SYNOPSYS: Multi-configuration Optimization

10/11/2023

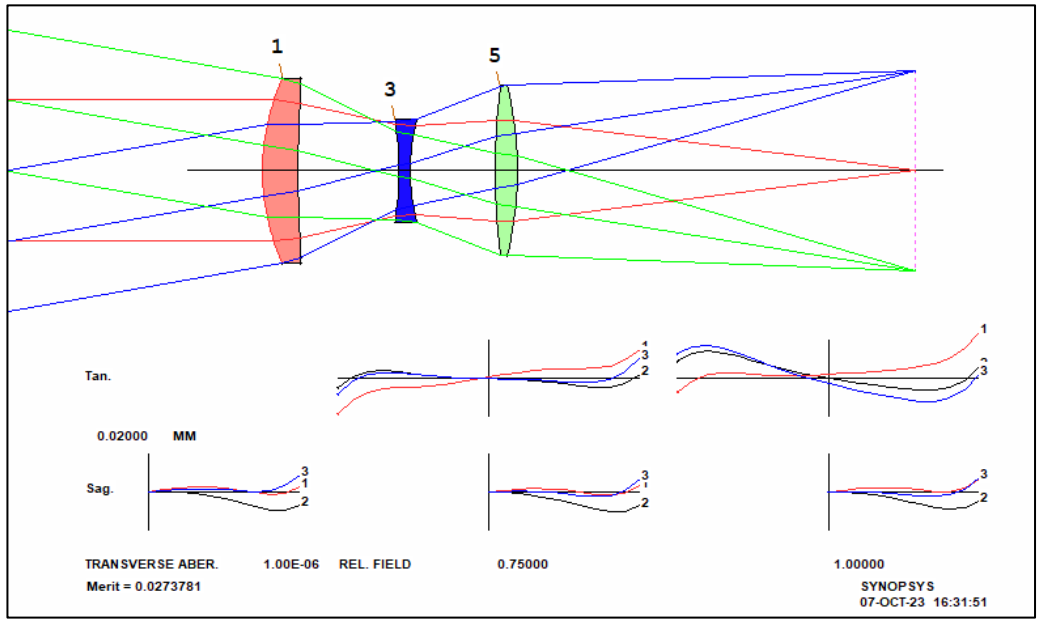
Multi-configuration optimization of a Cooke Triplet

We will use a simple Cooke triplet as an example to demonstrate multi-configuration optimization in SYNOPSYS.

We will start with the basic Cooke triplet as our initial configuration (ACON 1; filename: CookeTriplet.RLE). We will create two more configurations:

- ACON 2, where a -1 degree alpha tilt is added to the second element
- ACON 3, where a 1 degree alpha tilt is added to the third element

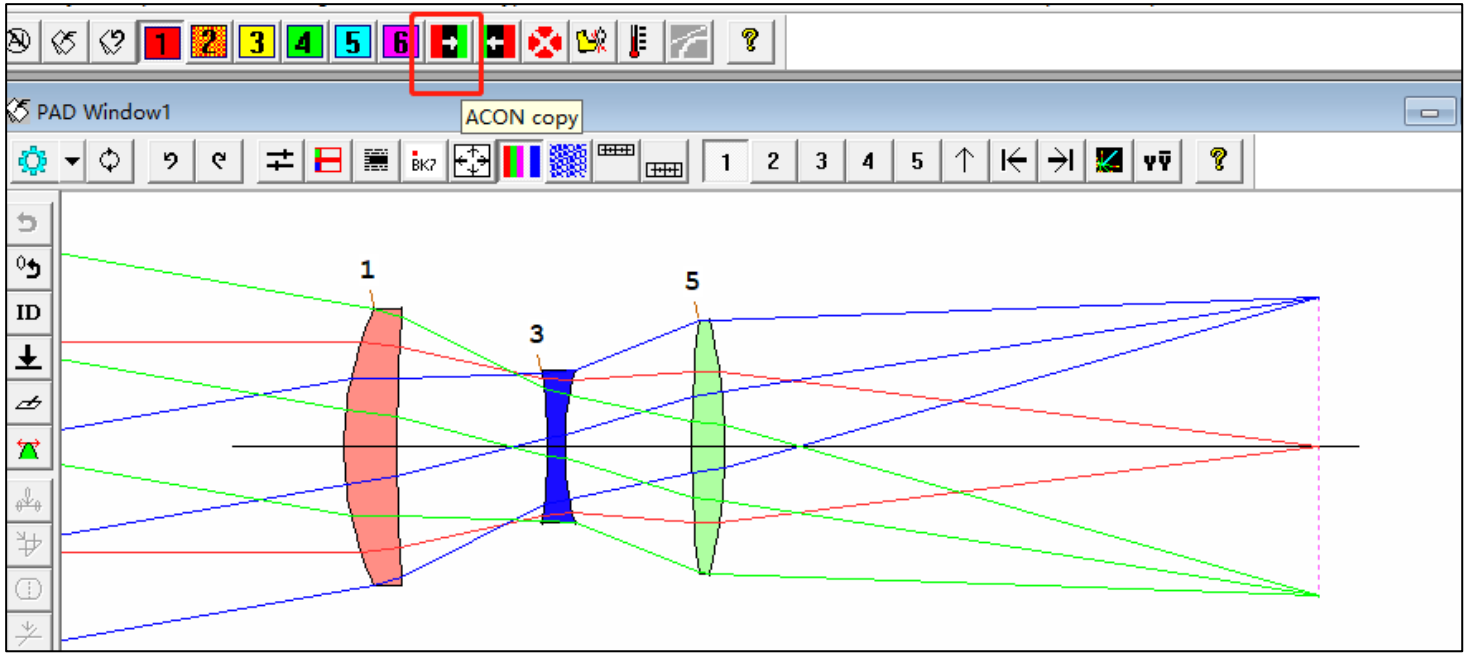
We will then optimize the three ACONs simultaneously.



Creating the Alternate configurations

To create the alternate configurations of the Cooke triplet, we will first use the ACON Copy button in the SYNOPSYS Top Toolbar to populate the base configuration from ACON 1 to the other configurations.

The ACON copy button copies the current configuration to the next ACON. click it twice to see the same lens as ACON 1 in ACONs 2 and 3.



This step can also be accomplished with the command: ACON BUMP. Running this command also copies the current ACON to the next ACON. For more details on the use of the ACON command, see User Manual 10.7.2 Alternate Configurations.

