# Lesson 3: PSD optimization

We have observed that modern software can optimize a lens many times faster than can a human expert. This lesson will underscore that point.

There has long been contention in the lens design industry between theorists and "number crunchers". The former endeavor to understand their lens and steer the design in a cogent way according to their deep knowledge of aberration theory. The latter employ enough optics knowledge to establish the goals in a cogent manner – but then turn the job of meeting those goals over to the computer. We believe that, for many problems, the number crunchers can far outpace the theorists today. And it is not even close. That is why much of what theorists struggle to understand is no longer important.

We present here a design problem that starts with a very bad lens, where all surfaces are flat, all thicknesses and airspaces are equal, and all glasses are in the middle of the glass chart. Then we show how a good optimization algorithm can very quickly turn that bad design into a rather good one.
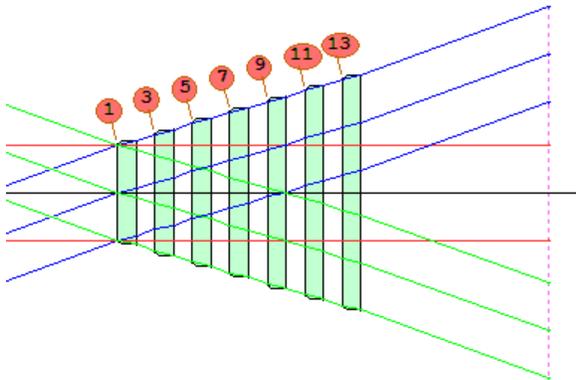
Here is our optimization MACro.

```
AWT: 0.074
OFF 67
RLE
ID START FROM FLAT
UNI MM
OBB 0 20 12.7
1 TH 5 GLM 1.6 50
2 TH 5 AIR
3 TH 5 GLM 1.6 50
4 TH 5 AIR
5 TH 5 GLM 1.6 50
6 TH 5 AIR
7 TH 5 GLM 1.6 50
8 TH 5 AIR
9 TH 5 GLM 1.6 50
10 TH 5 AIR
11 TH 5 GLM 1.6 50
12 TH 5 AIR
13 TH 5 GLM 1.6 50
14 TH 50 AIR
15
APS 1
END
```

```
STO 9
TIME
QUIET
PANT
VY 1 YP1
VLIST RAD 1 2 3 4 5 6 7 8 9 10 11 12 13 14
VLIST TH ALL EXCEPT 14
VLIST GLM ALL
END

AANT
AEC
ACC
M 33 2 A GIHT
GSR AWT 10 5 M 0
GNR AWT 2 3 M .7
GNR AWT 2 3 M 1

END

DAMP 10000
SNAP 20

SYNO 10
SYNO 70
LOUD
TIME

RMS M 0 600
Z1 = FILE 1
RMS M .5 600
Z2 = FILE 1
RMS M 1 600
Z3 = FILE 1
= (Z1 + Z2 + Z3)/3.0

ORD = FILE 1
```
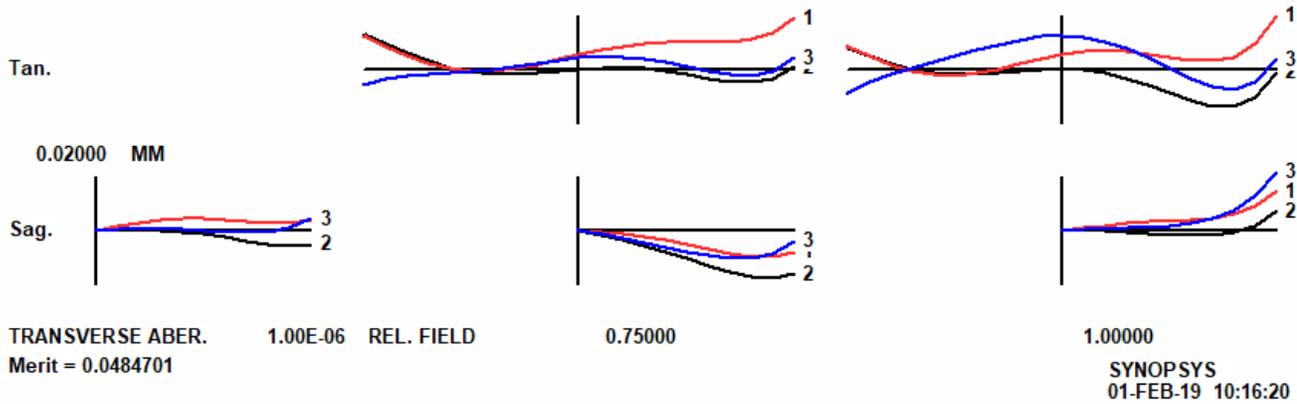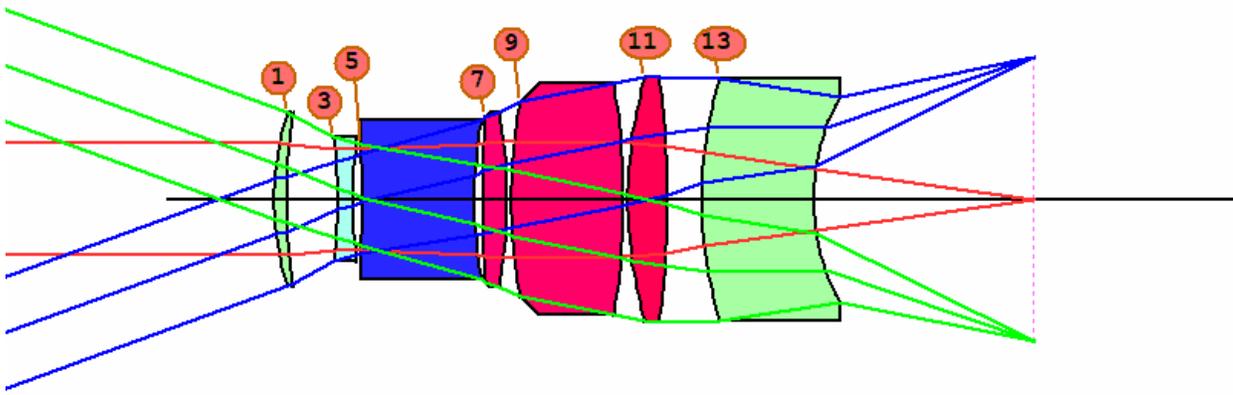
When we run this MACro, we get the following lens after about one second:

Tan.

