In this article

TOP

How to model laser beam propagation in OpticStudio: Part 2 - Using Paraxial Gaussian Beam analysis to model Gaussian beam

Zemax OpticStudio

Also available in **日本語**, **简体中文**

This article is part of the [Tutorial Series] Modeling Laser Beam Propagation in OpticStudio free tutorial.

Three tools can be used in OpticStudio sequential mode to model Gaussian beam propagation. They are:

- the ray-based approach
- Paraxial Gaussian Beam analysis
- Physical Optics Propagation

In this series of three articles, we'll discuss how to set up a Gaussian laser source, how to analyze the beam as it propagates through the optical system, and how to optimize for the smallest spot size using these three methods. We'll also discuss when is appropriate to use which methods.

This article is part 2 of the series focusing on how to use the Paraxial Gaussian Beam analysis tool to model Gaussian beam.

Authored By Hui Chen

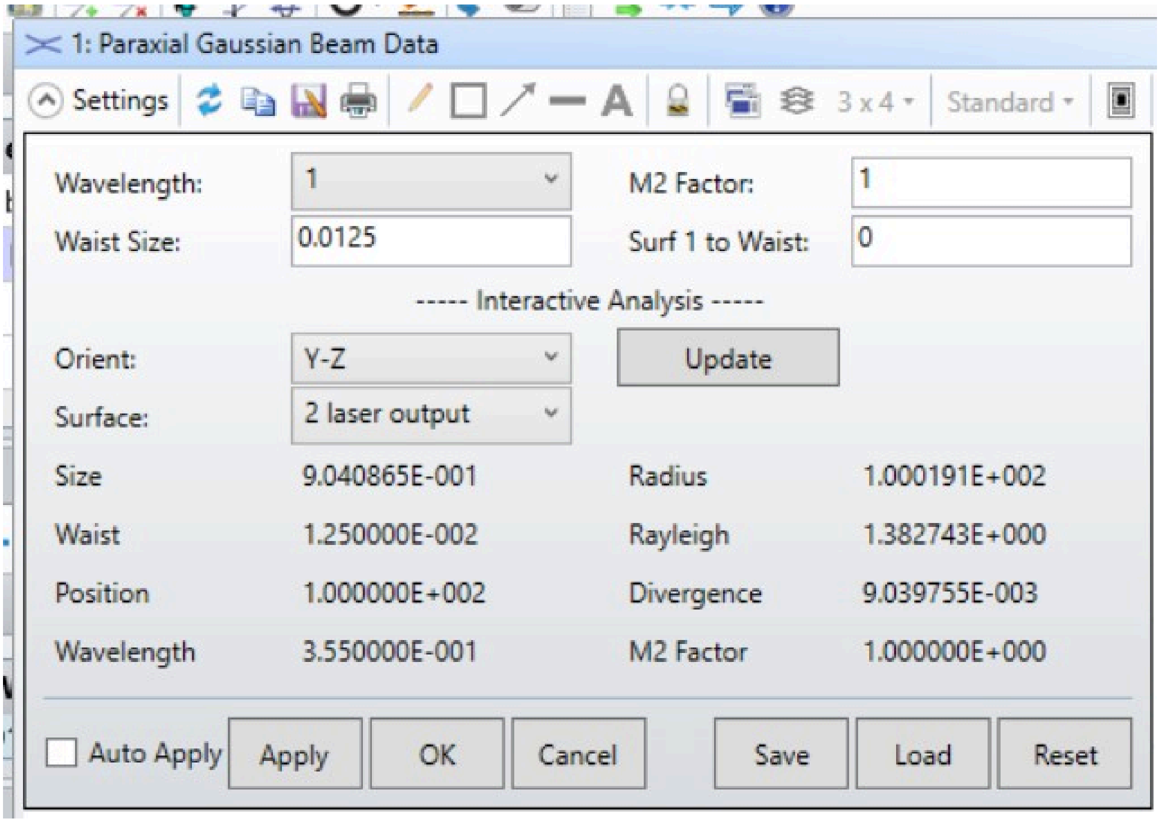
Introduction

OpticStudio Sequential Mode provides three tools to model Gaussian beam propagation: ray-based approach, Paraxial Gaussian Beam, and Physical Optics Propagation (POP). The ray based approach models beam propagation using geometrical ray tracing. Paraxial Gaussian Beam models Gaussian beam and reports various beam data, including beam size and waist location as it propagates through a paraxial laser beam propagation using Paraxial Gaussian Beam.

