How to Model an Adaptive Optical System

Summary: This advanced-level article will demonstrate how to create a segmented mirror-based adaptive optical system using the multi-configuration capability of Zemax. The example will illustrate:

- How to zoom the stop surface decenter to model an array of mirrors
- How to use the tolerancing capability to create random wavefront error to model atmospheric aberrations
- How to optimize for minimum geometrical and diffraction point spread function to compensate for these aberrations
- How to use solves to simplify system setup and parameter changes

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

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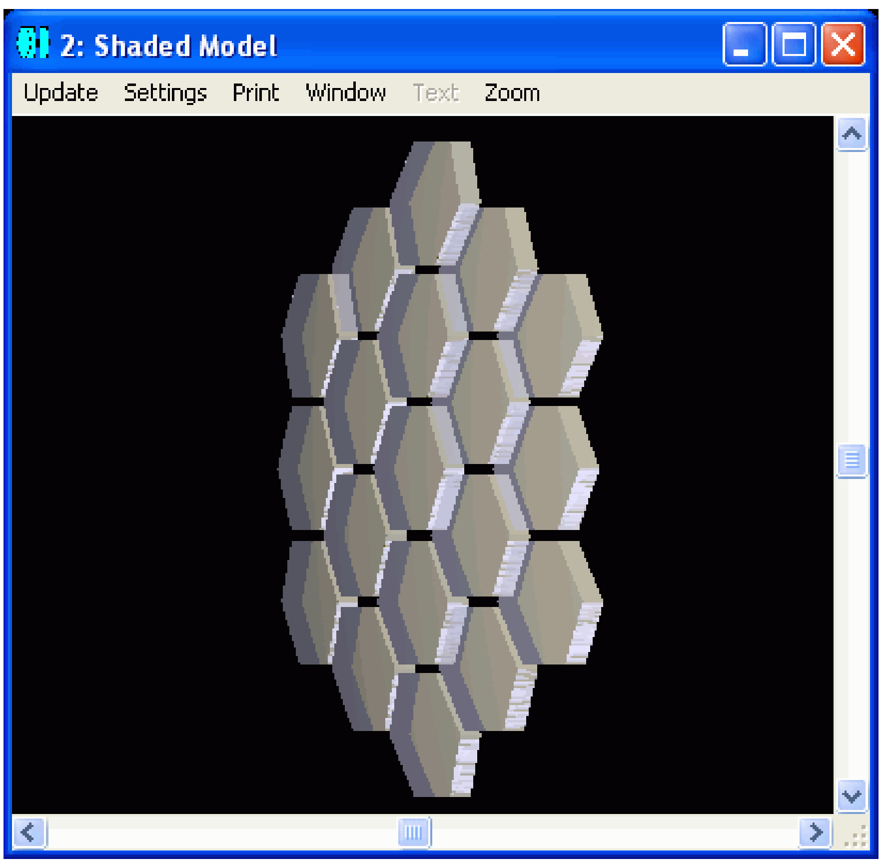
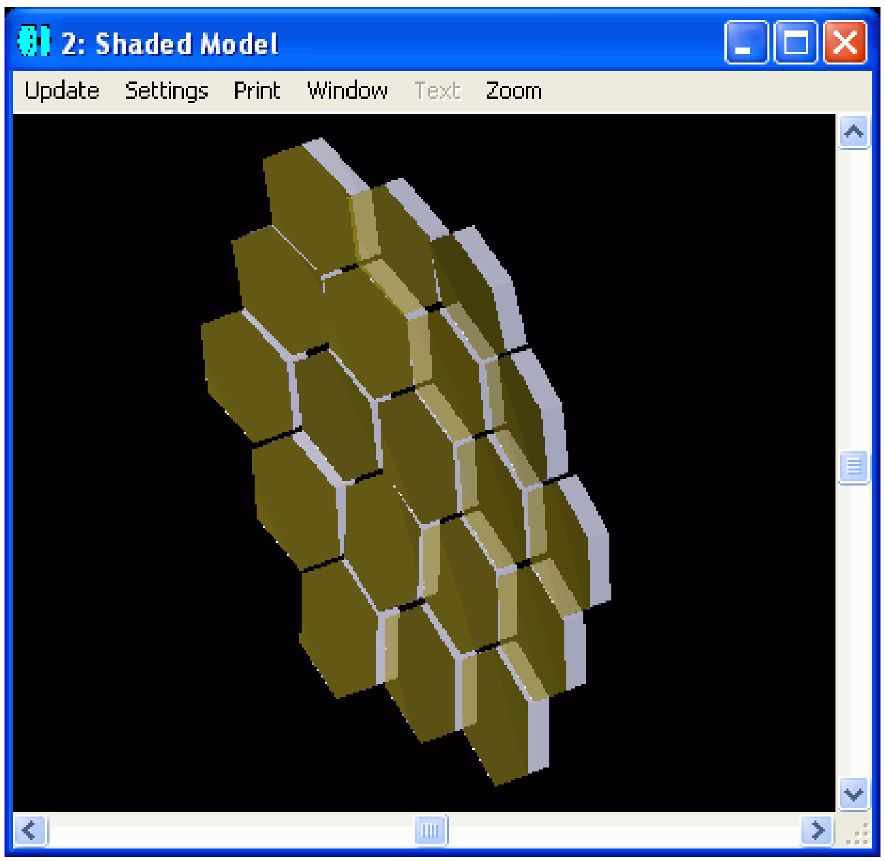
Applies to: System Modeling

Text: **Introduction**

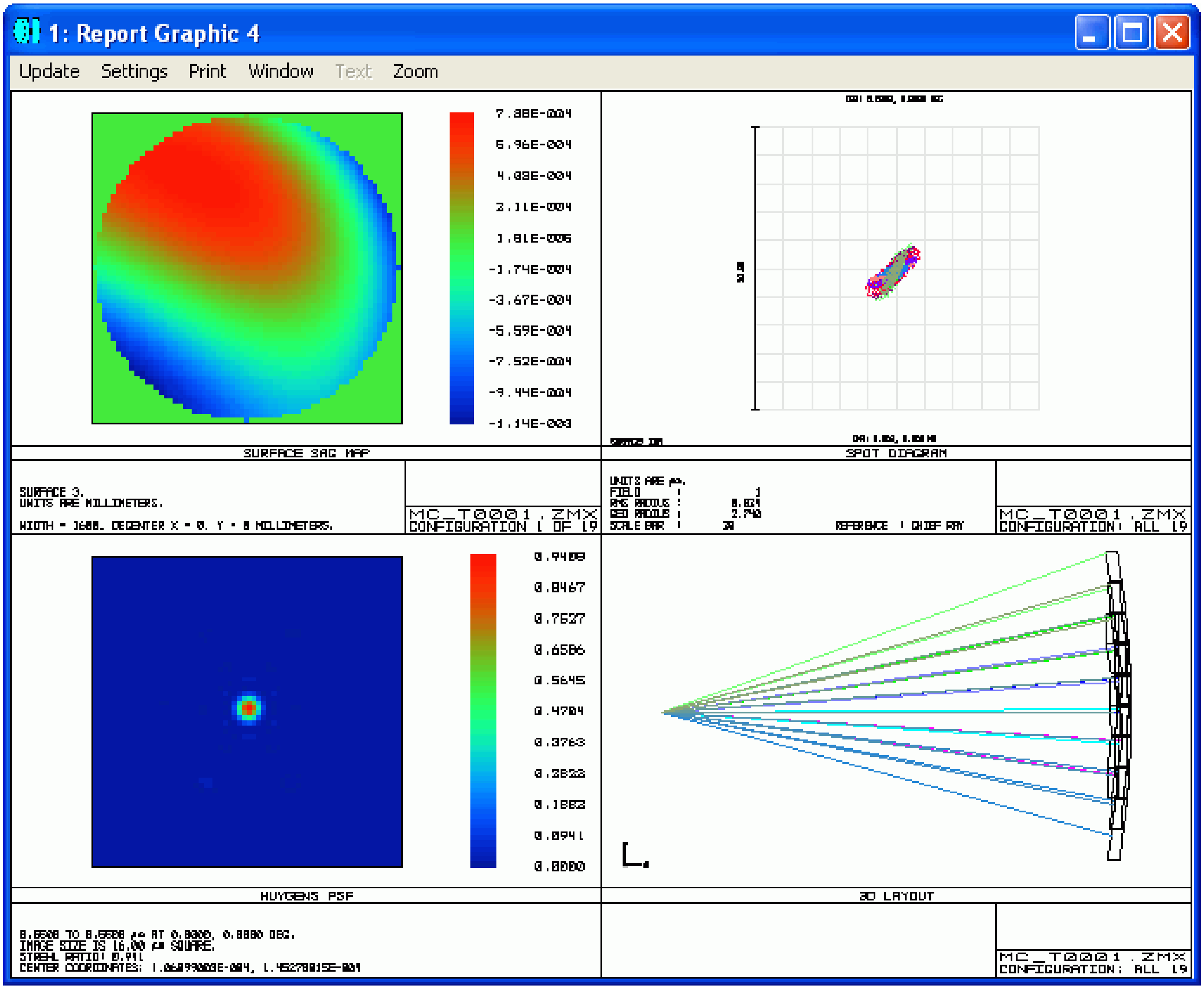
A segmented mirror adaptive optical system can adjust the positions of its segments to minimize aberrations. In an astronomical telescope, adaptive optics can reduce some of the aberrations introduced by the Earth's atmosphere. Zemax can model adaptive optics mirrors either in sequential/mixed mode or in purely non-sequential mode. For this tutorial, we will model a simple segmented mirror in pure sequential mode using multiple configurations.

The animations below show both the un-tilted segments (left) and the tilt of each segments about the center of the reflective surface (right).





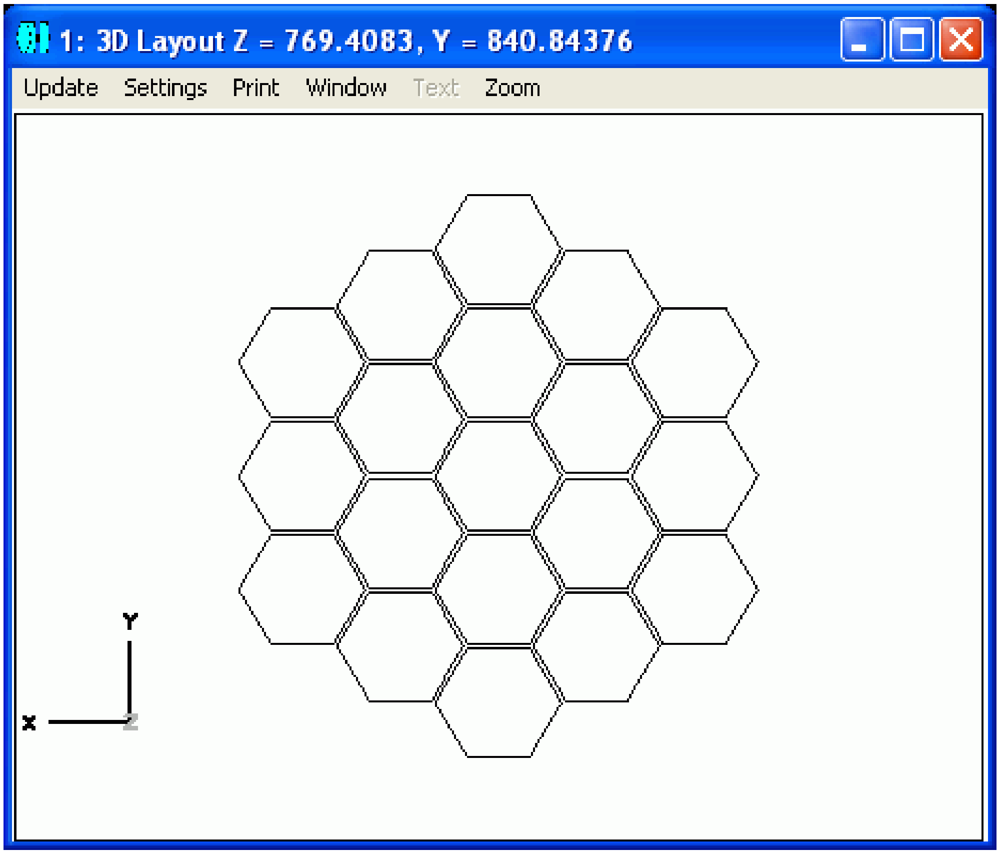
For analysis, we will introduce random aberrations to the input wavefront representing atmospheric effects and optimize the tilt and z-position of the segments to minimize the aberrations at the image plane. The random aberrations, shown on the top left hand corner of the Report Graphics window below, will be automatically generated to allow Monte Carlo type analysis. The animation below also shows the geometrical and the diffraction point spread function (PSF), before and after the optimization, for each input wavefront.



Design Goals and Assumptions

Here are some design goals and assumptions:

- We will only model the segmented parabolic primary mirror. No other elements of a complete telescope, such as the secondary mirror, will be modeled. This is done to reduce complexity, and can be easily added if required
- The mirror segments are not deformable. Again this is done just to make the article less complex: this can be easily added if required.
- The mirror has 19 segments and each of them will be entered manually in the editors. Mirrors with much larger number of segments can be created by using a ZPL macro to modify the editors(/support/knowledgebase/What-is-ZPL).
- The radial position of each segments relative to the vertex of the center segment should be picked-up (linked) from the decenter parameters of a particular segment. The animation below shows how the radial position of all segments change when the position of the single controlling segment is changed in the editor.
- Random aberrations, representing atmospheric effects, will be generated automatically by Zemax.



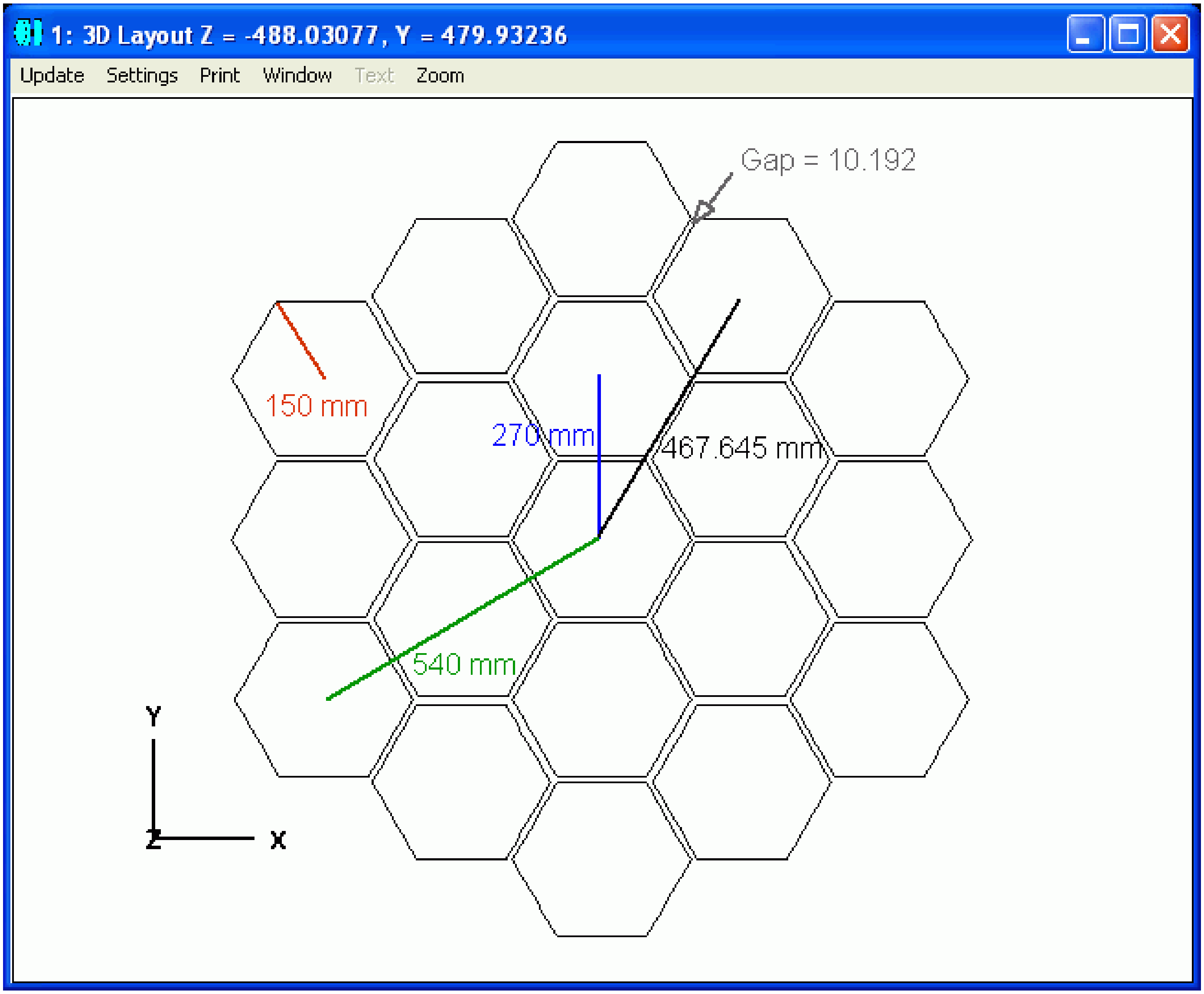
Here are some of the specifications:

Mirror sag shape = parabolic (conic = -1)

Radius of curvature = -4000 mm ; focal length = -2000mm

Shape of the segment = Hexagon

Semi-diameter of each segment = 150mm



This exercise will require understanding of concepts such as multi-configurations, ray-aiming and system aperture. If you are not familiar with these terms please refer to following articles and/or the Zemax user manual:

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

How to Use Ray Aiming (/support/knowledgebase/How-to-Use-Ray-Aiming)

How to Model a Beam Splitter in Sequential Zemax (/support/knowledgebase/How-to-Model-a-Beam-Splitter-in-Sequential-Zemax)

Initial system layout

Set up the following system properties:

System unit to mm (System > General > Units)

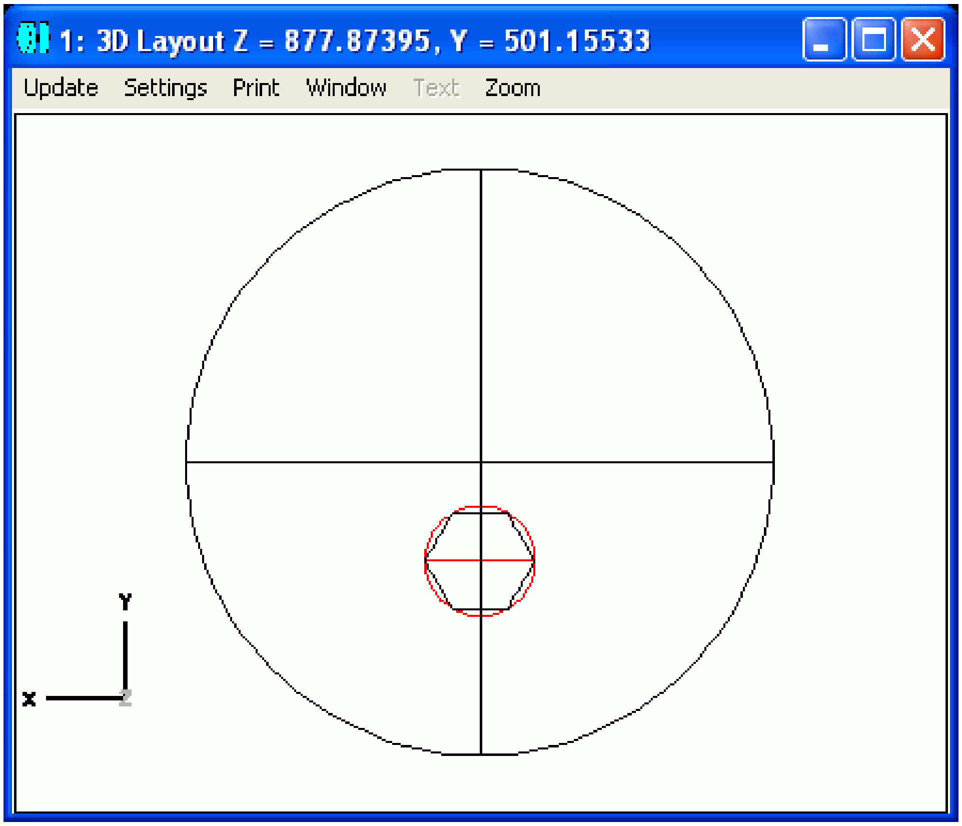
Wavelength to 550um (System > Wavelengths)

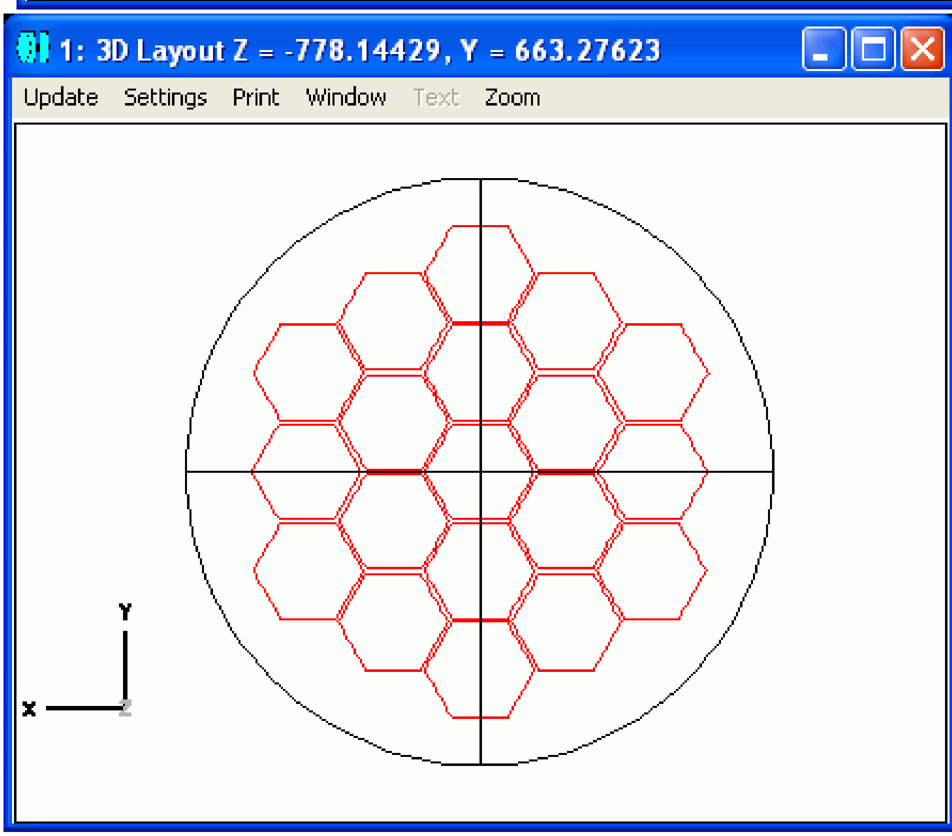
Set one field with values X=0 and Y=0 (System > Fields)

Set system aperture type to Float by Stop Size (System > General > Aperture)

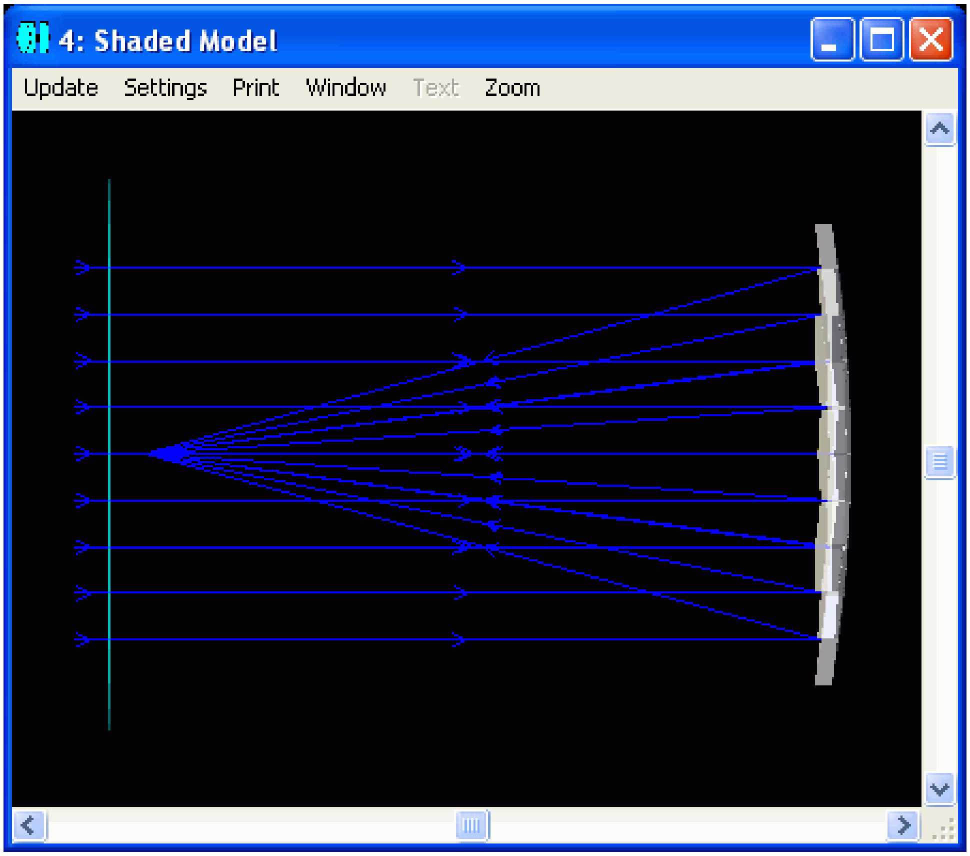
Turn Ray-Aiming on (System > General > Ray-Aiming)

By using multiple configurations, we will model one segment per configuration. The mirror surface will be the stop, having a hexagonal user-defined surface aperture (UDA). The stop XY decenter will be zoomed and the rays will be aimed at the decentered stop surface via Ray-Aiming(/support/knowledgebase/How-to-Use-Ray-Aiming). The animation below shows the effect of the zooming the stop position (the red circle around the hexagonal segment).



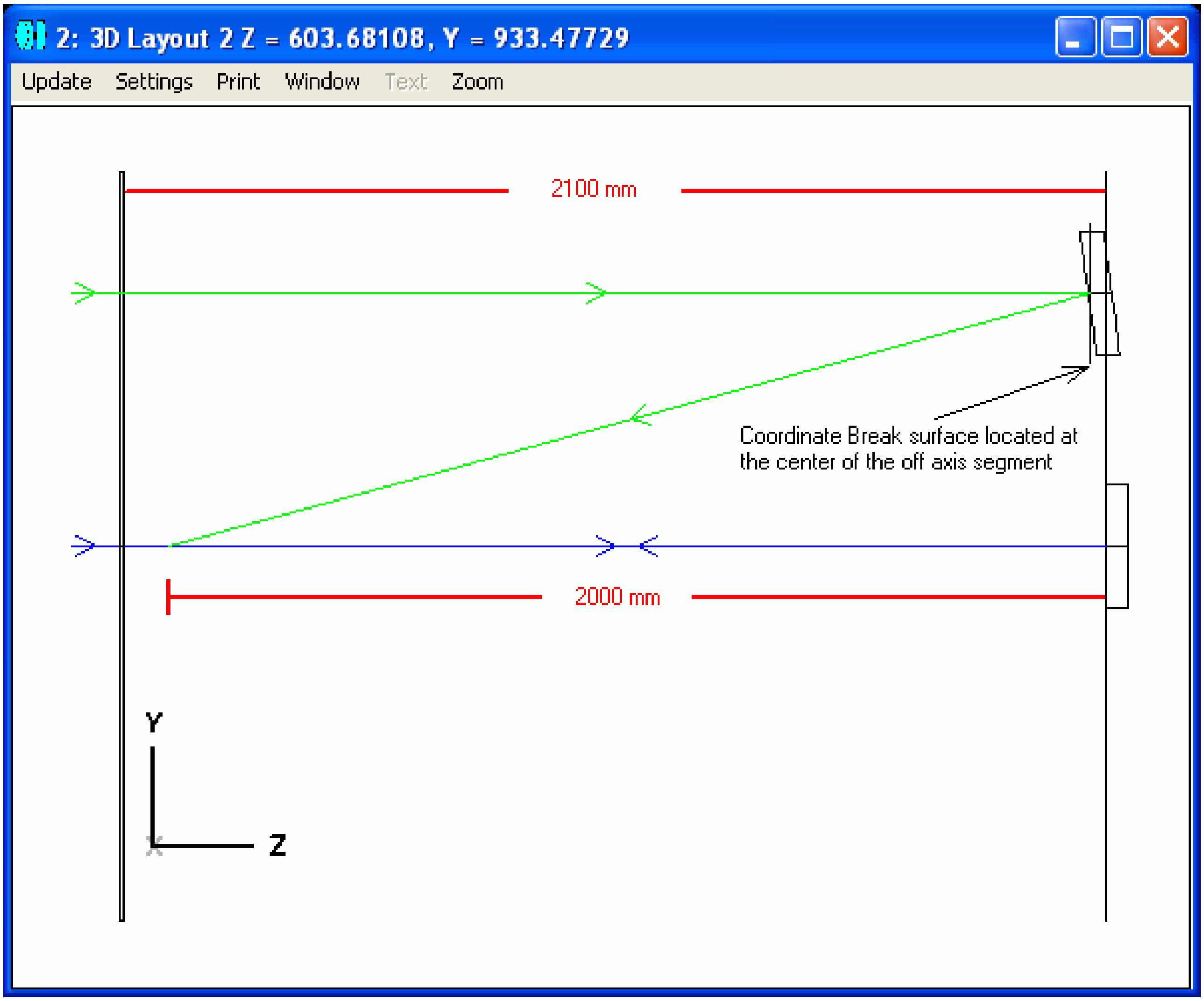


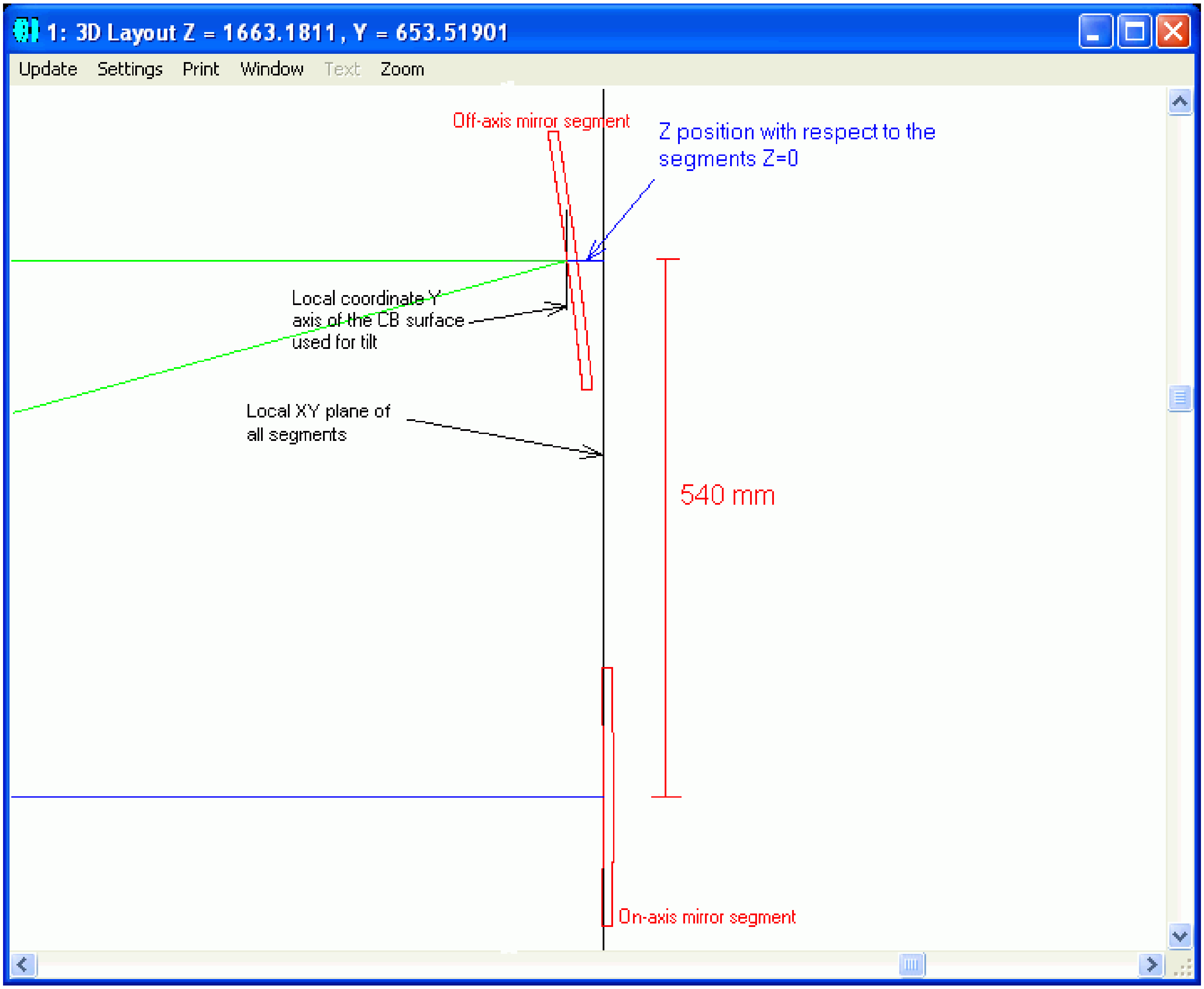
To aberrate the input wavefront, we will place a glass window before the mirror and deform the sag using the TEZI tolerance operand.

