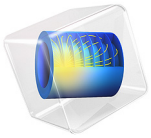

Model created in COMSOL Multiphysics 6.4

Plano-Convex Lens Orientation

Introduction

Light collimation or focusing is a basic task often needed when working with lasers in the lab where singlets are used due to their simplicity. If a plano-convex lens is used for the task, there is a correct lens orientation that minimizes aberrations. A useful rule-of-thumb is to minimize ray refraction at every surface, which can be achieved by placing the lens with the curved side facing the collimated beam.

Model Definition

This model uses two plano-convex lenses from the Part Libraries with the default options, as shown in Figure 1. Collimated beams traveling in the $+z$ direction are focused by each lens and the focusing performance is visualized using **Spot Diagram** and **Geometric Modulation Transfer Function (MTF)** plots.

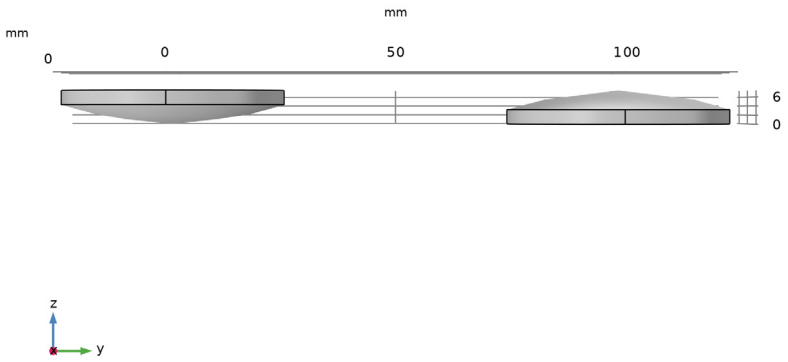

Figure 1: Two plano-convex lenses with different orientations.

Results and Discussion

The configuration where the convex side is facing the collimated beam provides the tightest focus, as qualitatively shown in Figure 2. The spot diagram and the geometric

modulation transfer function — shown in Figure 3 and Figure 4, respectively — provide a more quantitative measure.

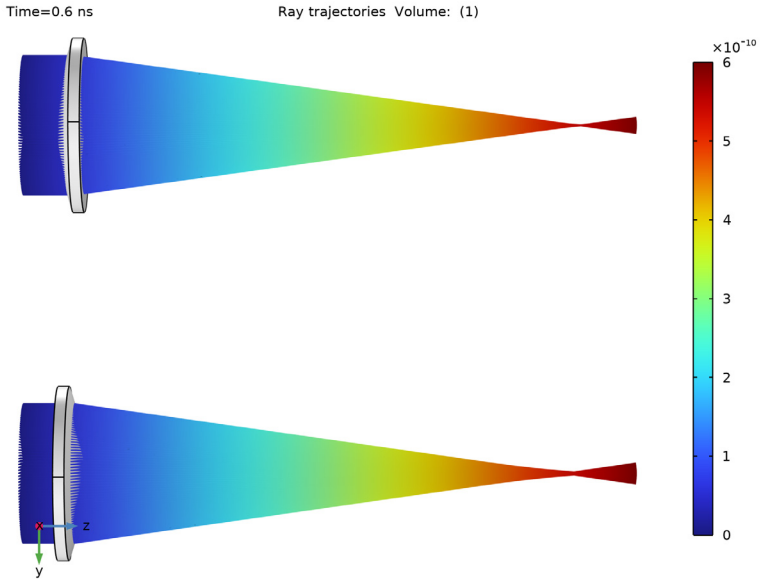

Figure 2: Ray trajectories plot shows convex side facing collimated beam focuses the beam more tightly.

Computing the geometric MTF requires multiple steps that are automatically set up but can be modified. An **Intersection Point 3D** dataset is created for the **Spot Diagram**. A line spread function is estimated from the **Intersection Point 3D** dataset by using an **Evaluation Group** for each release feature, which is then fed into **Kernel Density Estimation (KDE)** datasets. Each **Kernel Density Estimation (KDE)** dataset is subsequently fed into **Spatial FFT** datasets. Finally, **Spatial FFT** datasets are used to create a **Line Graph** for each release feature, resulting in the plot shown in Figure 4.

