How to Model an Off-Axis Parabolic Mirror

Summary:

This article demonstrates:

- How to model an off-axis parabolic mirror according to the manufacturer's specifications.
- How to center the image surface on the chief ray using the chief-ray solve.

The ZIP archive containing the sample file can be downloaded from the top of the article.

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Sample File:

Article Attachment (/ZMXLLC/media/Knowledge-Base/Attachments/10002_OAP.zip)

Applies to:

3D Geometries
OpticStudio
Sequential Ray Tracing

Article:

Introduction

An off-axis parabolic mirror has the advantage of not having to obscure the input beam to access the image plane. OpticStudio can easily model any off-axis portion of a surface, parabolic or not. This tutorial will show you how to model an off-axis parabolic mirror. The concept shown here applies to any decentered surface and is not limited to off-axis parabolic mirrors.

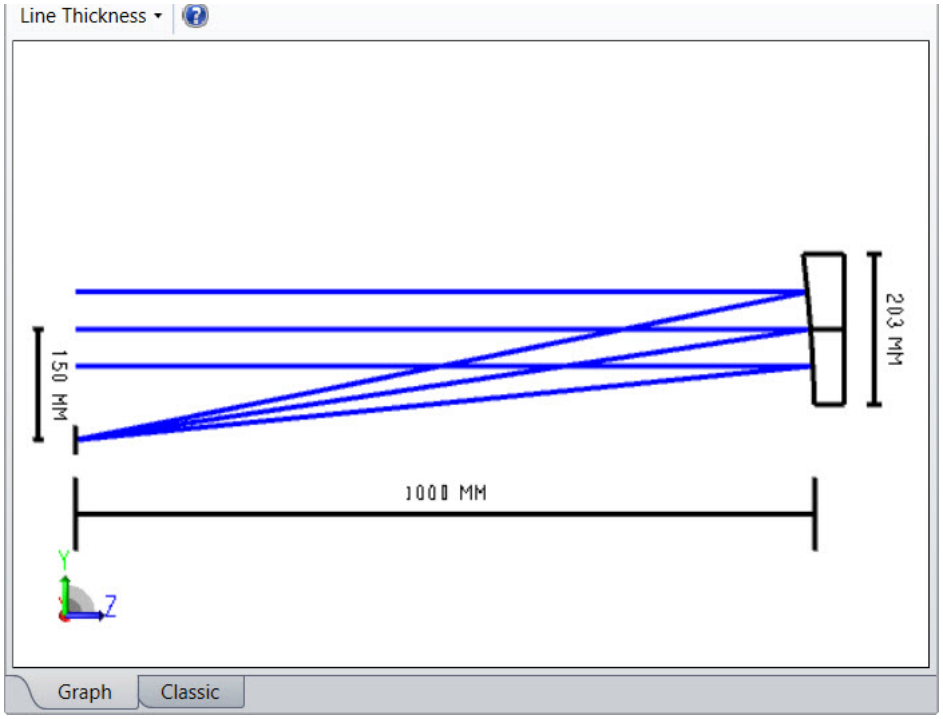
We will model a commercially-available (http://www.optisurf.com/frame5.htm) off-axis parabolic mirror. The goal of this exercise is to be able to tilt the mirror about the X axis at any point along the optical axis (Z axis). The specifications for the mirror, taken from the manufacturer's web site, are as following:

Off-axis distance = 150 mm

Focal length = 1000 mm

Component physical diameter = 203 mm

Back surface of the substrate is perpendicular to the optical axis



If you are not sure about any of the procedures used in this tutorial, please refer to the following articles first.

