Taking APEX for a Test Drive

This technical publication describes fundamental concepts of the workflow in APEX® from Breault Research Organization (BRO). These concepts are given in the form of an example project or "test drive" to facilitate your introduction to APEX.

BRO's APEX is an optical engineering application add-in for the industry-standard SolidWorks® 3D-modeling environment. The time-proven Advanced Systems Analysis Program (ASAP®), a non-sequential ray-tracing engine, is at the core of the APEX add-in.

Before beginning the test drive, both SolidWorks® and the APEX add-in to SolidWorks must be installed on your computer.

NOTE ***You can verify that APEX is installed when SolidWorks is launched by clicking*** **Tools, Add-Ins.** ***APEX should be listed and checked on the Add-Ins dialog box.***

The technical publication, "APEX Installation Guide" provides instructions, and is available on the Knowledge Base: http://www.breault.com/k-base.php?kbaseID=272&catID=63.

FOUR-STEP WORKFLOW

APEX is used for the design and analysis of optical and illumination systems according to a simple, easy-to-follow workflow:

- "Step 1: Design and Verify the Geometry"
- "Step 2: Design and Verify the Sources"
- "Step 3: Trace the Rays"
- "Step 4: Perform the Analysis"

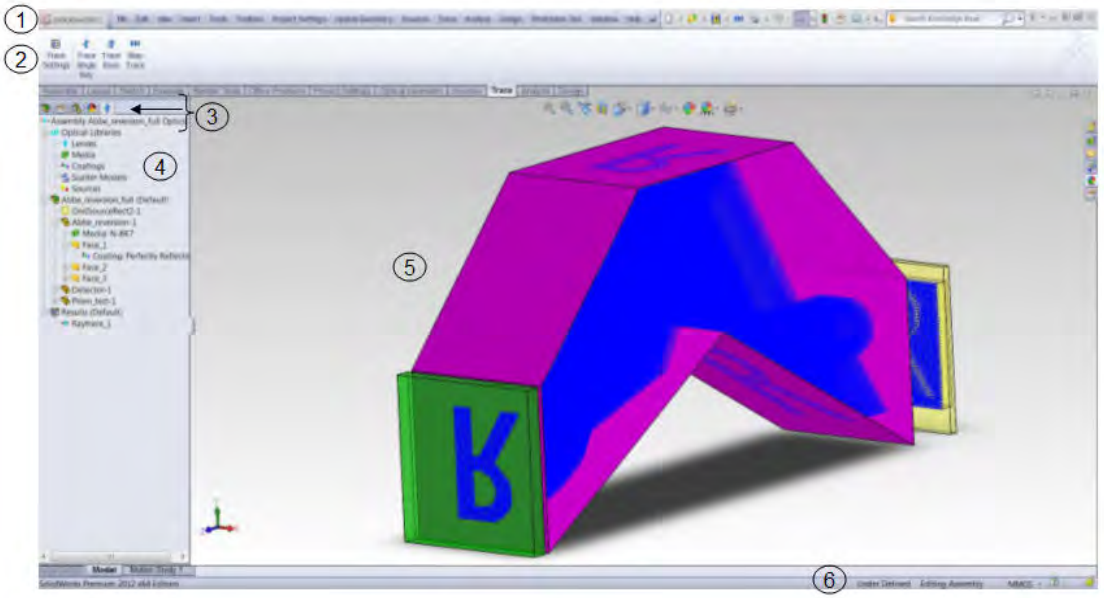
This test drive demonstrates the workflow in APEX for a reflector and an LED system.

Acknowledgments:

FOUR-STEP WORKFLOW

APEX UI

To familiarize you with the APEX user interface (UI), an annotated example of the window is shown in Figure 1. It highlights the main aspects of the UI, which are referenced throughout the Test Drive. The four-step workflow, described in "Four-step workflow" on page 1, is evident in the UI.



1 menu bar
2 CommandManager
3 APEX Optics Manager tab
4 APEX Optics Manager tree
5 graphics area
6 status bar

Figure 1 Annotated APEX window with a system in the graphics area

APEX HELP

APEX Help provides both conceptual and task-oriented content about APEX. To view Help, click Help on the SolidWorks main menu, scroll down to the APEX section, and click **APEX Help**. The Help section, *Introduction to APEX*, describes key concepts and overviews of the four-step APEX workflow and the Optics Manager. Other sections include topics that describe features as they fit in each step of the workflow.

When you see a question mark or the Help button in a specific area of the APEX user interface, click it to open the related Help topic, which gives step-by-step instructions. Links to other related topics are included.

DESIGN FORM

Figure 2 shows the design form, a radiometrically and geometrically accurate model of an LED from BRO Light Source Wizard, which is included with APEX. The light source is positioned inside a parabolic reflector. During the test drive, the output illumination is analyzed on the target surface to the right of the reflector.

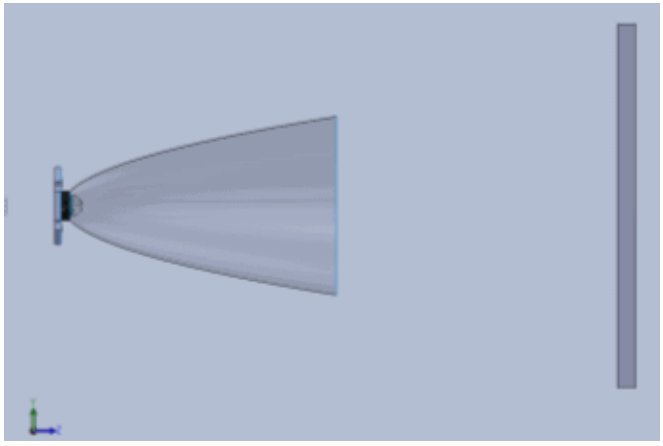


Figure 2 A reflector and LED system designed in APEX, as shown in the graphics area

GETTING STARTED

1. Create a folder on the desktop (or other suitable location) to store your working files, and name it TestDrive.
2. Start SolidWorks from your desktop by double-clicking the SolidWorks icon  .

The SolidWorks window initially launches, as shown in Figure 3.

TIP ***The figures in this test drive are representative of the UI you are viewing, and may vary in detail depending on the version of SolidWorks you are using and your operating system.***

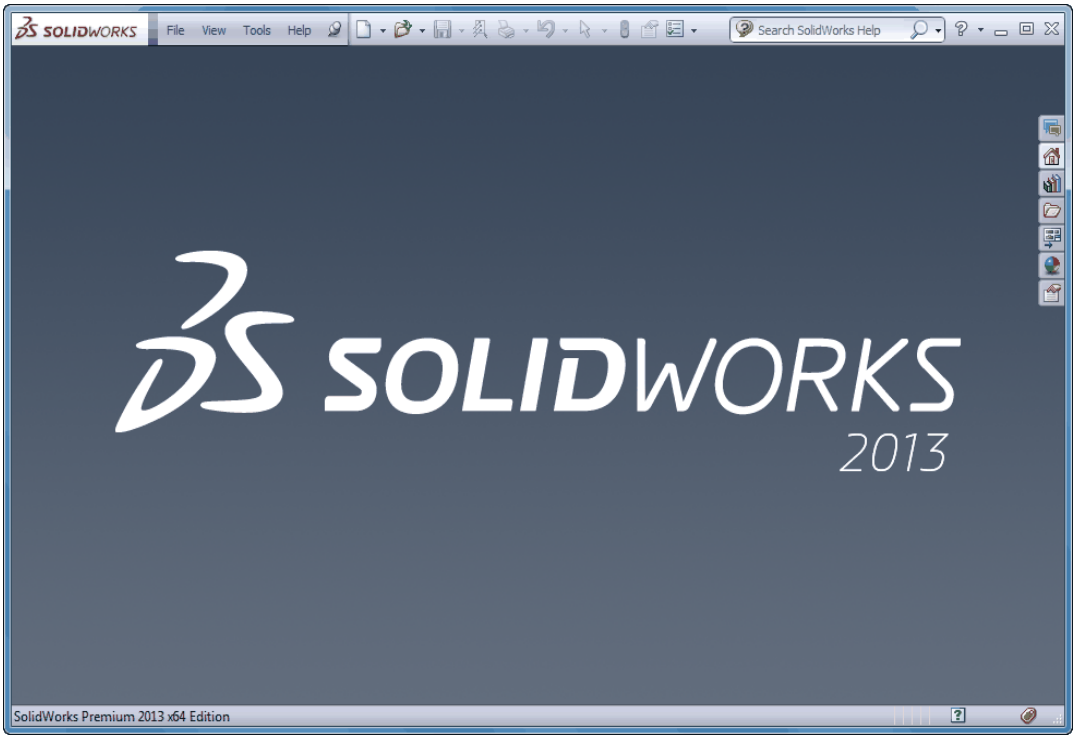


Figure 3 SolidWorks window at start-up

NOTE ***APEX opens and saves geometry data in SLDPRT or SLDASM file formats. An APEX file is a SolidWorks® assembly file, which can be made from any number of individual part or subassembly files. Additional files are used to maintain other data, such as optical property information.***

Start by generating a part file for the reflector.

3 Click the **New** icon on the menu bar to open a new file. See Figure 4.

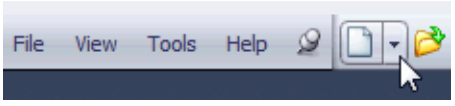


Figure 4 New document icon menu bar

4 Click the **APEX** tab on the New Document dialog box, and click a Part template in millimeter form (either ANSI or ISO). You may need to click the **Advanced** button to display a selection of

templates. The **Novice** button should be visible in the lower window. See Figure 5.

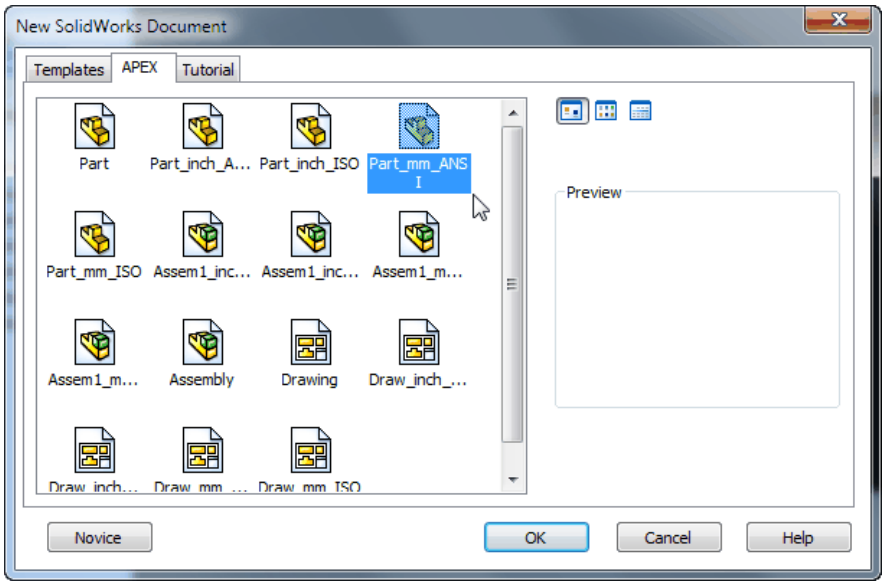


Figure 5 Selecting a Parts millimeter template for the new document type

5 Click **OK**.

SolidWorks is now in the mode of geometry creation, and you can use it to create geometry with any of the sketch features available in SolidWorks. You can also use any of the optical geometry features of APEX that are on the

Optical Geometry toolbar of the CommandManager. See Figure 6.

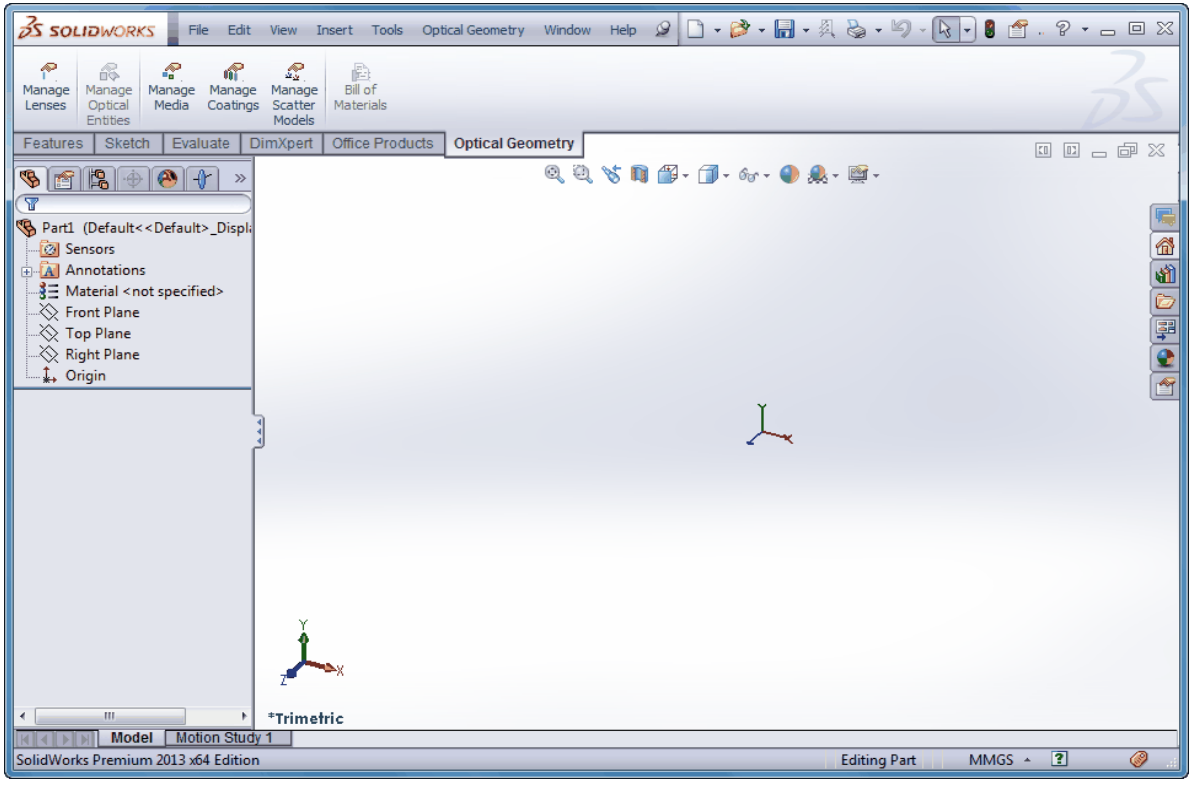


Figure 6 SolidWorks window in the mode of geometry creation

STEP 1: DESIGN AND VERIFY THE GEOMETRY

For your system, the parabola sketch tool is used to define the reflector. The reflector has a focal length of 2mm and an opening near the vertex to allow insertion of the LED. The emitting region of the LED is positioned near the focus of the parabola.

1 Click **Right Plane** on the FeatureManager to open the sketch. See Figure 7.

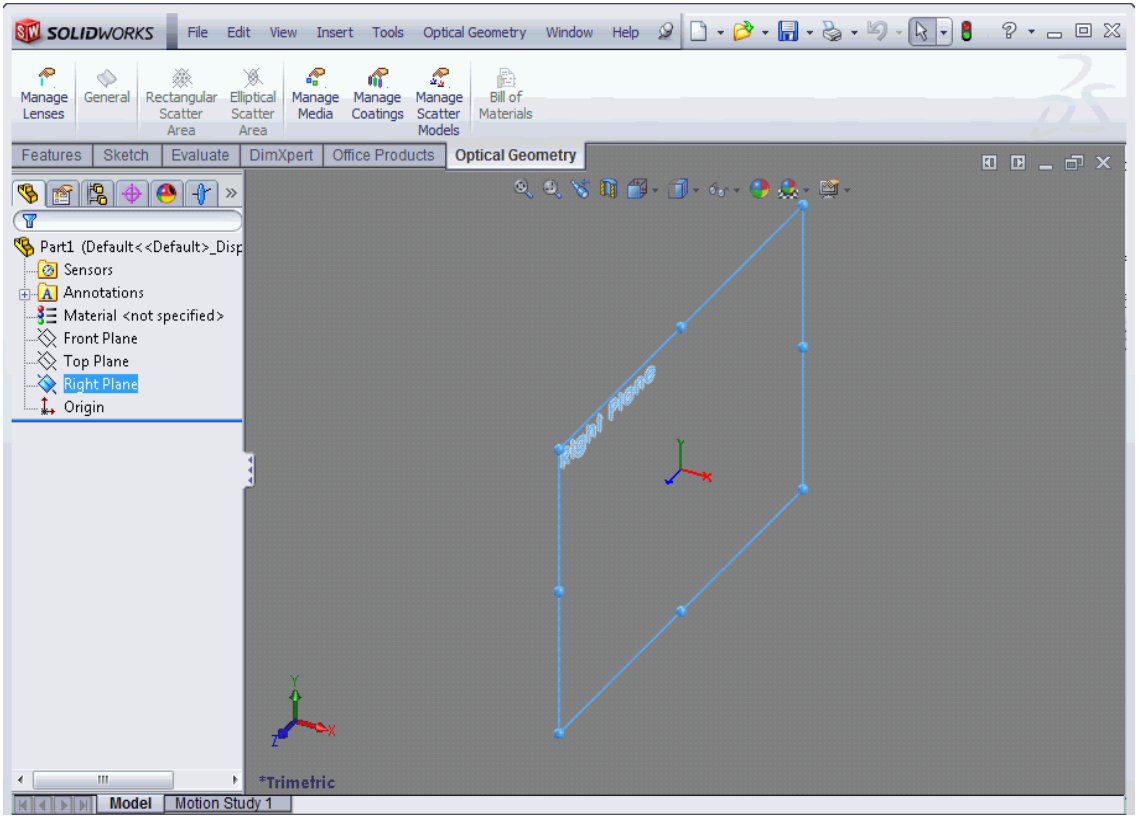


Figure 7 Opening the sketch in the right plane

STEP 1: DESIGN AND VERIFY THE GEOMETRY

2 Click the **Sketch** tab on the Command Manager, and click the **Sketch** tool. See Figure 8 and Figure 9.

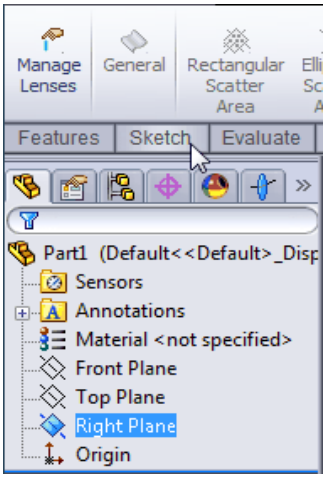


Figure 8 Clicking the Sketch tab on the Command Manager

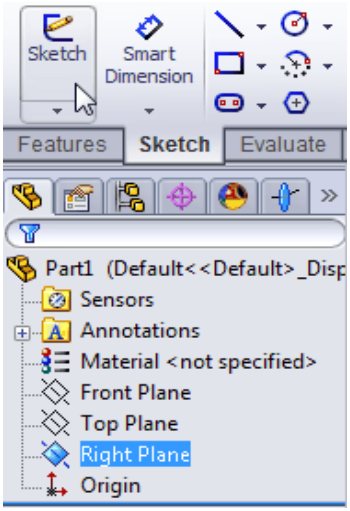


Figure 9 Clicking the Sketch tool on the Sketch toolbar (upper left)

The right plane is now aligned to the monitor view. See Figure 10.

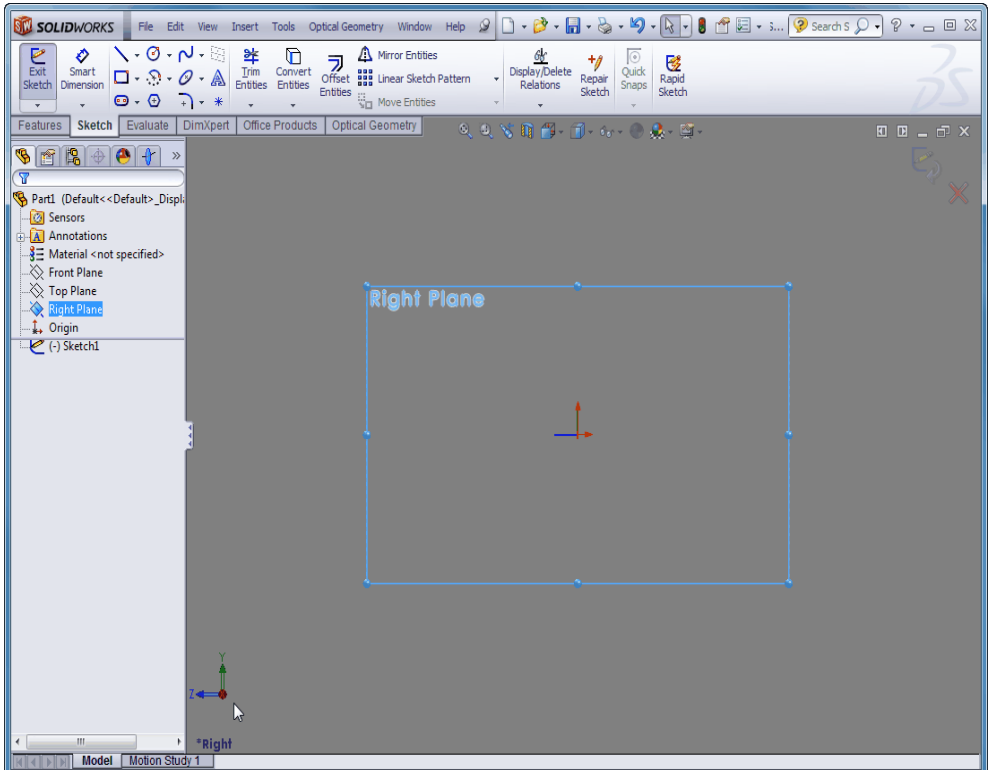


Figure 10 Aligned right plane displayed in the graphics area

3 To draw the parabola, click the down arrow next to the ellipse tool on the **Sketch** toolbar, and click **Parabola** on the menu. See Figure 11.

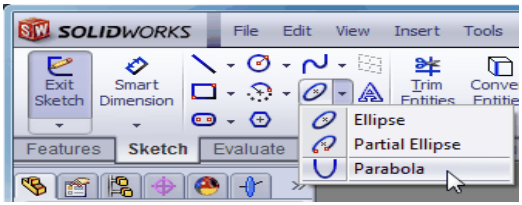


Figure 11 Preparing to draw a parabola

4 Move the cursor to a location near the origin indicator in the graphics area.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

Notice in the graphics area that the pointer icon has changed to a pencil; a parabolic curve is displayed near the pointer, indicating the shape of the sketch you will draw; and the yellow coincident icon is visible. See Figure 12.

