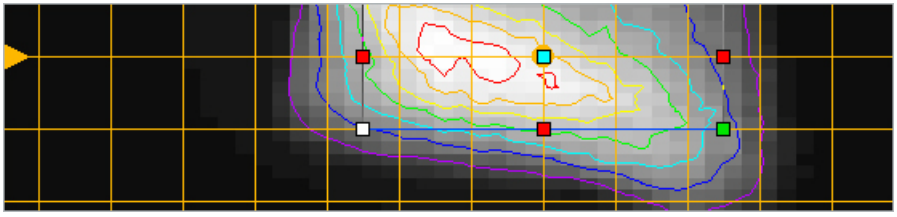
REFLECTORCAD

Segmented reflector design software



Test Guide

BREAULT RESEARCH ORGANIZATION, INC.
ISO 9001 CERTIFIED

This manual is for use with ReflectorCAD®.

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CHAPTER

1

QUICK TOUR

This quick tour introduces the basic principles of ReflectorCAD® from Breault Research Organization (BRO). Step-by-step instructions and illustrations are provided for building a simple reflector. Refer to ReflectorCAD Help for topics related to concepts, reference material, and tasks.

Reflector Design Workflow

ReflectorCAD typically embodies this five-step workflow in the design of reflectors:

1. Choose a base surface.
2. Select a light source.
3. Create and aim segments.
4. Adjust intersegment discontinuities.
5. Export the reflector design.

Choosing a base surface

All segments are initially created on the base surface. Vertex and segment heights are measured relative to it. Typically, this surface approximates the desired shape of the finished reflector. Simple, built-in base surfaces are provided. Virtually arbitrary surfaces also can be imported from an IGES file, using the utility, IgesToBaseSurf.exe, included with ReflectorCAD.

Selecting a light source

One or two light sources can be used. Only one source can be “on” at a time. The source is used for calculating the approximate output and aiming segments of the reflector.

Creating and aiming segments

Segments are created graphically. Each segment is directed to illuminate a specific region by moving and reshaping its aim box in the output view. Approximate reflector output (either positional or directional) can be quickly calculated at any time to aid in making aiming decisions.

Adjusting intersegment discontinuities

A typical goal is to minimize height discontinuities between segments, for both performance and manufacturing reasons. Where such discontinuities are necessary, they should normally be hidden, or shadowed, from the source to prevent undesired stray reflections. This is accomplished by adjusting segment aims and/or starting point heights. A simple method for checking edge shadowing is provided in ReflectorCAD.

Exporting the reflector design

Reflector designs can be exported to ASAP® (Advanced Systems Analysis Program) from BRO (via an INR file), or a CAD program (via an IGES file). Other geometric elements (for example, the bulb holder or shelves) can then be added. With this additional geometry in place, further analysis should be performed using an optical analysis package, like ASAP.

ReflectorCAD Window Layout

Figure 1.1 illustrates features of the main ReflectorCAD window. The reflector faces in the +Z direction and is viewed looking in the -Z direction. In other words, if the reflector were a headlamp, we would view it from in front of the car.

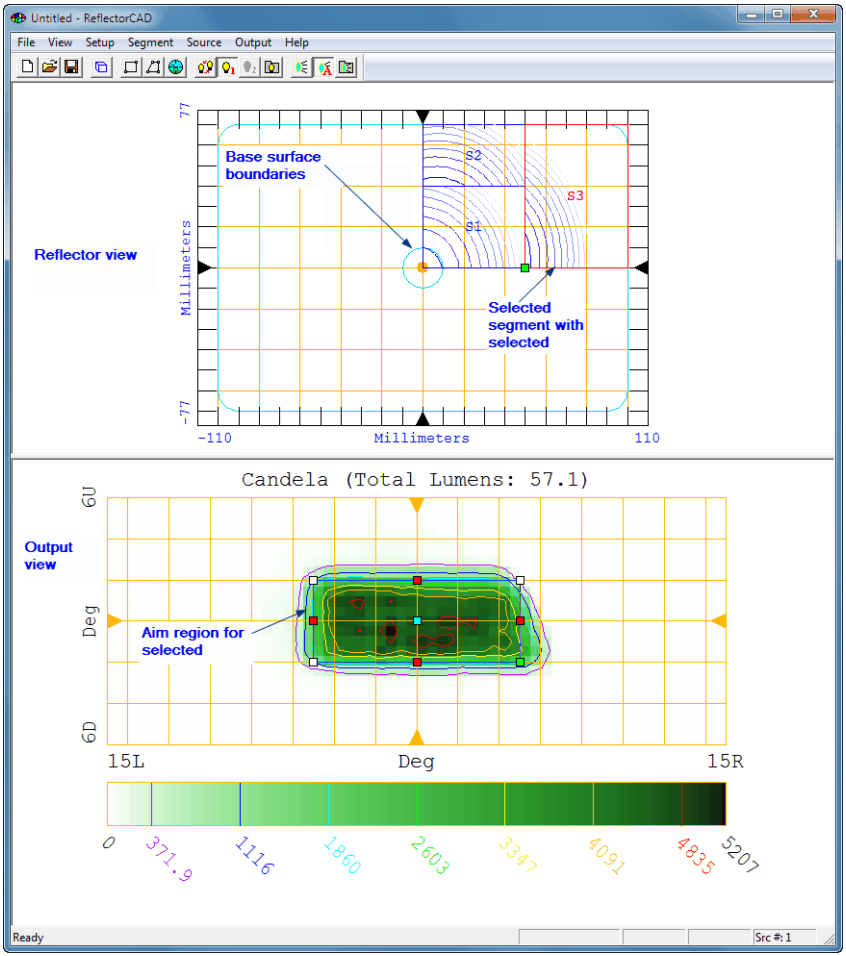

Figure 1.1 ReflectorCAD window with key features delineated. (In this figure, the window is shown in its vertical layout, with the reflector view above the output view. The layout can be changed to a horizontal view on the **View** menu.)

The output is viewed looking in the +Z direction, as if we were in the car looking at the output on a wall in front of the car. See Figure 1.2.

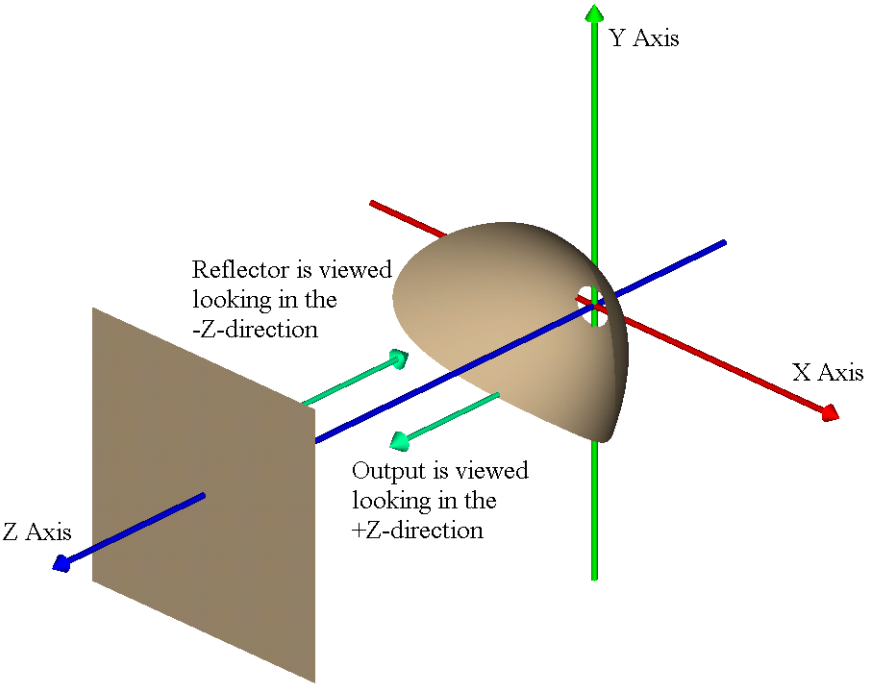

Figure 1.2 Viewpoint orientation for the reflector and output views

Design Goal

Our design goal in this quick tour is to create a reflector that produces an output pattern qualitatively similar to that shown in Figure 1.3.

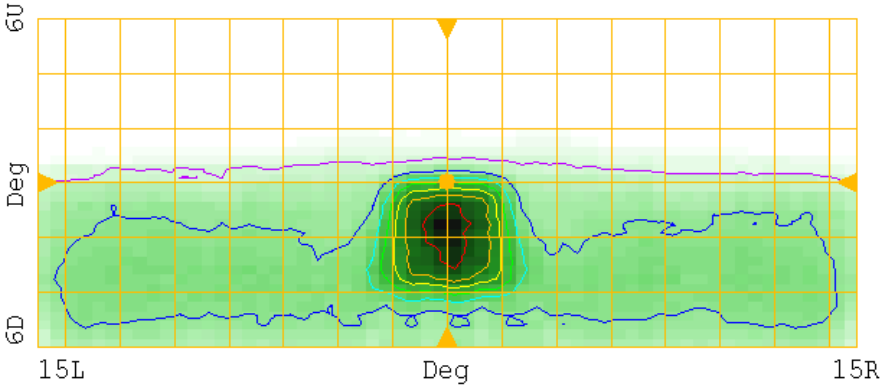

Figure 1.3 Desired output pattern for the reflector

We want a square hot spot at 2 degrees below the center and a relatively even spread from -15 degrees to 15 degrees horizontal and 0 degrees to -6 degrees vertical.

Preliminary Steps

After starting ReflectorCAD, the main window opens with a view similar to Figure 1.4.

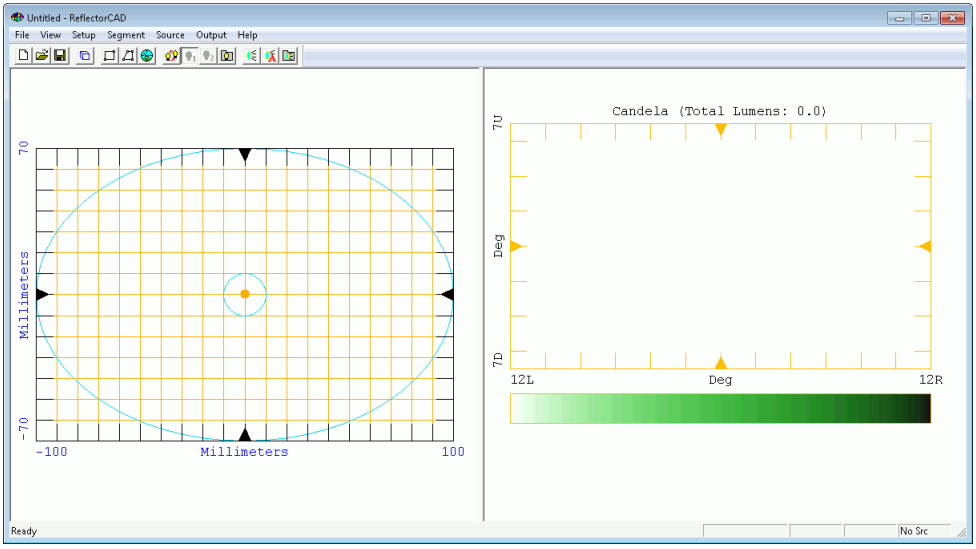

Figure 1.4 Initial display of the window, shown in the horizontal view

Before we can create our first segment, we must go through some preliminary steps. These steps include setting units, choosing a base surface, selecting a light source, and specifying the output properties.

Setting system units

- Click **System Units** on the **Setup** menu.
- Click **OK** to accept the default units, **Millimeters,** as shown in Figure 1.5.

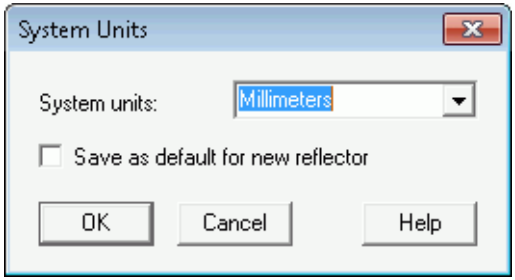

Figure 1.5 Setting system units

Defining a base surface

The base surface defines the height (Z coordinate) for the starting point of new segments. It also specifies boundaries of the reflector (in the X-Y plane).

- Click **Setup, Base Surface Properties**, complete the dialog box, as shown in Figure 1.6, and click **OK**.