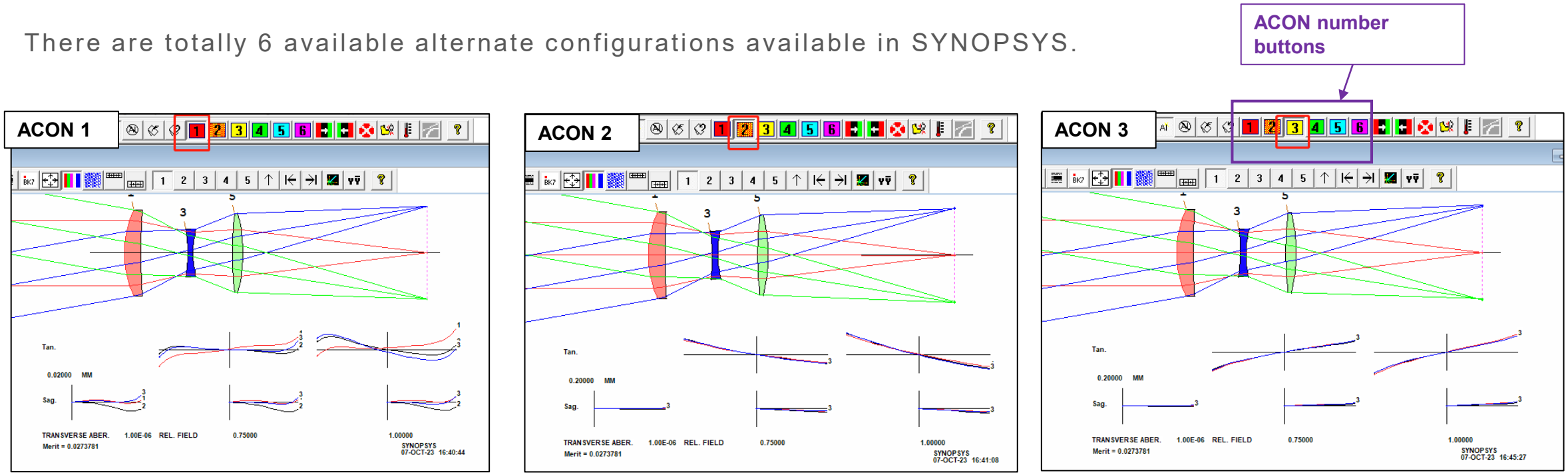
Modifying Different ACONs

You can switch to the different ACON by clicking at the corresponding ACON number button at the Top Toolbar. The alternate configuration is then launched in the SketchPad and you can edit it using the SPS, WS, or Lens Editor.

The screenshot below shows the 3 different ACONs of the Cooke triplet:

- ACON 1: the original Cooke triplet with no tilts (left panel)
- ACON 2: an alpha tilt of +1 degree is added to the 2nd element (central panel)
- ACON 3: an alpha tilt of -1 degree is added to the 3rd element (right panel)

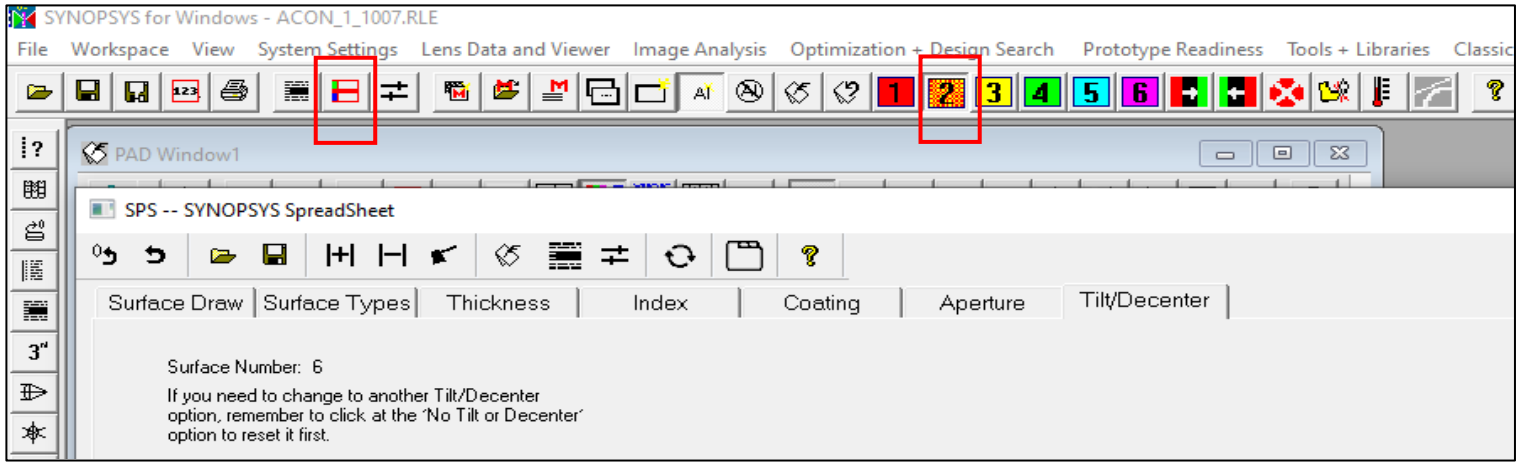
There are totally 6 available alternate configurations available in SYNOPSYS.



Setting tilt in ACON 2 and ACON 3

We can tilt the 2nd element in ACON 2 and 3 using the SpreadSheet (SPS).

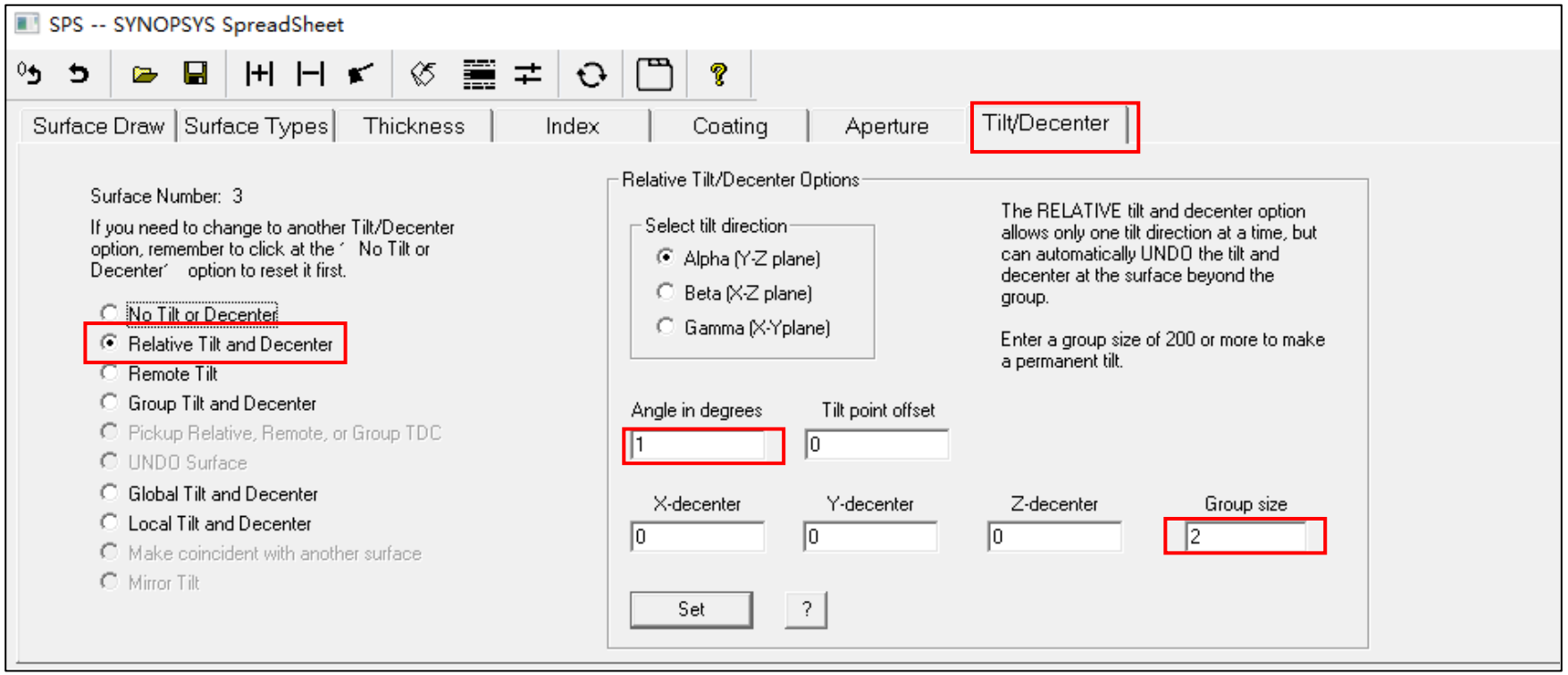
- First, click the ACON 2 button to activate the 2nd configuration. Then launch the SPS by clicking the SPS button. In the SPS, click the Tilt/Decenter cell of surface 3 (front surface of element 2) to open the Tilt/Decenter Editor tab.



