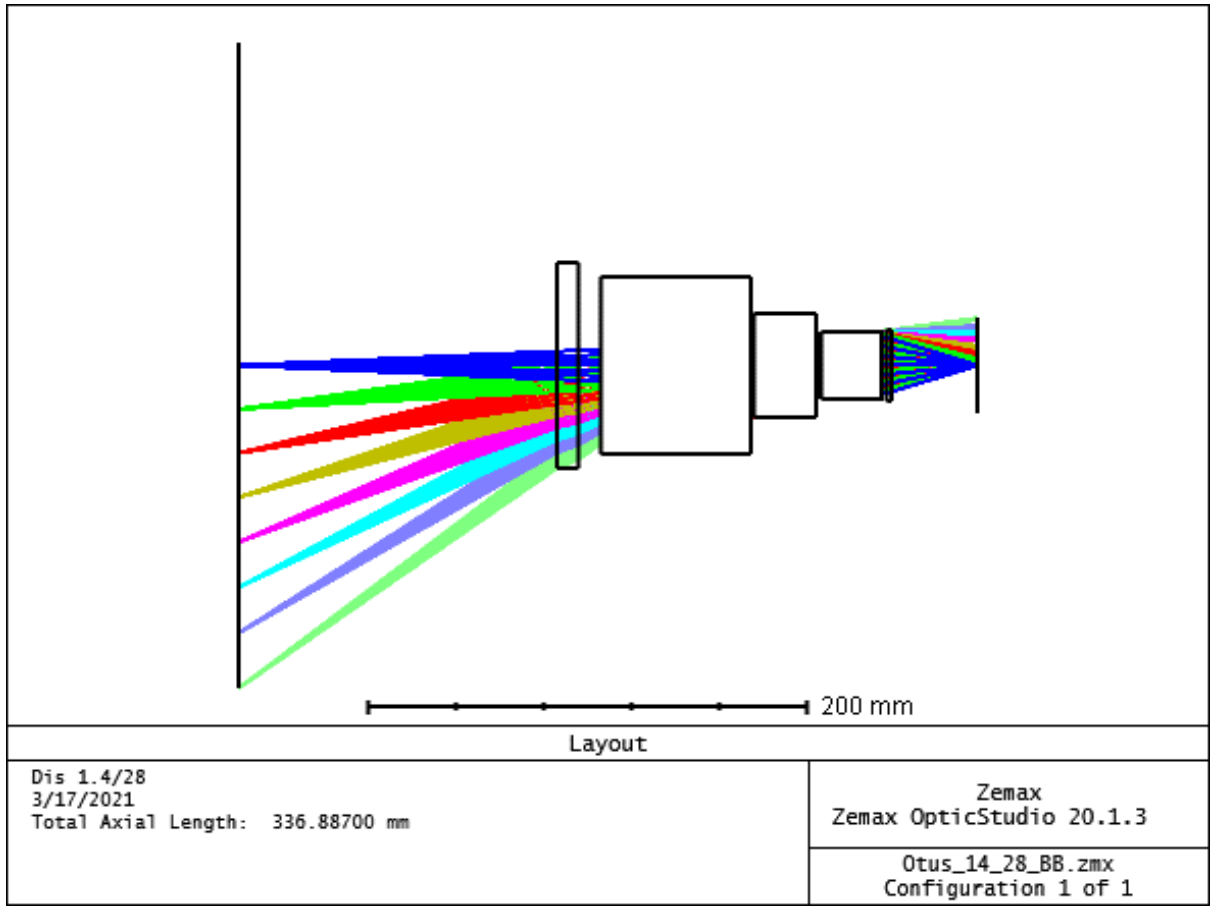
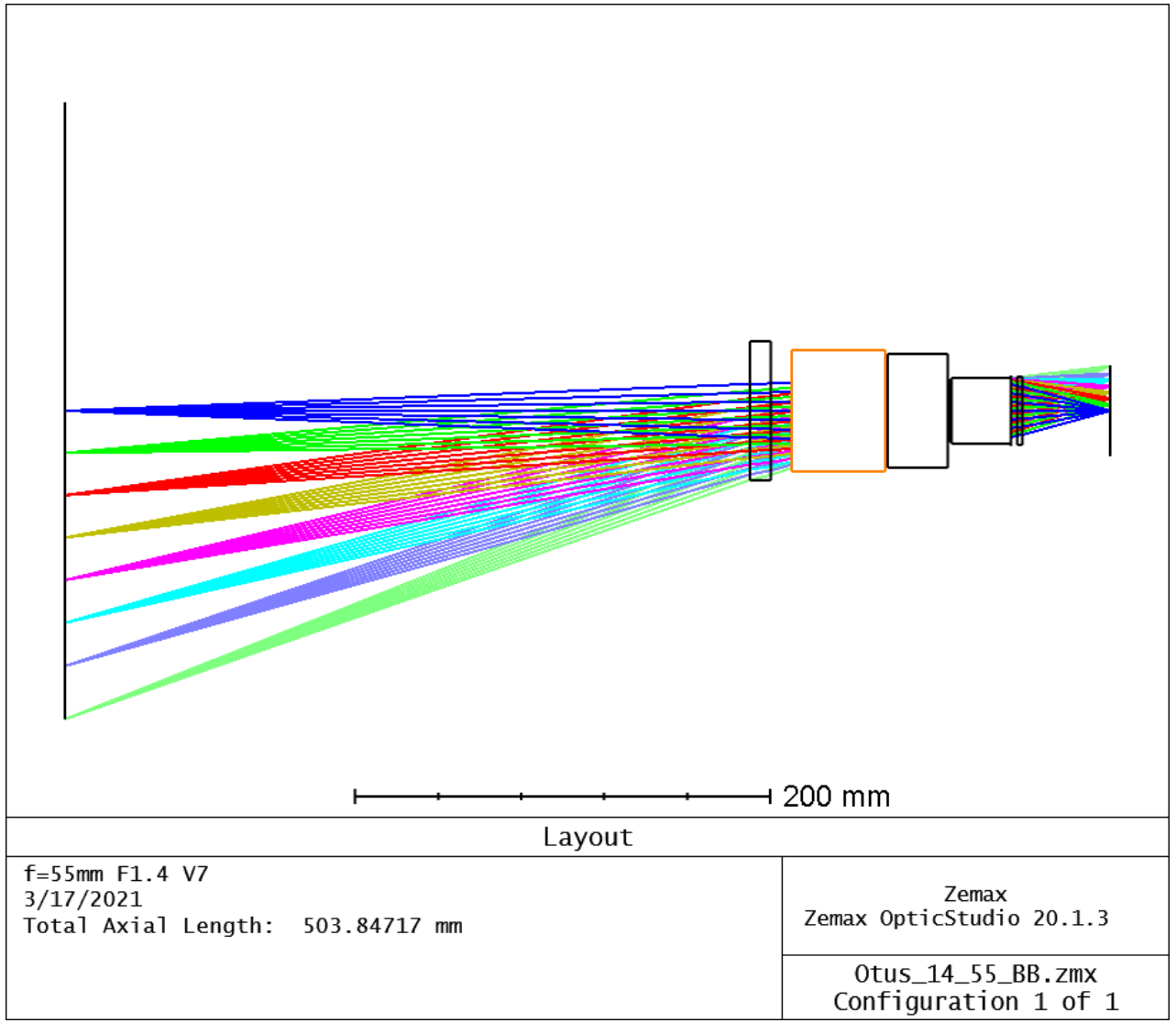
Some updated info on Zeiss OTUS 55 & 28mm focal length lenses

Andy Rasmussen Magis-100 mtg, 210318

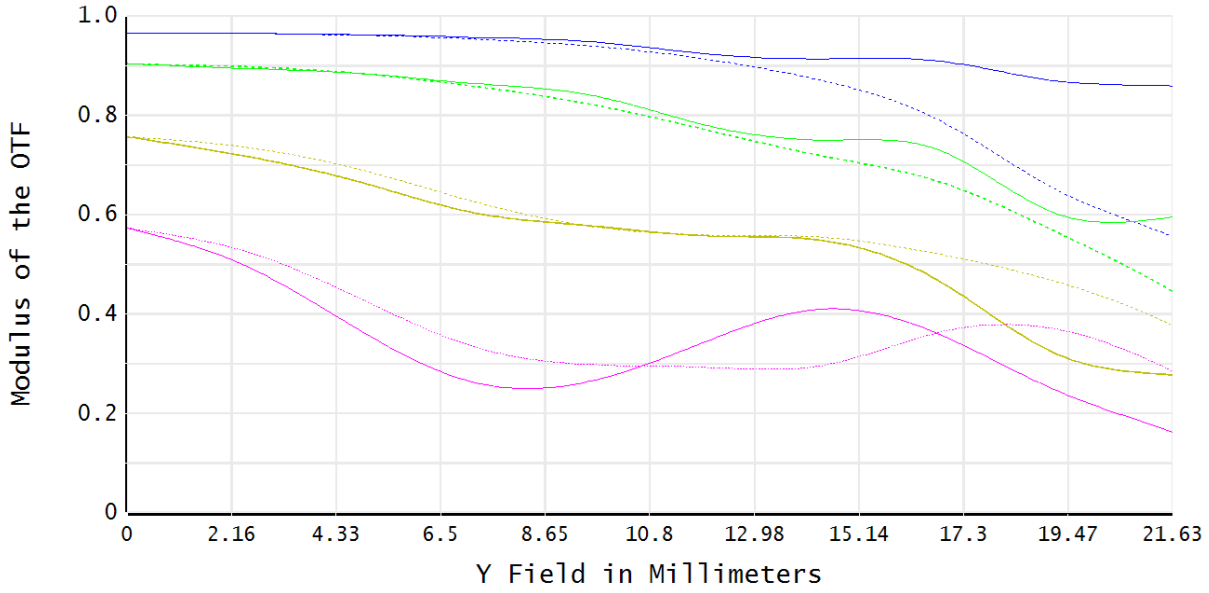
Roll-up of Michael Greenberg findings using Zeiss provided “black box” zemax files, and some window options