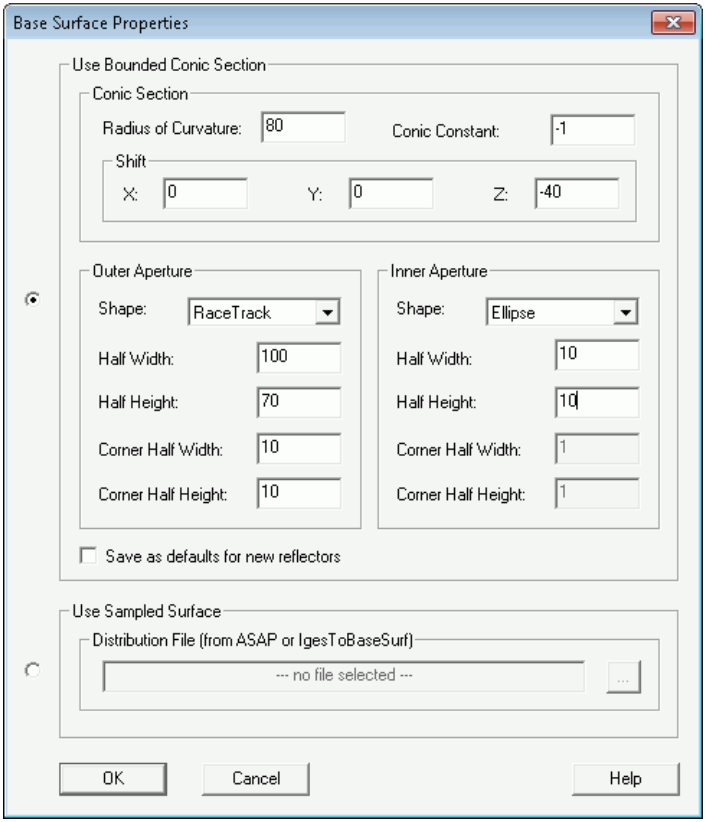

Figure 1.6 Setting the base surface properties

These properties make the base surface a parabola (because the **Conic Constant** is -1) with a focal length of 40 mm (because the **Radius of Curvature** is 80 mm). By shifting the base surface -40 mm along Z, we place the focus at the origin. The outer boundary is rectangular with rounded corners (called a racetrack). The circular inner boundary serves as the bulb hole.

Inserting a light source

1 Click **Source, Properties** or by clicking  on the toolbar.

2 Complete the Source Properties dialog box as shown in Figure 1.7, and click **OK**.

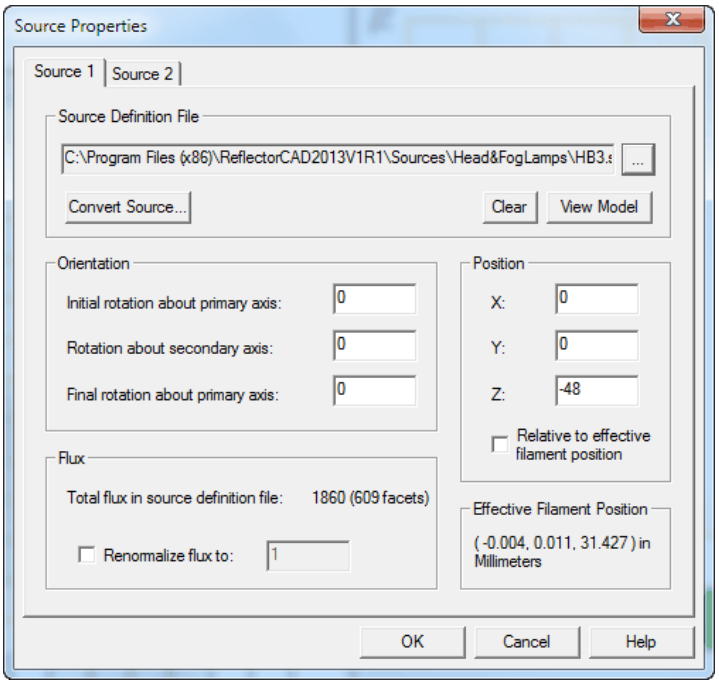

Figure 1.7 Setting source properties

3 Click  to select the bulb file from the source directory.

4 Click **View Model** in the dialog box to see details of the source model.

Note that the filament for this source is 31.5 mm above the reference point. We are positioning the reference point at (0,0,-48), which places the filament 16.5 mm inside the focus of the base surface at the origin.

When a valid source is selected, the **Effective Filament Position** (EFP) is reported in the lower right corner of the dialog box. This position is usually the best focus of the rays that are used to create this source model.

If the **Relative to effective filament position** box were checked (it should not be in this example), the EFP is used as the reference point of the bulb for positioning.

Since only one source is needed in this example, only the **Source 1** tab should be filled in. Click **OK** to close the dialog box.

Setting output properties

- Click **Output, Properties** (or click ), complete the dialog box as shown in Figure 1.8, and click **OK**.

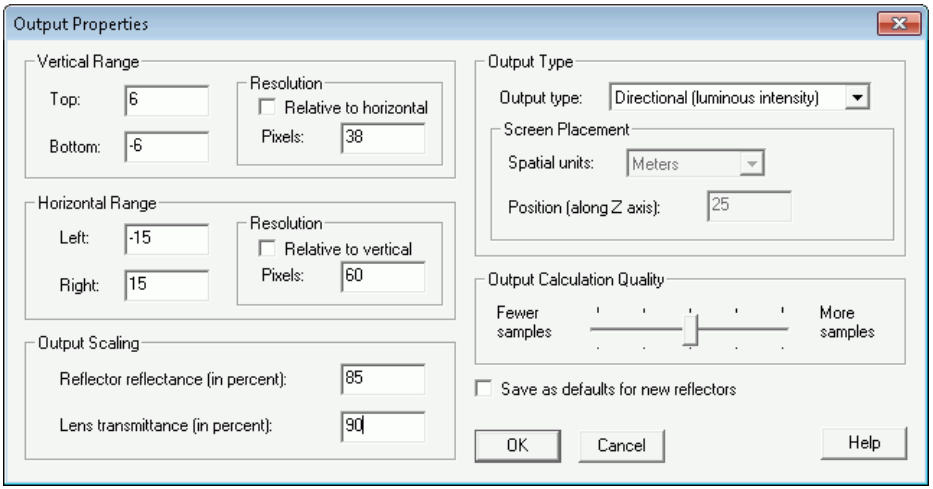

Figure 1.8 Setting output properties

For this example, we want far-field directional output with a vertical range of -6 to 6 degrees and a horizontal range of -15 to 15 degrees. The vertical range resolution is chosen to provide 3 pixels per degree, while the horizontal range resolution provides half-degree pixel spacing.

The **Reflector reflectance** (85%) and **Lens transmittance** (90%) act as simple scaling factors on the calculated output.

Using grids

ReflectorCAD provides grids to which you can set snapping intervals. These aid in positioning segment vertices and aim points.

1. In the reflector view, right-click and click **Grid/Snap Settings** on the shortcut menu. Complete the settings as shown in Figure 1.9 (left image). Click **OK**.
2. In the output view, right-click and click **Grid/Snap Settings** again. Complete the settings as shown in Figure 1.9 (right image), and click **OK**.

3 Right-click and confirm that **Enable Grid and Snapping** on the shortcut menu in each view is enabled.

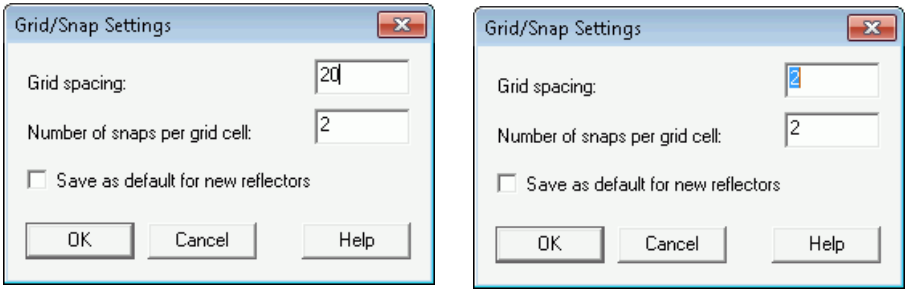

Figure 1.9 Grid/Snap Settings for Reflector view (left) and for Output view (right)

Setting default segment aiming

The default aim is assigned to new segments upon creation.

- Click **Segment, Default Aiming**, complete the dialog box as shown in Figure 1.10, and click **OK**.

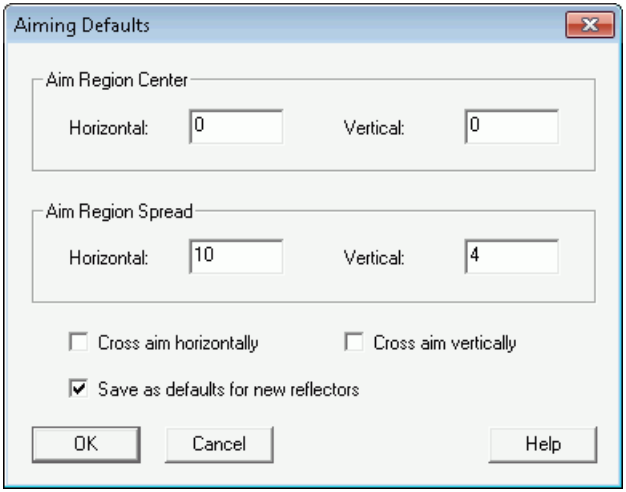

Figure 1.10 Setting default segment aiming

The settings give new segments a 10-degree horizontal and 4-degree vertical spread. When **Save as defaults for new reflectors** is selected, these defaults are in effect whenever ReflectorCAD starts.

Enabling automatic output recalculation

- Enable automatic output recalculation by clicking **Output, Auto Update** or clicking  (the button should look pressed in).

Reflector output is now calculated automatically whenever a relevant change is made.

TIP Because output calculation can often take several seconds, it may be faster to work with this option cleared when making a series of changes. In such a case, output can be calculated at any time by clicking  .

Creating and Aiming the First Segment

Now that we are done with the preliminary steps, it is time to create the first segment.

1. Click  .
2. Click the pointer at (0,0) in the reflector view, and click again to define the first corner.
3. Move the pointer to (50,40), and click to define the opposite corner.

TIP Refer to the current pointer coordinates that are displayed in the status bar at the lower right corner as you move the pointer to set the segment.

If you make a mistake while creating the segment, press the **Esc** key to cancel the creation. Alternatively, after any segment change (including creation of a new segment), click **Segment, Undo Last Segment Change** or press **Ctrl+Z** to undo the last change.

At this point, the reflector view should look similar to Figure 1.11.

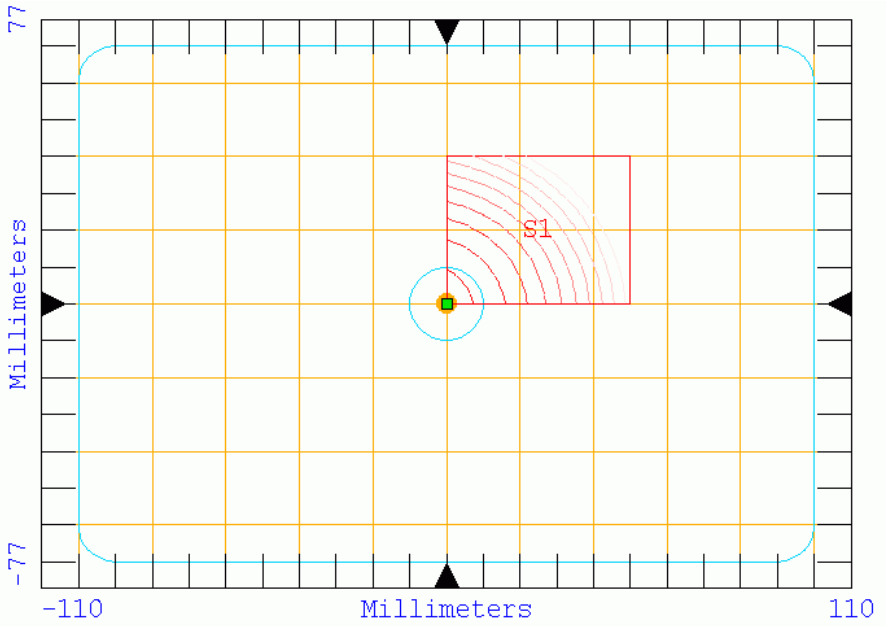

Figure 1.11 Reflector view after creating first segment

The new segment, labeled S1, is automatically selected as the current segment following its creation. The output produced by this segment is shown in the output view, and should look similar to Figure 1.12.

