

Optimization Tutorial Using OSLO Light

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INTRODUCTION

Note: Parts of this tutorial are very similar to the "Optimization Tutorial Using OSLO Standard & Premium." This has to be the case in order for each tutorial to stand on its own. If you are reading both tutorials, please be aware that steps #1 through #16 are exactly the same and could be skipped in one of the tutorials.

Optimization is the process by which the performance of a lens system is improved by changing the values of some of the lens data (variables) such that a measure of lens performance is improved. This measure of lens performance comes in the form of an error function or merit function.

An error function is a list of targets that OSLO tries to minimize during optimization (when the error function is minimized the lens is improved). When the total value of the error function is as small as it can be, then the system has been fully optimized and is as good as it can be. If the targets (operands) that make up the error function are not exactly zero then the error function has some residual error associated with it. Since the error function is the composite of the individual targets, in a way it is a measure of the composite error of the system - hence the name error function.

This tutorial will consist of performing additional optimization on a lens design form called the "Cooke" triplet. As a historical note, the name of the lens design form comes from the Cooke company which was involved in the initial invention of the Cooke triplet design form. The exact prescription of the lens that we will use (the surface curvatures, glasses and thicknesses) is an adaptation of a design done by R. Kingslake and included in his book "Lens Design Fundamentals," pp286-295, (Acadmeic Press 1978, ISBN 0-12-408650-1). The Cooke triplet design form has been used in millions of low cost cameras, projectors, and various other instruments. We will be using the Cooke Triplet as the starting point of our optimization.

Lenses like the Cooke triplet are typically designed for film cameras. The Cooke triplet lens prescription supplied with OSLO has a 50mm focal length, which suits the 24x36mm format used for 35mm cameras. The lens is not optimum for a typical digital camera, which has a smaller image size, because the focal length is too long. In this example we will redesign the lens to have a focal length of 10mm which is more suited to contemporary digital cameras. In addition, we will make the lens faster (re-design the lens to a lower f/number) so that the paraxial specifications become 10mm EFL, f/2.8 and +/-20 degrees field angle.

OUTLINE

The steps in this tutorial are as follows:

- **Lens Entry** - Create a starting lens that will be used for both optimization approaches in this tutorial.
 - Open the "demotrip.len" lens file.
 - Scale the entire lens to an effective focal length (EFL) of 10mm.
 - Change the Entrance Beam Radius so that the system now has an F-number of f/2.8.
 - Change the apertures radius of all the surfaces to 1.8 so that the larger beam can get through.
 - Increase the thickness of the first and third lens elements to 0.7mm. Increase the thickness of the center lens element to 0.3mm.
 - Apply a solve on the curvature of surface 6 so that the system EFL of 10 is maintained. As soon as you have applied the solve, remove the solve once again so that the EFL is not continually updated.
 - Set variables that vary all curvatures and all air spaces.
 - Update the title of the lens and save the lens as "Triplet10mm_Start.len" in your private directory.

- **Optimization using the Aberration Error Function**

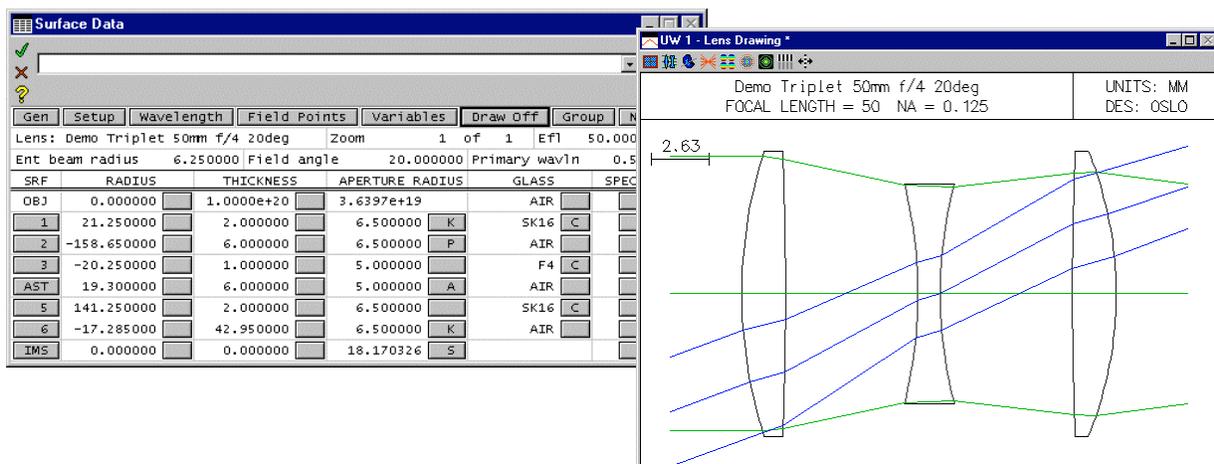
- Perform the Ray Intercept Curves (RIC) Report Graphic analysis as a baseline analysis of current system performance. Lock the graphic window against inadvertent updating.
- Generate Aberration Error Function operands.
- Set all operand weights to zero except for (1) the height of the marginal ray on the image plane, (2) total spherical aberration, and (3) the system EFL.
- Alter the EFL operand so that the system EFL is targeted to 10.
- Save the lens as "Triplet10mm_OptAberLT.len" in your private directory.
- Optimize the lens system.
- Perform the RIC Report Graphic analysis in a new graphic window to compare with the baseline analysis. Lock the graphic window against inadvertent updating.
- Save the lens with the same "Triplet10mm_OptAberLT.len" file name.

- **Optimization using the GENII Error Function**

- Restore "Triplet10mm_Start.len" from your private directory.
- Generate the GENII Ray Aberration Error Function operands.
- No need to alter operands.
- Save the lens as "Triplet10mm_OptGeniiLT.len" in your private directory.
- Optimize the lens system.
- Perform the RIC Report Graphic analysis in a new graphic window to compare with the baseline analysis. Lock the graphic window against inadvertent updating.
- Save the lens with the same "Triplet10mm_OptGeniiLT.len" file name.

DETAIL

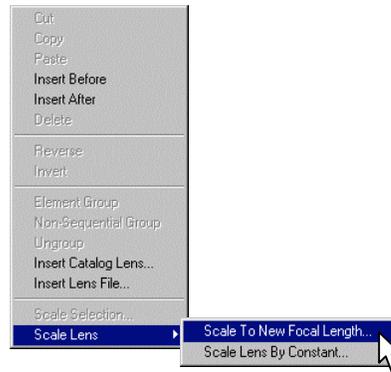
Lens entry



- 1) Open the lens file located at "...\\public\\len\\demo\\LT\\demotrip.len".
- 2) If it is not already open, open the surface data spreadsheet by choosing "Len>>Surface Data Spreadsheet" from the OSLO menu.

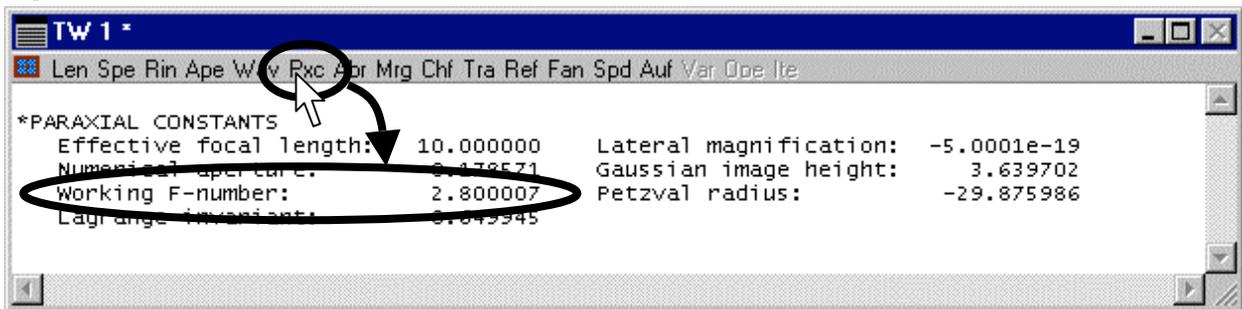
If you have a lens that is a good starting point except for its focal length, it is usually not a wise idea to force the lens to the new focal length through optimization.. Instead, it is better to simply scale the entire lens to the new focal length - of course this will also scale apertures, curvatures and thicknesses as well.