	Surface Type	Surface ID	Radius	Thickness	Material	Index	Coating	Aperture Type (Outer/Inner)	Y Semi-Width (Outer/Inner)	X Semi-Width (Outer/Inner)	Conic	Tilt/Decenter
0	Infinite Object (angular)		infinite	infinite	Air	1		Def (Circ)/none	0/0	0/0		
1	Spherical		31.3536558	5.0533746	GLM	1.75494	None	Def (Circ)/none	13.0962/0	13.0962/0		
2	Spherical		216.027573	14.267955	Air	1	None	Def (Circ)/none	12.3494/0	12.3494/0		
3	Spherical		-50.4618906	1.64886955	GLM	1.77763	None	Def (Circ)/none	6.99415/0	6.99415/0		
4	Spherical		27.6534557	12.0371771	Air	1	None	Def (Circ)/none	7.24082/0	7.24082/0		
5	Spherical		100.332271	3.18473186	GLM	1.8894	None	Def (Circ)/none	11.9287/0	11.9287/0		
6	Spherical		-49.1369385	56.3515282	Air	1	None	Def (Circ)/none	12.0617/0	12.0617/0		
7	Flat		infinite	0	Air	1	None	Def (Circ)/none	14.1382/0	14.1382/0		
8												

Setting tilt in ACON 2 and ACON 3

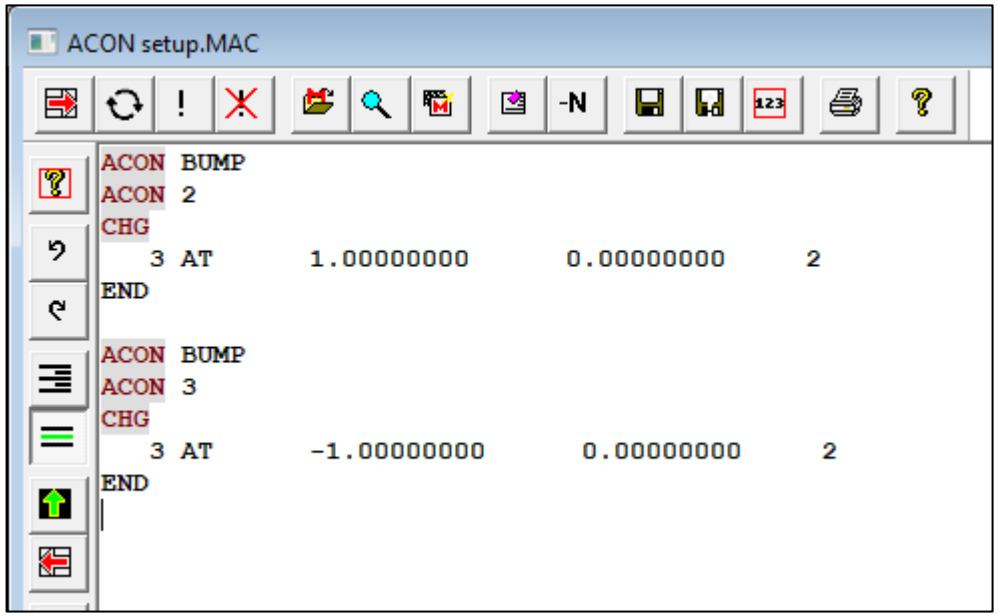
- In the ‘Tilt’Decenter’ tab, select ‘Relative Tilt and Decenter’. Then enter the the parameters shown below to set a +1 degree tilt to element 2. For ACON 3, you will enter -1 for the tilt angle to set the correct tilt for that configuration.



Setting tilt in ACON 2 and ACON 3

If you are familiar with the script, you can do this by running a macro as shown here (filename: ACON setup.mac) to change the configurations. First, use the ACON command to switch to the corresponding configuration, and then use the CHG file to set the surface tilt.

Refer to User Manual 10.7.2 Alternate Configurations for more information on ACON setup.



10.7.2 Alternate Configurations Next Previous TOC

SYNOPSYS can maintain six completely independent lenses at the same time. These are called *alternate configurations*, and it is simple to switch from one to another. The command

ACON NB

will change to configuration **NB**, which must be a number from 1 to 6. You can also change configurations by clicking on one of the toolbar buttons 1 2 3 4 5 6.

When you have selected the configuration you want, you may perform any of the normal SYNOPSYS tasks, such as FETCHING a lens, etc. If you later switch back to an earlier ACON, it will still be the same as it was before. You can see which ACON is current by typing the command

ACON

with no argument. To delete a current ACON (causing it to be ignored by subsequent multiconfiguration optimization) use the command

ACON NB NULL.

To immediately enforce any pickups that have been declared (see below), use the command

Multi-configuration Optimization

Simply creating the configurations does not allow the different configurations to be related to each other during optimization. Therefore it is necessary to use the ACON pickup to build the connection between ACONs for optimization.

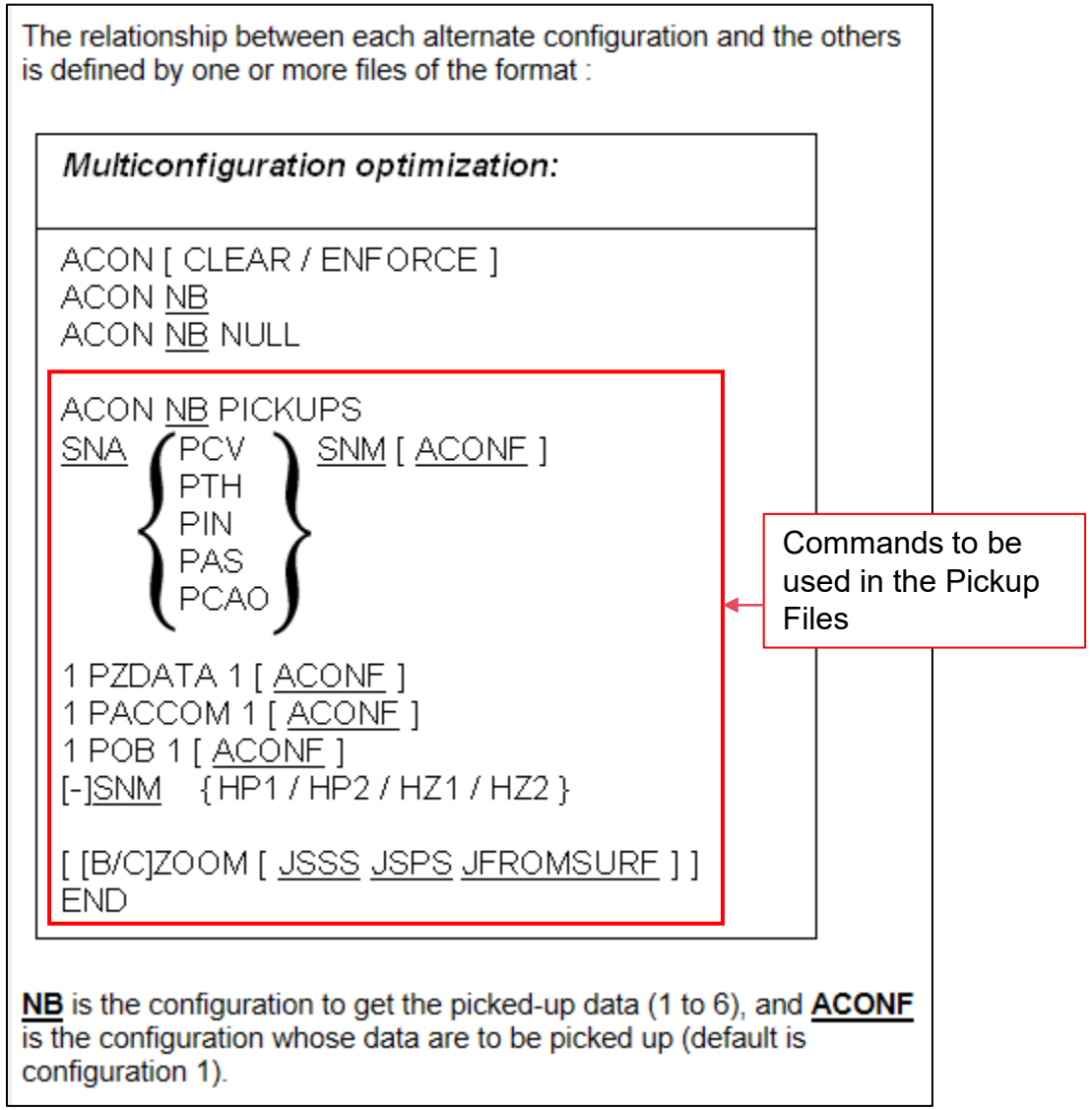
In the next few slides, we will use the Cooke triplet as a simple example to show how to set up ACON pickups, optimization variables, and merit functions for multi-configuration optimization.