Paraxial Gaussian Beam analysis

You can find the tool at **Analyze...Lasers and Fibers...Gaussian Beams...Paraxial Gaussian Beam**. The Paraxial Gaussian Beam analysis is an interactive feature that works as a "calculator" that quickly computes Gaussian beam characteristics.This feature computes ideal and mixed mode Gaussian beam data as a given input beam propagates through the lens system. It requires the definition of the initial input embedded beam properties and its M2 value. The advantage is it allows you to enter both ideal and mixed mode (M2>1) Gaussian beam and displays beam data as it propagates surface by surface in your optical system. The limit is that the calculation of Gaussian beam parameters is based upon paraxial ray data, therefore the results may not be accurate for systems which have large aberrations, or those cannot be described by paraxial optics, such as non-rotationally symmetric systems. This feature also ignores all apertures, and assumes the Gaussian beam propagates well within the apertures of all the lenses in the system.

- The input embedded beam is defined by its Wavelength, Waist Size (radius), and waist locationd which is specificed using the distance between the beam waist location and surface 1 in the system.
- M2 Factor. The ideal M2 value is unity, but real lasers will always have an M2 value greater than unity.

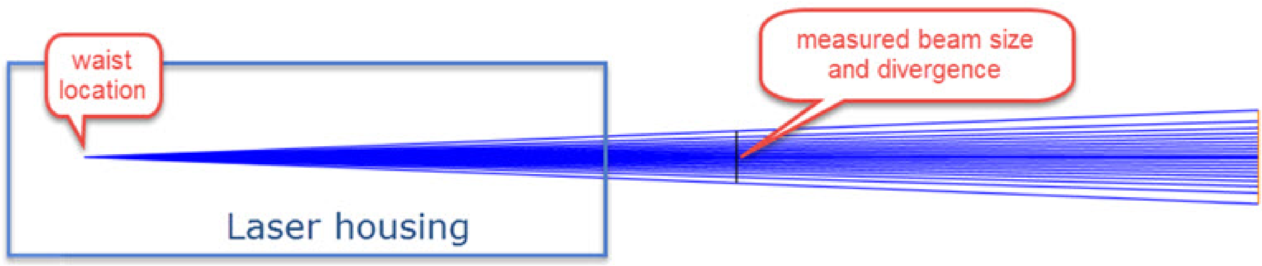


OpticStudio then propagates this embedded beam through the lens system, and at each surface the beam data, including beam size, beam divergence, and waist locations, is computed and displayed in the output window. OpticStudio computes the Gaussian beam parameters for both X and Y orientations.

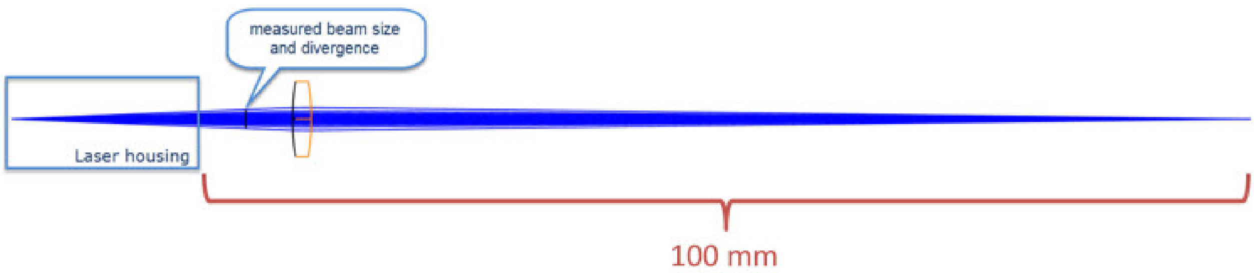
We'll tackle the same problem as described in part 1, design a laser beam focusing system using a singlet lens.