- Right click the mouse in any white cell of the surface data spreadsheet and choose "Scale Lens>>Scale Lens to New Focal Length..." from the resulting pop-up menu and scale the lens to a focal length of 10.



Note: The current system has an f/number of 4.0. To achieve an f/number of 2.8 you need to increase the system aperture by 4.0/2.8

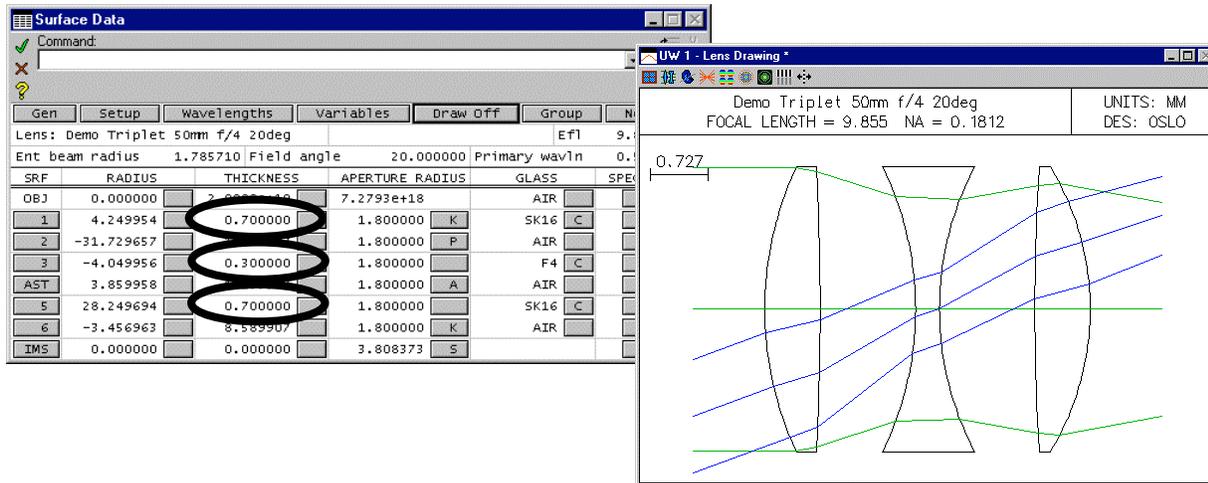
- Note that the almost all the parameters of the lens prescription have been changed. The entrance beam radius is now 1.249986. Change the Entrance Beam Radius value to 1.78571 to force the system to have an F-number of f/2.8.
- The F-number of the system can now be verified by choosing to list Paraxial Constants (Pxc) from the Text Window toolbar. If you are having trouble finding this button or you want to learn more about this button, please refer to Sideline #1 at the end of this tutorial.



- Notice that the apertures in the Aperture Radius column are all smaller than the Entrance Beam Radius just defined. Change the apertures of all the surfaces to 1.8 so that the larger beam can get through.

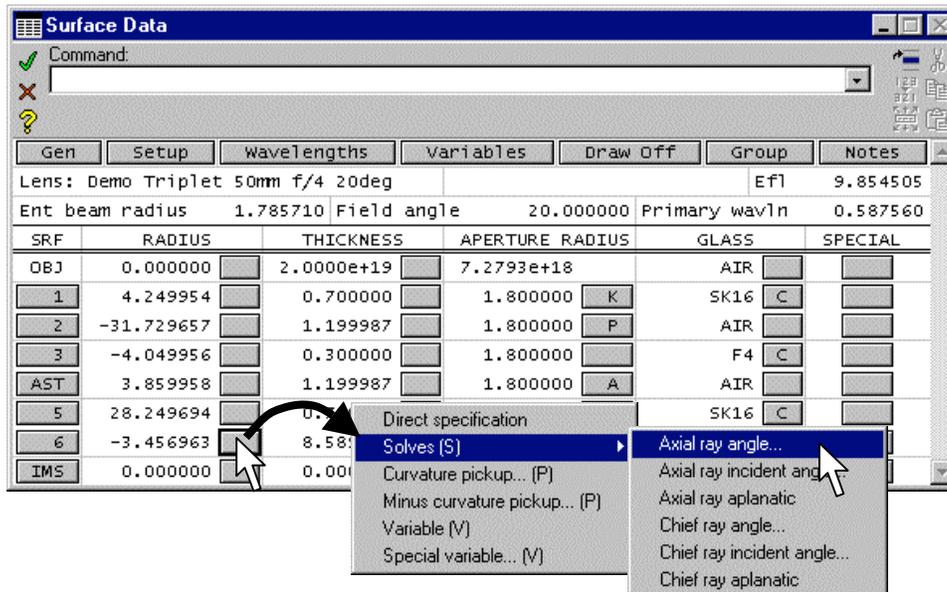
Angle	20.000000	Pr
APERTURE RADIUS		
	7.2793e+18	
	1.800000	K
	1.800000	P
	1.800000	
	1.800000	A
	1.800000	
	1.800000	K
	3.635425	S

- 7) Note that with the scaled lens the elements are too thin to support an aperture of 1.8. Increase the thickness of the front and back elements from $\sim 0.40\text{mm}$ to 0.7mm , and the thickness of the center element from $\sim 0.2\text{mm}$ to 0.3mm .

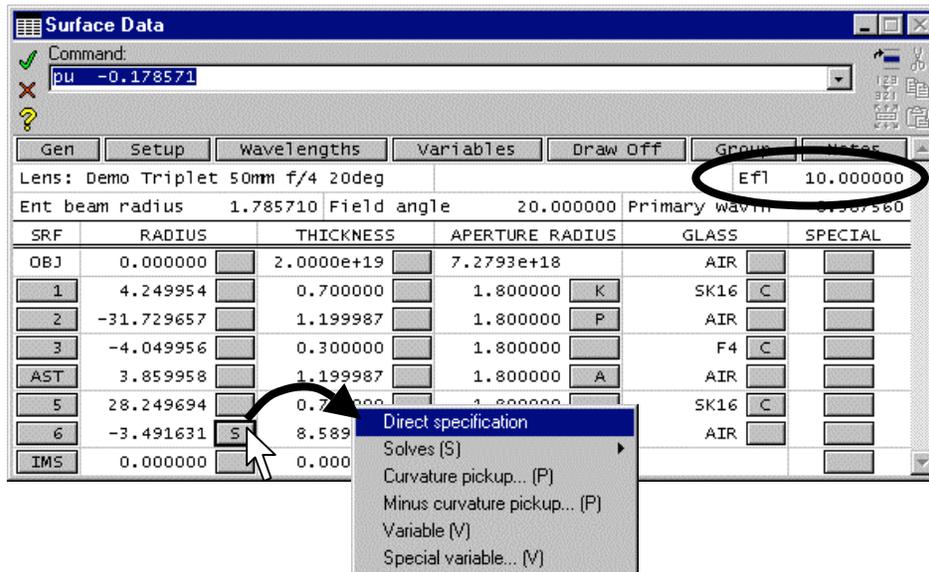


Now the on-axis beam can get through the lens system, but the focal length is no longer exactly 10mm because the thicknesses have been changed. To fix the focal length, we will apply a "solve" to the last refractive surface (surface 6). A "solve" adjusts a system parameter so that some condition is met. We will apply an "axial ray angle solve" which forces the surface curvature of surface 6 to be adjusted so that the angle of the axial ray leaving surface 6 is maintained at a certain value. With an entrance beam radius of 1.78751mm, the focal length of 10mm will be achieved with an axial ray angle solve of -0.178571 (radians).

- 8) To access the axial ray solve, click on the grey button on the right side of the radius column on surface 6 and choose "Solves(S)>>Axial Ray Angle..." from the resulting pop-up menu. Enter -0.178571 for the value of the solve.