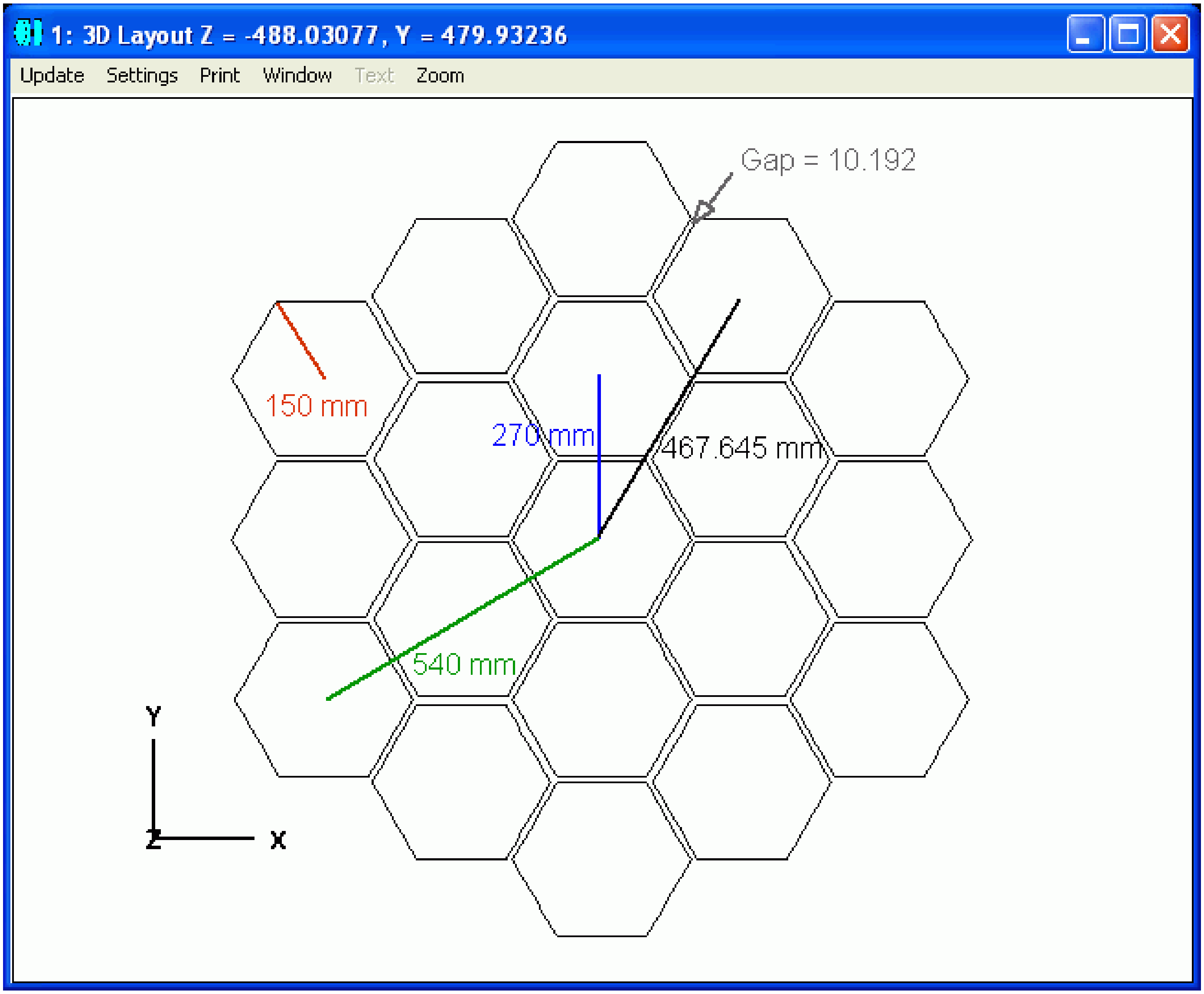


Setup A

The diagrams below show the center and one off-axis (Y=+540, X=0) segments. Notice how the XY and Z positions of the off-center segment has to change from that of the center segment. The segment pivot point is always at the center of its surface. The dummy glass window of constant index 2 will be placed 90mm in front of the local Z=0 (XY plane) of the segments, so that the sag error (to be introduced before analysis) correlates directly to the wavefront error.


2: 3D Layout 2 Z = 603.68108, Y = 933.47729
Update
Settings
Print
Window
Text
Zoom
2100 mm
Coordinate Break surface located at
the center of the off axis segment
2000 mm
Y
Z


1: 3D Layout Z = 1663.1811, Y = 653.51901
Update Settings Print Window Text Zoom
Off-axis mirror segment
Z position with respect to the segments Z=0
Local coordinate Y axis of the CB surface used for tilt
Local XY plane of all segments
540 mm
On-axis mirror segment

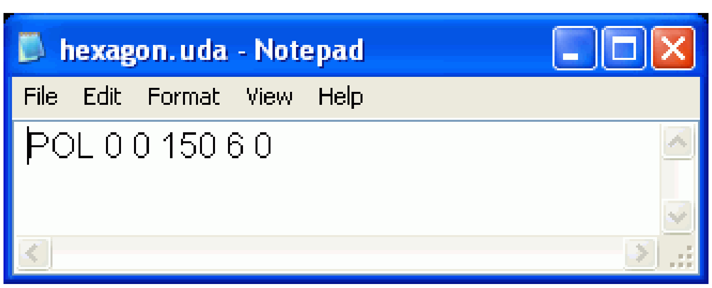


Setup B (Lens Data Editor)

Before entering the surfaces in the editors, we need to create the hexagonal User Defined Aperture (UDA) named "HEXAGON.UDA" and place it under the Zemax/Objects directory.

Open any ASCII text editor. Use the "POL" UDA entity to create the hexagon. The syntax is:

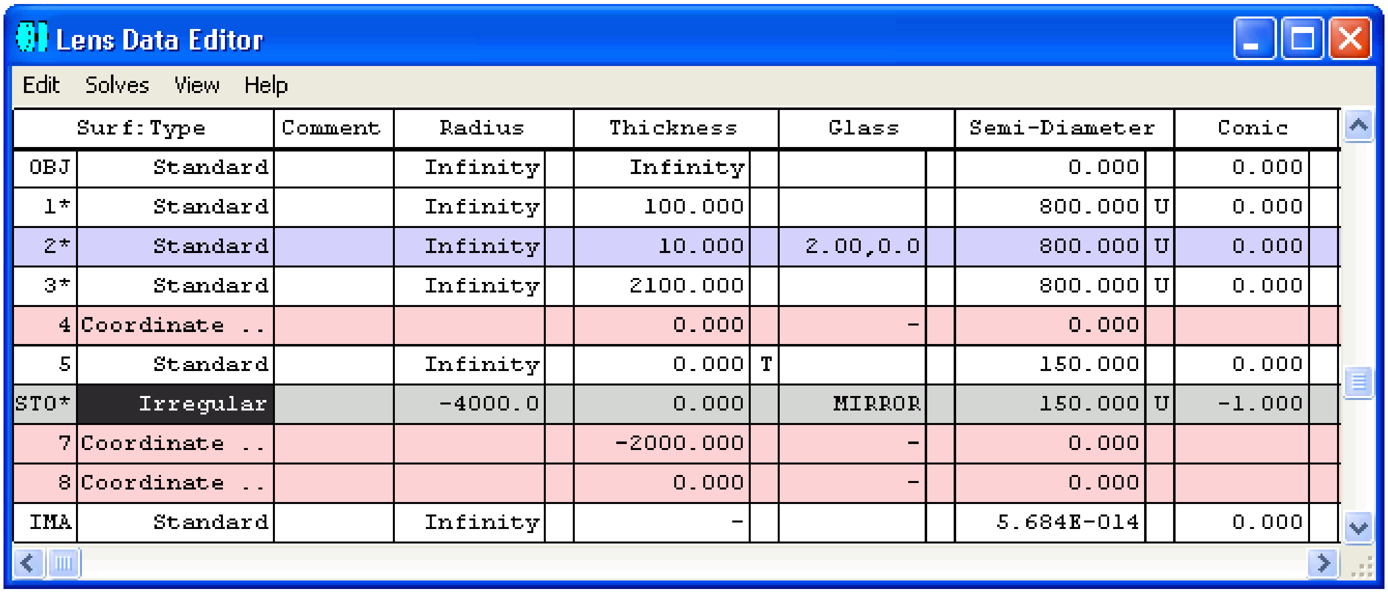
POL x_center y_center radius(vertex to corner) number_of_side(6 in our case) rotation_about_its_center(zero)



Save the file as HEXAGON.UDA in the Zemax/Objects directory.

For more information about the UDA entities, refer to chapter 5, section "The UDA file format", of the manual.

To model the center segment first, insert the following surfaces in the Lens Data Editor.



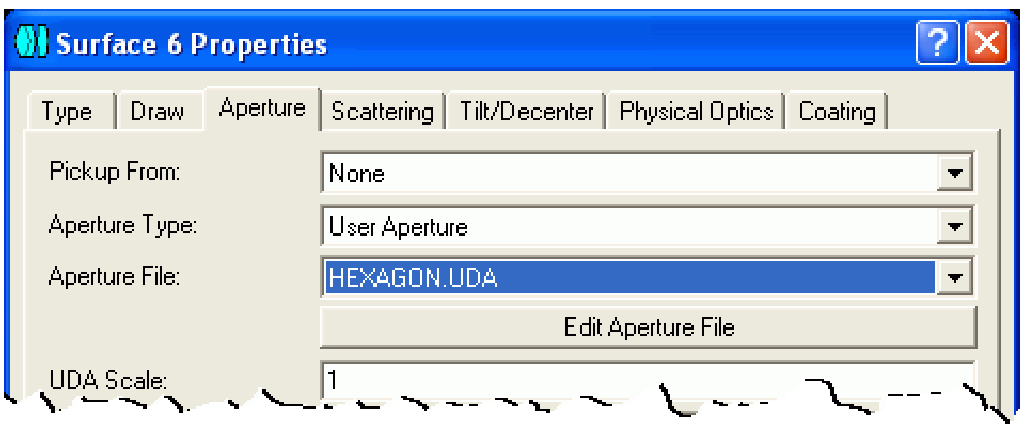
Surf:Type		Comment	Radius		Thickness		Glass		Semi-Diameter		Conic
OBJ	Standard		Infinity		Infinity				0.000		0.000
1*	Standard		Infinity		100.000				800.000	U	0.000
2*	Standard		Infinity		10.000		2.00,0.0		800.000	U	0.000
3*	Standard		Infinity		2100.000				800.000	U	0.000
4	Coordinate ..				0.000		-		0.000		
5	Standard		Infinity		0.000	T			150.000		0.000
STO*	Irregular		-4000.0		0.000		MIRROR		150.000	U	-1.000
7	Coordinate ..				-2000.000		-		0.000		
8	Coordinate ..				0.000		-		0.000		
IMA	Standard		Infinity		-				5.684E-014		0.000

Make surface #6 the stop with type Irregular and set the semi-diameter to 150mm. We will be using the Irregular surface instead of the Standard surface because the amount of decenter can be specified as one of the surface parameters in the Lens Data Editor. For the Irregular surface, the decenters are in lens units, and the tilts are in degrees (zero for the center segment). The tilt and decenter parameters of the Irregular surface work exactly like the coordinate break surface, however, the tilts and decenters are undone internally after the ray is traced to the surface. Ray tracing is done according to this algorithm:

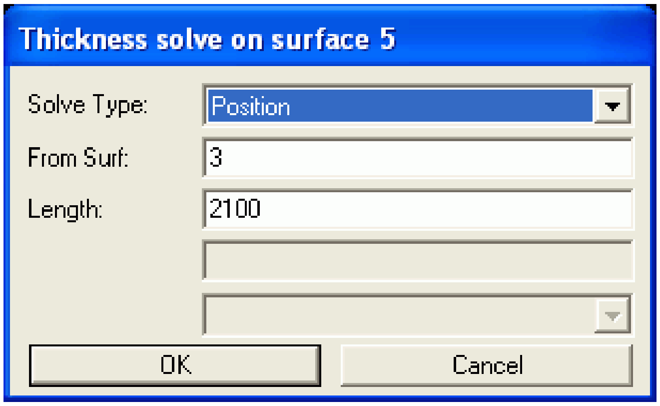
The Irregular surface is decentered, tilted about x, then about y.

The ray is traced to the surface.

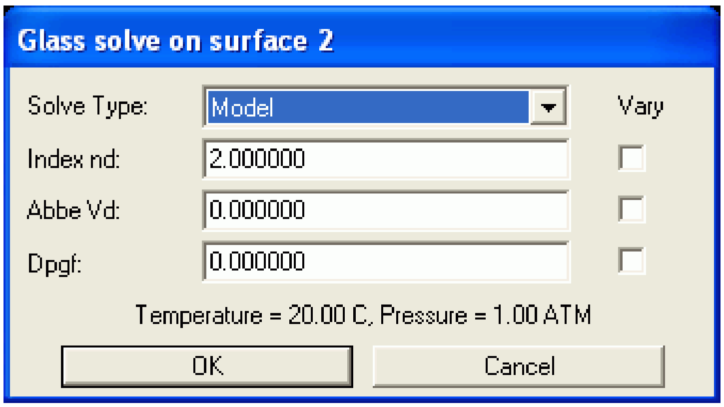
The surface is untilted about y, untilted about x, then undecentered.
Specify HEXAGON.UDA user defined aperture on the mirror surface #6.



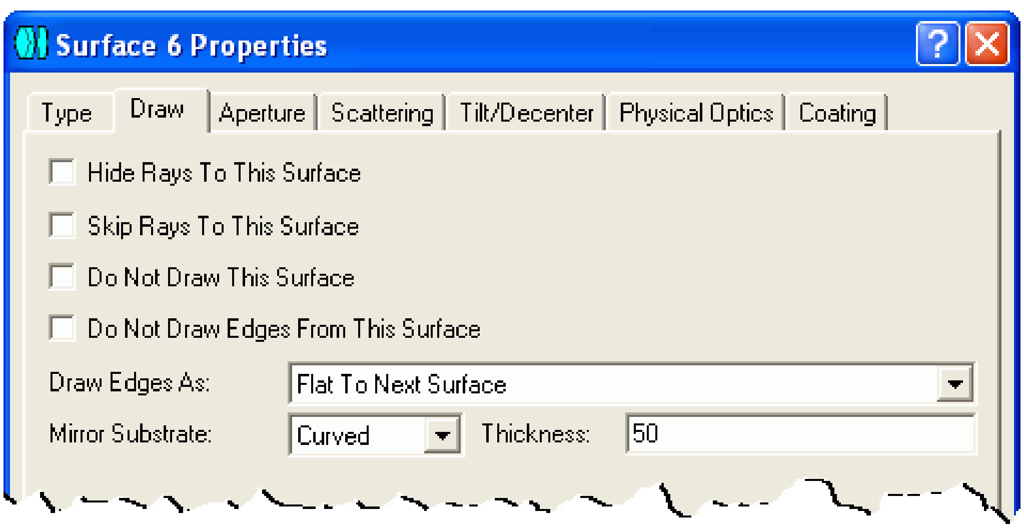
Place a position solve on surface 5 to make the total distance between surface 3 and 5 always 2100mm. This will ensure that when we add multiple copies of the mirror at various (x,y) shifts they will be at the correct z location automatically.



