AFOCAL DSEARCH Introduction

In this presentation, we demonstrate how to use DSEARCH for image side AFOCAL system (similar to an eyepiece).

- We use BACK to set an eye relief of 10mm from the last lens surface to the image plane. You can change it to your desired value.
- We set TOTL 30 1 to the distance between the first and the last lens surface (image plane not included). You can change it to your desired value. However, if you change TOTL to a smaller value for a more compact system, you may need to use ASPHERIC surfaces during DSEARCH, which is not covered in this demonstration.

There are three DSEARCH methods discussed:

1. The first one uses the STOP LAST and STOP FIX goals to make the last surface the stop. However, this control is only good for the paraxial rays.
2. In the second method, on top of STOP LAST and STOP FIX, we add an YA control in the SPECIAL AANT section to force the real chief ray height is zero at the last surface so that it's the real STOP. This method also allows the user the flexibility to increase the weight in the YA control to enforce this requirement when there are many competing aberrations to be controlled.
3. In the third method, we demonstrate how to use PYA target or CAO target in the SPECIAL AANT section to control the STOP size.

A general note:
It's better to keep the DSEARCH simple by using only the essential GOALS or essential controls in the SPECIAL AANT section. DSEARCH is a form of global optimization where the starting point of the search is far from any local minima. If we add a lot of specialized controls from the very beginning, the aberrations from these controls can dominate the merit function and pull the optimization algorithm sideways trying to correct those aberrations (when the system is not ready for such corrections), instead of working on the basic improvements like searching for the appropriate radius of curvatures. Sometimes, this will result in not well-behaved systems.
It's always more efficient to add the special controls gradually during the optimization process after DSEARCH.

If you have a valid Customer Service Contract with us, and you want to obtain a copy of the macro and lens files discussed in this document, please send an email to office@osdoptics.com, with your key number included in the email subject line.

General concept: AFOCAL

- Parallelism of rays (or collimated rays) in image surface is automatically controlled if AFOCAL is added in DSEARCH
- Just like the automatic spot size optimization in FOCAL DSEARCH
- No additional commands required to control collimation in AFOCAL mode
- AFOCAL DSEARCH will automatically control 0 diopter.

For more details, see user Manual 10.14 Design Search (DSEARCH)

General concept: BACK

- For AFOCAL systems, this quantity is the distance before the last two (dummy) surfaces, which makes it convenient for controlling the eye relief of an eyepiece.
- The BACK can be freely modified according to the requirements.
- In this case we use BACK 20 0.1

For more details, see User Manual 10.14 Design Search (DSEARCH)

BACK	The desired back focal distance. It is wise to specify a value, either here or in the SPECIAL AANT section, since the lenses can get rather weird otherwise. The weighting of this aberration may be specified in word 3. To bypass this control, enter a target of zero. If the lens will have a UMC solve (see FNUM, above) then the back focus is given a target in the merit function per this input. If you give a weight to FNUM, then the F/number is controlled by an entry in the AANT file instead of a paraxial solve, and in this case the quantity controlled for the BACK request is actually 1/BACK rather than BACK itself. In this case, it is best to enter a fairly large weight, say 1000 or so, since the quantity that is controlled becomes small for large values of BACK, and any errors also become small and have little effect on the merit function otherwise. Yet another option is to specify the word "SET" in word three of the line. Then the program sets the back focus to this distance and there is no YMT solve or target in the merit function. This option is only available for focal systems. Note that if you want the final BACK to go to zero, just entering that target value won't work, since that is the flag to bypass the control. In that case, just enter a very small nonzero target, so the program will see it. For AFOCAL systems, this quantity is the distance *before* the last two (dummy) surfaces, which makes it convenient for controlling the eye relief of an eyepiece.

General concept

Construction parameter aberrations: PYA, PYB, PUA, PUB

- All for paraxial rays. ‘A’ stands for axial marginal ray; ‘B’ stands for the chief ray
- PYA is marginal ray height, and can control axis image height
- PUA is marginal ray angle
- PYB is chief ray height, and can control stop position
- PUB is chief ray angle

For example, if we want to control the marginal ray height at surface 11 to be 3, we can do so by using the following command:

```
M 3 10 A PYA 11
```

The first word ‘M’ signifies that we want to Minimize the difference between the target and the controled value

- The numerical value (3) in the 2nd place is the desired target
- Then next parameter (10) is the weight for this control
- The next word A means that we want to Add the term specified next as a control in the merit function
- PYA (paraxial marginal ray height) is the name of the control term
- The last parameter specifies the number of the surface to be controlled

For more details, see User Manual 10.3.3 Construction parameter aberrations

PYA, PYB, PUA, PUB, POW, PIB	are the Y, U, and I (angle of incidence) values for the A and B paraxial rays. Ray A is the axial marginal ray, and ray B is the chief ray. POW is the element power.
PXA, PXB, PVA, PVB, PJA, PJB	correspond to the PYA, etc. aberrations above, except that they apply to the skew plane. These aberrations are zero unless XPXT is turned on. PJA is power in the X-Z plane.

