Lesson 14: A More Challenging Optimization Challenge

In Lesson 3 we designed a seven-element lens starting from plane-parallel surfaces, which is about as close to starting from scratch as you can get in this business. That lesson was intended to demonstrate the speed of the PSD III optimization algorithm, which is one of the factors that make modern number crunching so effective.

In this lesson, we will start with the same system – but in this case we want to achieve a high MTF at four field points and substitute catalog glass types for the glass models of the earlier lesson. To do the latter, we will use the automatic real-glass insertion program, **ARGLASS**[1].

Here is the input:

```
RLE                  ! The starting system.
ID TEST PSD III
OBB 0 20 12.7
WAVL CDF
UNITS MM
1 TH 5 GLM 1.6 50
2 TH 5
3 TH 5 GLM 1.6 50
4 TH 5
5 TH 5 GLM 1.6 50
6 TH 5
7 TH 5 GLM 1.6 50
8 TH 5
9 TH 5 GLM 1.6 50
10 TH 5
11 TH 5 GLM 1.6 50
12 TH 5
13 TH 5 GLM 1.6 50
14 TH 50
15
APS 7
END
PAD/U          ! Show the initial system.
PROJECT        ! Start a timer, then define a symbol, AWT, for the aperture weight

AWT: 0.5      ! almost equal weight over aperture
QUIET          ! not showing everything on the monitor speeds things up

PANT           ! Define variables.
CUL 1.9        ! Set upper limit of 1.9 on index variables.
FUL 1.9
VY 1 YP1        ! Vary the paraxial stop position.
VLIST RAD 1 2 3 4 5 6 7 8 9 10 11 12 13 14
VLIST TH ALL
VLIST GLM ALL
END

AANT                ! Start of merit function definition.
AEC
ACC
M 33 2 A GIHT
GSR AWT 5 5 M 0      ! Note how weights are assigned to the several field points.
GNR AWT 4 4 M .3    ! This creates a ray grid at the .3 field point
GNR AWT 4 4 M .6    ! These for the 0.6 field point
```

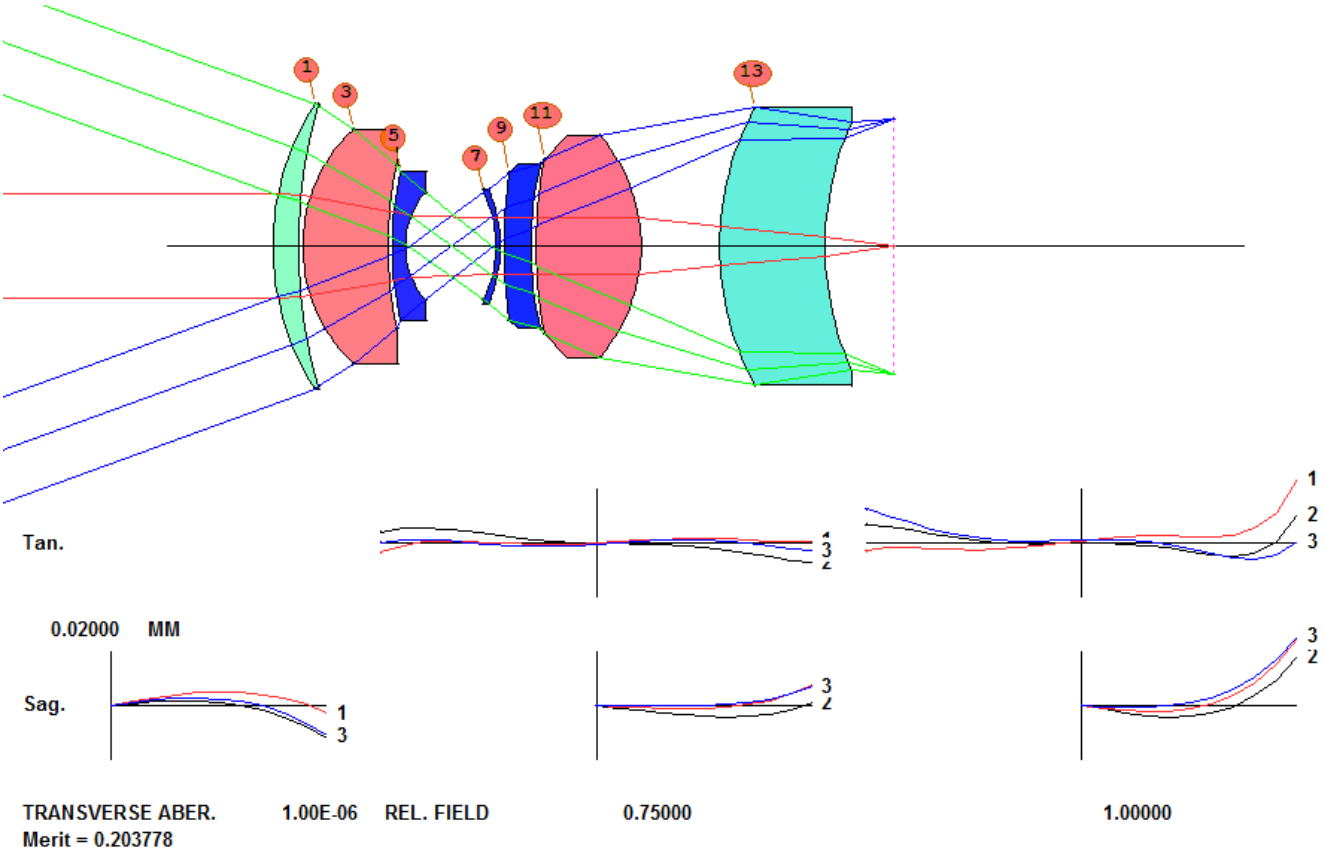
[1] ARGLASS™ is a trademark of Optical Systems Design, Inc., a Maine, USA corporation.

