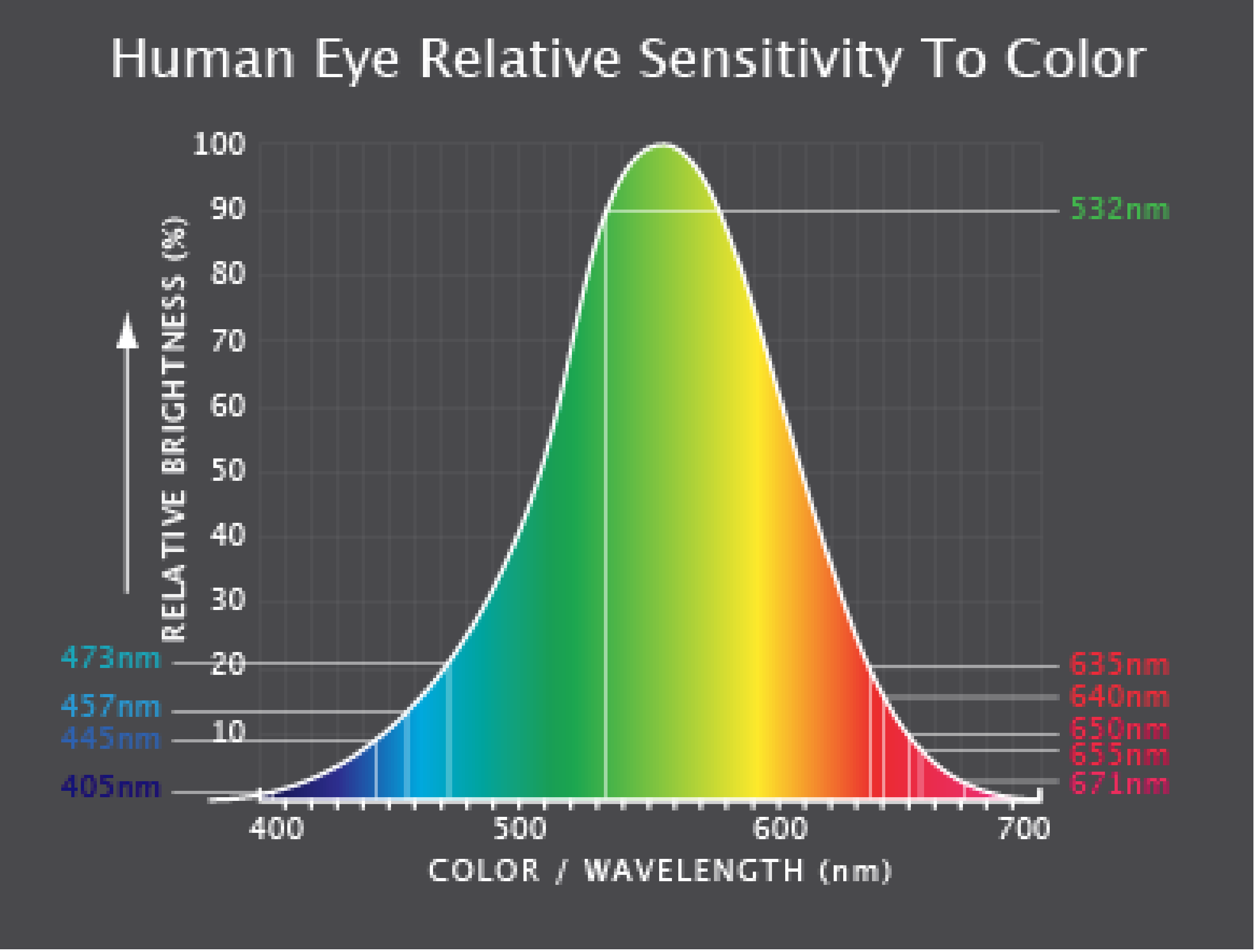
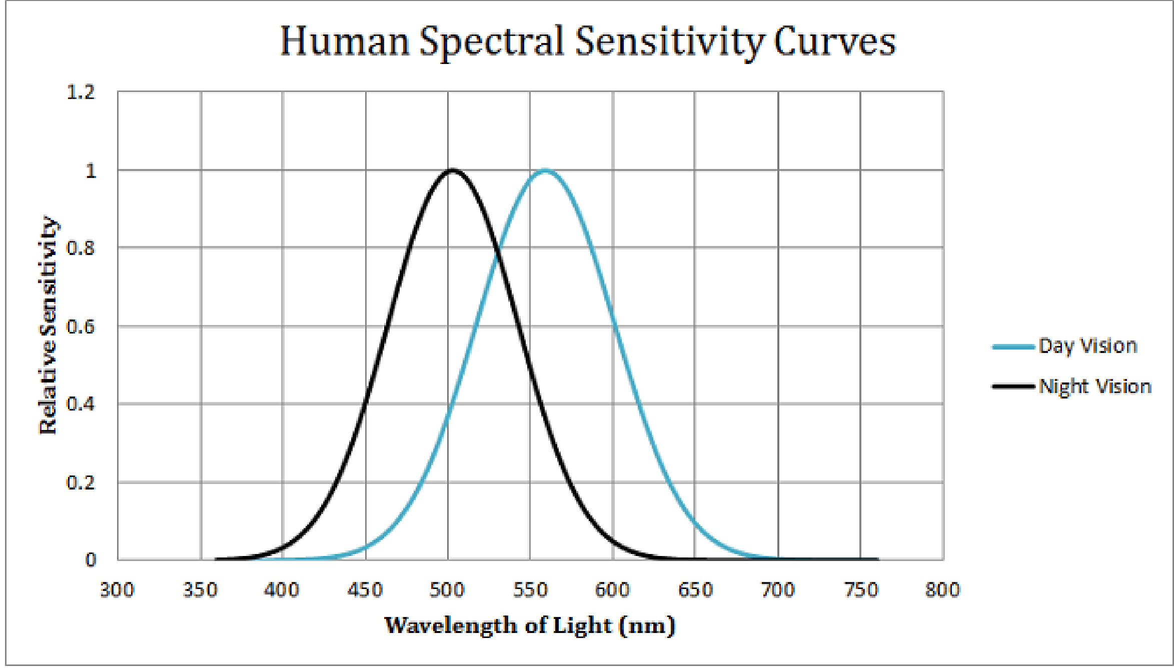
A remarkable new apochromatic telescope objective design