Set the surface #2 glass solve type as model with index of 2, zero dispersion and zero Abbe number. This is because we want to model a pure phase profile

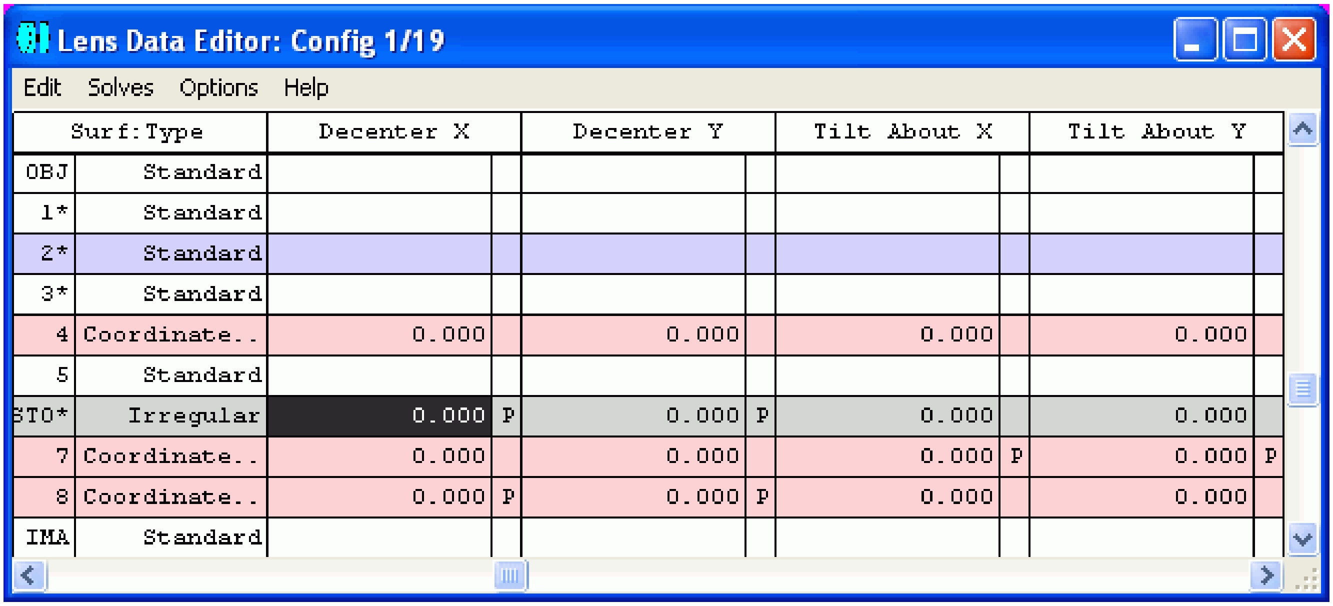


Specify 50mm substrate thickness for the mirror, in the surface property window. This only affects how the mirror is drawn in the layout plots, and has no other effect.

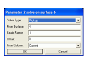


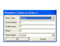
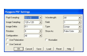
Setup C (Lens Data Editor)

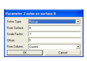
The decenter X and Y parameters of the Coordinate Break (CB) surface #4 will be zoomed by the multi-configuration editor to move the stop surface. The decenters will be automatically restored by the CB Surface #8 via pick-up solves. The tilt of the mirror segment will be controlled by the X and Y tilt parameters of CB #4 and the tilt will restored by CB #7. Also, the Irregular surface needs to be decentered by equal but opposite amount of the CB#4 decenters to correctly model the off-axis section of the parabola.



Place the following pick-up solves on the appropriate parameters.

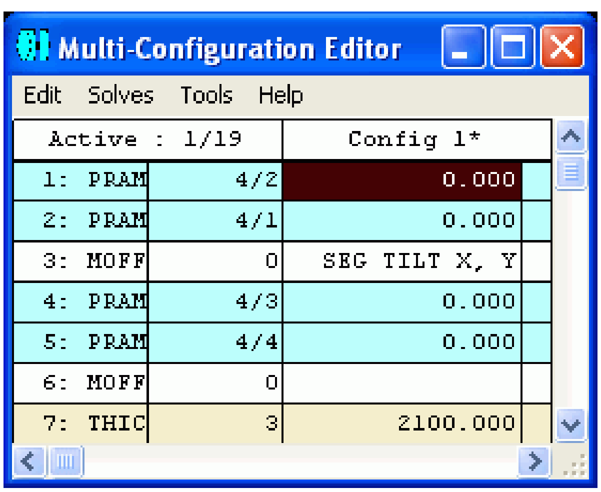
 

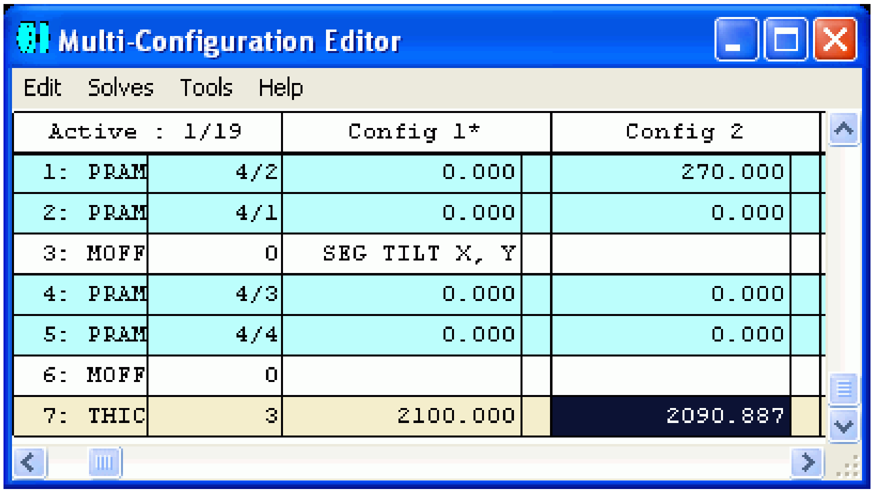
Setup D (Multi-Configuration Editor)

Set up the Multi-Configuration Editor (MCE) to control the XY tilt and decenters of CB surface #4 (PRAM 4/1 to 4/4). Also, insert THIC operand to control the thickness of surface #3, to place the off-axis segments at the correct Z locations.



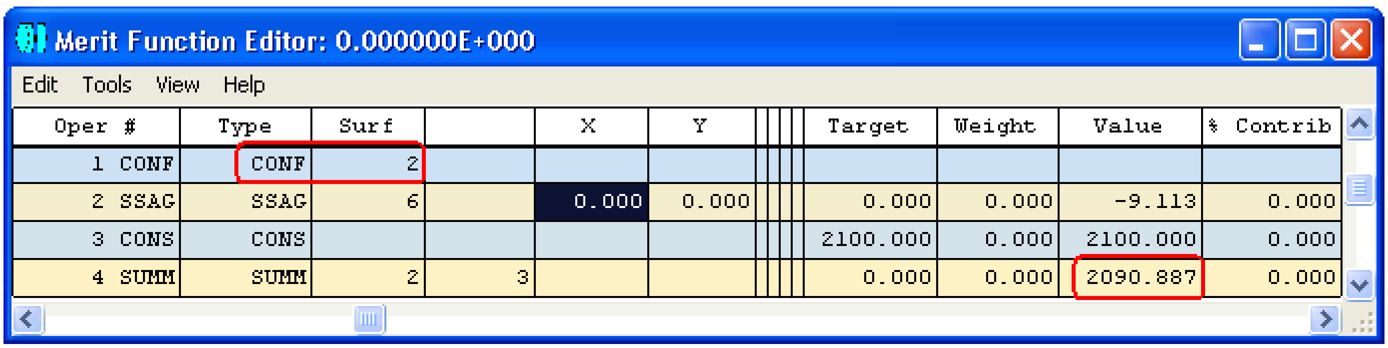
With all the tilt and decenter values set to zero, configuration #1 models the center segment. The thickness on surface 3 is set to 2100mm since that is the center segment distance from the rear of the dummy glass window.

Add another configuration to model the first off-axis segment.



Active : 1/19		Config 1*	Config 2
1: PRAM	4/2	0.000	270.000
2: PRAM	4/1	0.000	0.000
3: MOFF	0	SEG TILT X, Y	
4: PRAM	4/3	0.000	0.000
5: PRAM	4/4	0.000	0.000
6: MOFF	0		
7: THIC	3	2100.000	2090.887

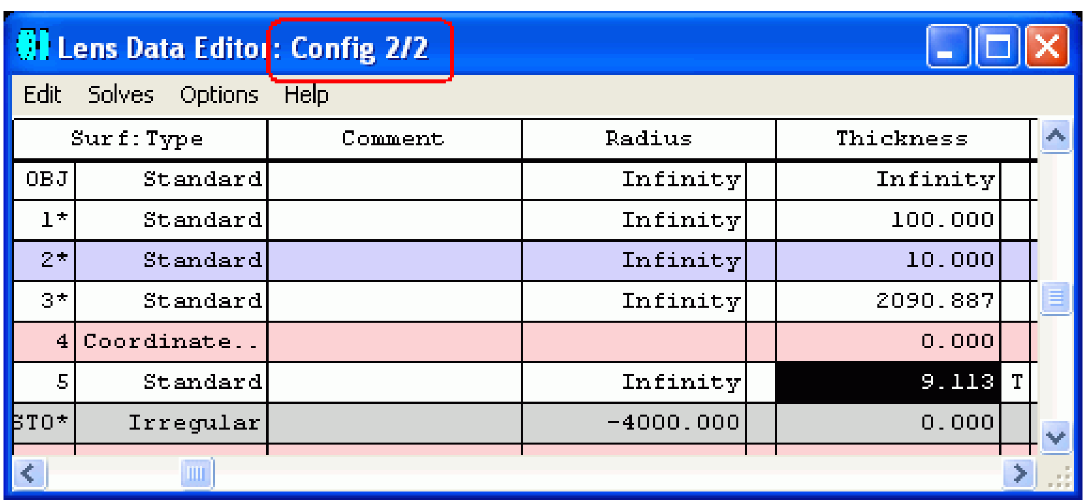
The configuration #2 models the segments positioned at Y=270mm and X=0. The Z distance from the dummy window to the center of the segments can be calculated by subtracting from 2100mm the sag of the unsegmented mirror at a radial distance 270mm from the vertex. The sag can be calculated using the equation for the standard surface, by entering conic of -1, radius curvature of -4000mm and radial coordinate of 270mm. However, it is much easier to let Zemax calculate this using the SSAG operand in the Merit Function Editor (MFE).



Oper #	Type	Surf		X	Y	Target	Weight	Value	% Contrib
1 CONF	CONF	2							
2 SSAG	SSAG	6		0.000	0.000	0.000	0.000	-9.113	0.000
3 CONS	CONS					2100.000	0.000	2100.000	0.000
4 SUMM	SUMM	2	3			0.000	0.000	2090.887	0.000

Note that the configuration (CONF) is 2 for the calculation. The X and Y parameter value for the SSAG operand is zero since the surface already has a decenter of -270mm in configuration 2. The value of 2100mm -9.113mm = 2090.887mm needs to be entered for the THIC operand of configuration 2 in the MCE.

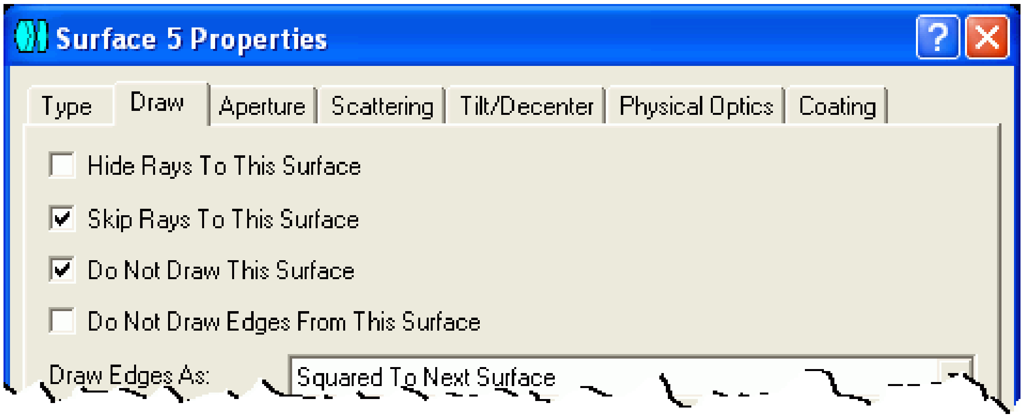
Let's take a look at the LDE for configuration #2.

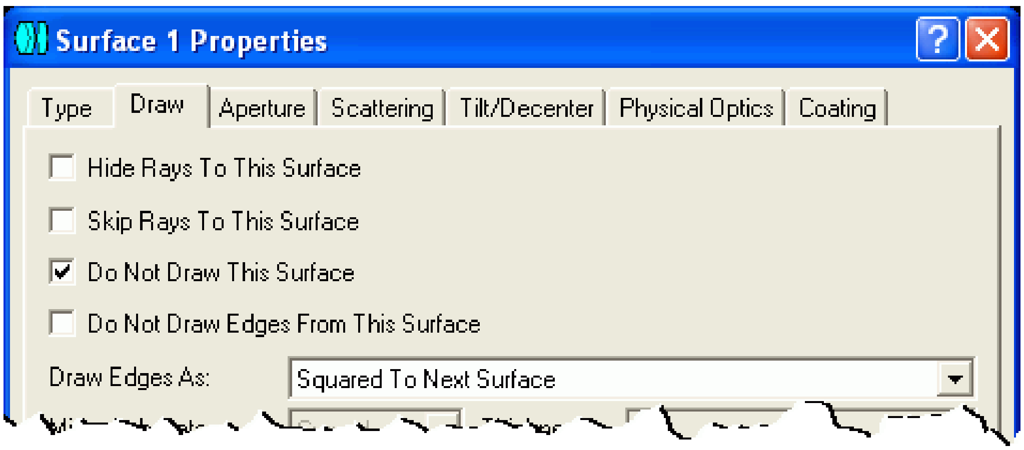


Surf:Type		Comment	Radius		Thickness	
OBJ	Standard		Infinity		Infinity	
1*	Standard		Infinity		100.000	
2*	Standard		Infinity		10.000	
3*	Standard		Infinity		2090.887	
4	Coordinate..				0.000	
5	Standard		Infinity		9.113	T
STO*	Irregular		-4000.000		0.000	

The dummy surface #5 is co-located with CB #4, therefore, the vertex of the mirror (not the center of the off-axis segment) is 9.112mm away in +Z from the coordinate break vertex. The center of the off axis segment is -9.113mm from the mirror vertex and co-located with the CB#4.

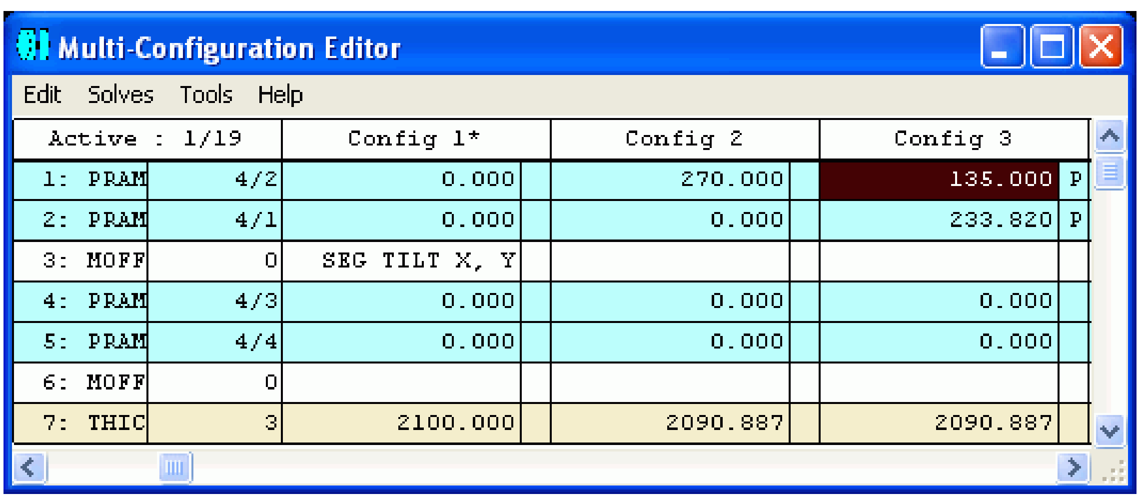
Since the surface #5 and #1 are dummy surfaces, we shall opt to not draw those surface in the layout by choosing the following options in the surface property window.

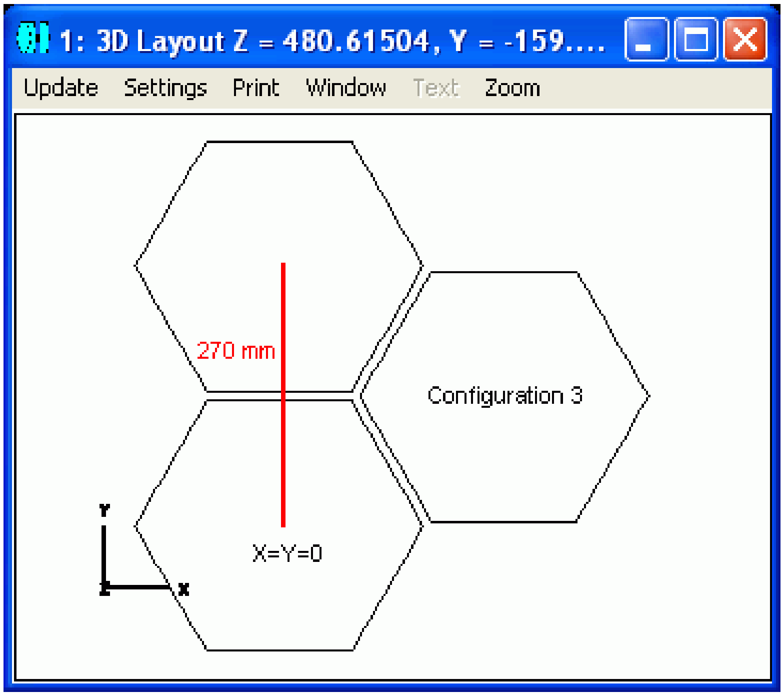




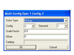
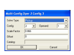
Setup E (Multi-Configuration Editor)

Add a third configuration.