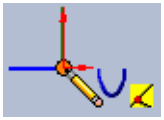


Figure 12 Pointer with pencil icon at origin

5 Click and release at the origin to fix the location of the focus at the origin.

6 Move the mouse to the right, which is in a negative Z direction as defined by the triad at the lower left corner of the graphics area.

As you move the pointer, a dashed outline of the parabolic curve is drawn. A horizontal indicator, a white box with a horizontal bar, is shown when the axis of the parabola is along the Z axis of the global coordinate system. See Figure 13.

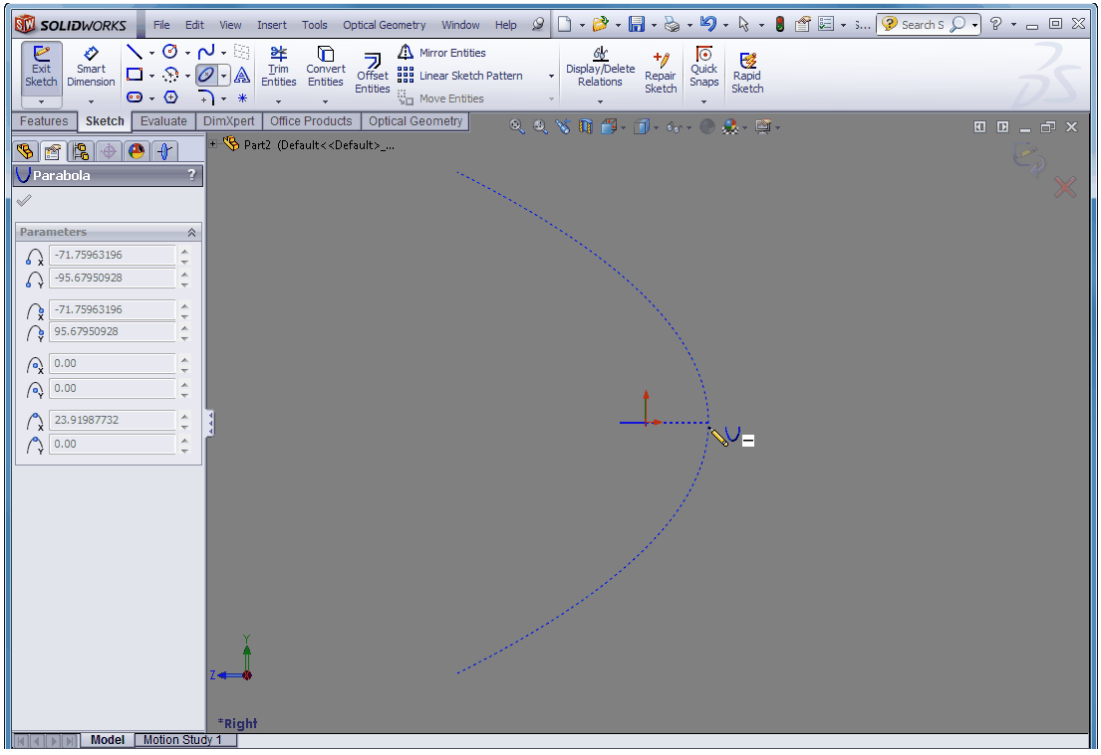


Figure 13 Outline of parabolic curve

7 Click again to fix the orientation of the parabola, and then release the pointer. The size of the parabola does not matter.

8 Position the pointer on the parabolic curve at a position above the axis.

9 Click and hold the pointer, moving it up and to the left along the dashed curve to draw out a segment of the curve.

10 Release the pointer after you have defined a curve. See Figure 14.

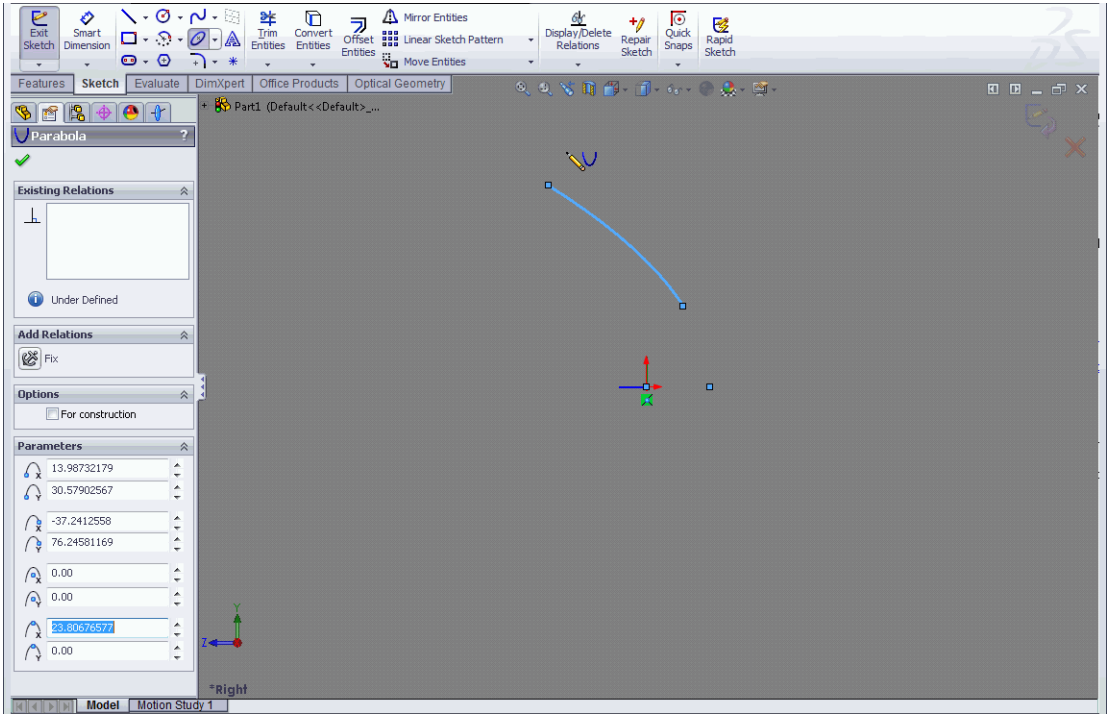


Figure 14 Defining a curve (the Parabola PropertyManager is displayed on left)

11 Click the green check mark, ✔ on the Parabola PropertyManager to accept the parabola settings and close the PropertyManager. The length of the curve does not matter; the dimensioning and relations functions of SolidWorks are used later to define the necessary surface properties.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

CONSTRAINING THE PARABOLIC GEOMETRY

To constrain the parabolic geometry for the illumination system, you first want to ensure that the vertex of the parabola is constrained on the optic (Z) axis. The opening at the input of the parabola needs to accept an LED with a base diameter of about 8mm, with the emitting area of the LED positioned at the focal point of the parabola. The total length of the reflector is 75mm. To meet these requirements, you use a pair of relations and two dimensions. The dimensions that fit these requirements are shown in Figure 15.

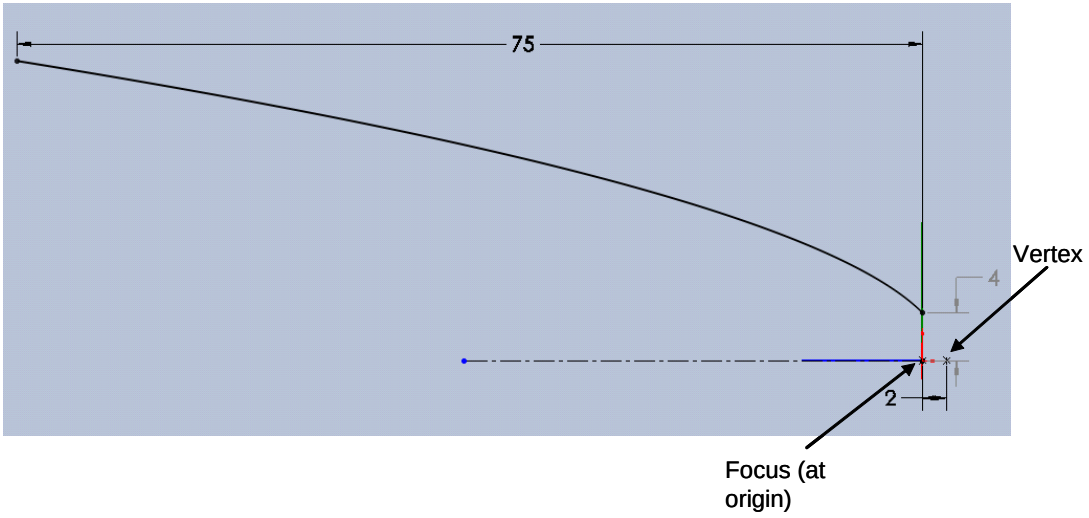


Figure 15 Dimensions of parabolic geometry

12 Click the down arrow below **Display/Delete Relations** on the **Sketch** toolbar, and select **Add Relation**. See Figure 16.

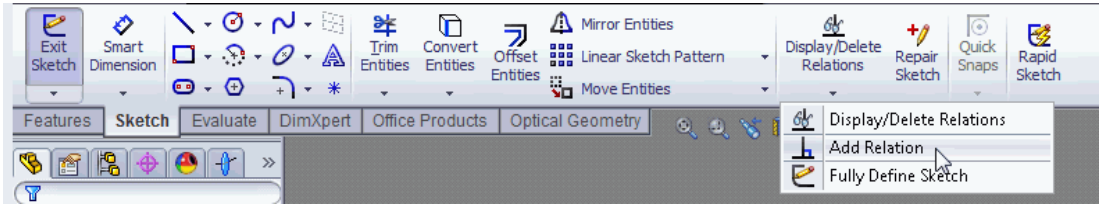


Figure 16 Add Relation on Sketch toolbar

***TIP* Since an entity number displayed in the figures may differ from the number displayed in the graphic or on your computer, the number is represented in the text of this document as [*].**

13 On the Add Relations PropertyManager under **Selected Entities**, if **Parabola[*]** is displayed, right click it, and click **Delete**. See Figure 17.

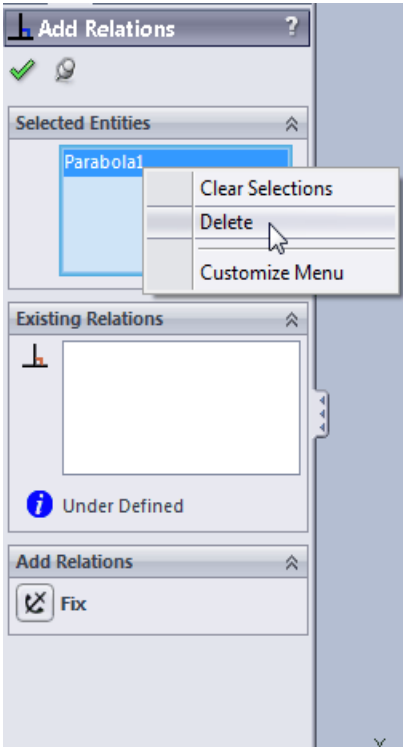


Figure 17 Deleting a relation on the Add Relations PropertyManager

14 Click two points in the graphics area: the origin and the vertex. See Figure 18.

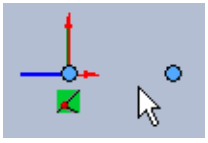


Figure 18 Click the origin and vertex

STEP 1: DESIGN AND VERIFY THE GEOMETRY

15 Click **Horizontal** on the PropertyManager, under **Add Relations**. See Figure 19.

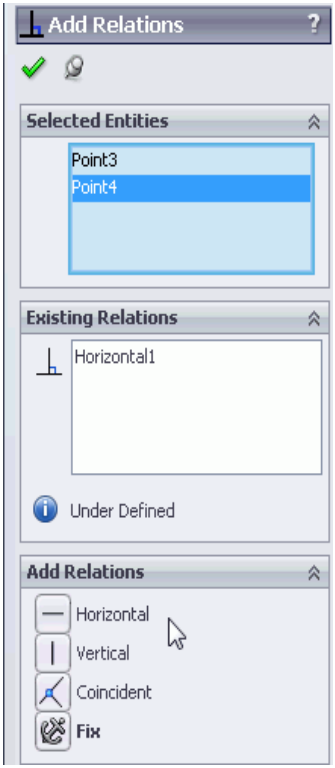


Figure 19 Adding a horizontal relation on the Add Relations PropertyManager

The first relation is indicated in the graphics area by two green boxes with horizontal bars to the left of the numeral. See Figure 20.

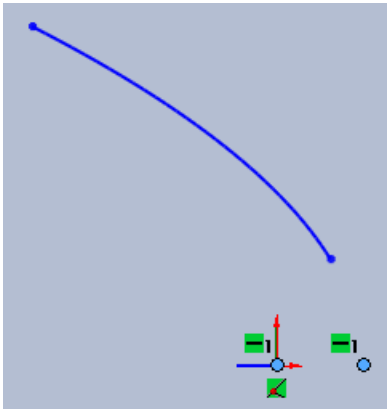


Figure 20 Two green boxes with horizontal bar indicate the first relation

16 Click ✔ on the Add Relations PropertyManager to accept the relation and close the PropertyManager.

Now it is time to constrain the reflector to begin at a point collinear with the origin (focus).

17 Open the Add Relations PropertyManager again, and delete any entries under **Selected Entities**.

18 Click the points at the origin in the graphics area and at the end of the reflector, nearest the vertex position.

19 Under **Add Relations** on the PropertyManager, click **Vertical**. See Figure 21.

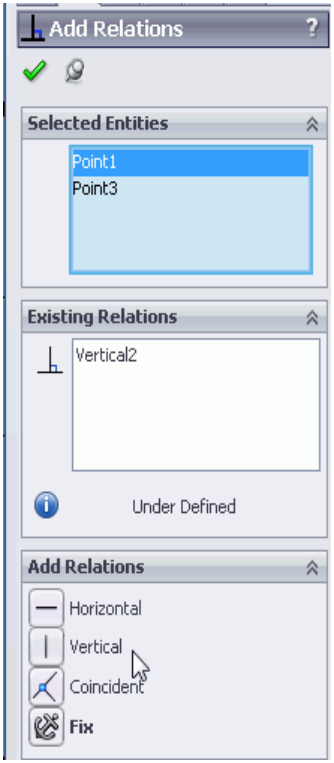


Figure 21 Adding a vertical relation on the Add Relations PropertyManager

20 The second relation is indicated in the graphics area by two green boxes, each with a vertical bar to the left of a numeral. See Figure 22.

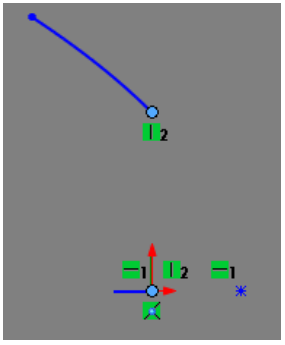


Figure 22 Green boxes with vertical bar indicate the second relation

21 Click ✔ on the PropertyManager.

Now it is time to fix the required dimensions.

22 Click 

on the **Sketch** toolbar.

As you move the pointer over the graphics area, its icon changes to a dimension tool  .

23 Click the point on the origin (parabola focus).

24 Press and hold the Shift key, and click the point to indicate the vertex location. The current length dimension is indicated in the graphic pane, which may vary from the figure. See Figure 23.

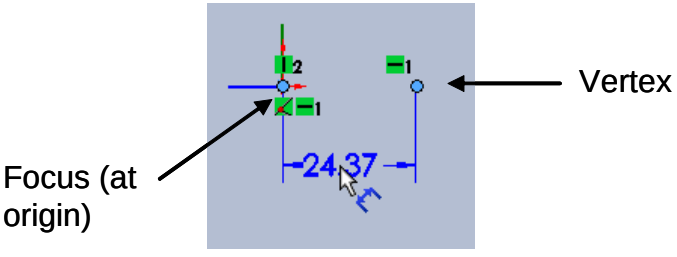


Figure 23 Vertex location

STEP 1: DESIGN AND VERIFY THE GEOMETRY

25 Slowly click and hold the pointer over the length dimension that is between the vertical lines to open the Modify dialog box. The current distance is indicated, which may vary from the figure. See Figure 24.

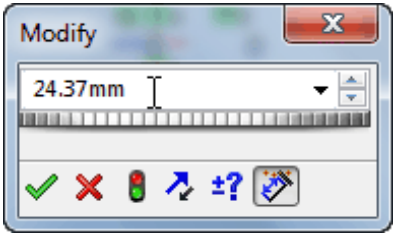


Figure 24 Length dimension shown on the Modify dialog box

26 Change the dimension to 2 on the Modify dialog box, and click on the dialog box. The dimension units were set with the original template and do not need to be re-entered. See Figure 25.

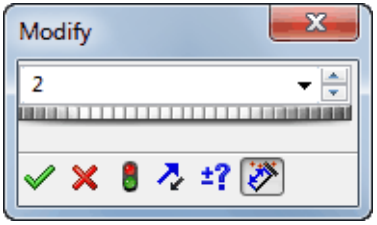


Figure 25 Changing the dimension to 2

27 Press the **F** key to expand the sketch to fill the graphics area. See Figure 26.

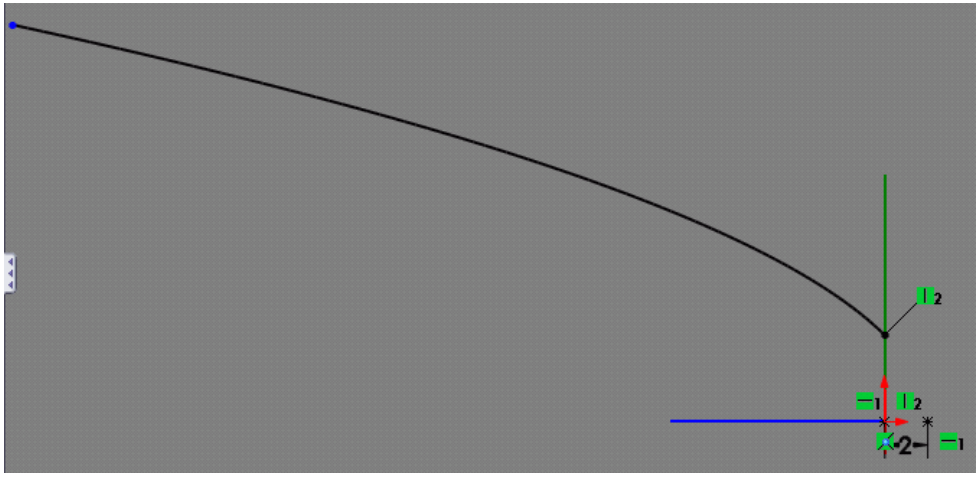


Figure 26 Expanded sketch in the graphics area

The final dimension restricts the total length of the reflector. You should still be in Dimensioning mode. To verify, look at the shape of the pointer. If necessary, click on the **Smart Dimension** tool again. Notice that clicking this tool switches dimensioning between on and off.

28 With the dimensioning pointer visible, click the two end points of the reflector.

The dimension, when measured along the axis, needs to be 75mm. By moving the pointer, several options (height, linear separation of points, and axial distance) are available. The dimension line is horizontal to the Z

axis. See Figure 27.

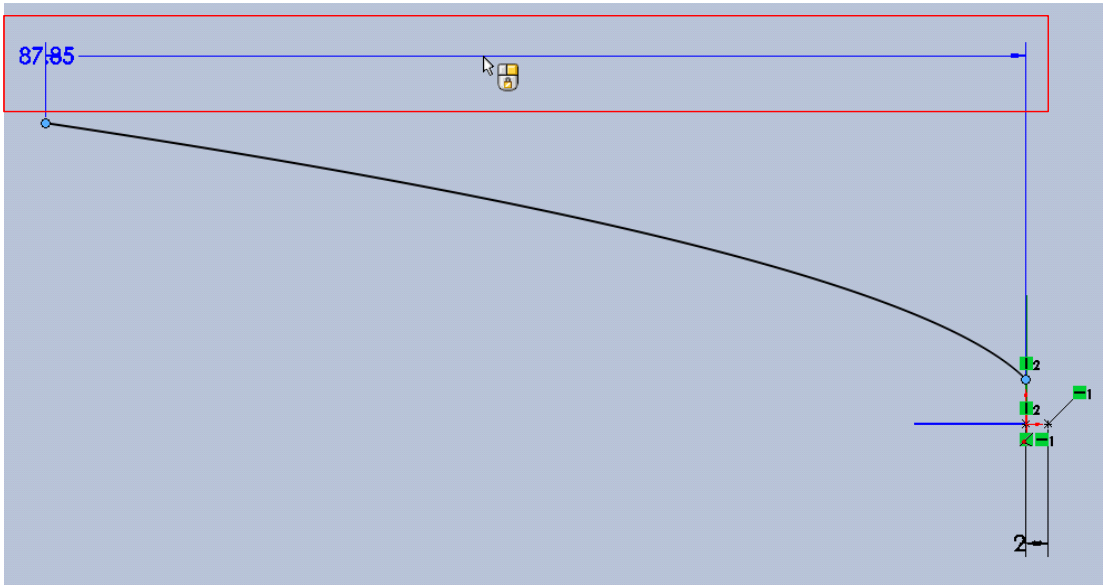


Figure 27 Axial length prior to modifying

29 Double-click the measure of axial length and change it to 75mm on the Modify dialog box, and click ✔ to close it. See Figure 28.

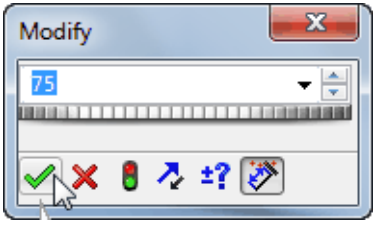


Figure 28 Changing the length dimension to 75 on the Modify dialog box

30 Click ✔ in the Dimensions Property Manager to exit dimensioning mode.

TIP ***The color of the sketch lines in the graphics area has changed to black, indicating that the sketch is "fully defined"; that is, fully constrained in size and position, and is easier to modify in a predictable manner.***

Creating a full surface of the reflector

The curve will be revolved around the Z axis to create the full surface of the reflector. A reference line is used to define the axis of revolution. On the **Sketch** toolbar, click the **Line** tool and click **Centerline** on the menu.

The pointer now displays an icon with a line form next to a pencil,  .

1. Position the pointer over the origin, and notice the yellow coincidence indicator,  .
2. Click and release the pointer.
3. Move the pointer a short distance along the Z axis (horizontal) to the left (the total length does not matter).

The angle indication seen along the line should be 0 degrees, and a horizontal indicator should be displayed near the pointer.