- 9) Note that the system focal length is now 10mm as desired. Observe the "Efl" cell in the upper right corner of the surface spreadsheet or choose "Pxc" from the Text Window for analysis.

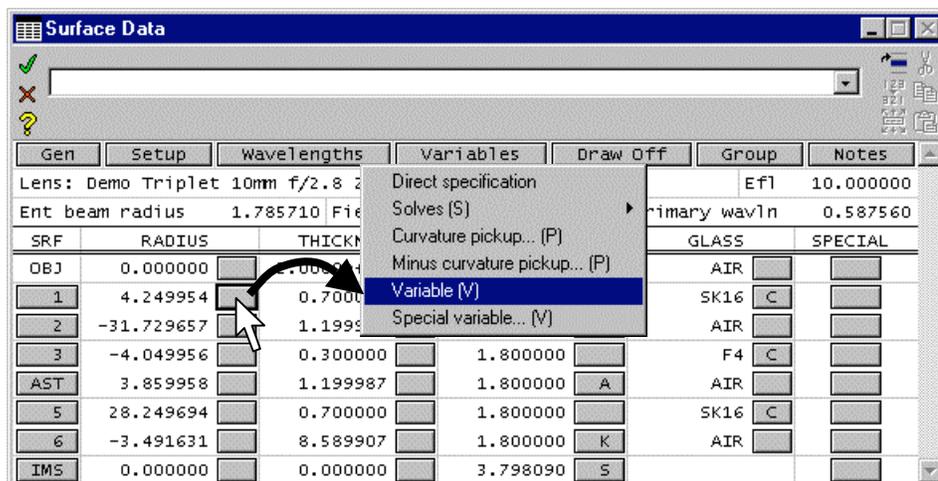


- 10) As soon as you have applied the solve, remove it again by choosing "Direct Specification" from the same pop-up menu. The letter "S" in the grey button of the "Radius" column will disappear, but the surface curvature will still be set to the value that causes the focal length to be 10mm. The surface curvature can now be used later as a variable during optimization (system parameters such as a surface curvature cannot have a solve applied at the same time it is being used as a variable during optimization).

If you are confused about the usage of the terms "Radius" and "Curvature" when describing a surface in a lens system, be aware that a surface "curvature" (cv) is the inverse of a surface "radius" (rd). They both refer to the same property and are mathematically related because $cv=1/rd$. Note the second column of the Surface Data Spreadsheet lists the surface radius by default. However when people discuss an optical design, they usually refer to surface "curvature" so that there is no confusion between surface radius and aperture radius (which is the item listed in the 4th column of the surface data spreadsheet).

- 11) Change the title of the lens to "Demo Triplet 10mm f/2.8 20deg" in the upper left corner of the surface spreadsheet window (next to the "Lens:" designation), and save the file as "Triplet10mm_Start.len" in your "...\private\len" directory.

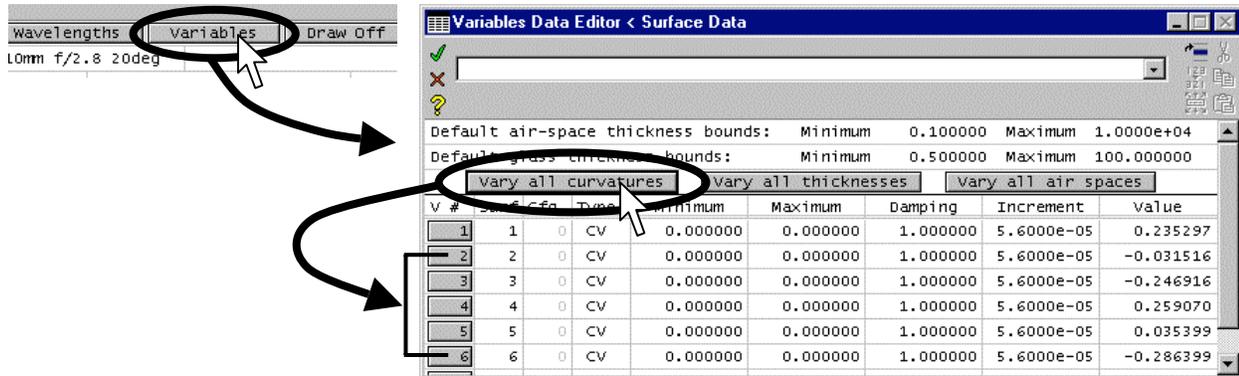
Now that you have the starting design set for our optimization, the next step is to set some system parameters to be variables. Eventually we want to set all 6 surface curvatures to be variables.



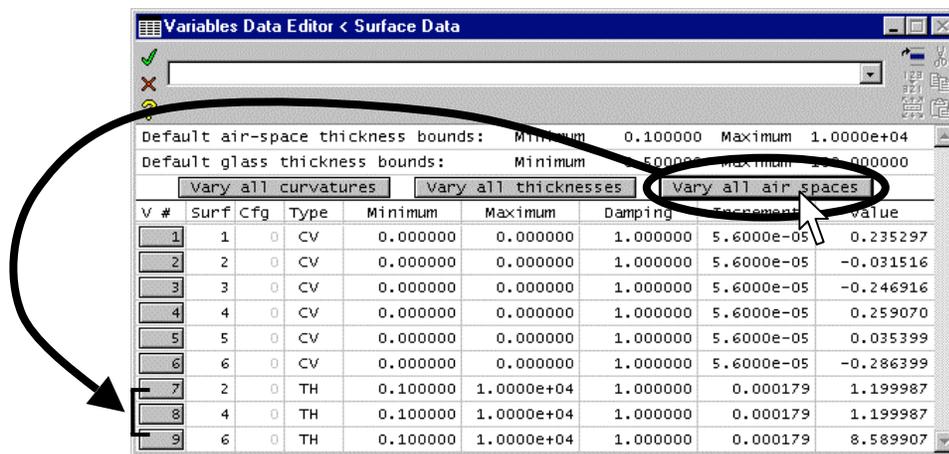
- 12) To set the first surface curvature as a variable, click on the grey button on the right side of the "Radius" column for surface #1, and choose "Variable (V)" from the resulting pop-up dialog. A letter "V" will appear in the grey button when you are done

You can continue doing this for all surfaces, or you can set all surface curvatures as variables all at once. OSLO allows you to manage the variables in your optical system together as a group:

- 13) Open up the Variables Data Editor by clicking on the "Variables" button near the top of the Surface Data Spreadsheet. Then click on the "Vary All Curvatures" button in the resulting dialog. This adds all the remaining surface curvatures to the variable list in the "Variables Data Editor".



- 14) We also want to vary all the air spaces in our design (just the thicknesses between the lenses - not the thickness of the lenses themselves). We do this by clicking on the "Vary All Air Spaces" button in the "Variables Data Editor."