Multi-configuration Optimization, ACON Pickups

You can find all the commands relating to setting up ACON Pickups in the second half of the User Manual 10.7.2, Alternate Configurations.

The commands used for Pickups must be put between the command ACON NB PICUPS and the keyword END. We sometimes refer this block of structure as the Pickup file.

For this example, we will demonstrate the use of the ZOOM (Note 1) and POB commands.



Note 1: the word, ZOOM, when it is not used in the Pickup Files, it is a command for zoom positions. For more details, see User Manual 10.7.1 ZFILE zoom lenses.

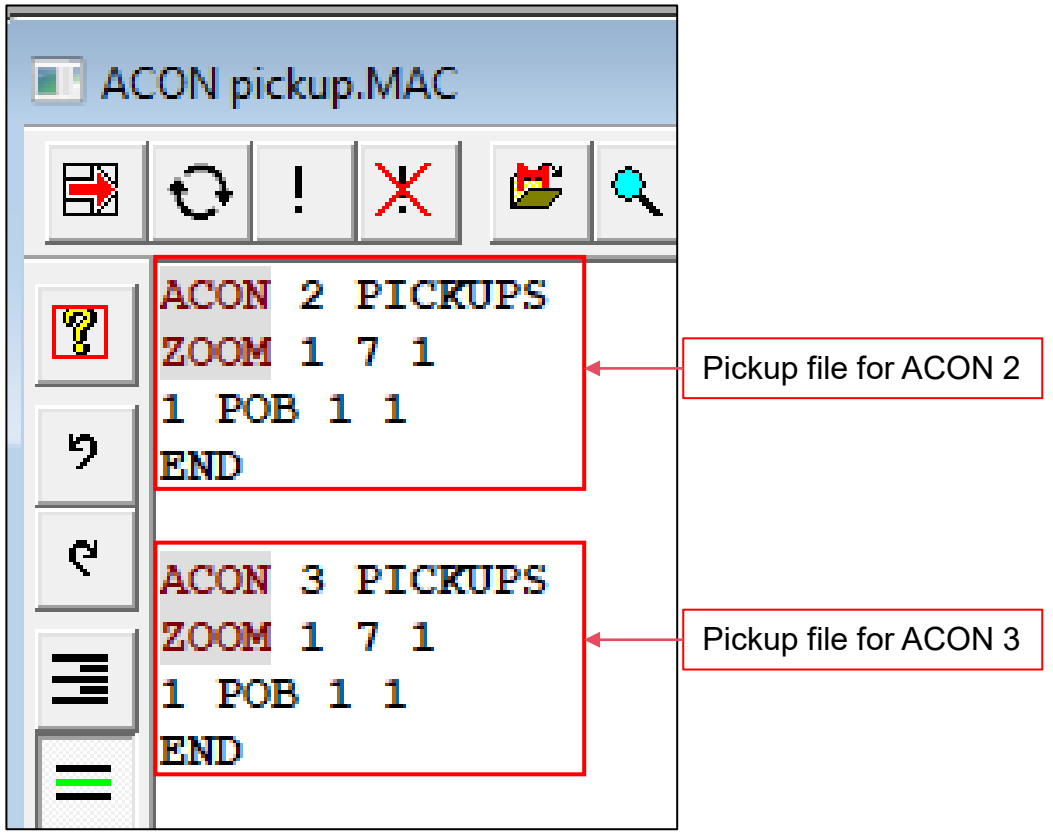
ACON Pickup

Here is a simple macro that contains two Pickup Files for ACON 2 and 3, respectively.

Each Pickup file has the same commands:

- ZOOM 1 7 1: causes all radii, thicknesses and airspaces, and indices to be picked up from ACON 1 by the alternate configurations. It means to cause surfaces 1 through 7 in configuration number 2 (or 3) to be the same as the surfaces beginning with number 1 in configuration 1
- 1 POB 1 1: makes the object data declared in ACON 1 to picked up by the other configurations.

With this setup the three ACONs are linked together, and when the parameters of ACON 1 are optimized, the parameters of ACON 2 and 3 are changed simultaneously. Since the ZOOM command does not pick up tilt and decenter, the tilt of ACON 2 and 3 can be set independently without being affected.



ACON Pickup, more information on the commands

- **POB** (Object data pickup):

Syntax: **1 POB 1 [ACONF]**

Object data, including YMP1, YP1, TH0, YP0, XMP1, XP1 XP0 and the object radius of curvature may be picked up by the entry POB in the ACON Pickup file. This is required if any of these quantities are variables in the main configuration and you wish the alternates to use the same values.

- **ZOOM**:

Syntax: ZOOM [jsss jsps jfromsurf]

This keyword causes all radii, thicknesses and airspaces, and indices to be picked up from ACON 1 by alternate configuration. Tilts, decenters, and clear apertures are not picked up by this option. This is useful when the lenses have the same parameters but have different tilts or decenters, as you might find in a scanning system. The ZOOM entry may optionally specify a range of surfaces that are to pick up data from the source configuration beginning at a specified surface number. For example, to cause surfaces 6 through 12 in configuration number 2 to be the same as the surfaces beginning with number 4 in configuration 1, the input would be

```
ACON 2 PICKUPS
ZOOM 6 12 4
END
```

Optimization variables and merit functions in multi-config optimization

You can establish the optimization variables and merit functions using the standard optimization PANT and AANT files (Note 1).

An example multi-configuration optimization macro is shown here.

```
PANT
ACON 1
VY 0 YP1
VLIST RD ALL
VLIST TH ALL
VLIST GLM ALL
END

AANT P

ACON 1
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

ACON 2
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

ACON 3
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

END

SNAP    0/DAMP    1.00000
SYNOPSYS    25 MULT
```

Declaration of optimization variables

Declaration of merit functions

Since the optimization program normally works on whatever ACON is current, and *only* that ACON, you must put the word **MULTICONFIGURATION** in word 3 of the SYNOPSYS command if you want to optimize more than one ACON at a time. This causes the program to accept ACON entries found in the AANT and PANT file, and to perform the pickups between the several configurations.

Note 1: For more details on the PANT and AANT files, see the following sections in the User Manual: 10.2 Parameter Input (PANT), 10.3 Aberration Input (AANT).