0.02000 MM

Sag.

TRANSVERSE ABER.   1.00E-06   REL. FIELD   0.75000   1.00000
Merit = 0.0484701   SYNOPSYS
                                                                                               01-FEB-19 10:16:20

The output in the CW contains the lines
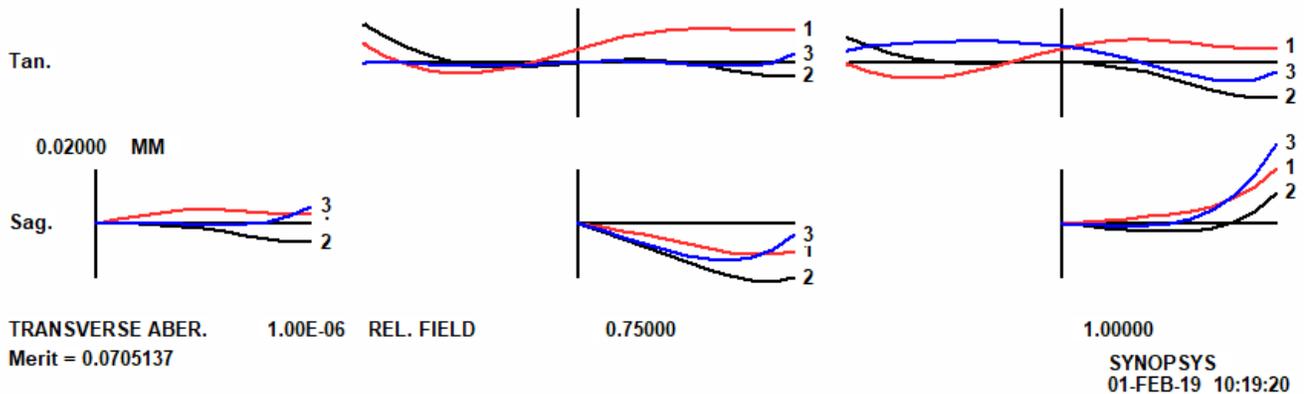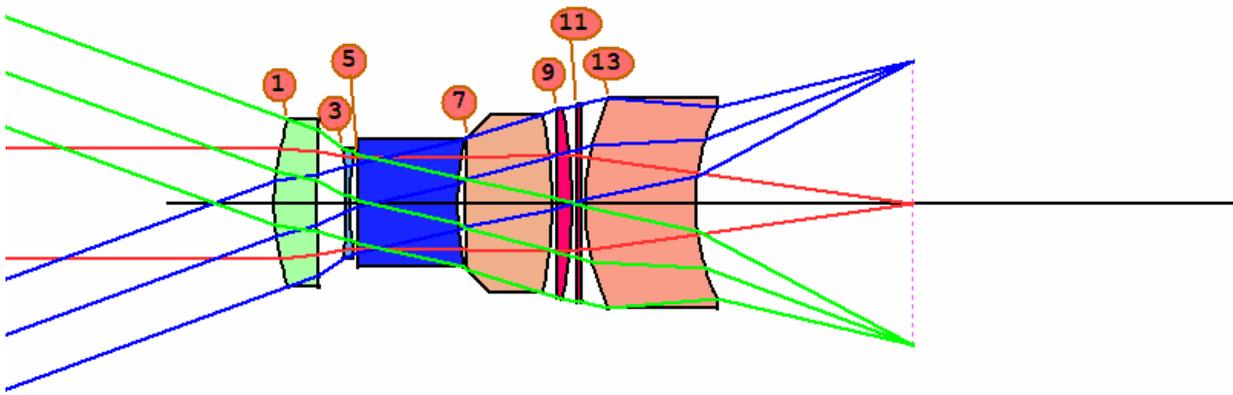
…
```
--- = (Z1 + Z2 + Z3)/3.0

The composite value is       0.00612788
```

which are from the end of this MACro and use the AI program to calculate the average RMS spot size at three field points. It comes out to just over 6 microns.

Now let's try a few things. The second parameter on the ray-generation directives currently is 0.074. This applies an aperture-dependent weighting on each ray, and if we increase the value to, say 0.1, then rays near the center of the pupil will be weighted more heavily than rays at the edge. Edit the MACro, changing the value of the symbol AWT:

```
        AWT: 0.1
```

If you then run it again, you get a very different lens. (That symbol appears in the AANT file and gets replaced with the characters 0.1 in this case.)

Tan.

0.02000 MM

Sag.

TRANSVERSE ABER.   1.00E-06   REL. FIELD   0.75000   1.00000
Merit = 0.0705137
                                                                                                 SYNOPSYS
                                                                                                 01-FEB-19 10:19:20

and the score is higher, at 0.0073 mm. It's still a very good lens, but this exercise shows an important insight: When you start with flat surfaces, the PSD algorithm can go anywhere – and a very slight change in the starting point or requirements can send it down a different path. At this point we would normally run the simulated annealing program, by clicking on the button 🌡 in the top toolbar. This brings the score down to 5.74 um. A good lens indeed!