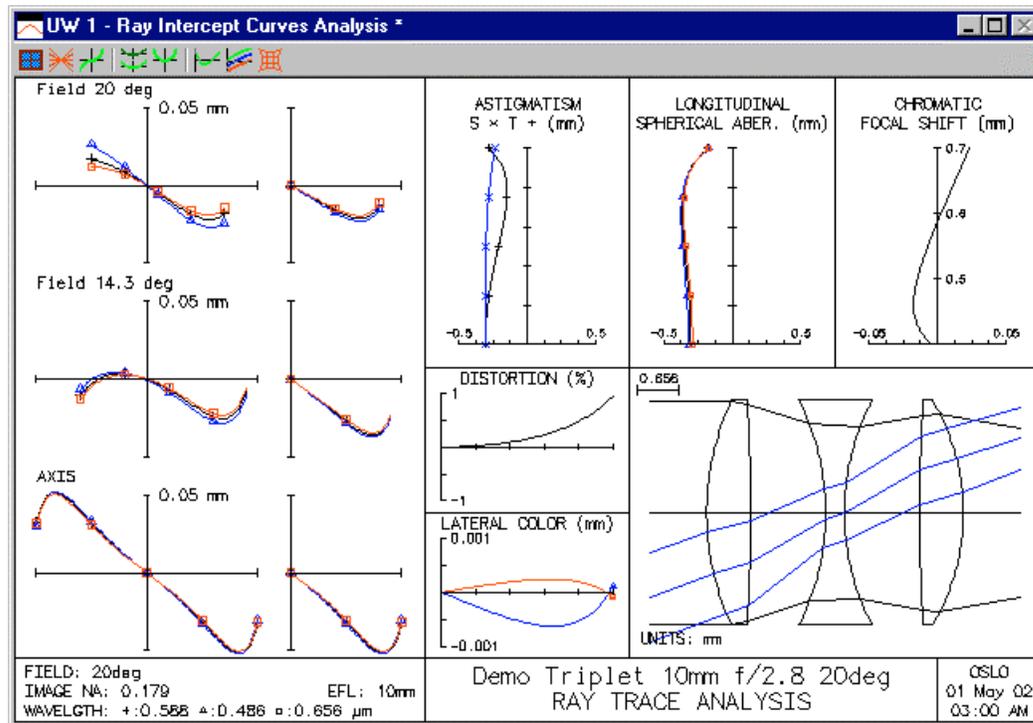
- 15) Click on the green check mark in the upper left corner of the "Variables Data Editor" to accept your changes and close out of this spreadsheet, but do not close the Surface Data Spreadsheet.
- 16) Before moving on, re-save the lens system by choosing "File>>SaveLens" from the OSLO menu or click on the floppy disk icon () from the main OSLO window toolbar.

Now that a starting lens system and variables have been defined, we need to specify an error function to control the optimization. Rather than generating an error function from scratch, OSLO allows you to choose from a couple of default error functions. In most cases you can use the default error functions with little modification, but keep in mind that in OSLO you can always manually modify an error function to fit your particular requirements. In this tutorial we will take a look at generating two different types of default error functions.

Optimization using the Aberration Error Function:

As we get ready to optimize, it is a good idea to check the performance of the system in a way that we can compare it with the system performance after the optimization takes place. For this tutorial we will compare the Ray Intercept Curves (RIC) of this beginning design to the RIC analysis of the designs that we have when we finish.

- 17) Choose the "RIC Report Graphic" icon () from the graphic window toolbar to perform the desired analysis. Once the analysis has been performed, lock the graphic against accidental updating by right clicking anywhere in the graphic and choosing "Lock" from the popup list.



- 18) To generate a default error function based on system aberrations, choose "Optimize>>Generate Error Function>>Aberration Operands..." from the OSLO menu.
- 19) An "Operands Data Editor" window is opened which displays a list of optimization operands that were just created. These operands make up the error function. The function of each column in the Operand Data Editor is identified in the accompanying figure. The optimization error function is simply the composite of this operand list.

The acronyms used in the "Name" column are common abbreviations for optical terms and aberrations. The definition of all these abbreviations are described in the OSLO on-line help under "Contents>>Optimization>>Error Functions>>Generate Error Functions>>Aberration Operands." In this tutorial we will only discuss a few of the abbreviations we will need to use.

The 21 different aberration operands shown here are a superset of the operands that will be typically be needed for any given task. In fact, some of the operands shown actually control conflicting system parameters. The intent is for the user to delete or otherwise modify several of the operands that are not suitable for a given task.

Numerical list showing each **Operand** number. You can add lines to this list just like any other spreadsheet in OSLO

This is the relative **Weight** of each operand when calculating the total error function. A weight of zero will not contribute to the optimization calculation. The important thing to remember is that the weights are relative and can be >1 if desired.

This column contains the mathematical **Definition** that is targeted to zero during optimization. In this example each operand Definition is just one of an array of variables (OCMx) that get calculated behind the scenes. Since the OCMx variables are not all that descriptive, users rely on the NAME column to remember the function of each operand.

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PY	OCM1
2	Min	1.000000	PU	OCM2
3	Min	1.000000	PYC	OCM3
4	Min	1.000000	PUC	OCM4
5	Min	1.000000	PAC	OCM5
6	Min	1.000000	PLC	OCM6
7	Min	1.000000	SAC	OCM7
8	Min	1.000000	SLC	OCM8
9	Min	1.000000	SA3	OCM9
10	Min	1.000000	CMA3	OCM10
11	Min	1.000000	AST3	OCM11
12	Min	1.000000	PTZ3	OCM12
13	Min	1.000000	DIS3	OCM13
14	Min	1.000000	SA5	OCM14
15	Min	1.000000	CMA5	OCM15
16	Min	1.000000	AST5	OCM16
17	Min	1.000000	PTZ5	OCM17
18	Min	1.000000	DIS5	OCM18
19	Min	1.000000	SA7	OCM19
20	Min	1.000000	TOTAL_SPH	OCM20
21	Min	1.000000	EFL	OCM21

Minimize or **Constraint mode** setting. This is not an option in OSLO LT and cannot be edited by the user here.

As a user, you can supply a **Name** here to remind you of the function of each operand. This column is simply reported by OSLO, it is not actually used by OSLO in any other way. In this tutorial example, the names were generated by the "opabs_template" command which is associated with the "Aberration Operands..." menu item. The meaning of the names shown are explained in the accompanying text of this tutorial.

For this optimization, we are only be interested in the operands that

- *Minimize total spherical aberration (TOTAL_SPH),*
- *Force the effective focal length to remain at 10mm (EFL), and*
- *Reduces the height of the marginal ray on the image plane (PY).*

For the rest of the items that we don't want to control during the optimization, we will change their value in the weight (WGT) column to be zero. This removes them from the error function calculation for now but enables us to add them back again later during subsequent optimizations by changing the weight back to a non-zero number.

- 20) To remove the undesired operands from this optimization change the weights (WGT) of all the operands to zero except for the three operands you want to use. The operands 1, 20 and 21 should be kept with a weight of 1.
- 21) Since the "DESCRIPTION" column is always targeted to zero in OSLO, you need to redefine the effective focal length (EFL) target so that when the target equals zero, the EFL is equal to 10 (our desired EFL). To do this, type "OCM21-10" (no quotes) in the description column of the 21st operand.
- 22) Accept your changes to this dialog by clicking on the Green check in the upper left corner of the Surface Data Editor.

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PY	OCM1
2	Min	0.000000	PU	OCM2
3	Min	0.000000	PYC	OCM3
4	Min	0.000000	PUC	OCM4
5	Min	0.000000	PAC	OCM5
6	Min	0.000000	PLC	OCM6
7	Min	0.000000	SAC	OCM7
8	Min	0.000000	SLC	OCM8
9	Min	0.000000	SA3	OCM9
10	Min	0.000000	CMA3	OCM10
11	Min	0.000000	AST3	OCM11
12	Min	0.000000	PTZ3	OCM12
13	Min	0.000000	DIS3	OCM13
14	Min	0.000000	SA5	OCM14
15	Min	0.000000	CMA5	OCM15
16	Min	0.000000	AST5	OCM16
17	Min	0.000000	PTZ5	OCM17
18	Min	0.000000	DIS5	OCM18
19	Min	0.000000	SA7	OCM19
20	Min	1.000000	TOTAL_SPH	OCM20
21	Min	1.000000	EFL	OCM21-10.0

- 23) Before proceeding with the optimization, evaluate the current error function by clicking on the OPE button () in the Text Window toolbar. Again, if you are having trouble finding this button or you want to learn more about this button, please refer to Sideline #1 at the end of this tutorial.

If you want to understand more about what the OCMx variables are all about, please refer to Sideline #2 at the end of this tutorial.

- 24) Note that the resulting analysis in the text window ensures that the error function is set up properly and that only three of the operands (1,20, and 21) contribute to the total error function.