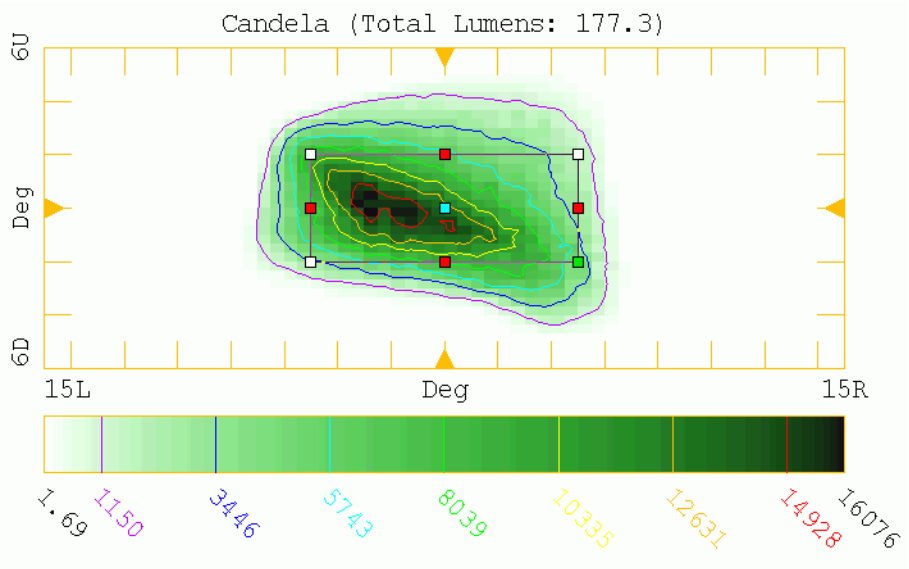

Figure 1.12 Output view after creation of first segment

When a segment is selected, its aim box is shown with the output.

- To clear a segment, click outside the segment of the reflector view area. Note that the aim box is no longer drawn in the output view. If no segment is selected, total output for all segments is displayed.
- To select the segment, click inside the segment.

The vertex closest to the cursor is highlighted with a green box when the segment is selected. If you click near another vertex inside the segment, that segment becomes the highlighted one. In the output view, the corresponding aim point is also highlighted with a green box. The box shows where on the output screen this particular vertex is to direct its light.

Changing segment properties

1. Click segment S1, right-click in the reflector view and click **Segment Properties** from the shortcut menu.
2. Complete the Segment Properties dialog box as shown in Figure 1.13.
3. Click **Save as defaults for new segments**, so all other segments we create will have these same properties, and click **OK**.

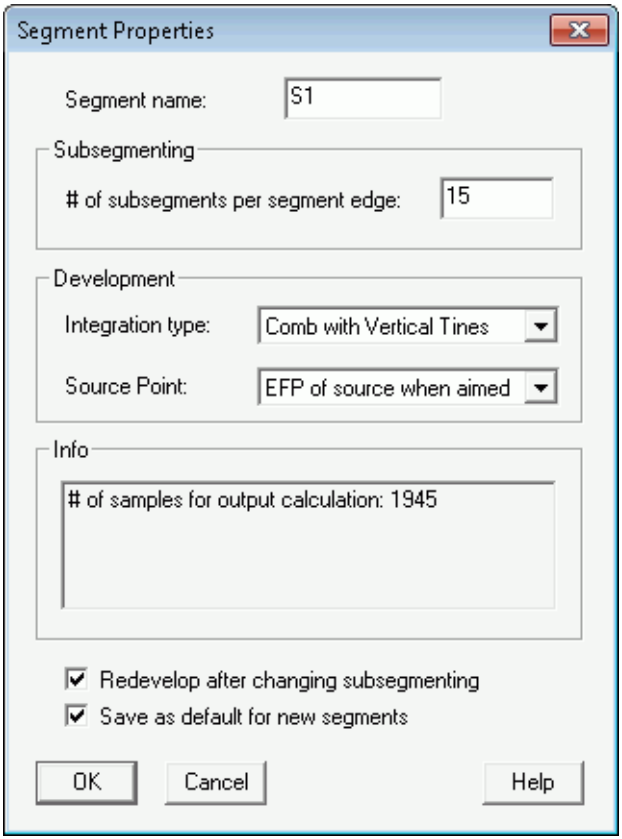

Figure 1.13 Setting segment properties for S1

Segment contouring

Contours are drawn inside the segment in the reflector view. They indicate height (along Z) as measured relative to the base surface. Red contours denote a positive (+) distance (for example, the segment is above the base surface), and blue contours denote a negative (-) distance. The contour colors fade as the height of the segment moves further from that of the base surface.

- Click **Segment, Contouring** to set the segment contouring properties, complete the dialog box as shown in Figure 1.14, and click **OK**.

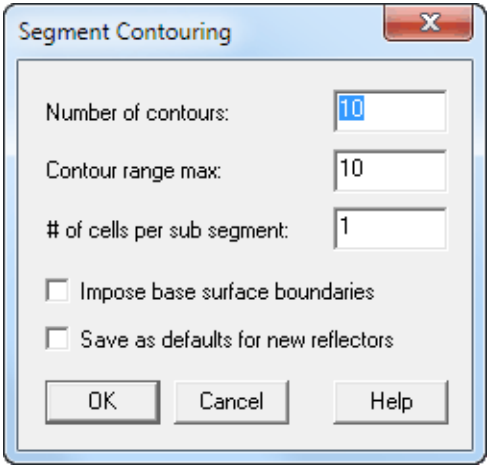

Figure 1.14 Setting segment contouring

With this setting, the contour range is from -10 to 10 millimeters, relative to the base surface, with 10 contours on each side of 0. Therefore, one contour is drawn for every 1 millimeter of deviation from the base surface.

Changing the aim of the segment

The next step is to change the aim of the segment.

1. Click inside the segment in the reflector view.
2. Right-click in the output view, and click **Move** on the shortcut menu.

3 Move the aim box to its new location, shown in Figure 1.15, and click.

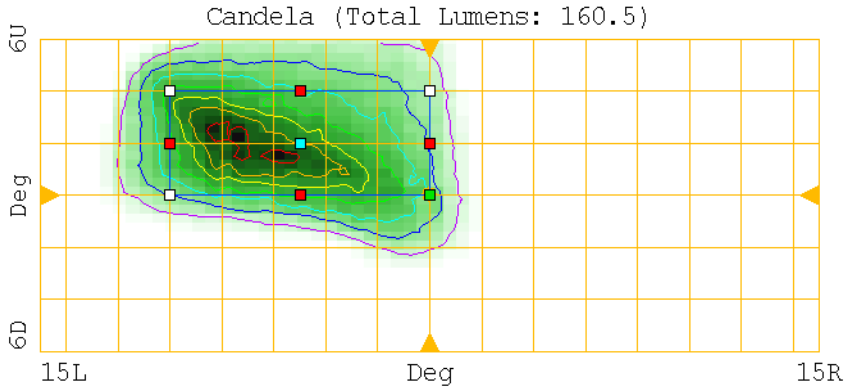

Figure 1.15 New location of segment aim box after move

4 Move the top edge of the aim box to a new location by dragging the corresponding red square, as shown in Figure 1.16.

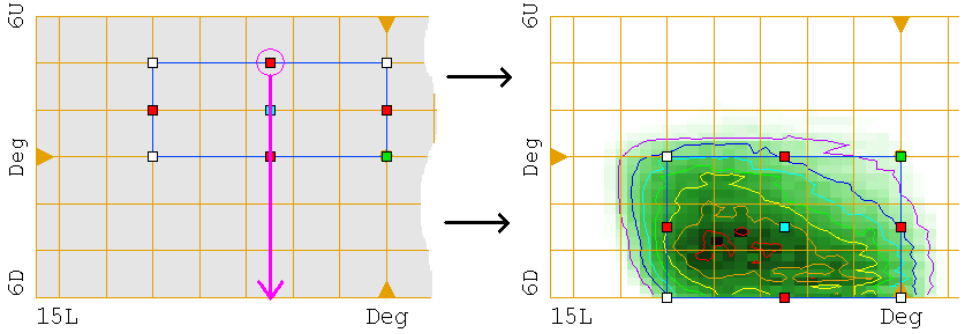

Figure 1.16 Dragging top edge of aim box

5 Drag the left edge as shown in Figure 1.17.

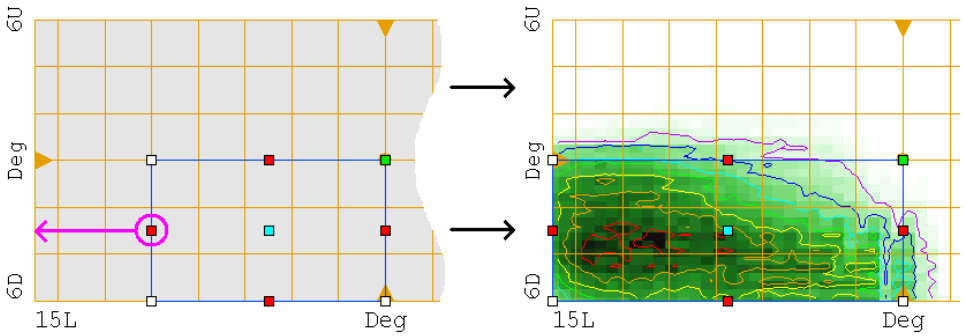

Figure 1.17 Dragging left edge of the aim box

Redeveloping the segment

Each time the aim of a segment changes, ReflectorCAD automatically reshapes the segment to achieve the desired aim. This reshaping is called developing the segment. The aim, along with the specified source point, is used to determine the necessary surface normals. These normals are, in turn, integrated, starting from the specified vertex (called the starting point), to form the new shape of the segment. By default, the starting point is the first vertex laid down when a segment is created. For our segment S1, the starting point is the lower left corner.

During integration, the prior shape of the segment is used as an approximation for its new shape to help evenly balance flux across the aim region. To the extent that the prior and new shapes are similar, this approximation is good. If the shape of a segment changes substantially, its performance often can be improved by redeveloping it after the last aim change.

1 Click segment S1.

2 Right-click in the reflector view and click **Redevelop** from the shortcut menu.

In this case, because the segment aim changes were small, the output pattern of the segment should change only slightly.

- At this point in the Quick Tour, save your work (**File, Save**).

Previewing in 3D

- To view the segment in three dimensions, click **View, Generate 3D View**.

After a few seconds, a separate 3D Viewer window should open, and its 3D view is similar to that in Figure 1.18.

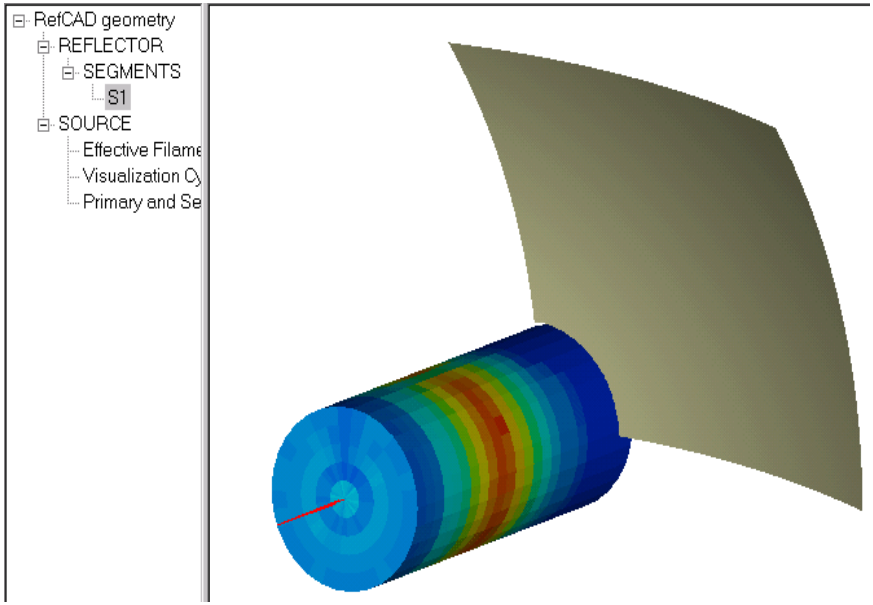

Figure 1.18 3D view of reflector with one segment created and aimed

The segment and a cylinder representing the source model are shown in the viewer. The view can be rotated by right-clicking and dragging the pointer. When you are done with the 3D Viewer, close it.