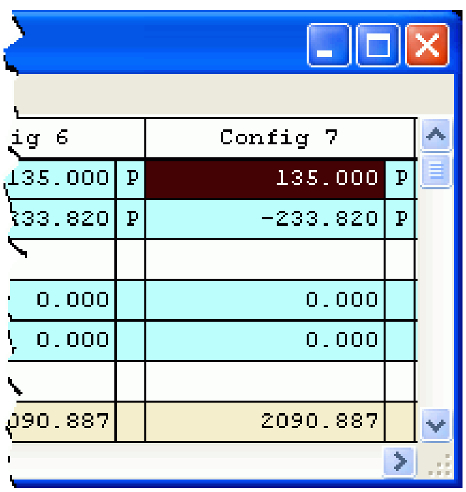




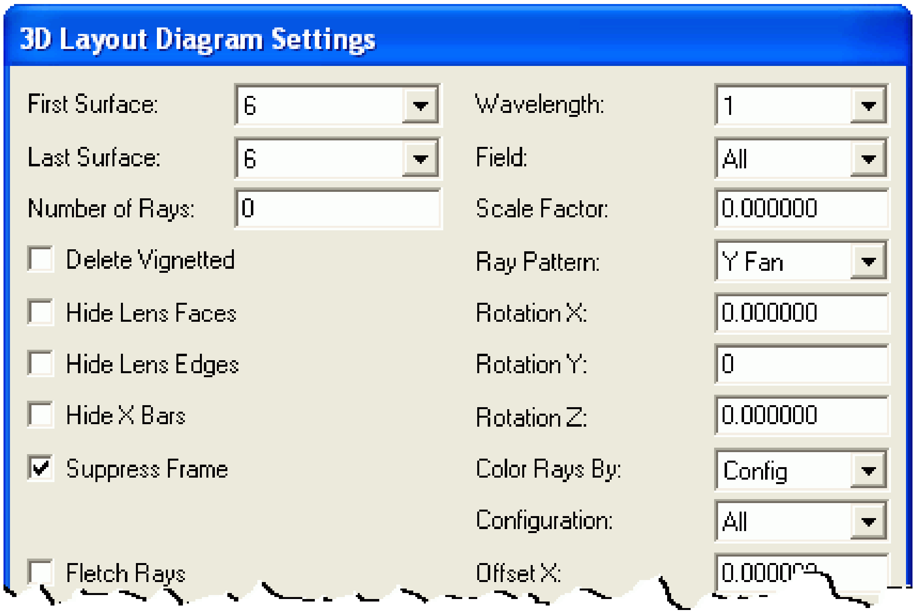
From geometry, the Y coordinate of the segment shown in the drawing above is 270mm*sin(30°) = 270*0.5 and the X coordinate is 270mm*cos(30°) = 270*0.866. For operands PRAM 4/1 and 4/2, we will pick up the values from the Y decenter parameter of configuration 2 by multiplying by these factors using pick-up solves:

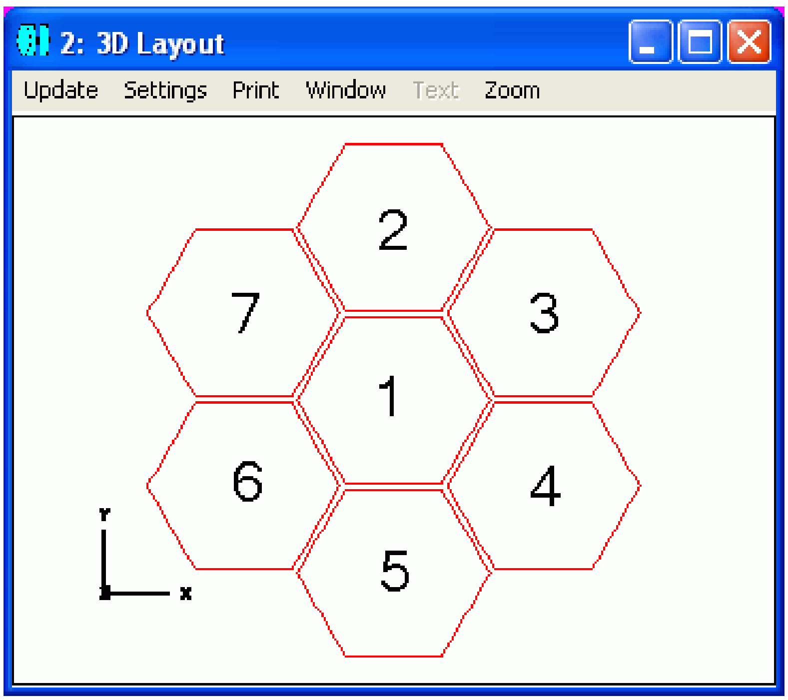
 

Repeat this process and add up to 7 configurations.



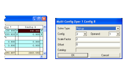
Open the 3D layout with the following settings to verify the set-up.



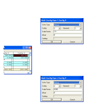


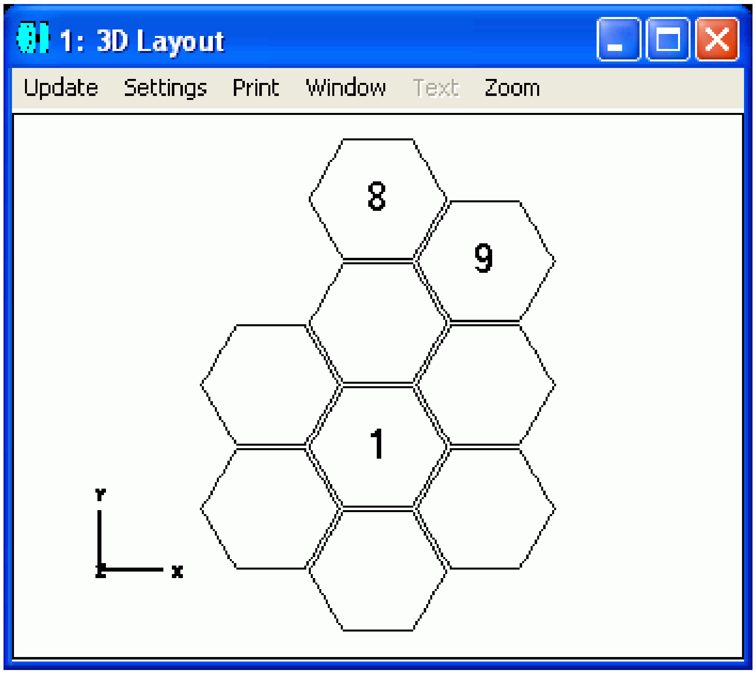
Insert configuration #8. This segment will be located at Y=270mm*2 and X=0.

The THIC operand on surface 3 is now 53.55mm, calculated using the SSAG operand for configuration 8.

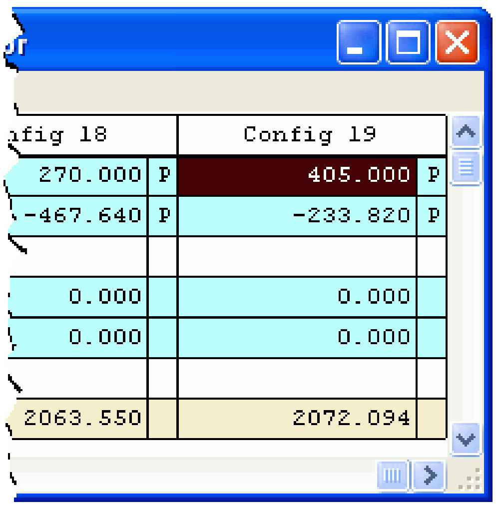


Insert configuration #9. The THIC operand value is 62.094mm and the Y coordinate = 270mm*1.5 and X = 270mm*0.866.



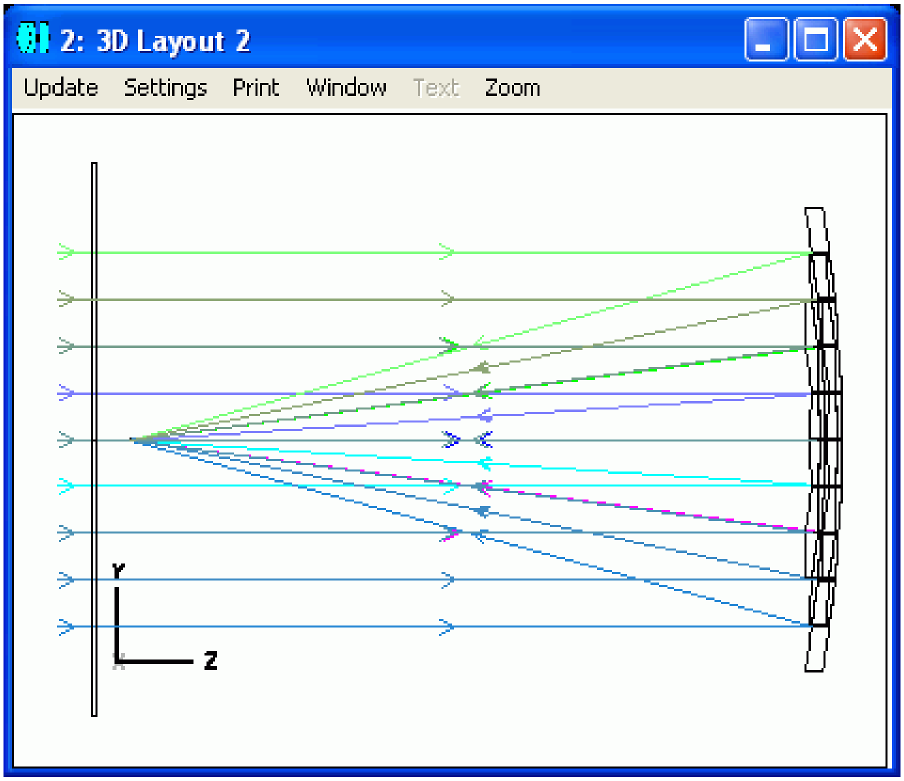


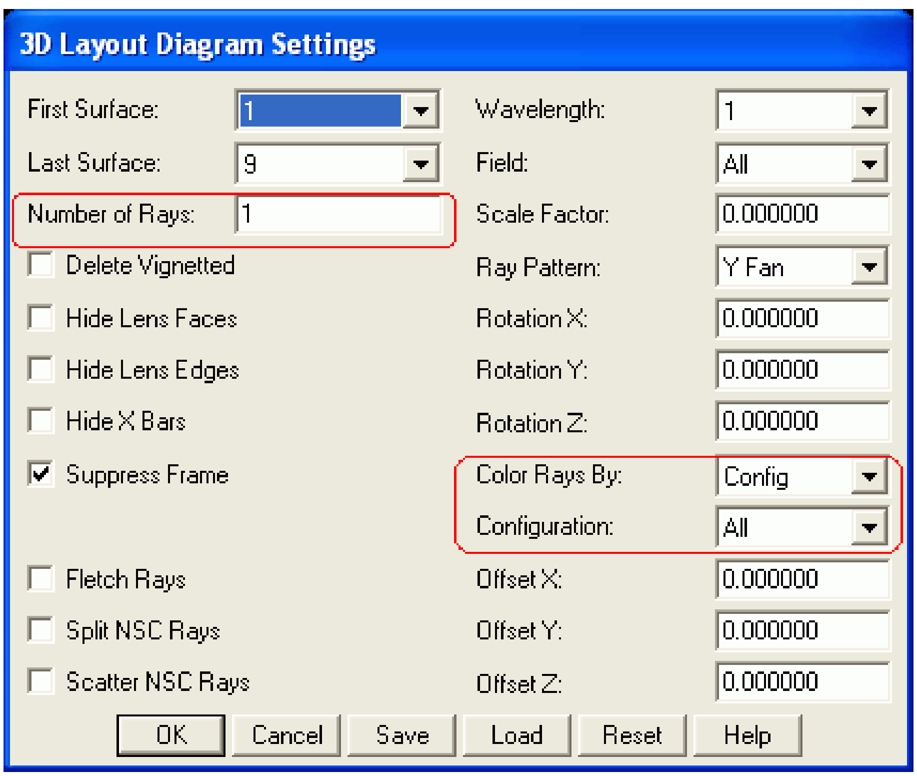
Repeat the process until configuration #19.



For a mirror with much larger number of segments, a ZPL macro can be written to insert the configurations and set appropriate pick-up solves on each.

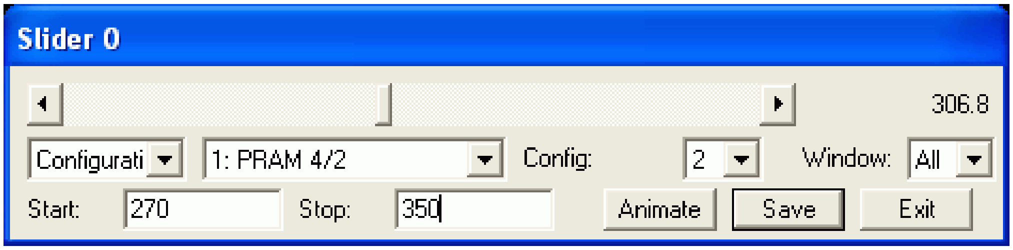
Open the 3D layout with the following settings

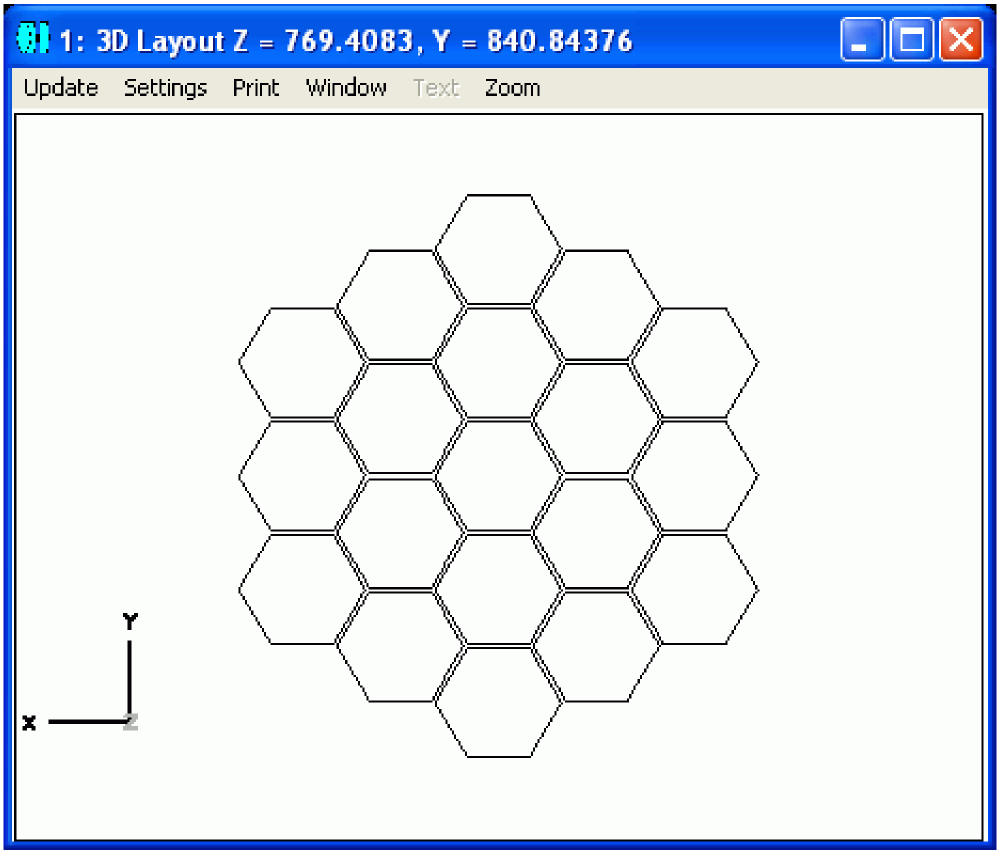




Setup F (Merit Function Editor)

Before we look at the merit function, let's verify that the multi-configuration editor is set up properly. Open the Slider under Tools > Miscellaneous >Slider and vary parameter 1 of configuration 2 from 270mm to 350mm. When you click the "Animate" button you should see the following animation.