Designing A Singlet in Zemax (/support/knowledgebase/How-To-Design-a-Singlet-Lens)

How to Tilt and Decenter a Sequential Optical Component (/support/knowledgebase/How-to-Tilt-and-Decenter-a-Sequential-Optical-Comp)

Entering the Basic Geometry

Set the following system parameters:

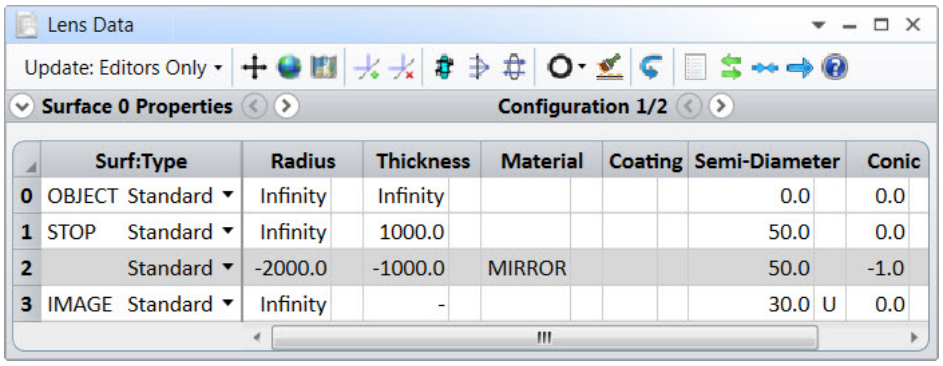
Lens units to mm (System Explorer > Units)

Wavelength of 0.550um (System Explorer > Wavelengths)

Set one field with values X=0 and Y=0 (System Explorer > Fields).

Set the system aperture as Entrance Pupil Diameter of 100 mm (System Explorer > Aperture).

Enter the following surfaces in the Lens Data Editor. The Image surface has a user-defined semi-diameter of 30 mm (U next to the column).



	Surf:Type	Radius	Thickness	Material	Coating	Semi-Diameter		Conic
0	OBJECT Standard	Infinity	Infinity			0.0		0.0
1	STOP Standard	Infinity	1000.0			50.0		0.0
2	Standard	-2000.0	-1000.0	MIRROR		50.0		-1.0
3	IMAGE Standard	Infinity	-			30.0	U	0.0

The "sag" or z-coordinate of the Standard surface is given by:

$$z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + \alpha_1 r^2 + \alpha_2 r^4 + \alpha_3 r^6 + \alpha_4 r^8 + \alpha_5 r^{10} + \alpha_6 r^{12} + \alpha_7 r^{14} + \alpha_8 r^{16}$$

where $r^2 = x^2 + y^2$, c is the curvature, k is the conic constant, and α_1 through α_8 are the coefficients of the 4th, 6th, 8th, 10th, 12th, 14th, 16th, and 18th order terms.

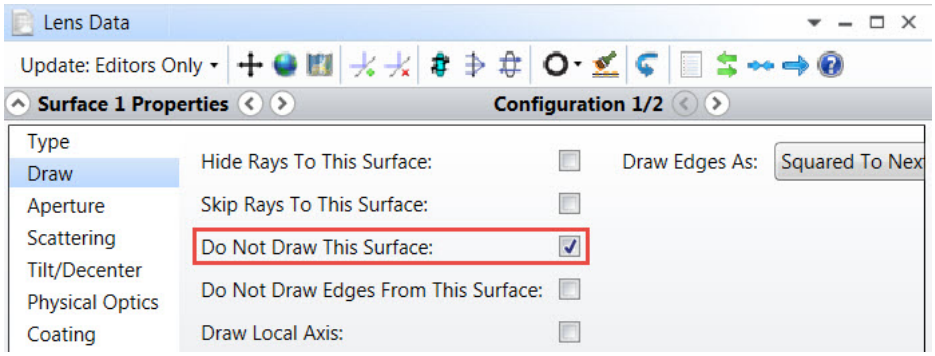
$$z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}}$$

where ***c*** is the curvature (the reciprocal of the radius), ***r*** is the radial coordinate in lens units and ***k*** is the conic constant. The conic constant is less than -1 for hyperbolas, -1 for parabolas, between -1 and 0 for ellipses, 0 for spheres, and greater than 0 for oblate ellipsoids. To make the mirror surface parabolic, enter a conic constant of -1.