4. Click the pointer to finish the line segment.

5 Right-click the graphics area, and click **Select** to close the Line tool. See Figure 29.

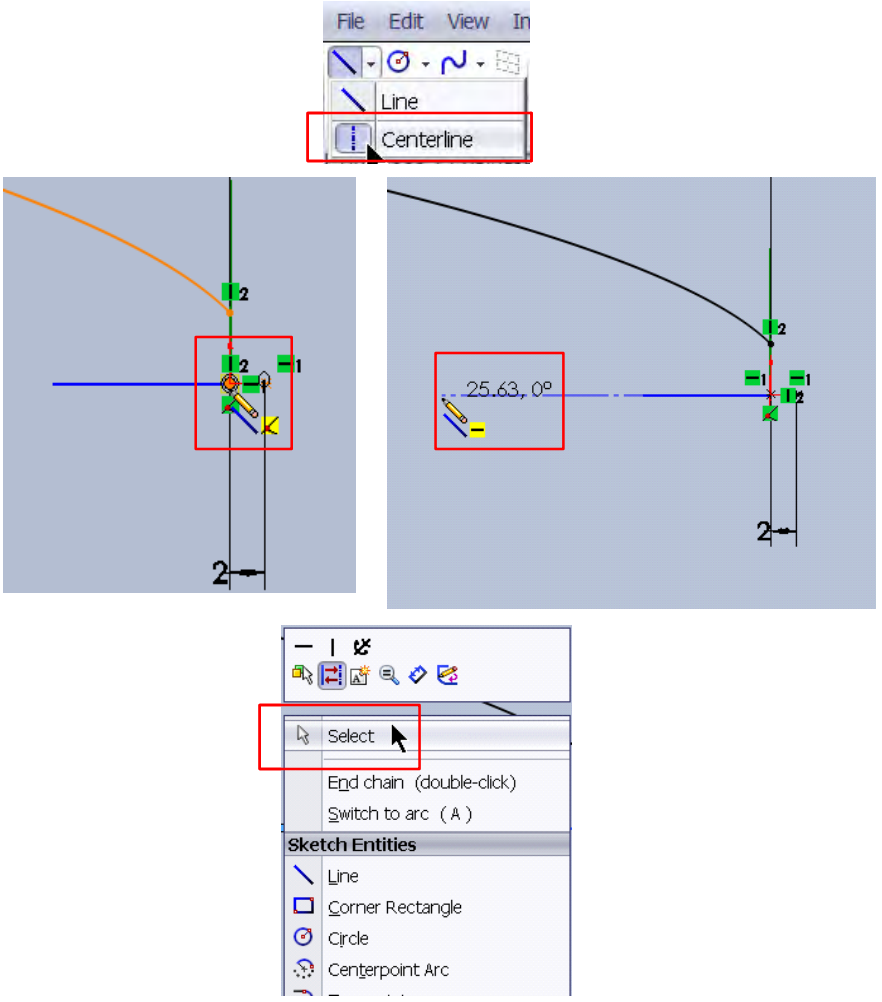


Figure 29 Views of Line menu (upper), line pointer (middle left), yellow coincidence icon (middle right), and the shortcut menu in the graphics area (lower)

Forming the surface

The Sketch is now ready to form the surface.

1 Click the **Surfaces** tab on the CommandManager. If this tab is not displayed, right-click any of the current tabs and select **Surfaces** from the shortcut menu to add the new tab. See Figure 30.

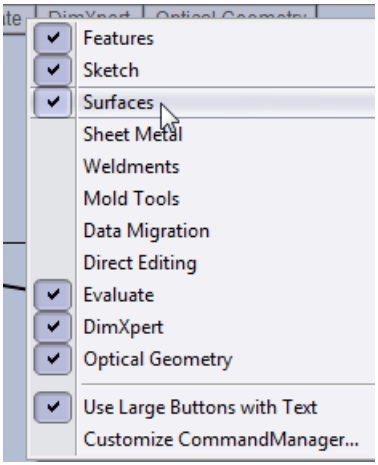


Figure 30 Adding the Surfaces tab to the CommandManager

2 Click the 

tool on the **Surfaces** toolbar to open the Surface-Revolve PropertyManager.

3 Confirm that **Line[*]** on the Surface-Revolve PropertyManager is set for **Axis of Revolution**. If necessary, click the line in the graphics area. See Figure 31.

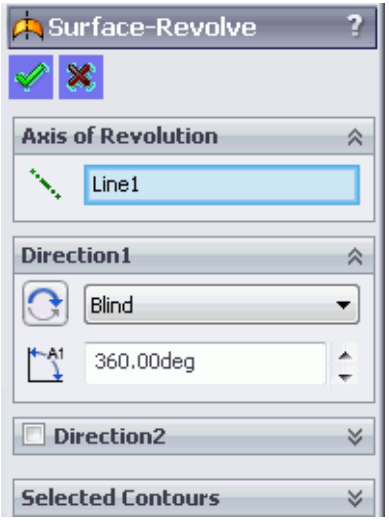


Figure 31 Reference line for the Axis of Revolution

4 On the Surface-Revolve PropertyManager, set the degree of the angle to 360 under **Direction[*]**. The surface is displayed in the graphics area. See Figure 32.

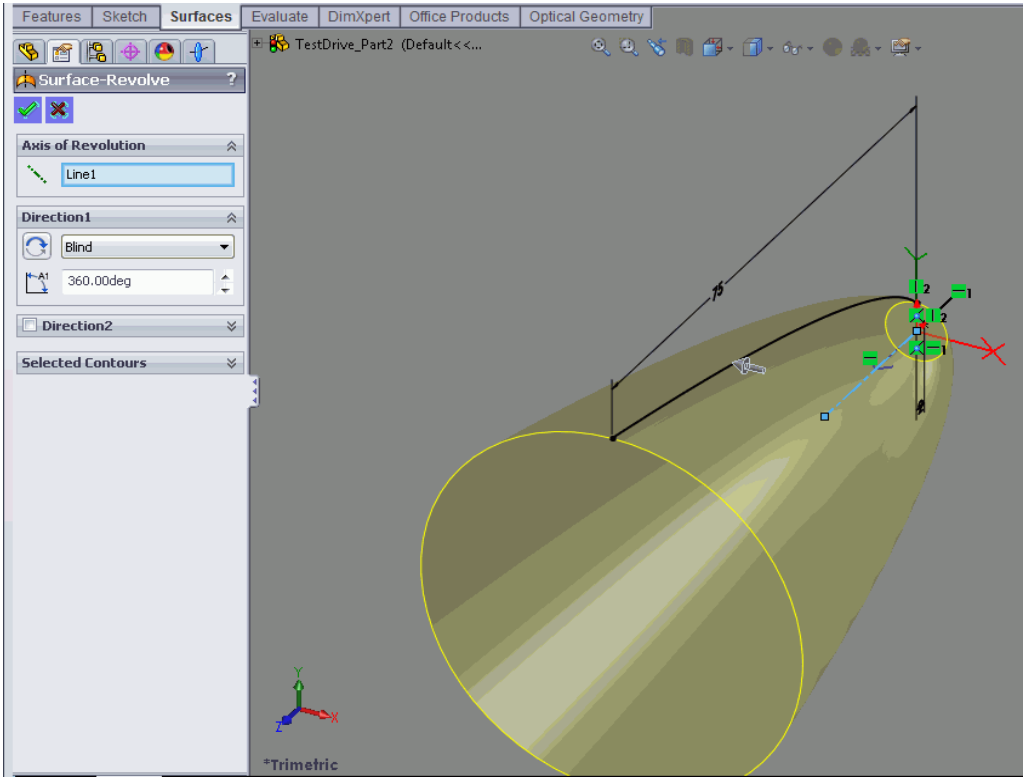


Figure 32 Surface-Revolve PropertyManager (left) and surface as displayed in the graphics area (right)

5 Click ✔ on the Surface-Revolve PropertyManager to accept the surface and close the PropertyManager. Now it is time to finish the design.

6 Right-click the Surface-Revolve node on the FeatureManager design tree. Click **Feature Properties** on the shortcut menu. See Figure 33 (left).

7 Change **Name** and **Description** on the Feature Properties dialog box to describe the actual component, and click **OK**. See Figure 33 (right).

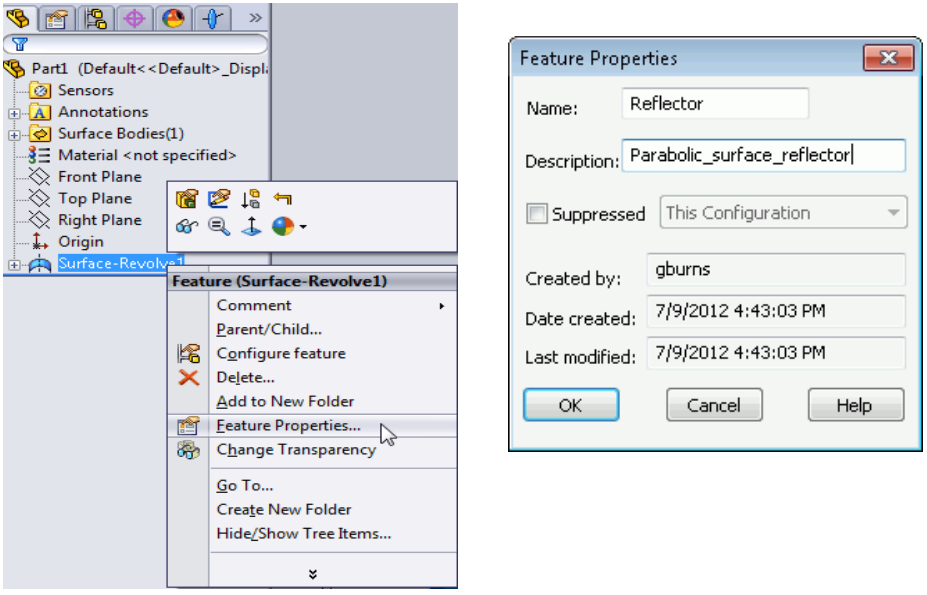


Figure 33 FeatureManager tree (left) for the part, and feature properties of the part (right)

The final step for this section is to apply a coating optical property to the reflector surface.

Applying a coating optical property

1 Click the Optics Manager tab,  on the Feature PropertyManager. See Figure 34.

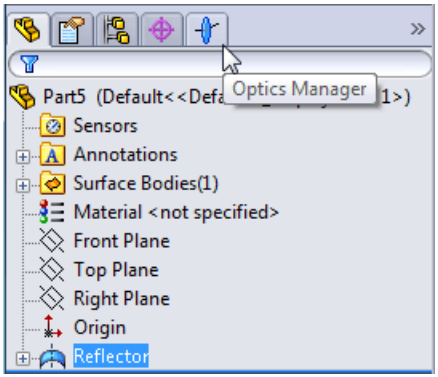


Figure 34 Clicking the Optics Manager tab on the FeatureManager

2 Right-click **Part[*] (Default)**, and click **Set Coating** on the shortcut menu to open the Coatings Manager. See Figure 35.

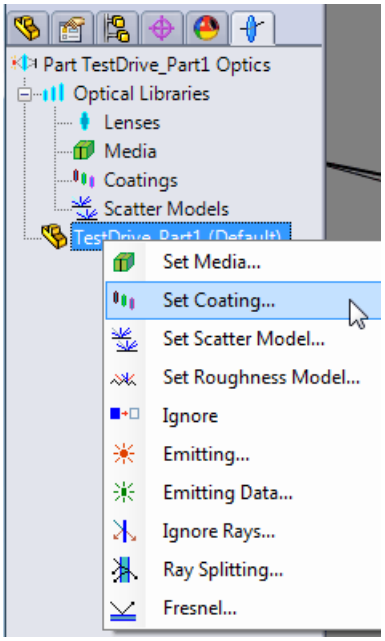


Figure 35 Clicking Set Coating on the Optics Manager to open the Coatings Manager

3 On the Coatings Manager, click **Ideal Coating** under **Category**, and click **Perfectly Reflecting** on the middle panel under **Items**. See Figure 36.

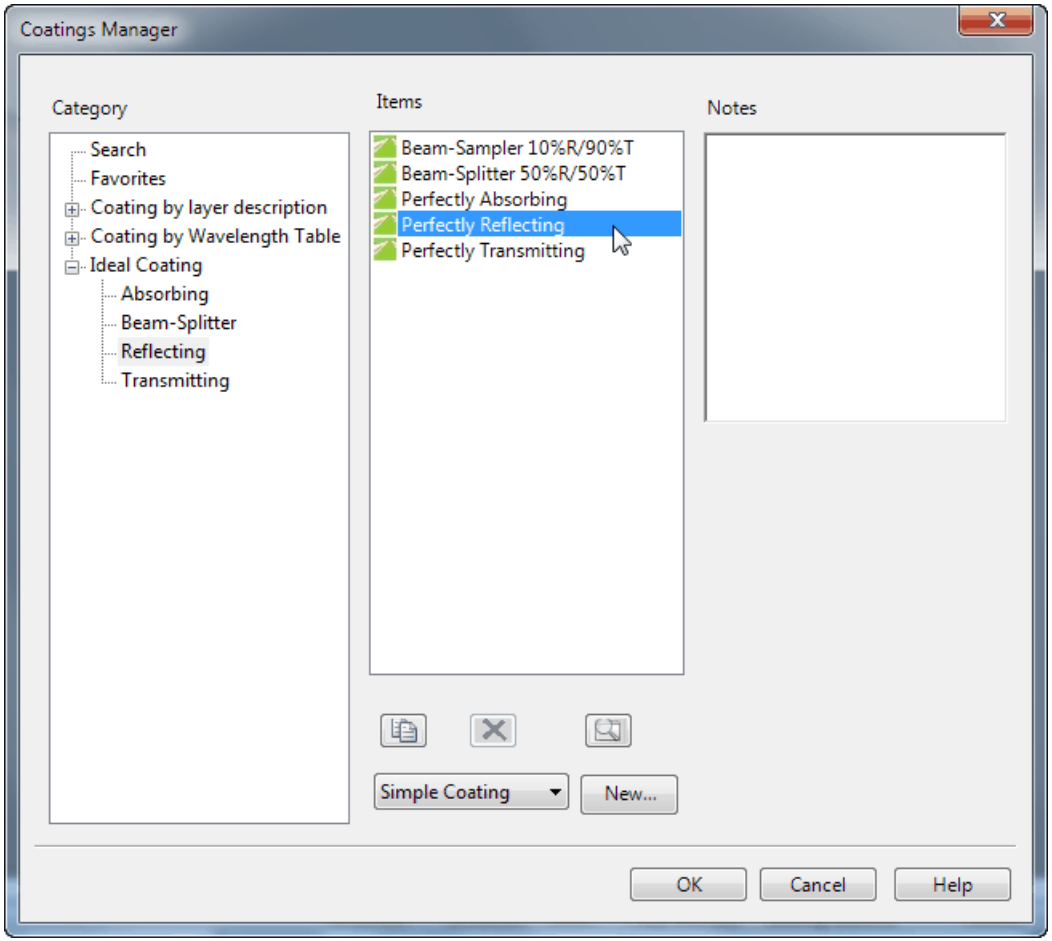


Figure 36 Applying a Perfectly Reflecting coating to the part using the Coatings Manager

4 Click **OK** to apply this coating to the part and close the Coatings Manager.

The Optics Manager now displays a node under the active part for the optical property, which in this case is the coating, as well as the type of coating (perfectly reflecting). The Optics Manager provides visual verification of

all optical properties for all components in a system. See Figure 37.

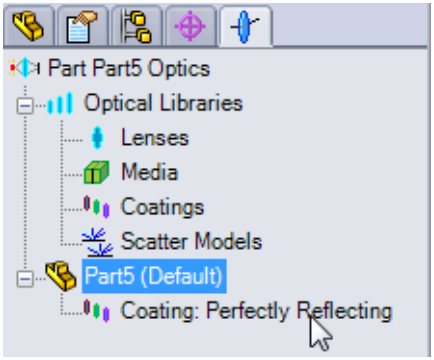


Figure 37 Verifying the coating on the Optics Manager tree

5 Click the down arrow next to the Save icon,  on the menu bar to save the part, and click **Save As**.

6 Browse to the TestDrive folder you created, and type “Reflector” for the file name of the part on the Save As dialog box.

7 Add a description for the surface (Windows 7), and click **Save**. See Figure 38.

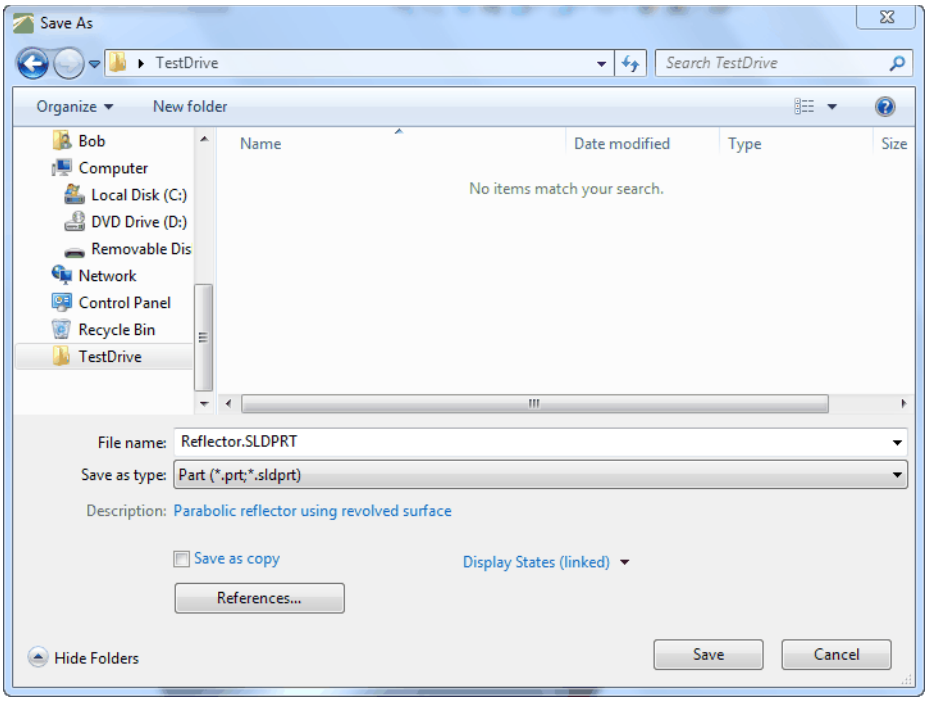


Figure 38 Save As dialog box (Windows 7)

8 Click the minimize button 

in the graphics area of the APEX window to hide the reflector file. Do not close the file.

Creating a target surface

The next step is to create a target surface for analyzing the output of the illuminator.

1. Click **New** on the toolbar to open a new parts file, and on the New Document dialog box, click the same Part millimeter template as was used for the reflector. (Remember to click the **Advanced** button if the templates are not displayed in this dialog box.)
2. Click **Front Plane** on the FeatureManager.
3. Click the **Sketch** tool on the **Sketch** tab of the CommandManager. The tool changes to **Exit Sketch**.
4. Click the down arrow next to the **Rectangle** tool on the **Sketch** toolbar, and click **Center Rectangle**. See Figure 39.

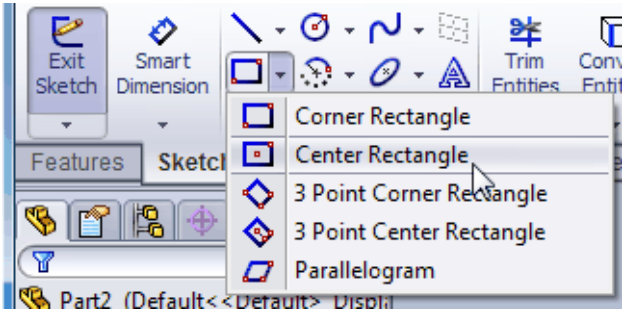


Figure 39 Clicking Center Rectangle on the Rectangle tool of the Sketch toolbar

5. Position the pointer in the graphics area at the origin. The center rectangle icon is attached to the pointer, and the coincident icon is to its right. See Figure 40.

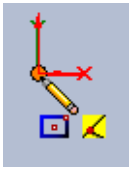


Figure 40 Center rectangle icon at origin with coincident icon to its right

6 Click the origin and move the pointer in a diagonal direction to form a rectangle that is approximately 100mm long, and click the pointer (the exact length does not matter at this time). See Figure 41.

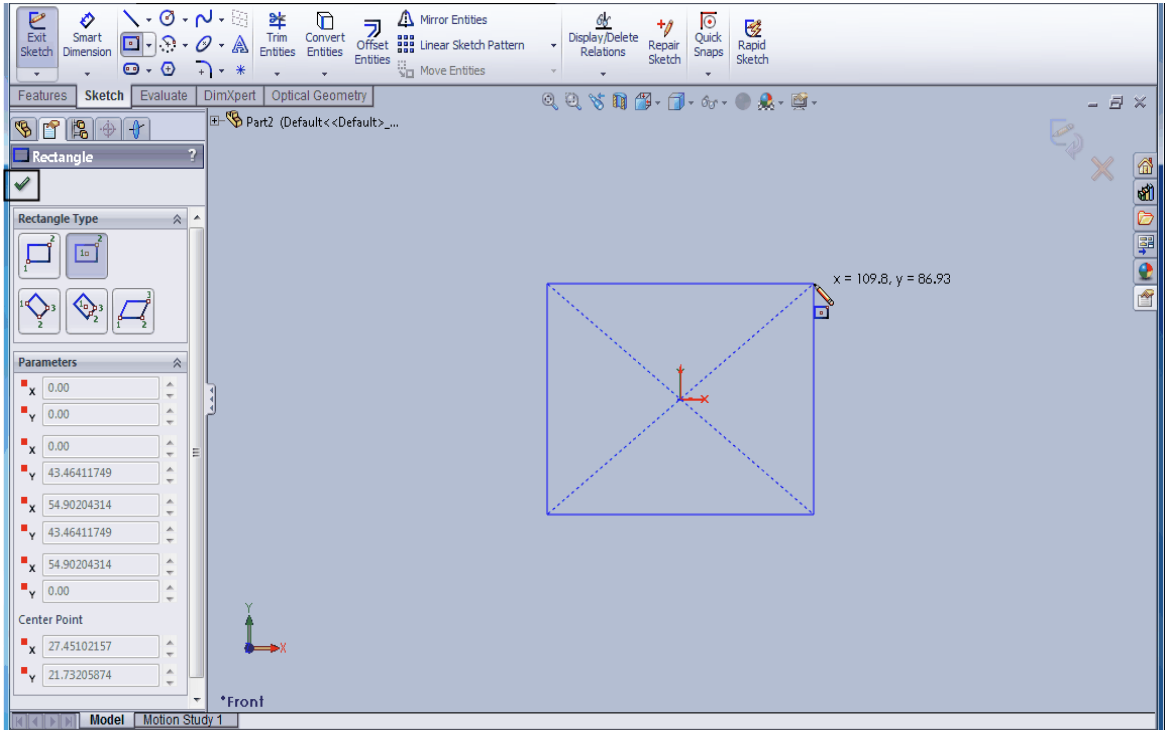


Figure 41 Forming a rectangle

7 Click ✔ on the Rectangle PropertyManager to accept the rectangle and close the PropertyManager.

CONSTRAINING THE TARGET SURFACE

Smart dimensions and relations constrain the shape and size of the target surface.