OP	MODE	WGT	NAME	VALUE	%CNTRB	DEFINITION
0 1	M	1.000000	PY	-0.054354	99.71	OCM1
0 2	M	--	PU	-0.178571	--	OCM2
0 3	M	--	PYC	3.743737	--	OCM3
0 4	M	--	PUC	0.341789	--	OCM4
0 5	M	--	PAC	-0.005261	--	OCM5
0 6	M	--	PLC	-0.001700	--	OCM6
0 7	M	--	SAC	-0.002726	--	OCM7
0 8	M	--	SLC	-0.001219	--	OCM8
0 9	M	--	SA3	-0.042443	--	OCM9
0 10	M	--	CMA3	-0.025341	--	OCM10
0 11	M	--	AST3	0.037885	--	OCM11
0 12	M	--	PTZ3	-0.038290	--	OCM12
0 13	M	--	DIS3	0.020699	--	OCM13
0 14	M	--	SA5	0.027232	--	OCM14
0 15	M	--	CMA5	-0.002263	--	OCM15
0 16	M	--	AST5	-0.011752	--	OCM16
0 17	M	--	PTZ5	0.023379	--	OCM17
0 18	M	--	DIS5	0.013852	--	OCM18
0 19	M	--	SA7	0.018134	--	OCM19
0 20	M	1.000000	TOTAL_SPH	0.002923	0.29	OCM20
0 21	M	1.000000	EFL	1.6342e-13	0.00	OCM21-10.0
MIN RMS ERROR:				0.031426		

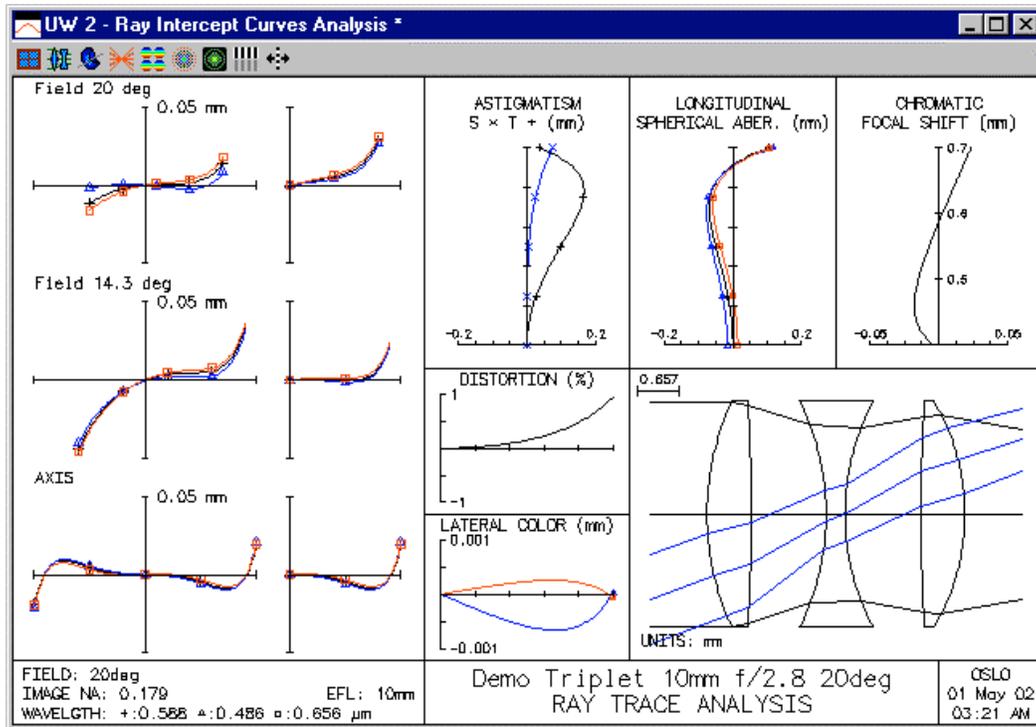
Since you now have variables and the error function has been created, you are ready to start the actual optimization. However, just in case something goes wrong, it is always wise to save your lens just before any optimization..

- 25) Save the lens as "Triplet10mm_OptAberLT.len" in your private directory.
- 26) Start optimization by clicking on the ITE button () from the text window toolbar. The optimization will then proceed with a maximum of 10 iteration cycles.

Note that this optimization only advances through 7 cycles. This is because the improvement in the error function was less than 0.01% after iteration #7. Refer to sideline #3 for more information about changing the default setting of this optimization parameter.

We can now evaluate the optimized lens system in the same way that we did prior to optimization.

- 27) Open up a new graphics window by choosing "Window>>Graphics>>New" from the OSLO menu and then click on the "RIC Report Graphic" icon () from the new graphic window's toolbar.
- 28) Lock this window in the same way as before by right clicking in the window and choosing "Lock" from the pop up list. You can now compare system performance with the baseline RIC Report graphic generated in step #17.



- 29) You should now have two graphic windows with Ray Intercept Curves Analysis open. One analysis shows the system before optimization and one afterwards. Note that the errors on the Ray Intercept Curves (the analysis on the left side of the analysis window) have been reduced along with the Astigmatism and Longitudinal Spherical Aberration.
- 30) If the performance of your system matches what is shown here, choose "File>>Save" from the OSLO menu to save this lens in the "Triplet10mm_OptAberLT.len" file. If you encountered some trouble along the way, consider retrieving the lens from Step #16 or #25 and re-perform the intervening steps.

In order to explore exactly what happens when using different operands during optimization, it is suggested that you spend some time exploring this section of the tutorial. Start by adjusting the weights of different operands as described in step #20. For example: turn off the marginal ray height (PY), turn on astigmatism (AST3, AST5), ...etc.), and observe what happens. You can verify how the error function responds by using the "Ope" command (step #23) to evaluate the error function before and after optimization.

Optimization using the GENII Error Function:

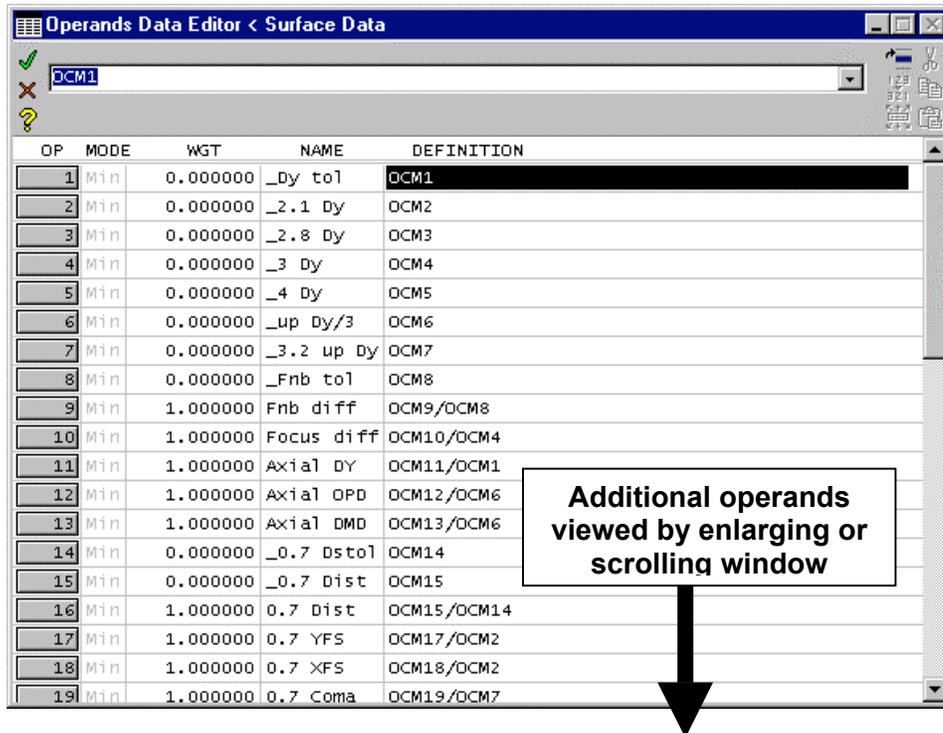
The GENII (pronounced "jean-ee") error function is based on the default error function of the former GENII optical design program. Some features of the GENII program have since been incorporated into OSLO. The GENII error function uses exact ray data to compute aberration-like operands in a highly efficient manner (it only traces 11 rays and consists of 31 active operands).

As you start to work with this different error function, you need to retrieve the lens you stored before the last optimization started.