TIP For information on other available manipulations, see Help in the 3D Viewer.

Adding More Segments

Creating and aiming segment S2

1 Create a second rectangular segment, starting at (0,40) with the opposite corner at (50,70). The reflector view should now look like Figure 1.19.

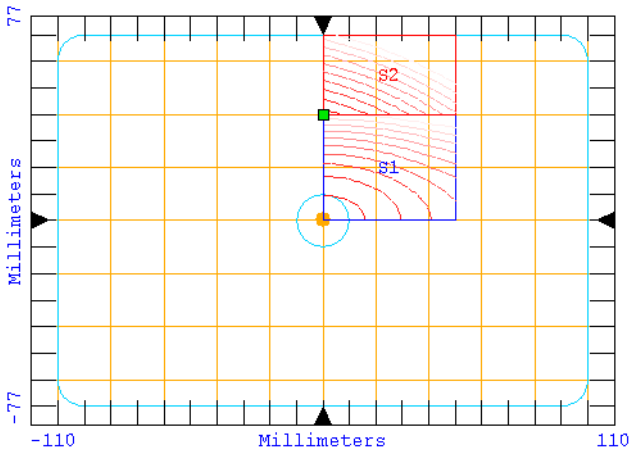

Figure 1.19 Reflector view following creation of second segment

2 Change the aim of the new segment as shown in Figure 1.20.

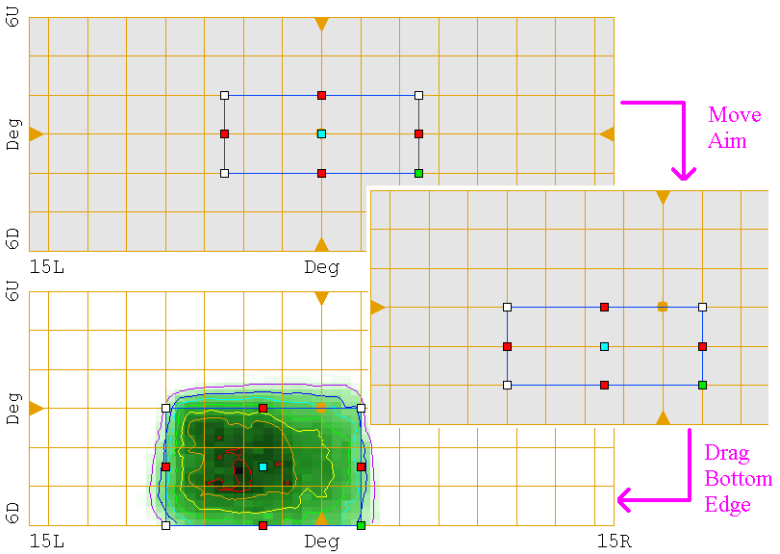

Figure 1.20 Changing aim of segment S2

Creating and aiming segment S3

1 Create a third rectangular segment, starting at (50,0) with the opposite corner at (100,70). The reflector view should now look like Figure 1.21.

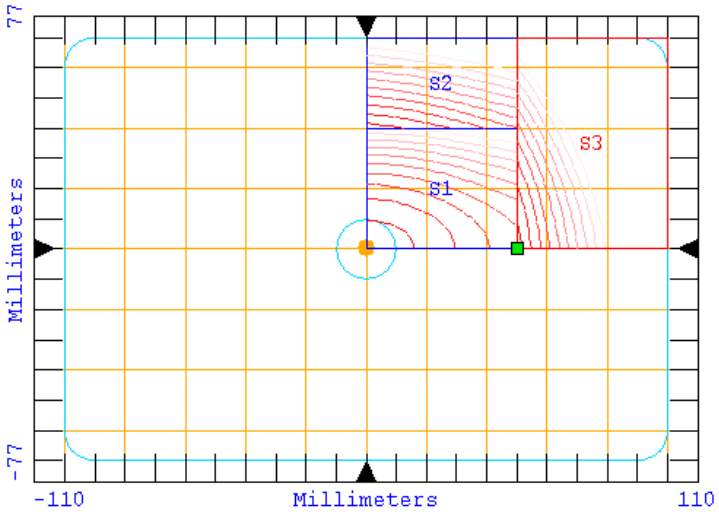

Figure 1.21 Reflector view following creation of third segment

2 Move and change the width of the aim box of the segment to match that shown in Figure 1.22.

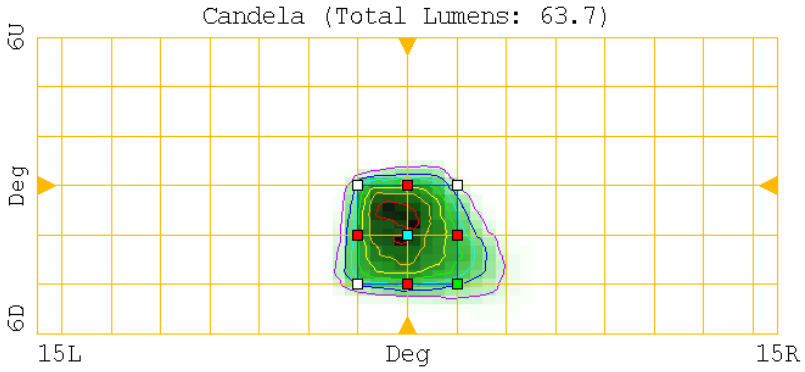

Figure 1.22 Output view showing desired aim for segment S3

3 Try clicking to select the different segments. Notice that only the selected output of the segment is shown in the output view. If no segment is selected, the combined output from all segments is shown.

Intersegment Discontinuities

Checking intersegment discontinuities

1 Click  to generate a three-dimensional view of the reflector. Rotate the view by right-clicking and dragging the pointer.

Note the discontinuities between adjacent segments, as shown in Figure 1.23. To avoid stray reflections in general, minimize such discontinuities and ensure they are hidden from the source (shadowed).

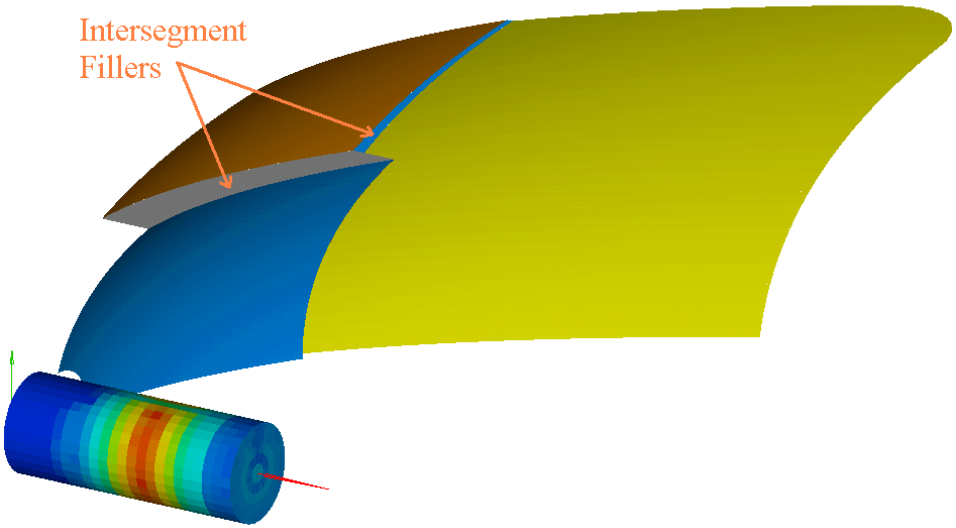

Figure 1.23 3D preview of reflector highlighting intersegment fillers

In this case, the discontinuity between segments S2 and S3 is exposed to the source. The other two discontinuities, while shadowed, are large.

ReflectorCAD also provides a more quantitative method for checking edge shadowing. To check the edge between segments S1 and S2:

1 Click S1.

2 Simultaneously hold down the pointer and shift key in S2 (note that this also works with S1 and S2 reversed).

A graph tip similar to that shown in Figure 1.24 is displayed. It indicates that S1 shadows the edge of S2 by at least 8.09 mm along their common edge. Since the edge is shadowed, the message text is colored green. If the edge had not been

shadowed, it would be colored red. The box containing -8.1 is conveying the same information as the graph tip, and indicates which edge is being checked.

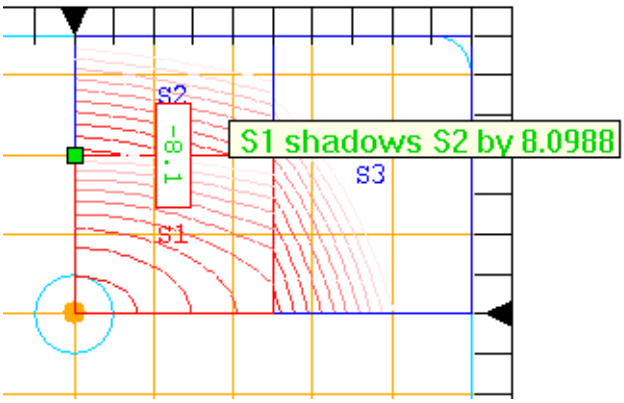

Figure 1.24 Checking edge shadowing between segments S1 and S2

Reducing intersegment discontinuities

The discontinuities can be reduced by adjusting the relative segment heights.

1. Select S2 and its lower left vertex by clicking inside S2 near this vertex (note the lower left vertex is chosen because it is the starting point of the segment).
2. Right-click and click **Vertex Properties** on the shortcut menu.

3 Change the position for **Z** to 5 mm above the base surface, as shown in Figure 1.25 (left side).

4 Proceeding in a similar fashion, change the lower left vertex (starting point) of S3 to have a Z Position of 2.7, as shown in Figure 1.25 (right side).

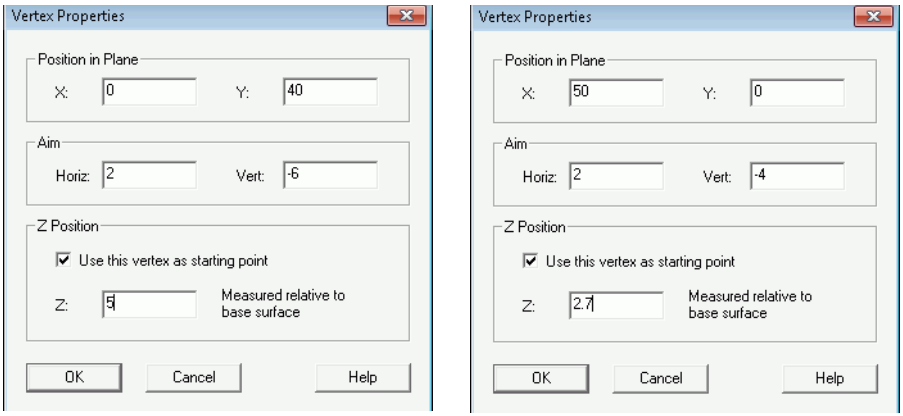

Figure 1.25 Changing height (Z position) of starting point for S2 (left) and S3 (right)

The discontinuity between S1 and S2 is now greatly reduced. In addition, the discontinuity between S2 and S3 is now shadowed.

Redeveloping all segments

Redevelop the effected segments (S2 and S3) at this time, since the segment height changes were fairly large. It is easiest to redevelop them all by clicking **Segment, Redevelop All Segments**, since there is only one unaffected segment.

- Save your work after redeveloping, and then generate a 3D preview to check the discontinuities.

Finishing the Reflector

Mirroring segments

At this point, the total output from the reflector, with only one quadrant complete, should look similar to Figure 1.26.

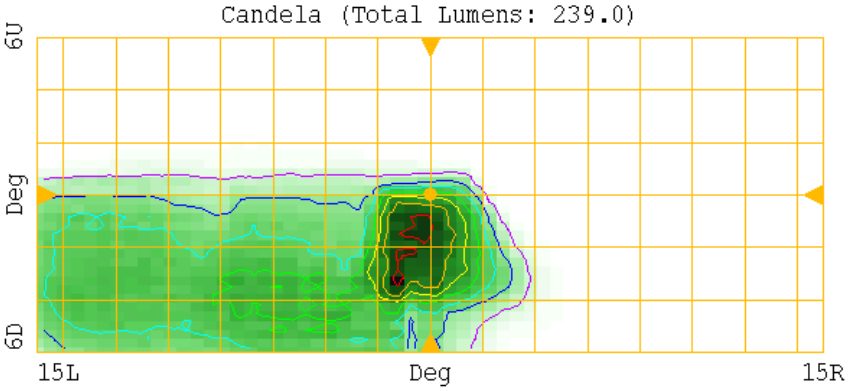

Figure 1.26 Total output from first quadrant

This output is essentially one-half the pattern we are looking for. The next step is to mirror the segments about the Y axis to produce the other half.