General concept
Construction parameter aberrations: CAO control

The CAO operand controls the aperture at a single surface

For example, if we want to control the outer aperture of surface 11 to be 3, we can do so by using the following command:

```
M 3 20 A CAO 11
```

- The first word ‘M’ signifies that we want to Minimize the difference between the target and the controled value
- The numerical value (3) in the 2nd place is the desired target
- Then next parameter (20) is the weight for this control
- The next word A means that we want to Add the term specified next as a control in the merit function
- CAO (Clear Aperture, Outer) is the name of the control term
- The last parameter specifies the number of the surface to be controlled

For more details, see User Manual 10.3.1.2 User-specified ray aberrations

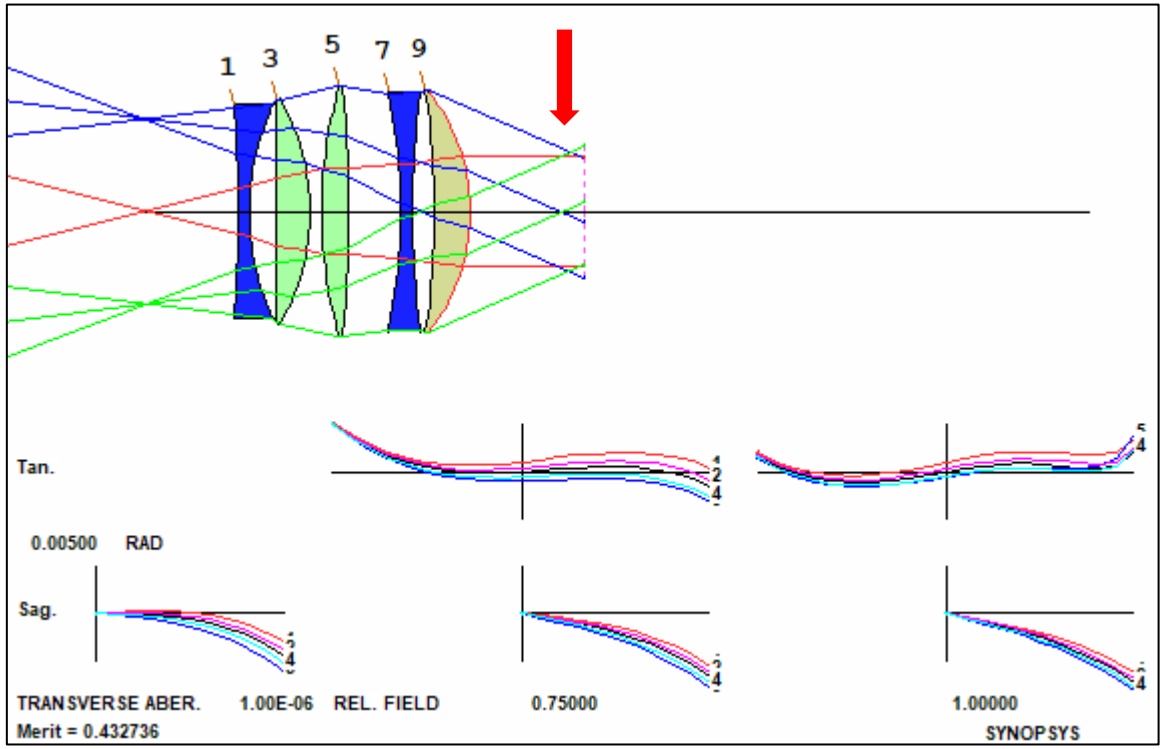
CAO	Is the radius of the clear aperture. This will be calculated during optimization, so it is always current. If the surface has a hard CAO, this quantity will be fixed unless the CAO is also a variable. See section 6.2.1 for a discussion of the default definition. If the surface has a hard EAO or RAO, the Y semi-axis is returned. See section 3.3.1.1 for a description of these features. This aberration will control the aperture at a single surface at the current ACON and ZOOM. If you want to control the apertures of all elements in the lens, use the AAC contro