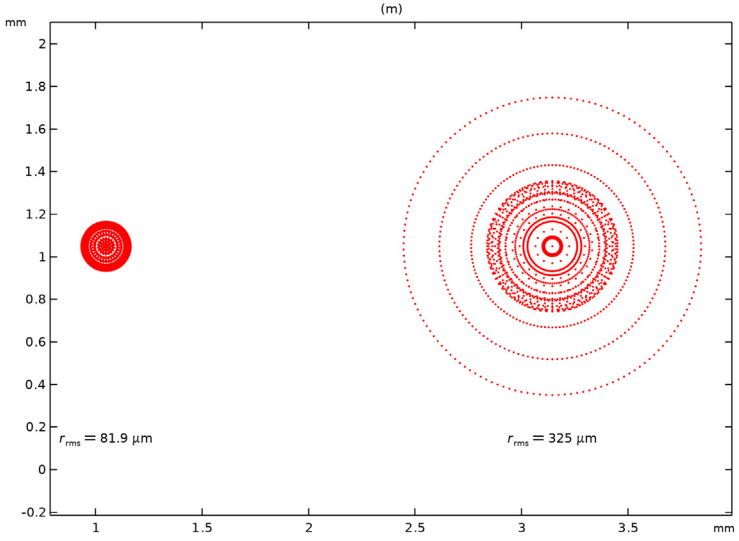

Figure 3: Spot diagram shows roughly four times difference in the spot size.

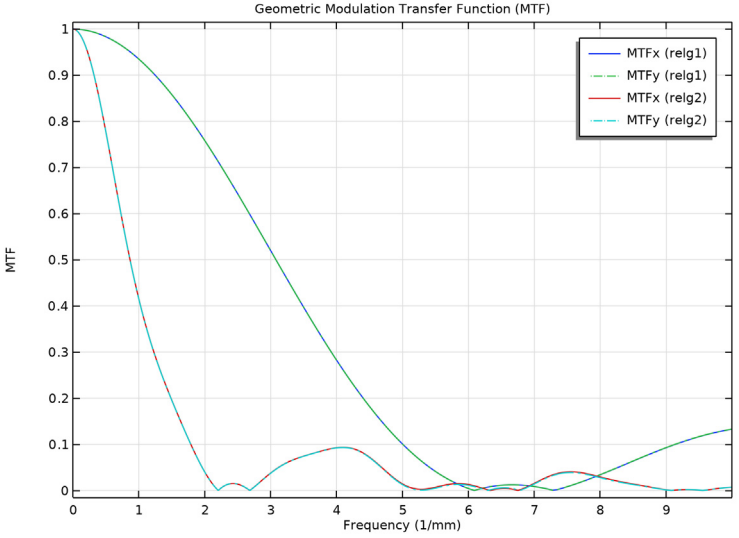

Figure 4: Geometric modulation transfer function (MTF).

Application Library path: `Ray_Optics_Module/Lenses_Cameras_and_Telescopes/planoconvex_lens_orientation`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **Optics** > **Ray Optics** > **Geometrical Optics (gop)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces** > **Ray Tracing**.

6 Click **Done**.

GEOMETRY 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.

2 In the **Settings** window for **Geometry**, locate the **Units** section.

3 From the **Length unit** list, choose **mm**.

PART LIBRARIES

1 In the **Geometry** toolbar, click **Part Libraries**.

2 In the **Part Libraries** window, select **Ray Optics Module** > **3D** > **Spherical Lenses** > **spherical_plano_convex_lens_3d** in the tree.

3 Click **Add to Geometry**.

4 In the **Select Part Variant** dialog, select **Specify effective focal length and center thickness** in the **Select part variant** list.

5 Click **OK**.

GEOMETRY 1

Spherical Plano-Convex Lens 3D 2 (pi2)

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometry 1** right-click **Spherical Plano-Convex Lens 3D 1 (pi1)** and choose **Duplicate**.

2 In the **Settings** window for **Part Instance**, locate the **Input Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
niz	-1	-1	Local optical axis, z-component

4 Locate the **Position and Orientation of Output** section. Find the **Displacement** subsection. In the **ywi** text field, type `100[mm]`.

5 In the **zwi** text field, type `7.5[mm]`.

6 Click **Build All Objects**.

7 Click the **Go to YZ View** button in the **Graphics** toolbar. Compare the geometry to Figure 1.

MATERIALS

Material 1 (mat1)

1 In the **Materials** toolbar, click **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Material Contents** section.

3 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Refractive index, real part	n_iso ; nii = n_iso, nij = 0	1.5	1	Refractive index

GEOMETRICAL OPTICS (GOP)

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometrical Optics (gop)**.

