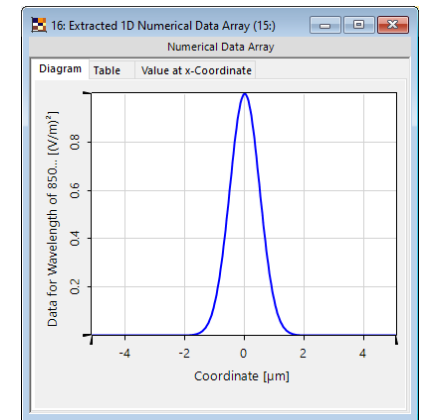
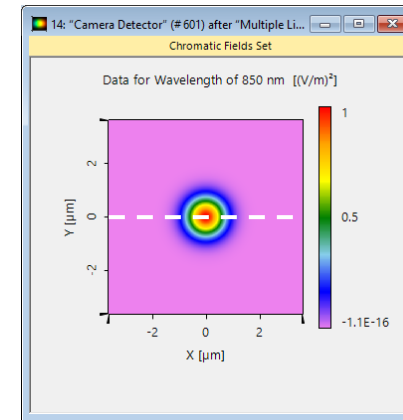
Mode 0,1

Order: 0, 1
M² Parameter: 2

Reference Wavelength (Vacuum): 850 nm

Select Achromatic Parameter:
 Waist Radius (1/e²) 1 μm
 Half-Angle Divergence (1/e²) 29.60430985°
 Rayleigh Length 1.848494763 μm

Astigmatism
Offset between y- and x-Plane: 0 mm

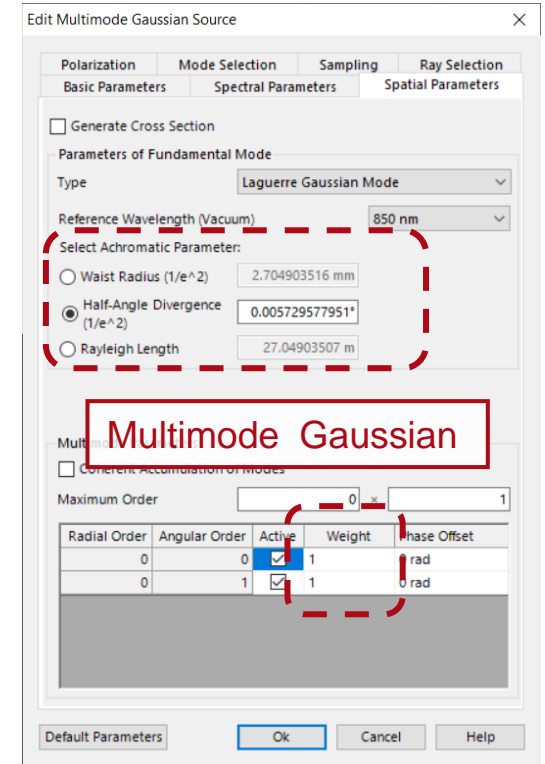
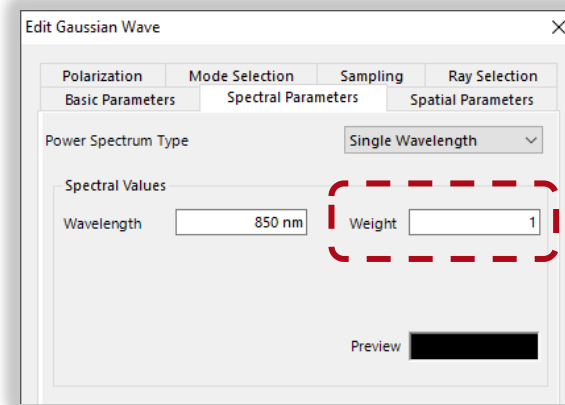
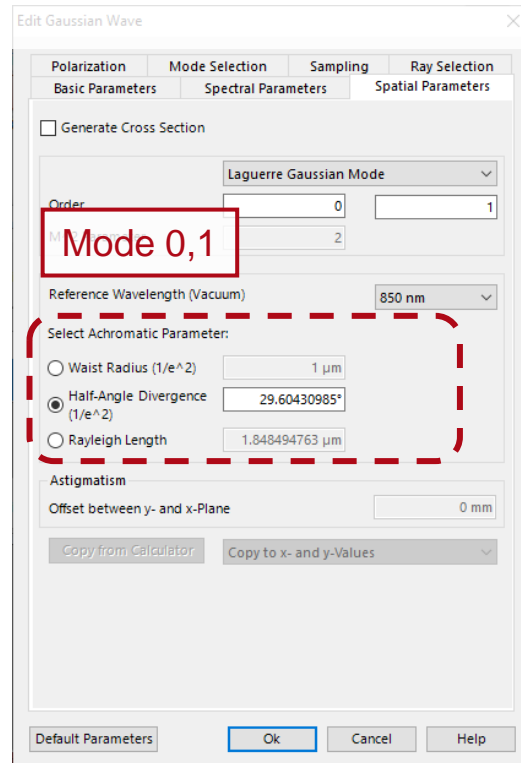
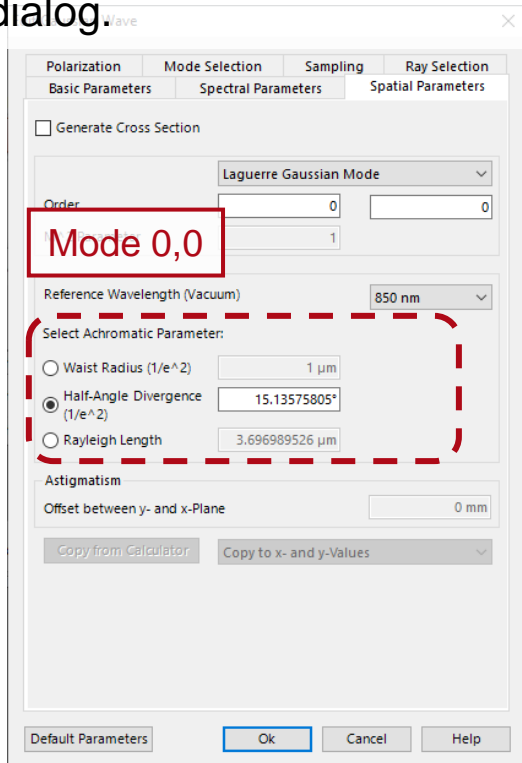