This shows that all segments are picking up the inter-segment distance correctly. Click Exit when done.

Now, let's think about how the Merit Function Editor (MFE) should be constructed to minimize atmospheric aberrations, thus decreasing the size of the geometrical and diffraction PSFs. One possible option (there are several) is to force the geometrical centroid position to be at the vertex of the image surface for all segments. Since the geometrical and the diffraction spot centroid are co-located, this method will yield the smallest diffraction point spread function and geometrical RMS spot size. In addition, we need to constrain the path length of the chief ray for each segment to be as close to one another as possible.

Open the Merit Function Editor and set the CENX and CENY (centroid positions) target at the image surface to zero for all configurations. To target path length, we will use a PLEN operand for the chief ray (Px = Py = 0) and constrain these to be equal for all configurations. For a mirror with much larger number of segments, a ZPL macro can be written to automatically insert the appropriate operands in the MFE. For each configuration define a CENX, CENY, and PLEN operand with arguments as shown below:

Merit Function Editor: 7.282821E-013

Edit Tools View Help

Oper #	Type	Surf	Wave	Field	Pol?	Samp		Target	Weight	Value	%
1 CONF	CONF	1									
2 CENX	CENX	9	0	1	0	5		0.000	1.000	2.651E-015	
3 CENY	CENY	9	0	1	0	5		0.000	1.000	2.863E-015	
4 PLEN	PLEN	0	9	0.000	0.000	0.000	0.000	0.000	0.000	4220.000	
5 CONF	CONF	2									
6 CENX	CENX	9	0	1	0	5		0.000	1.000	1.432E-015	
7 CENY	CENY	9	0	1	0	5		0.000	1.000	-7.636E-015	
8 PLEN	PLEN	0	9	0.000	0.000	0.000	0.000	0.000	0.000	4220.000	
9 CONF	CONF	3									
10 CENX	CENX	9	0	1	0	5		0.000	1.000	-1.061E-014	5
11 CENY	CENY	9	0	1	0	5		0.000	1.000	-5.090E-015	1
12 PLEN	PLEN	0	9	0.000	0.000	0.000	0.000	0.000	0.000	4220.000	

Note that we have not placed any weighting on the PLEN operands. We don't intend to target the absolute values of chief ray path length, but rather the difference between these values. To target the difference we will use the EQUA operand to compute the RMS to the average of a sequence of operands in the MFE. However, because the PLEN operands are broken up, we will need to use several OPVA operands to sequentially report the path length for each configuration and use these as the arguments for EQUA.

Define 19 OPVA operands at the end of the current merit function, and use the PLEN operands as the row arguments; leave the target and weightings at zero on these operands. Define a single EQUA operand that uses this range of OPVA operands as arguments; target should be zero and weighting should be one.

Merit Function Editor: 7.282821E-013

Edit Tools View Help

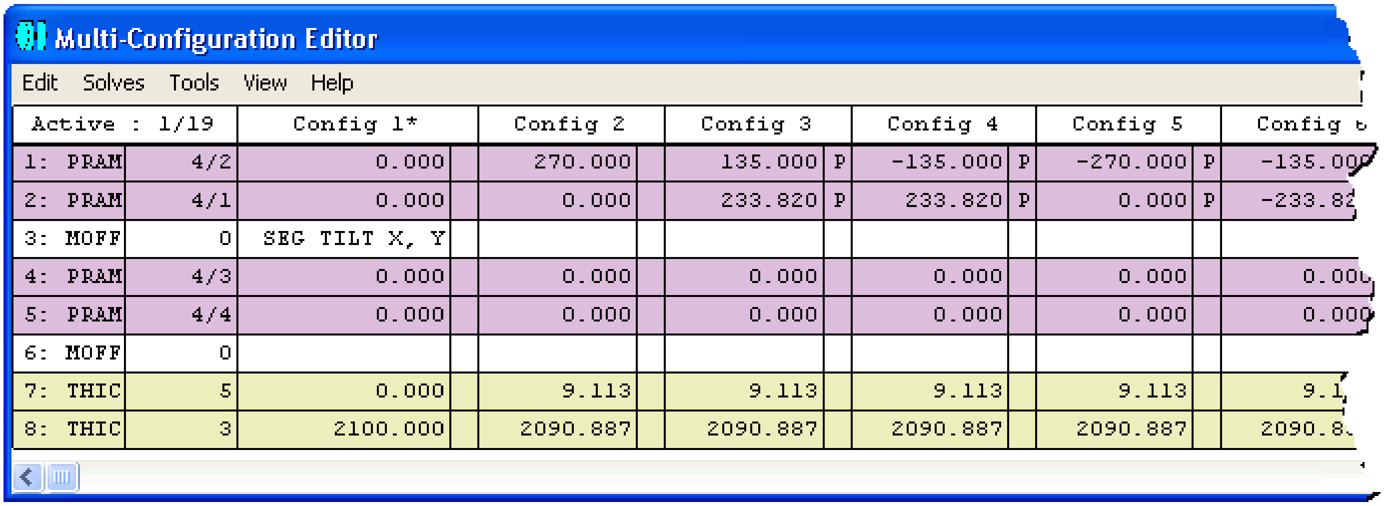
Oper #	Type	Op#						Target	Weight	Value	%
73 CONF	CONF	19									
74 CENX	CENX	9	0	1	0	5		0.000	1.000	1.697E-015	
75 CENY	CENY	9	0	1	0	5		0.000	1.000	5.939E-015	
76 PLEN	PLEN	0	9	0.000	0.000	0.000	0.000	0.000	0.000	4220.000	
77 OPVA	OPVA	4						0.000	0.000	4220.000	
78 OPVA	OPVA	8						0.000	0.000	4220.000	
79 OPVA	OPVA	12						0.000	0.000	4220.000	
80 OPVA	OPVA	16						0.000	0.000	4220.000	

Oper #	Type	Op#						Target	Weight	Value
90 OPVA	OPVA	56						0.000	0.000	4220.000
91 OPVA	OPVA	60						0.000	0.000	4220.000
92 OPVA	OPVA	64						0.000	0.000	4220.000
93 OPVA	OPVA	68						0.000	0.000	4220.000
94 OPVA	OPVA	72						0.000	0.000	4220.000
95 OPVA	OPVA	76						0.000	0.000	4220.000
96 EQUA	EQUA	77	95					0.000	1.000	4.547E-012

Setup G (Tolerance Data Editor)

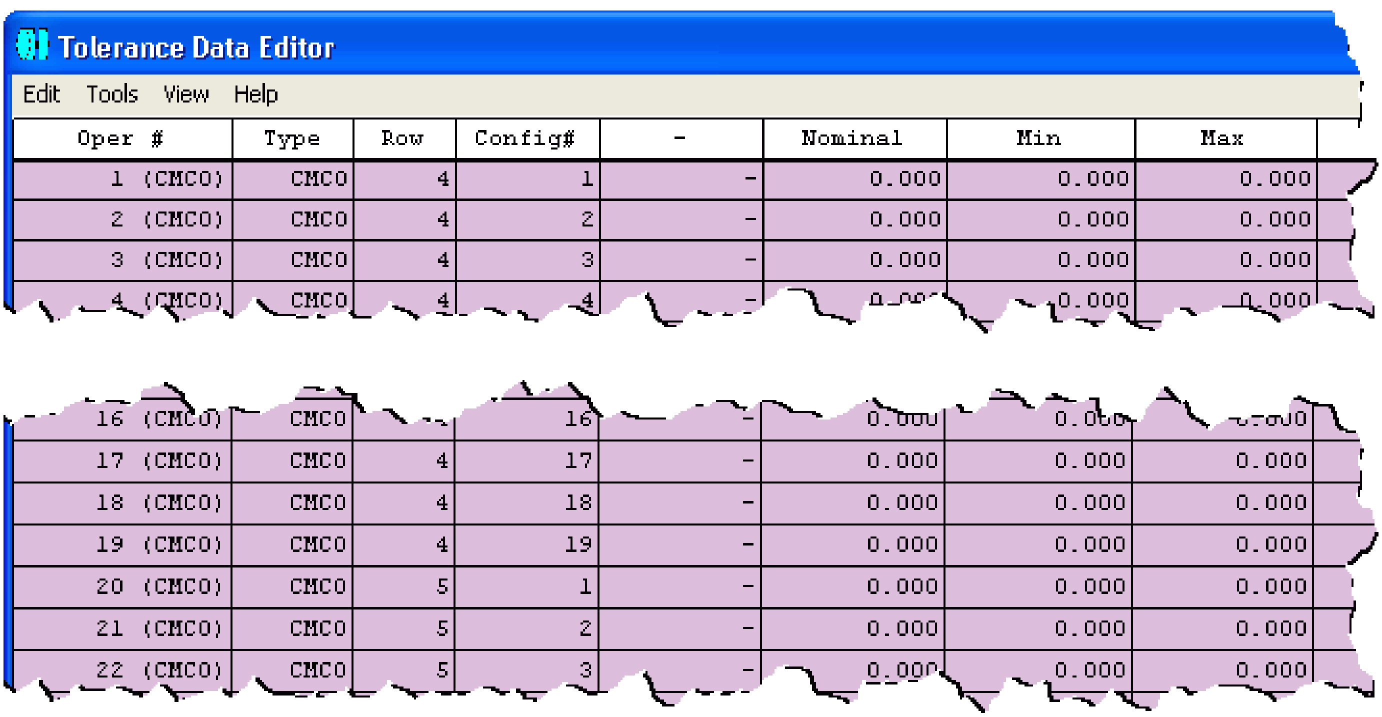
We will use the tolerancing feature in Zemax to introduce random wavefront error and compensate this error by adjusting the tilts and z-positions of the mirrors in the segmented array. We will specify the TEZI operand on the dummy glass window (surface #3) in the Tolerance Data Editor (TDE) to introduce random sag error. We also need to specify the X and Y tilt of CB surface #4 (operands 4 and 5 in the MCE) and the position of the mirror segments as compensators (variables) for optimization.

Remember that we used a thickness solve to control the locations of the mirrors. If we want to allow the mirror positions to act as compensators, we must remove this solve and define the nominal mirror positions in the MCE. Remove the thickness solve from surface 5 (change from "position" to "fixed"). Insert a line at row 7 in the MCE and define a THIC operand for surface 5. Set the value for each config such that the overall glass plate to mirror thickness is nominally 2100.



Active :	1/19	Config 1*	Config 2	Config 3	Config 4	Config 5	Config 6
1: PRAM	4/2	0.000	270.000	135.000 P	-135.000 P	-270.000 P	-135.000
2: PRAM	4/1	0.000	0.000	233.820 P	233.820 P	0.000 P	-233.82
3: MOFF	0	SEG TILT X, Y					
4: PRAM	4/3	0.000	0.000	0.000	0.000	0.000	0.000
5: PRAM	4/4	0.000	0.000	0.000	0.000	0.000	0.000
6: MOFF	0						
7: THIC	5	0.000	9.113	9.113	9.113	9.113	9.1
8: THIC	3	2100.000	2090.887	2090.887	2090.887	2090.887	2090.8

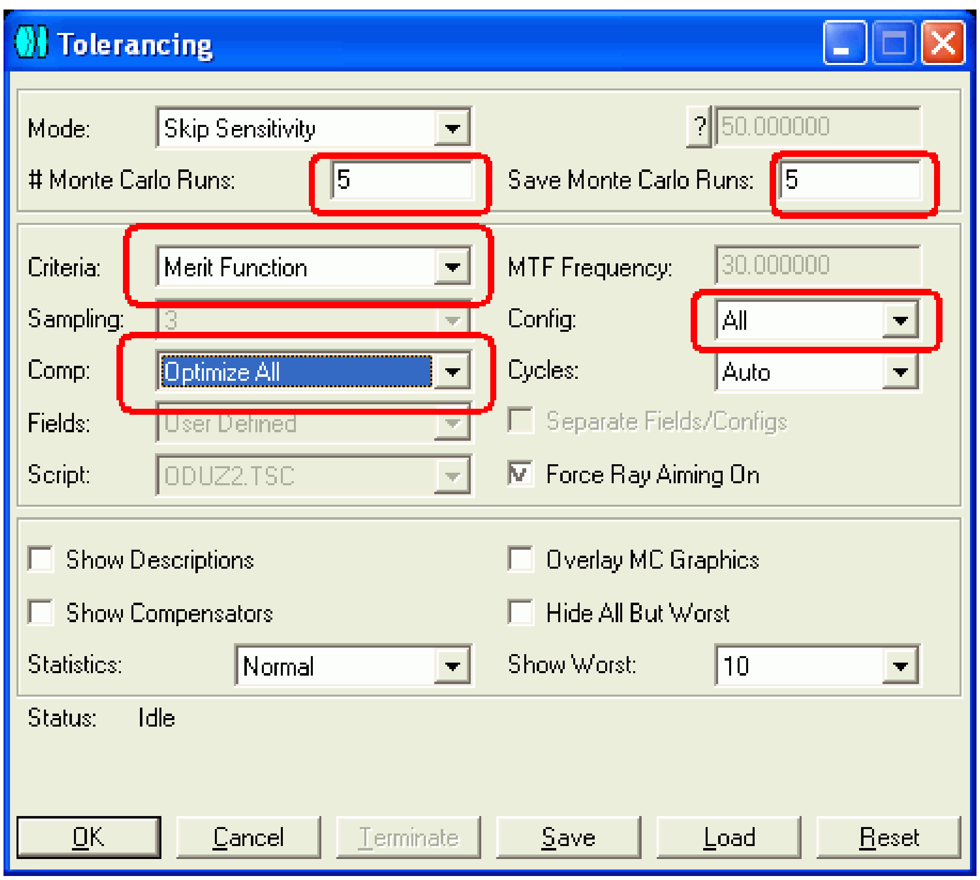
Open the TDE (Editors >Tolerence Data) and insert the compensator operands. We will need to define 3 CMCO operands for each config: x-tilt (MC operand 4), y-tilt (MC operand 5), and z-position (MC operand 7). When defining compensators, you must preferentially group those for each operand in the MCE (i.e. all compensators on operand 4, then all compensators on operand 5, etc.). At the end of the TDE, insert a TEZI operand and specify the following parameter values. We will use Zernike terms 2 to 9 to control the number of peaks and valleys of the sag over the semi-diamter. The RMS error is set at 0.5um.