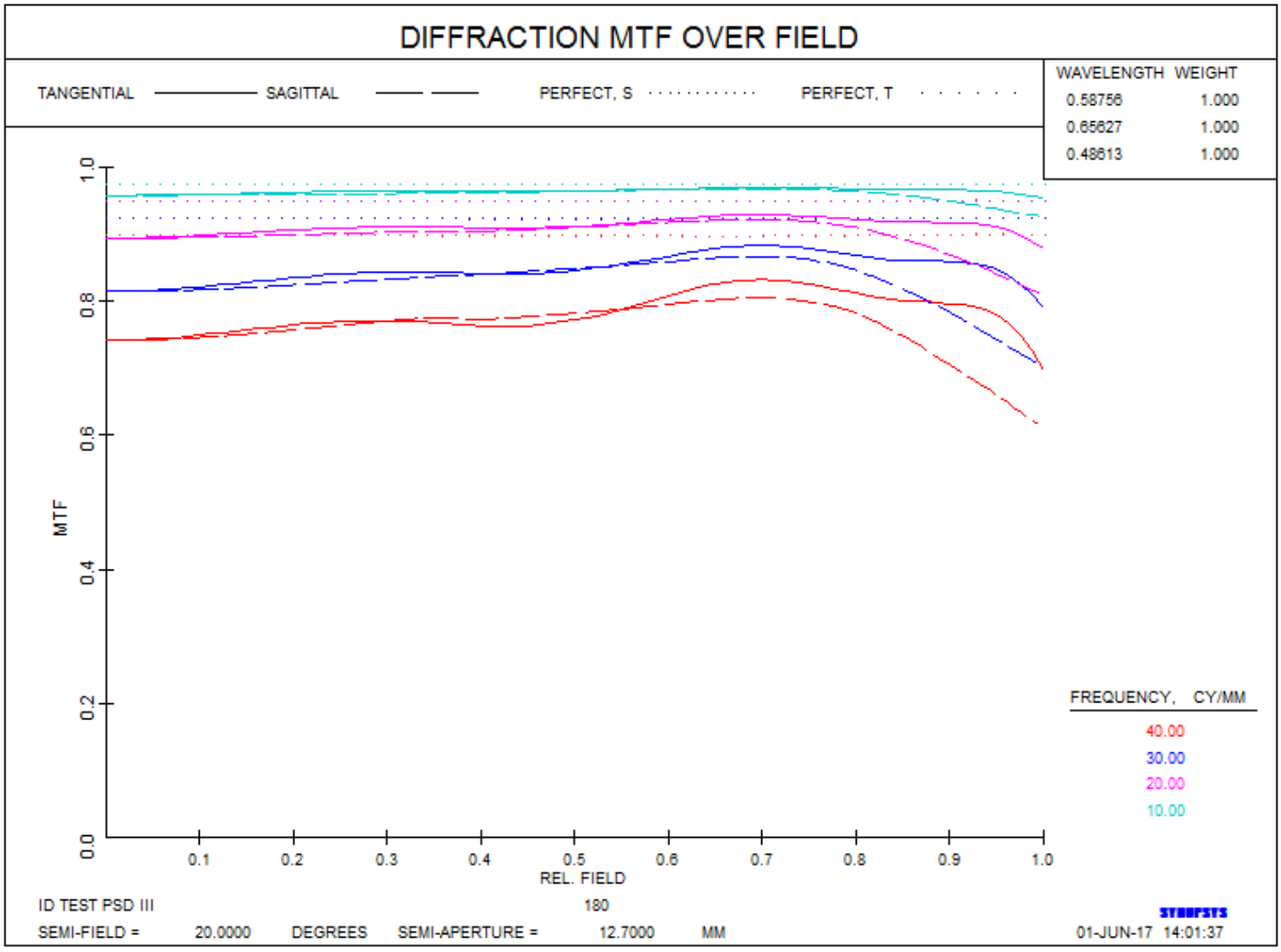
```
GNR AWT 5 4 M .75   ! These for the 0.75 field point
GNR AWT 4 4 M .8   ! These for the 0.8 field point
GNR AWT 4 4 M 1      ! Full field
END

SNAP 100
DAMP 1000
SYNOPSYS 5
SYNOPSYS 10
SYNOPSYS 15
SYNOPSYS 100
ANNEAL 50 10

LOUD              ! Restore output to the monitor
MERIT?

STORE 3           ! Store the results in the library.

ARGLASS 3 QUIET   ! Start of ARGLASS input.
CAT S             ! Specify the Schott glass catalog.
INCLUDE 1 TO 13   ! Do all surfaces.
PREF              ! Only use preferred glass types
SAFE              ! and environmentally safe glasses.
GO                ! Execute ARGLASS.

PROJECT                         ! See how long the job took
MOF M 0 40 80 0 Q 30 20 10      ! Calculate the MTF over field.
```