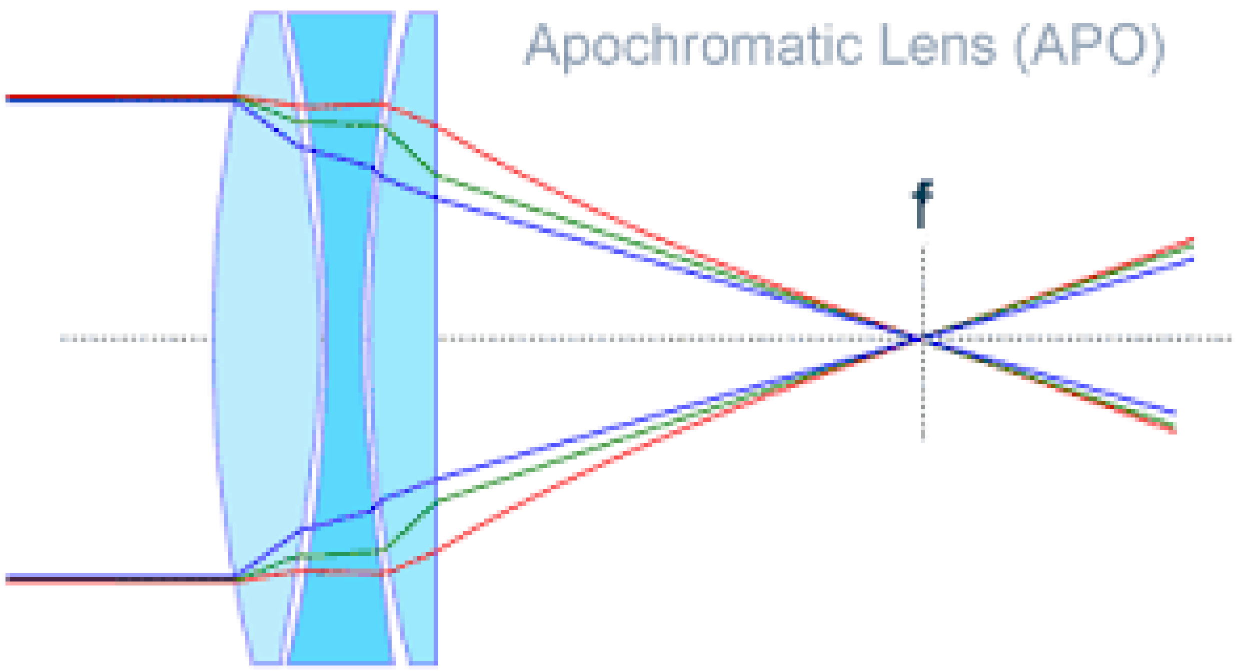
David Shafer
David Shafer Optical Design
shaferlens@sbcglobal.net





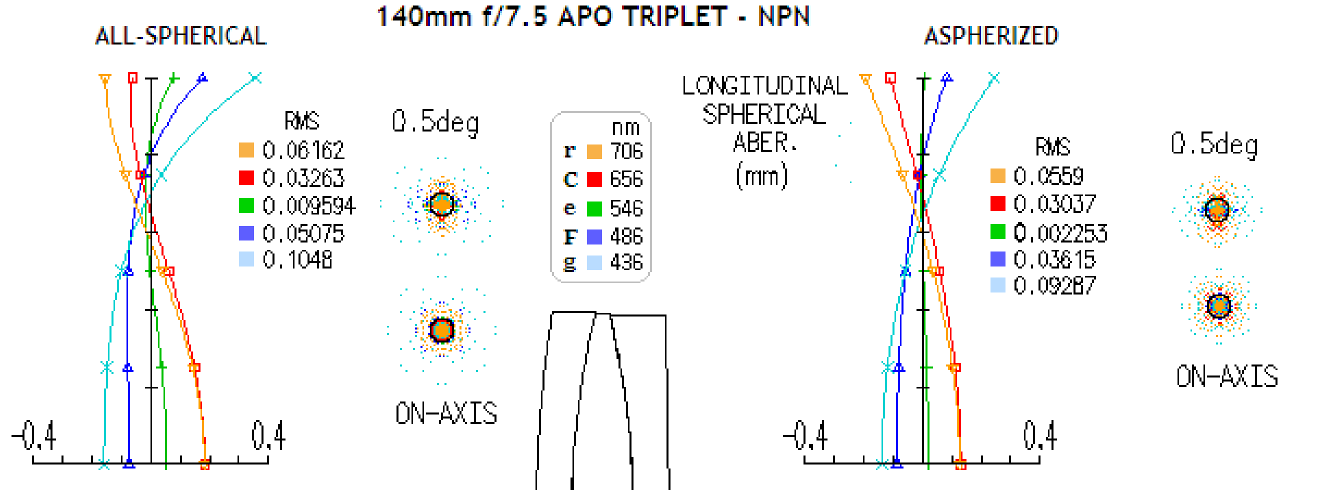
For a primarily visual use telescope the useful spectrum based on eye sensitivity is completely covered by the .4358u to .7065u spectral lines. But most of the sensitivity is between .4861u and .6563u. For dark adapted night vision you lose the red end but pick up a little bit in the .4047u to .4358u range. There is not much point in worrying about anything below .4358u