Method 1 Use STOP LAST and STOP FIX

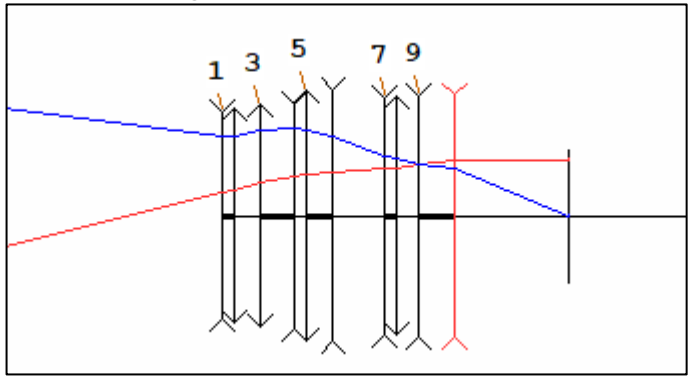
In this method, STOP LAST and STOP FIX is used in the DSERACH macro to set the STOP at the last surface. The macro content can be found in Appendix A.

- The GOALS STOP LAST and STOP FIX only controls the paraxial quantities. As shown below, in the paraxial raytrace plot, the STOP is indeed at the last surface, though the standard (real) raytrace in the SketchPAD shows that the real STOP is a little bit before the image plane.

```
END

GOALS
ELEMENTS 5
BACK 20 0.1
TOTL 0 0
!STOP TELECENTRIC
STOP LAST
STOP FIX
```



Paraxial raytrace plot

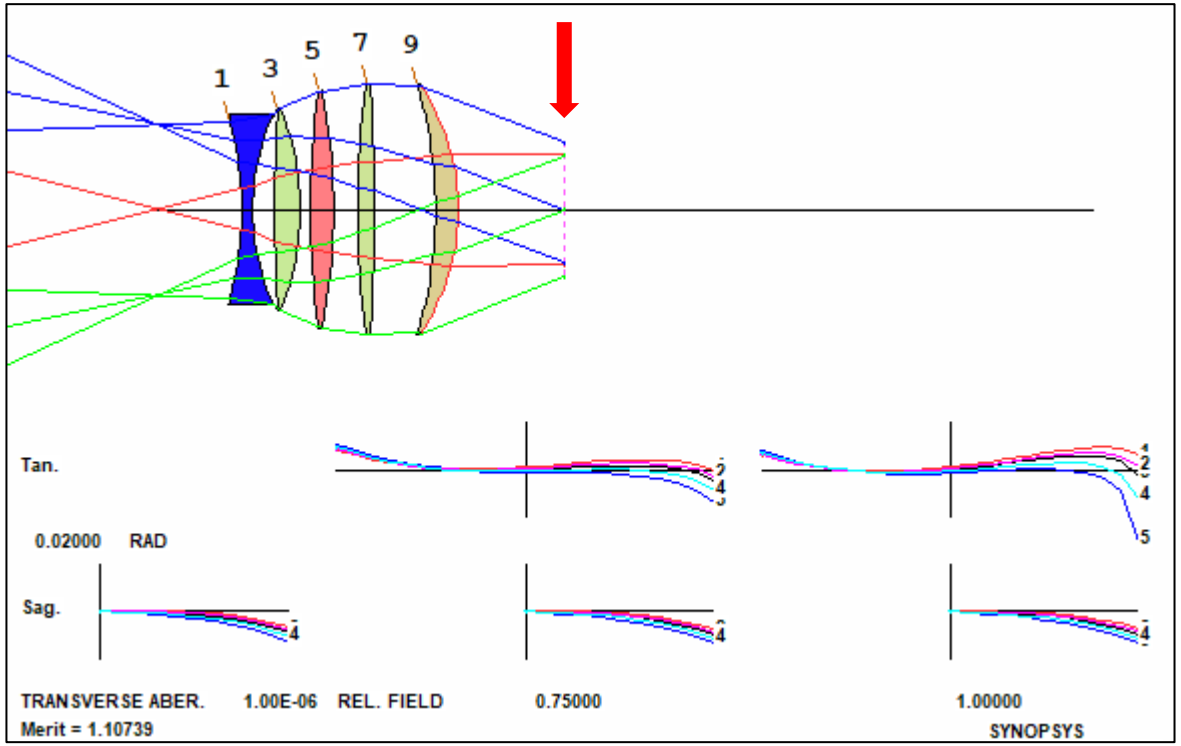


See Appendix B on how to display the paraxial raytrace plot in the SketchPAD.