8 Click the 

tool on the **Sketch** toolbar. The pointer icon changes to the Smart Dimension icon so that you can dimension the rectangle.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

9 Click the top line in the graphics area, and slowly click the dimension value to display the Modify dialog box. See Figure 42.

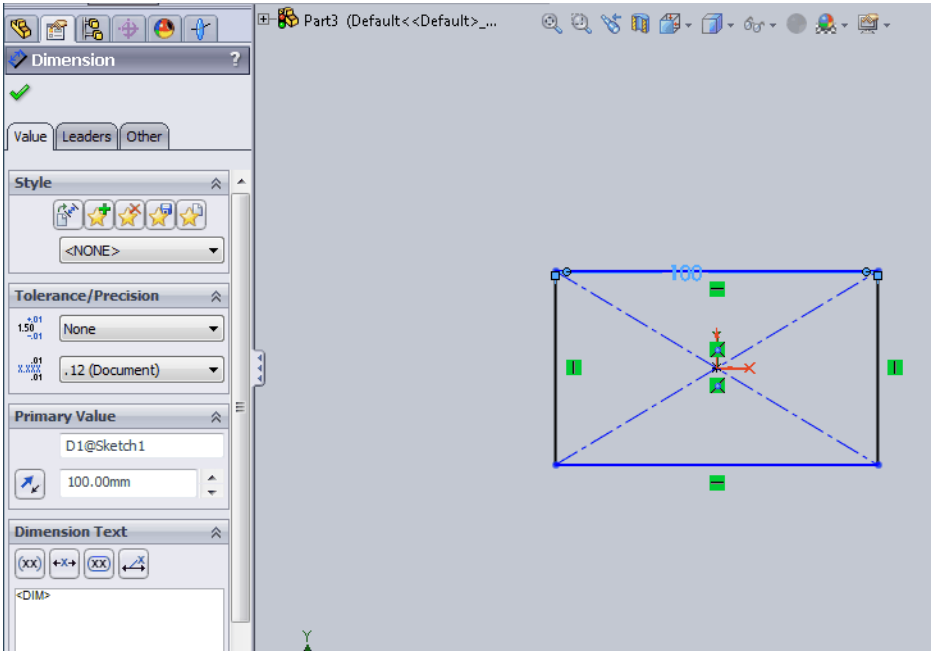


Figure 42 Rectangle in graphics area (right) and Dimension Properties PropertyManager (left)

10 Change the value to 100 on the Modify dialog box, and click ✔. See Figure 43.

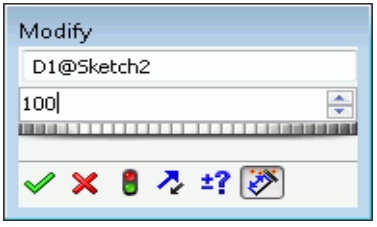


Figure 43 Modifying the dimension value to 100

11 Click ✔ on the Dimensions Properties PropertyManager to close it.

12 Hold down the Shift key, click either horizontal line, and click either vertical edge lines. This opens the Properties PropertyManager, in which you can set relations.

13 Click the **(=) Equal** icon under **Add Relations** on the Properties PropertyManager. See Figure 44.

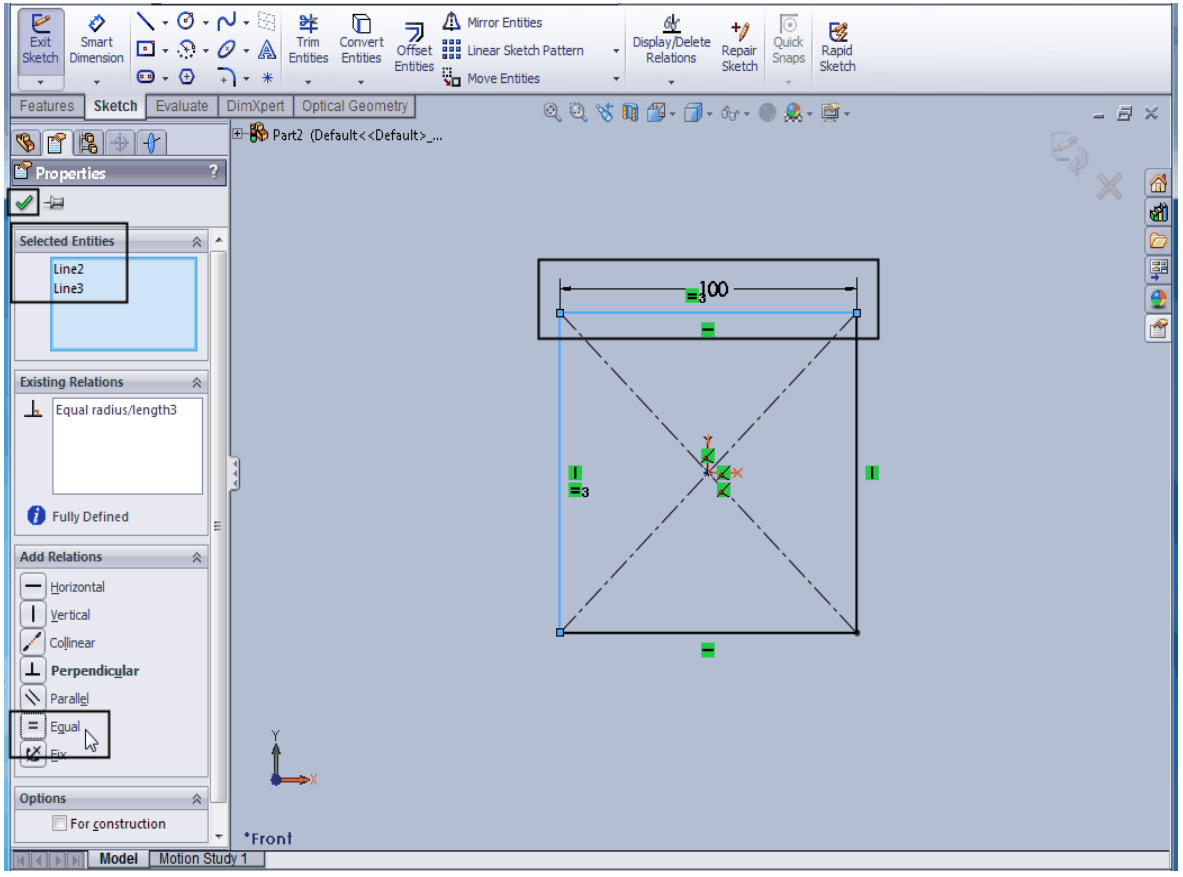


Figure 44 Clicking the Equal icon on the Properties PropertyManager to equalize the vertical lines

14 Click ✔ on the Properties PropertyManager to accept the relation and close the PropertyManager.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

At this point, the basic form of the target surface is complete. Now is the time to add thickness (physical structure) to the target.

15 Click the **Features** tab on the CommandManager, and click the **Extruded Boss/Base** tool. See Figure 45.

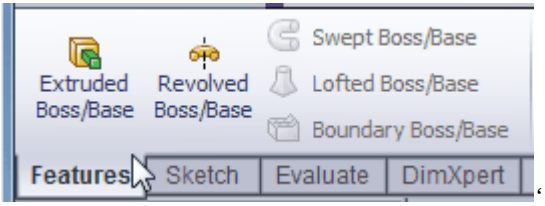


Figure 45 Clicking the Extruded Boss/Base tool on the Features toolbar

16 Click ✔ on the Boss-Extrude PropertyManager to accept the default values, and to create a solid plate that is 10mm thick. See Figure 46.

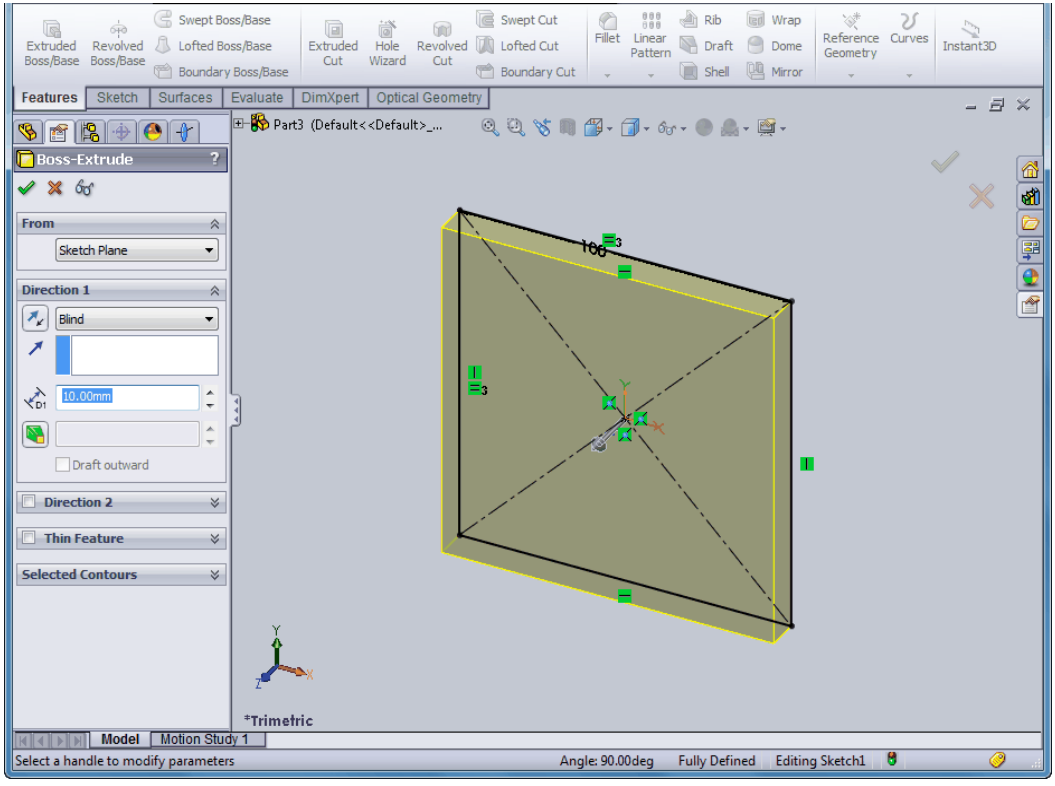


Figure 46 Solid gold plate in the graphics area (right) and the Boss-Extrude PropertyManager (left)

17 Right-click the **Boss-Extrude** node on the FeatureManager tree, and click **Feature Properties**. See Figure 47.

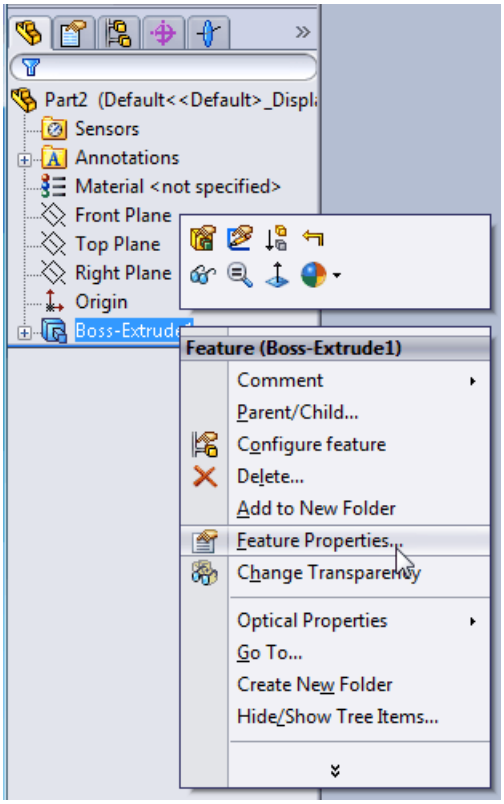


Figure 47 Right-clicking Boss-Extrude, Feature Properties on the FeatureManager, to open the Feature Properties dialog box

18 Change the **Name** and **Description** on the Feature Properties dialog box to describe the component, and click **OK**. See Figure 48.

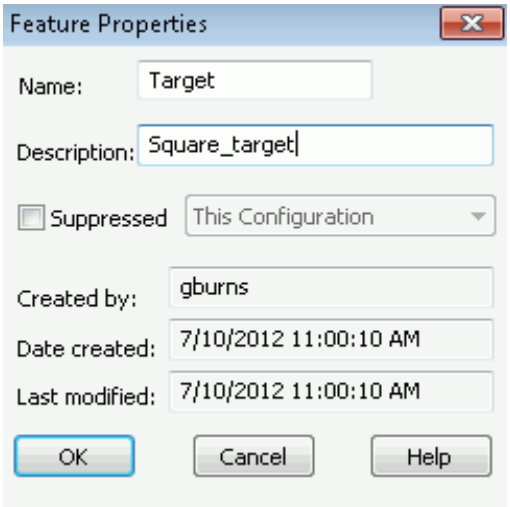


Figure 48 Name and description of component in the Feature Properties dialog box

19 To apply optical properties to the target, begin by clicking the Optics Manager tab on the FeatureManager.

20 Right-click the node named **Part[*]**, and click **Set Coating** on the shortcut menu. See Figure 49.

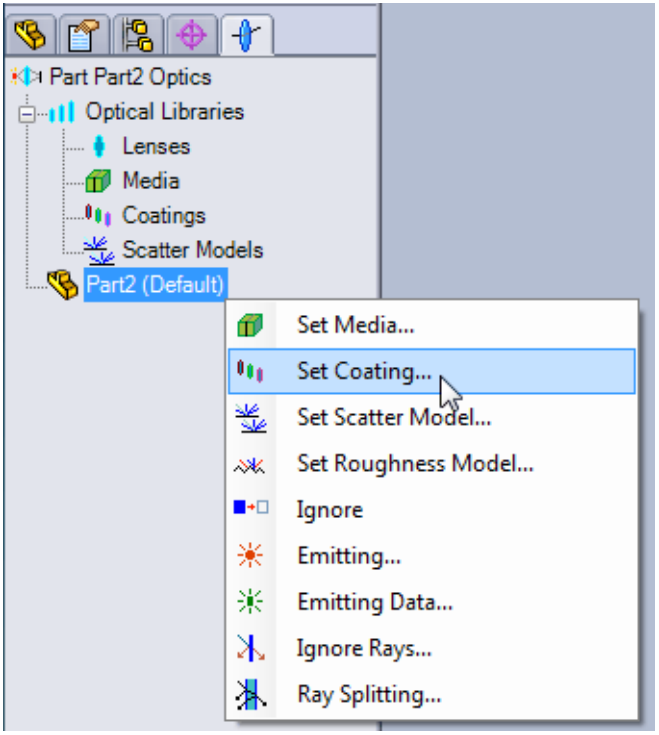


Figure 49 Right-clicking the active part and clicking Set Coating on the shortcut menu

21 Click **Absorbing** under **Ideal Coating** on the Coatings Manager, which highlights **Perfectly Absorbing** under **Items**.

22 Click **OK** to apply the coating to the part. See Figure 50.

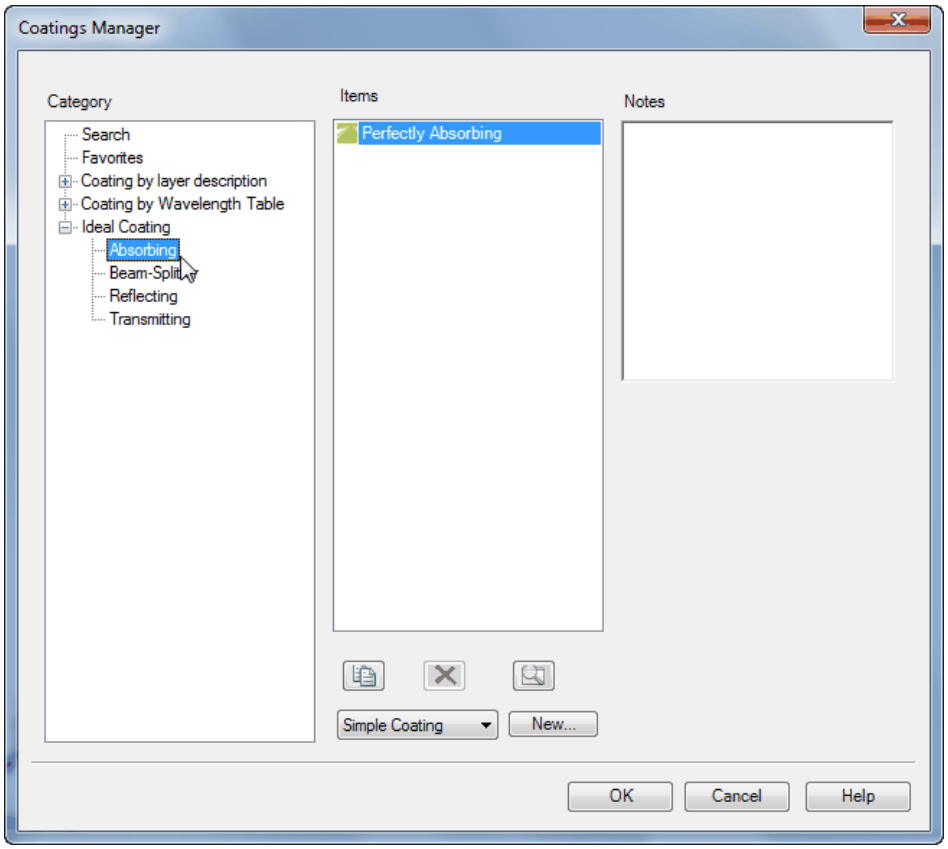


Figure 50 Applying a perfectly absorbing coating to the part

23 Save the part in the TestDrive folder as “Target”, and then minimize the open file. Do not close the file.

Combining parts in an assembly file

It is now time to combine the parts, along with an LED model, to form the illuminator assembly.

1 Click the down arrow next to **New** on the APEX toolbar. This time, click an assembly template in millimeter format on the New Document dialog box, and click **OK**. See Figure 51.

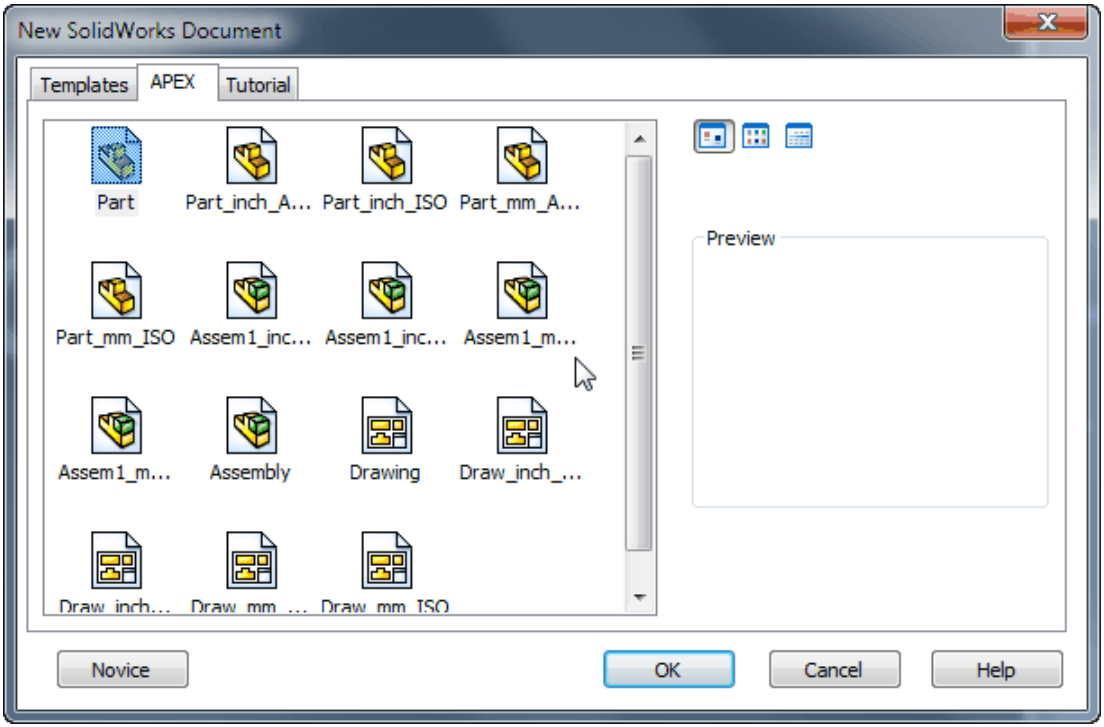


Figure 51 Clicking an Assembly millimeter template for the new document type

When the Begin Assembly PropertyManager is displayed, the Reflector and Target should both be listed under **Open Documents**. Click **Reflector** under **Part/Assembly to Insert** and click ✔ to insert the reflector into the

assembly. See Figure 52.

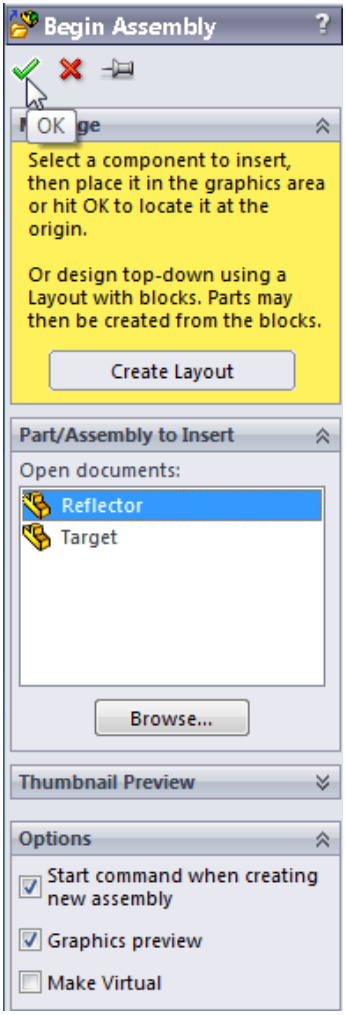


Figure 52 Clicking the reflector part on the Begin Assembly PropertyManager

This positions the origin of the Reflector at the coordinate origin of the assembly. The origin of the assembly is now aligned to the input of the reflector as desired. The Reflector node on the FeatureManager design tree is preceded by **(f)** to indicate that the position of the Reflector is fixed. The Reflector should be fixed; all other system geometry will be positioned relative to the Reflector. See Figure 53.