<u>Daytime eye sensitivity</u>



To get good image quality over a broad spectrum it is necessary to bring three or more widely separated wavelengths to the same focus, shown exaggerated here. In addition it is necessary to correct chromatic variation of spherical aberration (spherochromatism).

Much has been written about these types of design. They may consist of either positive/negative/positive lens configurations or negative/positive/negative ones, and be air spaced or oil spaced. It is necessary to use at least one glass type with anomalous dispersion. For fast speeds three lenses are needed to reduce the lens powers, tolerance sensitivities, and higher-order aberrations.



SRF	RADIUS	THICKNESS	GLASS
			AIR
AST	450.000000	12.000000	O_S-BSM14
2	299.000000	0.100000	O_NSL36
3	299.000000	21.000000	O_S-FPL53
4	-299.000000	0.100000	O_NSL36
5	-299.000000	12.000000	O_FSL3
6	-1.9110e+03	1.0000e+03	AIR
IMS	-388.000000	25.426218	

SRF	RADIUS	THICKNESS	GLASS	CC
OBJ	--	3.8176e+19	AIR	
AST	443.000000	12.000000	O_S-BSM16	-0.1100
2	299.000000	0.100000	O_NSL36	
3	299.000000	21.000000	O_S-FPL53	
4	-299.000000	0.100000	O_NSL36	
5	-299.000000	12.000000	O_FSL3	0.4000
6	-1.9330e+03	1.0000e+03	AIR	
IMS	-388.000000	24.602210		