Macro: AFOCAL_DS1.MAC (see Appendix A)
Best candidate: BC_ AFOCAL_DS1.RLE

Method 2 YA control

In this method, we add the real ray height control operand (YA) in the DSEARCH macro so that the chief ray passes the surface 11 (the STOP surface) on axis. This puts the STOP exactly at the last surface as shown below.



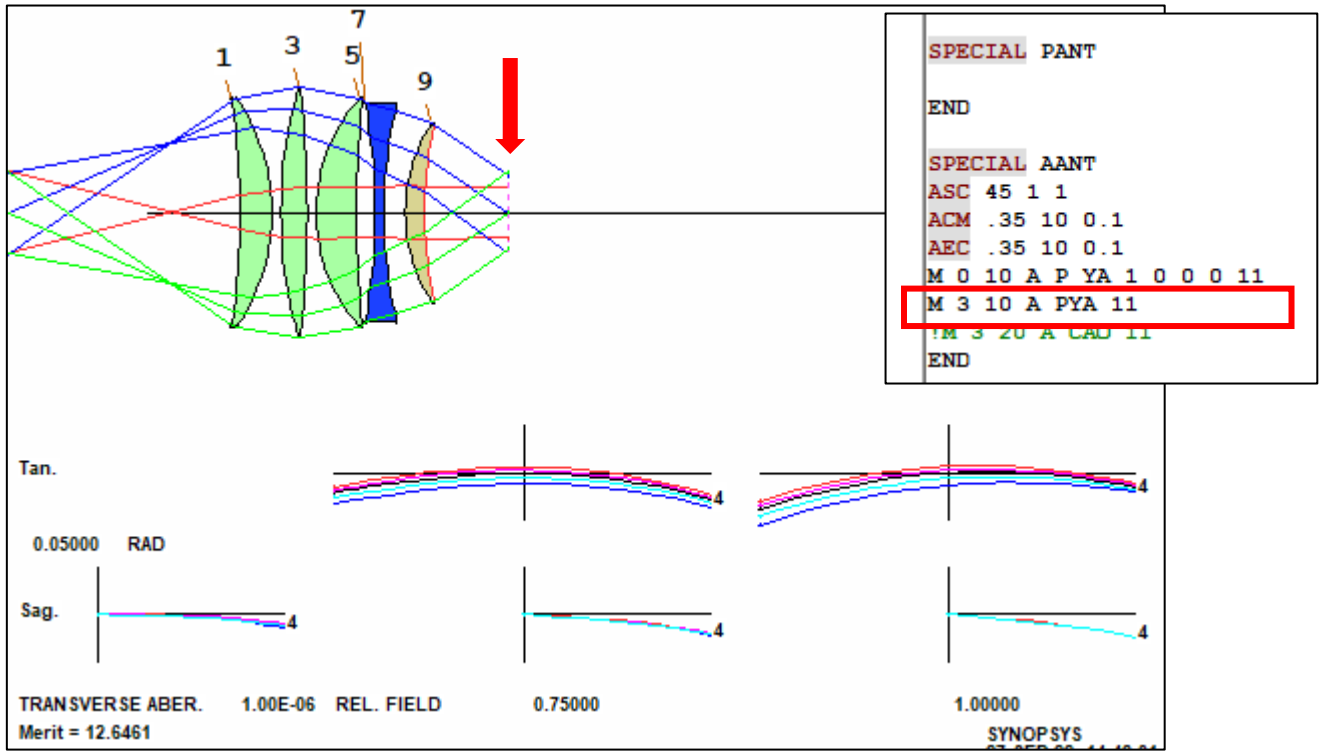

```
NPASS 30
NGRID 6
END

SPECIAL PANT

END

SPECIAL AANT
ASC 45 1 1
ACM .35 10 0.1
AFC .35 10 0.1
M 0 10 A P YA 1 0 0 0 11
END

GO ! run the search
TIME ! see how long it took
```

YA operand is added to the SPECIAL AANT section of the DSEARCH macro. For more details on the YA control, see User Manual 10.3.1.2 User-specified ray aberrations.