Variable Parameters of Laguerre-Gaussian Modes

The following parameters can be set as the variables for the parametric optimization:

- Waist radius / Half-angle divergence / Rayleigh length
- Weight of each mode

Since the waist, divergence and Rayleigh length depend on each other, only the primary choice of the parameters can be modified, the others are computed on the fly and are displayed in the dialog.

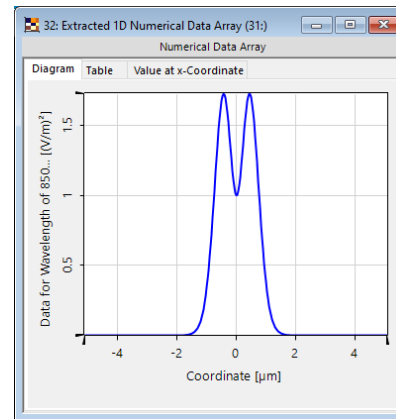
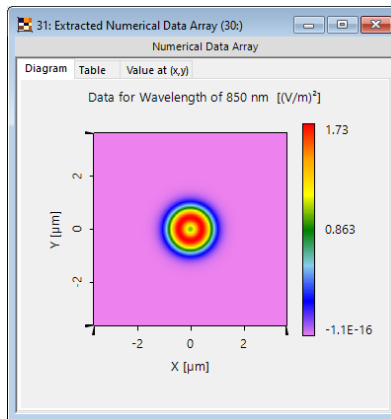


Please note: this use case can also be implemented with a Multimode Gaussian source. However, the selection range of variable parameters is more curtailed there. The beam profile parameters of the two modes can only be varied together.