More on optimization variables and pickup

Now let's take a closer look at the PANT file (ie, the optimization variable declarations).

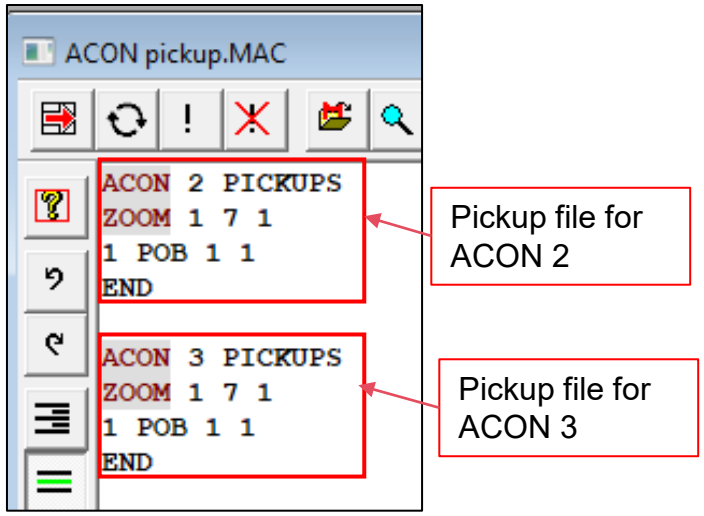
- In the PANT file, we explicitly declare the optimization variables for ACON 1. It includes all the radii, thicknesses, and glass models as declared in the lines 4-6 of the screenshot. Line 3 in the screenshot declares that the object property YP1 is also an optimization variable (see appendix for the use of YP1 as an optimization variable – the floating stop). That's the reason we need the POB(object data pickup) declaration in the Pickup file.

  Because we have set up the Pickup files as shown in the screenshot at the bottom, only ACON 1 is needed in the PANT. The other ACONs will pick up the values of these variables in ACON 1.

- When the AANT and PANT files are processed, the program assigns the aberrations and variables to the current ACON until another ACON directive is encountered within that file. Since one usually intends the first of these to apply to ACON 1, it is wise to either change to this ACON before entering these files, or to start the AANT and PANT files with an explicit ACON 1 directive. Failure to do this can result in the data being applied to the wrong configuration, since the program has not yet seen the SYNOPSYS ... MULTI command that is to follow, and it therefore defaults to the usual interpretation of the AANT and PANT data, which apply to the current configuration.

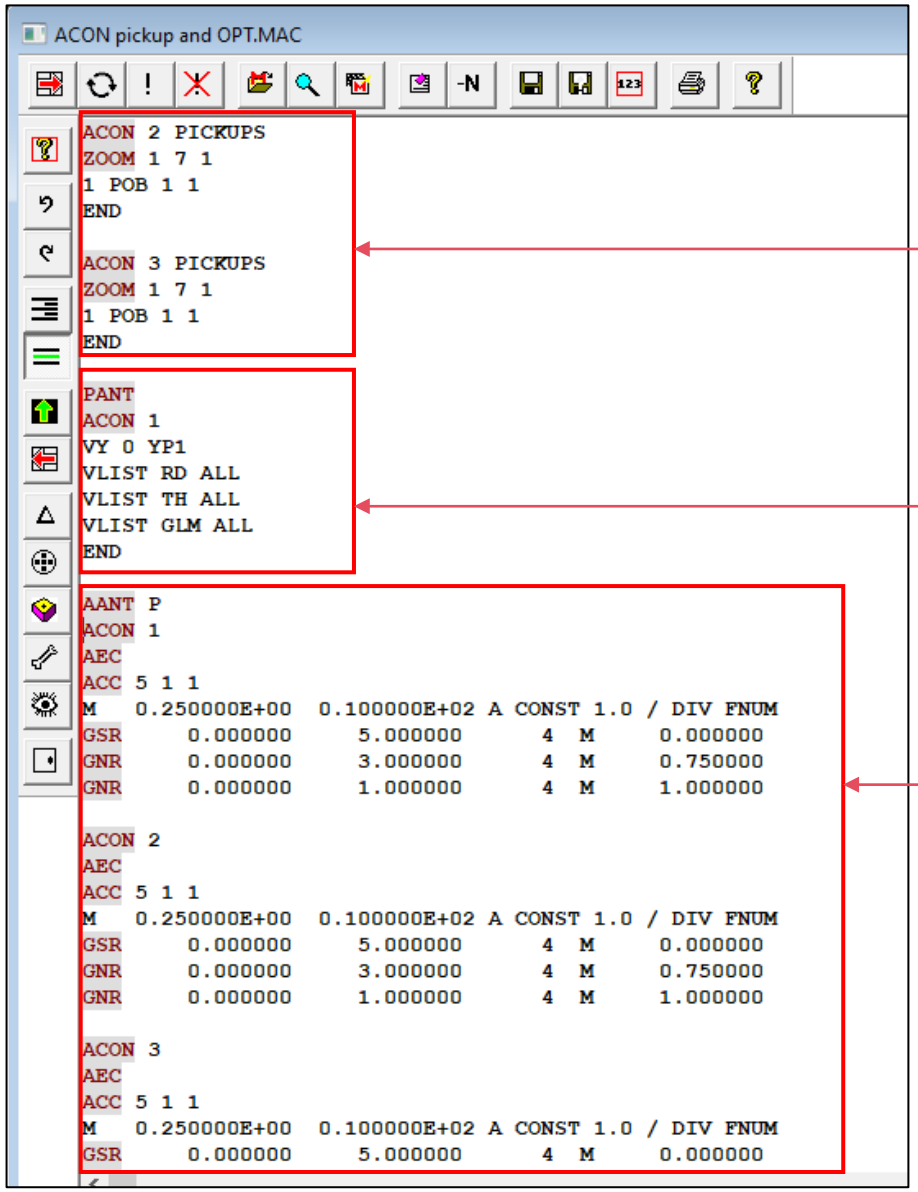
  You can also put an ACON 1 command at the start of your optimization MACro for the same purpose.

```
PANT
ACON 1
VY 0 YP1
VLIST RD ALL
VLIST TH ALL
VLIST GLM ALL
END
```



More on optimization variables and pickup

- You can combine the ACON Pickup.Mac (shown in the 2nd screenshot of the last slide) with the standard optimization macro by copy and paste the ACON Pickup Files before the PANT file so that you can track the Pickup and variable declaration in the one place. This new optimization macro is saved as 'ACON pickup and OPT.mac'.



Pickup files: Connections between different configurations

PANT file: Declaration of optimization variables

AANT file: Declaration of merit functions

More on merit functions

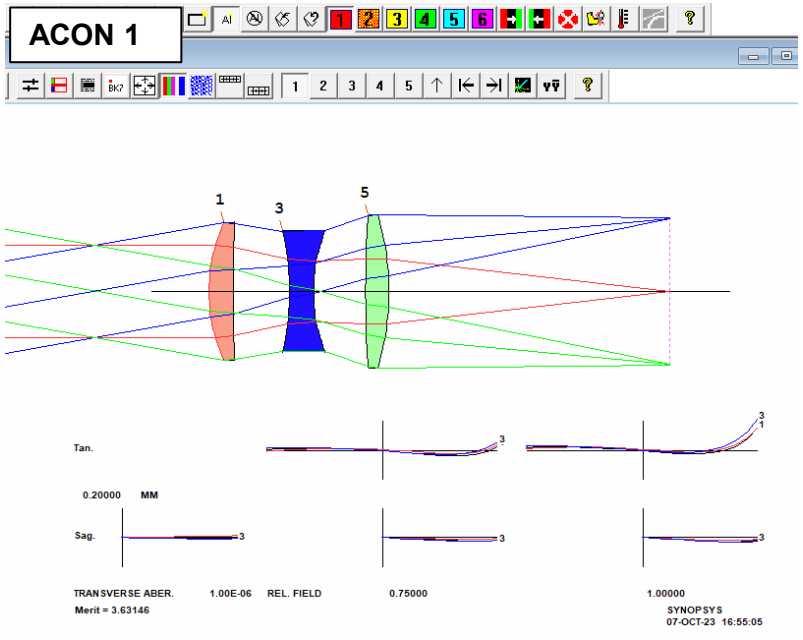
Because there is no pickup for the merit functions, we must include explicitly the merit functions for each ACONs, even though they may be the same as shown in this example.