- 31) Choose "File>>Open" from the OSLO menu and open the "Triplet10mm_Start.len" lens stored in your private directory.
- 32) Choose "Optimize>>Generate Error Function>>GENII Ray Aberration..." from the OSLO menu.
- 33) In the resulting dialog box that pops up with the title "Genierf_It", keep the default values and click on the "OK" button.

After the dialog window closes, it might appear that nothing has happened. However behind the scenes, a set of operands has been created which comprises a complete error function. Unlike in the previous example however, the Operand Data Editor was not automatically opened.

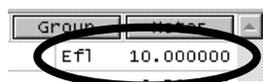
34) View the operand list you just generated by choosing "Optimize>>Operands" from the OSLO menu.



OP	MODE	WGT	NAME	DEFINITION
1	Min	0.000000	_Dy to1	OCM1
2	Min	0.000000	_2.1 Dy	OCM2
3	Min	0.000000	_2.8 Dy	OCM3
4	Min	0.000000	_3 Dy	OCM4
5	Min	0.000000	_4 Dy	OCM5
6	Min	0.000000	_up Dy/3	OCM6
7	Min	0.000000	_3.2 up Dy	OCM7
8	Min	0.000000	_Fnb to1	OCM8
9	Min	1.000000	Fnb diff	OCM9/OCM8
10	Min	1.000000	Focus diff	OCM10/OCM4
11	Min	1.000000	Axial DY	OCM11/OCM1
12	Min	1.000000	Axial OPD	OCM12/OCM6
13	Min	1.000000	Axial DMD	OCM13/OCM6
14	Min	0.000000	_0.7 Dsto1	OCM14
15	Min	0.000000	_0.7 Dist	OCM15
16	Min	1.000000	0.7 Dist	OCM15/OCM14
17	Min	1.000000	0.7 YFS	OCM17/OCM2
18	Min	1.000000	0.7 XFS	OCM18/OCM2
19	Min	1.000000	0.7 Coma	OCM19/OCM7

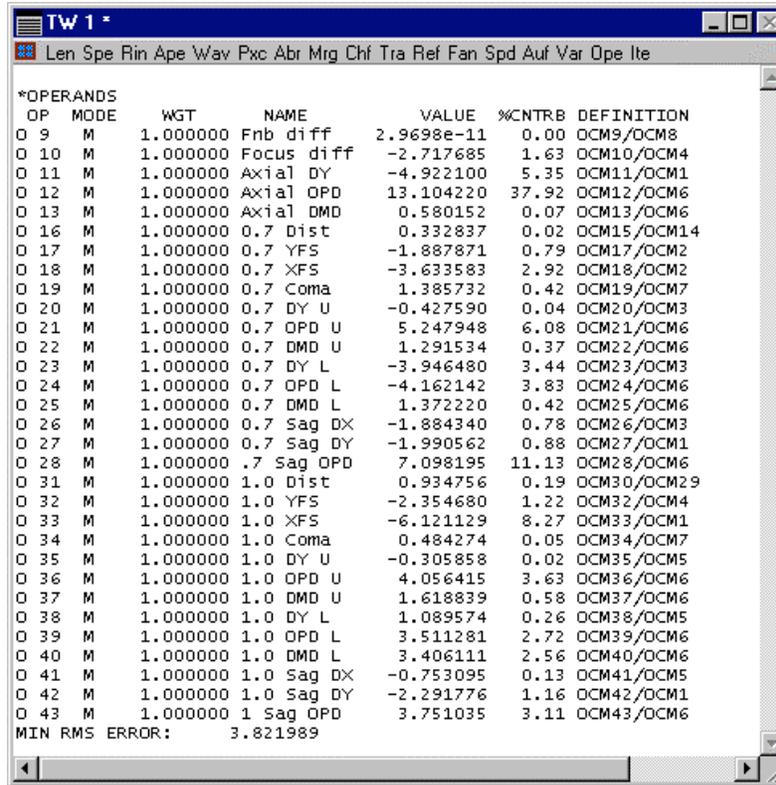
Unlike the Aberration Operands error function, the GENII error function does not need to be adjusted. In combination with the values shown in the previous popup dialog, the operands in the error function operate as a complete set and do not need manual adjustment by the user. One particularly interesting item to note is that with the GENII error function, the EFL of the system does not need to be added as an operand. The GENII error function effectively stores the current EFL of the optical system and targets the system EFL to remain a constant throughout the optimization.

- 35) Note that a few of the operands have a weight of zero. These operands calculate values that then get used by other operands. All this takes place behind the scenes in a CCL function attached to the optimization. See Sideline #2 at the end of this tutorial to learn more about this CCL function.
- 36) When you are done observing the operands, close the Operands Data Editor by clicking on the Red "X" in the upper left corner of the spreadsheet. You do not want to save any changes you might have inadvertently made in the window.
- 37) Note that in the upper right corner of the Surface Data Spreadsheet (the Operands Data Editor needs to be closed to see the Surface Data Spreadsheet), the EFL is currently 10mm. This system EFL will be maintained at 10mm throughout the optimization by the GENII error function.



Group	Value
EFL	10.000000

- 38) Before proceeding with the optimization, evaluate the current error function by clicking on the OPE button () in the Text Window toolbar. The resulting analysis in the text window ensures that the error function is set up properly.



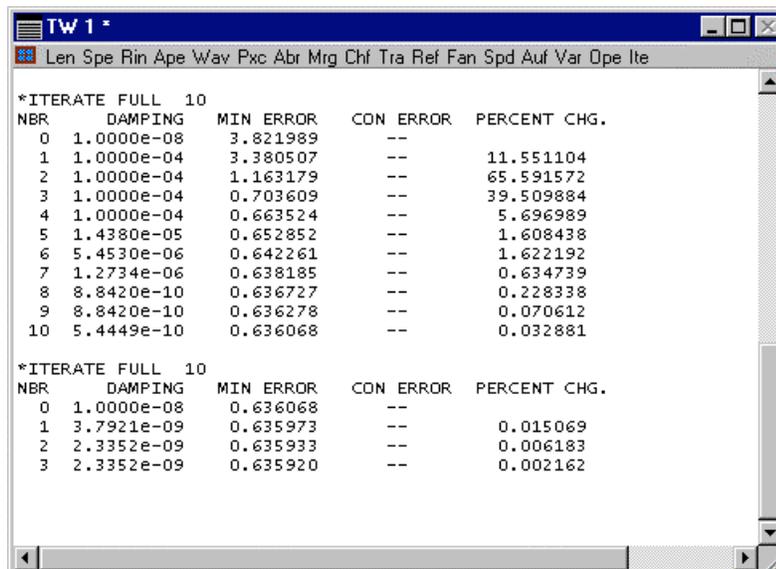
The screenshot shows a window titled "TW 1" with a menu bar containing "Len Spe Rin Ape Wav Pxc Abr Mrg Chf Tra Ref Fan Spd Auf Var Ope Ite". The main area displays a list of operands for optimization, with columns for OP, MODE, WGT, NAME, VALUE, %CNTRB, and DEFINITION. At the bottom, it shows "MIN RMS ERROR: 3.821989".