2 In the **Settings** window for **Geometrical Optics**, locate the **Ray Release and Propagation** section.

3 In the **Maximum number of secondary rays** text field, type `0`.

4 Locate the **Results** section. From the **Results** list, choose **Plot spot diagram and geometric MTF**.

Material Discontinuity 1

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometrical Optics (gop)** click **Material Discontinuity 1**.

2 In the **Settings** window for **Material Discontinuity**, locate the **Rays to Release** section.

3 From the **Release reflected rays** list, choose **Never**.

Release from Grid 1

1 In the **Physics** toolbar, click **Global** and choose **Release from Grid**.

2 In the **Settings** window for **Release from Grid**, locate the **Initial Coordinates** section.

3 From the **Grid type** list, choose **Hexapolar**.

4 Specify the $\mathbf{q}_c$ vector as

0	x
0	y
-10[mm]	z

5 Specify the $\mathbf{r}_c$ vector as

0	x
0	y
1	z

6 In the R_c text field, type `20[mm]`.

7 In the N_c text field, type `25`.

8 Locate the **Ray Direction Vector** section. Specify the $\mathbf{L}_0$ vector as

0	x
0	y
1	z

Release from Grid 2

1 Right-click **Release from Grid 1** and choose **Duplicate**.

2 In the **Settings** window for **Release from Grid**, locate the **Initial Coordinates** section.

3 Specify the $\mathbf{q}_c$ vector as

0	x

100[mm]	y
-10[mm]	z

MESH 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.

2 In the **Settings** window for **Mesh**, locate the **Physics-Controlled Mesh** section.

3 From the **Element size** list, choose **Coarser**.

4 Click **Build All**.

STUDY 1

Step 1: Ray Tracing

1 In the **Model Builder** window, under **Study 1** click **Step 1: Ray Tracing**.

2 In the **Settings** window for **Ray Tracing**, locate the **Study Settings** section.

3 In the **Output times** text field, type `range(0,0.01,0.6)`.

4 In the **Study** toolbar, click **Compute**.

RESULTS

Volume 1

In the **Ray Trajectories (gop)** toolbar, click **Volume**.

Material Appearance 1

1 In the **Ray Trajectories (gop)** toolbar, click **Material Appearance**.

2 Click the **Show Grid** button in the **Graphics** toolbar.

3 Click the **Rotate Right 90°** button in the **Graphics** toolbar.

4 Click the **Zoom Extents** button in the **Graphics** toolbar. The ray trajectories should look like Figure 2.

5 Click the **Go to Default View** button in the **Graphics** toolbar.

Intersection Point 3D 1

1 In the **Model Builder** window, expand the **Results** > **Datasets** node, then click **Intersection Point 3D 1**.

2 In the **Settings** window for **Intersection Point 3D**, locate the **Surface** section.

3 Find the **Point** subsection. In the **x** text field, type `0`.

4 In the **y** text field, type `0`.

5 In the **z** text field, type `150[mm]`.

Spot Diagram

1 In the **Model Builder** window, under **Results** click **Spot Diagram**.

2 In the **Spot Diagram** toolbar, click **Plot**.

3 Click the **Zoom Extents** button in the **Graphics** toolbar. The spot diagram should look like Figure 3.

LSF Data (relg1)

1 In the **Model Builder** window, click **LSF Data (relg1)**.

2 In the **LSF Data (relg1)** toolbar, click **Evaluate**.

LSF Data (relg2)

1 In the **Model Builder** window, click **LSF Data (relg2)**.

2 In the **LSF Data (relg2)** toolbar, click **Evaluate**.

Geometric MTF

1 In the **Model Builder** window, click **Geometric MTF**.

2 In the **Settings** window for **1D Plot Group**, locate the **Axis** section.

3 Select the **Manual axis limits** checkbox.

4 In the **x minimum** text field, type 0.

5 In the **x maximum** text field, type 10.

MTFy (relg1)

1 In the **Model Builder** window, expand the **Geometric MTF** node, then click **MTFy (relg1)**.

2 In the **Settings** window for **Line Graph**, click to expand the **Coloring and Style** section.

3 Find the **Line style** subsection. From the **Line** list, choose **Dash-dot**.

MTFy (relg2)

1 In the **Model Builder** window, click **MTFy (relg2)**.

2 In the **Settings** window for **Line Graph**, click to expand the **Coloring and Style** section.

3 Find the **Line style** subsection. From the **Line** list, choose **Dash-dot**.

4 In the **Geometric MTF** toolbar, click **Plot**. The MTF plot should look like Figure 4.