Optimize

Non-Spherical Surfaces

There are many types of non-spherical surfaces in CODE V, ranging from conics and cylinders to diffractive optical elements. A conic should do fine in this case.

1. Right-click anywhere on surface 1 (Stop surface) in the Lens Data Manager window and choose Surface Properties from the shortcut menu.

2. Click Surface Type in the Surface Properties window's navigation tree (it may be selected by default).

Click the down arrow in the Type field and choose Conic from the drop-down list.

Note that the small spreadsheet to the right changes to add the new parameters available for the chosen surface type. The conic constant (K) defaults to zero. You can accept this value for now, but make it a variable for optimization.

3. Left-click the cell containing the conic constant. This selects the value.

4. Right-click the cell containing the conic constant.
5. Choose **Vary Parameter** from the shortcut menu.

Note that a small "v" appears next to the value to indicate its variable status. You need to do the same thing for the surface type and conic constant of surface 2.

6. Click the down arrow in the **Surface** field at the top of the window and choose **2 - Secondary**.

7. Change the surface type to **Conic** and make the conic constant variable, as you did for surface 1.

8. Click the **Commit Changes** button.

9. Close or minimize the Surface Properties window.

**Other Variables**

You will also vary the radius of curvature of the secondary, mainly to allow controlling the focal length of the system. You will finally also let the image surface thickness (defocus) vary, so AUTO can determine best focus.

1. Right-click the **Y Radius** value of surface 2 in the **Lens Data Manager** window and choose **Vary** from the shortcut menu.

2. Right-click the **Thickness** of surface 3 (Image) and choose **Vary** from the shortcut menu.
3. Save the lens with the File > Save Lens menu.

You are now ready to optimize the lens.

Running AUTO

The AUTO run for this lens will be very similar to the one for the first example. You almost always need to constrain EFL (effective focal length) or another quantity that holds the scale of the system (this time we want EFL=200 mm). You will also want to make a drawing of the lens on each cycle, as before. Instructions for these steps will be provided without illustrations (see Session 1 if you want to see these steps in more detail).

1. Choose Optimization > Automatic Design.
2. Click the Specific Constraints tab.
3. Click the Insert Specific Constraint button.
4. Choose the Optical Definitions category.
5. Choose Effective Focal Length and click Calculate Default Target (the value will be around 180 mm - not the desired value).
6. Choose = for the constraint mode.
7. Type 200 for the constraint target value.
8. Click OK to enter this EFL constraint.
9. Click the Output Controls tab.
10. Click the Draw system at each cycle checkbox and select Image for the end surface.

There is one new thing to add. Since this system can be nearly diffraction-limited, it is better to use an RMS wavefront variance error function rather than spot size.

11. Click the Error Function Definitions and Controls tab.
12. In the Error Function Type field, choose Wavefront Error Variance.
Saving Inputs for AUTO and Other Options

Before running the AUTO option, you can save yourself some future work by saving the settings used for this AUTO run. This feature is very useful when, as in this example, you have many inputs that you’d like to re-use in future CODE V sessions. You can save any number of named “option sets” for each option in CODE V.

1. In the Automatic Design dialog box, click the Option Set button.
   
The Option Sets dialog box is displayed.

2. Click the Save As... button.

3. Type a name for the option set, such as “cassf10 WFR EFL 200 draw” then click OK.

4. Click the Close button in the Option Sets dialog box.

   The next time you want to optimize with a set of commands like this, you can click the Option Set button, select the set you want, and click Load. You will then have all the inputs available—of course you can then change them and add others. Other options such as MTF, SPOT, TOR, etc., can each have multiple saved sets of inputs.

---

Tip: If you want to see the commands that are generated by the settings you have made in an option, you can click the Option Set button, then click the Preview button. You can’t modify the list of commands that is displayed, but you can select them and copy them (using the CTRL-C keys) for use in a macro, as an aid for learning the commands, or for reporting what you are doing to ORA technical support when they are helping you with a problem.
Now back to the optimization task at hand.

5. Click **OK** in the **Automatic Design** dialog box to run AUTO.

The resulting lens doesn't look all that different.

When AUTO completes, run another Quick Best Focus. You probably still have this window open, so you can just recalculate it for the optimized lens.