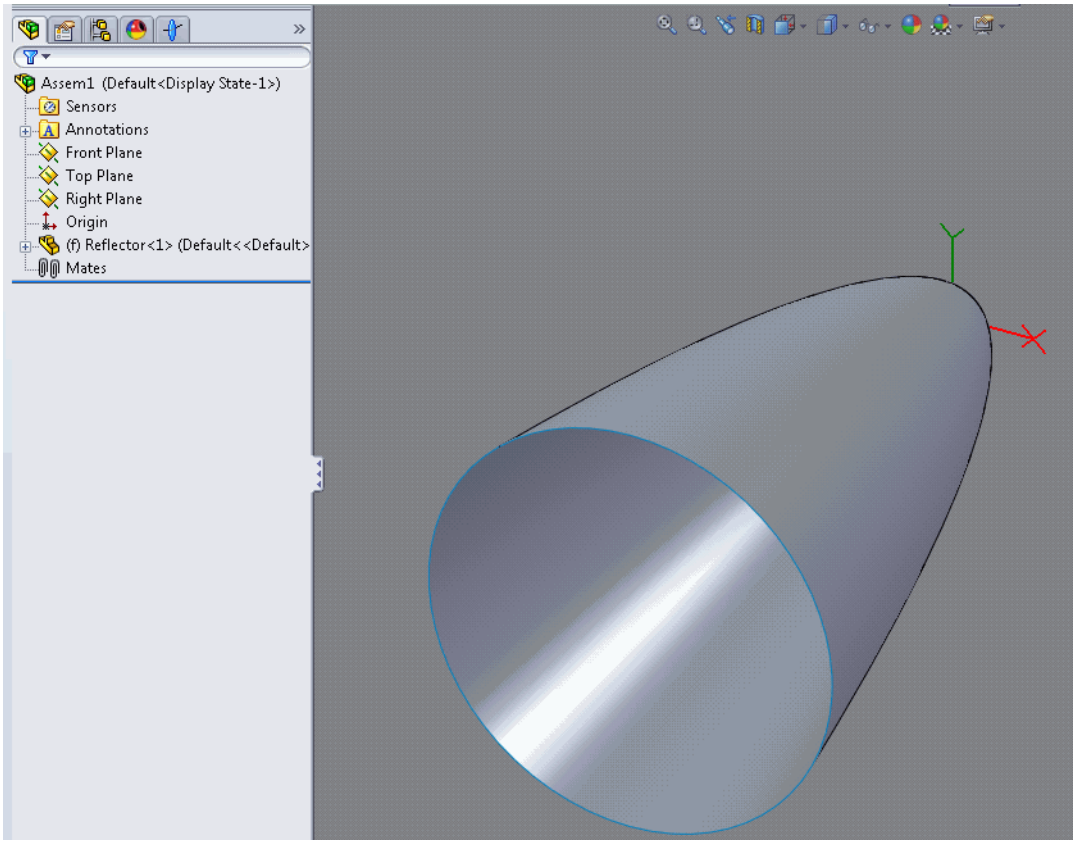


Figure 53 Origin of assembly is aligned to the input of the reflector, and the Reflector node on the FeatureManager is displayed as fixed (f)

2 Click the **View Orientation** tool under the CommandManager toolbar, and click the **Left** icon. See Figure 54 and Figure 55.

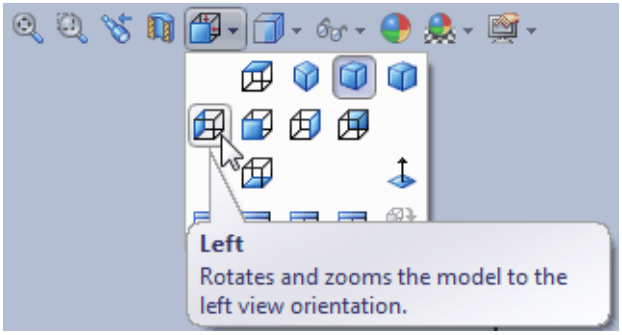


Figure 54 View Orientation toolbar highlighting the Left tool

STEP 1: DESIGN AND VERIFY THE GEOMETRY

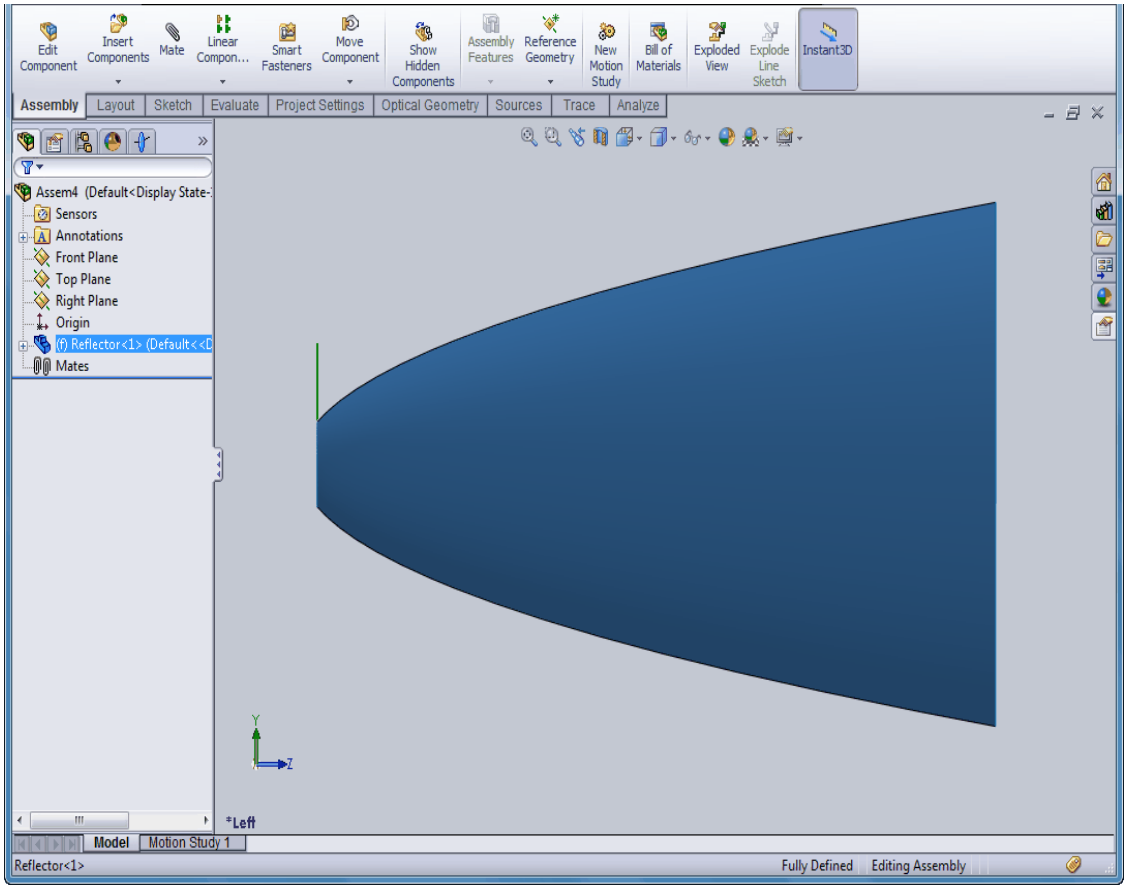


Figure 55 FeatureManager (left) highlighting fixed (f) reflector, and reflector displayed in the graphics area (right)

The Target now needs to be positioned in the assembly. The target should be 250mm from the origin, in a positive Z direction.

3 Click the **Insert Components** tool on the **Assembly** toolbar of the CommandManager. See Figure 56.

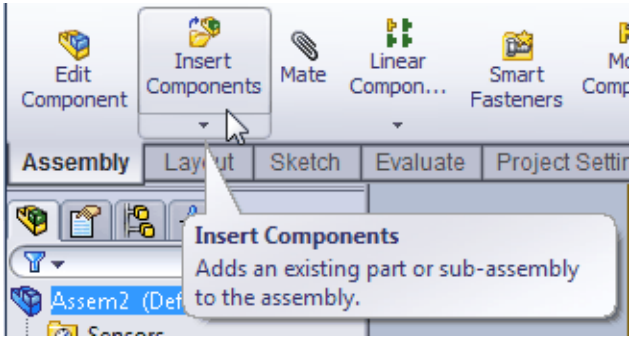


Figure 56 Clicking Insert Components on the Assembly toolbar of the CommandManager

4 Click **Target** under **Part/Assembly to Insert** on the Insert Component PropertyManager, and move the pointer to the graphics area. Note that the target follows the pointer.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

5 Position the target to the right of the reflector in the graphics area. The exact position does not matter at this time. See Figure 57.

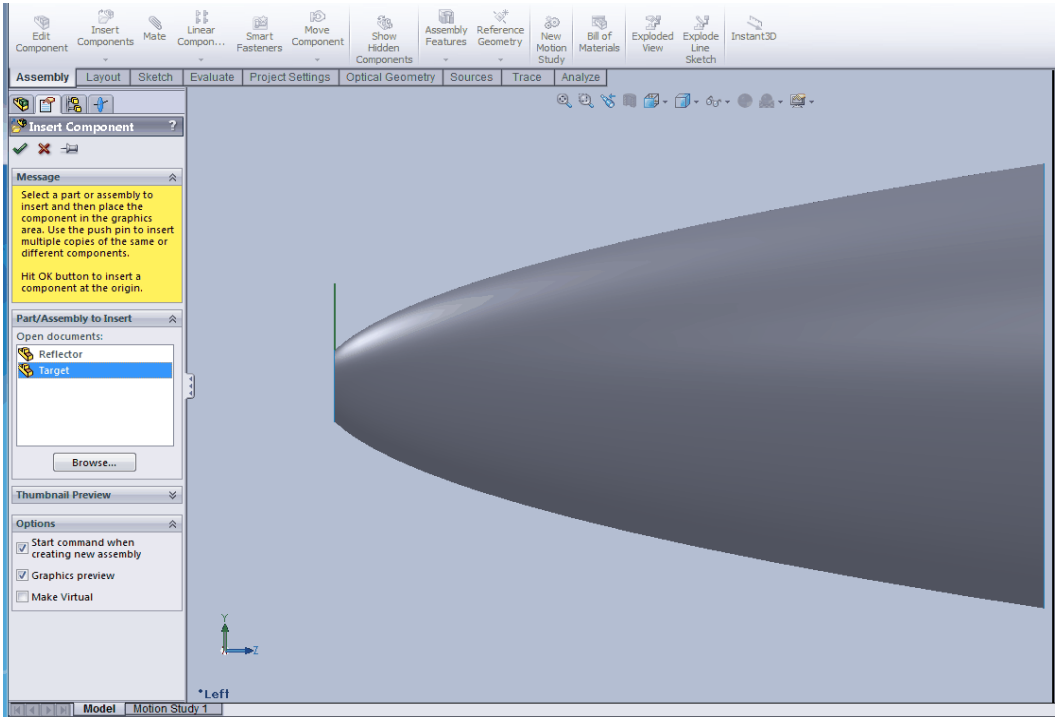


Figure 57 Using the Insert Component PropertyManager to move the target to right of the reflector

6 Click the pointer, which sets the position of the target and closes the Insert Components PropertyManager.

On the FeatureManager design tree, the Target node is preceded by **(-)** to indicate that the position of the target is floating. In this state, the target can be moved or rotated. See Figure 58.

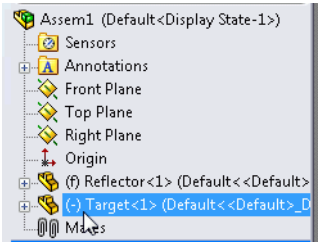


Figure 58 Target node on Feature Manager, preceded by minus (-) sign

Using mates

When the reflector and target were defined, you used dimensions and relations to enforce geometric constraints to fully define the components. However, to fully define an assembly, mates are used. Mates apply constraints between components or system geometry. The target is free to move in three directions and three rotations.

You need three mates to fully constrain the target. By properly mating the target to the reflector, changes in the position or orientation of the reflector automatically result in adjustments to the location of target to maintain the constraint conditions. Proper use of dimensions, relations, equations, and mates is an integral part of SolidWorks best practices.

In this task, the target is constrained relative to the global coordinate frame, and three constraints are applied:

- The front plane of the target is 250mm from the front plane of the assembly (the front plane of the system).
- The right plane of the target is coincident to the right plane of the assembly.
- The top plane of the target is coincident with the top plane of the assembly.

STEP 1: DESIGN AND VERIFY THE GEOMETRY

1 Click the **Mate** tool on the **Assembly** toolbar of the CommandManager to open the Mate PropertyManager. See Figure 59 and Figure 60.

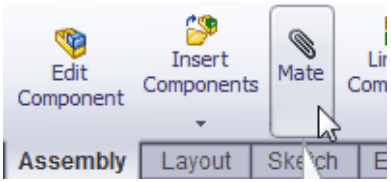


Figure 59 Clicking the Mate tool on the Assembly toolbar of the CommandManager

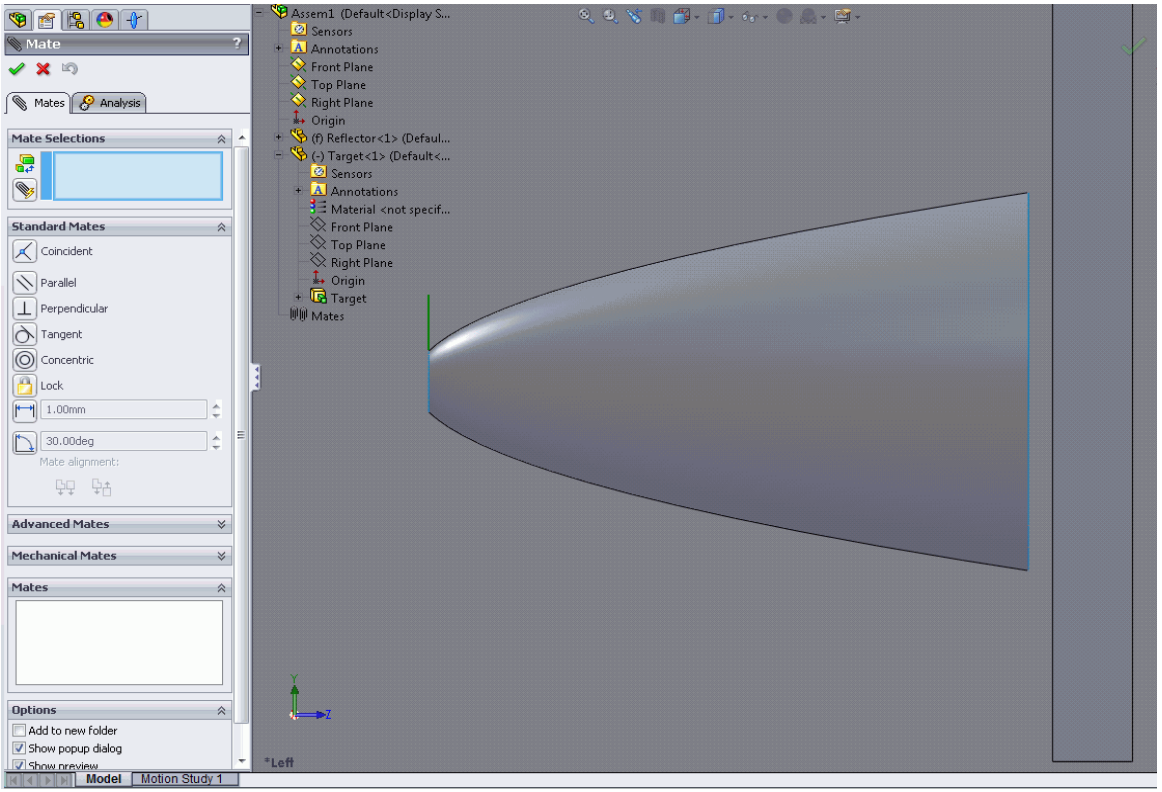


Figure 60 The Mates PropertyManager (left) and the assembly tree (left of the reflector) with (+) highlighted

2 Open the assembly tree on the graphics area, click **Front Plane** under the **Assem** node, and click **Front Plane** under the **Target** node.

3 The mate defaults to coincident, and the target moves to the origin location. See Figure 61.

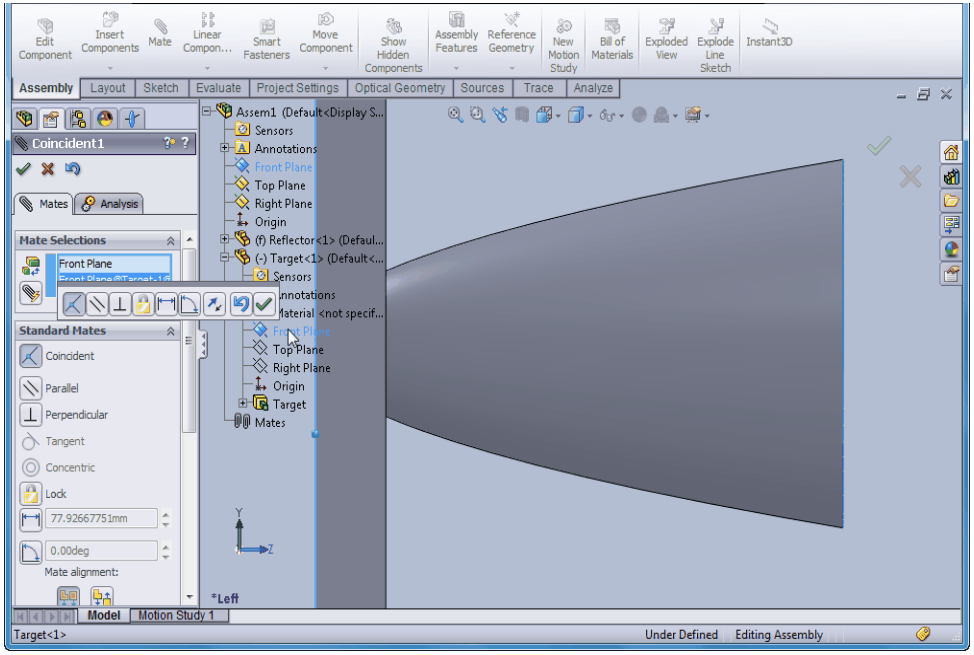


Figure 61 Coincident PropertyManager (left) with Coincident standard mate highlighted, the assembly tree with Front Plane highlighted, and target at origin in graphic area

STEP 1: DESIGN AND VERIFY THE GEOMETRY

4 Click the distance icon  under **Standard Mates**, type 250 for the distance, and click the pointer. See Figure 62.

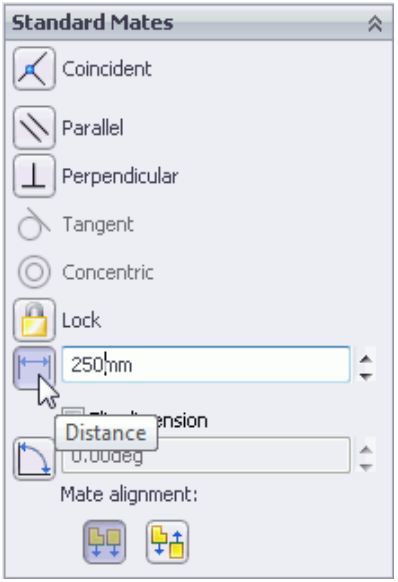


Figure 62 Designating a distance of 250mm between the front planes of the target and assembly

5 Press the **F** key to zoom out in the graphics area, and click ✔ once on the floating toolbar.

TIP ***The PropertyManager remains open since, in most instances, more than one mate is required.***

The target is now properly positioned, but it is not fully constrained. It can still move relative to the reflector. Now it is time to mate the top planes.

6 Click **Top Plane** under **Assem[*]**, and click **Top Plane** under **Target**.

7 Accept the default mate type of **Coincident** by clicking ✔ on the floating toolbar.

8 Repeat the previous two steps for the right planes.

9 Click ✔ to close the toolbar, and again to close the Coincident PropertyManager.

The assembly is now fully defined as indicated at the lower part of the SolidWorks window. See Figure 63.

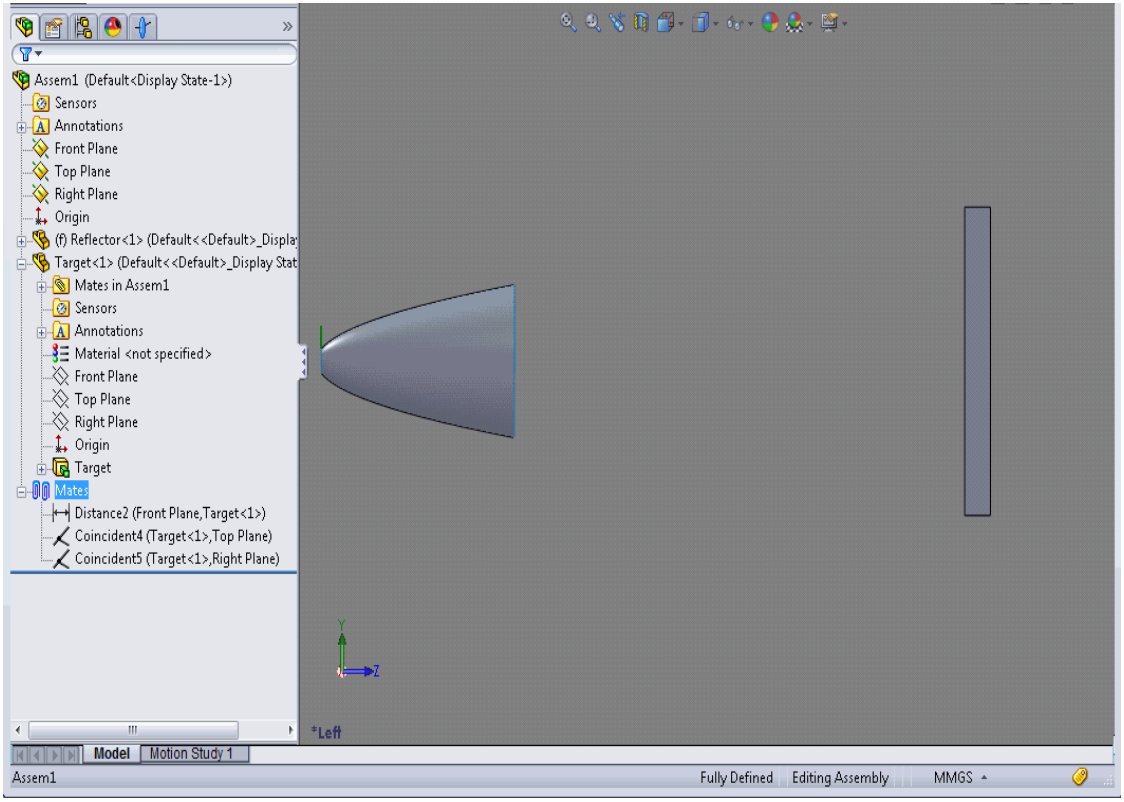


Figure 63 FeatureManager tree highlighting Mates node, and fully defined assembly in graphics area

TIP ***While you can work with a system that is Under Defined, you risk having the system unintentionally move. Occasionally, SolidWorks indicates the system is Under Defined, although each component is fixed and cannot be moved. If your system incorrectly indicates it is Under Defined in the status bar, a work-around is to right-click the fixed reflector node on the FeatureManager and click*** **Float** ***on the shortcut menu. Immediately reopen the shortcut menu and click*** **Fix.** ***The status bar should now indicate that the system is Fully Defined.***

10 Save the assembly in the TestDrive folder with the file name, “Illuminator” and the description, “Parabolic reflector system”. The file name extension for an assembly, SLDASM, is automatically assigned.