-0.15 magnification for each system



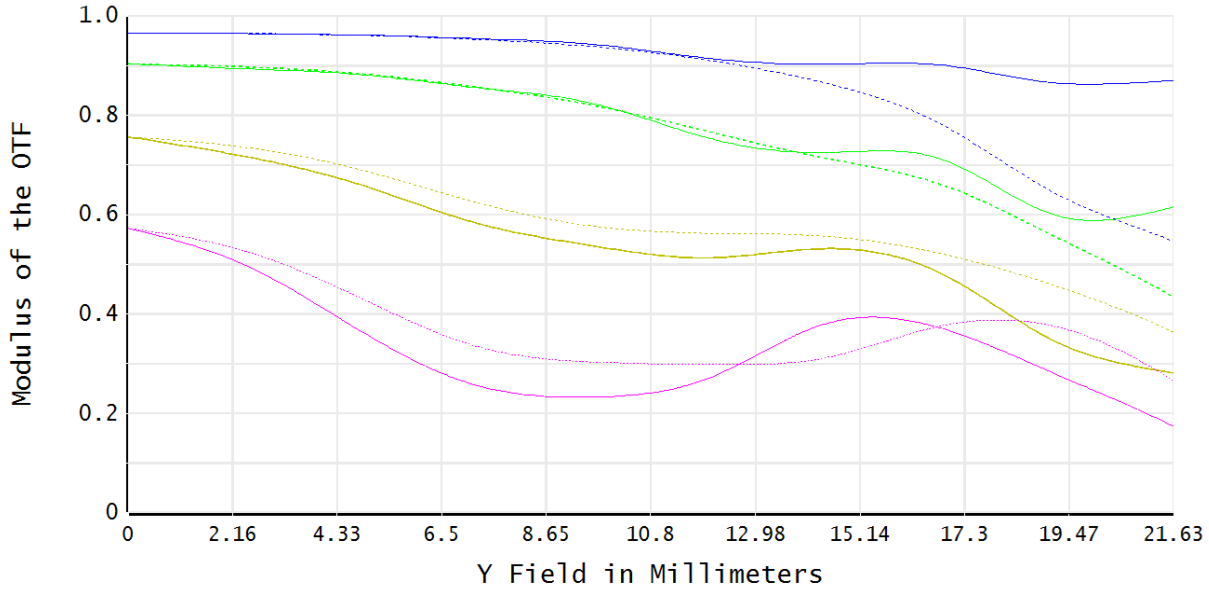


55mm without (left) and with (right) 10mm vacuum barrier and reoptimized (cf. Michael G's email):



FFT MTF vs. Field

f=55mm F1.4 V7, 2/16/2021 Data for 0.4500 to 0.4500 µm. Freq 1: 10.00 cyc/mmFreq 5: 67.50 cyc/mm Freq 2: 20.00 cyc/mm Freq 4: 40.00 cyc/mm Legend items refer to Tangential(T)/Sagittal(S) frequency	Zemax Zemax OpticStudio 16.5 Otus_14_55_BB.zmx Configuration 4 of 4



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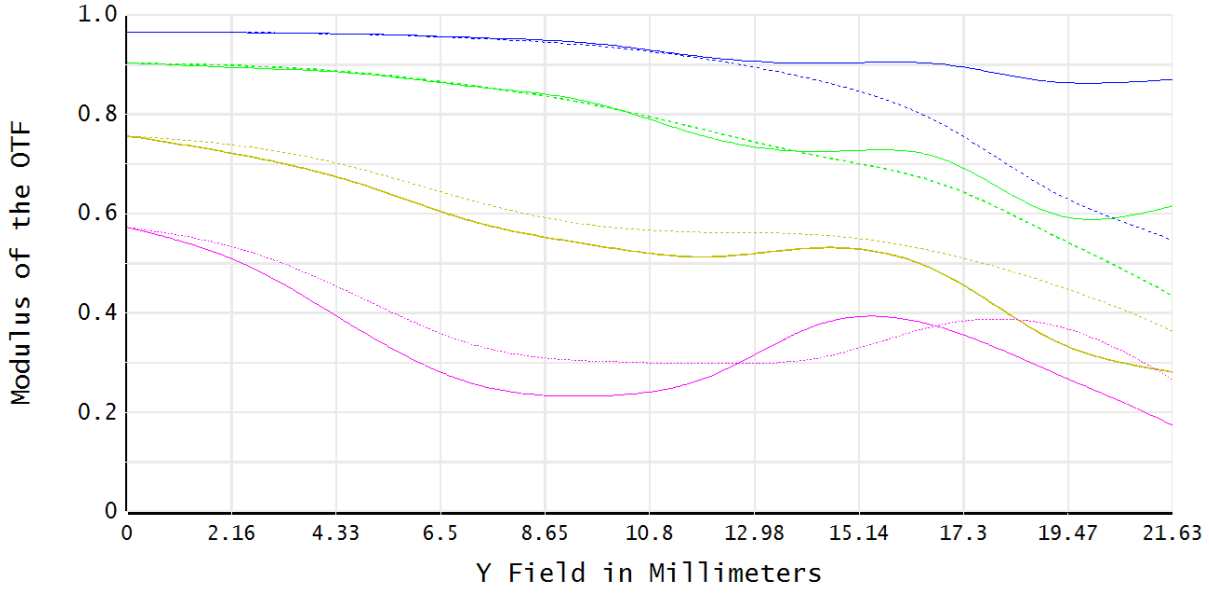
55mm with barrier (left) and then optimized for on-axis performance (67.5 lp/mm) (right):



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f=55mm F1.4 V7, 2/16/2021	Zemax
Data for 0.4500 to 0.4500 µm.	Zemax OpticStudio 16.5
Freq 1: 10.00 cyc/mmFreq 5: 67.50 cyc/mm	
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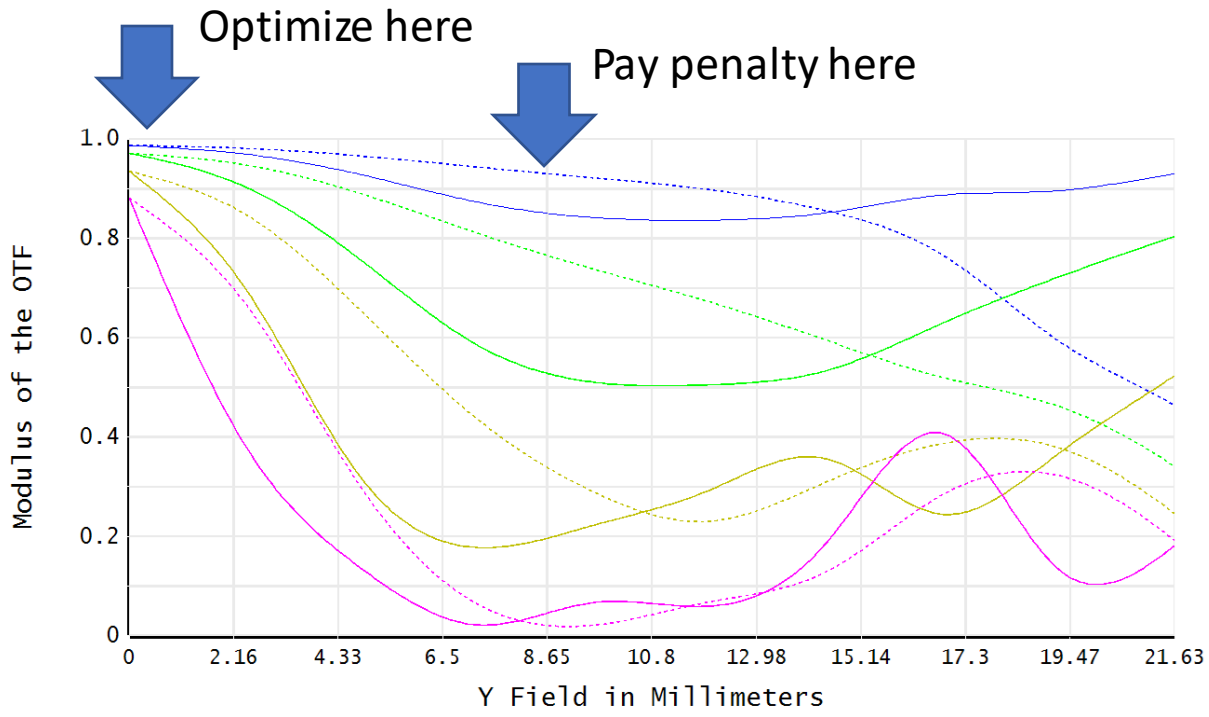
Legend items refer to Tangential(T)/Sagittal(S) frequency	Configuration 4 of 4