Macro: AFOCAL_DS2.MAC
Best Candidate: BC_AFOCAL_DS2.RLE

Method 3 YA + PYA

In this macro, we add PYA (paraxial marginal ray height) to control the size of the STOP (surface 11) to be 3. By running the CAP command, we find that the clear aperture at surface 11 is actually 4.615, larger than the control target 3. This is because we control the paraxial marginal ray height (rays in red), but the clear aperture is determined by the real ray height of the chief rays (blue and green rays) as shown below.



CLEAR APERTURE RADIUS

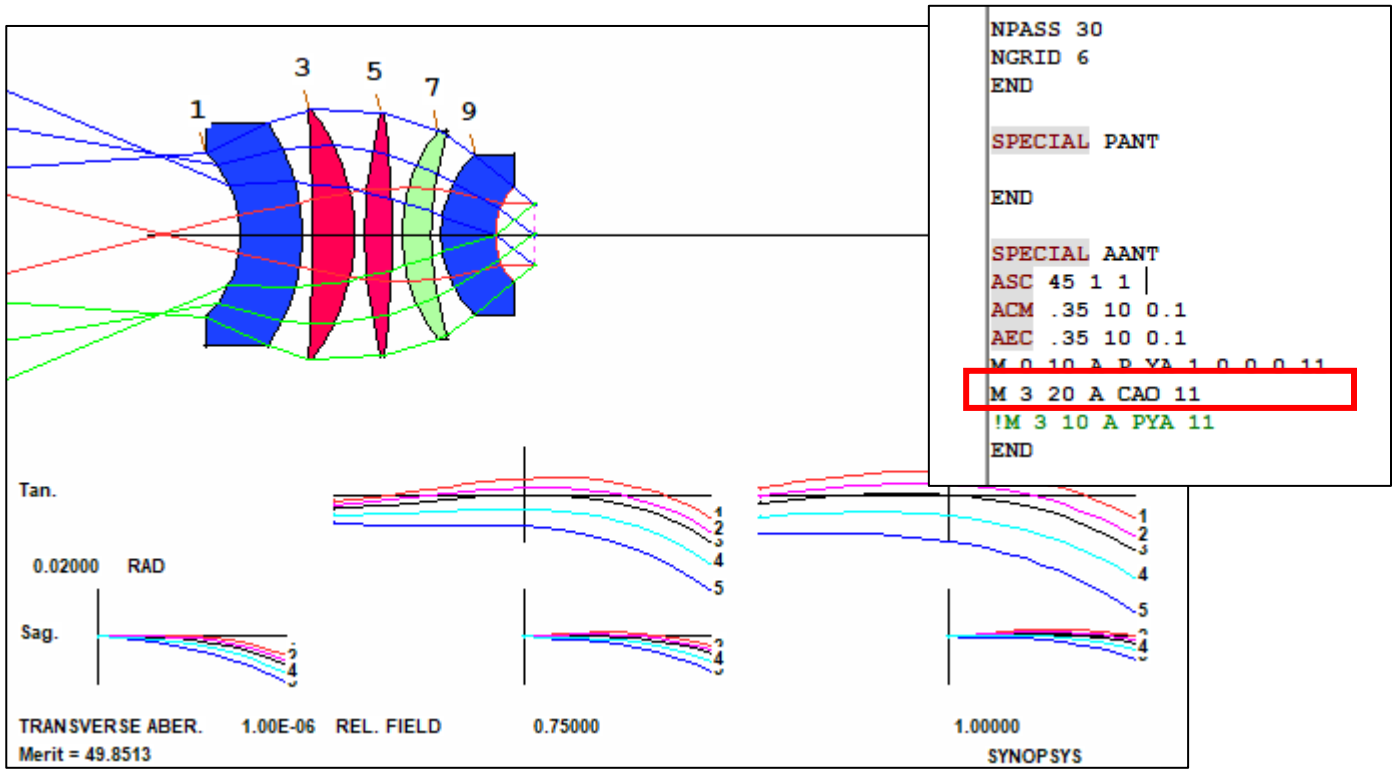
SURF	X OR R-APER.	Y-APER.	REMARK
1	12.8032		Soft CAO
2	13.0318		Soft CAO
3	14.2254		Soft CAO
4	14.2091		Soft CAO
5	12.9905		Soft CAO
6	12.8251		Soft CAO
7	12.4728		Soft CAO
8	11.5191		Soft CAO
9	10.1724		Soft CAO
10	10.0139		Soft CAO
11	4.6150		Soft CAO
12	4.6150		Soft CAO