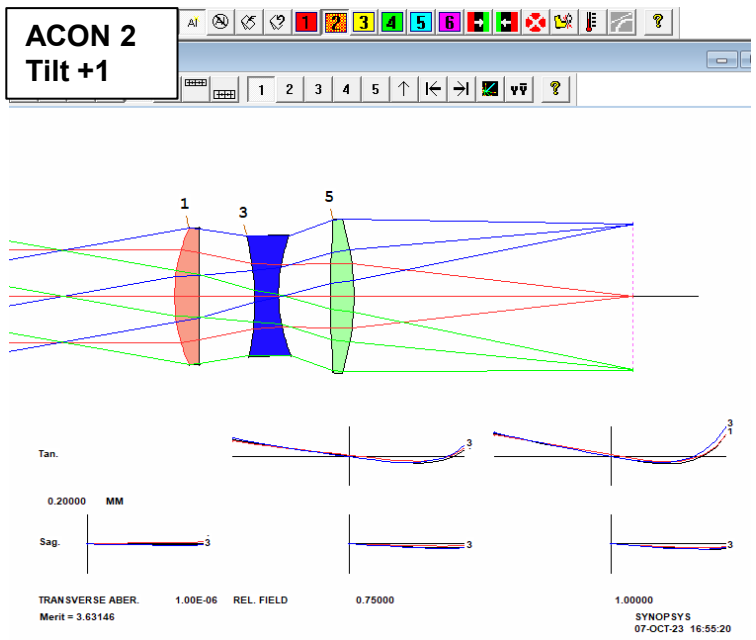
If you fail to declare the merit function for a particular ACON, that configuration will not be optimized even though you have set up the pickup file and/or optimization variables for that ACON.

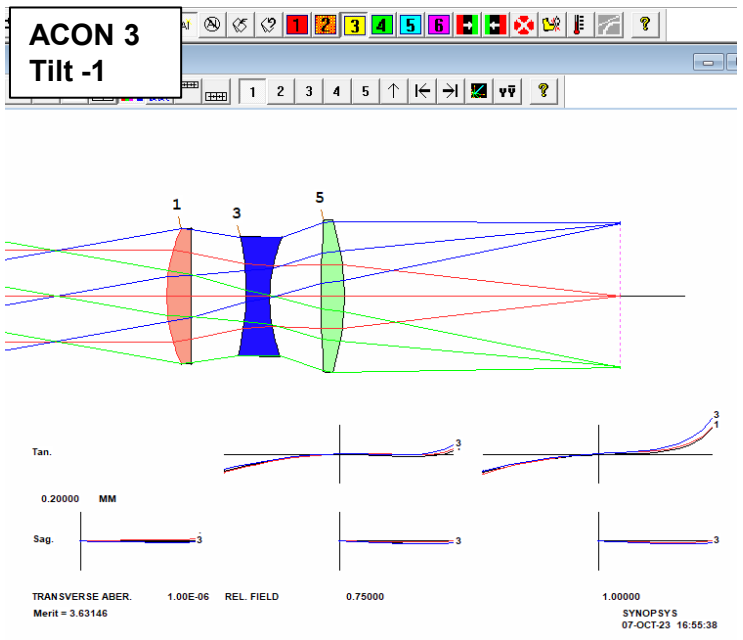
```
AANT P

ACON 1
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

ACON 2
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

ACON 3
AEC
ACC 5 1 1
M   0.250000E+00  0.100000E+02 A CONST 1.0 / DIV FNUM
GSR      0.000000      5.000000      4  M      0.000000
GNR      0.000000      3.000000      4  M      0.750000
GNR      0.000000      1.000000      4  M      1.000000

END
```

Multi-configuration optimization result

After optimization, we can see that lenses in the different configurations are all improved:

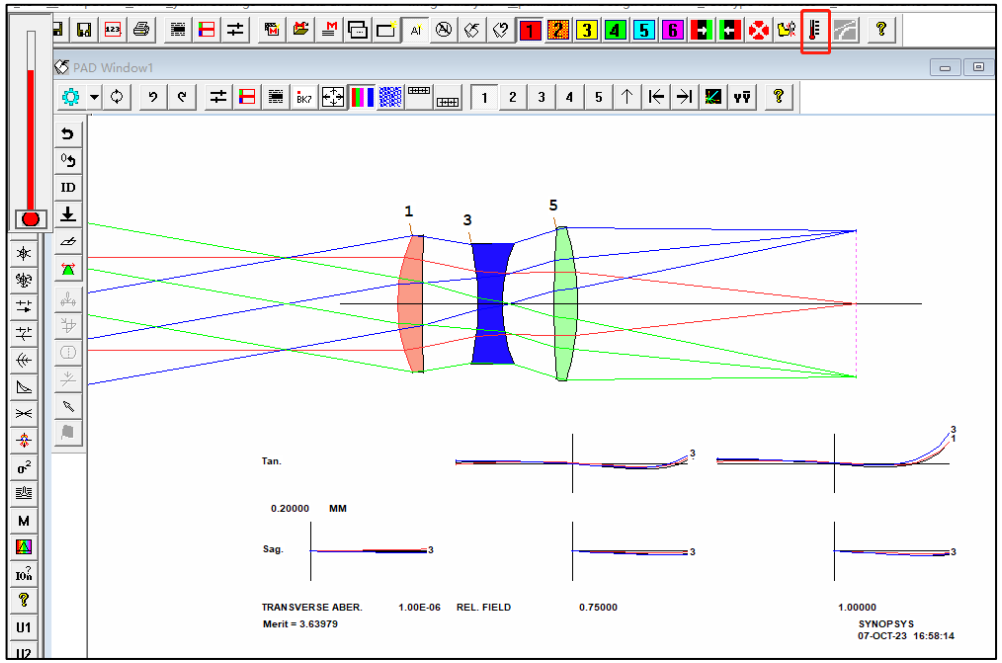






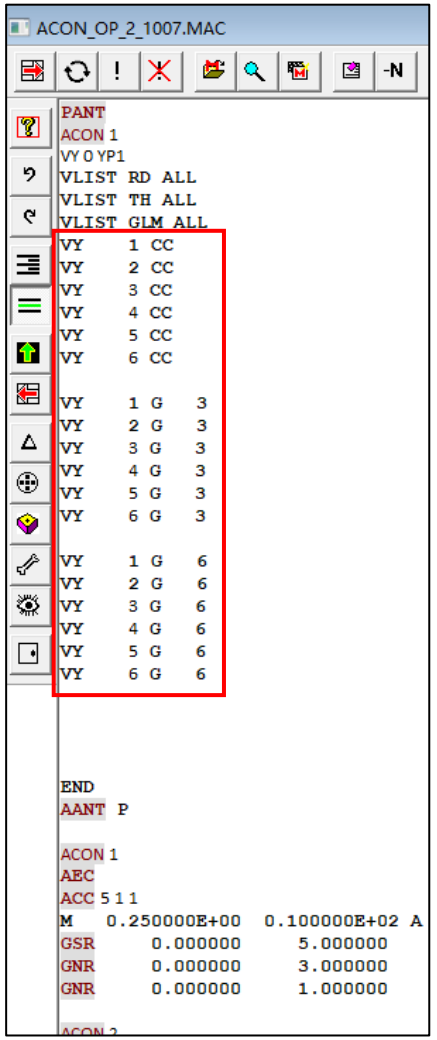
Multi-configuration annealing

Simulated annealing can be run normally after optimization as long as the pickup between different configurations are still in place and you are still using the same multi-config optimization macro.