OP	MODE	WGT	NAME	VALUE	%CNTRB	DEFINITION
0 9	M	1.000000	Fnb diff	2.9698e-11	0.00	OCM9/OCM8
0 10	M	1.000000	Focus diff	-2.717685	1.63	OCM10/OCM4
0 11	M	1.000000	Axial DY	-4.922100	5.35	OCM11/OCM1
0 12	M	1.000000	Axial OPD	13.104220	37.92	OCM12/OCM6
0 13	M	1.000000	Axial DMD	0.580152	0.07	OCM13/OCM6
0 16	M	1.000000	0.7 Dist	0.332837	0.02	OCM15/OCM14
0 17	M	1.000000	0.7 YFS	-1.887871	0.79	OCM17/OCM2
0 18	M	1.000000	0.7 XFS	-3.633583	2.92	OCM18/OCM2
0 19	M	1.000000	0.7 Coma	1.385732	0.42	OCM19/OCM7
0 20	M	1.000000	0.7 DY U	-0.427590	0.04	OCM20/OCM3
0 21	M	1.000000	0.7 OPD U	5.247948	6.08	OCM21/OCM6
0 22	M	1.000000	0.7 DMD U	1.291534	0.37	OCM22/OCM6
0 23	M	1.000000	0.7 DY L	-3.946480	3.44	OCM23/OCM3
0 24	M	1.000000	0.7 OPD L	-4.162142	3.83	OCM24/OCM6
0 25	M	1.000000	0.7 DMD L	1.372220	0.42	OCM25/OCM6
0 26	M	1.000000	0.7 Sag DX	-1.884340	0.78	OCM26/OCM3
0 27	M	1.000000	0.7 Sag DY	-1.990562	0.88	OCM27/OCM1
0 28	M	1.000000	.7 Sag OPD	7.098195	11.13	OCM28/OCM6
0 31	M	1.000000	1.0 Dist	0.934756	0.19	OCM30/OCM29
0 32	M	1.000000	1.0 YFS	-2.354680	1.22	OCM32/OCM4
0 33	M	1.000000	1.0 XFS	-6.121129	8.27	OCM33/OCM1
0 34	M	1.000000	1.0 Coma	0.484274	0.05	OCM34/OCM7
0 35	M	1.000000	1.0 DY U	-0.305858	0.02	OCM35/OCM5
0 36	M	1.000000	1.0 OPD U	4.056415	3.63	OCM36/OCM6
0 37	M	1.000000	1.0 DMD U	1.618839	0.58	OCM37/OCM6
0 38	M	1.000000	1.0 DY L	1.089574	0.26	OCM38/OCM5
0 39	M	1.000000	1.0 OPD L	3.511281	2.72	OCM39/OCM6
0 40	M	1.000000	1.0 DMD L	3.406111	2.56	OCM40/OCM6
0 41	M	1.000000	1.0 Sag DX	-0.753095	0.13	OCM41/OCM5
0 42	M	1.000000	1.0 Sag DY	-2.291776	1.16	OCM42/OCM1
0 43	M	1.000000	1 Sag OPD	3.751035	3.11	OCM43/OCM6

MIN RMS ERROR: 3.821989

Since you now have variables and the error function has been created, you are ready to start the actual optimization. However, just in case something goes wrong, it is always wise to save your lens just before any optimization..

- 39) Save the lens as "Triplet10mm_OptGeniiLT.len" in your private directory.
- 40) Start the optimization by clicking on the "Ite" button from the text window toolbar. The optimization will then proceed with a maximum of 10 iteration cycles with each button click.
- 41) Note that the optimization advances through all 10 cycles. If you click on the "Ite" button again, the optimization does an additional 3 cycles before stopping. This is because the improvement in the error function was less than 0.01% after iteration #3. Look at sideline #3 for more information about changing the default setting of this optimization parameter.



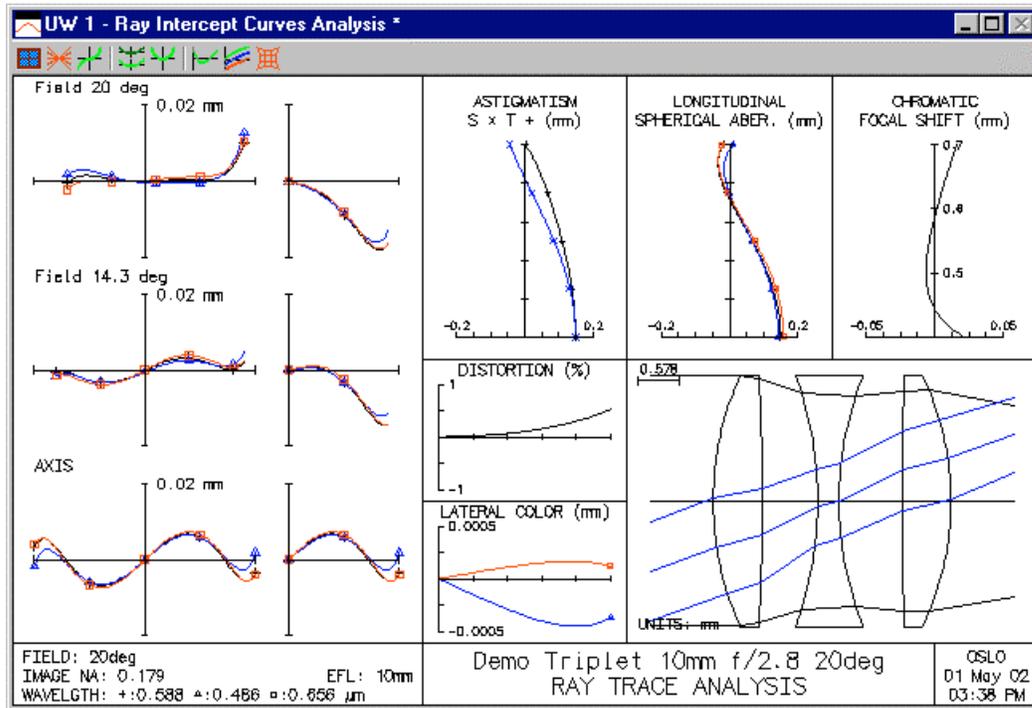
The screenshot shows the same window as above, but now displaying the optimization progress table. The table has columns for NBR, DAMPING, MIN ERROR, CON ERROR, and PERCENT CHG. It shows two iterations of 10 cycles each.

NBR	DAMPING	MIN ERROR	CON ERROR	PERCENT CHG.
0	1.0000e-08	3.821989	--	
1	1.0000e-04	3.380507	--	11.551104
2	1.0000e-04	1.163179	--	65.591572
3	1.0000e-04	0.703609	--	39.509884
4	1.0000e-04	0.663524	--	5.696989
5	1.4380e-05	0.652852	--	1.608438
6	5.4530e-06	0.642261	--	1.622192
7	1.2734e-06	0.638185	--	0.634739
8	8.8420e-10	0.636727	--	0.228338
9	8.8420e-10	0.636278	--	0.070612
10	5.4449e-10	0.636068	--	0.032881

NBR	DAMPING	MIN ERROR	CON ERROR	PERCENT CHG.
0	1.0000e-08	0.636068	--	
1	3.7921e-09	0.635973	--	0.015069
2	2.3352e-09	0.635933	--	0.006183
3	2.3352e-09	0.635920	--	0.002162

We can now evaluate the optimized lens system in the same way that we did prior to optimization.

- 42) Open up a new graphics window by choosing "Window>>Graphics>>New" from the OSLO menu and then clicking on the "RIC Report Graphic" icon () from the graphic window's toolbar.
- 43) Lock this window in the same way as before by right clicking in the window and choosing "Lock" from the pop up list.