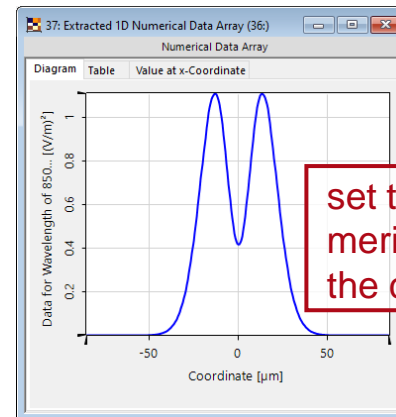
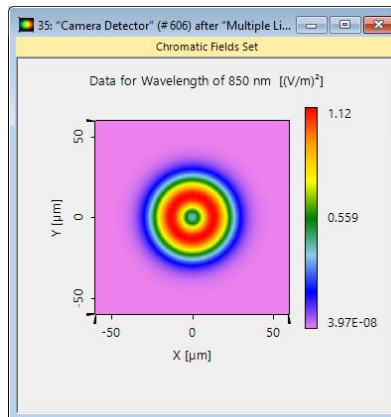
Customized Diffractive Optics Merit Functions Detector

To generate appropriate merit functions for the optimization, a customized *Diffractive Optics Merit Functions* detector is applied to define the constraint specifications according to the desired output VCSEL intensity.

initial energy density of two uncorrelated modes in far-field



desired energy density of VCSEL source in far-field



The screenshot shows the "Edit Programmable Detector" dialog box with the "Detector Function" tab selected. The "Parameters" section is highlighted with a red dashed box and contains the following options:

- AllowScaleFreedom
- AreEfficienciesRelatedToSourceField
- CalculateWindowEfficiency
- CalculateConversionEfficiency
- CalculateSNR

A red speech bubble points to this section with the text: "activate merit functions that evaluate the optimization".

Below the parameters, the "Reference Field" section is highlighted with a red dashed box and contains the following options:

- CalculateZerothOrderIntensity
- CalculateZerothOrderEfficiency
- CalculateMaxRelIntensityOfStrayLight
- CalculateOptimalScaleFactor

A red speech bubble points to this section with the text: "set the signal field into the merit function detector as the calculation reference".

The "Number of Resulting Physical Values (for Optimization)" is set to 2. The "Set" button is highlighted with a red box.

Optimize the Combination of Single Modes

39: Parametric Optimization from "2: Optical Setup"

Parameter Selection
Select the parameters which shall be varied during optimization.

You can select one or more parameter which shall be varied within the optimization.

Filter by... Show Only Varied Parameters

1	2	*	Object	Category	Parameter	Vary	Original Value
			"Multiple Light Source" (# 0)	Light Source 1 (Gaussian Wave)	Weight	<input checked="" type="checkbox"/>	1
					Half-Angle Divergence (1/e^2)	<input checked="" type="checkbox"/>	15.13575805*
				Light Source 2 (Gaussian Wave)	Weight	<input checked="" type="checkbox"/>	1
					Half-Angle Divergence (1/e^2)	<input checked="" type="checkbox"/>	29.60430985*

select parameters to be varied during optimization

39: Parametric Optimization from "2: Optical Setup"

Constraint Specifications
Select and specify the constraints which shall be considered during optimization.

Constraint Host	Constraint Name	Use	Weight	Constraint Type	Value 1	Value 2	Start Value	Contribution
"Multiple Light Source" (# 0)	Light Source 1 (Gaussian Wave) Weight	<input checked="" type="checkbox"/>	1	Range	0	1E+300	1	N/A
	Light Source 1 (Gaussian Wave) Half-Angle Divergence	<input checked="" type="checkbox"/>	1	Range	0.0001*	89.999*	15.13575805*	N/A
	Light Source 2 (Gaussian Wave) Weight	<input checked="" type="checkbox"/>	1	Range	0	1E+300	1	N/A
	Light Source 2 (Gaussian Wave) Half-Angle Divergence	<input checked="" type="checkbox"/>	1	Range	0.0001*	89.999*	29.60430985*	N/A
"Programmable Detector" (# 602)	Value #1: Conversion Efficiency	<input checked="" type="checkbox"/>	6	Target Value	1		0.1241890752	N/A
	Value #2: Signal-to-Noise Ratio	<input checked="" type="checkbox"/>	1	Target Value	25		0.0053968159	N/A

Tools

Target Function Value: 630.7152949

< Back Next > Show ▾

specify the constraints

7: C:\Users\...\Parametric Optimization from "2_ C_Users_..._test.os".opt

General Settings
Set up general settings for the optimization (e.g. the optimization algorithm).