The specifications are the same:

- Nominal Wavelength = 355 nm
- Measured 5 mm from laser output:
  - Beam diameter = 2 mm
  - Measured divergence = 9 mrad

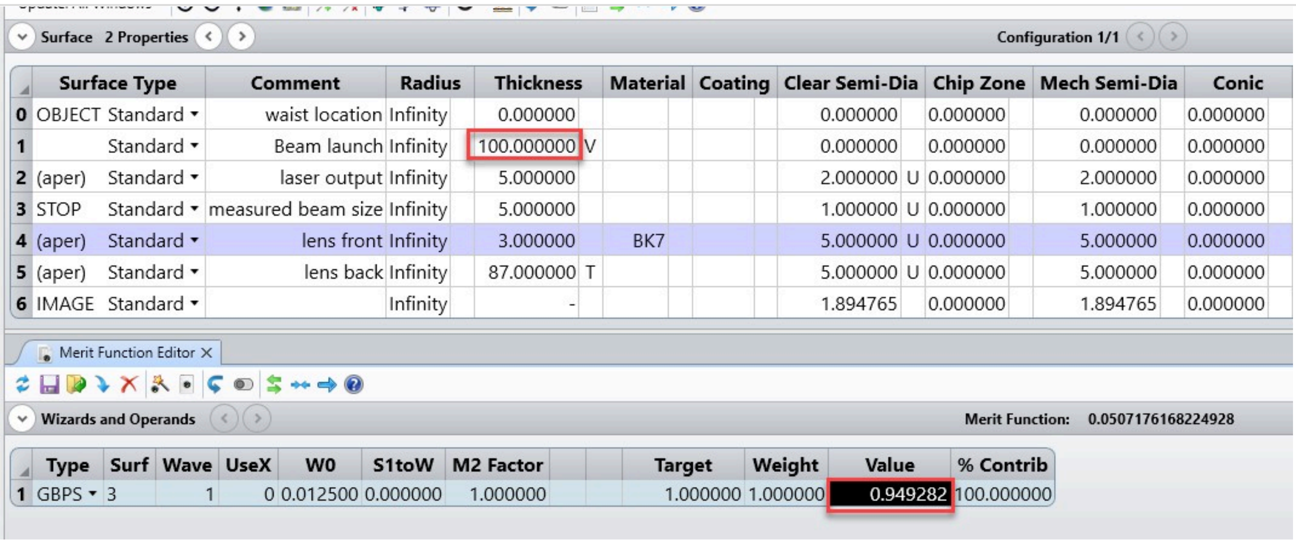


Knowing the wavelength and the far field divergence angle, using equations (1) through (3), the beam waist is calculated to be 0.0125 mm, with a Rayleigh range of 1.383 mm. We will model this system using Paraxial Gaussian beam analysis tool so that the beam spot is the smallest at 100 mm away from the laser output.



The starting system is very similar to that of the ray-based approach. The only difference is that Paraxial Gaussian Beam analysis does not allow beam to be launched at Object surface 0. Therefore, a dummy surface needs to be inserted after the Object. The Object thickness is set to 0 so the dummy surface is co-located with the object and the beam will be launched from this dummy surface instead. To start we will enter 100 mm as the thickness on the dummy surface and set it as a variable for optimization. Instead of looking at the beam divergence angle, we'll look at the beam size.