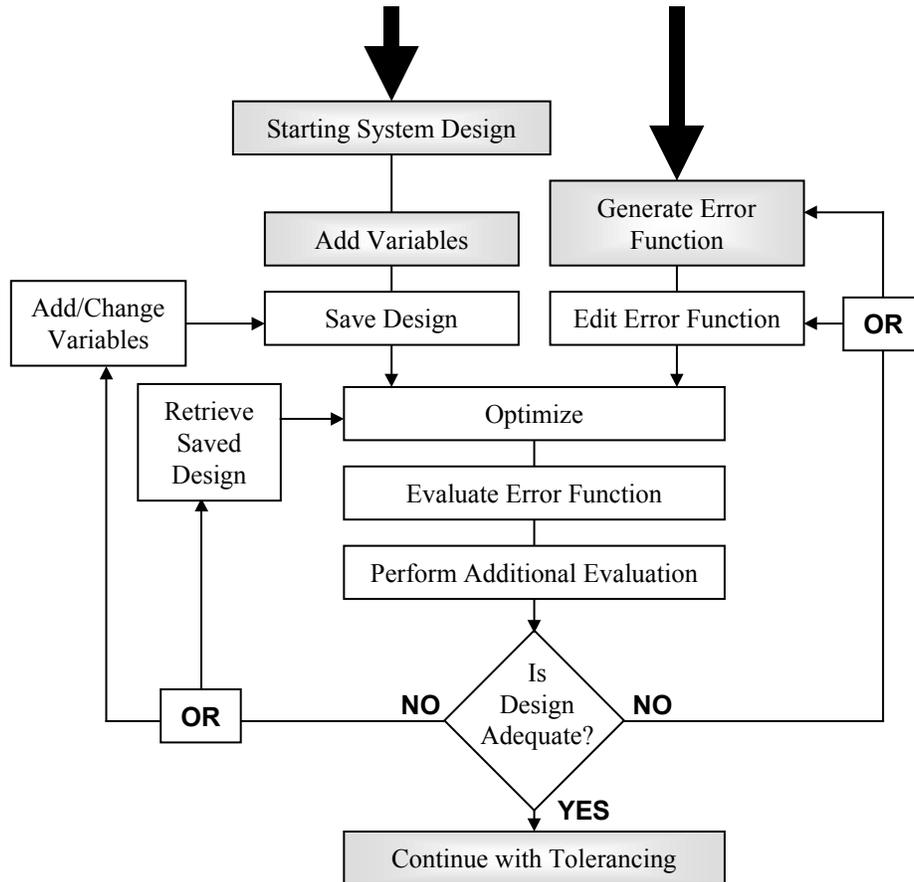


Now you should have three Ray Intercept Curves Analysis windows open: One window before optimization (step #17), one after using Aberration operands for optimization (step #27) and one using the GENII error function for optimization (step #42). Of course both of the different optimizations improved the system, however in this particular example it appears that the GENII error function improved the system better than the Aberrations operands did. Note the scale change on the Ray Intercept Curve for the GENII optimization where the scale has been reduced by 2.5x. The Lateral Color has also been significantly improved, but all of this was done at the expense of some Longitudinal Spherical Aberration. What design criteria are most important (ray intercept curves, certain aberrations, or something else) is usually dictated by the customer or the application, but for most instances, we could assume that the GENII optimization provided a better system.

As an exercise, you may want to go back to the optimization using the Aberration operands and see if there are other aberrations or different weightings you can add to the error function to make the performance rival that of the GENII error function optimization.

- 44) If the performance of your system matches what is shown here, choose "File>>Save" from the OSLO menu to save this lens in the Triplet10mm_OptGeniiLT.len file. If you encountered some trouble along the way, consider retrieving the lens from Step #31 or #39 and re-perform the intervening steps.

The purpose of this tutorial was to teach some of the mechanics associated with performing optimization in OSLO. What you have covered here is just a small portion of the optical design process. An example matrix of this process is shown below.



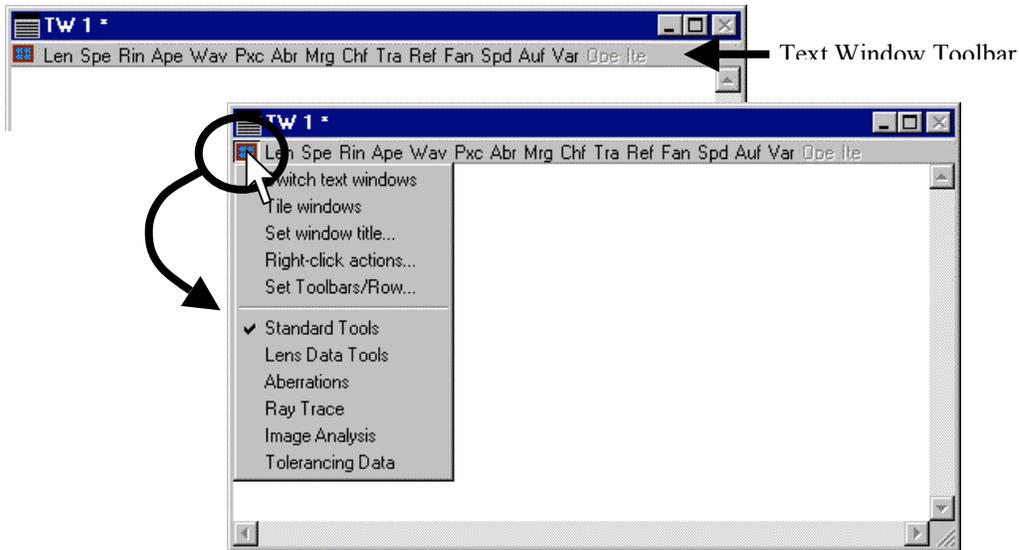
To become an expert optical designer, you will need to gain enough experience to handle all the decision points of the optical design matrix. This however, is way beyond the scope of this tutorial.

SIDELINE #1

Note that there is a series of three letter acronyms (Len, Spe, Rin, ...etc.) underneath the title bar of the text window "TW 1":



These acronyms are actually icons associated with the current set of active toolbars for the window. You can change the toolbars that are shown by clicking on the leftmost icon (a red framed blue window) to expose a checked list of toolbars in the popup list. Note that in the figure below, the "Standard Tools" item is checked which means that the "Standard Tools" is the only toolbar now showing in the text window. The Standard Tools toolbar consists of 17 text icons ranging from "Len" to "Ite". If an icon is greyed out, that means it is unavailable at the time. In the example shown below, the "Ope" icon is unavailable because no operands have been defined yet. Likewise, "Ite" is only available after at least one Variable and one Operand have been defined.



SIDELINE #2

OSLO Light uses a different method to implement an error function than that in OSLO Standard and Premium. In OSLO Standard and Premium, users can directly add and delete operands based on ray, aberration and system parameters (these are called "built-in" operand components). In OSLO Light, users can only implement operands that have been pre-defined in a CCL or SCP command (these are called "user defined" operand components). While the user defined approach in OSLO Light can sometimes be a little more complicated to implement, it allows users to have extreme flexibility in creating customized operands.

If you are interrupting the following of this tutorial to read this sideline, you may want to save your work before continuing. Some of the steps you perform below may affect the state of your current lens system.

- 1) To investigate how user defined operands are implemented in OSLO Light, we first make sure that an error function has been created. For purposes of discussion, implement the Aberration Error function by choosing "Optimize>>Generate Error Function>>Aberration Operands".
- 2) When the Operands Data Editor opens, note that all the definitions refer to OCM1 through OCM21.

Each OCM_x is an element within an variable array. The value within each of these array elements is actually calculated behind the scenes in a CCL command attached to the optimization function. Now we will see where and how the OCM_x values are defined:

- 3) Choose "Optimize>>Optimization Conditions" from the OSLO menu.
- 4) In the resulting dialog, note that the "Command for CCL/SCP operands" is specified to be "opcb_abs". This is the name of the CCL command that calculates the OCM_x operands for the Aberration Operands Error Function.

The "opcb_abs" command is defined in the "optim_callbaks.ccl" file in your public CCL directory

- 5) Choose "Window>>Editor>>Open" from the OSLO menu.
- 6) In the resulting "Text Editor" window, choose "File>>Open" and locate the "optim_callbaks.ccl" file in your "...\\public\\ccl\\" directory.

If you understand even a small amount of the CCL language (or even the "C" programming language) you will see that the "opcb_abs" command is defined at the top of this file. You will also notice that the "opcb_abs" command defines the elements of the OCM[x] array throughout the lines of the code.

If you think about what you've just seen, you will soon realize that you could define your own custom OCM optimization operands in OSLO. All you have to do is perform the following three easy steps:

- A) Create an error function that contains at least one OCMx command. Note that the operand spreadsheet is just like any other spreadsheet in OSLO: you can add and delete lines manually. A operand list with as little as one operand in it is still a valid error function.
- B) Create a CCL function named "my_example" which defines the value of the OCMx commands you used in (A). It is best to store this file in your private directory. Compile your private CCLs.
- C) Go the "Optimization Conditions" dialog and specify that you want to link "my_example" to the optimization function (this gets saved with the lens when you save it).

SIDELINE #3

To adjust parameters that control the optimization process, choose "Optimize>>Optimization Conditions" from the OSLO menu. The resulting dialog box allows you to change a number of optimization parameters. The default value for "Percent improvement for continuing full iterations" is 0.01%. This means that once an error function is reduced by less than 0.01% in a cycle, the optimization process stops before executing another cycle.