Optimization Strategy
 Local Optimization Global Optimization

Local Optimization Settings

Optimization Algorithm: Downhill Simplex

Maximal Number of Iterations: 500

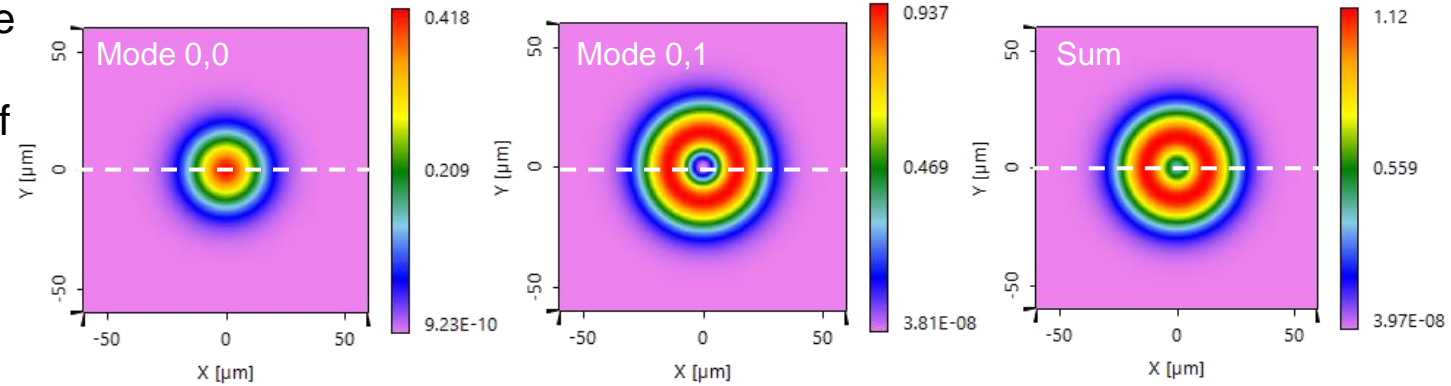
Maximum Tolerance: 1E-12

Initial Step Width Scale Factor: 1

We use the parametric optimization of conversion efficiency and signal-to-noise ratio with the downhill simplex algorithm, in which the half-angle divergence, waist radius and the weight of each mode can be varied to find the combination that delivers the expected VCSEL far-field energy density.

Parametric Optimization Results

After a few iterations, the two Gaussian beams have been found, with a conversion efficiency of the resulting VCSEL compared to the expected beam of over 98%.



Edit Gaussian Wave

Polarization: Generate Cross Section

Mode Selection: **Laguerre Gaussian Mode**

Order: M^2 Parameter:

Reference Wavelength (Vacuum): 850 nm

Select Achromatic Parameter:

Waist Radius (1/e^2) 1.239348602 μm

Half-Angle Divergence (1/e^2) 12.31185599°

Rayleigh Length 5.678520297 μm

Astigmatism: Offset between y- and x-Plane 0 mm

Spectral Values: Wavelength 850 nm Weight 129.9703317

Edit Gaussian Wave

Polarization: Generate Cross Section

Mode Selection: **Laguerre Gaussian Mode**

Order: M^2 Parameter:

Reference Wavelength (Vacuum): 850 nm

Select Achromatic Parameter:

Waist Radius (1/e^2) 1.852097305 μm

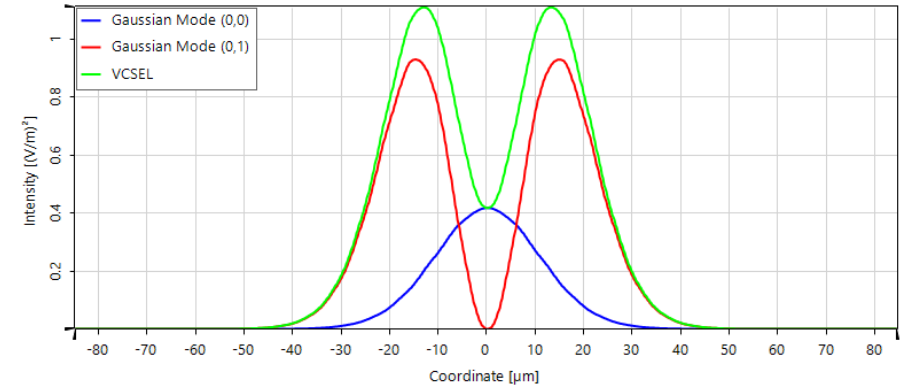
Half-Angle Divergence (1/e^2) 16.50351341°

Rayleigh Length 6.340825831 μm

Astigmatism: Offset between y- and x-Plane 0 mm

Spectral Values: Wavelength 850 nm Weight 226.0147769

1D intensity profile

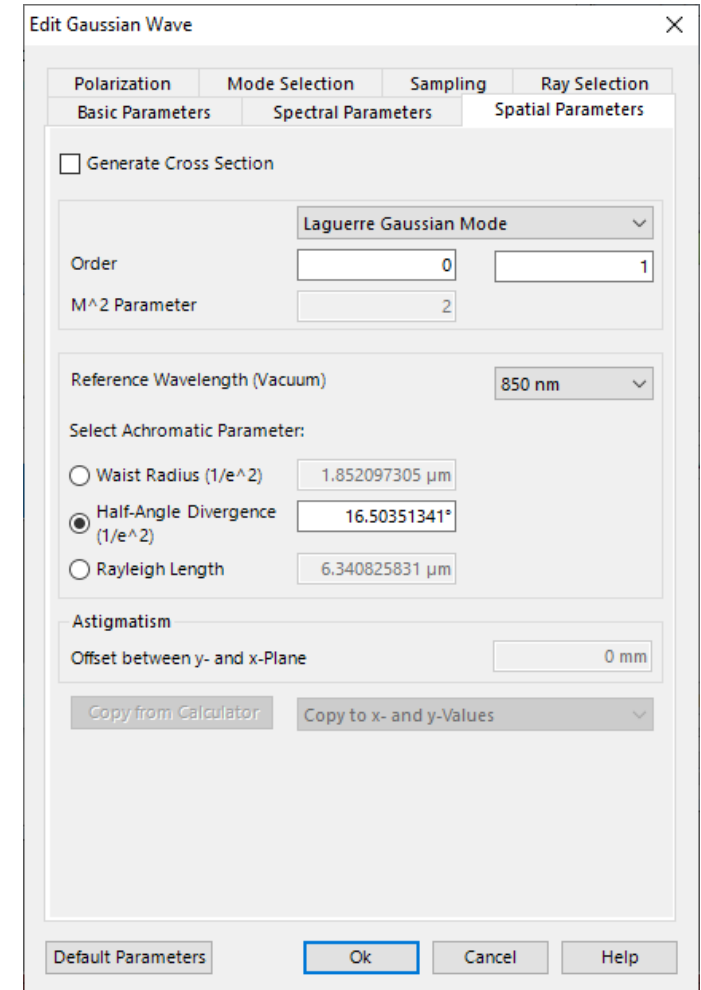


Customized diffractive optics merit functions detector result:

Detector	Sub - Detector	Result
"Programmable Detector" (# 602) after "Multiple Light Source" (# 0) (-) (Diffractive Optics Merit Functions) (Field Tracing)	Conversion Efficiency	98.35817551 %
	Signal-to-Noise Ratio	22.41279532 dB

Workflow in VirtualLab Fusion

- Set up input field
 - [Basic Source Models](#) [Tutorial Video]
 - [Simulation of Multiple Light Source with VirtualLab Fusion](#) [Use Case]
- Use Parametric Optimization to find proper parameters of two uncorrelated modes, whose combination gives desired far-field energy density of VCSEL source



Document Information

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