Step 1, design and verify system geometry, is now complete.

STEP 2: DESIGN AND VERIFY THE SOURCES

For Step 2, the source definition, an LED from the BRO Light Source Library is used to generate a radiometrically accurate set of rays.

1. Click the **Sources** tab on the CommandManager, and click **Manage Sources**. This opens the Light Source Manager.
2. Click **LED** under **Category** on the left column, and then scroll down the list under **Items** in the middle column to locate **LW3C**. Information and pictures of the source are displayed on the right column of the Manager. See Figure 64.

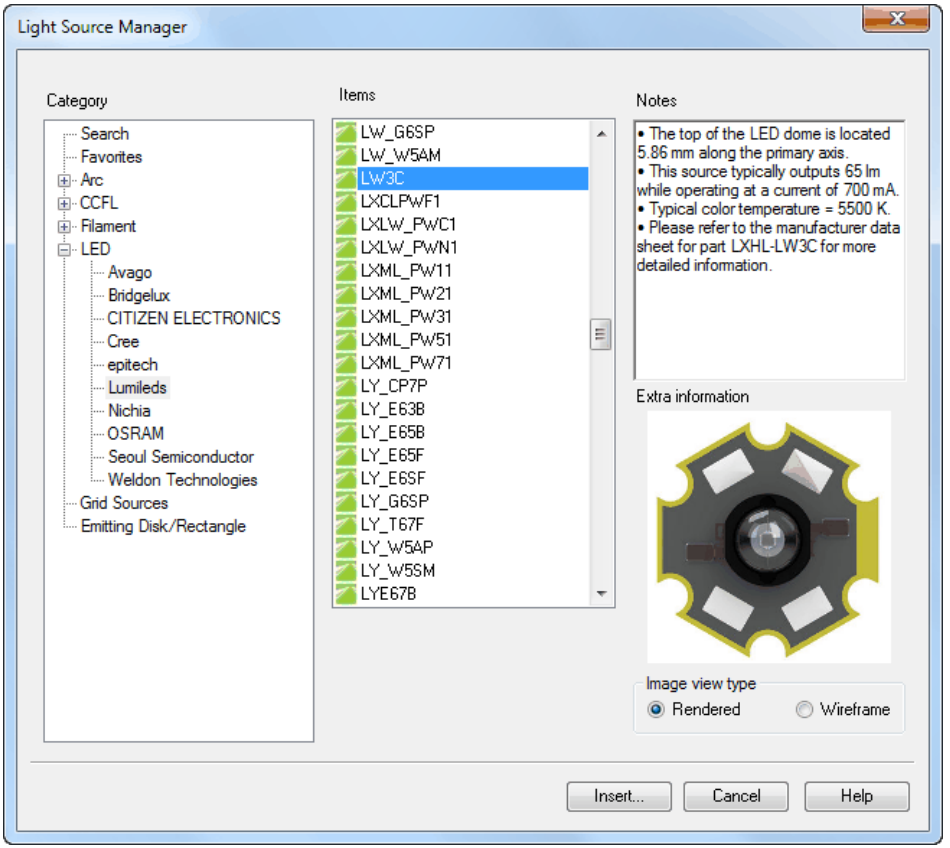


Figure 64 (1) Sources tab on Command Manager, (2) Manage Sources tool on the Sources toolbar; Light Source Manager showing the (3) LED category the (4) LW3C source, and the (5) Insert button

3 Click **Insert** in the lower part of the Light Source Manager to open the Light Source Wizard. Note that LW3C is displayed next to **Source**, so you can confirm the correct source. See Figure 65.

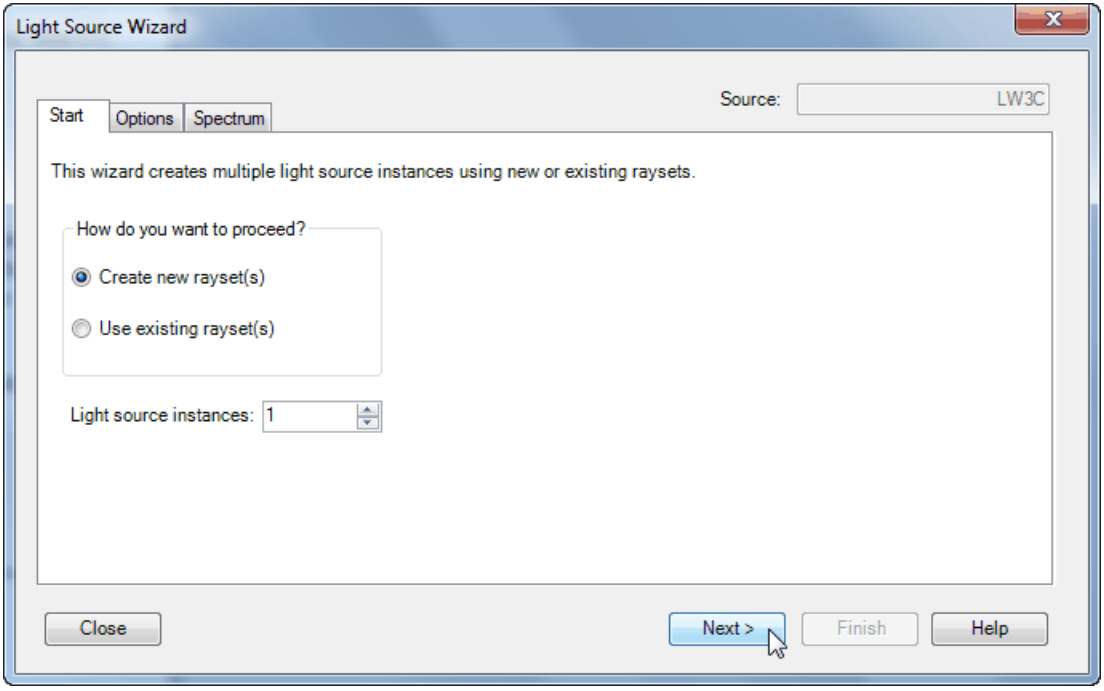


Figure 65 Light Source Wizard with default settings on the Start page for LW3C

4 Click **Next** to create a new rayset with the default settings on the **Start** page.

5 Click **Finish** to accept the default settings on the **Options** page and generate the raysets. See Figure 66.

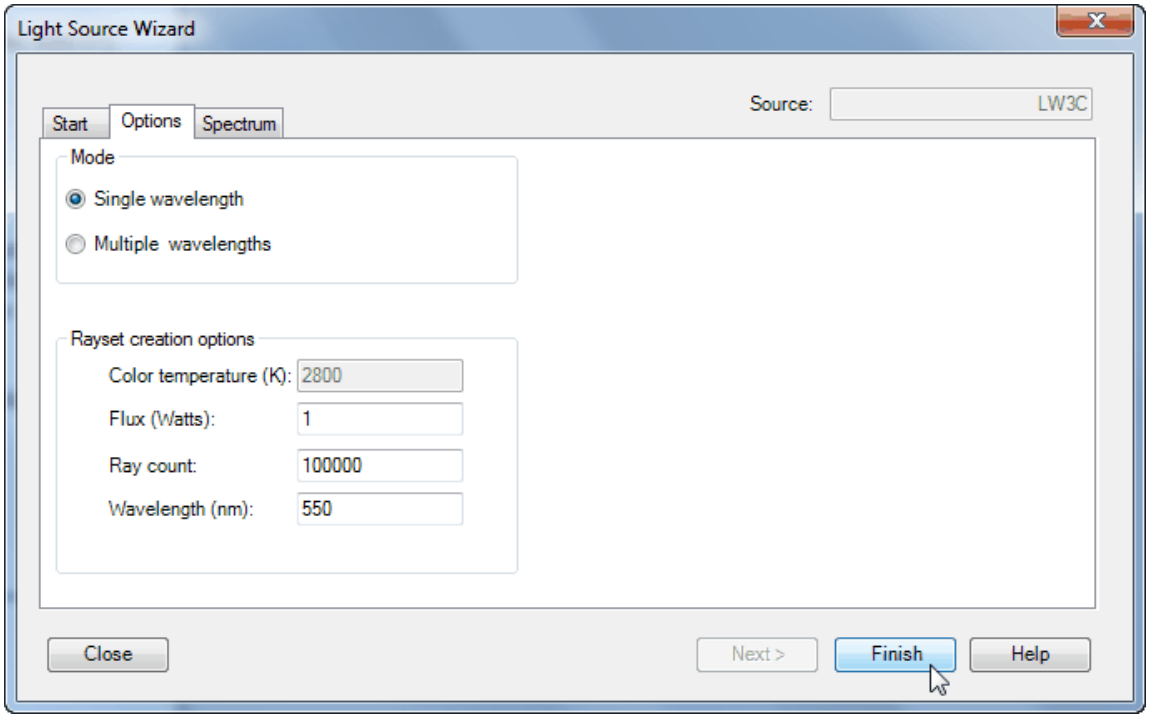


Figure 66 Light Source Wizard with default settings on the Options page for LW3C

A radiometrically accurate set of about 100,000 rays is generated, and a geometrically accurate model of the LED is inserted at the global coordinate origin. Now, the LED needs to be moved to the proper location and mated to remain in place.

6 Click the Zoom to Area icon  on the graphics area toolbar.

7 Isolate the LED and reflector by clicking and moving the pointer to capture a region.

8 Click  again to exit the Zoom to Area mode.

9 Right-click the reflector in the graphics area, and click the Change Transparency icon on the toolbar. See Figure 67.

Figure 67 Change Transparency icon

The LED is now visible in the transparent body of the reflector. See Figure 68.

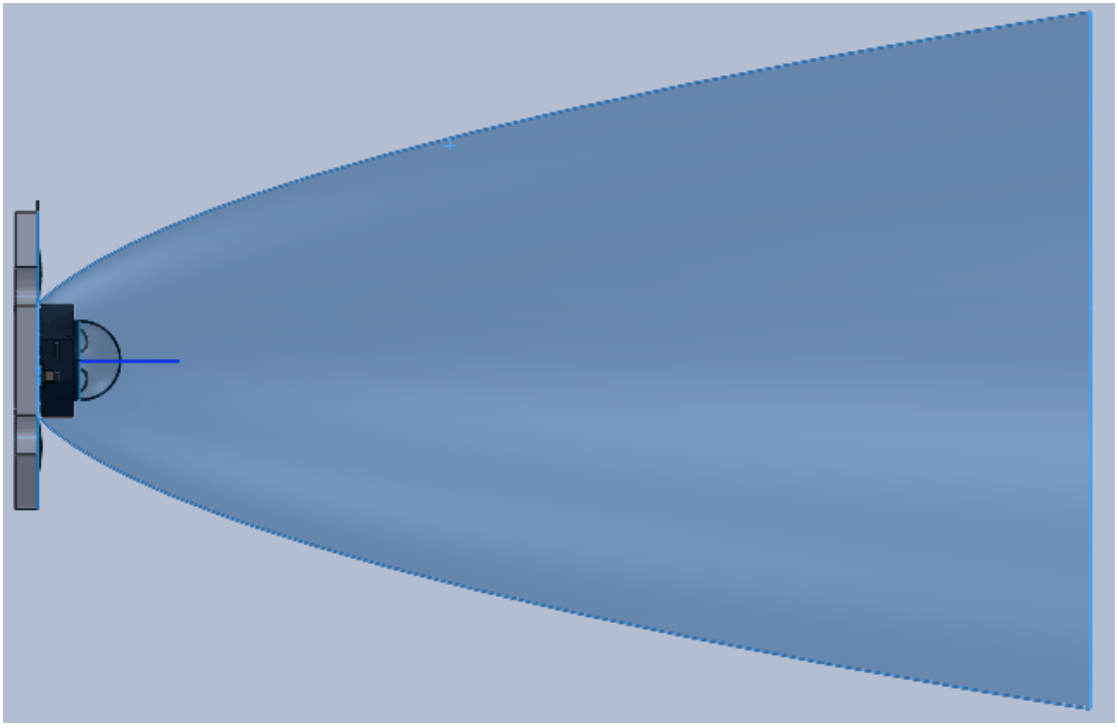
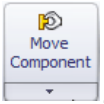


Figure 68 Zoomed area view of LED model inserted at the global coordinate origin

Positioning the LED

The LED needs to be positioned at the base of the reflector so that the LED die is at the focus of the reflector. It also needs to be constrained to remain in the proper coordinate system. To accomplish this, three mates are used:

- Back edge of the reflector is mated to the LED face.
- Top plane of the assembly is coincident with the top plane of the LED.
- Right plane of the assembly is coincident with the right plane of the LED.

1 Click **LW3C** on the FeatureManager design tree. On the **Assembly** toolbar, click 

.

2 **Free Drag** should be selected under **Move** on the Move Component PropertyManager for the SmartMates.

3 Move the pointer to the LED in the graphics area, click and drag the pointer to the left so that the LED is well separated from the reflector, and release the pointer. See Figure 69.

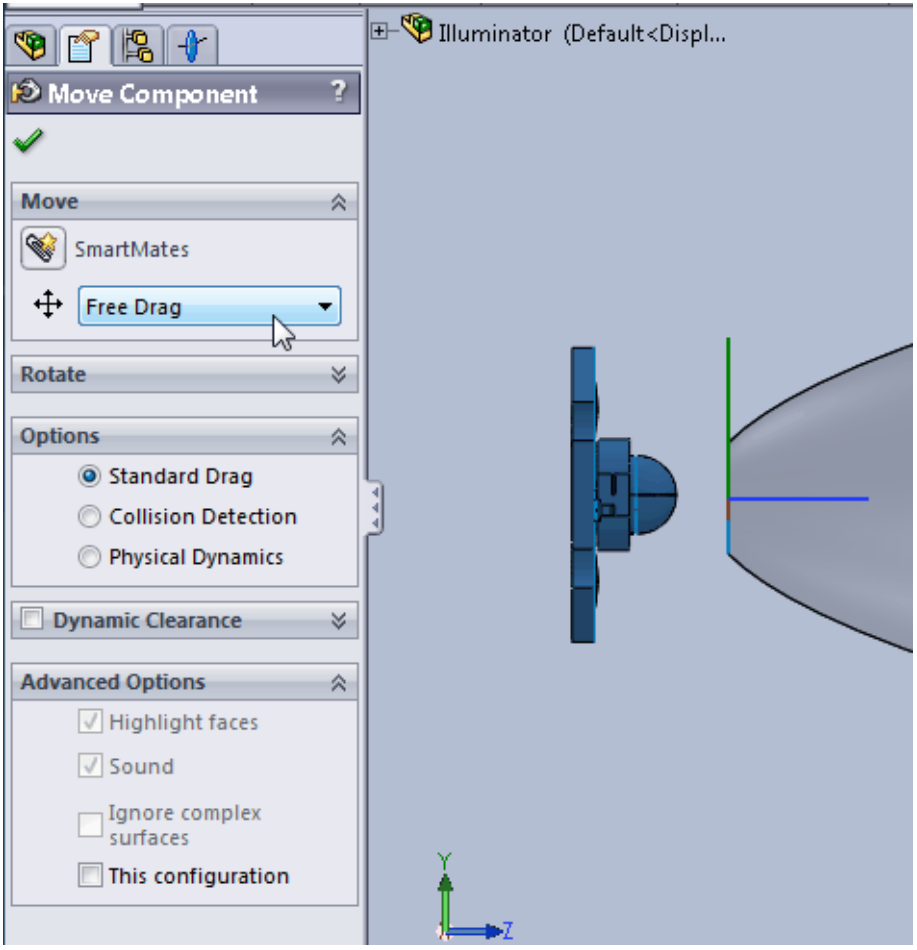


Figure 69 Move Component PropertyManager with Free Drag selected

4 Click ✔ on the Move Component PropertyManager to accept the move and exit.

STEP 2: DESIGN AND VERIFY THE SOURCES

If you notice a green icon on the FeatureManager, next to the LW3C node, it indicates that changes were made to the geometry, which may not have been updated in the graphics area. To save redrawing time, graphic windows are not automatically updated.

Best Practice Tip

Rebuild your geometry after each set of actions is completed, especially for sources.

5 Click the  tool on the APEX toolbar (at the top right) to completely refresh the graphics area to rebuild.

Applying mates

1. To apply the first mate, click the 

tool on the **Assembly** toolbar of the CommandManager. The Mate PropertyManager is displayed.
2. Carefully move the pointer over the edge of the reflector near the LED until only the edge is highlighted in orange.

3 Click the orange highlighted edge to select it as the first mate. See Figure 70 and Figure 71.

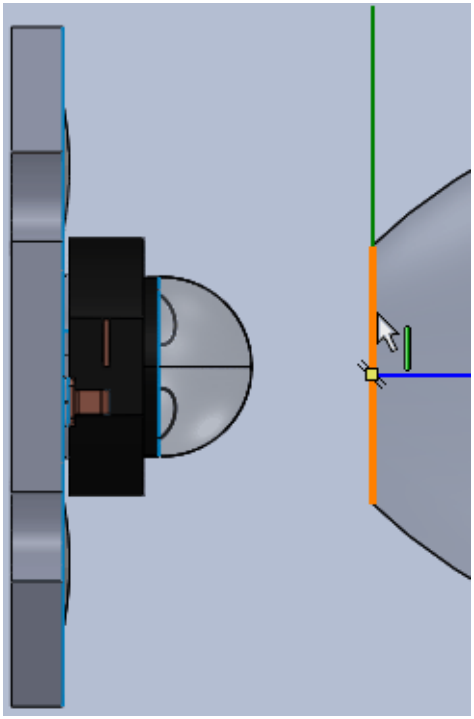


Figure 70 Edge of the reflector with orange highlight

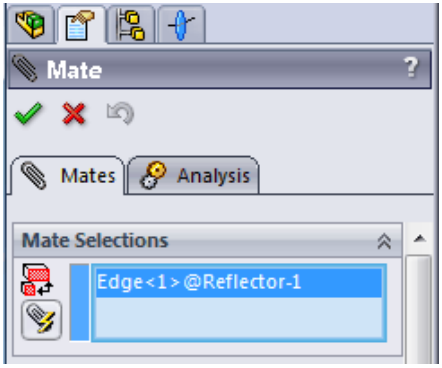


Figure 71 Mate PropertyManager highlighting the first mate selection

The second part of the mate is the LED.

4 Move the pointer until the face of the LED is highlighted, as in Figure 72.

***TIP* Use the left and right arrow keys to rotate the view orientation, or hold down the pointer in the graphics area while moving it in any direction. Use the left arrow key to rotate the geometry slightly towards you. When selecting small pieces of geometry, use the pointer scroll wheel to move in or out.**

5 When the face is highlighted in orange, click to select it. See Figure 72. The LED should move into place with the reflector.

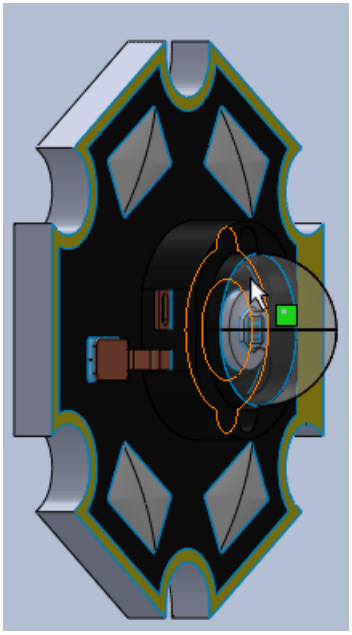


Figure 72 Face of LED highlighted in orange

The Coincident PropertyManager lists the face under **Mate Selections** on the Mates tab. See Figure 73.

