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.
TIME       ! Start a timer, then define a symbol, AWT, for the aperture weight

AWT: 0.5     ! weight center of aperture more than edges
QUIET         ! not showing everything on the monitor speeds things up

PANT          ! Define variables.
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
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
```

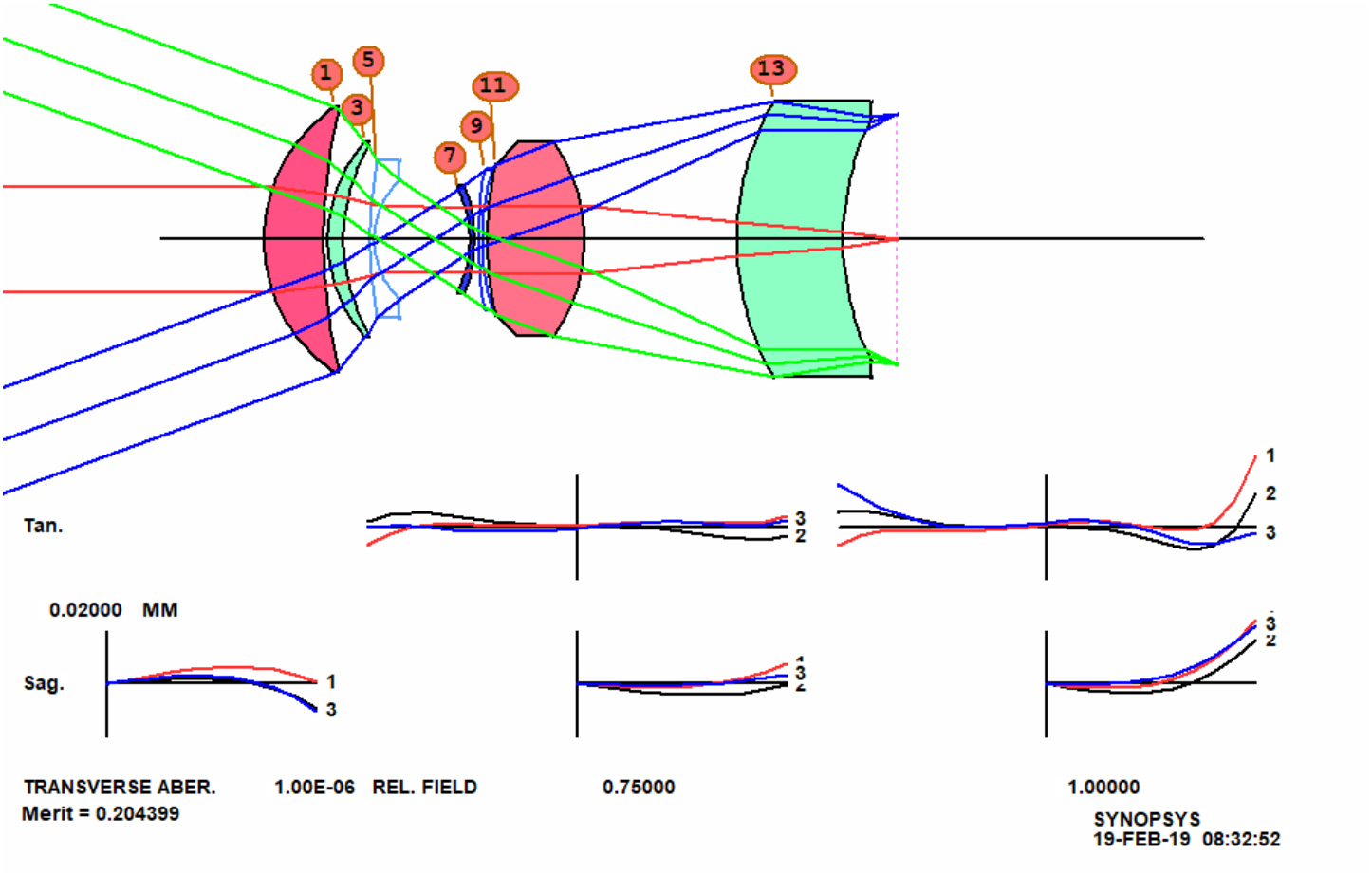
[1] ARGLASS™ is a trademark of Optical Systems Design, Inc., a Maine, USA corporation.

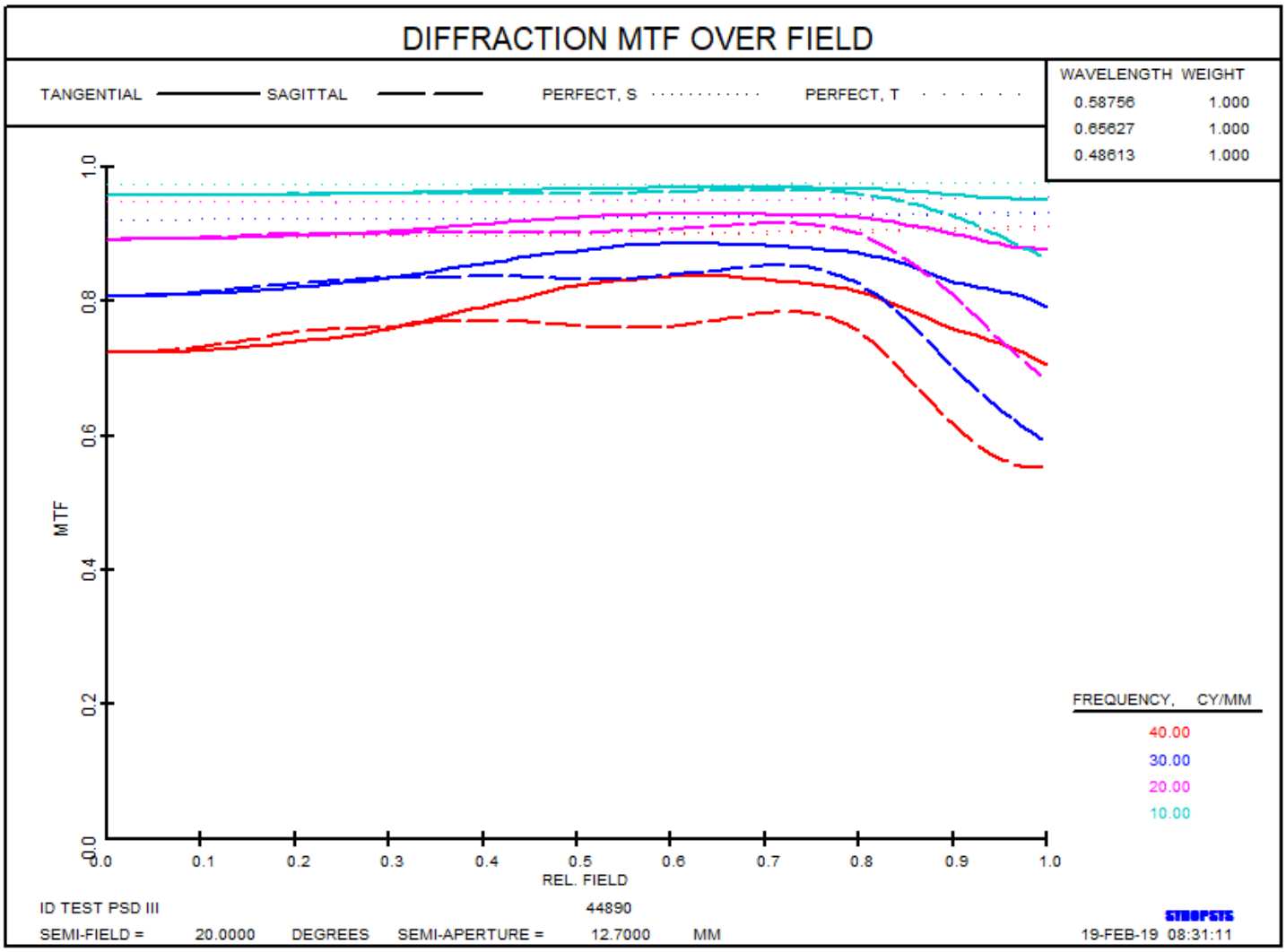
```
GNR AWT 4 4 M 1      ! Full field
END

SNAP 100
DAMP 1
SYNOPSYS 10
SYNOPSYS 50
SYNOPSYS 50
SYNOPSYS 100
ANNEAL 50 10
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.