Macro: AFOCAL_DS3_PYA.MAC

Best Candidate: BC AFOCAL_DS3_PYA.RLE

Method 3 YA + CAO

In this macro, we use the CAO operand to control the size of the STOP (surface 11) to be 3. One can see that now the rays from the different fields fill the STOP nicely. We can find that the STOP aperture size is very close to our target by running the CAP command. However, in this system, the BACK (distance from the last lens surface (surface 10) to the STOP surface (surface 11)) is smaller than the previous one. In order to maintain the desired BACK target, one would need to increase the weight for that control in the DSEARCH, or try to correct it in the post-search optimization.




```
NPASS 30
NGRID 6
END

SPECIAL PANT

END

SPECIAL AANT
ASC 45 1 1
ACM .35 10 0.1
AEC .35 10 0.1
M 0 10 A P YA 1 0 0 0 11
M 3 20 A CAO 11
!M 3 10 A PYA 11
END
```

Run CAP to verify the apertures:

CLEAR APERTURE RADIUS

SURF	X OR R-APER.	Y-APER.	REMARK
1	8.3359		Soft CAO
2	11.3254		Soft CAO
3	12.5995		Soft CAO
4	12.6764		Soft CAO
5	12.3254		Soft CAO
6	12.2806		Soft CAO
7	10.6117		Soft CAO
8	10.1489		Soft CAO
9	8.1447		Soft CAO
10	4.8007		Soft CAO
11	3.1089		Soft CAO
12	3.1089		Soft CAO

Macro: AFOCAL_DS3_CAO.MAC

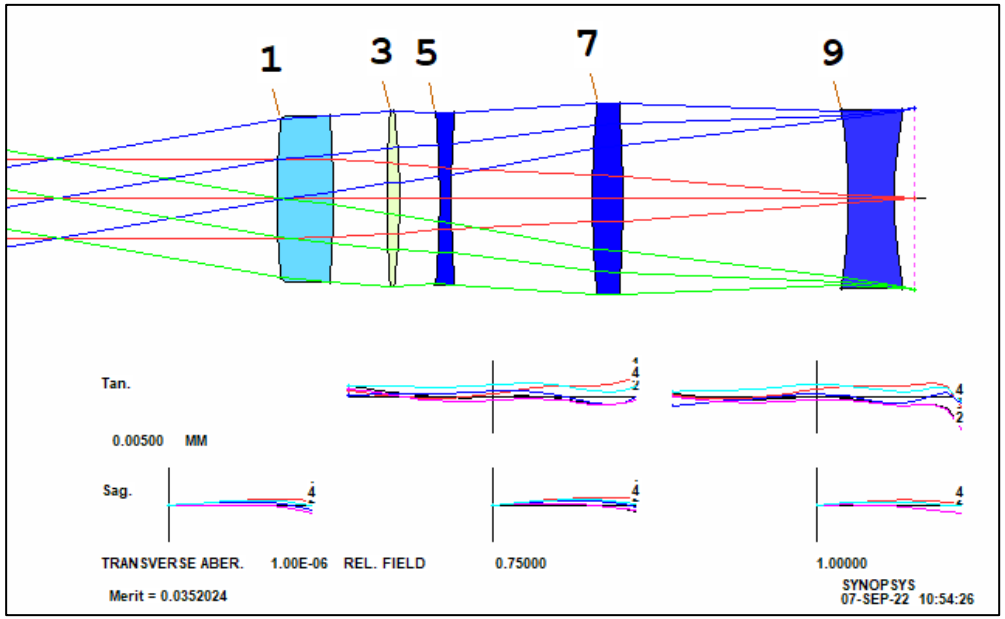
Best Candidate: BC_AFOCAL_DS3_CAO.RLE

FAQs

FAQ: Regarding Reverse search

Sometimes you can also do a reverse search for AFOCAL system design. Start the DSEARCH for a focusing system (FOCAL) then reserve the system after a few optimizations.

If you want to use reverse search, you will use OBB (object at infinity) as your object in the DSEARCH macro. You can then use command REVERSE to reverse the lens after optimization.