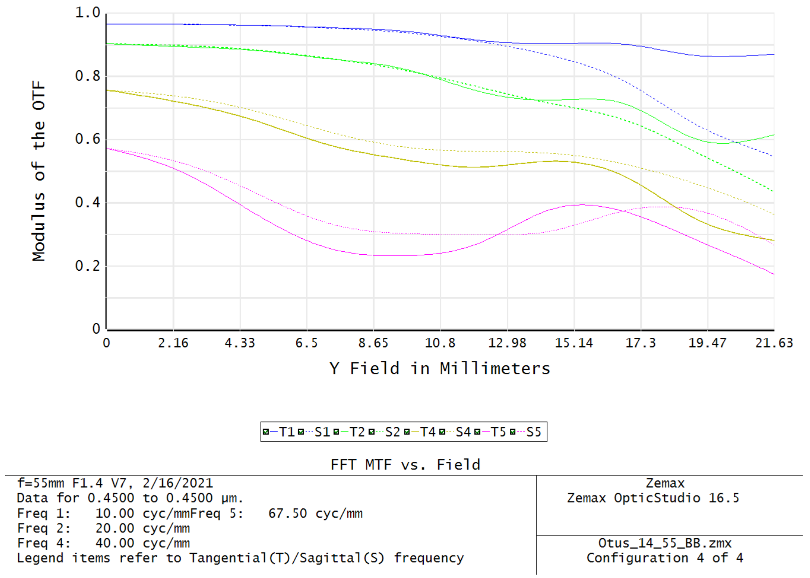


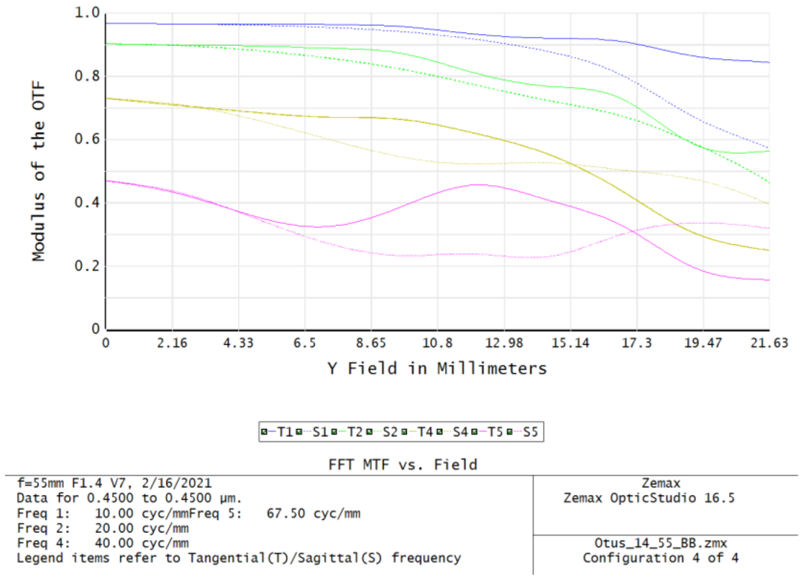
FFT MTF vs. Field

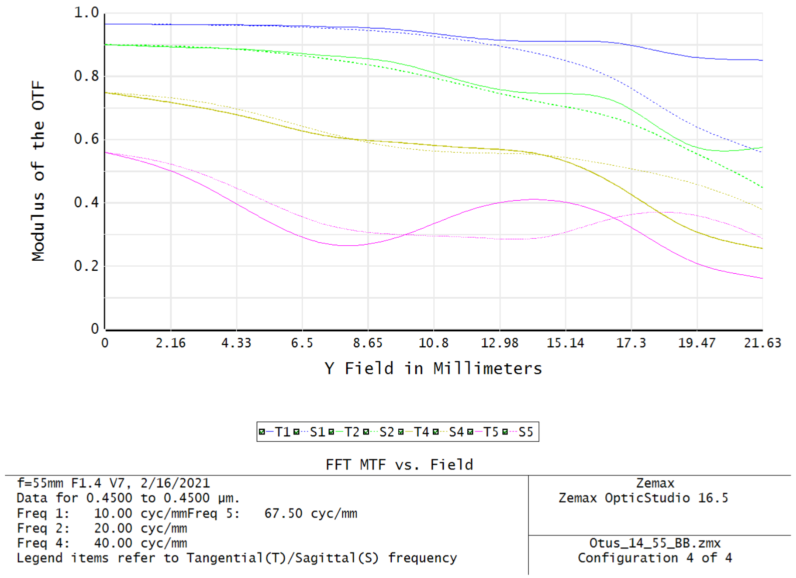
f=55mm F1.4 V7, 2/16/2021	Zemax
Data for 0.4500 to 0.4500 µm.	Zemax OpticStudio 16.5
Freq 1: 10.00 cyc/mmFreq 5: 67.50 cyc/mm	
Freq 2: 20.00 cyc/mm	
Freq 4: 40.00 cyc/mm	Otus_14_55_BB.zmx
Legend items refer to Tangential(T)/Sagittal(S) frequency	Configuration 4 of 4

More attempts to optimize global performance using the OTUS 55mm black box:

Michael G. also tried optimizing imaging parameters for off-axis (10mm image height-center) and then relaxed other parameters to achieve better contrast on-axis (right), and got results similar to the first attempt, arguably with some astigmatism penalty:

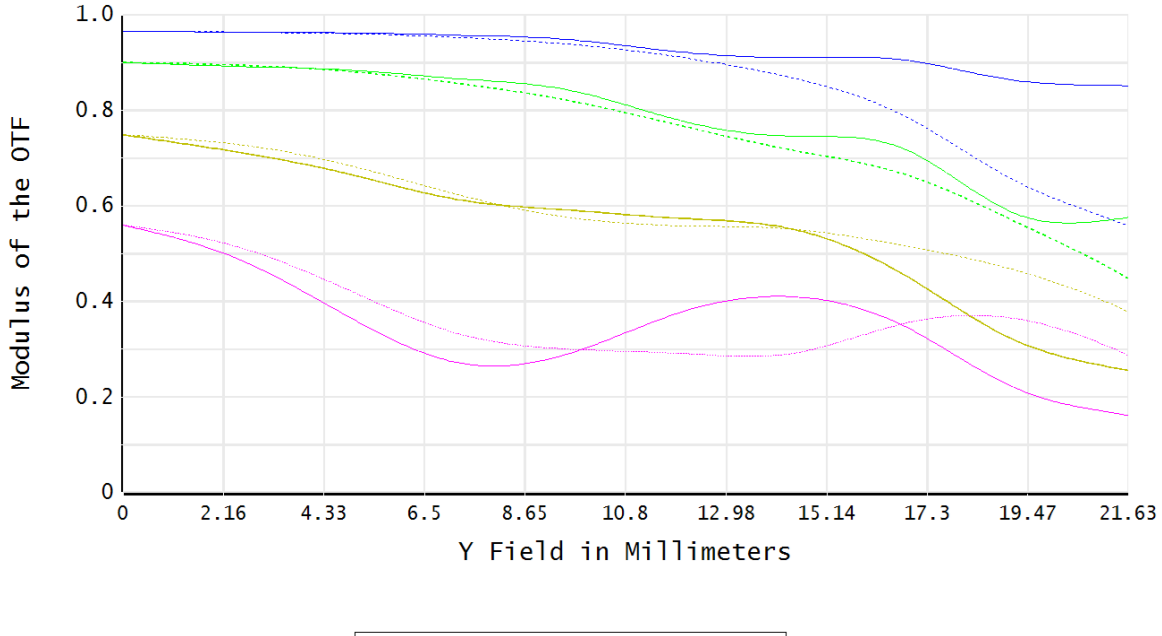




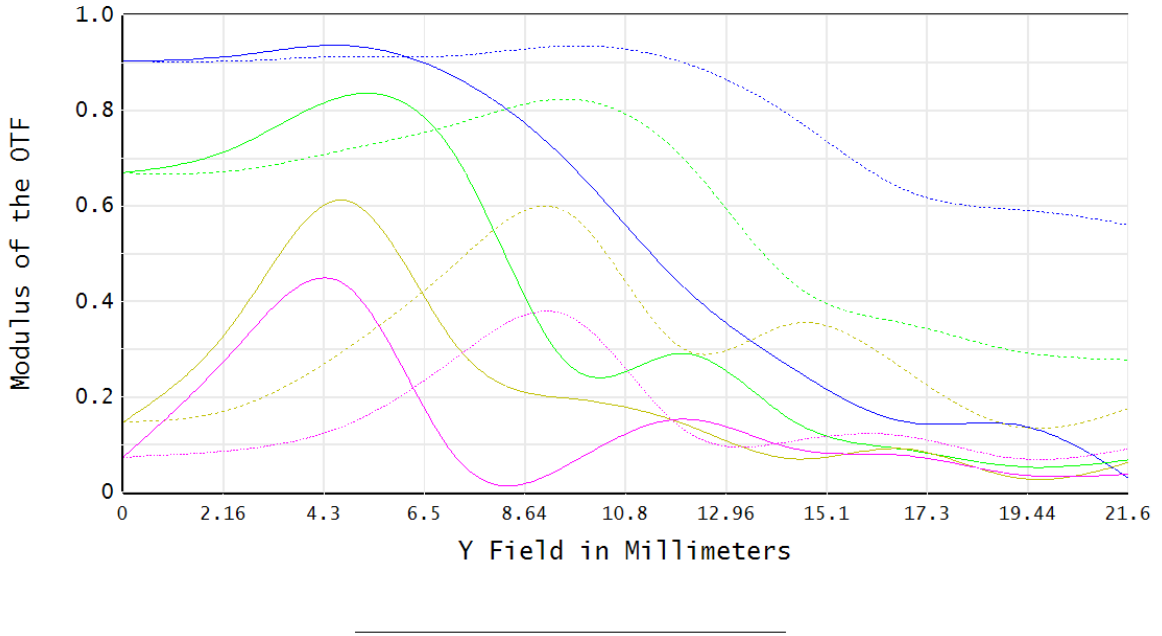


Similar corresponding investigations using the 28mm model, taking the same optimization strategy. 55mm (left), 28mm (right):

55mm



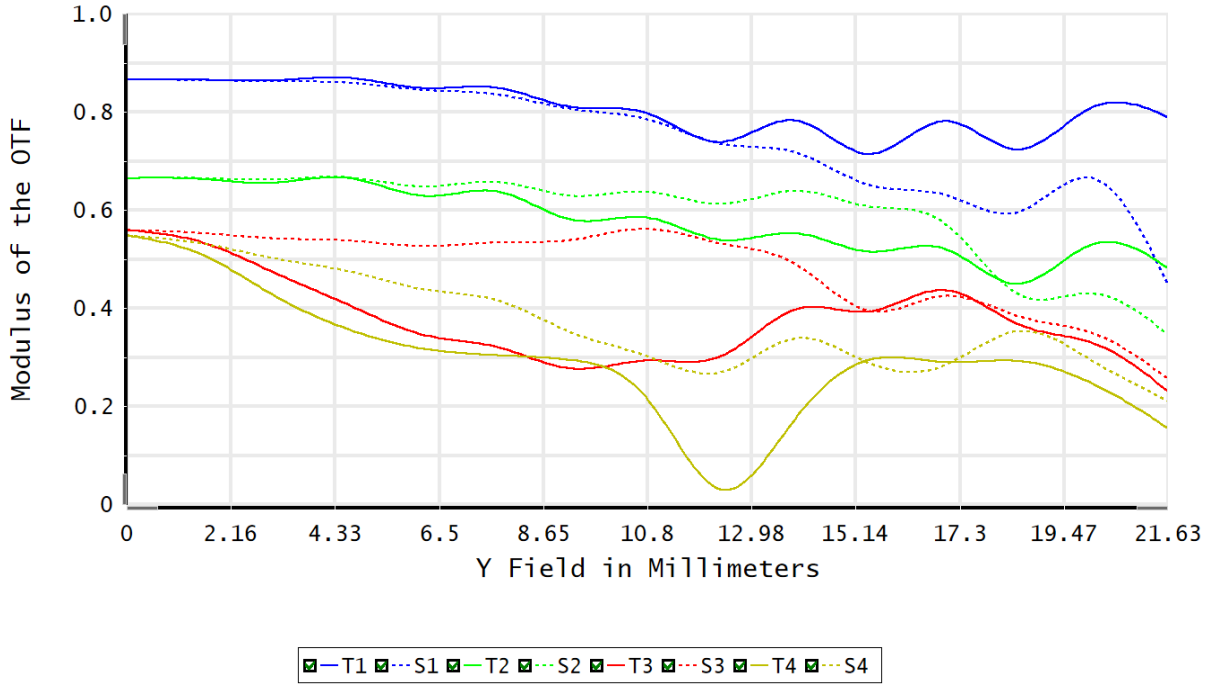
28mm



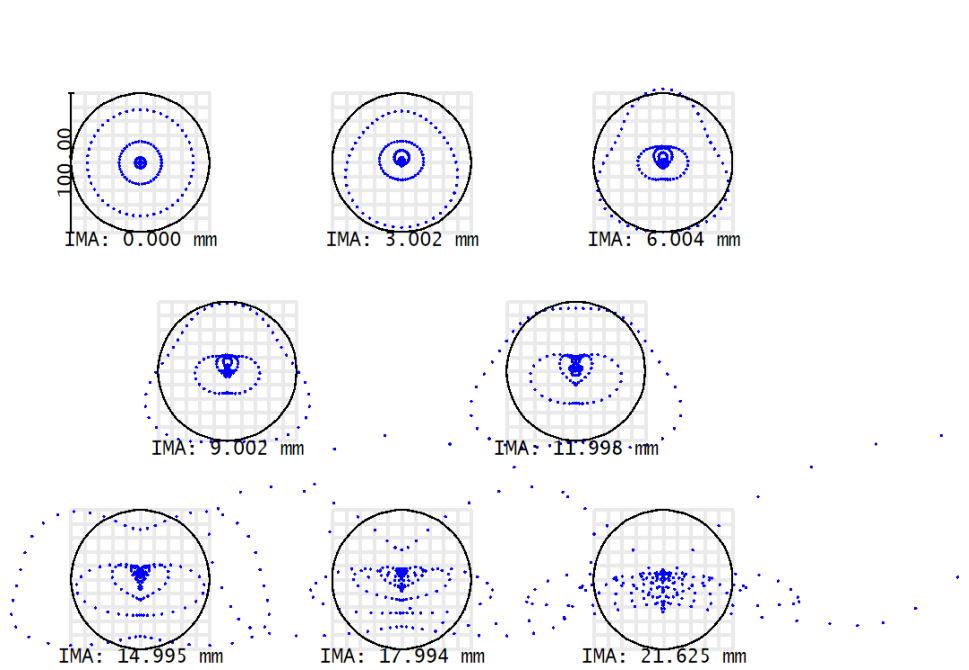
28mm lens doesn't offer as much imaging resolution as 55mm but probably has significantly more light for the same image space F/#.

Michael G. shared his progress files with us so that we could investigate further. Adopted working F/# of 1.706, magnification –0.147 set by object distance.

Continuing where he left off, the archive apparently wasn't saved with the recipes he used for evaluating the MTF vs. Field (configuration #4). Details depend on working F/#, field and pupil sampling, etc.



FFT MTF vs. Field	
f=55mm F1.4 V7, 3/18/2021 Data for 0.4500 to 0.4500 µm. Freq 1: 10.00 cyc/mm Freq 4: 67.00 cyc/mm Freq 2: 20.00 cyc/mm Freq 3: 40.00 cyc/mm Legend items refer to Tangential(T)/Sagittal(S) frequency	Zemax Zemax OpticStudio 20.1.3 Otus_14_55_BB.zmx Configuration 4 of 5



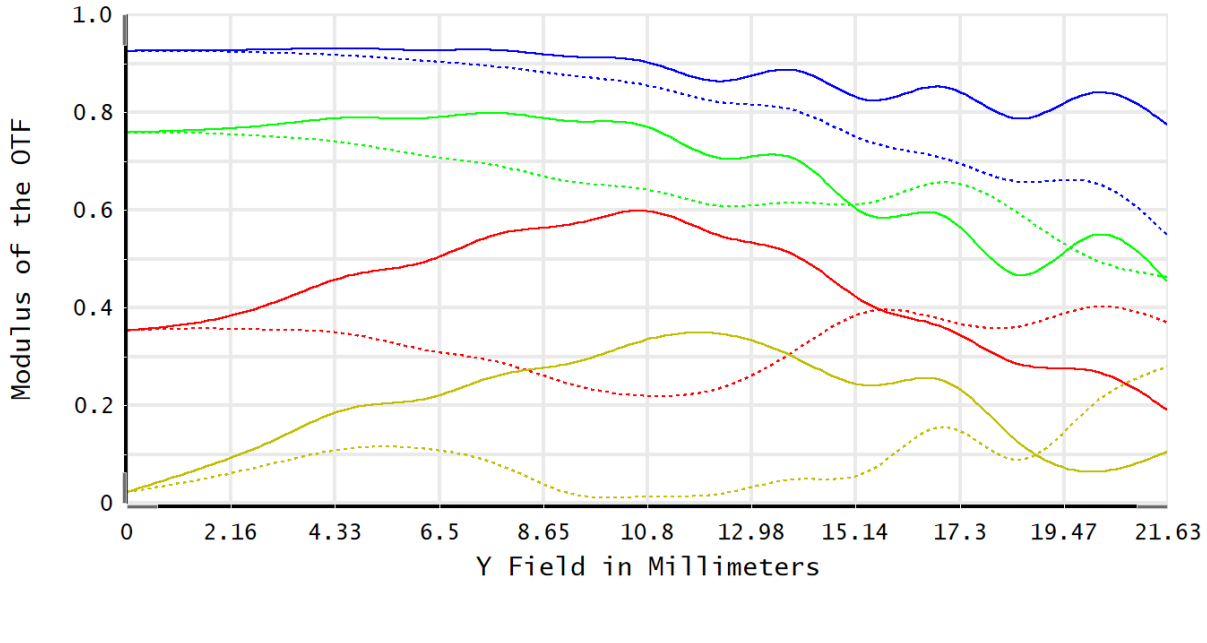
Surface: IMA

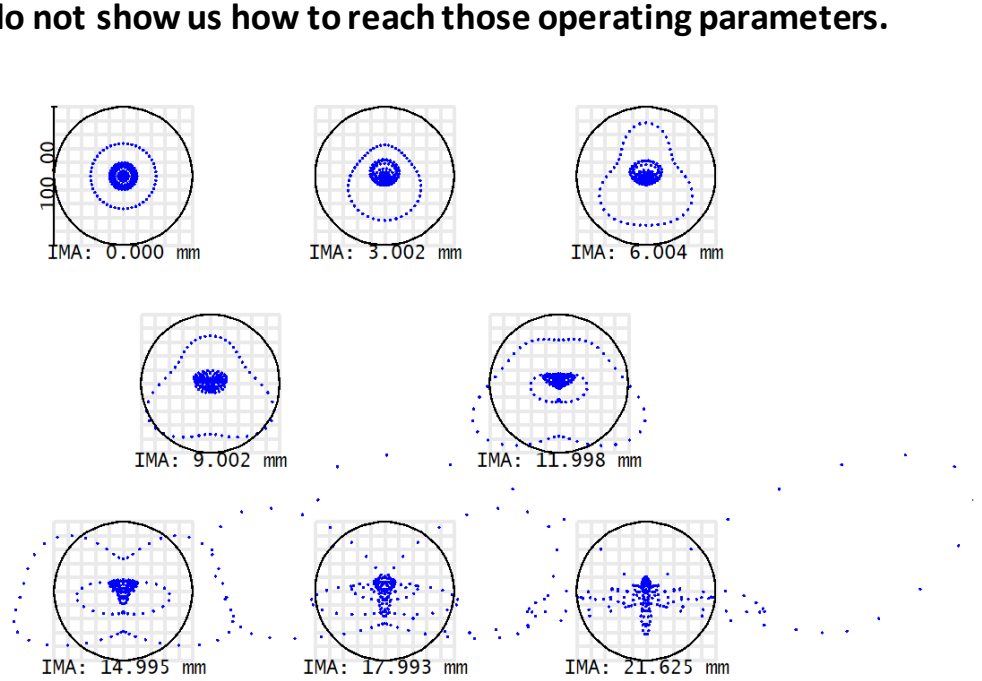
Spot Diagram									
f=55mm F1.4 V7, 3/18/2021 Units are µm. Legend items refer to Wavelengths Field : 1 2 3 4 5 6 7 8 RMS radius : 19.269 20.368 23.522 26.314 31.086 36.063 47.503 72.611 GEO radius : 38.249 46.532 53.256 65.819 82.189 96.232 142.678 260.541 Circle diam: 100 Reference : Centroid								Zemax Zemax OpticStudio 20.1.3 Otus_14_55_BB.zmx Configuration 4 of 5	

Minimizing on wavefront error appears to do a good job in terms of spot rms, but MTF displays significant elongation/astigmatism in the spots.

NB: only 1 degree of freedom was adjusted, axial position of the focus group of lens elements. Optimization translated this group by 53 microns.

Optical simulations suggest reasonable performance may be available, but do not show us how to reach those operating parameters.





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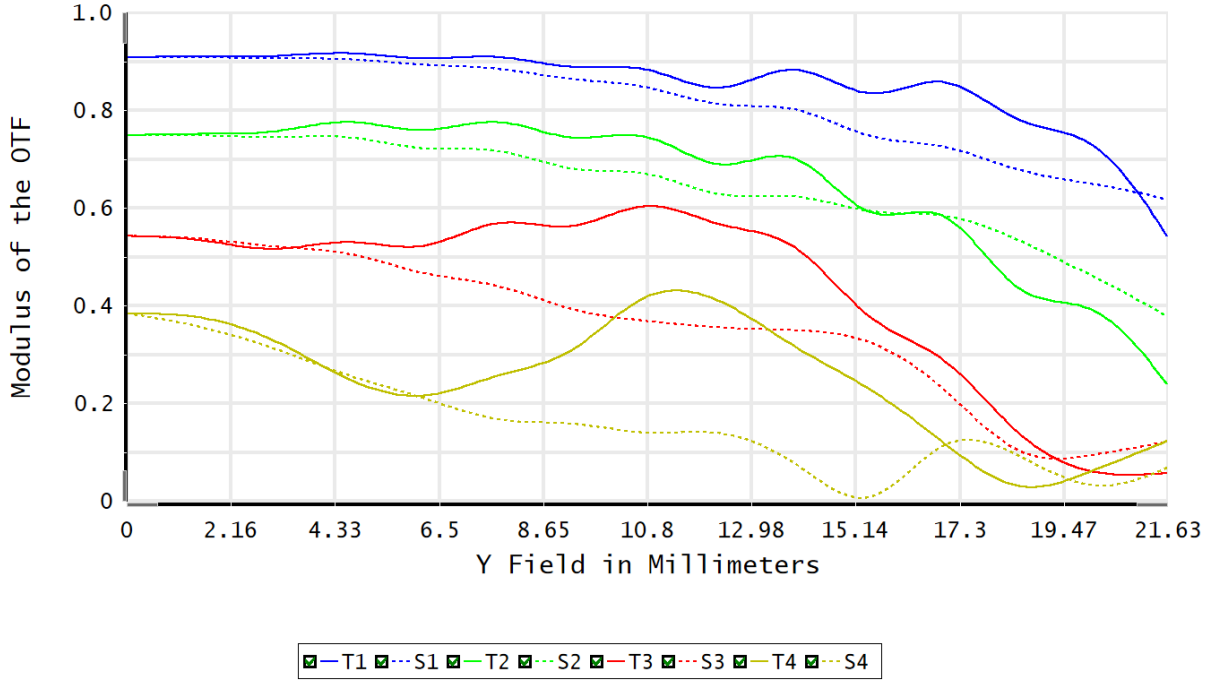
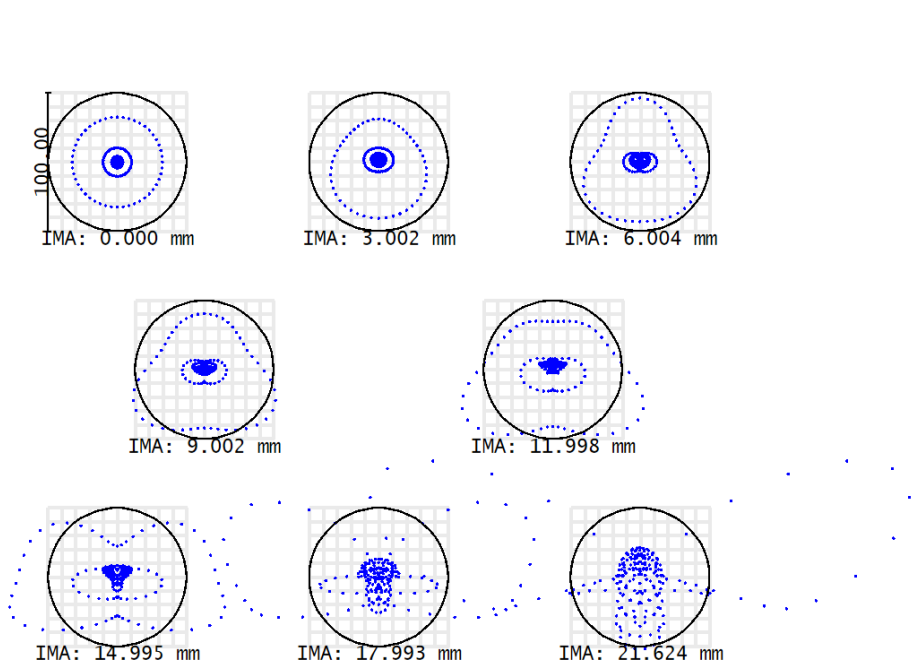
Surface: IMA

Spot Diagram	
f=55mm F1.4 V7, 3/18/2021 Units are µm. Legend items refer to Wavelengths Field : 1 2 3 4 5 6 7 8 RMS radius : 12.656 13.715 16.697 19.251 23.721 28.715 40.489 66.082 GEO radius : 23.662 31.998 38.887 51.578 68.228 82.015 127.891 245.526 Circle diam: 100 Reference : Centroid	Zemax Zemax OpticStudio 20.1.3 Otus_14_55_BB.zmx Configuration 5 of 5

Finally, allow object plane to become an even aspheric object surface with fixed apex. (solution has additional 33 micron axial shift of focus group and aspheric terms on next page.



FFT MTF vs. Field	
f=55mm F1.4 V7, 3/18/2021 Data for 0.4500 to 0.4500 µm. Freq 1: 10.00 cyc/mm Freq 4: 67.00 cyc/mm Freq 2: 20.00 cyc/mm Freq 3: 40.00 cyc/mm Legend items refer to Tangential(T)/Sagittal(S) frequency	Zemax Zemax OpticStudio 20.1.3 Otus_14_55_BB.zmx Configuration 6 of 6

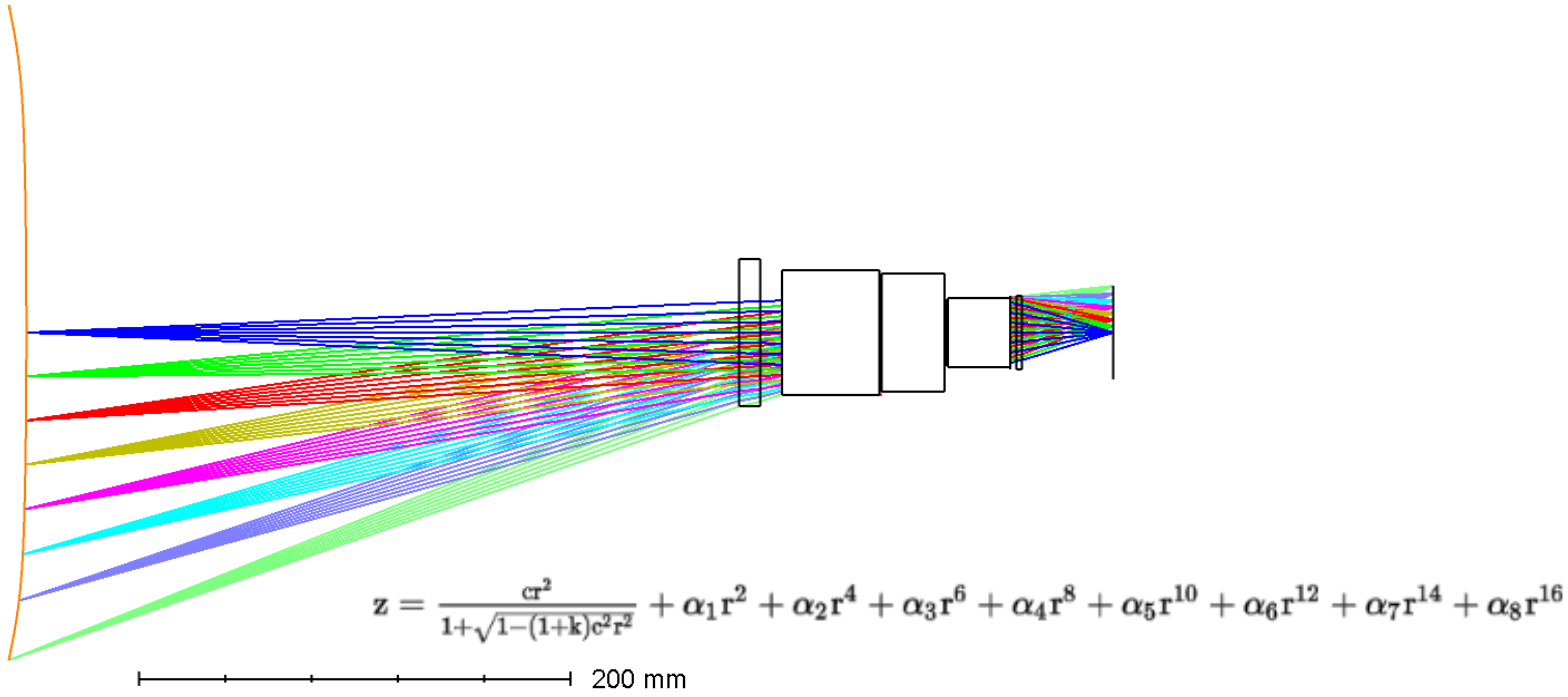


Surface: IMA

Spot Diagram									
f=55mm F1.4 V7, 3/18/2021 Units are µm. Legend items refer to Wavelengths Field : 1 2 3 4 5 6 7 8 RMS radius : 16.116 17.105 19.852 21.812 25.218 28.068 35.491 51.959 GEO radius : 32.543 40.583 46.494 57.471 71.400 80.532 115.139 202.849 Circle diam: 100 Reference : Centroid								Zemax Zemax OpticStudio 20.1.3 Otus_14_55_BB.zmx Configuration 6 of 6	

Best object surface solution for performance on previous page. Peak-to-valley of object surface is roughly 7mm and provides modest performance improvements seen last slide.

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6	2nd Order Ter	4th Order Ter	6th Order Term	8th Order Term	10th Order Term	1
0	O Even Asphere		2.983E+04 V	330.343 P			151.599	0.000	151.599	0.000	0.000	-1.139E-04 V	-1.023E-08 V	1.562E-12 V	-1.388E-16 V	3.010E-21 V	
1	Standard		Infinity	10.000	LITHOSIL-Q		34.209	0.000	34.209	0.000	-						
2	Standard		Infinity	10.000			31.915	0.000	34.209	0.000	0.000						
3	Standard		Infinity	0.000			28.446	0.000	28.446	0.000	0.000						



Layout

f=55mm F1.4 V7
3/18/2021
Total Axial Length: 503.84717 mm

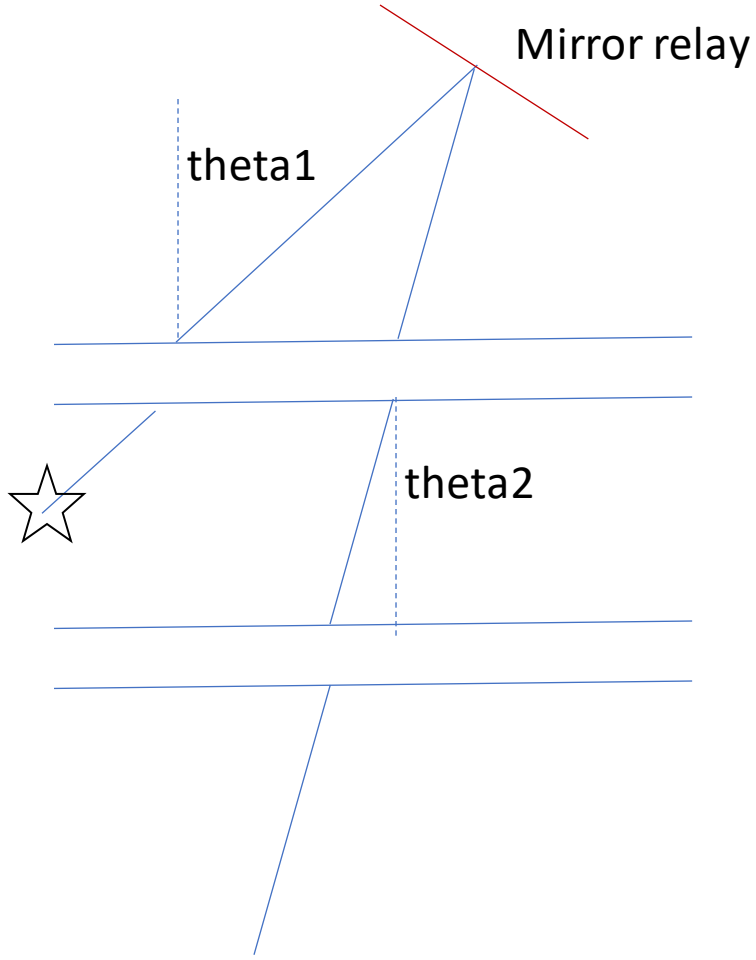
Zemax
Zemax OpticStudio 20.1.3

Otus_14_55_BB.zmx
Configuration 6 of 6

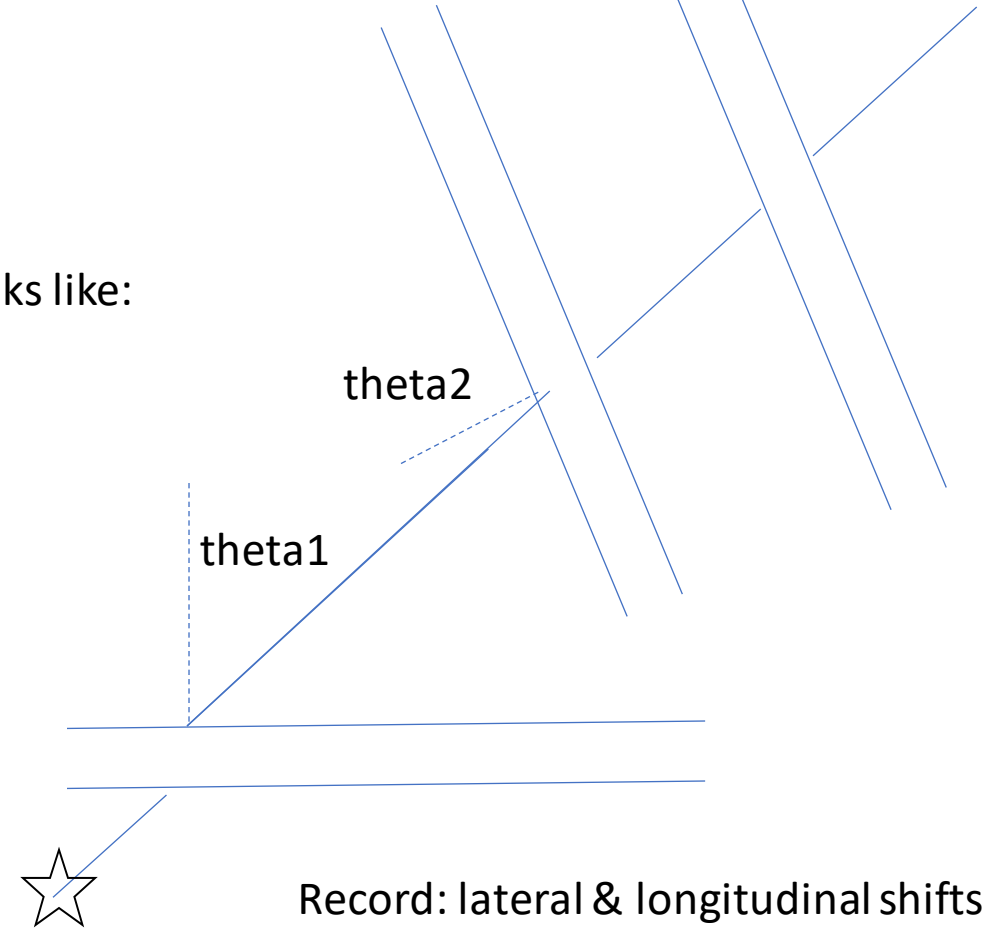
The above zemax studies using OTUS 55mm black box lens included a 10mm plano-plano vacuum barrier.

- Introduction of the vacuum barrier was found by Michael G. to have modest, maybe negligible impact on imaging performance.
- If the optical relay mirrors are arranged outside the vacuum on the far side, the light would need to pass through 3 windows and 6 interfaces:
  - Vacuum-glass, glass-air, (reflector), air-glass, glass-vacuum, vacuum-glass, glass-air, (camera lens).
  - The first pass through the window on the reflector side will have the steepest angle. In the following, we study the aberrations induced by that pass, to estimate impact on imaging fidelity. Expect astigmatism and an effective blur circle diameter in the case where desired image has no net ellipticity.

Geometric impact of 3 passages throguh window



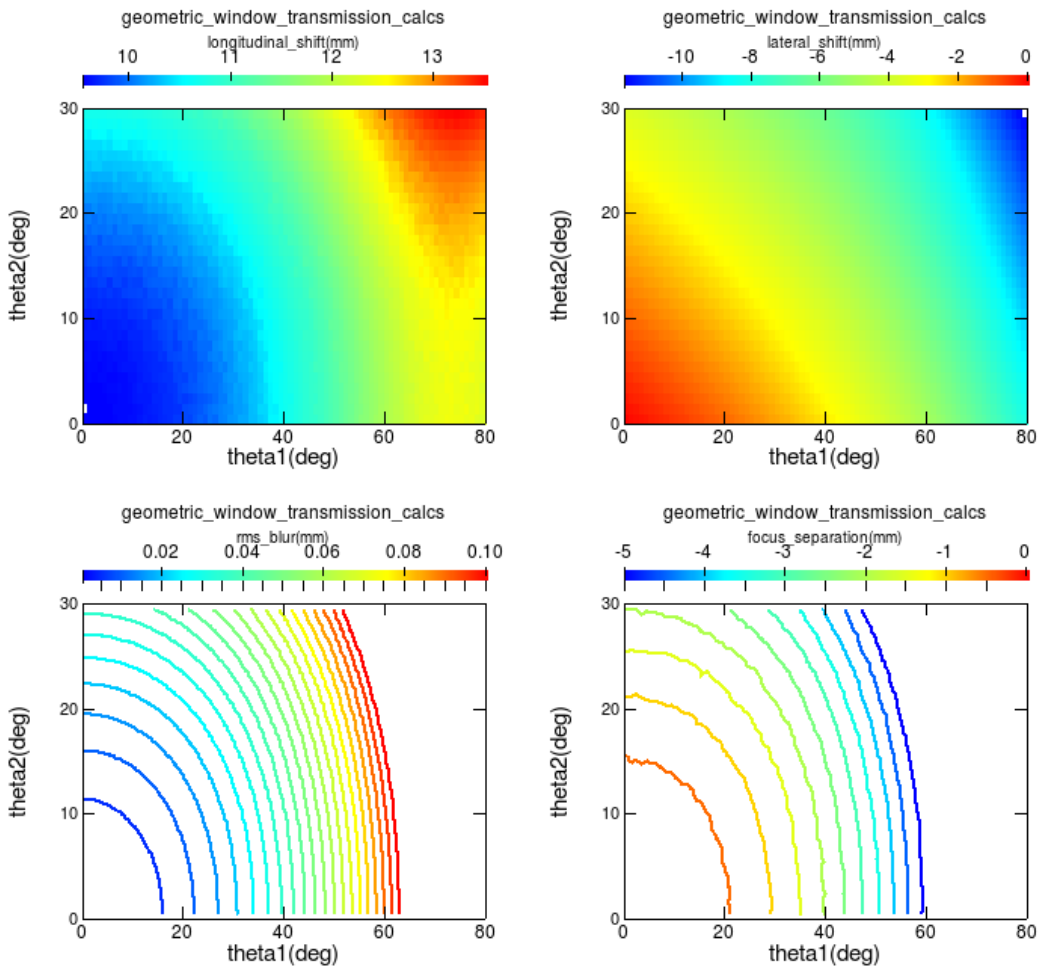
Looks like:

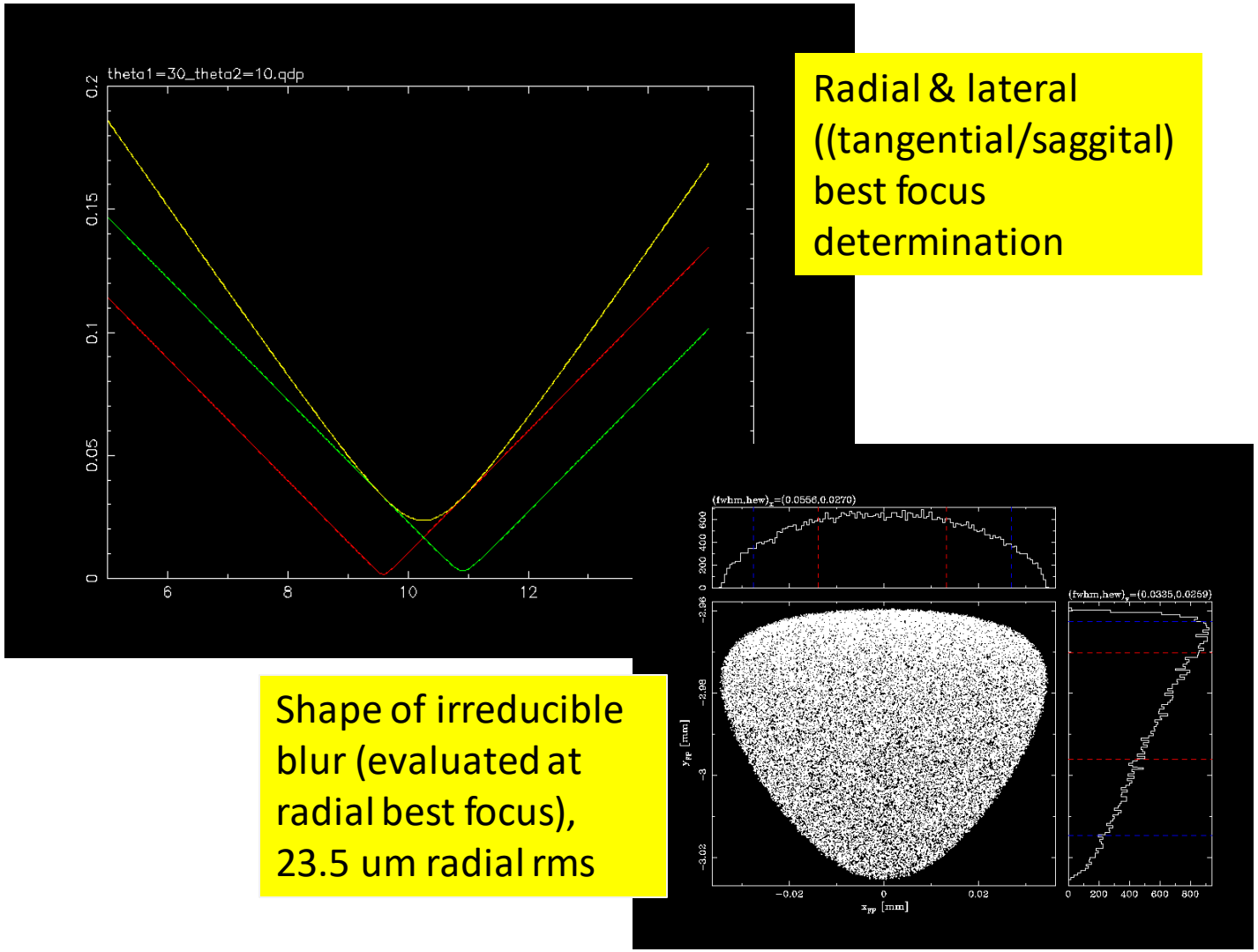


Record: lateral & longitudinal shifts of the apparent source, separation between orthogonal best focus, and minimum blur size.

