Lesson 21: Designing an Athermal Lens

This lesson will show how to design a lens that must stay in focus over a wide temperature range.

First, we must discuss the interesting concept of the "achrotherm", which applies to lenses that are corrected for chromatic aberration and temperature changes at the same time. The theory is actually quite simple, and you can read the original paper at Applied Optics Vol. 33, No. 34, 8009-8013 (1 December 1994).

To design this kind of system, we have to select two glass types that obey a special requirement. They may be found by using the glass table display (MGT), where you click on the Graph button and then select Thermal properties.

The graph in this case shows the quantity 1/V on the abscissa and the quantity β on the ordinate. The latter is defined as

$$\beta = \alpha_g - \frac{1}{n-1} \frac{dn}{dT}$$

where α_g is the coefficient of thermal expansion of the glass, *n* is the index of refraction, and dn/dt is taken from the glass table. The idea is to select two glasses on the diagram and draw a line connecting them. Extend this line to the right to where 1/V equals zero. The height of this intercept, which can be read from the ordinate axis, is the CTE of the housing required to athermalize the lens.

This feature needs to know the thermal expansion coefficient of the housing material. We open any lens file and declare that material to be aluminum 6061:

CHG ALPHA A6061 END

Now we can use the glass table and select some likely glass pairs. In MGT, select the Ohara catalog and look at the thermal properties, as explained above. The program draws a green symbol over to the right. Click on the left-most glass, and it draws a line between that glass and the symbol.



Our line starts at glass S-NPH3. Now we need another glass that falls close to the same line. Type S-FPM3 is quite close, so those two look like a good pair. It might be useful to have a second set, so we click on the glass S-LAH79 and then see type S-FTL10 on the new line.



Okay, we have selected four glass types. Now let's design a lens with those glasses and hope the thermal properties can be controlled.

We create a DSEARCH MACro, specifying only the first two glasses we found. We will aim for a good image at first and will look at the thermal properties later. The dialog **MDS** is a good place to enter the requirements. Give it a file name when you click OK, and it creates a MACro, which you can further edit as needed.

CORE 14 DSEARCH 1 QUIET SYSTEM ID DSEARCH ATHERMAL OBB 0 25 2.5 WAVL 0.6563 0.5876 0.4861 UNITS MM END GOALS ELEMENTS 5 FNUM 2 BACK 0 0 TOTL 10 0.1 STOP MIDDLE STOP FREE RT 0.5 FOV 0.0 0.75 1.0 0.0 0.0 FWT 5.0 3.0 1.0 1.0 1.0 NPASS 40 GLASS POSITIVE O S-NPH3 GLASS NEGATIVE O S-FPM3 ANNEAL 200 20 Q COLORS 3 SNAPSHOT 10 QUICK 33 40 END SPECIAL PANT END SPECIAL AANT END

GO

We run this, and in a minute we see the best lens it found, shown below. We optimize the lens some more, using the MACro that DSEARCH created for us. The image is pretty good, at least at a temperature of 20 degrees C.

Now we have to check the thermal characteristics. In the WorkSheet[™] (WS), declare the housing to be aluminum 6061, as we did above. Then delete the thickness solve, so the lens won't automatically get refocused as the temperature changes. In WS, type **NTOP** to remove the solve. (The shadowed lenses will automatically remove the curvature solve.)

Now prepare another MACro to initiate thermal shadowing of this lens.

THERM ATS 50 2 ATS 100 3 END

Run this, and the program puts a copy of the lens in ACON 2, recalculated for 50 degrees, and in ACON 3 at 100 degrees.



Now the critical test: Click the button for ACON 2, and ... nothing changes! The rayfan curves look almost identical to those in ACON 1. How about ACON 3, at 100 degrees? Again, almost identical!

Our lens is satisfactorily athermal.

What if it had not been so good? Well, we would then correct the image in all three ACONs in the optimization file. That should tweak up any remaining problems.

And we didn't even need the second pair of glasses we found. What happens if we use those instead of the first pair? Try it and see!

This lesson shows how designing an achrotherm lens is not difficult, using the tools in SYNOPSYS[™].