Ultra-broad spectrum color correction

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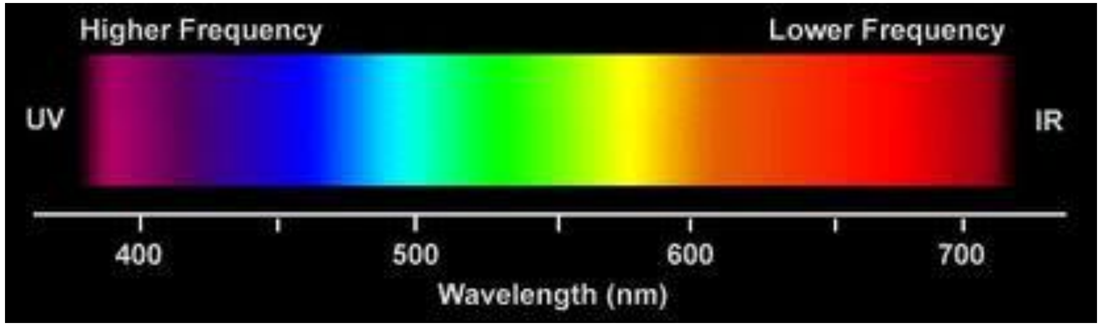
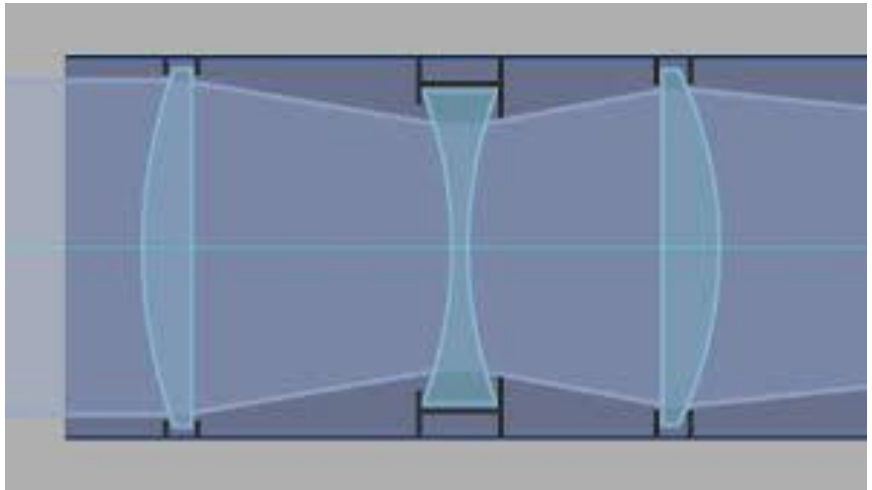
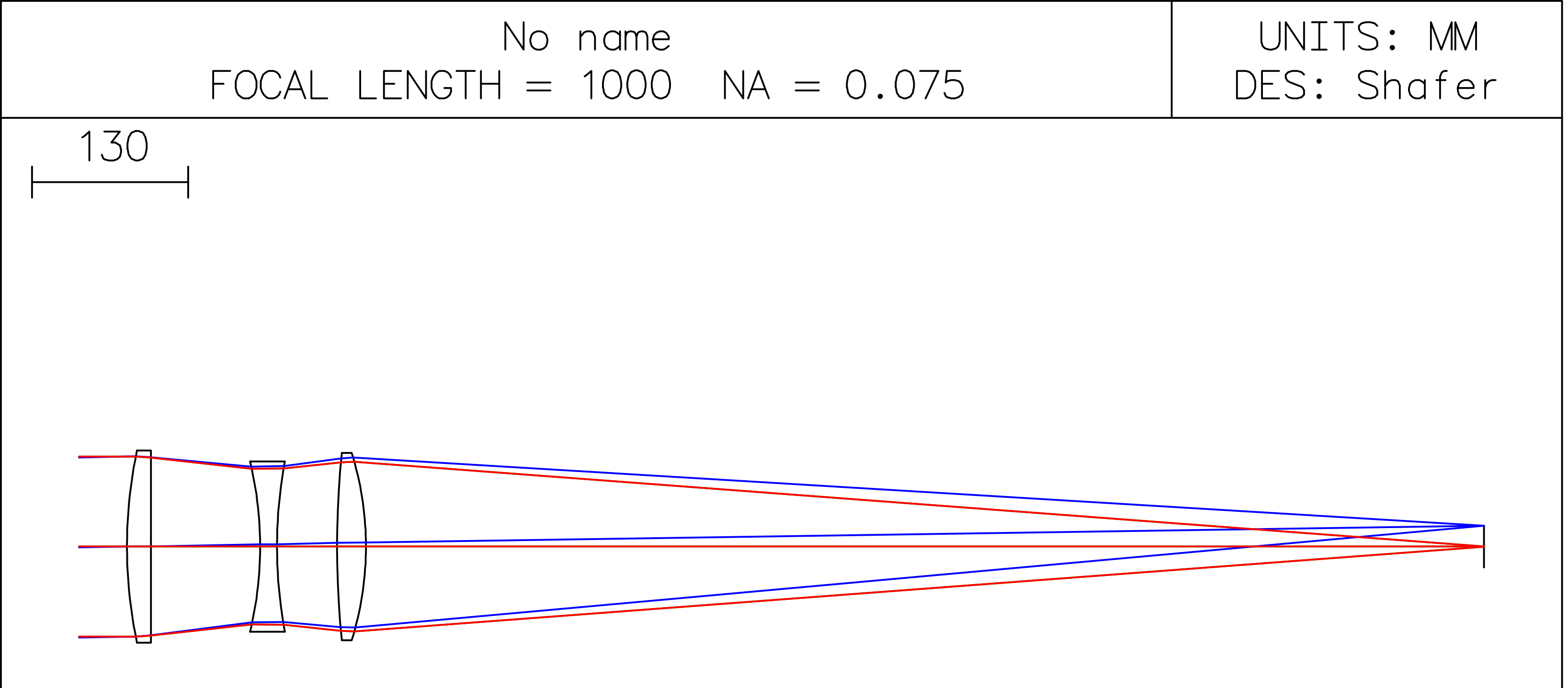




A good tutorial on this subject is this one, which can be found at slideshare.net if you search on this title or my name.