1 Click **Segment, Mirror Existing Segments** and complete the dialog box as shown in Figure 1.27 (left side). This step creates three additional segments with mirrored vertices and aiming (because **Mirror aim points** is selected).

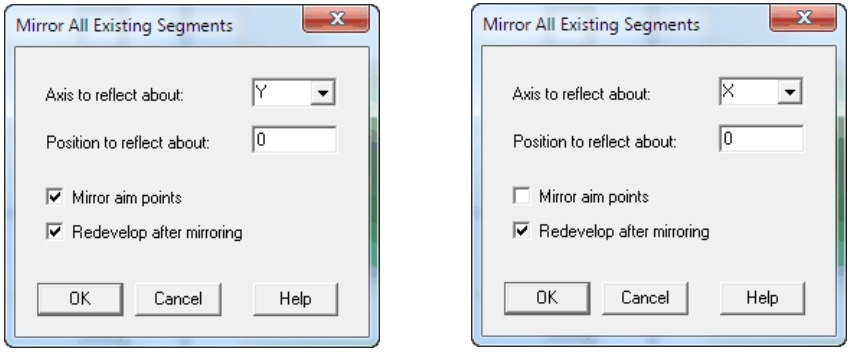

Figure 1.27 Mirroring about the Y axis (left) and X axis (right)

Because we want output only on the lower half, **Mirror aim points** should not be selected this time, as shown in Figure 1.27 (right side). With the top half finished,

2 Create the bottom half by mirroring about the X axis.

Replacing two segments

Generate a three-dimensional preview of the reflector. Note that the two segments in the center at the bottom (S8 and S11) have large discontinuities with their neighboring segments. Rather than adjust these segments, we are going to replace them with a single segment.

1 Click segment S8, and press **Delete** (or click **Delete Segment** from the shortcut menu).

2 Do the same for segment S11.

3 Create a new segment in their place, starting at (-50,-40) (the upper left corner), with the opposite corner at (50,-70).

4 Adjust the aim for the new segment as shown in Figure 1.28.

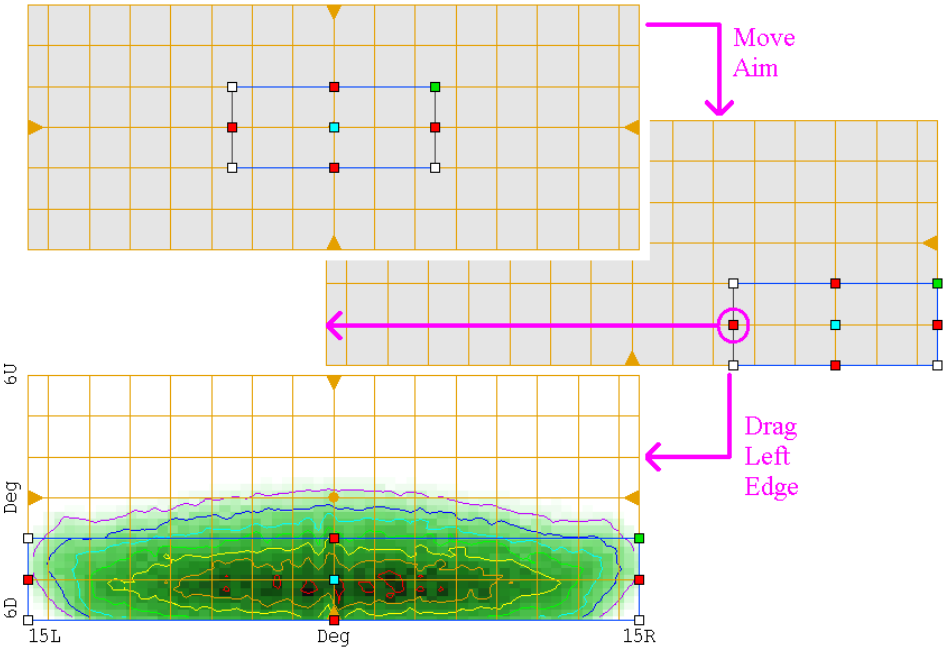

Figure 1.28 Adjusting aim of segment

5 Adjust the starting point height of the new segment. Click S13 within the segment, near the upper left vertex (the starting point of the segment).

6 Adjust its **Z Position** to 5 mm above the base surface.

7 Redevelop S13, because the height change is significant, by clicking **Redevelop** on the shortcut menu.

Viewing the finished reflector

The reflector should now be finished. This is a good time to save your work. The reflector view should look similar to Figure 1.29.

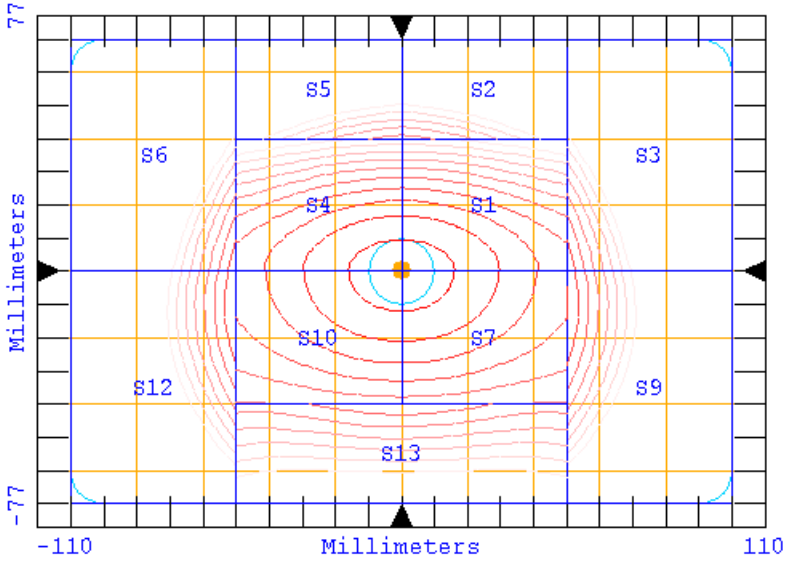

Figure 1.29 View of finished reflector

Figure 1.30 shows the total output for the reflector, which achieves our initial output goal. The basic quick tour of ReflectorCAD is now done.

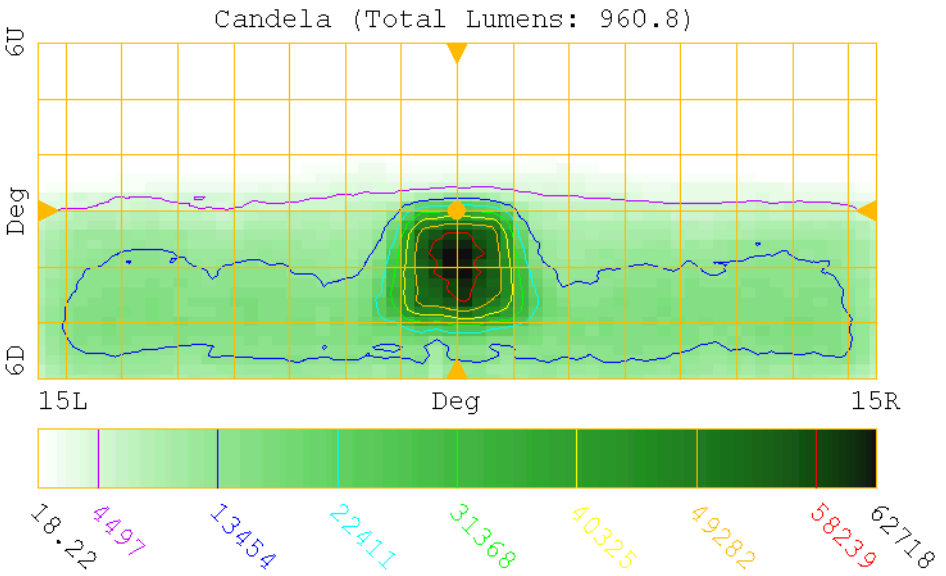

Figure 1.30 Total output of finished reflector

Chapter 2, ”Exploring More About ReflectorCAD” goes deeper into understanding ReflectorCAD and its capabilities.

CHAPTER

2

Exploring More About ReflectorCAD

This chapter outlines some aspects of using ReflectorCAD that were not introduced in the basic quick tour. These features are explored:

- Setting output contour levels
- Exporting to ASAP for further analysis
- Measuring vertical gradients
- Defining and assigning source points
- Using aim balance
- Output calculation quality
- Sub-segmenting
- Aiming mismatches
- Moving groups of vertices

Use the reflector that you created in the Quick Tour to follow in this chapter.

Setting Output Contour Levels

You may often want to have output contours drawn for specific levels.

1. Change the contour levels by selecting **Output, Contouring**. The dialog box, Output Contour Properties, is displayed.
2. Delete any existing contour set(s) by selecting them and clicking **Delete** in the Output Contour Properties dialog box.
3. Click **Add** to display the dialog box, Contour Set Properties, which is used to add the single value contours for the levels shown in Figure 2.1, and click **OK**.

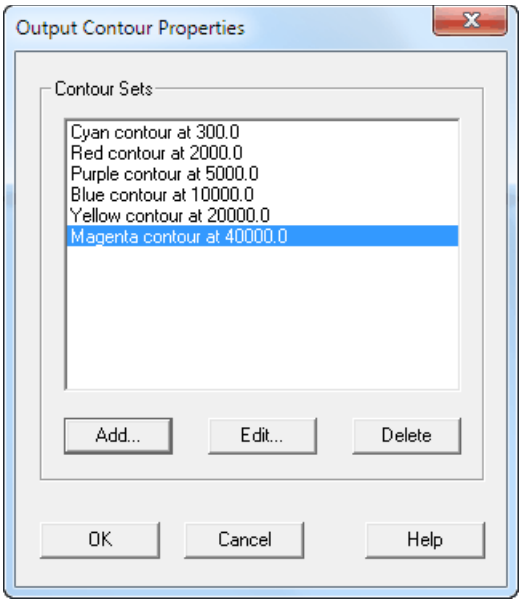

Figure 2.1 Setting fixed contour levels

Contour display is controlled with the **Show** setting in the **Output Contour Properties** dialog box (**Output, Appearance**).

Exporting to ASAP for Further Analysis

Please keep in mind that ReflectorCAD output calculations are approximate (see ReflectorCAD Help for more details).

A more thorough evaluation of the reflector should be performed using an optical analysis program, such as ASAP. Generally this evaluation should be done after completing the design in ReflectorCAD, and again, after all remaining geometric elements (for example, the bulb holder, lens, and shelves) are added to the design.

- To export the reflector design to an ASAP input file, click **File, Export, To ASAP** and complete the dialog box as shown in Figure 2.2.

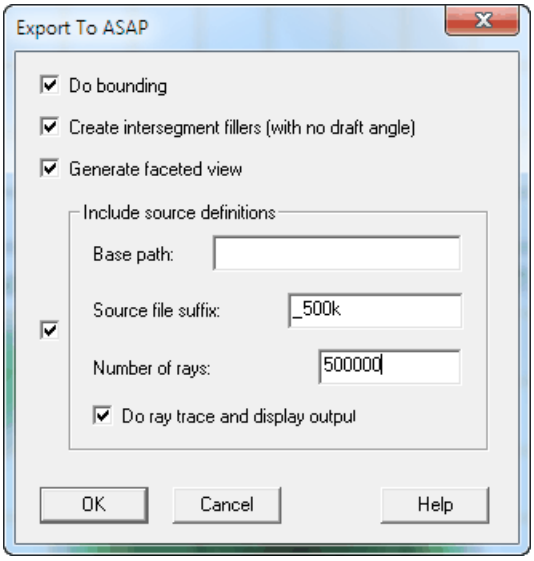

Figure 2.2 Exporting to ASAP

TIPS

- A stored ray set for the HB3 bulb, which our reflector design uses, must be available or generated before the exported file is run in ASAP.
- The **Base path** must be the directory where your ASAP light source files are stored.
- The **Source file suffix** entry shown assumes that the 500,000 ray version of the source is used.
- The **Base path** and **Source file suffix** are combined with the name of the source (HB3) to form the complete source file name, which is used with the `EMIT DATA` command in the ASAP input file.

When run in ASAP, the resulting output resembles that shown in Figure 2.3. The corresponding output calculated in ReflectorCAD is also shown for comparison.

