Advanced Tutorial – Designing a Linear Fluorescent Reflector with the Parametric Optical Design Tools

Prerequisites

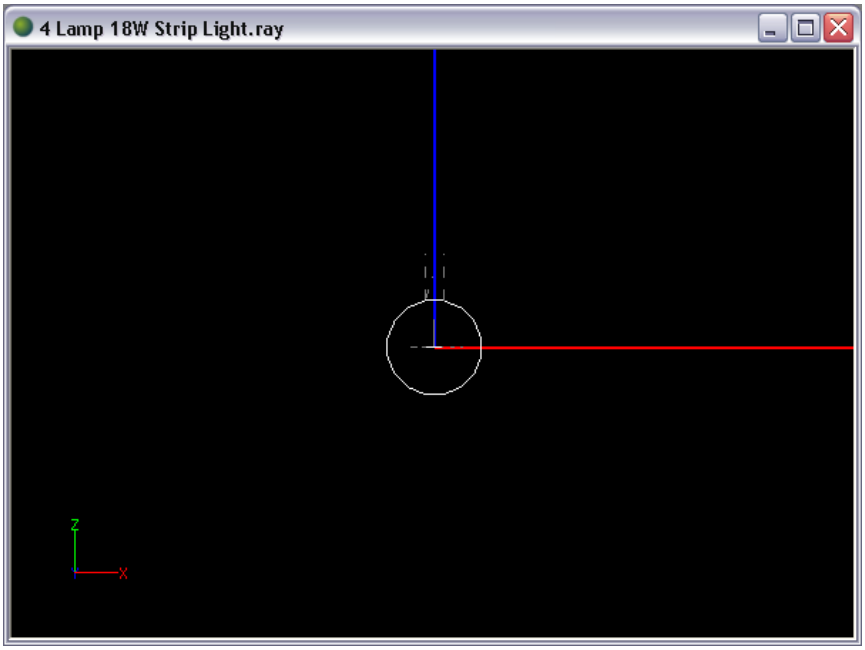
This tutorial is written with the assumption that you have already completed and understand the Beginner Tutorials under **Help > Beginner Tutorials** or in Chapter 3 of the User's Guide. This tutorial does not therefore repeat all of the basic information about how to start a project, setup the analysis, run the raytrace and view the results. If you have not yet completed the Beginner Tutorials, then please do so before you proceed.

Design Overview

This project will create an open 4-lamp T8 fluorescent luminaire with a reflector that produces a medium-wide beam with a spacing criterion (S.C.) between 1.3 and 1.5. S.C. is the ratio of the spacing to the mounting height at which the illuminance half way between two luminaires equals the value directly underneath the luminaire. It therefore indicates the spacing that is achievable while maintaining relatively even illuminance.

Getting Started

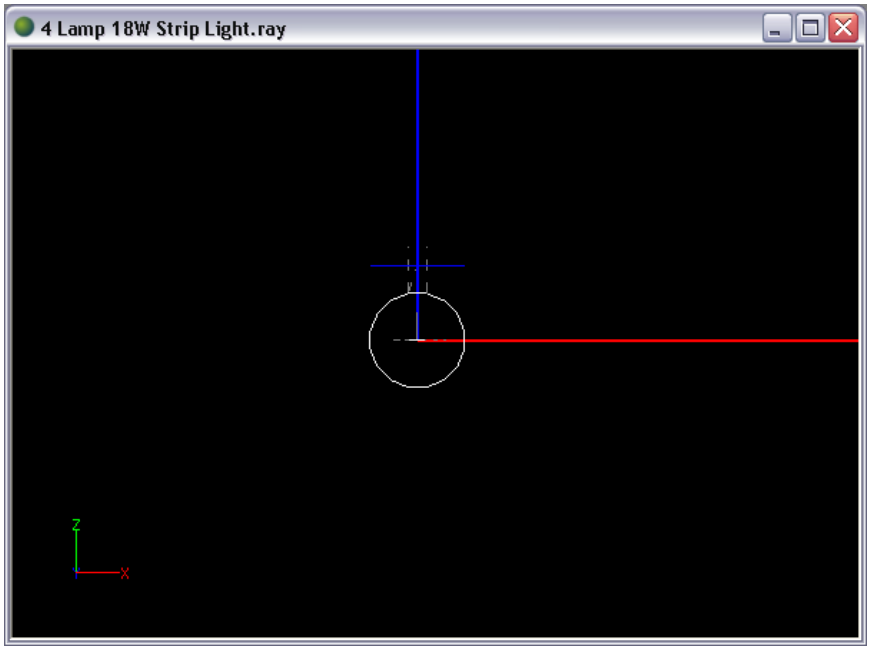
1. Start Photopia and create a new project and save it as *4 Lamp 18W Strip Light.ray*.
2. This project will be done in mm, so make sure the project units are set to mm. This is indicated next to the coordinate readout in the lower left corner of the screen. You can change the units under **File > Preferences** or by typing the UNITS command.
3. The luminaire is to be 600 mm long, so import an 18W tubular fluorescent lamp using **File > Import Lamp**. Choose the lamp model named *F18-33*. The complete list of lamps is found under the **Library > Lamp List** menu. Insert the lamp at 0,0,0.
4. Go to front view. Your CAD view should look like the following image.



The reflector will first be made around a single lamp and then it will be arrayed to make a 4 lamp luminaire. Note that if the complete luminaire will be an array of the same reflector profile around each lamp, then it is best to work with the single reflector until the desired distribution is achieved. Then the 4 lamp array can be made. Each iteration of the reflector design will benefit from quicker analyses when using only a single lamp.

The reflector profile can be started from either directly over the top of the lamp or from the outer rim. The choice to start your reflector from either point usually depends on your constraints. If you are using a specific length lamp holder for example and the reflector must therefore start at a specific distance from the lamp center, then it is best to use the point directly over the lamp as the start point. In this case, you need to iteratively determine the exact angular extent of the reflector to obtain a specific reflector width. If you have flexibility on the distance between the reflector and the lamp, which depends on how your lamp holder is mounted, then you might find it easier to start the reflector at a point on the end of the reflector opening so that you can fix its width to a specific value. This example will start the reflector over the top of the lamp and an assumed lamp holder length of 20 mm from the reflector to the lamp center. Furthermore, the reflector will also start with a flat reflector segment that is 25 mm wide so that the lamp holder can easily be snapped into this segment and the reflector can easily be mounted to the housing.

5. Choose **Design > Reflector: Polyline Based > Extruded Symmetric**.
    a. Accept the default of 0,0 for the lamp center.
    b. Enter 0,20 for reflector start point and @12.5,0 for the next point. Then press Enter when prompted for another point to end the polyline.
    c. Enter 600 for the extrusion length. The reflector should look like the following image.



Design an Aiming Based Reflector

The curved reflector that will control the bulk of the distribution will start where the flat polyline-based reflector ends. To ensure it will always start where the first reflector ends, we can link the two together. Reflectors are linked by name, so we first need to name this reflector.

6. Select the flat reflector in the CAD view and enter *Flat* in the Name property of the main property control in the right side of the screen.
7. Now choose **Design > Reflector: Aiming Based > Extruded Symmetric**.
    a. Accept the default lamp center.

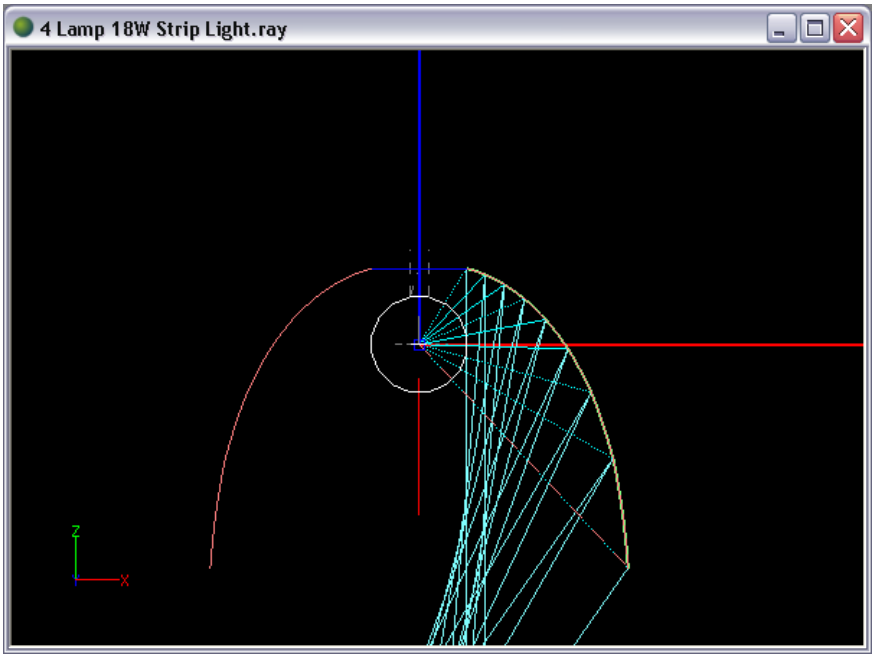
b. For the start point, just click a point on the screen near the end of the right side of the reflector. We will link the reflectors after this reflector is created.

c. To enter the angular extent, hold down the Ctrl key and then move your mouse to the right and down to sweep an angle clockwise (CW) about the lamp center. Sweep an angle about 45º below the X axis.

d. To choose an initial set of reflector aiming angles, we should look at our S.C. goal. If we aim for an S.C. of 1.4, this means that light should be aimed at least toward half way between two luminaires spaced 1.4 times their mounting height apart, or 0.7, and this is an angle of 35º from nadir. So, specify 0º for the first section and -35º for the last section.

e. Accept the default of 5º as the aiming angle increment.

f. Then enter 600 for the extrusion length.

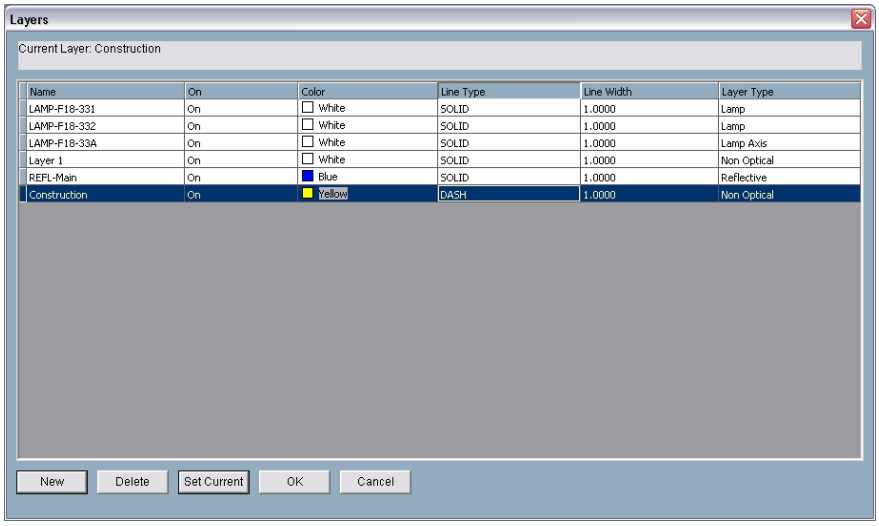


8. After the reflector definition is finished, select it and choose *Flat* from the drop down list in the Start Linkage property under **Start & Extent** in the main property control.

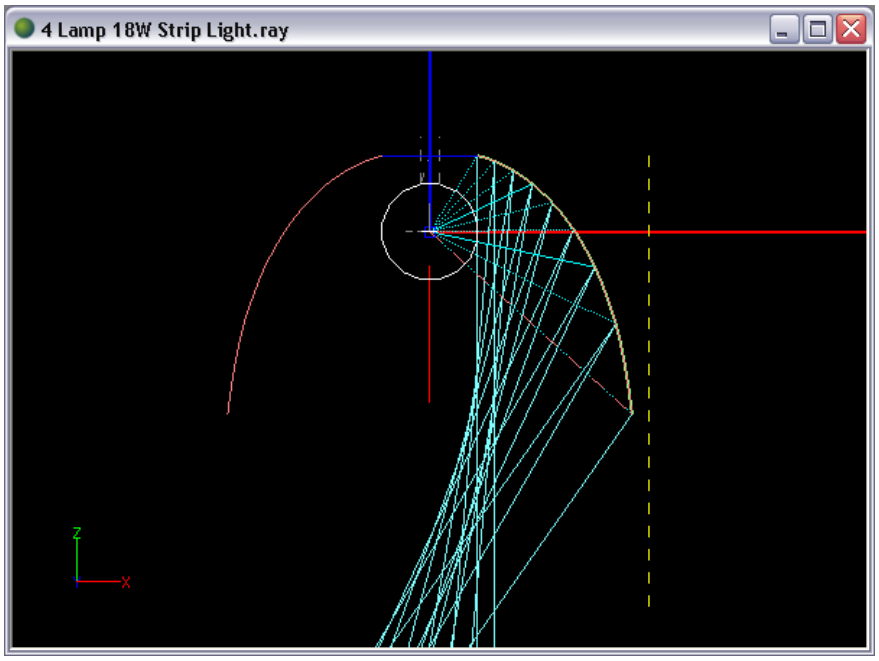
Start & Extent	
Start X	12.5000
Start Y	20.0000
Start Z	0.0000
Start Linkage	Flat
Linkage Corner	End to Start
Linkage Offset X	0.0000
Linkage Offset Y	0.0000
Linkage Offset Z	0.0000
Extent	-104.8525

We will assume each of the 4 reflectors can be 115 mm wide. We will therefore set the widest point to which this reflector can expand to be 57.5 mm to either side of the lamp center. We now need to find the reflector angular extent that results in a reflector that is this wide.

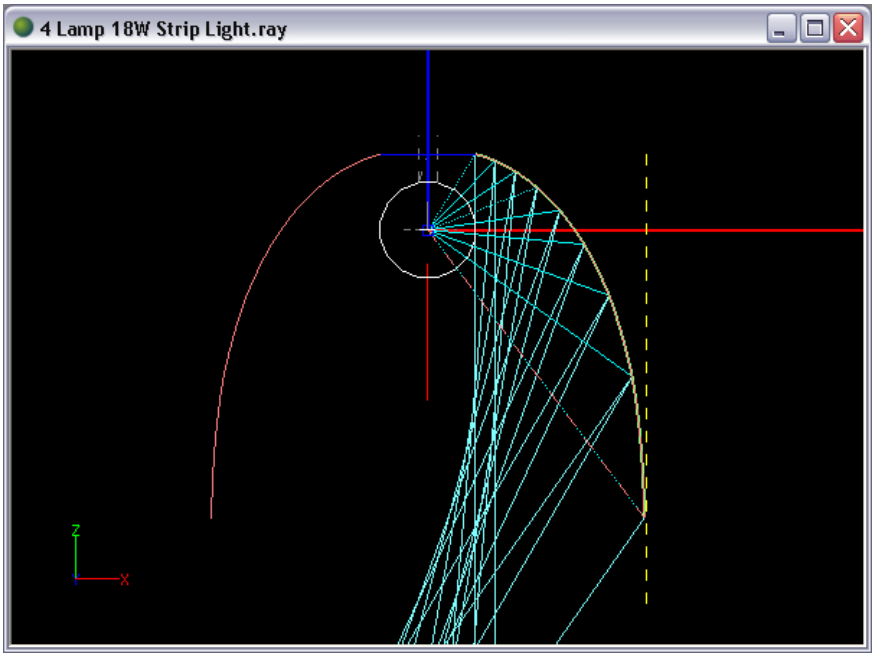
9. To help in doing this, create a new layer named *Construction*, make it yellow, and choose DASH for Line Type in the layers dialog. Also make this layer current.



10. Then use the LINE command to create a vertical line from 57.5,20 to 57.5,-100.



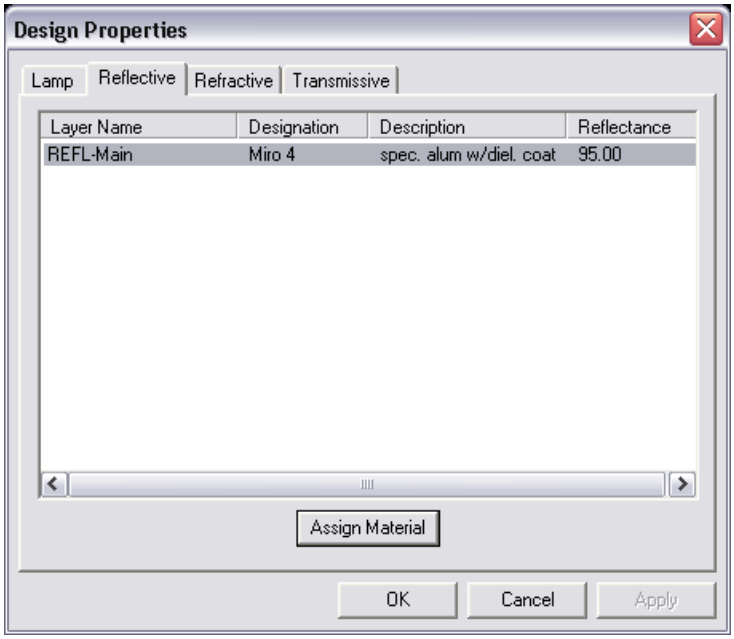
11. Now select the aiming based reflector and change its Extent property to a larger value than you originally specified. After arriving to an Extent value of -111º, the reflector appears to be the right width. This value was arrived at iteratively and may need to change later after the reflector aiming parameters are changed.



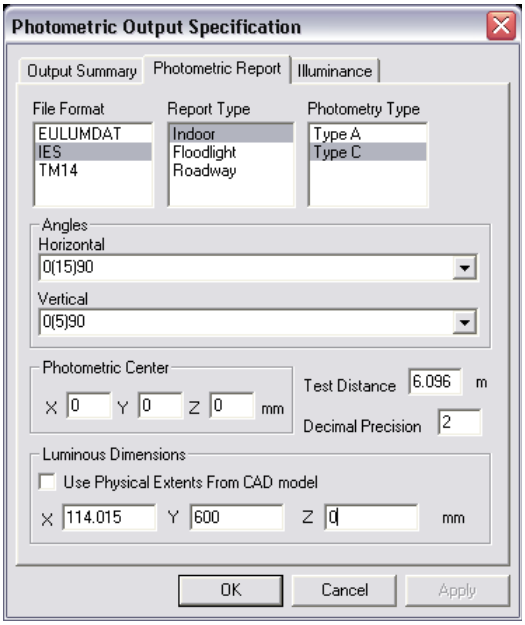
Setup the Raytrace

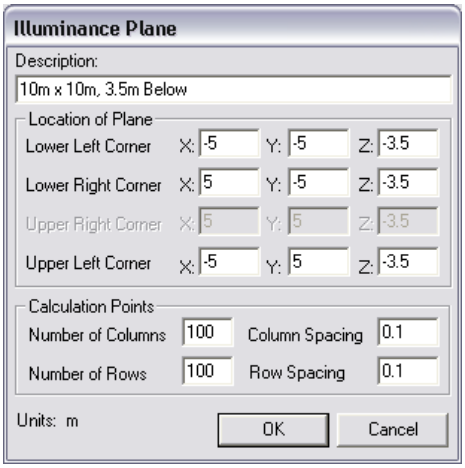
Now that we have an initial reflector design that aims light to the range of angles we desire and is about the right width, we can analyze its performance to see how close we are to our S.C. goal.

12. Before the analysis is started, first assign *Alanod Miro 4* to the REFL-Main layer that was created for our reflector in **Edit > Design Properties**.



13. Then, in **Analysis > Specify Photometric Output**, set the horizontal angles of the candela distribution to (0(15)90) and keep the default of (0(5)90) for the vertical angles. Set the Luminous Z Dimension to 0 since this luminaire will eventually have end caps and have no luminous height. Also define an illuminance plane that is 10m x 10m, 3.5m below the luminaire, using 100x100 columns and rows. We will use this plane to judge the smoothness of the beam.

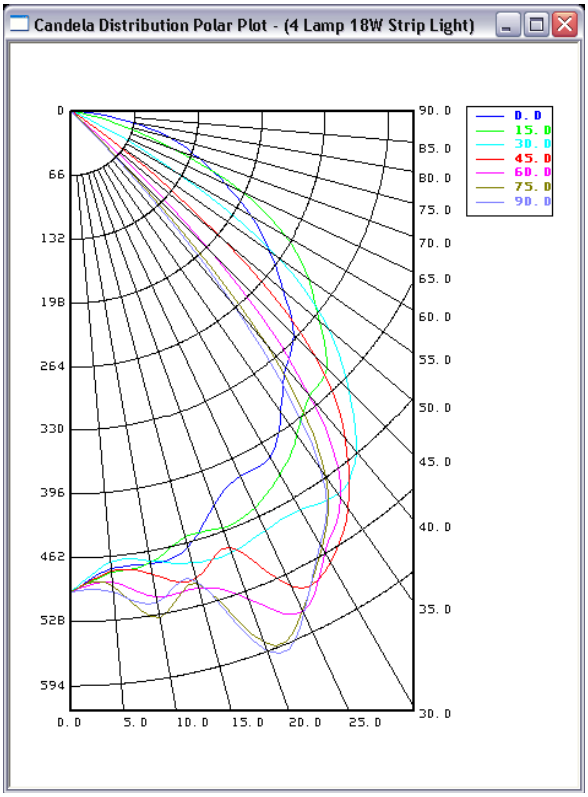




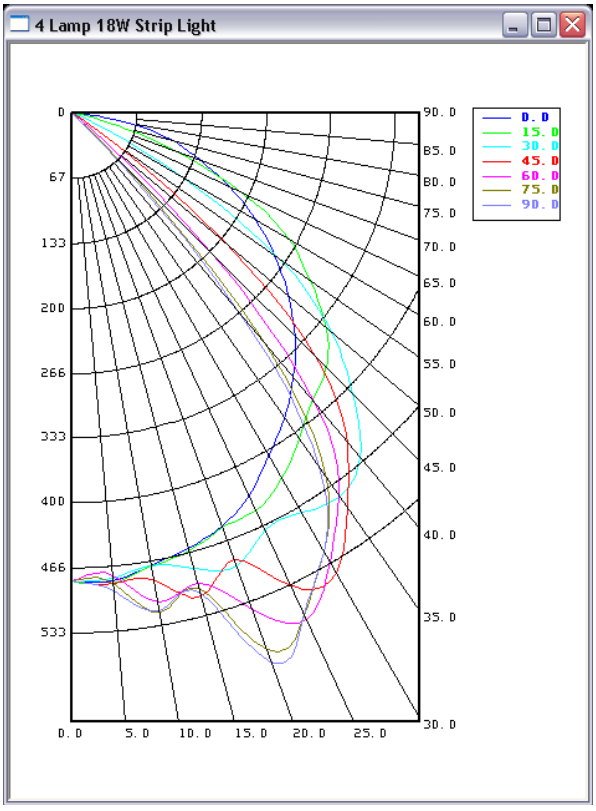
14. Under **Analysis > Specify Raytrace Settings**, change the Initial Source Rays to 500,000 to start with to get a quick analysis of the reflector. If its performance is close to what we are seeking, then we will increase the number of rays. If the performance is significantly off, then we will keep the number of rays low and manipulate the reflector parameters until we get close before increasing the resolution of the analysis. This will allow you to get close to the results you desire more quickly.

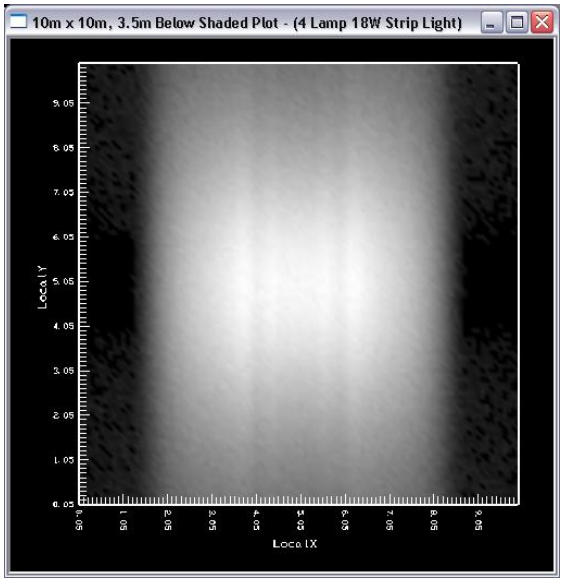
Analysis Results & Design Iterations

15. Run the analysis. Under **View > Photometric Report**, we see that the reflector results in an S.C. of 1.40 in the 90º plane, the plane in line with the cross section of our reflector and thus the plane we are controlling. Also, the candela distribution looks like the following image.

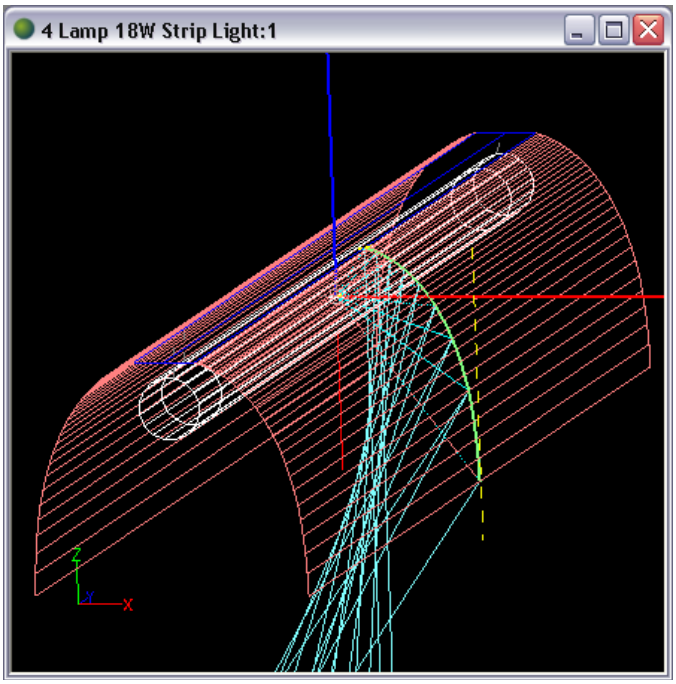


16. Since these results are close to what we want, we will run more rays to get a smoother candela distribution and see the details that need to be addressed. Running 5,000,000 rays results in the following candela distribution and illuminance distribution.





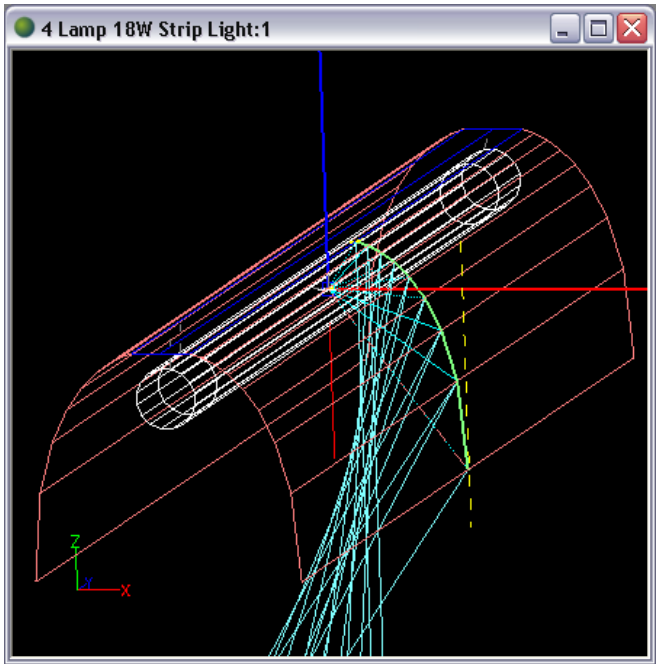
The general shape of the candela distribution did not change much with more rays but the illuminance plane is much clearer. Although this design has the general beam width we desire, it has some striations in the beam pattern that are undesirable. There are several possible ways to address these, so we will experiment with various reflector parameters in order to see their effects. First of all, note that the current reflector uses the default values for the Curve Resolution in the property control. This defines the smoothness of the reflector profile, essentially the angular size of the reflector facets that approximate the parabolic aiming sections. The default value is 4º, which defines a fairly smooth reflector. See Chapter 5 of the manual for more details about this parameter. The following image shows the reflector mesh with the default curve resolution.



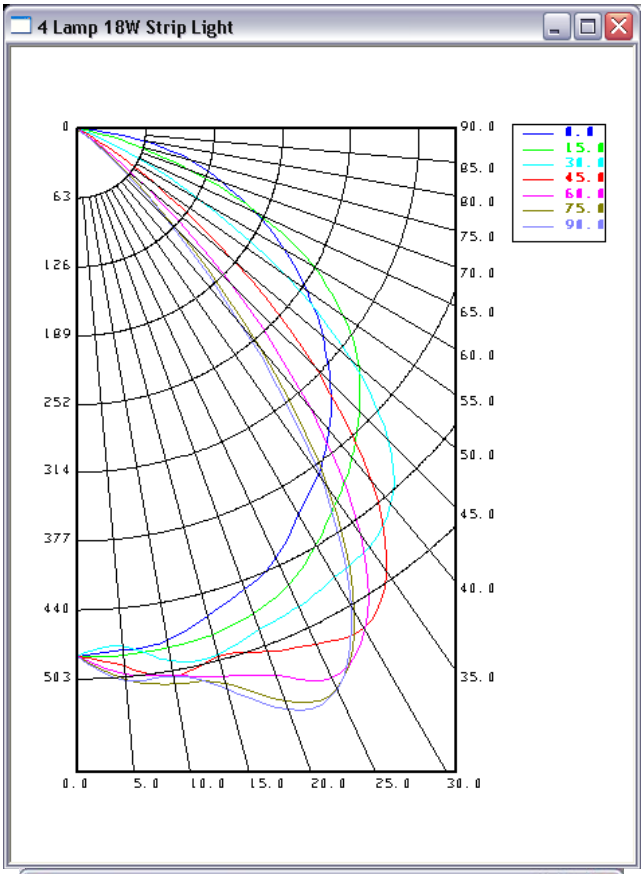
You can see several reflector facets in each reflector aiming section. The more precisely the shape of the individual parabolic sections is defined, the more likely it is that the reflector will create individual spikes of light toward each aiming angle, which are spaced 5º apart. The large lamp will provide spread from each reflector section and help blend the beam, but even with a 4º curve resolution, this spread is not enough to avoid the striations in the light pattern. One technique for spreading the light even further is to decrease the precision of this reflector and make each reflector aiming section a flat segment. The flat segments will spread light to a wider range of angle than a parabolic curved section.

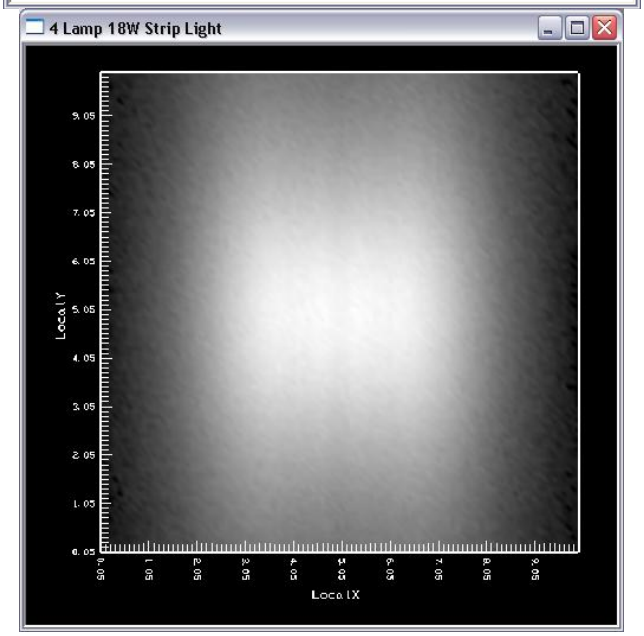
17. In order to get a single flat segment for each reflector section, enter 90º for the Curve Resolution parameter. Since the total angular extent of each section is less than 90º, Photopia will only create a single facet for each section. The reflector will now look like the following image.

Section/Profile	
Num Sections	8
Curve Resolution	90.0000
Profile Length	225.0458
Profile Only	No
Display Mesh	Yes
Mesh Construction	Smooth (Hydrofor…



18. Run the analysis after this change. The results are shown below. You can see a significant smoothing in the beam as a result of the larger reflector facets.

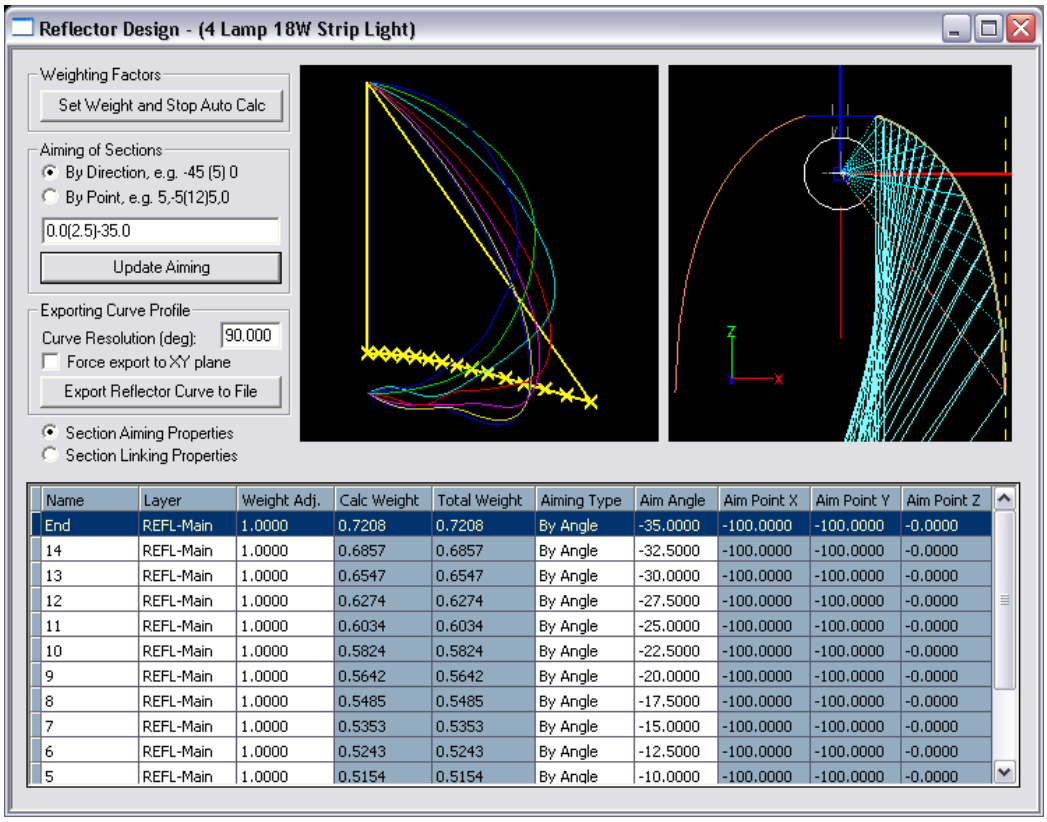




If you require even further smoothing, then you can try some additional changes. One option is to increase the number of aiming angles. The reflector still uses the original 5º steps between the individual aiming angles. We accepted that default because we had no reason to choose something different at that time. If

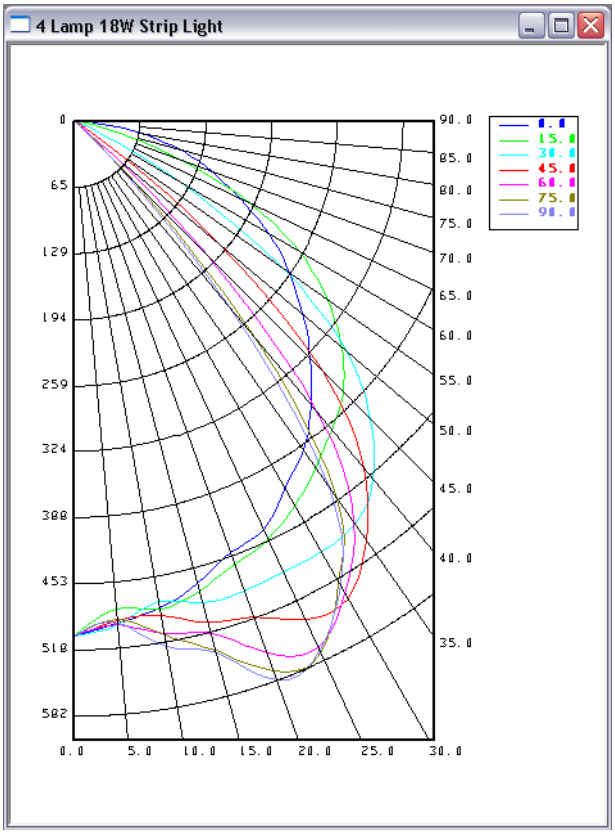
a reflector has too few facets aimed at angles that are too far apart, then you can sometimes have difficulty in smoothing out striations. So we can try redefining this reflector with 2.5º increments between the aiming angles yet keeping a single face for each reflector section.

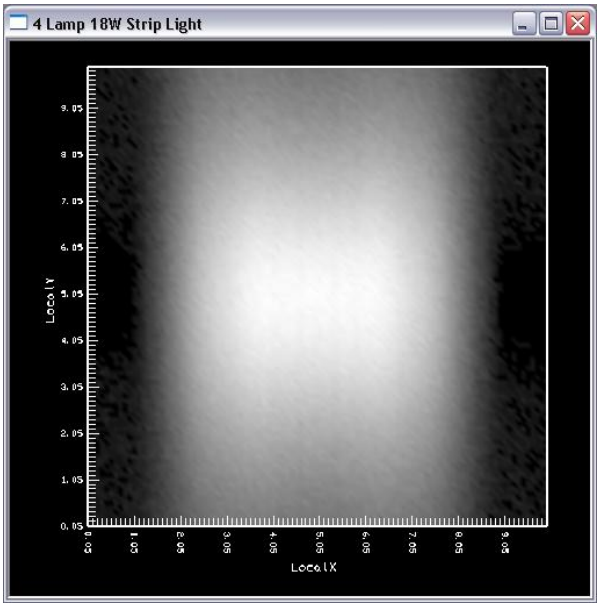
19. This can easily be done by opening the **View > Parametric Optical Design** screen. Enter 0(2.5)-35, representing the start angle, increment, and ending angle for the reflector sections, in the text box in the Aiming of Sections portion of the screen and click the Update Aiming button. You will then see the same general reflector shape but with more aiming sections.



Name	Layer	Weight Adj.	Calc Weight	Total Weight	Aiming Type	Aim Angle	Aim Point X	Aim Point Y	Aim Point Z
End	REFL-Main	1.0000	0.7208	0.7208	By Angle	-35.0000	-100.0000	-100.0000	-0.0000
14	REFL-Main	1.0000	0.6857	0.6857	By Angle	-32.5000	-100.0000	-100.0000	-0.0000
13	REFL-Main	1.0000	0.6547	0.6547	By Angle	-30.0000	-100.0000	-100.0000	-0.0000
12	REFL-Main	1.0000	0.6274	0.6274	By Angle	-27.5000	-100.0000	-100.0000	-0.0000
11	REFL-Main	1.0000	0.6034	0.6034	By Angle	-25.0000	-100.0000	-100.0000	-0.0000
10	REFL-Main	1.0000	0.5824	0.5824	By Angle	-22.5000	-100.0000	-100.0000	-0.0000
9	REFL-Main	1.0000	0.5642	0.5642	By Angle	-20.0000	-100.0000	-100.0000	-0.0000
8	REFL-Main	1.0000	0.5485	0.5485	By Angle	-17.5000	-100.0000	-100.0000	-0.0000
7	REFL-Main	1.0000	0.5353	0.5353	By Angle	-15.0000	-100.0000	-100.0000	-0.0000
6	REFL-Main	1.0000	0.5243	0.5243	By Angle	-12.5000	-100.0000	-100.0000	-0.0000
5	REFL-Main	1.0000	0.5154	0.5154	By Angle	-10.0000	-100.0000	-100.0000	-0.0000

20. Running the raytrace with the increased number of aiming angles results in the following performance.



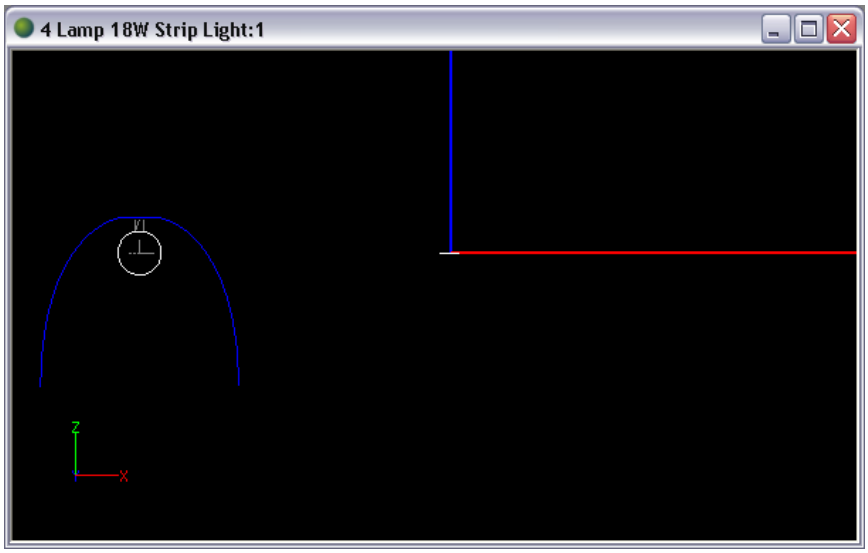


The increased number of aiming angles did help fill in the dark stripe that was in the beam center in the previous analysis, but the difference in performance might not be large enough to justify the potential increase in manufacturing cost of creating the higher number of facets. This depends on the manufacturing method. If the reflector is made on a break press, then each bend has a cost so you have an incentive to keep them to a minimum. If the reflector is made on progress rollers however, then there will be no increase in cost and you should take the higher number of aiming angles.

Array the Reflector

Now that the single reflector performance is satisfactory, we will create an array of four reflectors that are all still parameterized and can be changed together. To do this, we will use the Array parameters in each reflector's property control. (Remember we have two reflectors, the flat top and the aiming based.) We will assume that each reflector gets a total width of 120mm. This gives us 5mm to create a return in the reflector if it was made from a single piece or if the pieces were fastened together.

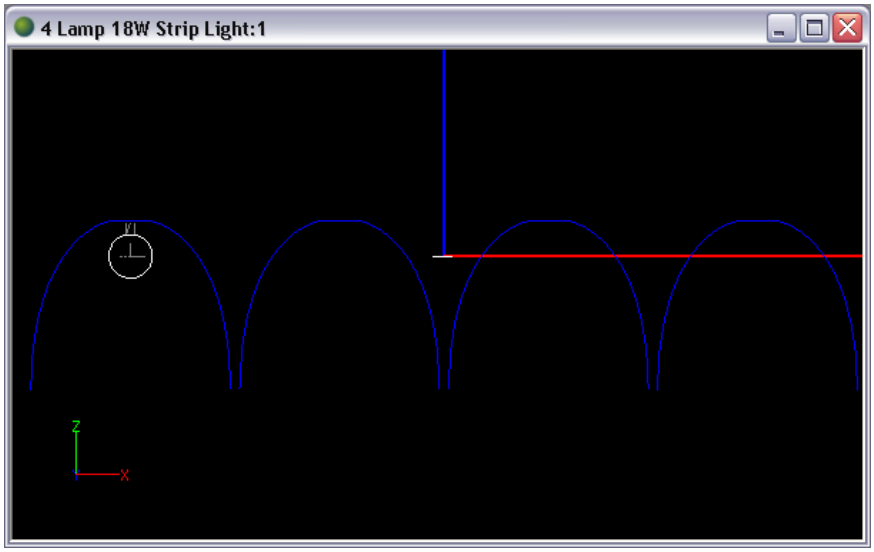
21. From the front view with the CPlane set to this view, move the lamp and reflectors to the left by 180mm. (You can turn off the Construction layer since it isn't really needed any longer.)



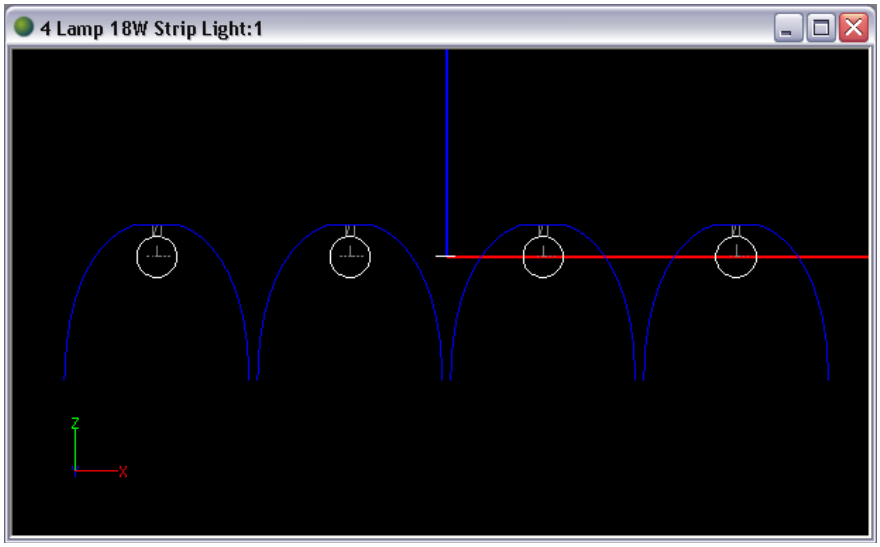
Different from the CAD Array function which simply arrays a reflector or other geometry to make new ones, using the Arraying section in the properties control creates arrayed reflector images that are actually a property of the reflector itself. That way, when you make changes to the reflector profile, those changes will also be updated in the arrayed parts of the reflector.

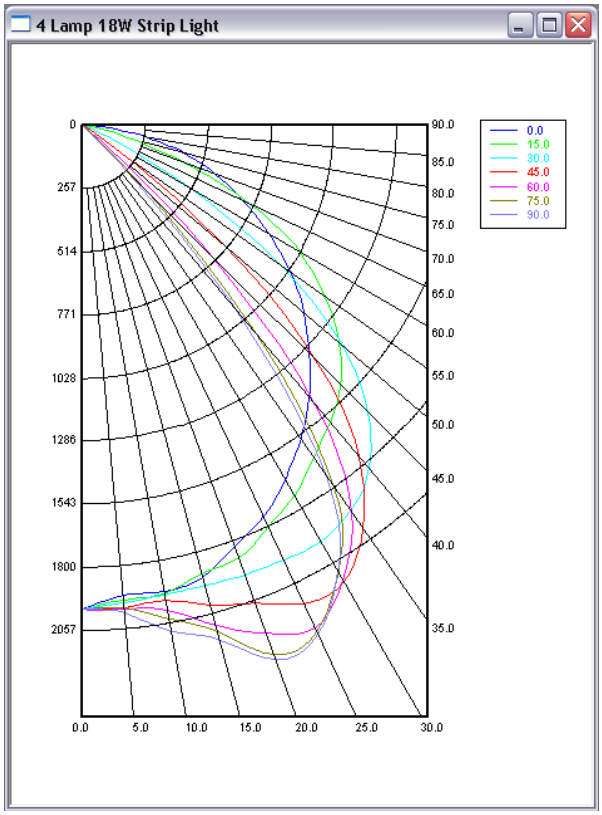
22. Select the flat top reflector in the CAD view and find the Arraying section of its property control. Choose *Rectangular* as the array type. Enter 4 for Num Columns and 120 as the Colum Spacing. Deselect this reflector and select the curved reflector to enter the same values in its Arraying section.

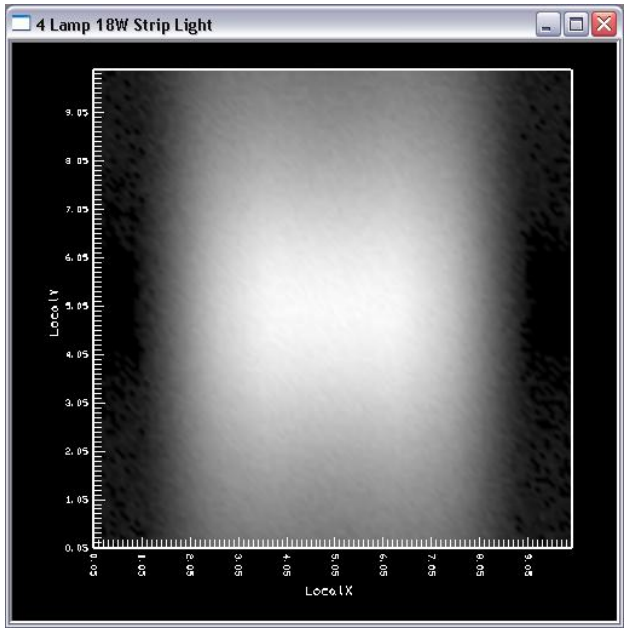
Arraying	
Type	Rectangular
Num Columns	4
Column Spacing	120.0000
Num Rows	1
Row Spacing	1.0000
Num Z	1
Z Spacing	1.0000
Polar Center X	-180.0000
Polar Center Y	0.0000
Polar Center Z	0.0000
Polar Items	1
Polar Extent	360.0000



23. Next array the lamp with the **Modify > Array** command on the main menu. Enter the same rectangular array parameters. The final reflector and its results are shown in the next few images.




4 Lamp 18W Strip Light
0
257
514
771
1028
1286
1543
1800
2057
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
15.0
30.0
45.0
60.0
75.0
90.0


4 Lamp 18W Strip Light
Local Y
Local X