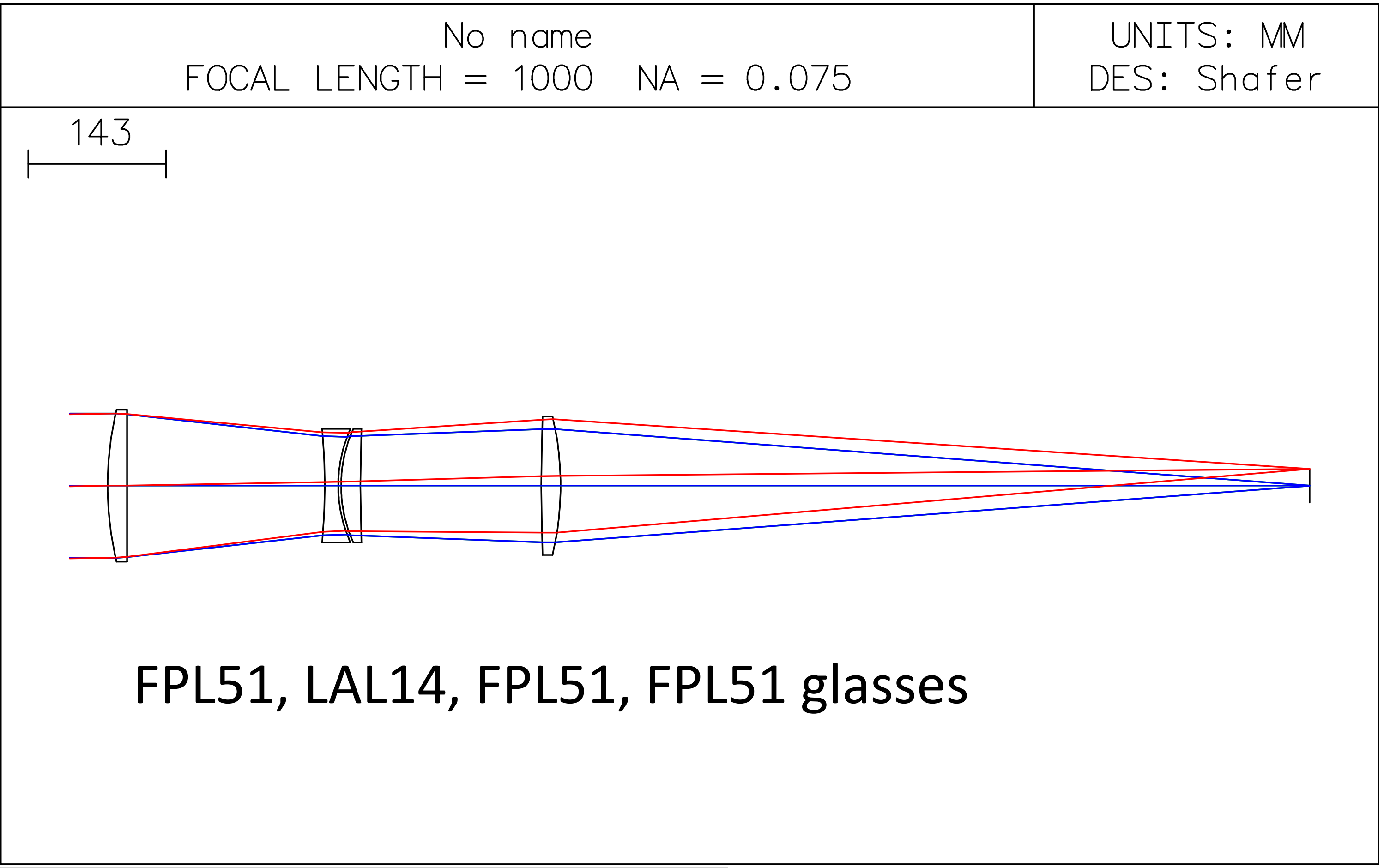
The subject of this current study is different. All of these apochromatic designs that consist of lenses in close contact or with small airspaces have the same characteristic – they are not corrected for astigmatism and cannot be. That limits the field size that is possible with good performance. In order to be corrected for astigmatism the designs need to have substantial airspaces in them, like the classical Cooke triplet.



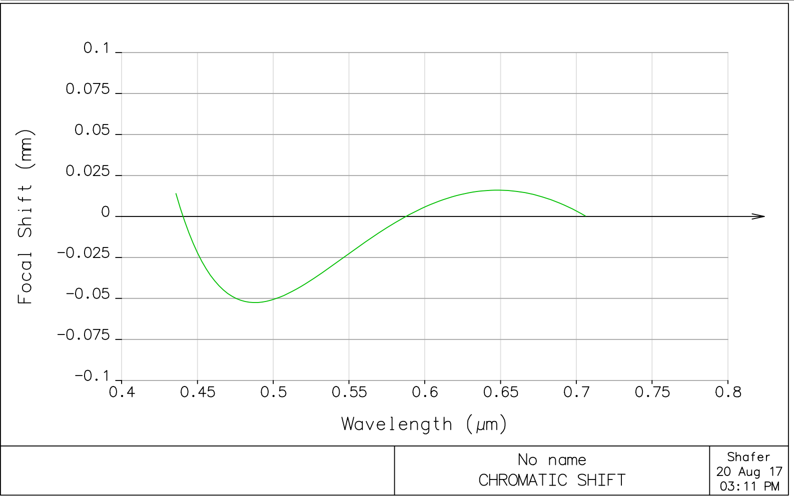
FPL51, KZFSN2, FPL51 glasses

We will be looking at designs that have a 1000 mm focal length, with a 150 mm diameter aperture, and cover a 2 degree diameter flat image. At least three lenses are needed to correct for spherical aberration, coma, astigmatism, and axial and lateral color.

The classical Cooke triplet has almost no variables left for controlling secondary color and spherochromatism. We will start off looking at only two different glass types. Then the best choice for the design shown here is Ohara FPL51 glass for the two positive lenses and Schott KZFSN2 for the negative lens. There is no Ohara exact equivalent to that Schott glass but an Ohara alternate that is almost as good is LAL14.