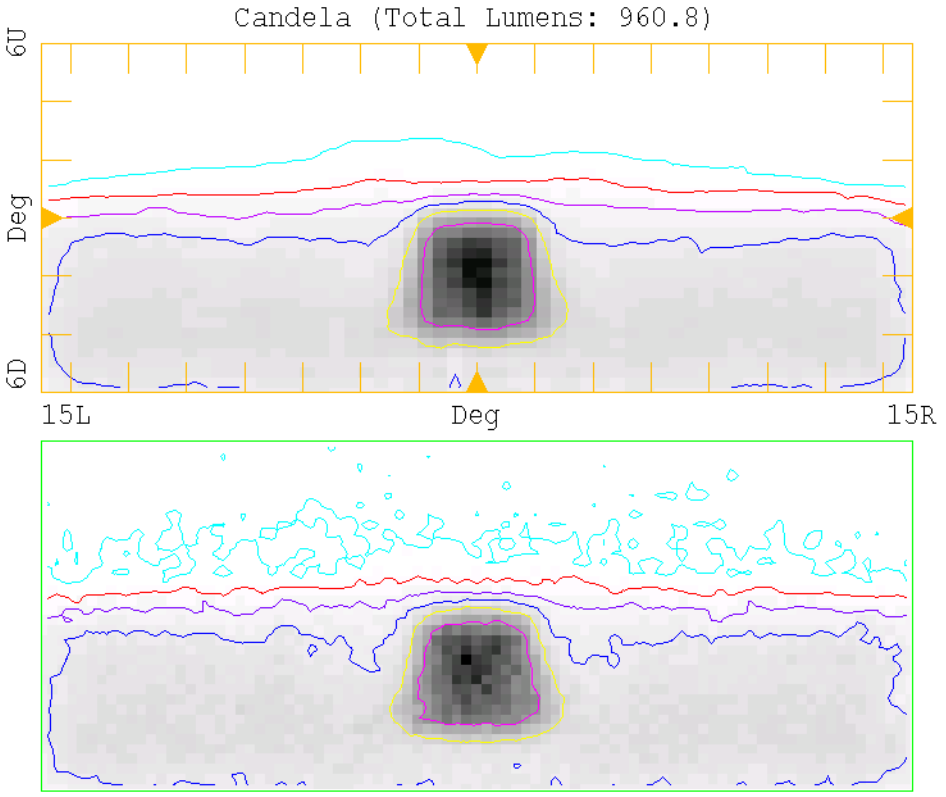

Figure 2.3 Comparison of output calculated in ReflectorCAD (upper frame) and ASAP (lower frame). (The ASAP calculation used 500,000 source rays and yielded a total flux of 957 lumens. Contours were added manually in the ASAP display window.)

Measuring Vertical Gradients

ReflectorCAD provides a convenient method for measuring vertical gradients in the output of the reflector.

1 In the output view, right-click and click **Gradient Query Settings** on the shortcut menu. Complete the dialog box as shown in Figure 2.4.

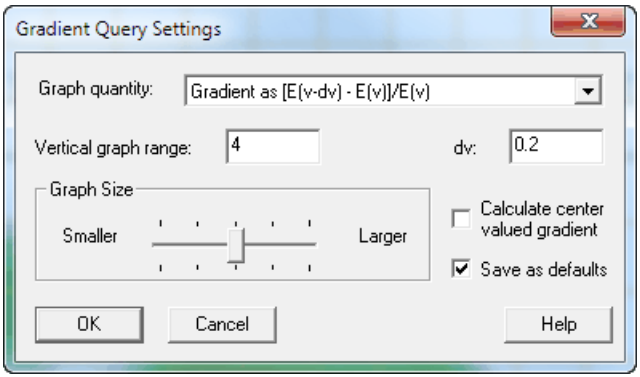

Figure 2.4 Gradient measurement settings

2 To measure the vertical gradient in the output, click the output view while pressing the **Ctrl** key.

A small graph popup window, similar to that in Figure 2.5, opens.

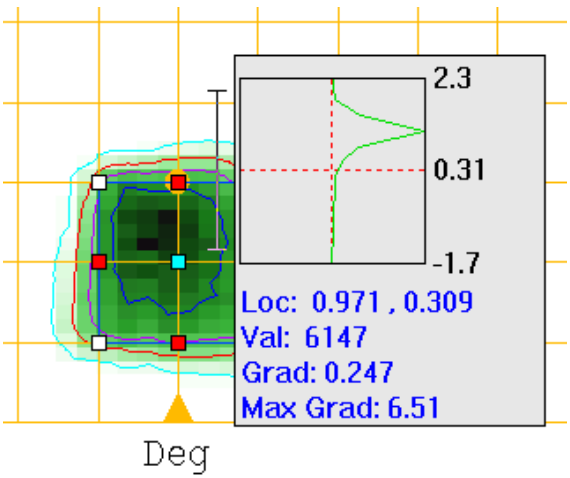

Figure 2.5 Measuring vertical gradient for output of segment

As the pointer is moved, the graph and values change. The plot shows the vertical gradient calculated along the I-shaped cursor. The gradient (**Grad**) at the pointer

location and the maximum gradient (**Max Grad**) along the pointer bar are among the values displayed.

The Gradient Query Settings dialog box controls the method that is used for gradient calculations (click **Help** on the dialog box for more information).

Defining and Assigning Source Points

When we are trying to achieve sharp vertical cutoffs, using a filament end as the source point may help in developing a segment. While the present example reflector does not try to produce sharp cutoffs, we can still use it to see how this feature works.

1 Click **Source, Source Point Properties, Add** to add a new source point at the inner end of the filament: (0,0,-19), and give the new point the name **Inner Filament End**. The dialog box should look similar to Figure 2.6.

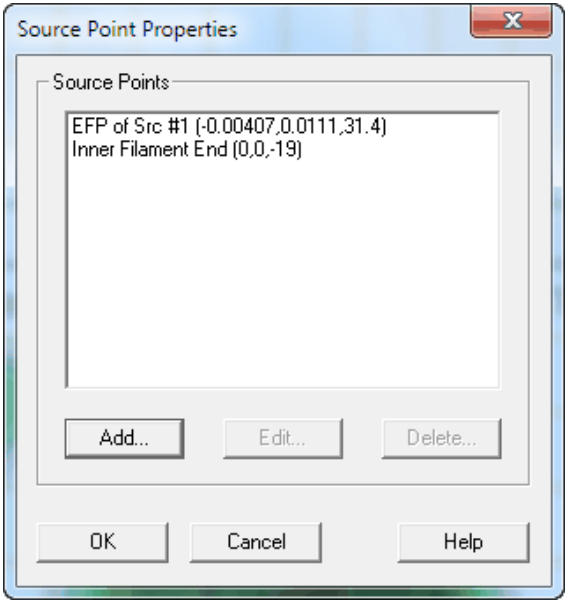

Figure 2.6 Adding a source point at the inner filament end

2 Click segment S2 and change its aim to a horizontal line by dragging the bottom edge up.

The resulting aim should look like Figure 2.7. Due to the size of the filament, the output pattern has significant flux, up to 2 degrees on either side of the horizontal.

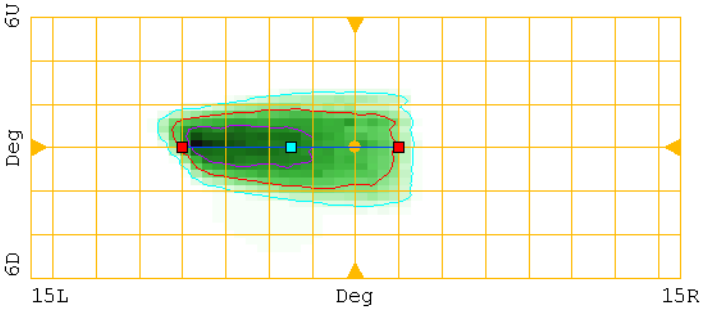

Figure 2.7 New Aim of S2

Note that the peak vertical gradients (measured with the settings used in RefCAD2_MoreExploration.fm35) vary between 2 and 7.

1. With S2 selected, right-click in the reflector view and select **Segment Properties** from the shortcut menu.
2. Change the source point of the segment source point to **Inner Filament End**.

The output pattern should now resemble Figure 2.8.

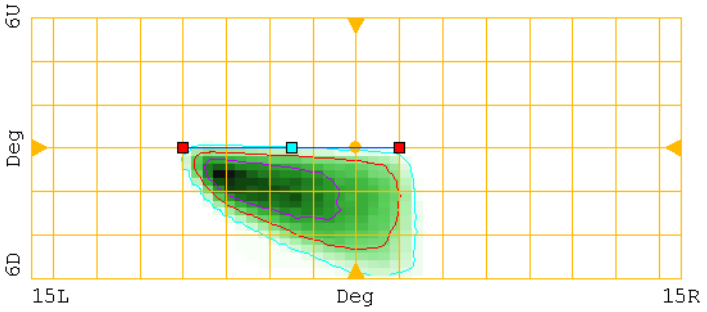

Figure 2.8 Output pattern for segment S2 with filament used as source point

Notice that the output essentially cuts off at the horizontal. Peak vertical gradients now range between 4 and 15.

Using an Aim Balance Point

In addition to the vertex aim points, ReflectorCAD provides an aim balance point that allows flux to be directed preferentially to one region of the aim box.

1. Click segment S5. Its aim balance point (the small cyan square) is currently centered, so its aim balance is neutral. In this case, ReflectorCAD attempts to spread light evenly throughout the aim region.
2. Drag the balance point to one side of the aim region to direct more flux to that side.

Figure 2.9 shows the resulting output patterns for several aim balance positions.

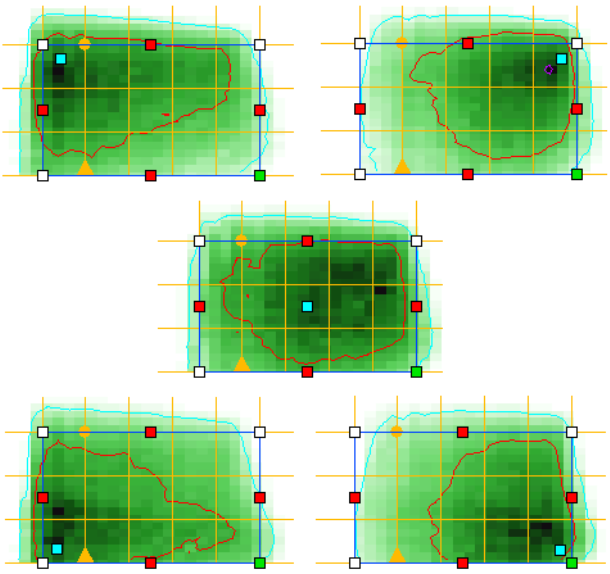

Figure 2.9 Impact of different aim balance settings on output pattern for segment S5

Output Calculation Quality

ReflectorCAD provides a control for output calculation quality in the Output Properties dialog box. To see the effect of this control on output for a specific segment,

1. Click segment S7.
2. Click Output, Properties on the menu or click  .
3. Vary the **Output Calculation Quality** setting, noticing that as quality increases the output becomes smoother and that calculation time increases. Figure 2.10 shows S7's output for three quality settings.

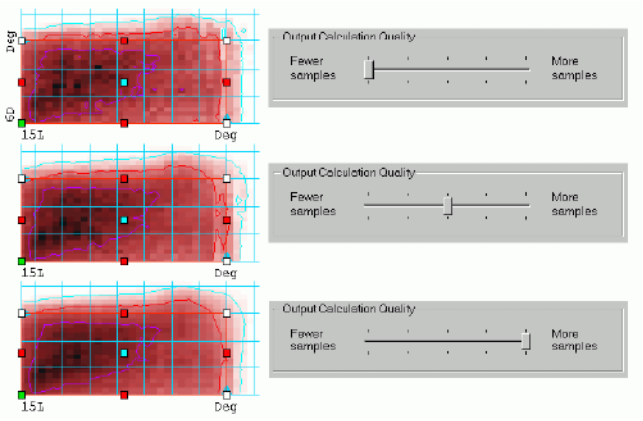

Figure 2.10 Calculated output for segment S7 at three quality settings

See "Appendix A: Comparison of Output Calculated by ReflectorCAD and ASAP", and the Help topic, "Calculation Output Method in ReflectorCAD", for more information.