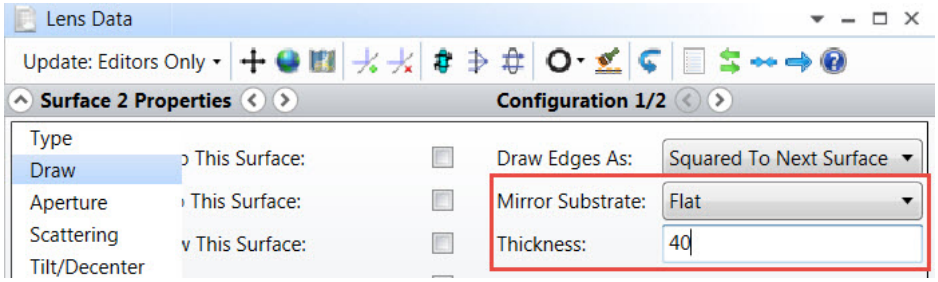
Since the focal length of a mirror is half the radius of curvature, enter -2000 mm in the Radius column. The sign of the radius of curvature is negative since the center of curvature is to the left (toward -Z axis) of the mirror.

Since surface 1 and the image surface are co-located, we will choose not to draw surface 1 in the layout so that we can see only the image surface at that location.

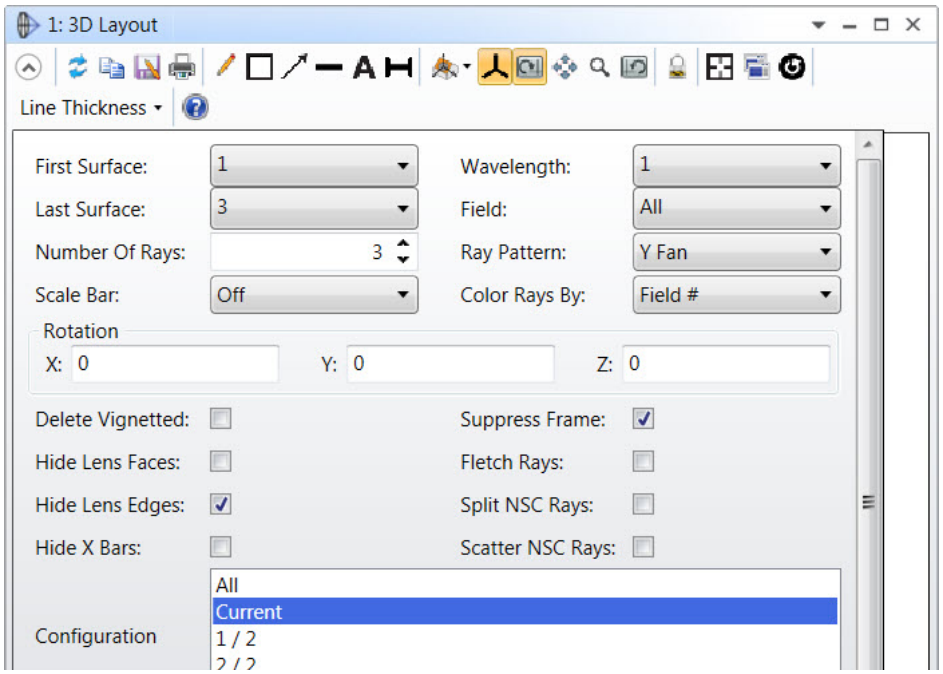
Set the following property in the Surface Properties dialog.