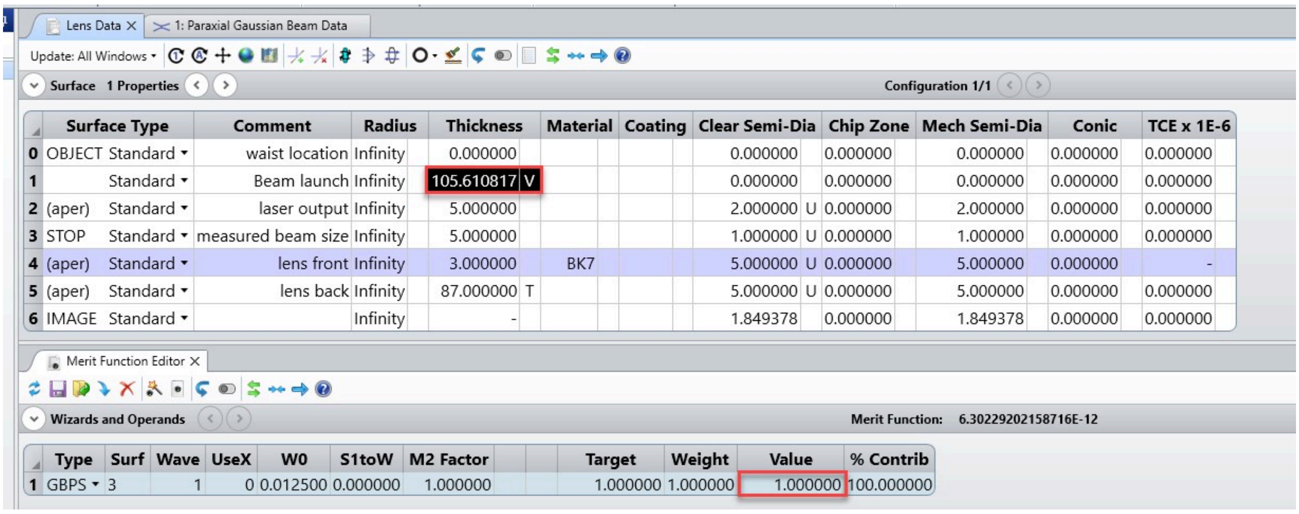
The operand GBPS returns paraxial Gaussian beam size, computed by the Paraxial Gaussian Beam analysis tool. In the Merit Function Editor, we'll enter one line using GBPS as shown below. The current beam size (radius) at the Stop surface is 0.949 mm. This file “2_PGB start_1.zar” can be found in the Download section.



	Surface Type		Comment	Radius	Thickness		Material	Coating	Clear Semi-Dia		Chip Zone	Mech Semi-Dia	Conic
0	OBJECT	Standard	waist location	Infinity	0.000000				0.000000		0.000000	0.000000	0.000000
1		Standard	Beam launch	Infinity	100.000000	V			0.000000		0.000000	0.000000	0.000000
2	(aper)	Standard	laser output	Infinity	5.000000				2.000000	U	0.000000	2.000000	0.000000
3	STOP	Standard	measured beam size	Infinity	5.000000				1.000000	U	0.000000	1.000000	0.000000
4	(aper)	Standard	lens front	Infinity	3.000000		BK7		5.000000	U	0.000000	5.000000	0.000000
5	(aper)	Standard	lens back	Infinity	87.000000	T			5.000000	U	0.000000	5.000000	0.000000
6	IMAGE	Standard		Infinity	-				1.894765		0.000000	1.894765	0.000000

	Type	Surf	Wave	UseX	W0	S1toW	M2 Factor		Target	Weight	Value	% Contrib
1	GBPS	3	1	0	0.012500	0.000000	1.000000		1.000000	1.000000	0.949282	100.000000

Our target beam radius at surface 3 should be 1 mm based on the measurement data. This suggests the first guess of 100 mm separation between the beam launch (surface 1) and the laser output (surface 2) is off. Through optimization OpticStudio can find the proper beam launch location so the beam diameter is 2 mm as measured on Stop surface 3.