Grid Resolution (Sub-segmenting)

In ReflectorCAD, a segment's surface is defined as a grid of second-order Bezier patches. The grid resolution (sub-segmenting) for a given segment can be set in its Segment Properties dialog box. To see how sub-segmenting affects output beam performance,

1. Click segment S13.
2. Right-click the Reflector view and select **Segment Properties** on the shortcut menu.
3. Change the **# of subsegments per segment edge** to 3 under **Subsegmenting** on the Segment Properties dialog box, as shown in Figure 2.11, and click **OK**.

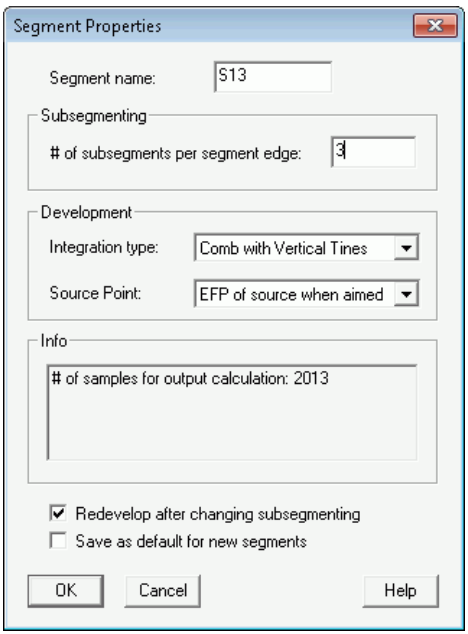

Figure 2.11 Setting grid resolution (sub-segmenting)

Note that the output pattern for S13 now has two prominent hot spots, instead of the relatively even pattern it previously produced.

See Figure 2.12. In each case, the hot spots in the output pattern correspond to output from a single subsegment, or column of subsegments.

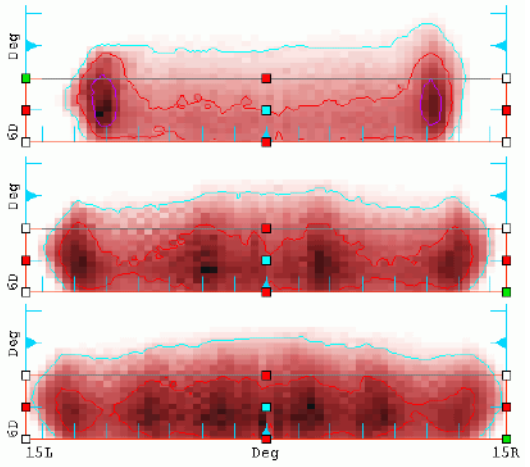

Figure 2.12 Output produced by S13 with subsegmenting settings of 3 (upper frame), 5 (middle), and 7 (lower).

Aiming Mismatches

Sometimes ReflectorCAD cannot produce a segment that achieves the specified aim. Each aim, when combined with the specified source point, corresponds to a field of surface normals. ReflectorCAD essentially integrates these surface normals to form the segment's surface, but not all normal fields correspond to an actual surface. In such cases, the segment that is produced by the integration process may fail to achieve the desired aim.

To illustrate this, consider segment S7. By selecting its various vertices, and noting their associated aim points, notice that horizontal variations in its aim correspond to horizontal spatial variations across the segment. Similarly, vertical aim variations correspond to vertical spatial variations. This is shown in the upper frame of Figure 2.13. To see what happens when this correspondence is flipped,

1 Click S7 and its lower right vertex in the Reflector view.

2 Right-click in the Output view, and click **Swap Corners** on the shortcut menu.

This exchanges the aim points of the current vertex with those diagonally opposite it.

The segment's horizontal/vertical aim and spatial differences are now mismatched, and the output pattern no longer achieves the desired aim, as shown in the lower frame of Figure 2.13. In general, segments with such mismatches rarely produce the desired pattern.

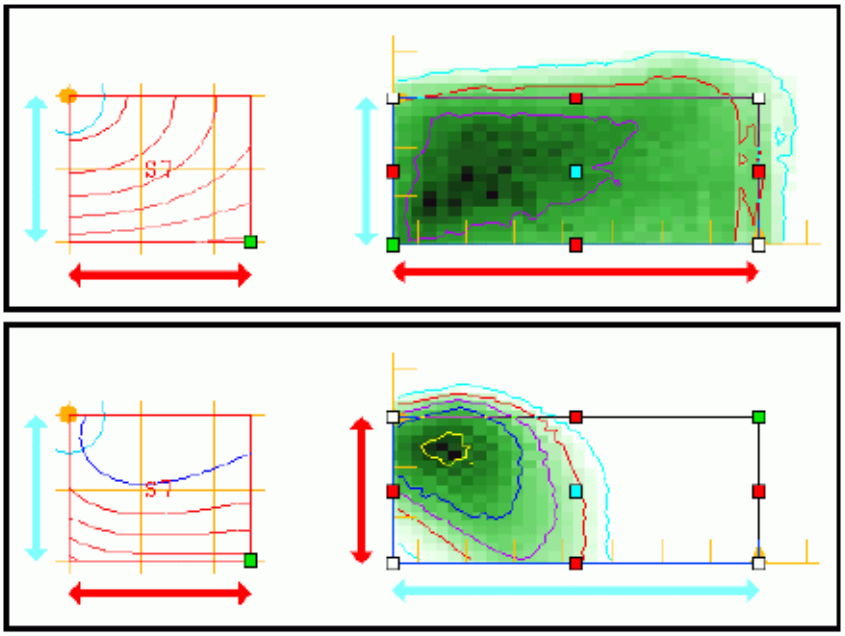

Figure 2.13 The upper frame shows segment S7 aimed so that horizontal and vertical aim differences correspond to horizontal (red arrows) and vertical (cyan arrows) spatial differences, respectively. The lower frame shows the same segment with horizontal/vertical aim and spatial differences mismatched.

Shifting Groups of Vertices

ReflectorCAD provides an easy way to shift a group of segment vertices by a specific distance in the X-Y plane. Try out this feature by shifting the vertices that lie along a particular line in our current reflector.

1 Press the **Ctrl** key and drag the pointer in the Reflector view to enclose the vertices, and release the pointer. See Figure 2.14.

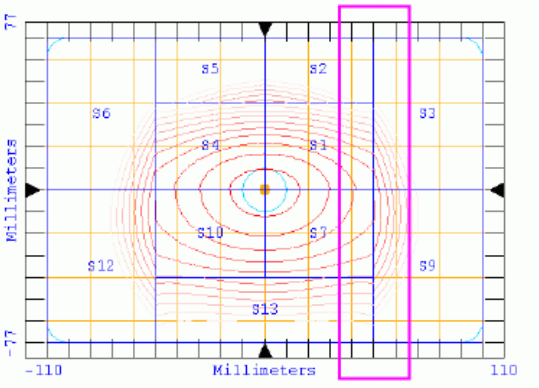

Figure 2.14 Shifting a group of vertices. The rectangle shows the vertices to enclose for shifting.

2 Type the desired shift in the Shift Multiple Vertices dialog box, as shown in Figure 2.15.

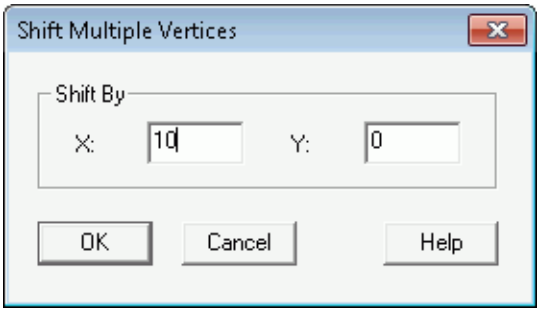

Figure 2.15 Setting the shift for a group of vertices

This setting shifts all the enclosed vertices 10 units to the right. After the shift is performed, all the affected segments are first reset to the base surface and then redeveloped according to their aiming. This has the side effect of undoing any starting point offsets that the affected segments may have had. As with other segment changes, this change can be undone by pressing **Ctrl-Z** or clicking Segment, Undo Last Segment Change.

Learn more about ReflectorCAD in ReflectorCAD Help.

APPENDIX A: COMPARISON OF OUTPUT CALCULATED BY REFLECTORCAD AND ASAP

This appendix compares output that is calculated by ReflectorCAD and ASAP, for the VisualAimLowBeam example, which is in the ReflectorCAD installation folder. This reflector is not an actual headlamp – it is the first-pass at a conceptual design intended to meet the visual aim standard.

Figure A.1 and Figure A.2 show the output calculated by ReflectorCAD and ASAP, respectively. Comparing contours, the results agree well. The peak output values are 31,637 for ReflectorCAD and 32,664 for ASAP, while total flux on the screen is 575.9 lumens for ReflectorCAD and 594 for ASAP.

The approximate output calculated by ReflectorCAD does not include light that travels from the source directly to the screen, while the ray trace performed in ASAP includes everything. Consequently, we expect the numbers from ASAP to be slightly larger than those from ReflectorCAD. A separate ray trace, with just the source and detector screen, was performed to quantify this effect. The total flux due to direct illumination was found to be 16.5 lumens. Subtracting it from the total number for ASAP, we now get 577.5 lumens for the total flux, which agrees well with the value calculated by ReflectorCAD.

On a 500 MHz Pentium-series processor, ReflectorCAD took 30 seconds to calculate output for the entire reflector. Since most design changes affect only a portion of the reflector, output can typically be updated in just a few seconds when working in ReflectorCAD. ASAP took a little more than two hours to perform the calculation, using 2 million rays (pre-traced through the bulb's geometry) for the source model. The bulb's geometry was not present during the trace with the reflector. The ASAP results were averaged horizontally (using the `AVERAGE 0 2` command).

We also compared vertical gradients in the region between 1 and 3 degrees right. Figure A.3 shows three screen dumps of the interactive gradient-query tool in ReflectorCAD for this region. The gradient, in this case, is calculated as a partial derivative along the vertical direction. Peak values vary between 23,700 and 26,400. Figure A.4 shows the relevant results from ASAP. Peak derivative values vary between 23,300 and 25,600.

For purposes of headlamp testing, vertical gradients are typically not defined as derivatives. For example, SAE J1735 of January 1995 (Harmonized Vehicle Headlamp Performance Requirements) defines the vertical gradient as,

$$G(v) = \frac{\left[I(v-0.2) - I(v) \right]}{I(v)}$$

where $I(v)$ is the intensity at vertical angle *v* (measured in degrees). Using this definition, screen dumps of the gradient measurement in ReflectorCAD are shown in Figure A.5. Peak values range from 0.857 to 0.994. The corresponding plots for the output calculated by ASAP are shown in figure A.6. Peak values, ranging from 0.857 to 0.887, agree well with those from ReflectorCAD. Figure A.7 shows the gradient query settings used in ReflectorCAD for the screen captures shown in figure A.5.

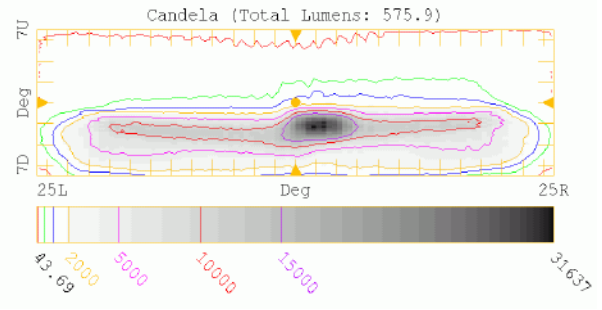

Figure A.1 Output calculated by ReflectorCAD. Resolution is 70 pixels vertical and 100 pixels horizontal. Calculation quality is at the middle (default) setting. The standard ReflectorCAD source model for the 9005 bulb (with approximately 600 facets) was used.