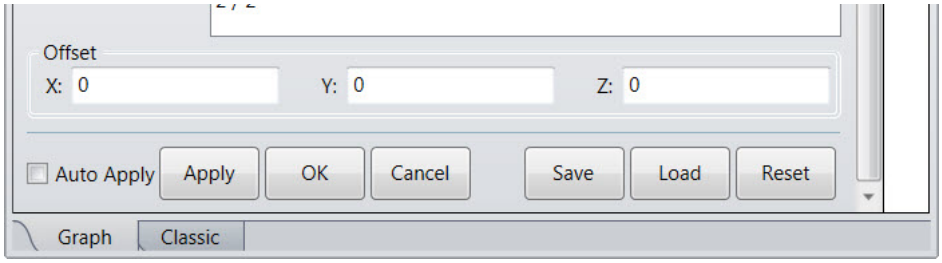


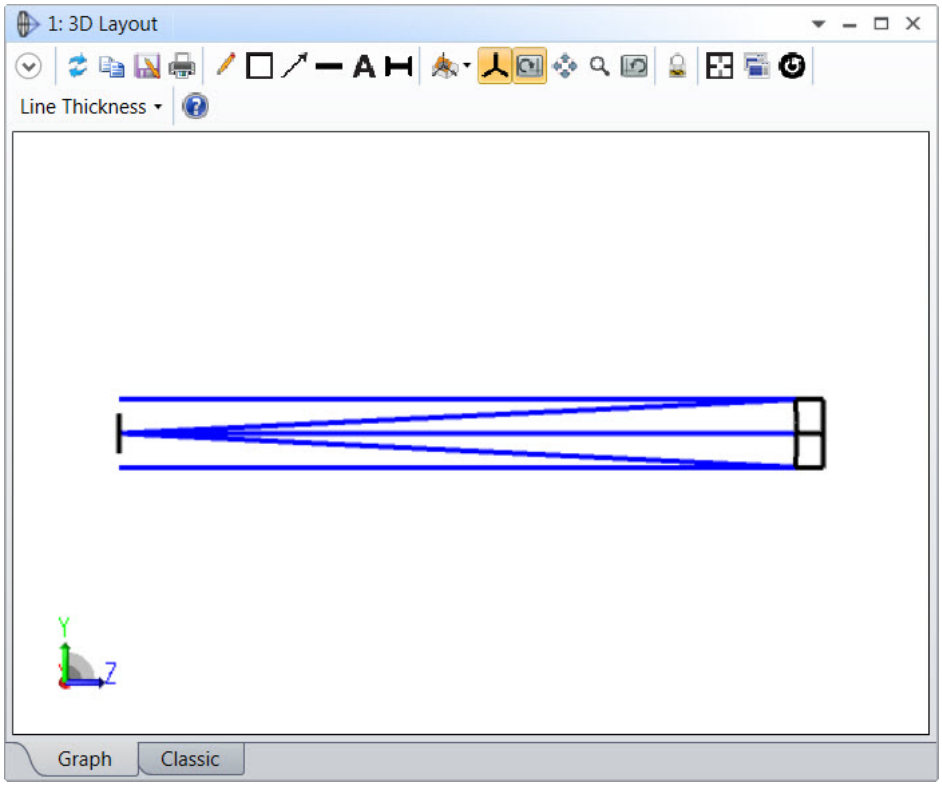
To make the mirror substrate flat and orthogonal to the optical axis, choose the following options in the Surface Properties dialog. We will chose the thickness of 40 mm since the manufacturer does not specify the substrate thickness on their website.



Open the 3D Layout with the following settings.