	Surface Type		Comment	Radius	Thickness		Material	Coating	Clear Semi-Dia		Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6
0	OBJECT	Standard	waist location	Infinity	0.000000				0.000000		0.000000	0.000000	0.000000	0.000000
1		Standard	Beam launch	Infinity	105.610817	V			0.000000		0.000000	0.000000	0.000000	0.000000
2	(aper)	Standard	laser output	Infinity	5.000000				2.000000	U	0.000000	2.000000	0.000000	0.000000
3	STOP	Standard	measured beam size	Infinity	5.000000				1.000000	U	0.000000	1.000000	0.000000	0.000000
4	(aper)	Standard	lens front	Infinity	3.000000		BK7		5.000000	U	0.000000	5.000000	0.000000	-
5	(aper)	Standard	lens back	Infinity	87.000000	T			5.000000	U	0.000000	5.000000	0.000000	0.000000
6	IMAGE	Standard		Infinity	-				1.849378		0.000000	1.849378	0.000000	0.000000

	Type	Surf	Wave	UseX	W0	S1toW	M2 Factor		Target	Weight	Value	% Contrib
1	GBPS	3	1	0	0.012500	0.000000	1.000000		1.000000	1.000000	1.000000	100.000000

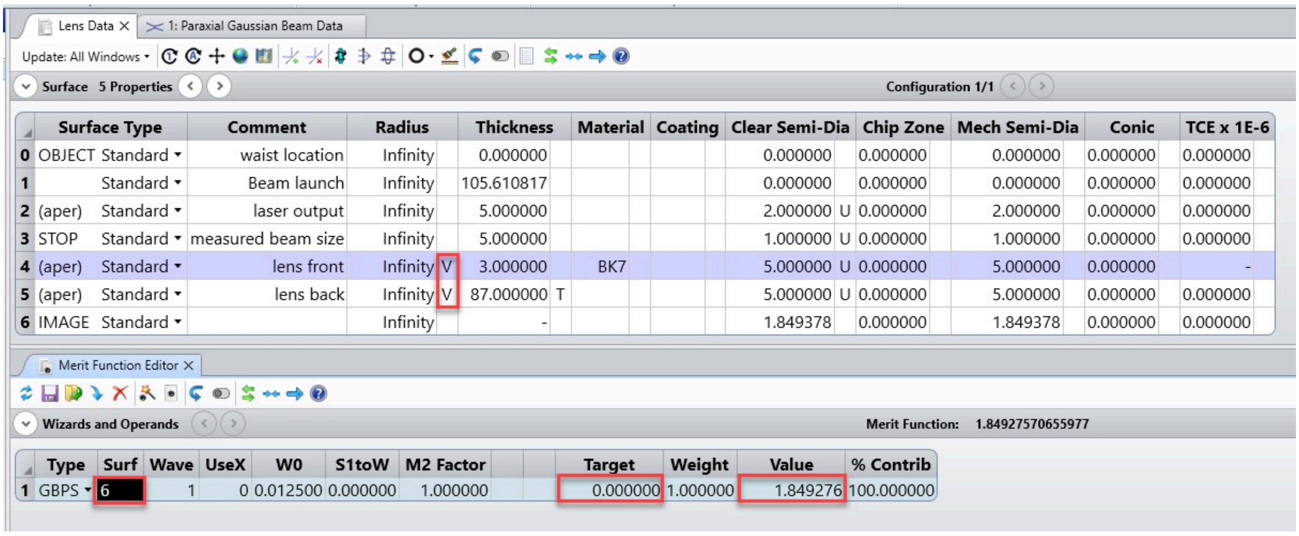
After a quick optimization, OpticStudio finds a new beam launch position that's 105.611 mm to the left of surface 2 laser output. This will be our new beam launch location. If you recall in the previous section where we used ray approach to find the beam waist location, the value returned was 106.108 mm in front of the laser output. This small discrepancy is expected, because these two analysis tools use different computational method. This file "2_PGB start_2.zar" can be found in the Download section.

Next, we will optimize the singlet lens to focus the beam to the smallest beam size at 100 mm from the laser output.

- Change the Solve Type on surface 1 Thickness from Variable to Fixed.

- Set the Target to 0 to minimize the beam radius.
- Set the Weight to 1.0. The current beam size at the image plane is calculated to be 1.849 mm.

This is the file “2_PGB start_3.zar” in the Download section.