FPL51, LAL14, FPL51, FPL51 glasses

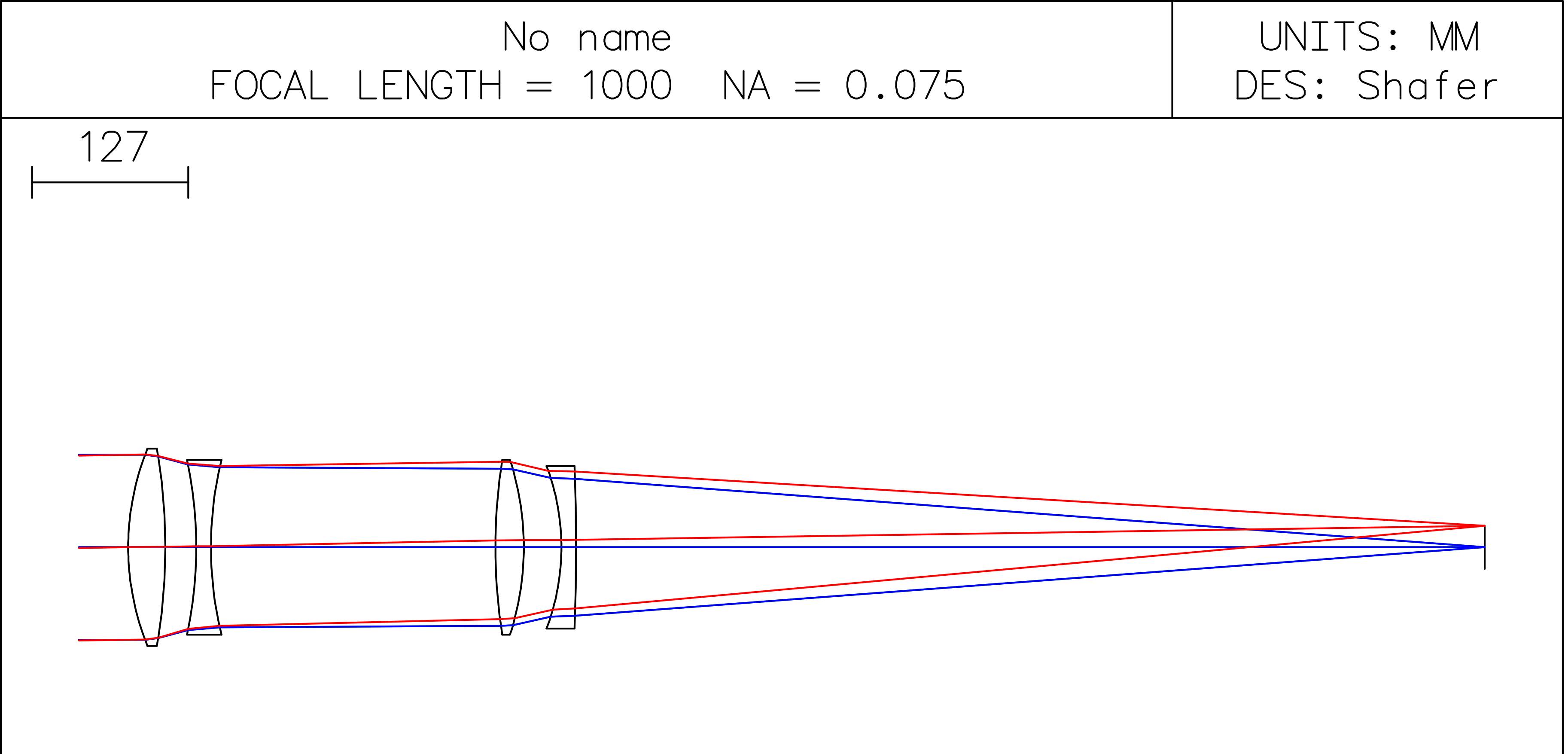


Cubic focus shift

With just these three lenses with substantial airspaces there is very little improvement possible by using three glass types instead of two. What is needed is another lens to get a four-lens design. With those extra variables there are very many possible designs and design types. And then glass choice becomes much more relevant.

A good four lens design with two glass types is shown here. One characteristic of good four lens designs with the best correction is that there are large airspaces within the design and the system length is also long.

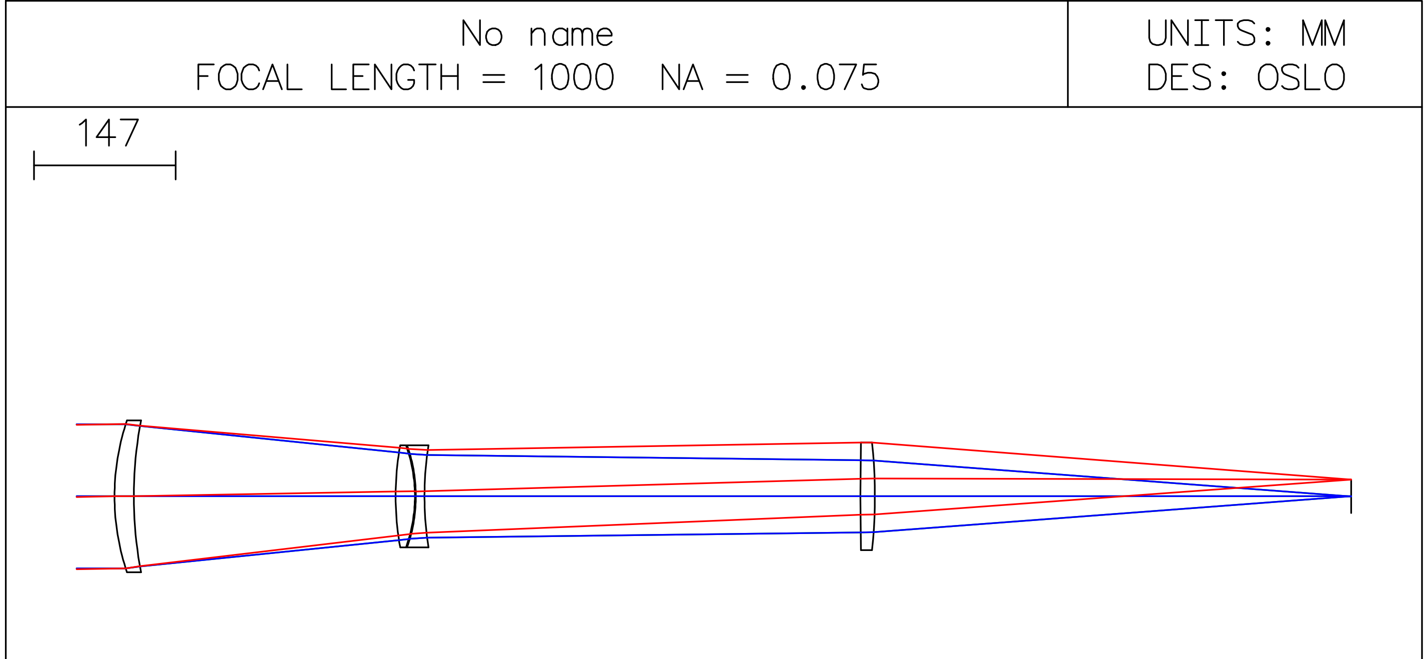
This design is diffraction-limited from .4358u through .7065u over a 2 degree diameter field on a curved image (900 mm radius).



FPL51, BSM7, FPL51, BSL21 Ohara glasses

This shows the best <u>flat image</u> design I have found so far. The length is 1100 mm, just a little longer than the focal length. It is diffraction-limited from .4358u to .706u over a 2 degree diameter flat image. It is possible that there are other glasses with better performance but this is good right now.

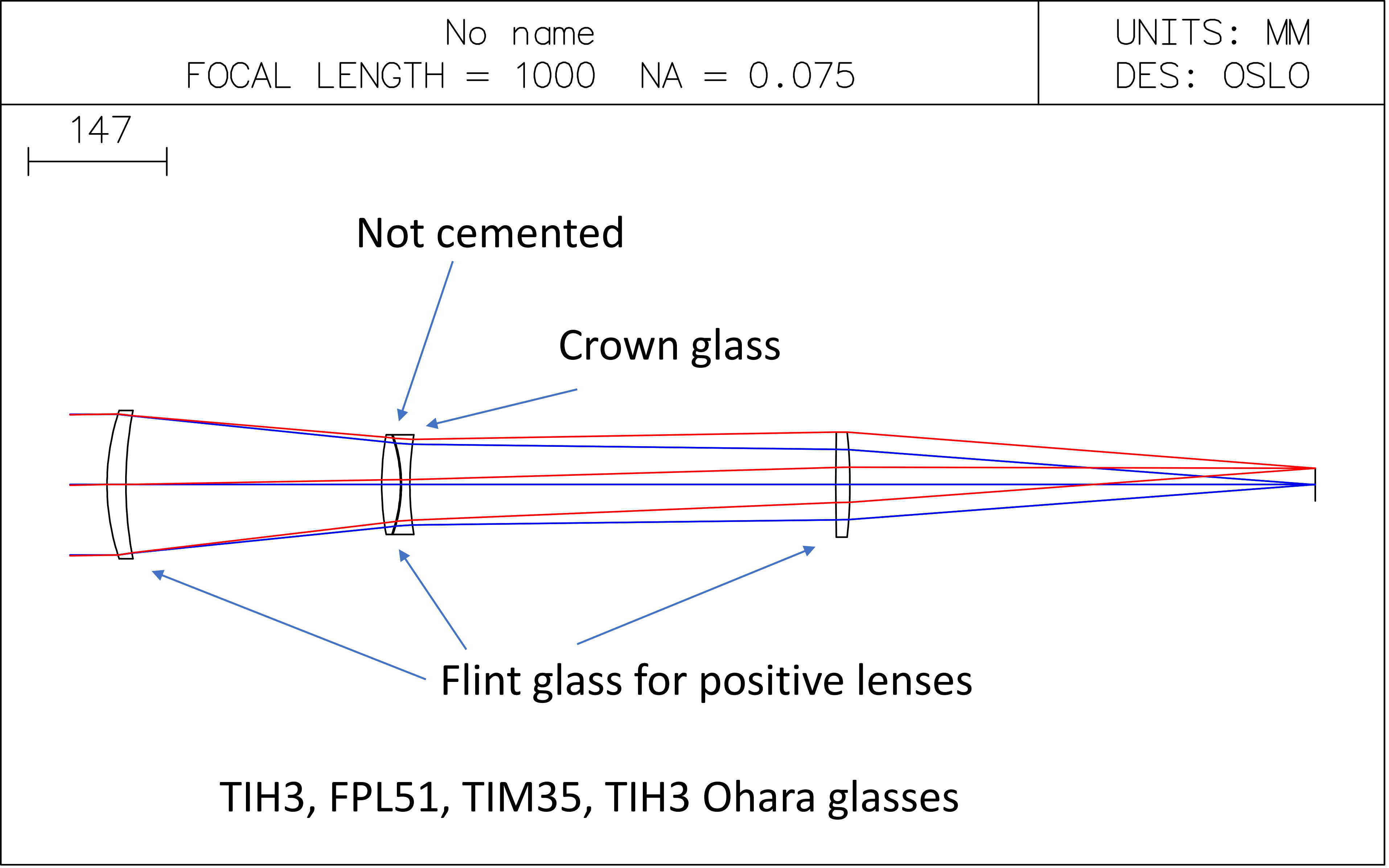
Because the doublets are not self-corrected for color there is some induced secondary color at the second doublet due to color coming into it from the first doublet. It is not a big effect but it is important in this design.