5.11 Lens Reversal (REVERSE)

Next Previous TOC

The command

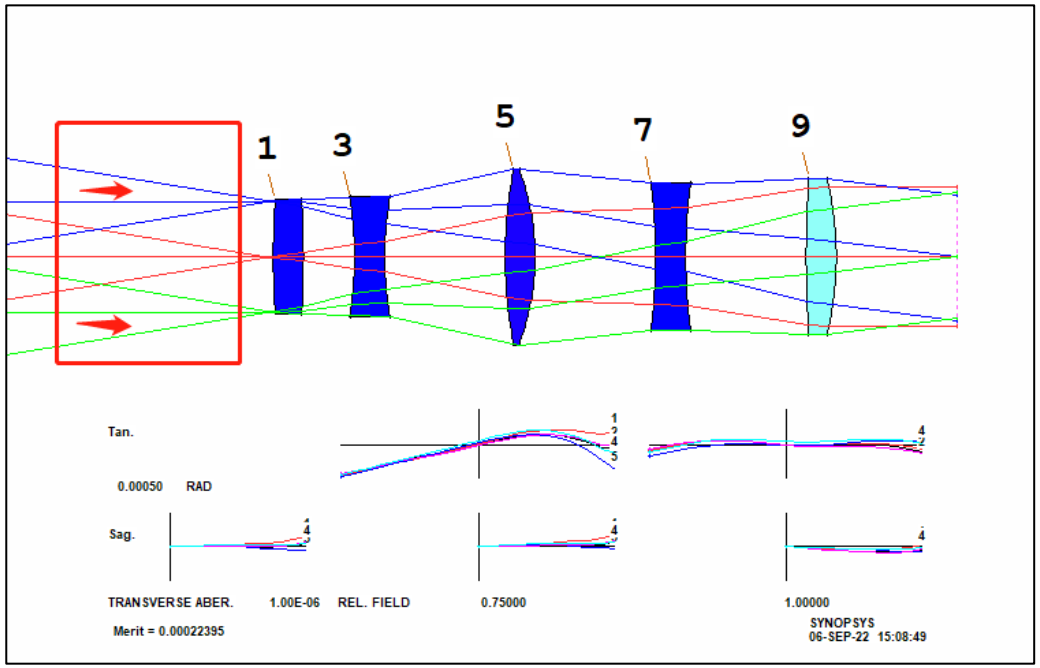
REVERSE

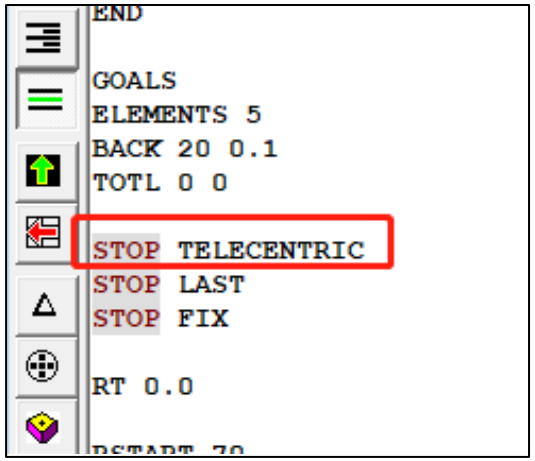
will cause the entire lens to be reversed, end for end. If tilts or decenters are present, the program will:

1. Convert all surfaces to GLOBAL coordinates.
2. Find the global positions in the coordinates of the last surface.
3. Reverse the lens.
4. Assign new global coordinates all surfaces by inverting the position matrix just found.
5. Change all of the new global coordinates to relative, if possible.

FAQ: Should I use 'STOP Telecentric' for AFOCAL DSEARCH?