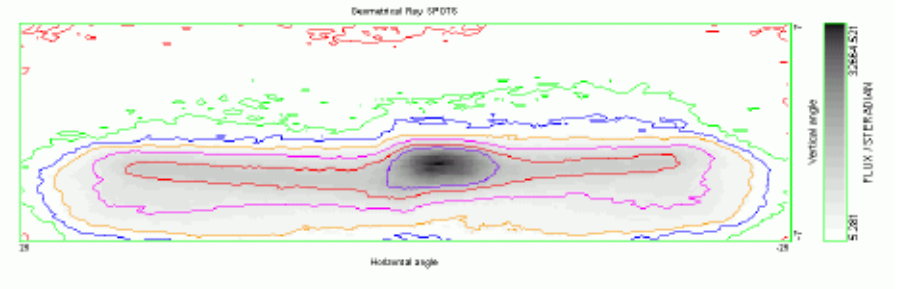

Figure A.2 Output calculated by ASAP. Resolution is 70 pixels vertical and 243 pixels horizontal

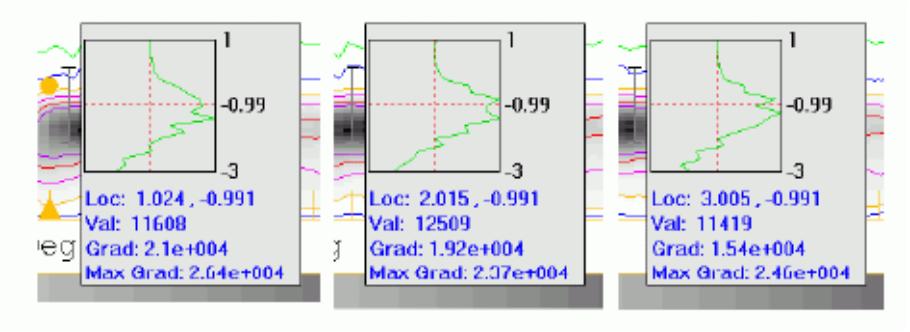

Figure A.3 Vertical derivative for output slices along 1, 2 and 3 degrees right, as measured in ReflectorCAD, using the gradient query feature

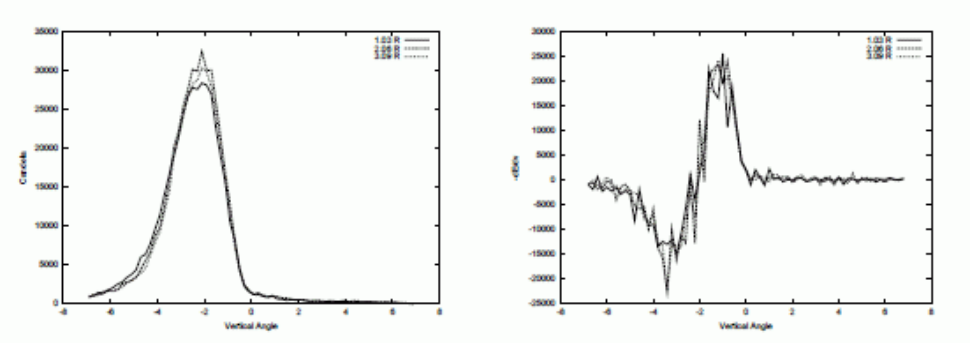

Figure A.4 Vertical slices along 1, 2 and 3 degrees right, showing the output (left) and vertical partial derivative of the output (right), as calculated by ASAP

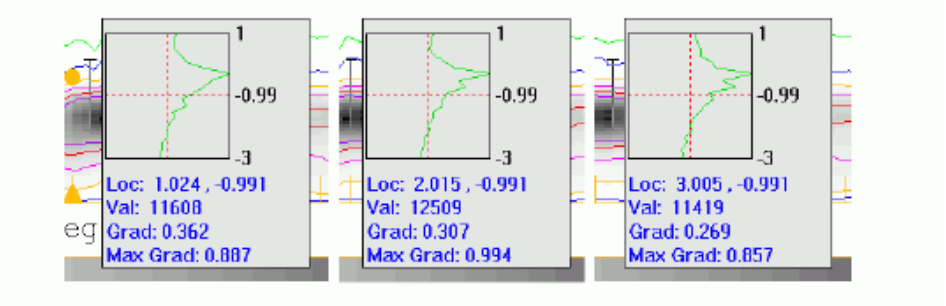

Figure A.5 Vertical gradients for slices of output along 1, 2 and 3 degrees right, as calculated by ReflectorCAD

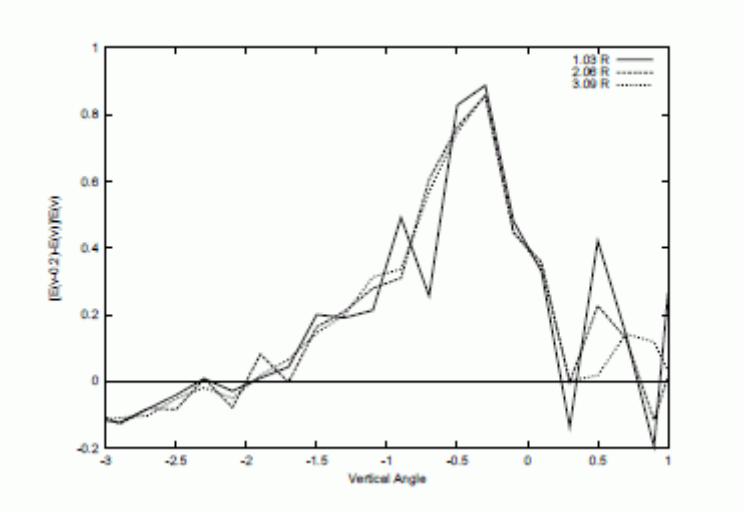

Figure A.6 Vertical gradient for slices of output along 1, 2 and 3 degrees right, as calculated by ASAP

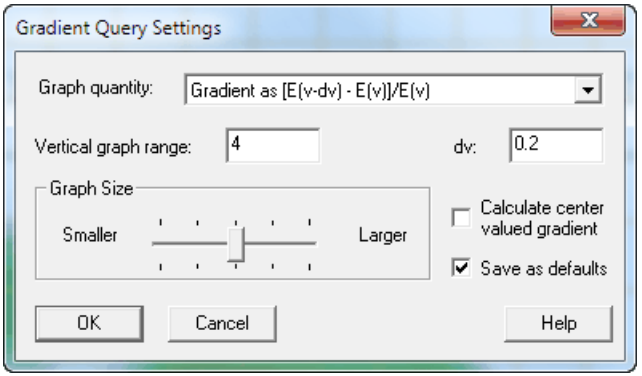

Figure A.7 Gradient query settings used in ReflectorCAD for measurements shown in Figure A.6

Table A.1 summarizes the results of this comparison. Overall, there is good agreement.

Quantity	ReflectorCAD	ASAP
Total Lumens	575.9	594
direct illum. subtracted		577.5
Peak Candela	31,637	32,664
Calculation Time	$\sim$ 30 seconds	$\sim$ 2 hours
Peak Vertical Derivatives		
1° Right	26,400	25,600
2° Right	23,700	23,300
3° Right	24,600	24,200
Peak Vertical Gradients		
1° Right	0.887	0.887
2° Right	0.994	0.857
3° Right	0.857	0.859

Table A.1 Summary of results, calculated by ReflectorCAD and ASAP

NOTE Remember that the quick output engine in ReflectorCAD makes use of several approximations, the validity of which can vary between reflectors. For typical uses, it achieves accurate results, but *you must verify the performance of finished designs* by using a more complete analysis program, like ASAP.

Appendix B: NOTES FOR THE TIGHT CUTOFF SEGMENTS EXAMPLE

The notes in this appendix are associated with the example file, TightCutoffSegments.rdf, which is included with ReflectorCAD in the Visual Aim Headlamp example directory. After loading the file in ReflectorCAD, the reflector view should look similar to Figure B.1.

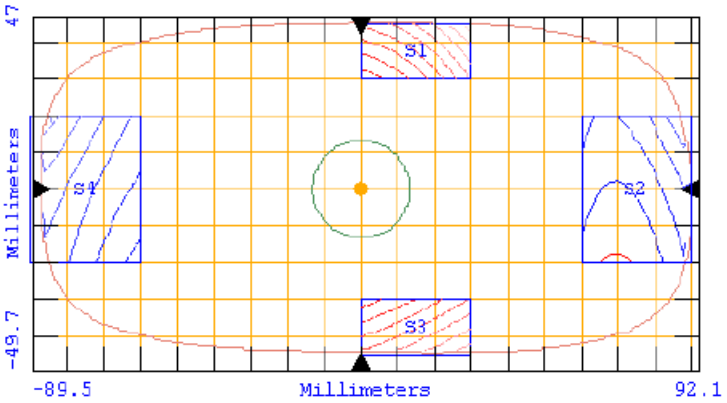

Figure B.1 Reflector view of the example file, TightCutoffSegments.rdf

1. Confirm that output was calculated for the reflector by clicking  .
2. Click inside segment S1. Its output is displayed in the output view.
3. While S1 is selected, right-click the Reflector view and select **Segment Properties**.
4. Notice that the Source Point for this segment is the inner edge of the filament, which provides for a tighter cutoff on the upper boundary of its aim region. To see this effect, change the Source Point to **EFP of Src #1** (essentially, the filament's center).

Figure B.1 shows the output of S1 when it is developed using the filament center (left) and the filament's inner edge (right) as the source point. In both cases, the segment is aimed to a horizontal line.

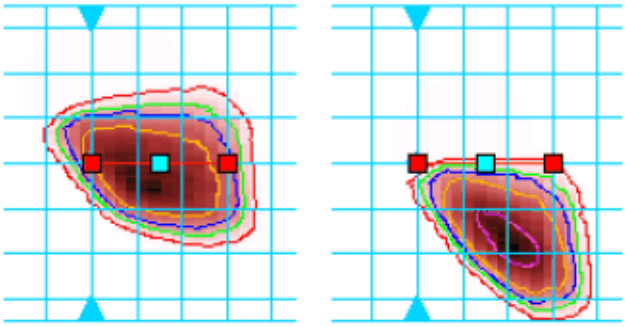

Figure B.1 Output of S1

When the filament's inner edge is used, vertical gradients in the 0.2 to 0.4 range are calculated in ReflectorCAD, using the gradient query settings.

5. Right-click the Output view and click **Gradient Query Settings**. Complete the dialog box as shown in Figure B.2

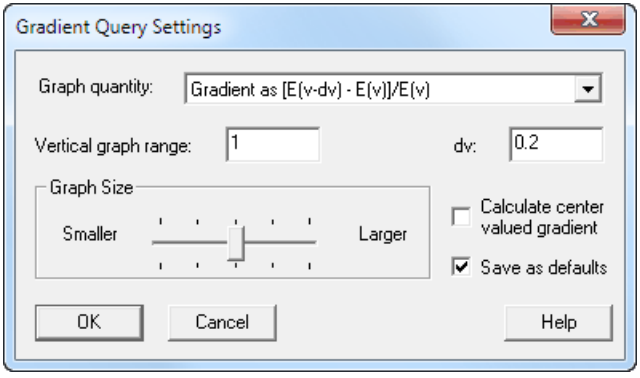

Figure B.2 Gradient Query Settings with vertical gradients in the 0.2 to 0.4 range

6 Press Ctrl+pointer to calculate the gradients simultaneously in the Output view.

Segment S2 was developed using the lower center of the filament as the source point. See Figure B.3.

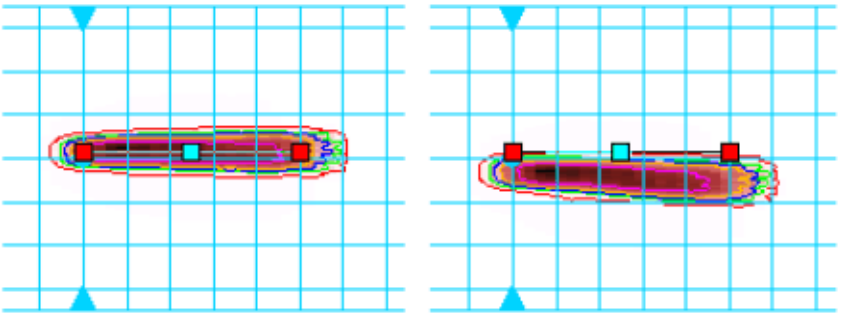

Figure B.3 Output of S2 when developed using the filament center (left) and the filament's lower center (right) as the source point.

When the lower center is used as the source point, the output pattern stays below the segment's horizontal aim line. Calculated gradients vary between 0.3 and 0.5 along the top of this output pattern. See Figure B.4.

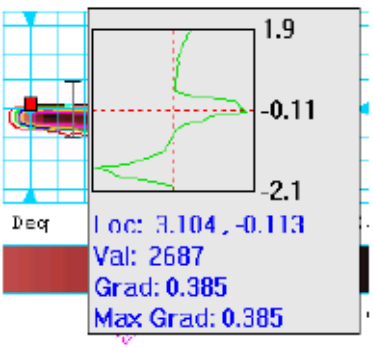

Figure B.4 Gradient query results from one location in the pattern

Segment S3 employs the same idea as S1, except that the outer filament end is used as the source point, because the segment is below the filament. Segment S4 uses the lower center of the filament, as S2 does.