The job runs for about 30 seconds, and produces this result:

```
RLE
ID TEST PSD III                              180
 WAVL .6562700 .5875600 .4861300
 APS               1
 UNITS MM
 OBB  0.000000     20.00000     12.70000    -25.39490      0.00000      0.00000
12.70000
   0 AIR
   1 RAD     63.9324304819396   TH      6.13775631
   1 N1 1.82743442 N2 1.83402633 N3 1.84979432
   1 CTE   0.584000E-05
   1 GTB S    'N-LASF40         '
   2 RAD    121.4260973202004   TH      1.00000000 AIR
   3 RAD     38.9734739086511   TH     20.57680176
   3 N1 1.72508287 N2 1.72915286 N3 1.73846093
   3 CTE   0.581000E-05
   3 GTB S    'N-LAK34          '
   4 RAD     87.2688769717594   TH      1.01574402 AIR
   5 RAD     76.7614323395048   TH      3.26054685
   5 N1 1.72090550 N2 1.72827542 N3 1.74642643
   5 CTE   0.940000E-05
   5 GTB S    'N-SF10           '
   6 RAD     19.7361513224512   TH     21.84758786 AIR
   7 RAD    -29.7587962681538   TH      1.00000000
   7 N1 1.83649445 N2 1.84665729 N3 1.87209365
   7 CTE   0.846000E-05
   7 GTB S    'N-SF57           '
   8 RAD    -38.0771643426431   TH      1.00000000 AIR
   9 RAD    148.7057065172241   TH      6.45696908
   9 N1 1.91038602 N2 1.92285755 N3 1.95457944
```

```
  9 CTE    0.590000E-05
  9 GTB S     'N-SF66           '
 10 RAD      84.7349933920333    TH       1.28380951 AIR
 11 RAD     116.5460118813826    TH      25.45671730
 11 N1 1.64820928 N2 1.65159874 N3 1.65934342
 11 CTE    0.710000E-05
 11 GTB S     'N-LAK7           '
 12 RAD     -40.6054550188090    TH      18.94463076 AIR
 13 RAD      70.2471757058936    TH      25.49467569
 13 N1 1.84254602 N2 1.85024035 N3 1.86897227
 13 CTE    0.737000E-05
 13 GTB S     'N-LASF9          '
 14 RAD      73.0342740343945    TH      16.56312158 AIR
 15 CV       0.0000000000000    TH       0.00000000 AIR
END
```