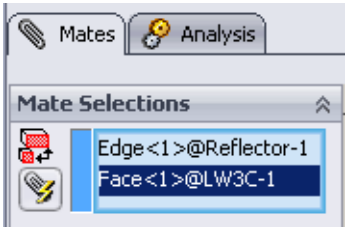


Figure 73 Mate selection for the LW3C-1 face

6 Click ✔ on the graphic area toolbar (not on the PropertyManager) to accept the default coincident mate. See Figure 74.

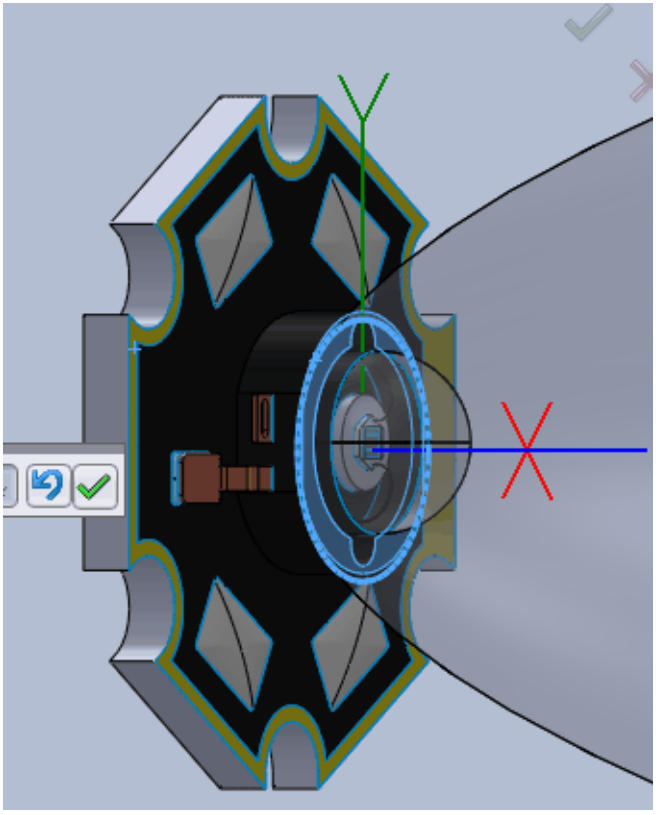


Figure 74 Mated LED and reflector prior to clicking green check mark on toolbar

7 Click the **+** sign on the graphics area, near the Illuminator node to expand the tree.

8 Click **Top Plane** on the **Illuminator** assembly tree.

9 Click to expand the **LW3C** node on the tree, and click **Top Plane** under this node. See Figure 75.

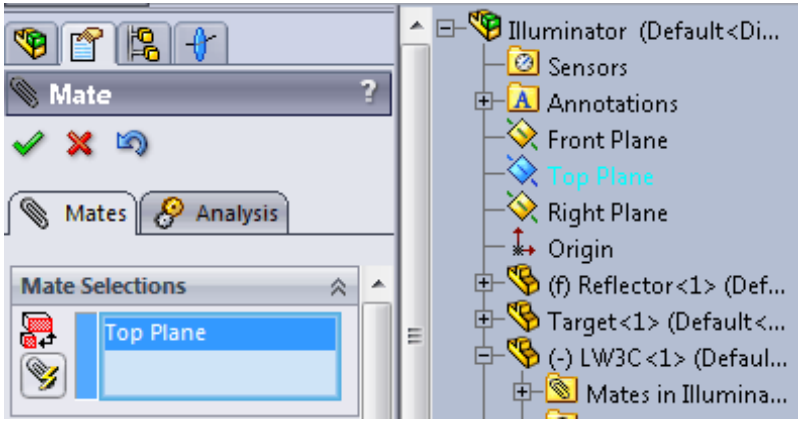


Figure 75 Mate PropertyManager and Illuminator tree showing highlighted Top Plane

10 Click ✔ on the toolbar in the graphics area to accept the mate.

TIP ***The Coincident PropertyManager stays open until you are done adding mates.***

11 Click **Right Plane** under the **LW3C** node of the Illuminator assembly to start the next mate.

12 Click **Right Plane** on the Illuminator assembly tree.

TIP ***Collapse the LW3C node to view the Illuminator node if necessary.***

13 When both right planes are selected, click ✔ on the toolbar and then on the Mate PropertyManager to close them.

The system is now fully defined, as indicted in the status bar on the lower portion of the APEX window.

STEP 2: DESIGN AND VERIFY THE SOURCES

14 Click the graphics area and press the **F** key to zoom out. All the mates are listed on the FeatureManager as nodes. See Figure 76.

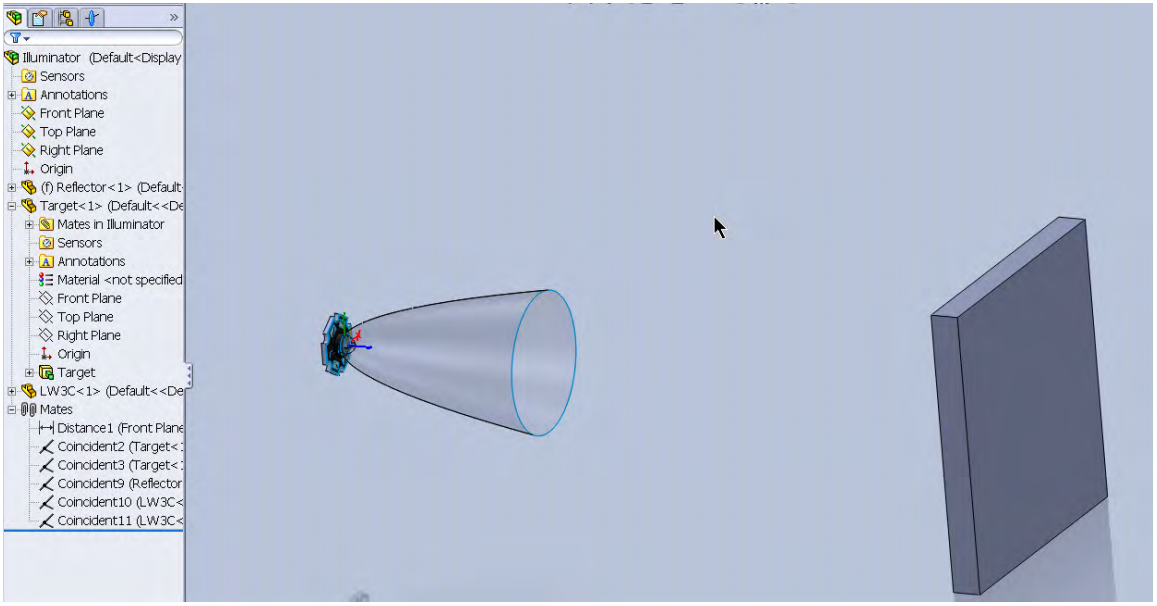


Figure 76 Feature Manager and graphics area at end of step 2

15 Click Save to save the file.

Step 2, Design and Verify Sources, is now complete.

STEP 3: TRACE THE RAYS

The third step in the APEX workflow is to trace the rays. Ray tracing is used to efficiently and accurately model the flow of energy through your system.

1 Click the **Project Settings** tab on the CommandManager, and click the 

tool.

The APEX Project Settings dialog box is displayed, which includes many options you can change as needed for different analysis requirements. For this test drive, only options for display information are adjusted.

2 Click **Ray Trace Display** to view its options.

3 Change the value to 1000 next to **Display nth ray, where n is**. See Figure 77.

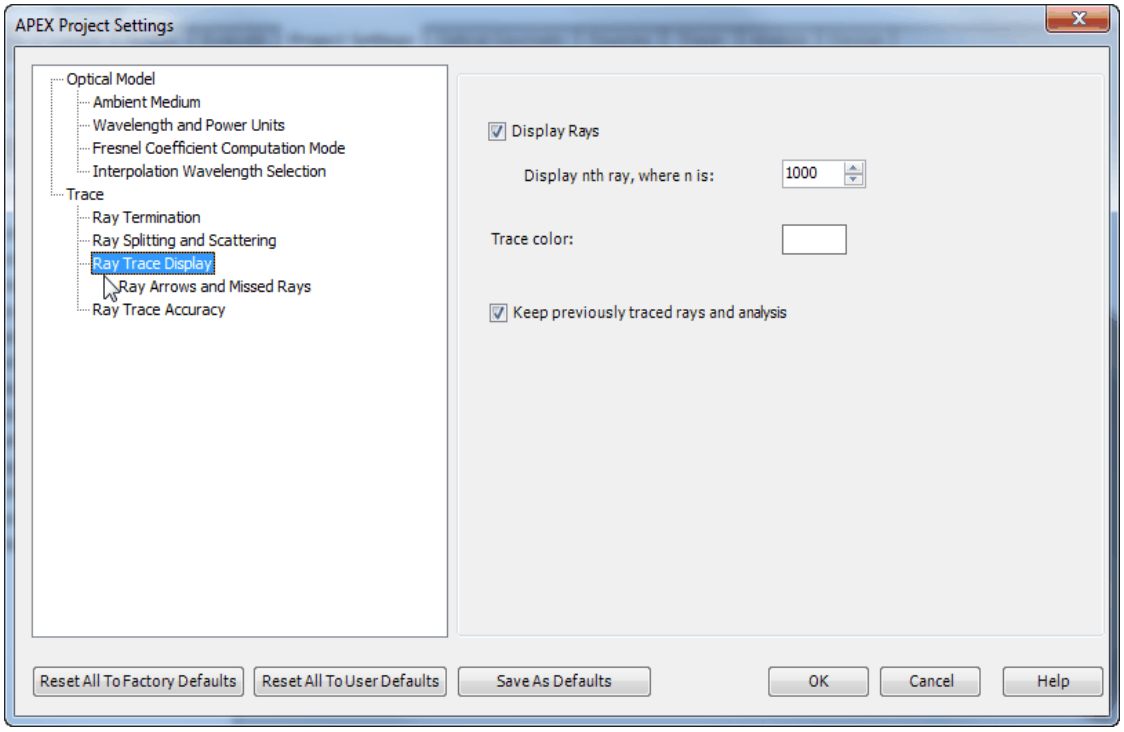


Figure 77 APEX Project Settings dialog box with Ray Trace Display settings

Only a small portion of the rays are drawn on the graphics area, but all are traced for analysis.

STEP 3: TRACE THE RAYS

4 Click **Ray Arrows and Missed Rays** on the left panel, and change the value to 250 for **Distance to extend rays in 3D**. See Figure 78.

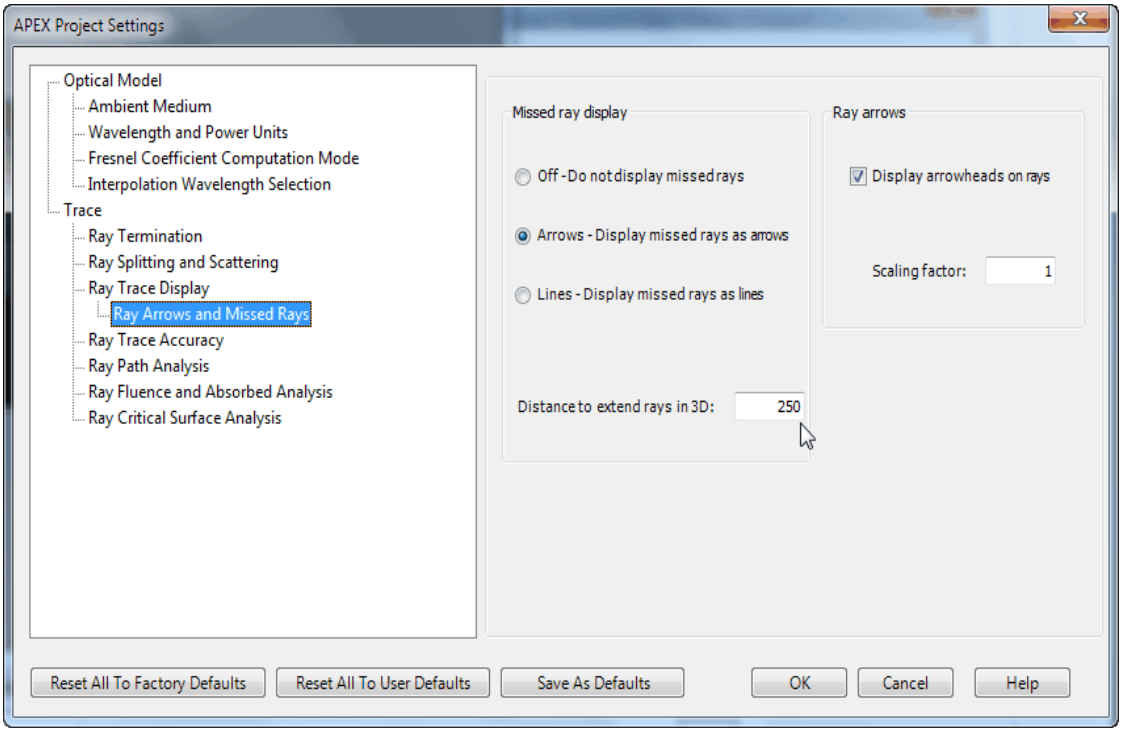


Figure 78 APEX Project Settings dialog box with Ray Arrows and Missed Rays settings

5 Click **OK** to accept the changes and close the APEX Project Settings dialog box.

6 Click the **Trace** tab on the CommandManager, and click the 

tool.

The Trace Rays progress bar is displayed. See Figure 79.

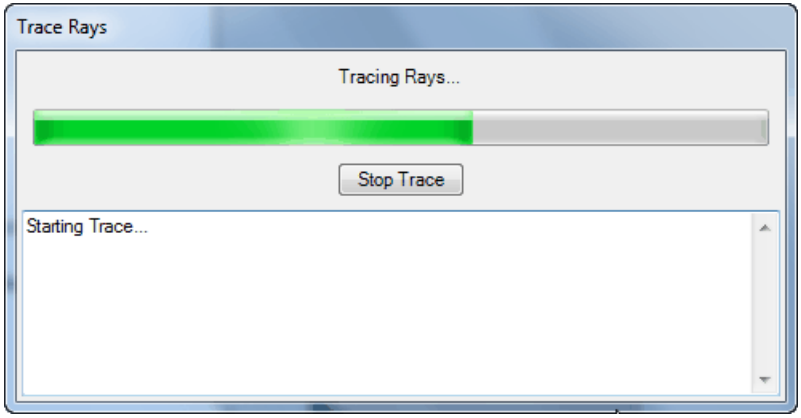


Figure 79 Status bar shows progress during ray trace

At the completion of the ray trace, the graphics area is updated to show some of the traced rays. Many of these rays reach the target, but several exit from the reflector assembly at an angle too large to be captured on the target.

7 Move the display in the graphics area, either with the scroll wheel or arrow keys, to view the different orientations.

STEP 3: TRACE THE RAYS

8 Click the Optics Manager tab on the FeatureManager to view the Results node. A Raytrace node is now on the tree. See Figure 80.

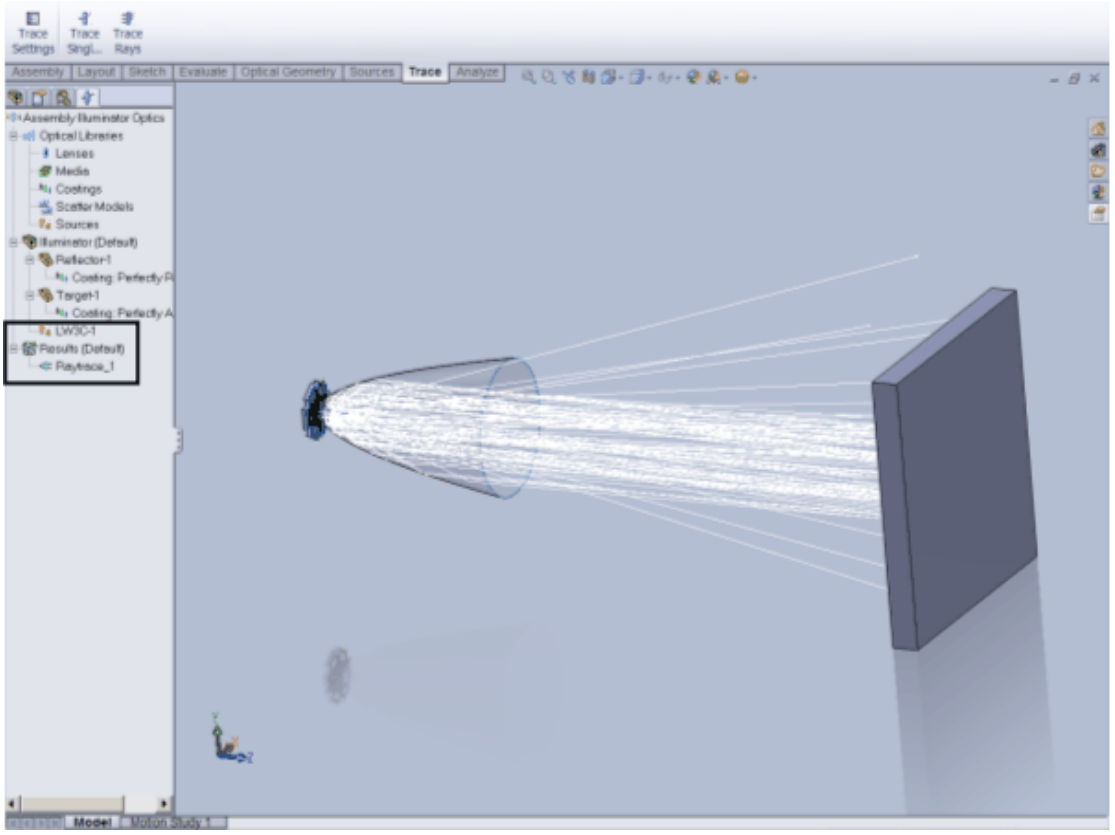


Figure 80 Reflector showing some of the traced rays, and the new Raytrace node on the Optics Manager

STEP 4: PERFORM THE ANALYSIS

The final step is to generate numerical or graphical analyses of the system. You can view the distribution of light on the front face of the target as a function of position of the light, the irradiance, and the function of the direction of the light, or the intensity.

1. Rotate the system in the graphics area (hold down scroll wheel and move pointer) to see the incident face of the target.
2. Click the front face of the target to highlight it. See Figure 81.

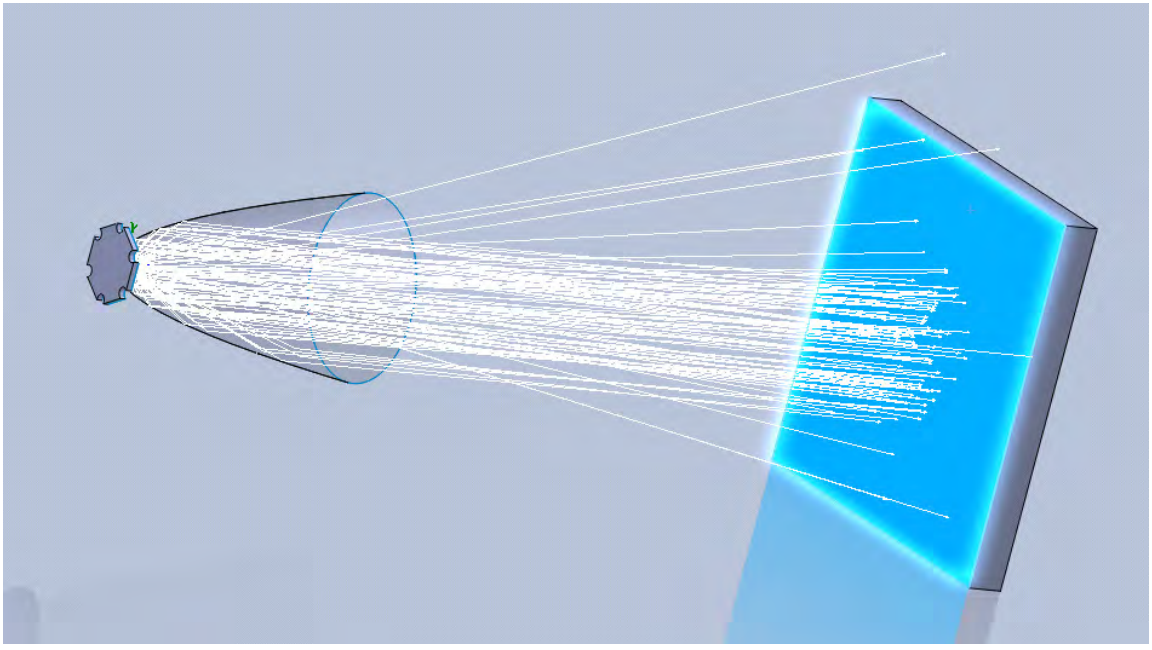


Figure 81 Highlighted front face

3. Click the **Analyze** tab on the CommandManager. Some of the tools are available, while others require a prerequisite calculation to become available. Click the Irradiance tool. See Figure 82.

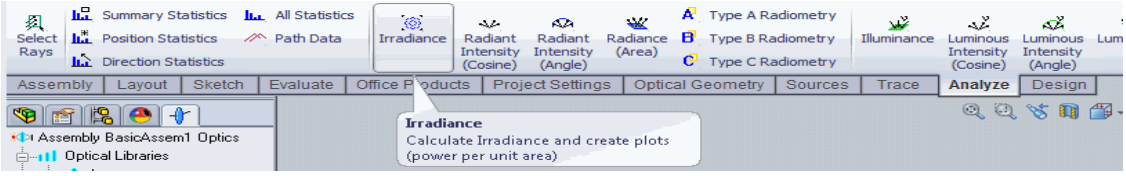


Figure 82 Analyze toolbar (partial view) with the Irradiance tool selected

STEP 4: PERFORM THE ANALYSIS

4 Click **Selected Surfaces**, under **Geometry** on the Irradiance PropertyManager.

Selected Surfaces accounts for the previously selected geometry. Only those rays reaching the selected face on the target are considered during the analysis.

5 Click all the plot options under **Plots**, and adjust data resolution to 101 square pixels.

6 Click ✔ to accept the changes and perform the calculation. See Figure 83.

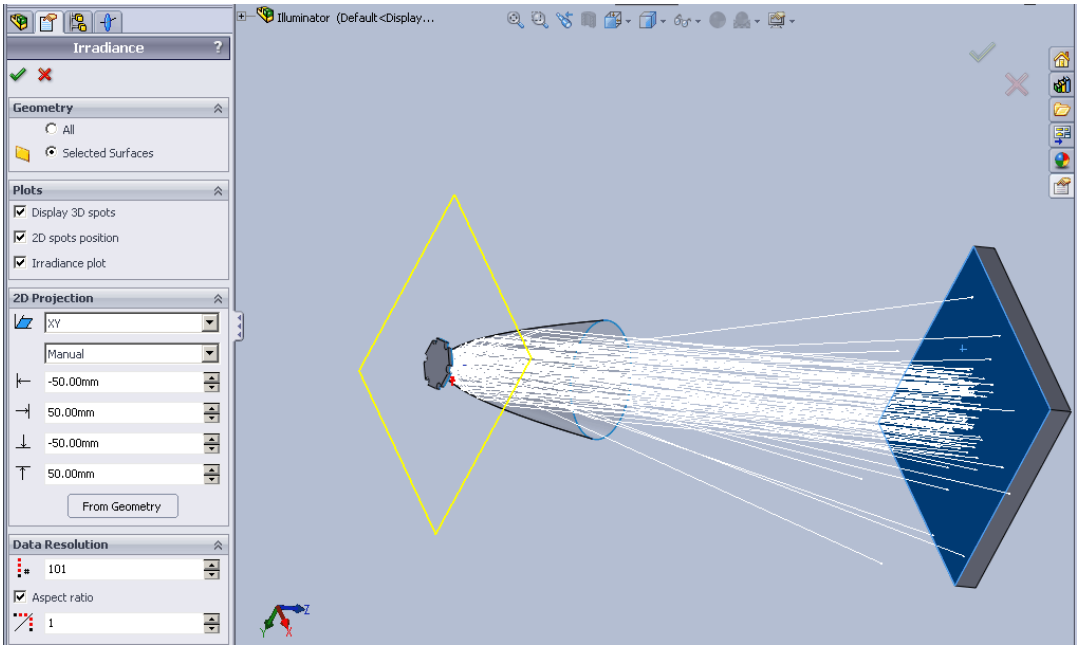


Figure 83 Irradiance PropertyManager (left) and irradiance graphic (right)

7 Click the Optics Manager tab on the FeatureManager to view the node for each requested analysis. Each **ResultSet** is listed under the **Raytrace**_[*] node. See Figure 84.