Lens Data × | 1: Paraxial Gaussian Beam Data

Update: All Windows

Surface 5 Properties | Configuration 1/1

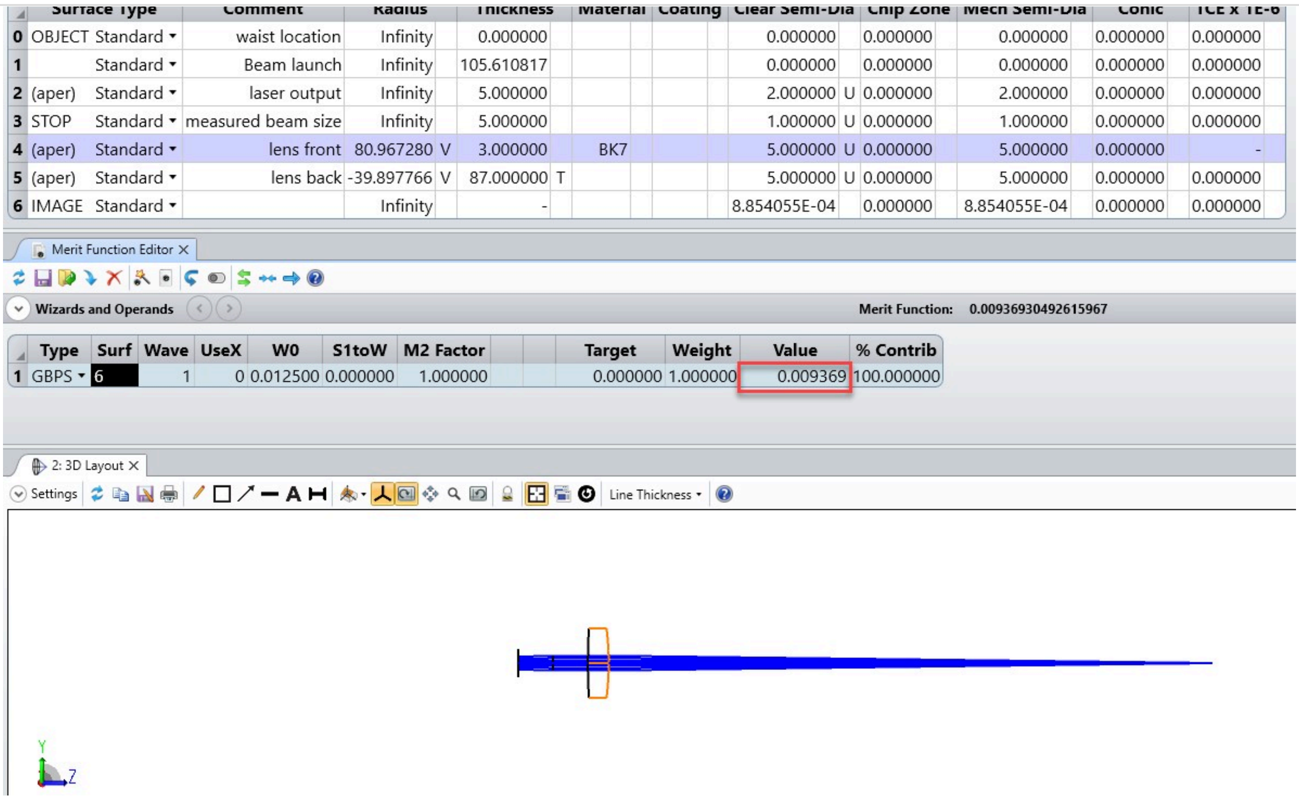
	Surface Type		Comment	Radius		Thickness		Material	Coating	Clear Semi-Dia		Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6
0	OBJECT	Standard	waist location	Infinity		0.000000				0.000000		0.000000	0.000000	0.000000	0.000000
1		Standard	Beam launch	Infinity		105.610817				0.000000		0.000000	0.000000	0.000000	0.000000
2	(aper)	Standard	laser output	Infinity		5.000000				2.000000	U	0.000000	2.000000	0.000000	0.000000
3	STOP	Standard	measured beam size	Infinity		5.000000				1.000000	U	0.000000	1.000000	0.000000	0.000000
4	(aper)	Standard	lens front	Infinity	V	3.000000		BK7		5.000000	U	0.000000	5.000000	0.000000	-
5	(aper)	Standard	lens back	Infinity	V	87.000000	T			5.000000	U	0.000000	5.000000	0.000000	0.000000
6	IMAGE	Standard		Infinity		-				1.849378		0.000000	1.849378	0.000000	0.000000