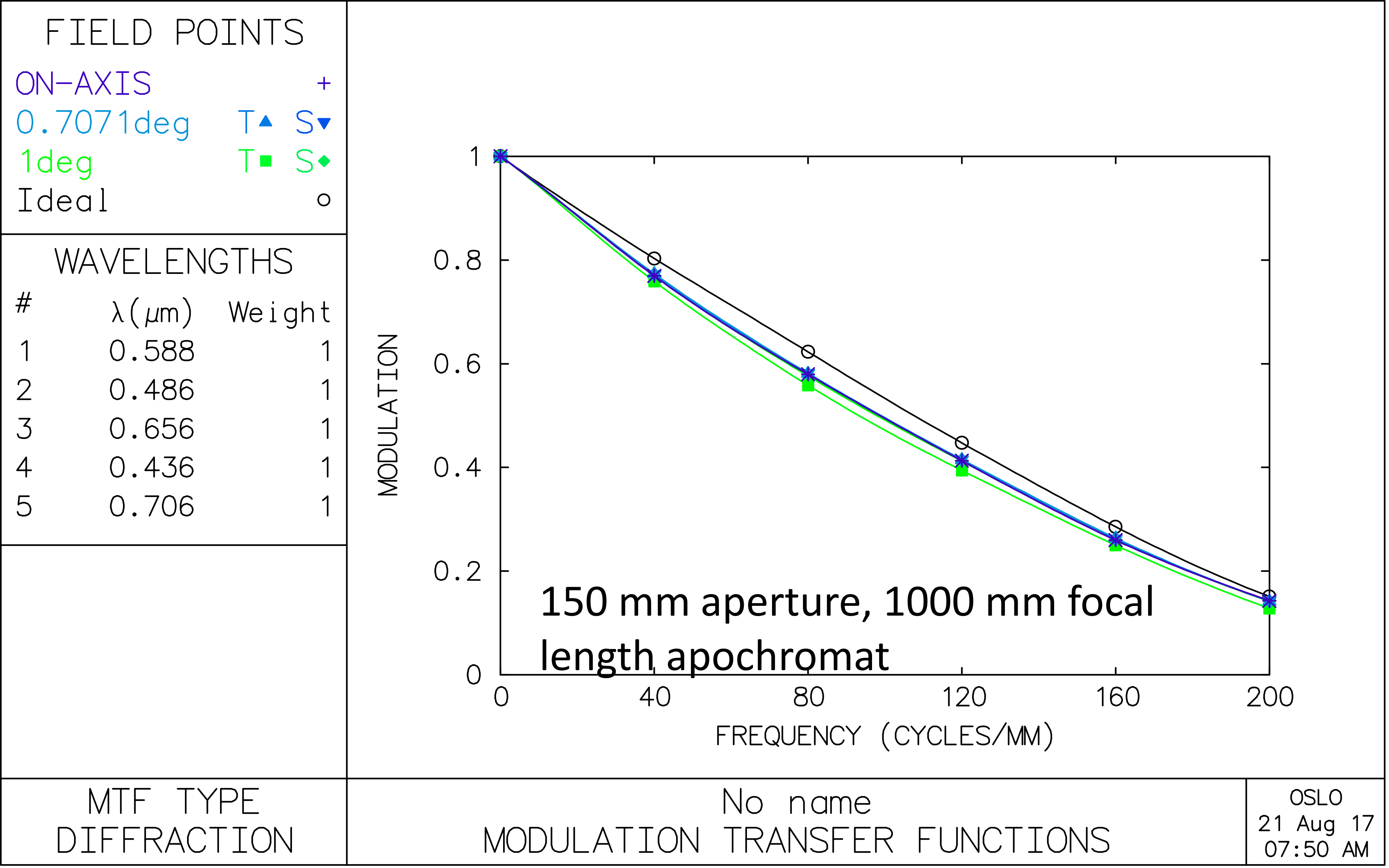
Joe Bietry's new apochromat design

And now for the remarkable new design, which is from Joe Bietry in Rochester, New York. It is described in his very recent US patent # 9,588,332. There are three remarkable aspects to this design. The first is that the front lens is a flint glass, not a crown. That is very unusual and 3 of the 4 lenses are flint glass – all of them positive lenses.

That leads to the second odd thing about this design – induced secondary color plays a major role in the excellent color correction of the design. There is a lot of color coming from the very dispersive front positive lens. That then induces a lot of secondary color at the middle lens doublet and is a key aspect of the design's success.



The third way in which this is a very unusual design is that the very expensive glass FPL51, essential to the design, is only about 60% of the full aperture size and there is only one element of it. The cost of that glass is strongly dependent on the blank size needed and having it be 2/3 or less of the full aperture size makes a big difference in the total cost of the complete objective.



On a weakly curved image (radius of about 830 mm) the performance is exceptionally good over the a 2 degree diameter field (35 mm image diameter). If the design is reoptimized for a flat image it is still quite good but not quite diffraction-limited over the field unless the glasses are changed. Then it becomes extremely good again.

Just as film has become obsolete Ohara keeps changing which glasses they no longer make. The design examples shown here can usually be reworked with other glass types, still being made, to give similar performance. It may be necessary to combine Schott glasses with Ohara glasses to find what gives the optimum performance.

If you do not have lots of money to throw around then Joe Bietry's new design is the perfect combination of very high performance and relatively low cost. It is perfect for larger aperture designs, where the cost of large FPL51 glass blanks can be very high.