TIME                          ! 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 113 seconds, and produces this result:

```
RLE
ID TEST PSD III                          44890
 MERIT   0.204399
 LOG    44890
 WAVL .6562700 .5875600 .4861300
 APS               1
 UNITS MM
 OBB  0.000000     20.00000     12.70000    -25.33771      0.00000      0.00000     12.70000
   0 AIR
   1 RAD     38.4079023609482   TH     14.35089618
   1 N1 1.63724049 N2 1.64049314 N3 1.64789652
   1 CTE   0.680000E-05
   1 GTB S    'N-LAK21         '
   2 RAD    140.5699449088332   TH      1.00000000 AIR
   3 RAD     35.5921405897023   TH      3.70370460
   3 N1 1.82743442 N2 1.83402633 N3 1.84979432
   3 CTE   0.584000E-05
   3 GTB S    'N-LASF40        '
   4 RAD     45.0393604934514   TH      6.39598799 AIR
   5 RAD    114.4033786095286   TH      1.00000000
   5 N1 1.61505248 N2 1.62004704 N3 1.63207017
   5 CTE   0.784000E-05
   5 GTB S    'N-F2            '
   6 RAD     20.0661328987595   TH     23.07970611 AIR
   7 RAD    -25.2619912229711   TH      1.00000000
   7 N1 1.69221172 N2 1.69891453 N3 1.71535096
   7 CTE   0.804000E-05
   7 GTB S    'N-SF15          '
   8 RAD    -35.8068058665658   TH      1.00000197 AIR
   9 RAD    102.6617448586162   TH      1.00000000
   9 N1 1.91038602 N2 1.92285755 N3 1.95457944
   9 CTE   0.590000E-05
   9 GTB S    'N-SF66          '
  10 RAD     62.8252793060342   TH      1.12264527 AIR
  11 RAD     80.5244211831911   TH     23.24561045
```

```
 11 N1 1.64820928 N2 1.65159874 N3 1.65934342
 11 CTE    0.710000E-05
 11 GTB S     'N-LAK7          '
 12 RAD     -40.9359580805576    TH      36.76148667 AIR
 13 RAD      66.1933202531976    TH      25.50655823
 13 N1 1.82743442 N2 1.83402633 N3 1.84979432
 13 CTE    0.584000E-05
 13 GTB S     'N-LASF40        '
 14 RAD      65.7208508010634    TH      12.95169485 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-SF66            HAS BEEN ASSIGNED TO SURFACE    9; MERIT =    0.185182
 GLASS N-LASF40          HAS BEEN ASSIGNED TO SURFACE    3; MERIT =    0.189720
 GLASS N-LASF40          HAS BEEN ASSIGNED TO SURFACE   13; MERIT =    0.196494
 GLASS N-LAK21           HAS BEEN ASSIGNED TO SURFACE    1; MERIT =    0.205686
 GLASS N-SF15            HAS BEEN ASSIGNED TO SURFACE    7; MERIT =    0.198788
 GLASS N-LAK7            HAS BEEN ASSIGNED TO SURFACE   11; MERIT =    0.218319
 GLASS N-F2              HAS BEEN ASSIGNED TO SURFACE    5; MERIT =    0.204399
```

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.   11
```

```
SCHOTT          N-LAK7
GLASS IS A PREFERRED TYPE.
GLASS IS ENVIRONMENTALLY SAFE (NO Pb OR As).

PRICE    BUBBLE    HUMIDITY    STAIN    ACID RESIST    ALKALI RESIST    SP GRAVITY
  3.5         0           3        3              7                3          3.84
THIS GLASS HAS A LIST OF TRANSMISSION VALUES ATTACHED
VALID RANGE OF TRANSMISSION DATA:
LOW      HIGH
 0.310    2.500
GLASS HAS SELLMEIER INDEX COEFFICIENTS:
 0.1236799E+01 0.4450518E+00 0.1017459E+01 0.6101055E-02 0.2013883E-01 0.9063804E+02
GLASS HAS 6 DNDT VALUES FROM GLASS TABLE:
-3.4000E-06  1.1700E-08  2.3800E-11  4.9600E-07  4.4400E-10  1.0700E-01
THERMAL COEFFICIENT (ALPHA) =  0.710E-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.