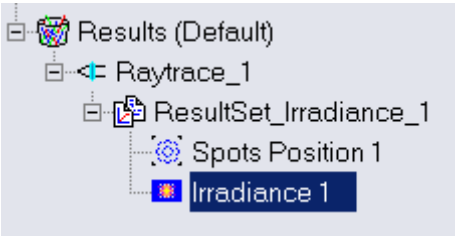


Figure 84 ResultSet node on the Optics Manager, listing Spots Position and Irradiance

8 Click the ResultSet node for **Spots Position[*]** to view the results in the graphics area.

The Spots position analysis shows where all the rays landed. In addition to producing the graphic, it creates a data file that allows more calculations to be performed. See Figure 85.

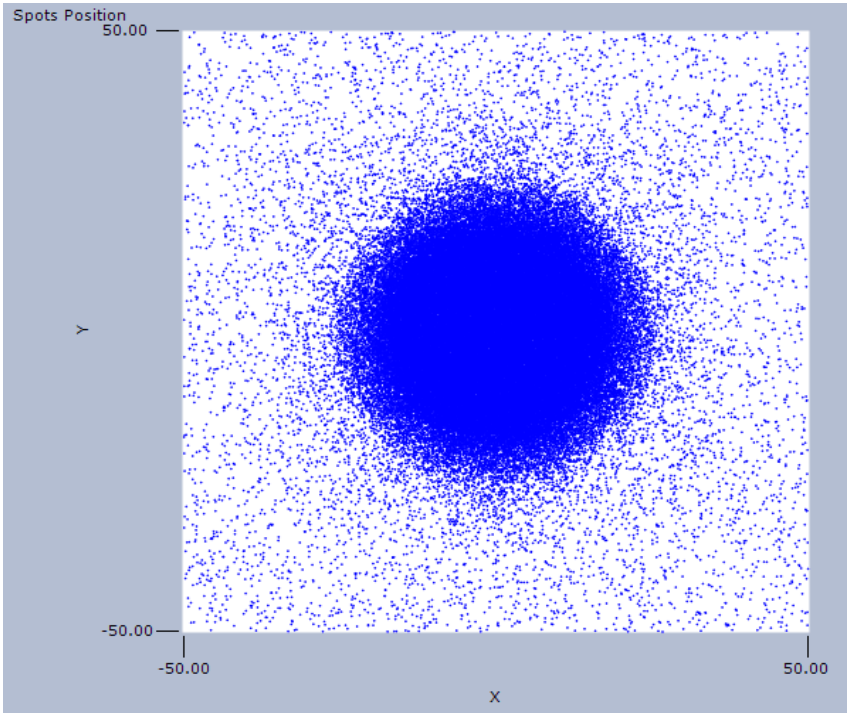


Figure 85 Spots position analysis

STEP 4: PERFORM THE ANALYSIS

9 Click the **Irradiance[*]** node on the Optics Manager to view the false color irradiance Plot, and move the cross hairs to view the irradiance value at different locations. See Figure 86.

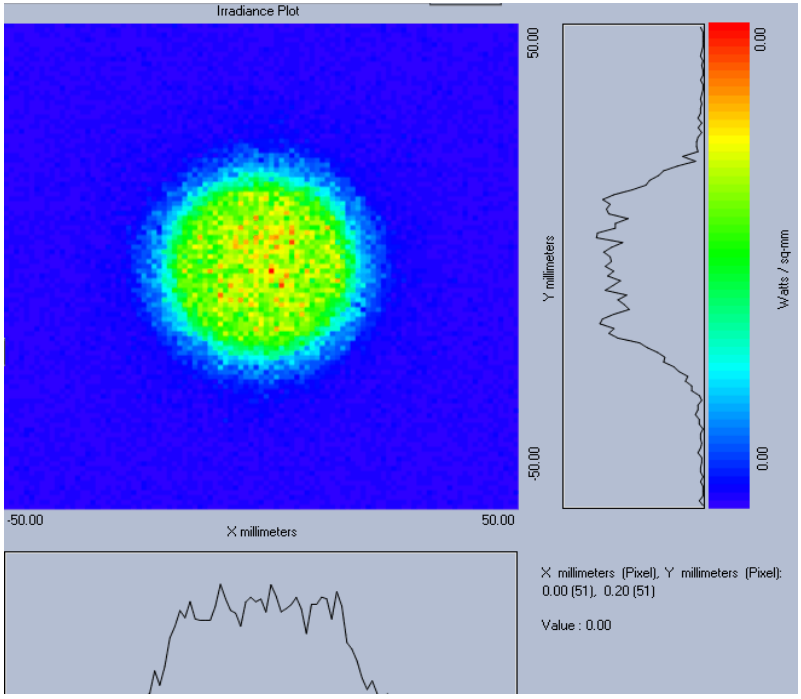


Figure 86 False color plot

The irradiance analysis shows a false color representation of the energy distribution across the target.

10 Click the **Model** tab on the lower portion of the graphics area to view the Spots diagram calculation. Results of the spots diagram calculation overlay the target. See Figure 87.

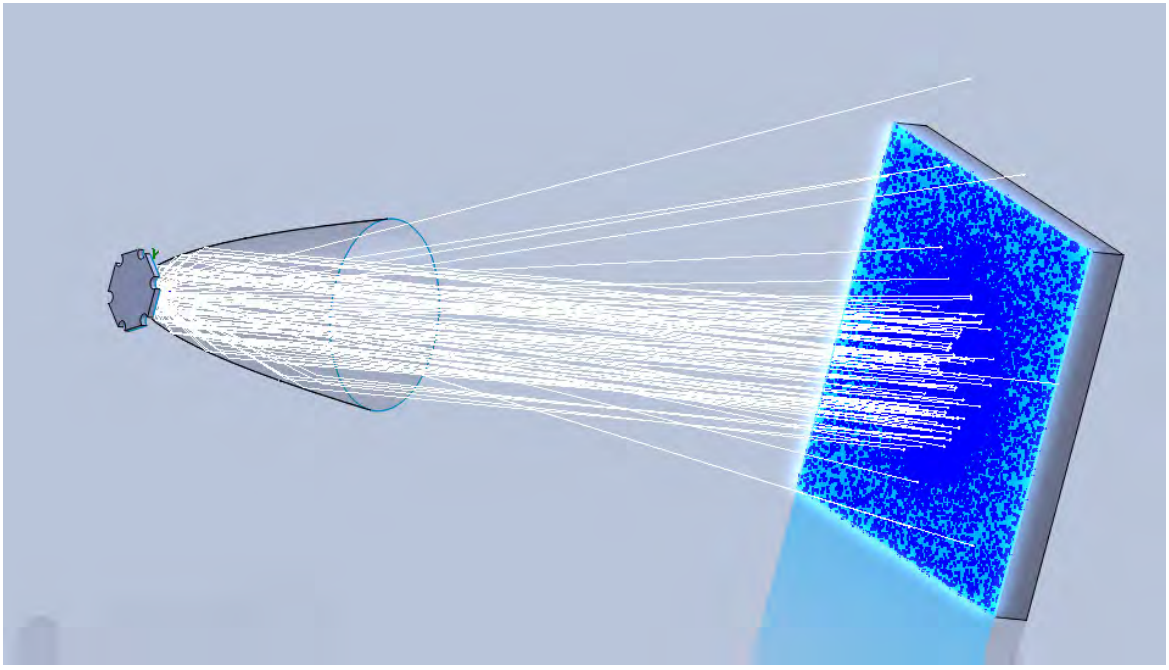


Figure 87 Results of the spots diagram calculation, overlaying the system model

Many more tools on the **Analyze** toolbar of the CommandManager are now available. Data can also be processed to account for statistical noise.

11 Right-click the node, **ResultSet_Irradiance_[*]** on the Optics Manager tree.

12 Click **Process Dataset** on the shortcut menu. See Figure 88.

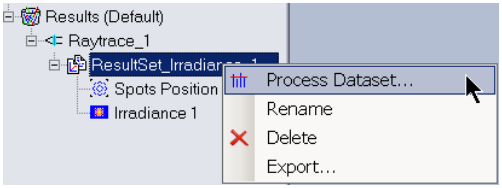


Figure 88 ResultSet shortcut menu on the Optics Manager

The Process Data PropertyManager is displayed.

13 Note the default settings under **Data** and **Average** on the Process Data PropertyManager, and click ✔ to accept the settings. See Figure 89.

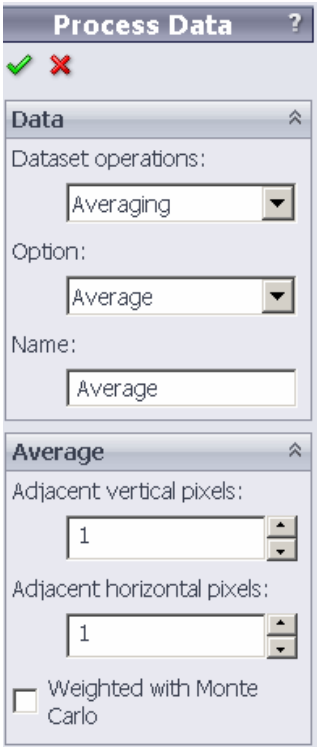


Figure 89 Process Data PropertyManager with default values

APEX averages the data over adjacent pixels to reduce the impact of statistical noise.

14 Click **Average_[*]** on the Optics Manager tree, and click the Picture Plot tool on the **Analyze** toolbar of the CommandManager. An Average node is now visible on the Optics Manager tree. See Figure 90.

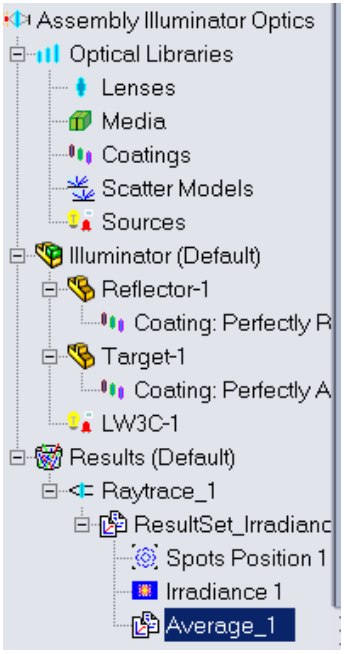


Figure 90 Results node for Average plot

15 Compare the results of the averaged data with the previous irradiance data. See Figure 91.

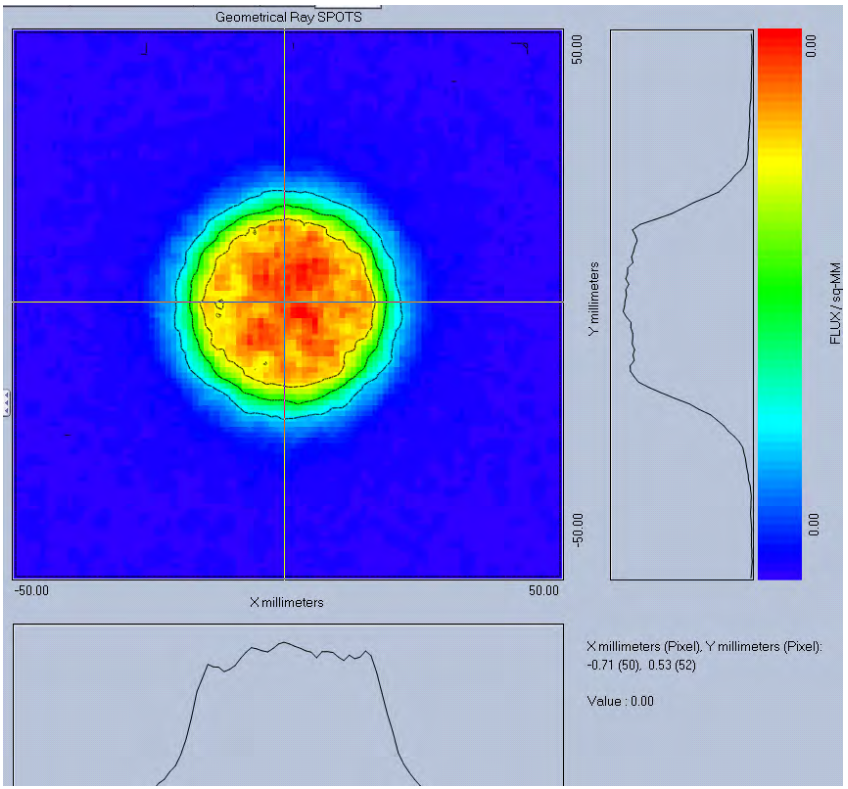


Figure 91 Results of averaged plot

***TIP* Appropriate use of averaging techniques can assist you in evaluating results of any measurement.**

An intensity calculation provides information about the direction the energy is traveling. If the system uses a point source positioned at the focus of the parabola, all rays that hit the reflector emerge as traveling parallel to the Z axis. However, the LED, although small, is not a point source, and not all rays emerging from the LED contact the reflector.

16 Click the 

tool on the **Analyze** toolbar of the CommandManager.

17 Click **Cosine space** and **Conversion to angle space** on the Intensity PropertyManager under **Plots**,.

18 Click the front surface of the target if it is not highlighted, and then click **Selected Surfaces** under **Geometry** on the Intensity PropertyManager. See Figure 92.

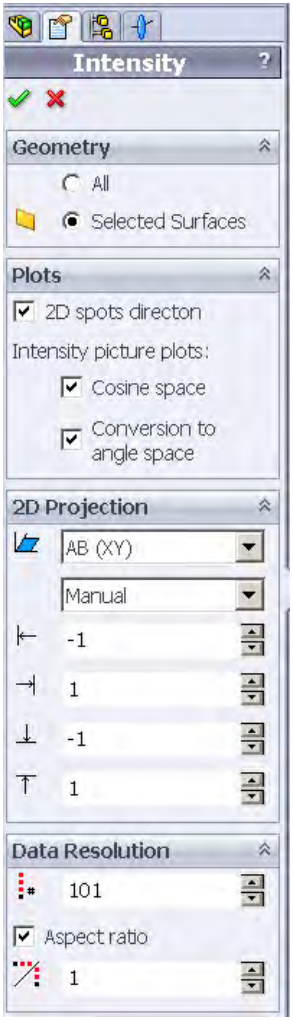


Figure 92 Intensity PropertyManager with selected options

STEP 4: PERFORM THE ANALYSIS

19 Click  to start the intensity calculation in direction cosine space. Figure 93.

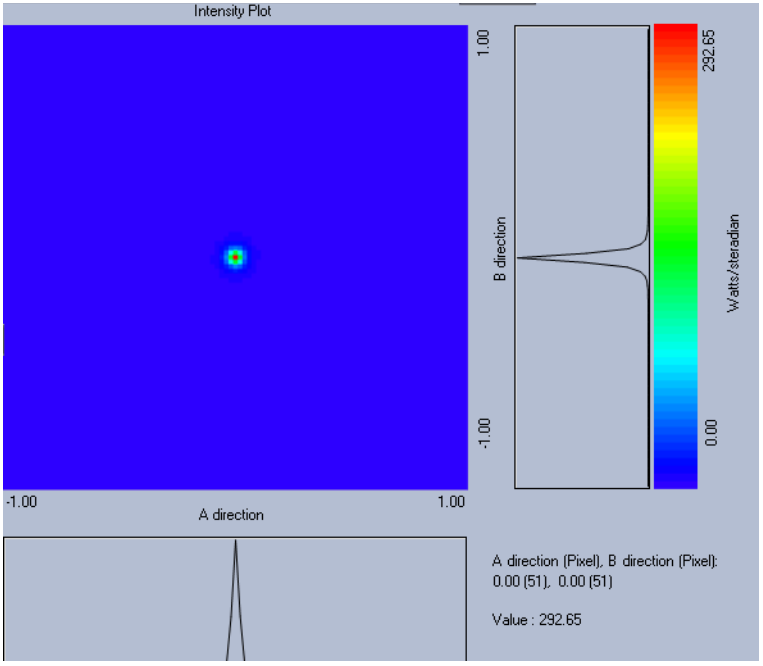


Figure 93 Intensity Plot in direction cosine space

20 Right-click the **Angles_1** node on the Optics Manager, and click **Process Dataset** on the shortcut menu to do the averaging.

21 Click **Average** and generate another picture plot.

22 Compare the averaged data in the direction cosine space (Figure 94) with averaged data in angle space (Figure 95).

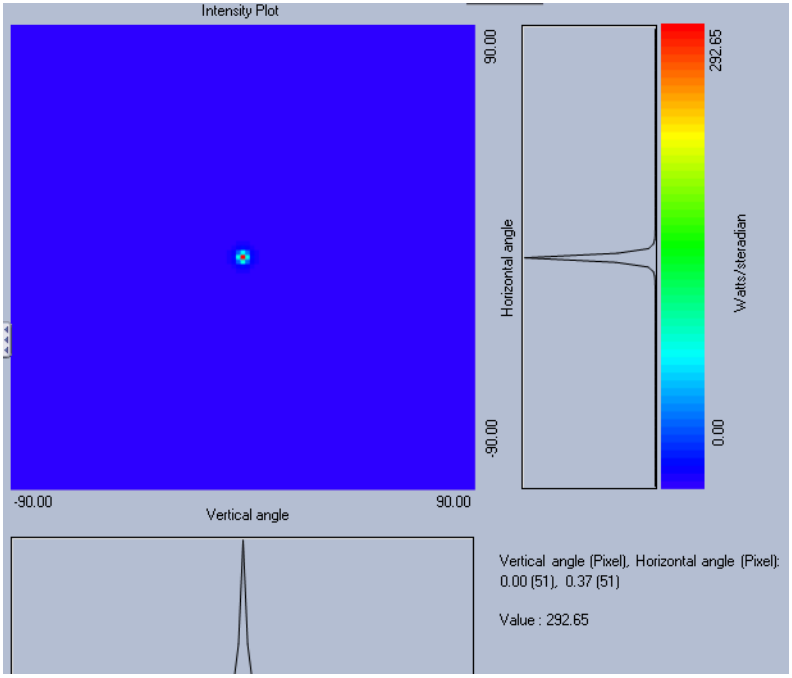


Figure 94 Intensity plot in angle space

STEP 4: PERFORM THE ANALYSIS

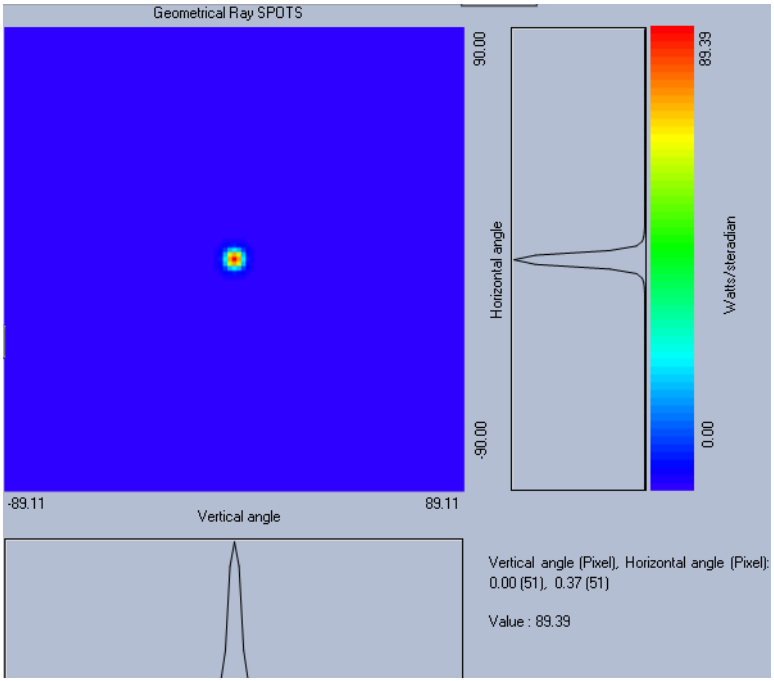


Figure 95 Averaged data plot in angle space

23 Click the **Distribution Section** tool on the **Analyze** toolbar.

24 On the **Distribution Section** PropertyManager, click **Z (XY Plane)** under **Section Normal Axis**, and click ✔. See Figure 96 and Figure 97.

Figure 96 Distribution Section PropertyManager with Z selected as the Section Normal Axis

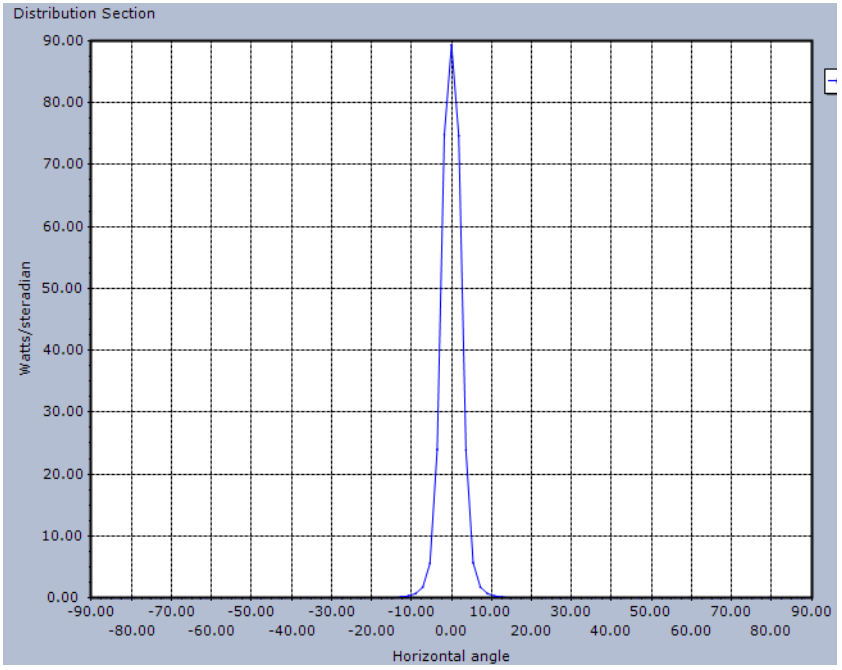


Figure 97 Distribution section results (data may vary from your results)

All measurable energy is incident on the target at angles of 10 degrees or lower, as is expected for such a design.

25 Save the file.

This completes Step 4 of the APEX workflow.

SUMMARY

This test drive demonstrates the four-step workflow process in APEX, using the combined capabilities of the SolidWorks CAD environment and BRO's powerful optical ray trace and analysis capabilities.

Only a small subset of the total APEX capability is explored in this example. The completed file can be used to explore any of the other analytical tools available in APEX, or different systems can be designed to further investigate the many possibilities of APEX.