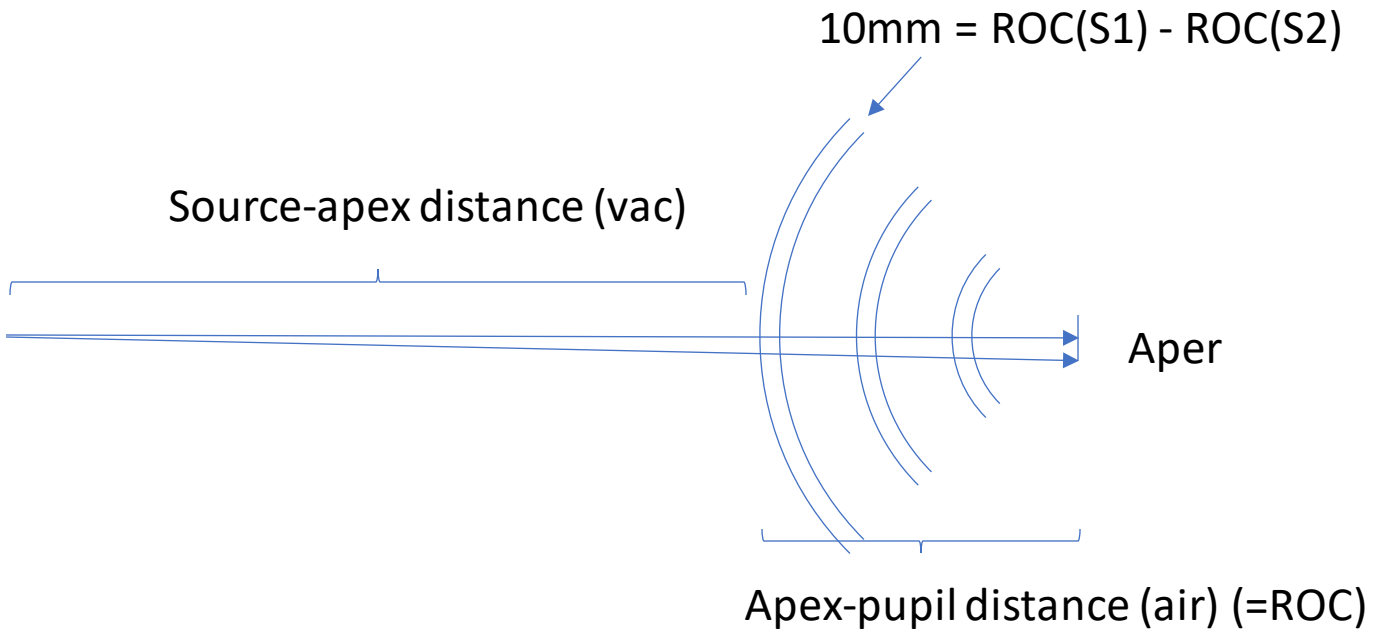
Camera entrance

Results of 3x window passage, for 10mm thick window. Trial full cone opening angle is 5.7 deg (F/10 beam)
NB: blur rapidly exceeds 40um beyond 30 degrees in theta1.



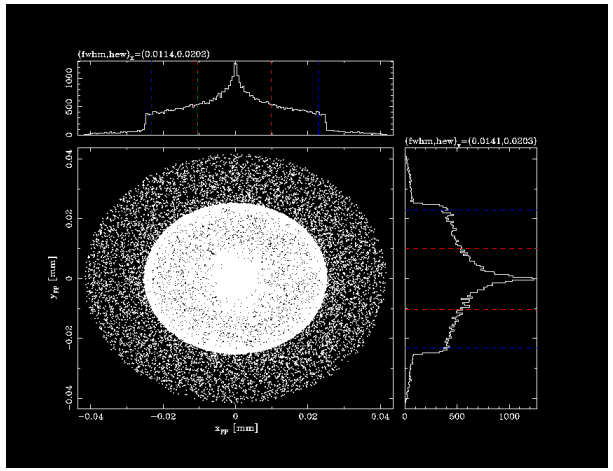


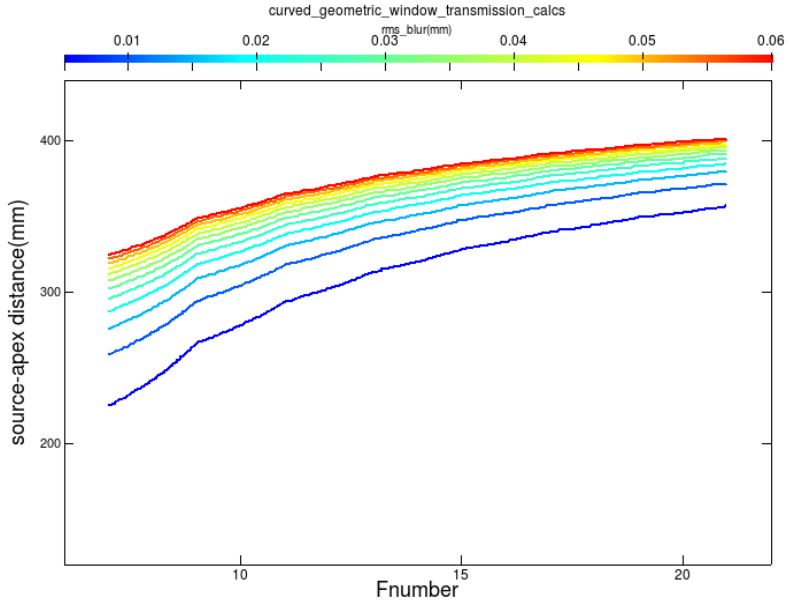
Aberrations due to diverging beam passing through a curved window with surface normal coincident with prime rays approaching entrance pupil:

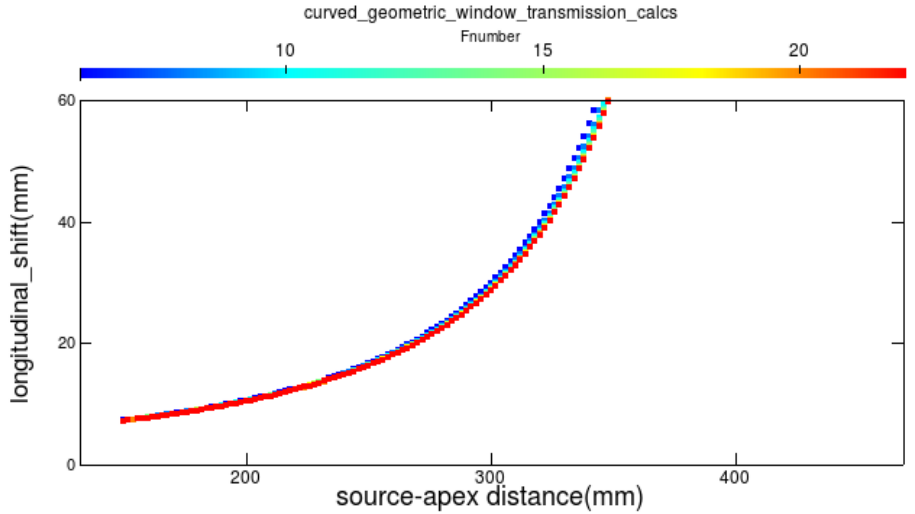


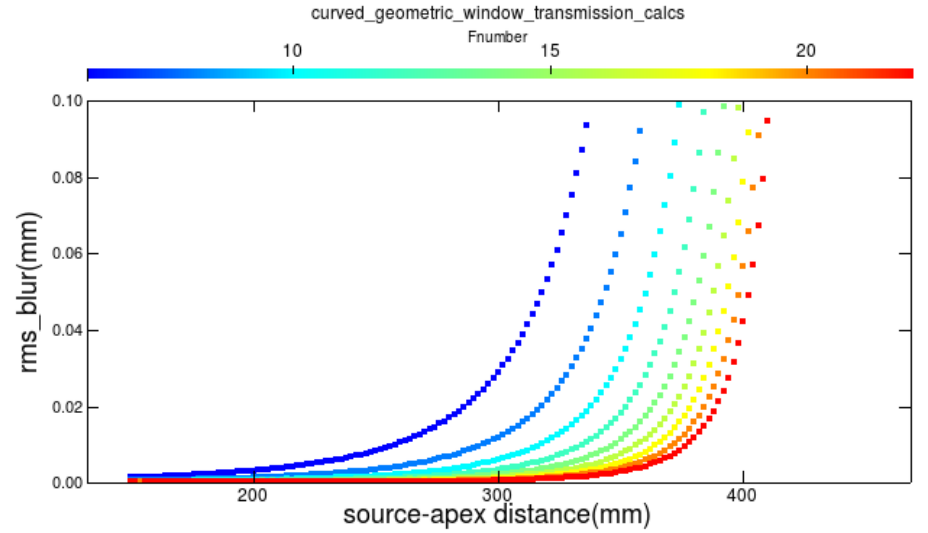
F/# = (source-apex + apex-pupil)/Aper

For combinations of F/#, source-apex & ROC, tracing rays back to minimum radial RMS gives an irreducible blur at the object, driven by spherical aberration.









Here constraints were:
ROC + source-apex = 450mm
F/# ~ 450mm/Aper
Window thickness = 10mm