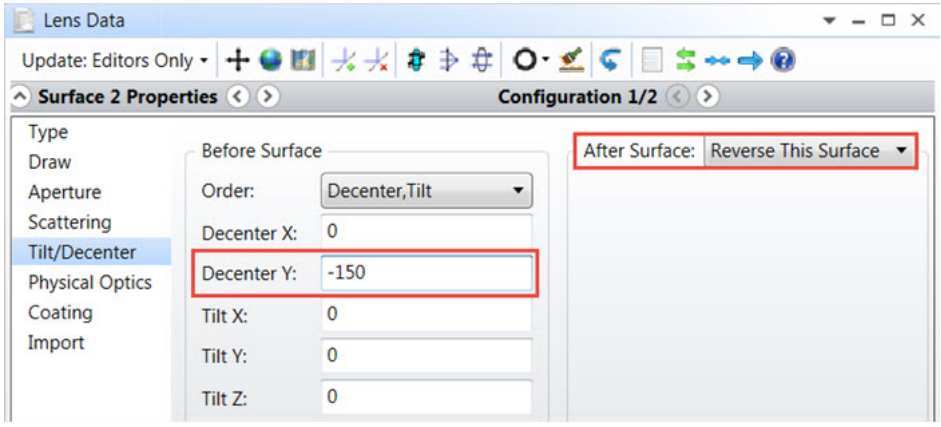




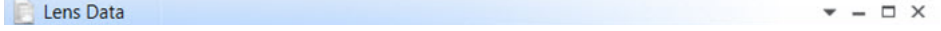


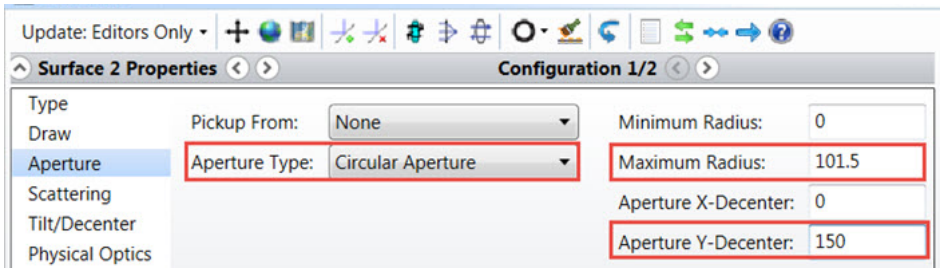
Add the Off-Axis Distance

Specify a Y-decenter of -150 mm in the Surface Properties for surface 2.

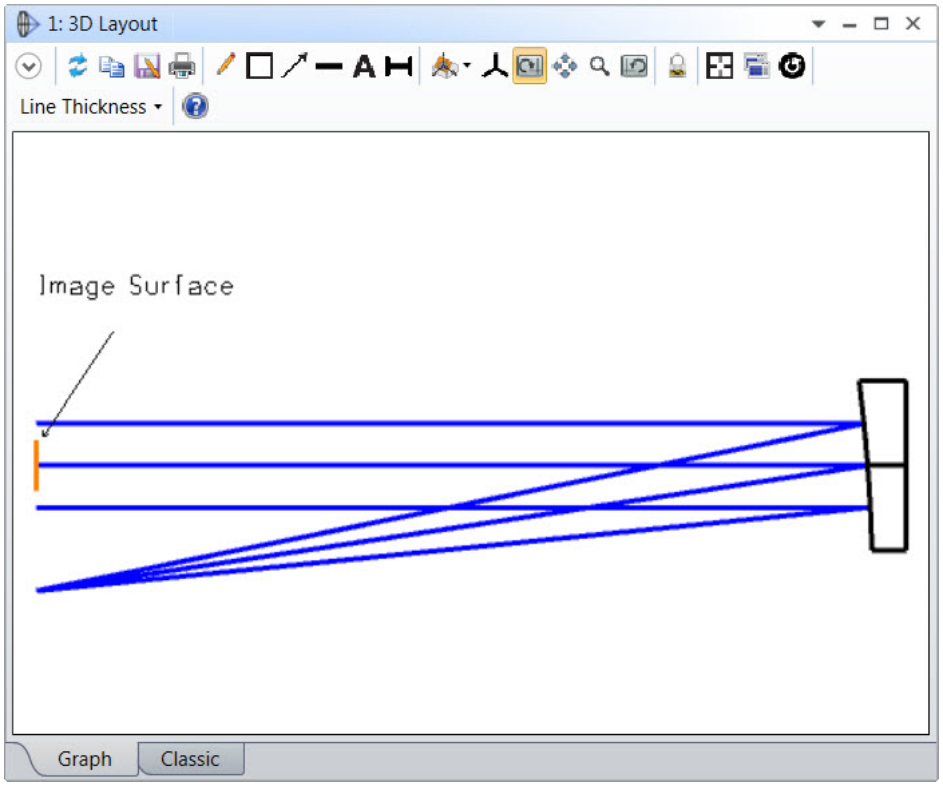


From the manufacturer's specification, the off-axis distance is 150 mm and the physical diameter of the mirror is 203 mm. Specify the correct aperture size and location.

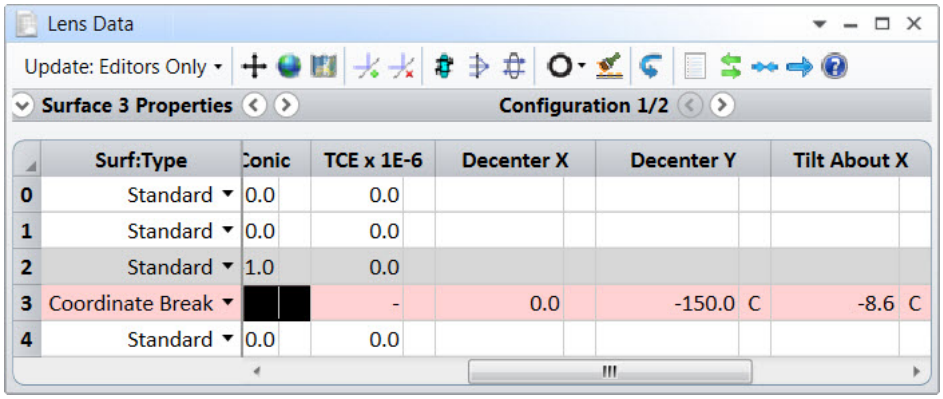


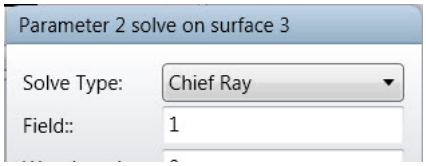


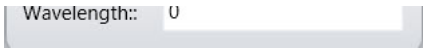
Open the 3D Layout.



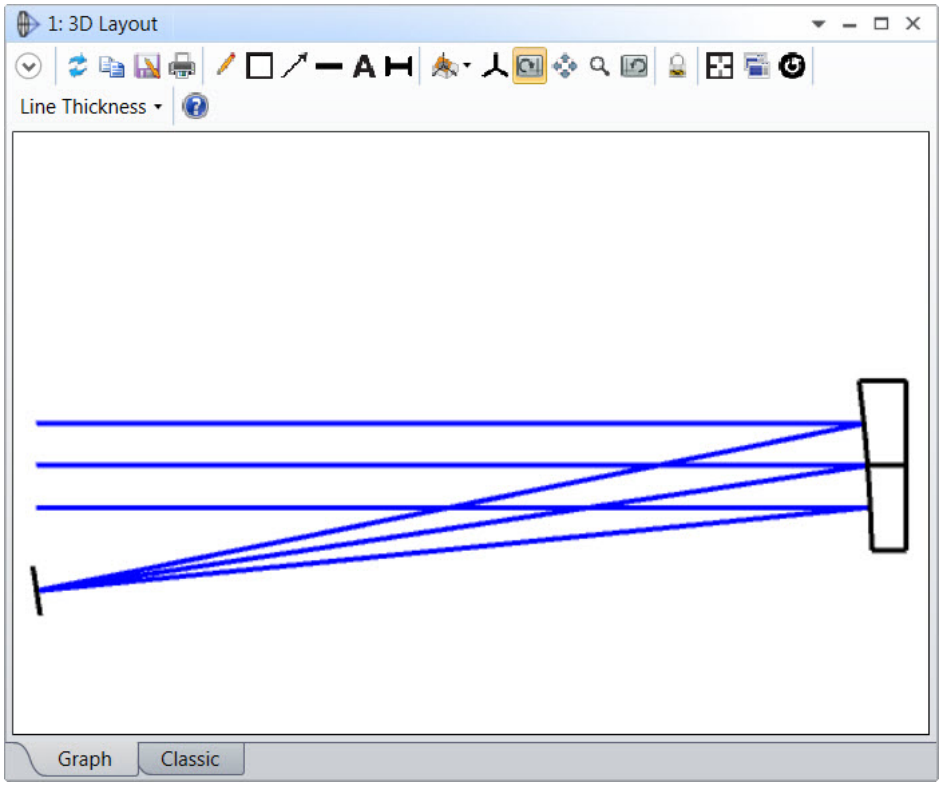
Note that the rays are moving away from the coordinate system. In order to center the image surface and make it orthogonal to the chief ray, insert a Coordinate Break surface before the image surface and place a Chief Ray solve on the Y-decenter and the X-tilt parameters. OpticStudio will automatically calculate the amount of decenter and tilt needed to make the chief ray hit at the center of this surface at normal incidence.







Update the layout.



Perfect!

Summary and References

This article has demonstrated how to model an off-axis parabolic mirror in sequential mode of OpticStudio. In summary:

- Surface and aperture decenters can be specified in the Surface Properties dialog.
- The Chief Ray solve can automatically center the coordinate system to the chief ray.