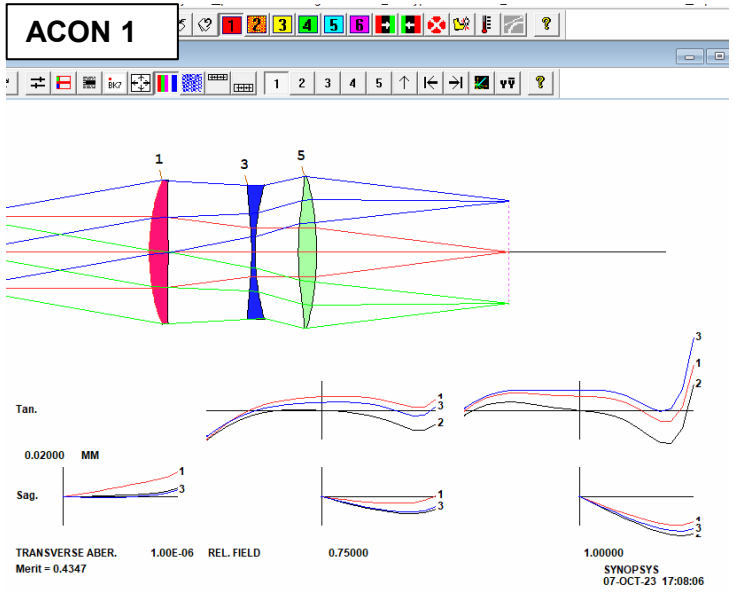


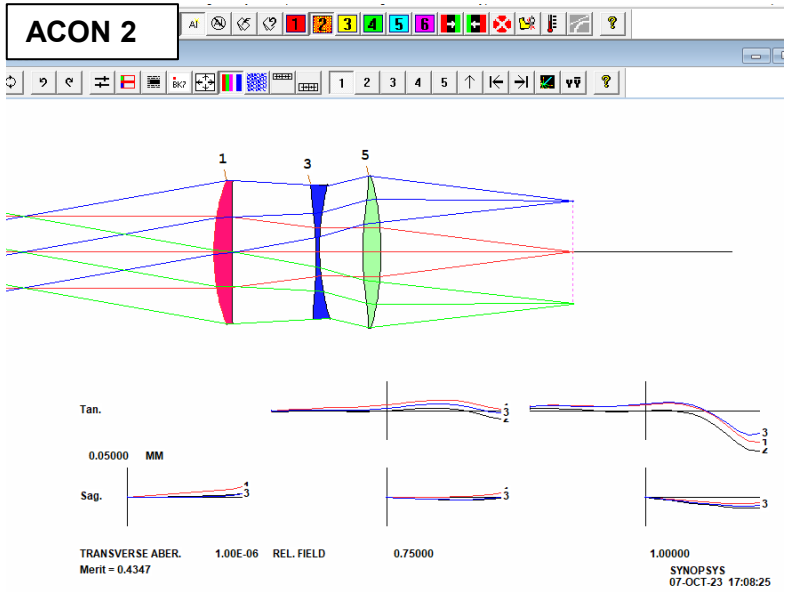
Multi-config optimization with G terms

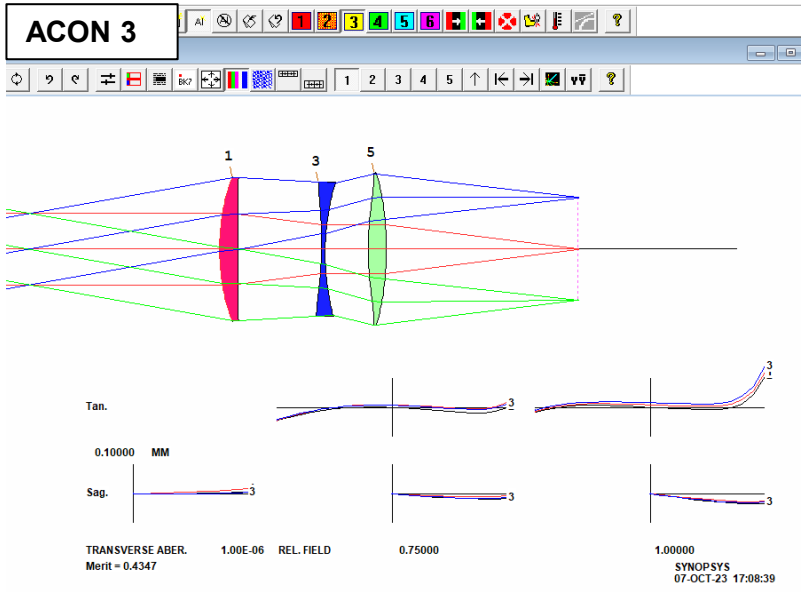
- If you want to include G terms in the optimization, you can simply modify the previous optimization macro by adding the G terms in the PANT under ACON 1 as shown in the screenshot to the right.
- The conic constants (CC), G3 (4th order term), and G6 (6th order term) for surfaces 1-6 will be pickuped up by ACON 2 and 3 because the ZOOM directive in the Pickup File.