Merit Function Editor ×

Wizards and Operands | Merit Function: 1.84927570655977

	Type	Surf	Wave	UseX	W0	S1toW	M2 Factor		Target	Weight	Value	% Contrib
1	GBPS	6	1	0	0.012500	0.000000	1.000000		0.000000	1.000000	1.849276	100.000000

After optimization, the smallest paraxial Gaussian beam size is calculated to be 9.369 μm (this is a more accurate value for the focused beam size at the waist than the geometric ray trace values calculated in the Spot Diagram in part 1 of this series). This is the file “2_PGB optimized.zar” found in the Download section.



	Surface Type		Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6
0	OBJECT	Standard	waist location	Infinity	0.000000			0.000000	0.000000	0.000000	0.000000	0.000000
1		Standard	Beam launch	Infinity	105.610817			0.000000	0.000000	0.000000	0.000000	0.000000
2	(aper)	Standard	laser output	Infinity	5.000000			2.000000 U	0.000000	2.000000	0.000000	0.000000
3	STOP	Standard	measured beam size	Infinity	5.000000			1.000000 U	0.000000	1.000000	0.000000	0.000000
4	(aper)	Standard	lens front	80.967280 V	3.000000	BK7		5.000000 U	0.000000	5.000000	0.000000	-
5	(aper)	Standard	lens back	-39.897766 V	87.000000 T			5.000000 U	0.000000	5.000000	0.000000	0.000000
6	IMAGE	Standard		Infinity	-			8.854055E-04	0.000000	8.854055E-04	0.000000	0.000000

	Type	Surf	Wave	UseX	W0	S1toW	M2 Factor		Target	Weight	Value	% Contrib
1	GBPS	6	1	0	0.012500	0.000000	1.000000		0.000000	1.000000	0.009369	100.000000

The Paraxial Gaussian Beam analysis is an interactive feature that works as a "calculator" to quickly computes Gaussian beam characteristics, allowing you to enter both ideal and mixed mode (M2>1) Gaussian beam and displays beam data as it propagates surface by surface in your optical system. The limit is that calculation of Gaussian beam parameters is based upon paraxial ray data, so the results may not be accurate for systems with large aberrations, or those cannot be described by paraxial optics, such as non-rotationally symmetric systems. This feature also ignores all apertures, and assumes the Gaussian beam propagates well within the apertures of all the lenses in the system.

This article is part of the [Tutorial Series] Modeling Laser Beam Propagation in OpticStudio free tutorial.

Previous article: How to model laser beam propagation in OpticStudio: Part 1 - Gaussian beam theory and ray-based approach
Next article: How to model laser beam propagation in OpticStudio: Part 3 - Using Physical Optics Propagation to model Gaussian beams

Associated files

Article attachments

Related articles

How to model laser beam propagation in OpticStudio: Part 3 - Using Physical Optics Propagation to model Gaussian beams

How to model laser beam propagation in OpticStudio: Part 1 - Gaussian beam theory and ray-based approach

Recently viewed articles

How to model laser beam propagation in OpticStudio: Part 1 - Gaussian beam theory and ray-based approach

[Tutorial Series] Modeling Laser Beam Propagation in OpticStudio

Using Physical Optics Propagation (POP), Part 2: Inspecting the beam intensities

How to convert FWHM measurements to 1/(e^2) halfwidths

Aspheric Surfaces - Part 1: Introduction to Aspherical Surfaces in Optical Design