6. Click the **button to recalculate the WAV best focus.**
You can see that the lens is much improved. RMS values are now in the range of 0.04 to 0.11 waves, essentially diffraction-limited. You can confirm this with some diffraction analysis, but you'll first insert a fold mirror and look at some 3D lens pictures.

7. Choose the **File > Save Lens As** menu and give this optimized lens a new file name.
Inserting a Fold Mirror

Adding a Tilted Surface

Fold mirrors are one of the most common cases of a tilted or decentered system. CODE V has a number of features for handling non-centered systems, including a special form specifically for non-scanning folds called “decenter and bend.”

1. In the Lens Data Manager window, right-click on the Image surface and choose Insert from the shortcut menu.

2. Click OK in the Insert Surface dialog box to insert a single blank surface in front of the Image surface.

3. Select the thickness value for surface 2 and change it to 44.

Note that when you tab or click in another cell, the solved thickness value on surface 3 is recalculated to reflect the change just made.

<table>
<thead>
<tr>
<th>Surface #</th>
<th>Surface Name</th>
<th>Surface Type</th>
<th>Y Radius</th>
<th>Thickness</th>
<th>Glass</th>
<th>Refract Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sphere</td>
<td>Infinity</td>
<td>Infinity</td>
<td>Infinity</td>
<td></td>
<td>Reflect</td>
</tr>
<tr>
<td>1</td>
<td>Stop</td>
<td>Primary</td>
<td>-90.9091</td>
<td>-36.0000</td>
<td></td>
<td>Reflect</td>
</tr>
<tr>
<td>2</td>
<td>Secondary</td>
<td>Conic</td>
<td>-40.0000</td>
<td>44.0000</td>
<td></td>
<td>Reflect</td>
</tr>
<tr>
<td>3</td>
<td>Image</td>
<td>Sphere</td>
<td>Infinity</td>
<td>24.0000</td>
<td></td>
<td>Reflect</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Sphere</td>
<td>Infinity</td>
<td>-0.1327</td>
<td></td>
<td>Reflect</td>
</tr>
</tbody>
</table>

4. Double-click the Refract Mode for surface 3 and change it to Reflect.

Notice that the sign of the solved thickness 3 value has now automatically reversed, according to the sign convention for thickness values following a reflection (thickness values are positive after an even number of reflections, negative after an odd number). You will need to change the sign of the defocus as well (this is not a solved value).

5. Select the minus sign in front of the image surface thickness and delete it.

Now you have a mirror, but you need to tilt it to fold the light path (directing the light upward in this case, which will also move the image surface location).

6. Right-click anywhere on surface 3 and choose Surface Properties from the shortcut menu.

7. In the Surface Properties window’s navigation tree, click Decenters (under Advanced).
8. For the **Decenter Type**, choose **Decenter and Bend** from the drop-down list.

![Surface Properties](image)

9. Type a value of **-45** (degrees) for the alpha tilt (this will rotate the mirror in the YZ plane, directing the light upwards).

10. Click the **Commit Changes** button.

11. Click the Quick 2D Plot toolbar icon to see the folded system:

    ![Quick 2D Plot](image)

    The following plot is generated.

Add Thickness to the Mirrors

For these first-surface mirror surfaces, substrate thickness will not affect the ray trace, but it will make the lens pictures look more realistic, especially for 3D pictures. The substrate data are used in cost, weight, and environmental (temperature) change calculations. We can change the mirror substrate thickness in the **Materials** page of **Surface Properties**.
1. In the Lens Data Manager window, right-click on surface 1 (primary, Stop surface) and choose the Lens > Surface Properties menu.

2. In the Surface Properties window’s navigation tree, click Materials.

3. Enter a value of 1.0 in the Thickness field (First Mirror Substrate Data area).

4. Click the Commit Changes button.

5. Change the Surface field (upper left side of Surface Properties) to surface 2 (secondary).

6. Enter 0.6 for substrate thickness and click Commit Changes.

7. Change the Surface field to surface 3 (fold).

8. Enter 0.5 for substrate thickness and click Commit Changes.

9. Make a Quick 3D Hidden Line Plot by clicking this toolbar icon: 

   The following plot is generated.

10. Optional: Save this modified lens by choosing the File > Save Lens As menu.