Optimization results with aspherical terms



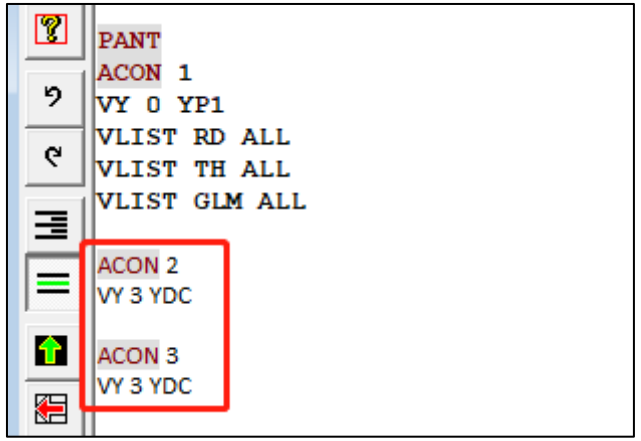




Declare independent optimization variables for different configurations

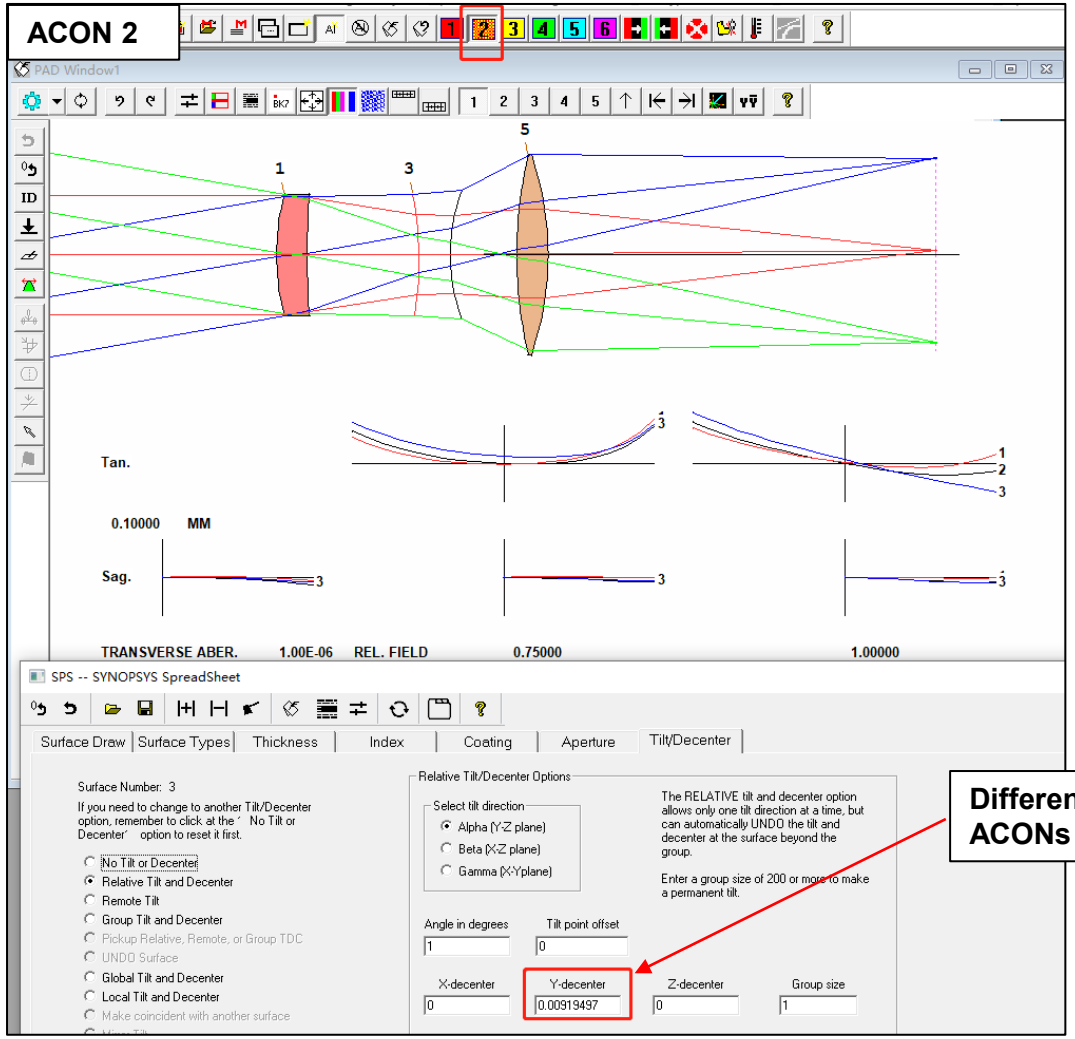
Sometimes we may want to keep some variables in the different ACONs independent (ie, not tied by pickup) during optimizations. You can do that by explicitly declaring those variables under its own ACON number in the PANT file.

For example, if we want surface 3 to be shifted (decentered) independently in ACON 2 and 3, we can add the declarations enclosed in the red square to the PANT file to make the Y-decenter amount (YDC) independent variables for ACON 2 and 3.

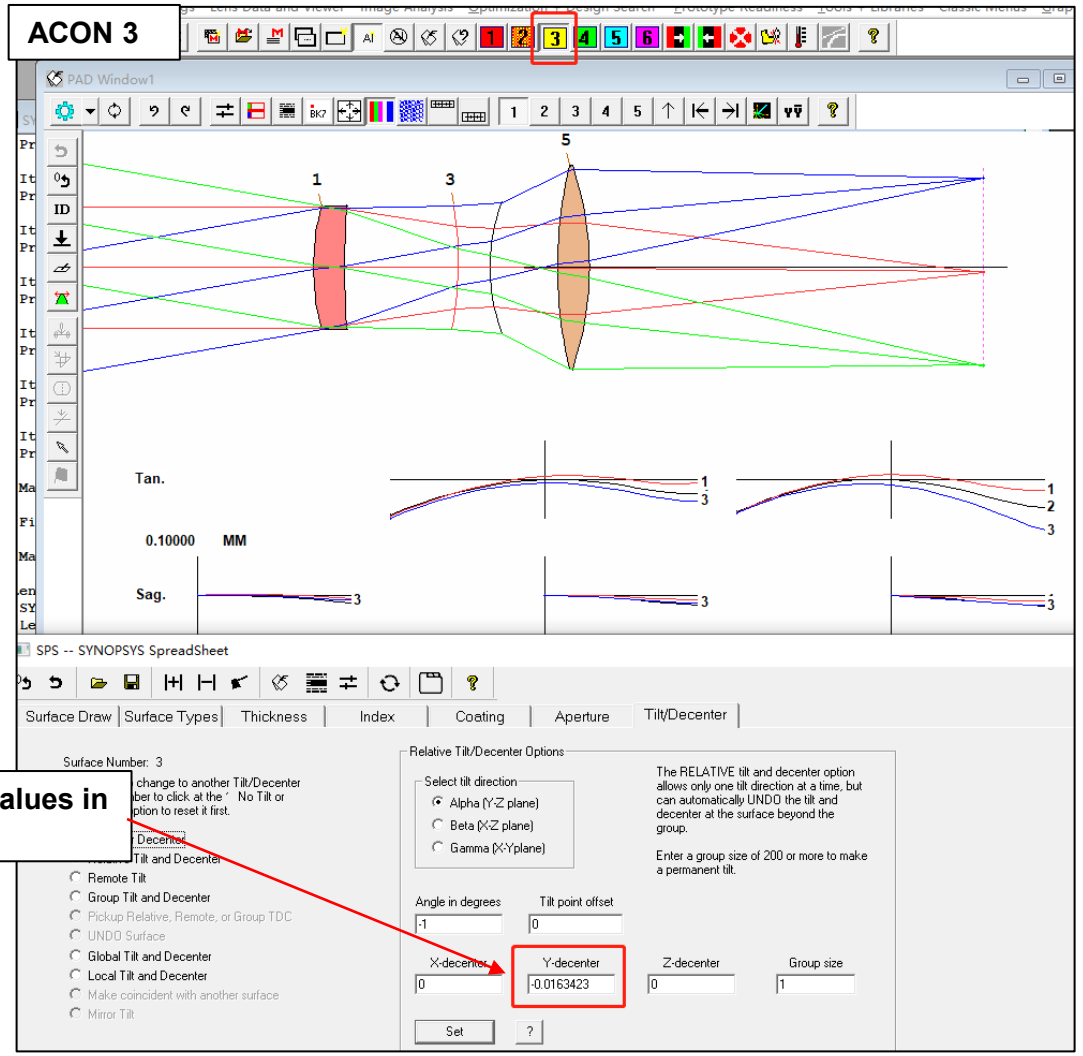


Declare independent optimization variables for different configurations

After optimization, YDC changes separately for configurations 2 and 3:



Different YDC values in ACONs 2 and 3



Appendix 1 Floating Stop

Stop location has direct impact to system performance

Where should the pupil (stop) be?

- Other lens design software requires specifying a pupil location (that ties to the stop)
- In SYNOPSYS™, you can start with a guess stop location, and ask the software to help find the best location via optimization. All you need to do is to tell SYNOPSY that you want to make the stop location as an optimization variable by adding one line of command to your optimization macro – the floating stop
  - VY 0 YP1: declare floating stop for optimization

Variable parameters:

```
PANT
VY 0 YP1
VLIST RAD ALL
VLIST TH ALL
VLIST GLM ALL
END
```