The ARGLASS feature lets you specify a number of filters that affect which glasses the program selects. You might only want inexpensive glasses, or those with good acid resistance, for example. In this exercise we only wanted to use preferred types with good environmental characteristics. Here is what is selected:

```
--- ARGLASS 3 QUIET ! START OF ARGLASS INPUT.
Lens number     3 ID TEST PSD III
 GLASS N-LASF40          HAS BEEN ASSIGNED TO SURFACE   1; MERIT =   0.248127
 GLASS N-LAK34           HAS BEEN ASSIGNED TO SURFACE   3; MERIT =   0.370709
 GLASS N-SF10            HAS BEEN ASSIGNED TO SURFACE   5; MERIT =   0.772238
 GLASS N-SF57            HAS BEEN ASSIGNED TO SURFACE   7; MERIT =   0.290459
 GLASS N-SF66            HAS BEEN ASSIGNED TO SURFACE   9; MERIT =    10.2718
 GLASS N-LAK7            HAS BEEN ASSIGNED TO SURFACE  11; MERIT =   0.214292
 GLASS N-LASF9           HAS BEEN ASSIGNED TO SURFACE  13; MERIT =   0.203867
```

To examine the properties of these glasses, we enter the command

PGA ALL ! Print Glass Attributes, all glasses

And get a table, part of which is shown here:

```
**********************************************************
 GLASS ATTRIBUTE FOR SURFACE NO.   1
```

```
SCHOTT         N-LASF40
GLASS IS A PREFERRED TYPE.
GLASS IS ENVIRONMENTALLY SAFE (NO Pb OR As).

PRICE   BUBBLE   HUMIDITY   STAIN   ACID RESIST   ALKALI RESIST   SP GRAVITY
  6.0        1          1       2             5               1         4.55
THIS GLASS HAS A LIST OF TRANSMISSION VALUES ATTACHED
VALID RANGE OF TRANSMISSION DATA:
LOW     HIGH
 0.365   2.500
GLASS HAS SELLMEIER INDEX COEFFICIENTS:
 0.1985503E+01 0.2740570E+00 0.1289457E+01 0.1095833E-01 0.4745516E-01 0.9690853E+02
GLASS HAS 6 DNDT VALUES FROM GLASS TABLE:
 8.1000E-06  1.2500E-08 -1.7300E-11  8.2700E-07  1.0800E-09  2.3800E-01
THERMAL COEFFICIENT (ALPHA) =  0.584E-05

**********************************************************
```

If this looks like what you are after, add an ADT monitor to the AANT file and optimize some more to fix up the thin elements. That's how you do it: Analyze the lens to identify problems, and then tell AANT about them. That's how you approach a great design.

We recommend you run this exercise yourself (you will need a license, since the read-only mode will not allow you to save the lens, and the 12-surface mode will not allow seven elements). Try changing some of the field weights or the aperture weight, and running it again. The results are rather sensitive to those changes, and you will need to get a feel for what works and what doesn't as you develop your own lens design skills.

This example started with plane-parallel plates and produced a rather good lens. What happens if you run it on DSEARCH? (That program starts with nonzero powers, assigned according to its rules, and finds many more designs.) We tried it on this problem and got an even better solution. Try it yourself and see! Adjust the input variables to see what happens. This is your most powerful tool, so it makes sense to learn how to use it.