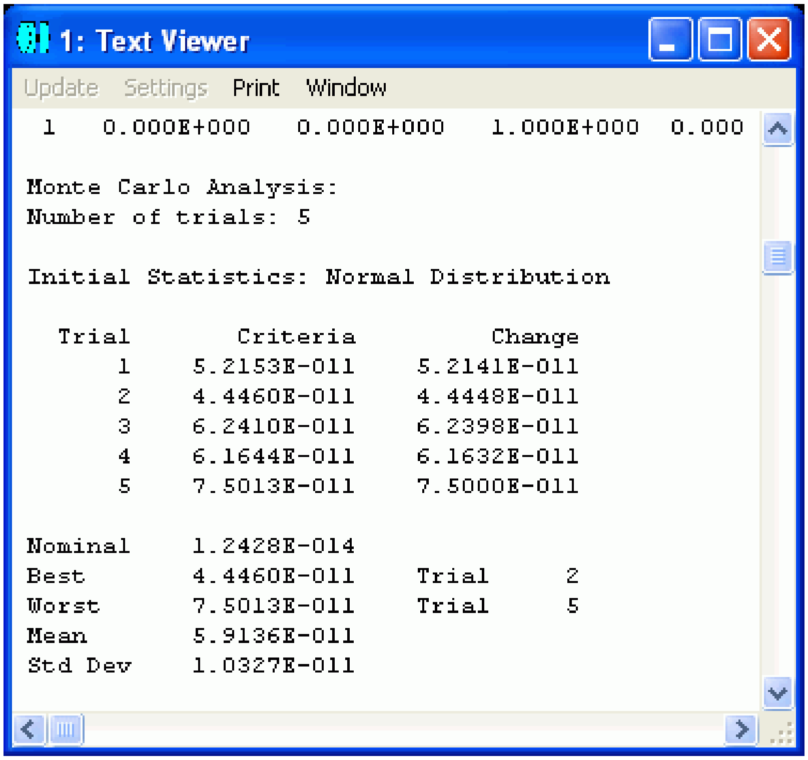
Oper #	Type	Row	Config#	-	Nominal	Min	Max
1 (CMCO)	CMCO	4	1	-	0.000	0.000	0.000
2 (CMCO)	CMCO	4	2	-	0.000	0.000	0.000
3 (CMCO)	CMCO	4	3	-	0.000	0.000	0.000
4 (CMCO)	CMCO	4	4	-	0.000	0.000	0.000
16 (CMCO)	CMCO		16	-	0.000	0.000	0.000
17 (CMCO)	CMCO	4	17	-	0.000	0.000	0.000
18 (CMCO)	CMCO	4	18	-	0.000	0.000	0.000
19 (CMCO)	CMCO	4	19	-	0.000	0.000	0.000
20 (CMCO)	CMCO	5	1	-	0.000	0.000	0.000
21 (CMCO)	CMCO	5	2	-	0.000	0.000	0.000
22 (CMCO)	CMCO	5	3	-	0.000	0.000	0.000

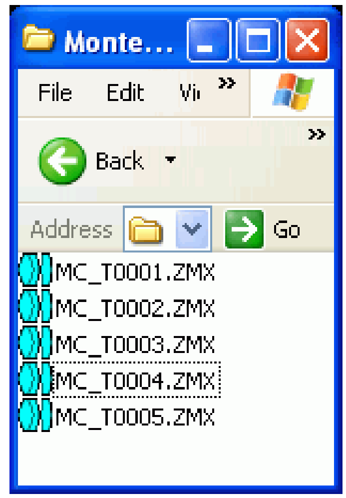
36 (CMCO)	CMCO	5	17	-	0.000	0.000	0.000
37 (CMCO)	CMCO	5	18	-	0.000	0.000	0.000
38 (CMCO)	CMCO	5	19	-	0.000	0.000	0.000
39 (CMCO)	CMCO	7	1	-	0.000	0.000	0.000
40 (CMCO)	CMCO	7	2	-	9.113	0.000	0.000
41 (CMCO)	CMCO	7	3	-	9.11[illegible]	0.000	0.000
54 (CMCO)	CMCO	7	16	-	36.450	0.000	0.000
55 (CMCO)	CMCO	7	17	-	27.906	0.000	0.000
56 (CMCO)	CMCO	7	18	-	36.450	0.000	0.000
57 (CMCO)	CMCO	7	19	-	27.906	0.000	0.000
58 (TOFF)	TOFF	-	-	-	-	-	-
59 (TEZI)	TEZI	3	9	2	0.000	-5.000E-004	5.000E-004

Run the tolerance (Tools > Tolerancing > Tolerancing) using the following options. Click OK to the warning message.



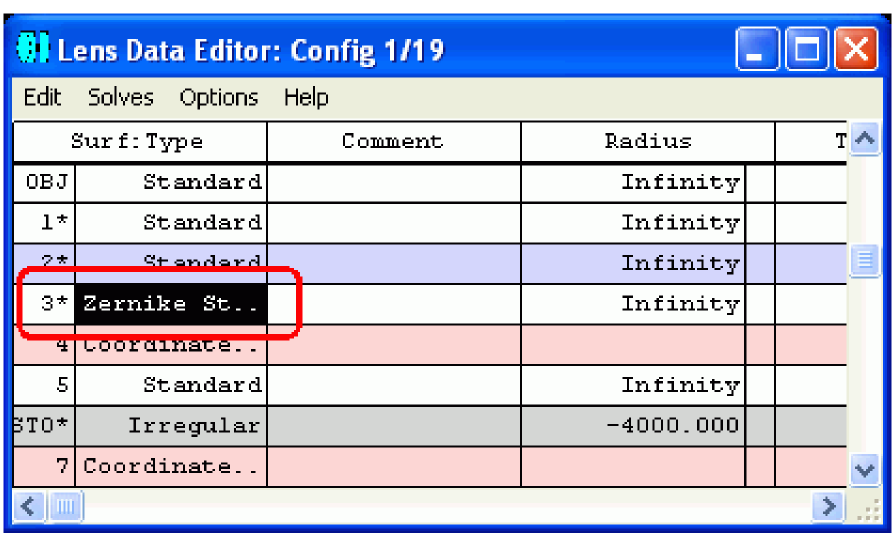
At the end of tolerancing, Zemax will open the tolerance report window. The 5 Monte Carlo files are saved in the save directory as the current lens file.

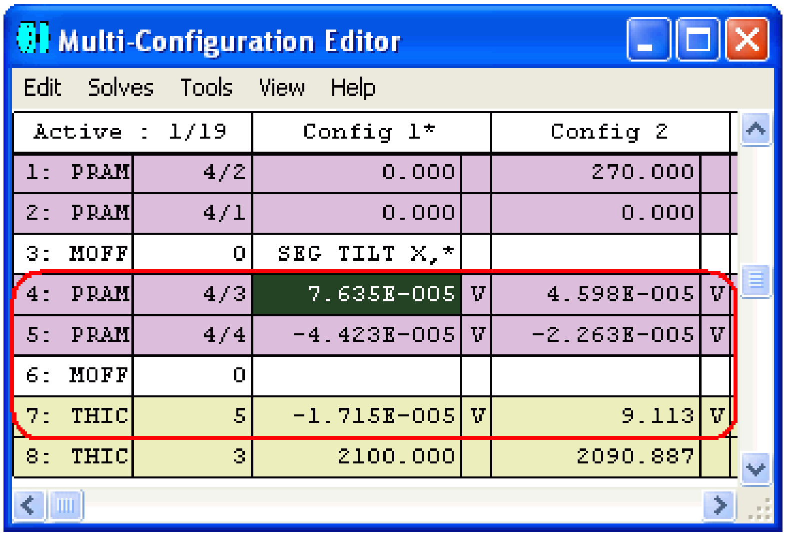




Anaysis A

Save the current lens file and open any one of the Monte Carlo files. Notice how the surface #3 type in the LDE is Zernike Standard Surface, due to the TEZI operand in the TDE in the original lens file. The operands #4, #5, and #7 in the MCE are set as variable for all configurations, due to the CMCO tolerance operands. The variables have non-zero values because during tolerancing the compensators ware changed to minimize the Merit Function.

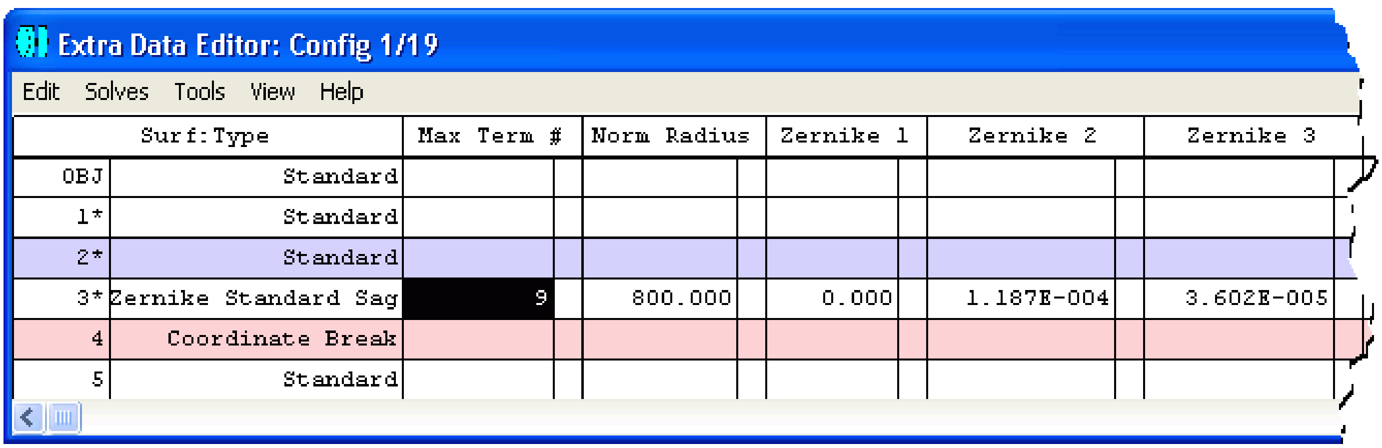




Active : 1/19		Config 1*		Config 2	
1: PRAM	4/2	0.000		270.000	
2: PRAM	4/1	0.000		0.000	
3: MOFF	0	SEG TILT X,*			
4: PRAM	4/3	7.635E-005	V	4.598E-005	V
5: PRAM	4/4	-4.423E-005	V	-2.263E-005	V
6: MOFF	0				
7: THIC	5	-1.715E-005	V	9.113	V
8: THIC	3	2100.000		2090.887	

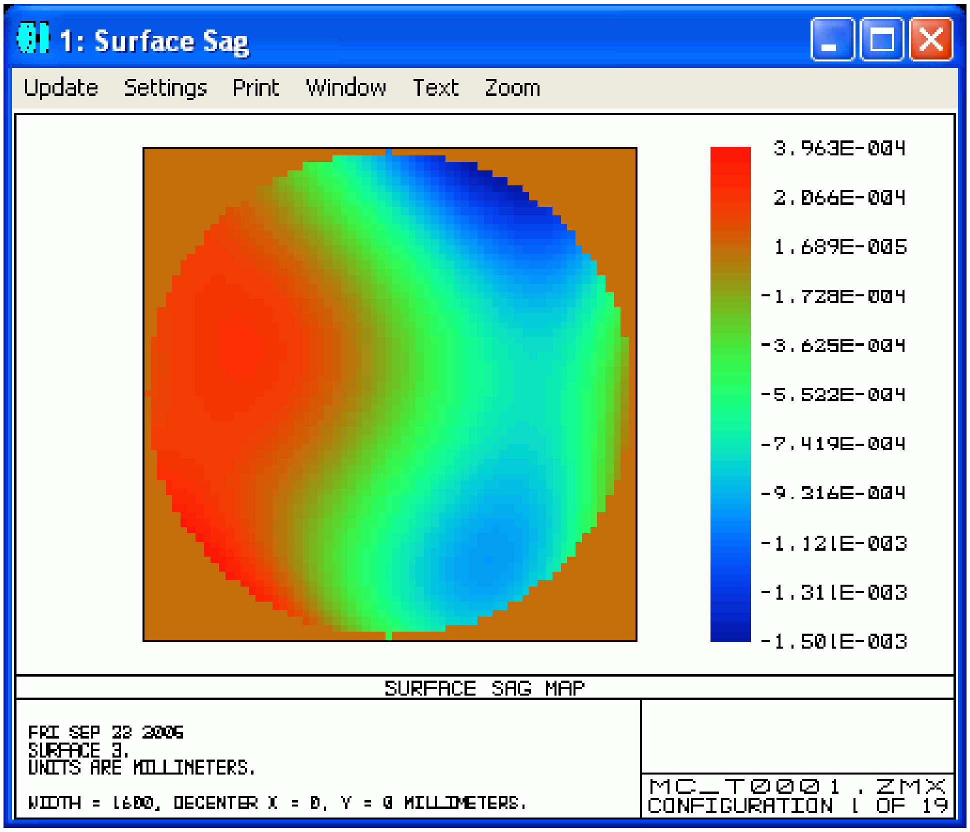
Open the Extra Data Editor (Editors > Extra Data).

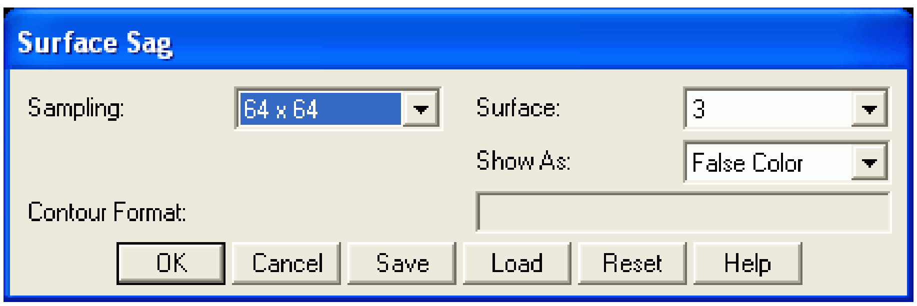
The Norm Radius is set to 800mm which corresponds to the surface #3 semi-diameter in the LDE.



Surf:Type		Max Term #	Norm Radius	Zernike 1	Zernike 2	Zernike 3
OBJ	Standard					
1*	Standard					
2*	Standard					
3*	Zernike Standard Sag	9	800.000	0.000	1.187E-004	3.602E-005
4	Coordinate Break					
5	Standard					

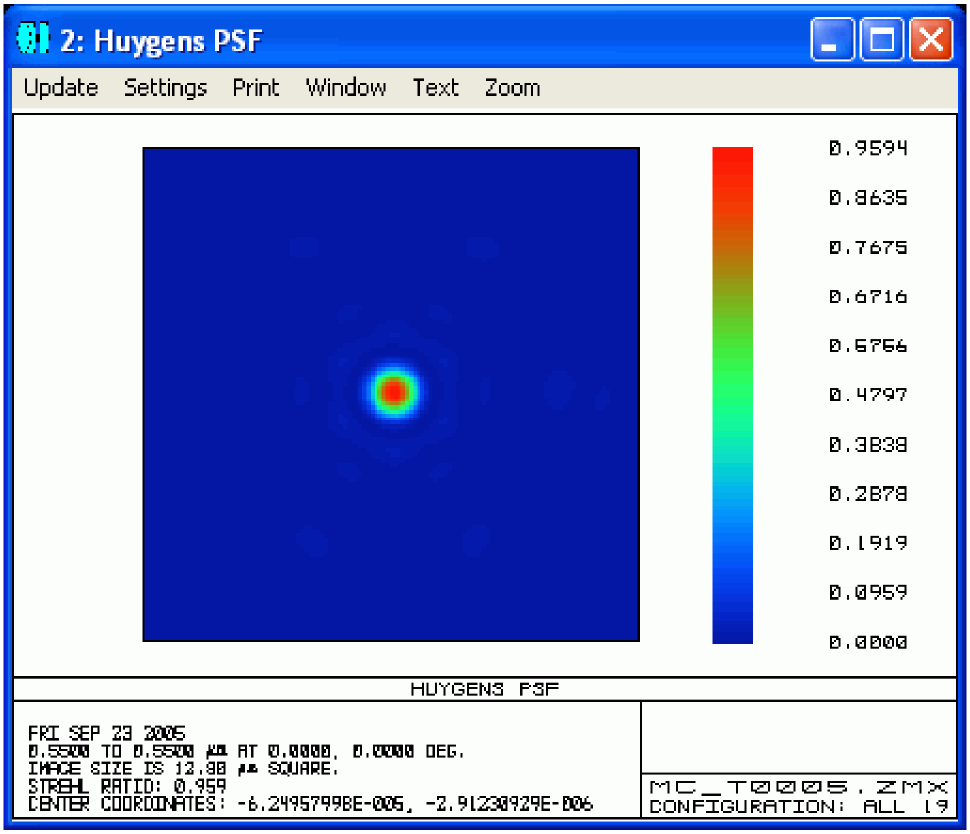
To see the shape of surface #3, hence the input wavefront, open the Surface Sag plot under Analysis > Surface > Surface Sag with the following settings. The animation below shows the surface sag plot for each of the Monte Carlo files. You probably have different looking plots since the sag error is randomly generated.

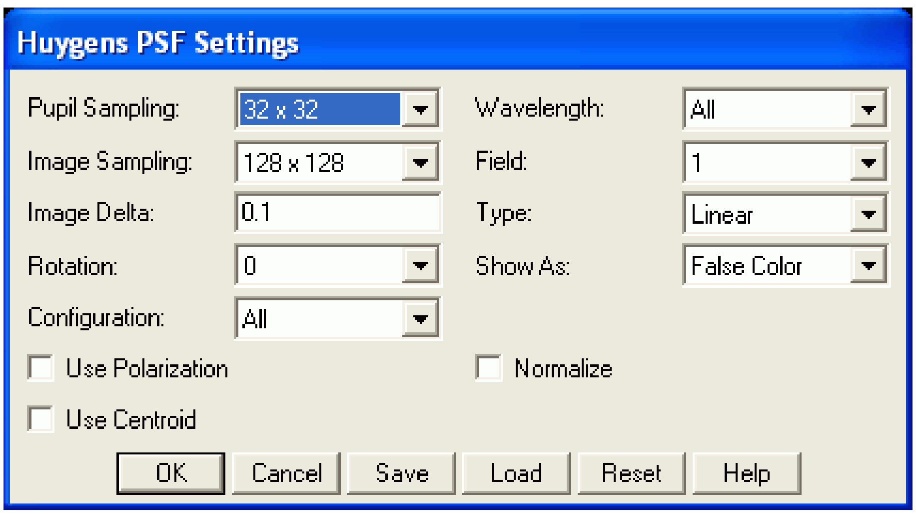


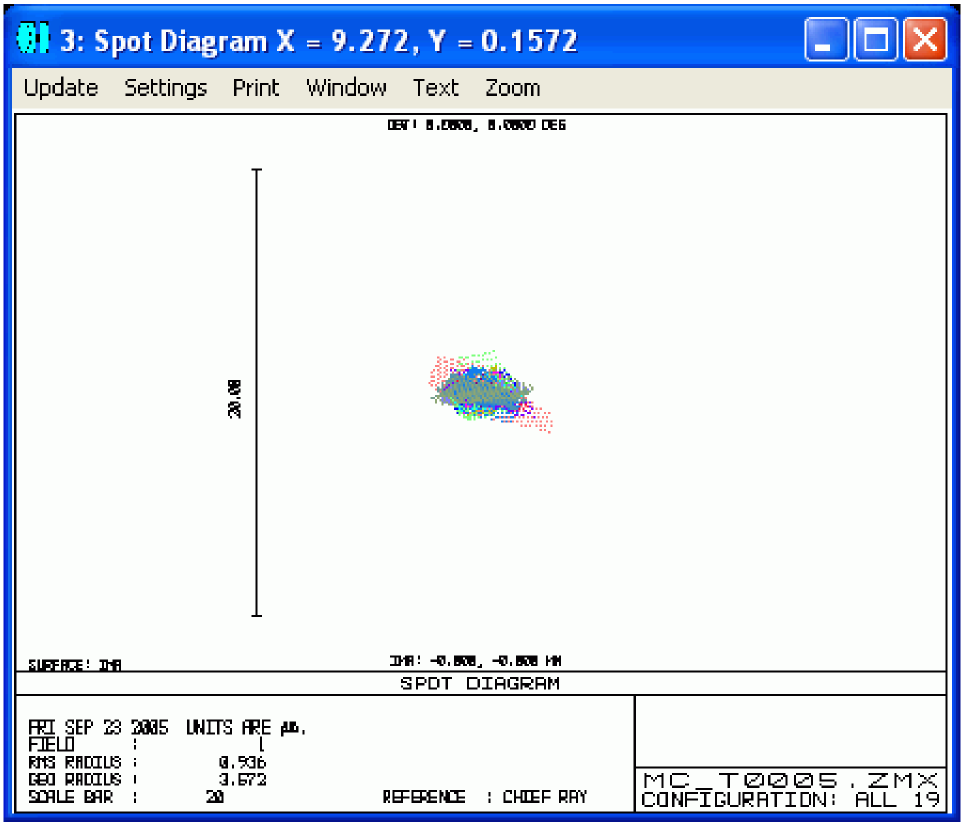


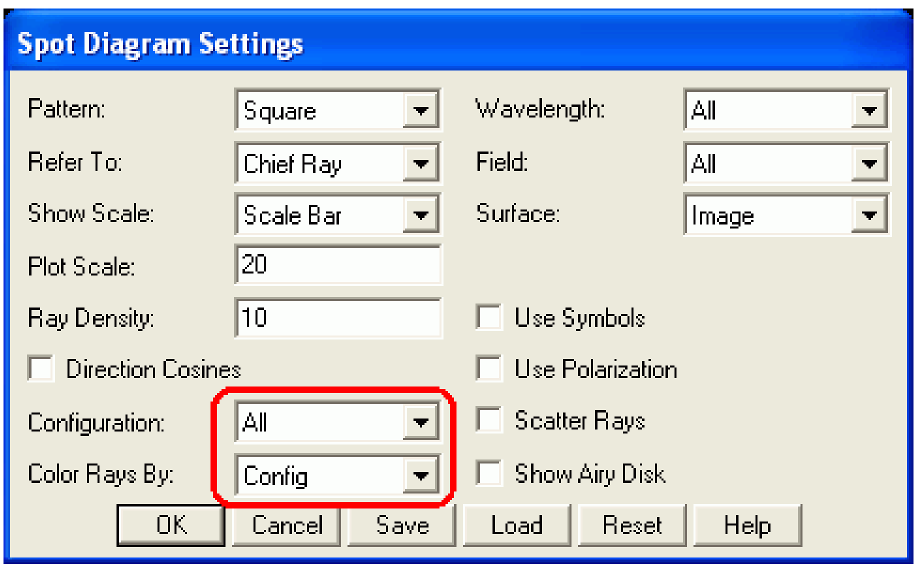
Analysis B

Open the Huygens Point Spread Function (/support/knowledgebase/What-is-a-Point-Spread-Function)analysis windows under Analysis > PSF > Huygens PSF, and the Spot Diagram under Analysis >Spot Diagram >Standard.

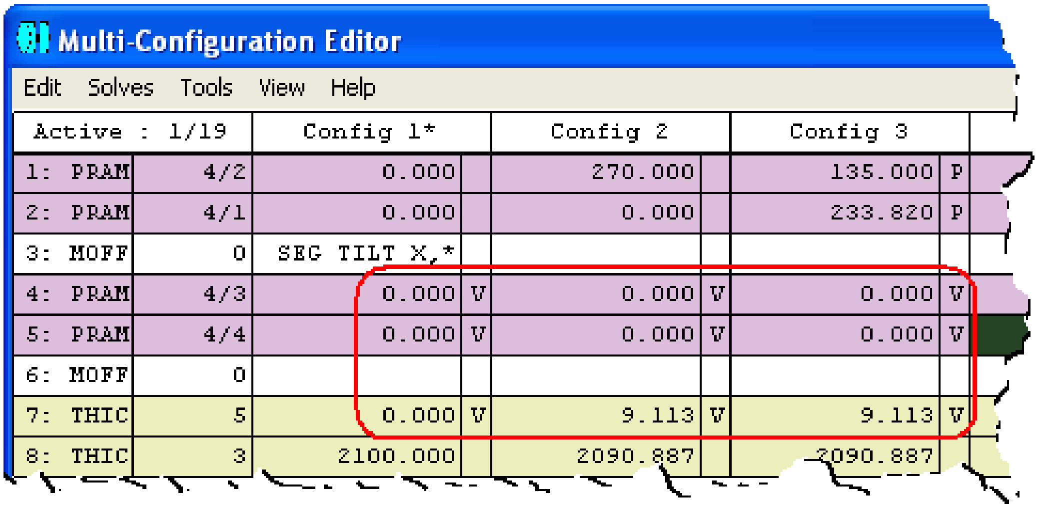

2: Huygens PSF
Update Settings Print Window Text Zoom
0.9594
0.8635
0.7675
0.6716
0.5756
0.4797
0.3838
0.2878
0.1919
0.0959
0.0000
HUYGENS PSF
FRI SEP 23 2005
0.5500 TO 0.5500 µm AT 0.0000, 0.0000 DEG.
IMAGE SIZE IS 12.80 µm SQUARE.
STREHL RATIO: 0.959
CENTER COORDINATES: -6.24957998E-005, -2.91230929E-006
MC_T0005.ZMX
CONFIGURATION: ALL


Huygens PSF Settings
Pupil Sampling: 32 x 32
Image Sampling: 128 x 128
Image Delta: 0.1
Rotation: 0
Configuration: All
Wavelength: All
Field: 1
Type: Linear
Show As: False Color
Use Polarization
Normalize
Use Centroid
OK Cancel Save Load Reset Help

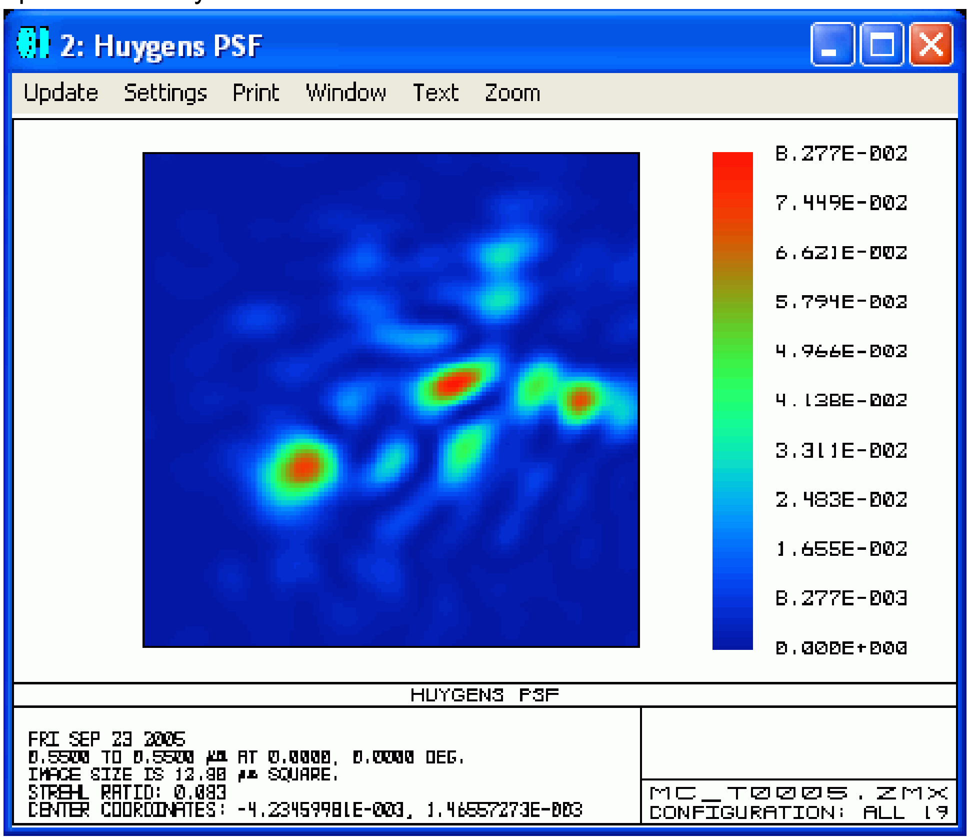


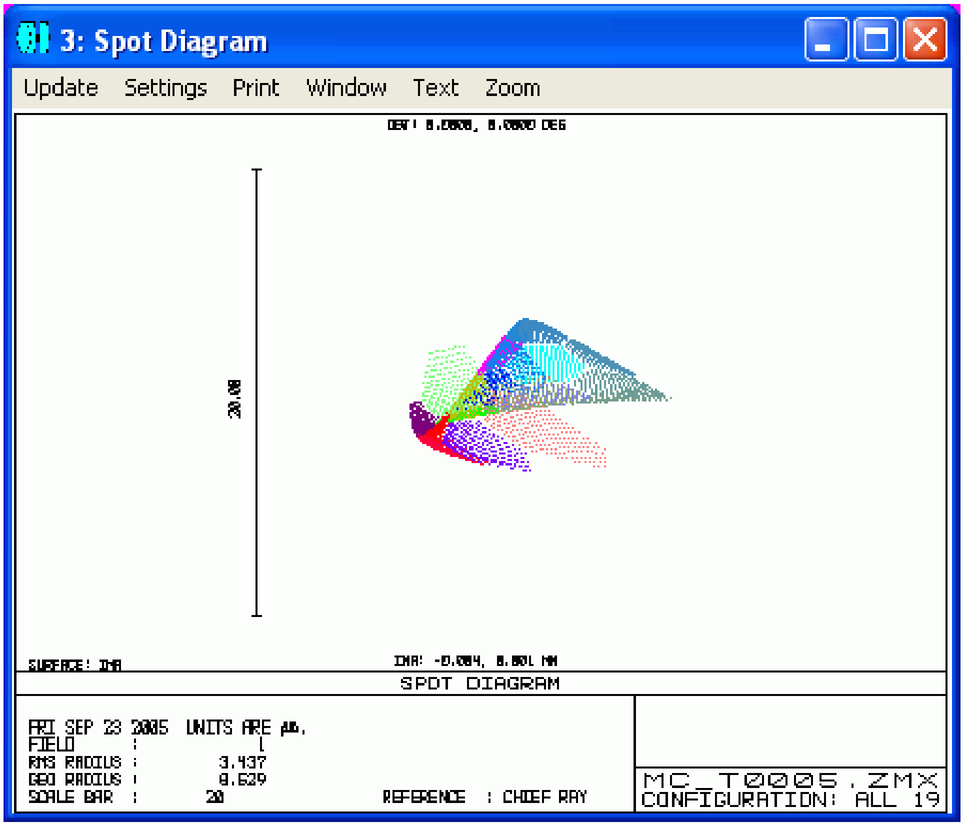


To see the geometric and diffraction PSF before optimization, set all the tilt values to zero and reset the mirror positions.



Update the analysis windows.

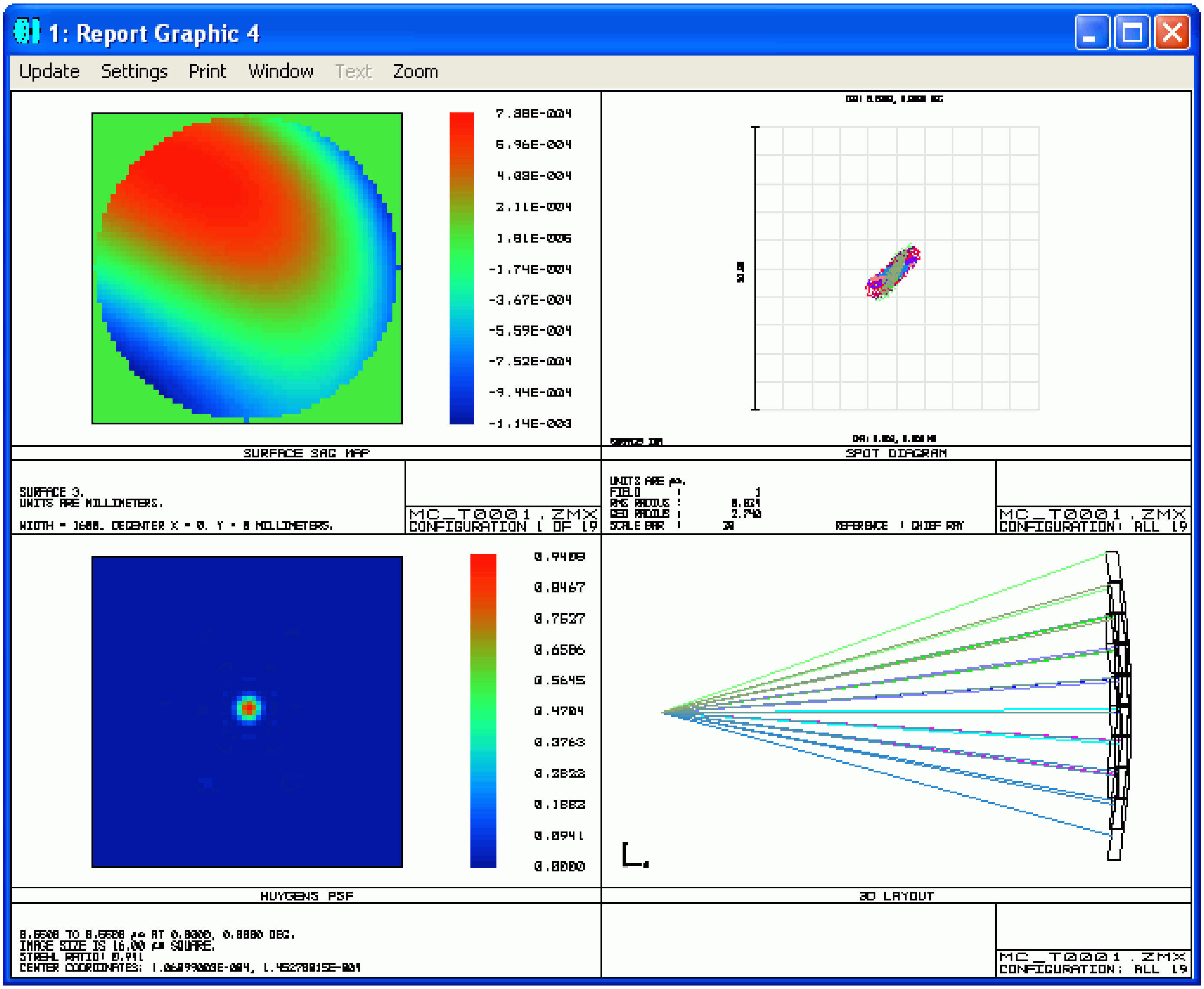




You can see that the tilt of the segments reduces the abberations dramatically.

You can also use the report graphics feature under Report >Report Graphics 4 >New Report to plot 4 analysis in a single window.

The Report Graphics below show the optimized and un-optimized PSFs for each of the 5 Monte Carlo files.



Summary and References

This article demonstrated how to model an adaptive optics in sequential Zemax. In summary:

- Each segment can be modeled in a configuration
- Tolerancing feature can be used to generate random wavefront error
- Large number of segments can be created by using the ZPL macro
- Careful use of pick-up solves can reduce the complexity of the lens file

See also: Article Attachment(/support/knowledgebase/Knowledgebase-Attachments/How-to-Model-an-Adaptive-Optical-System/Adaptive_optics_final.aspx)