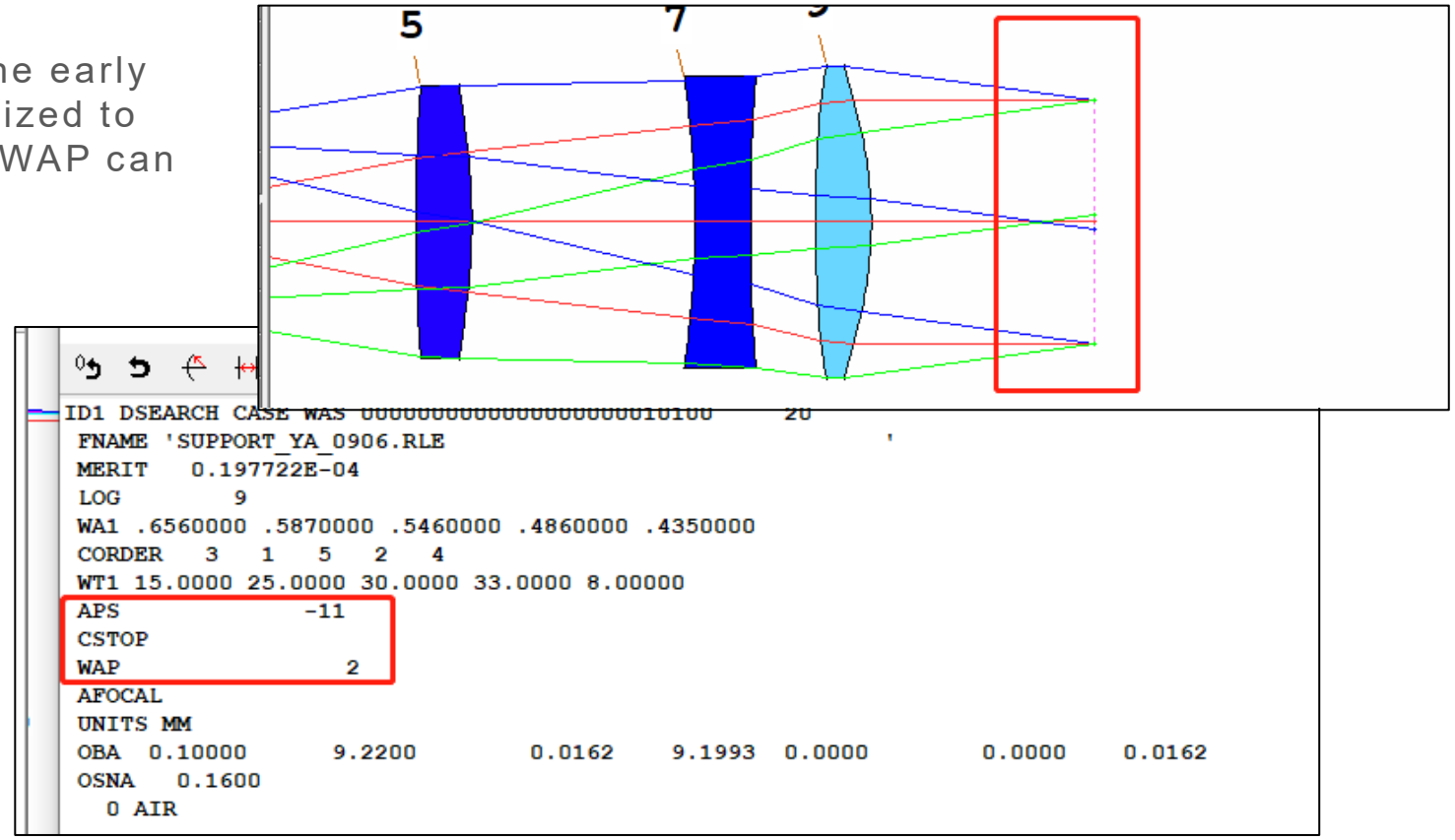
- STOP Telecentric is for designing system that is telecentric in the object space, where incident chief rays at different fields are parallel to each other, which is different from AFOCAL system. Therefore, STOP TELECENTRIC is not the appropriate GOAL to use for AFOCAL system.





FAQ: What WAP mode is recommended?

In general, we use the default simple WAP in the early stage of optimization. After the system is optimized to better image quality, CSTOP + WAP 2 or other WAP can be set according to your design objectives.



APPENDIX

Appendix A:

DSERACH macro, AFOCAL_DS1.MAC

DSEARCH macro:

```
CORE 6
TIME
DSEARCH 1 QUIET

SYSTEM
ID DSEARCH SAMPLE
OBA 8 8 2
WA1 0.656 0.587 0.546 0.486 0.435
WT1 15 25 30 33 8
CORDER 3,1,5
AFOCAL
UNITS MM
END

GOALS
ELEMENTS 5
BACK 10 1
TOTL 30 1
STOP LAST
STOP FIX

RT 0.0

RSTART 70
FOV 0.0 .3 .6 .9 1
FWT 15.0 3.0 3 3 10
ANNEAL 100 10 Q 30
SNAPSHOT 10
QUICK 30 30
```

DSEARCH macro, continued:

```
NPASS 30
NGRID 6
END

SPECIAL PANT

END

SPECIAL AANT
ASC 45 1 1
ACM .35 10 0.1
AEC .35 10 0.1
END

GO ! run the search
TIME ! see how long it took
```

Appendix B: Paraxial Raytrace plot

Click PAD TOP button in the SketchPAD top toolbar. Select Paraxial Raytrace and click OK to display paraxial raytrace plot in the SketchPAD window: