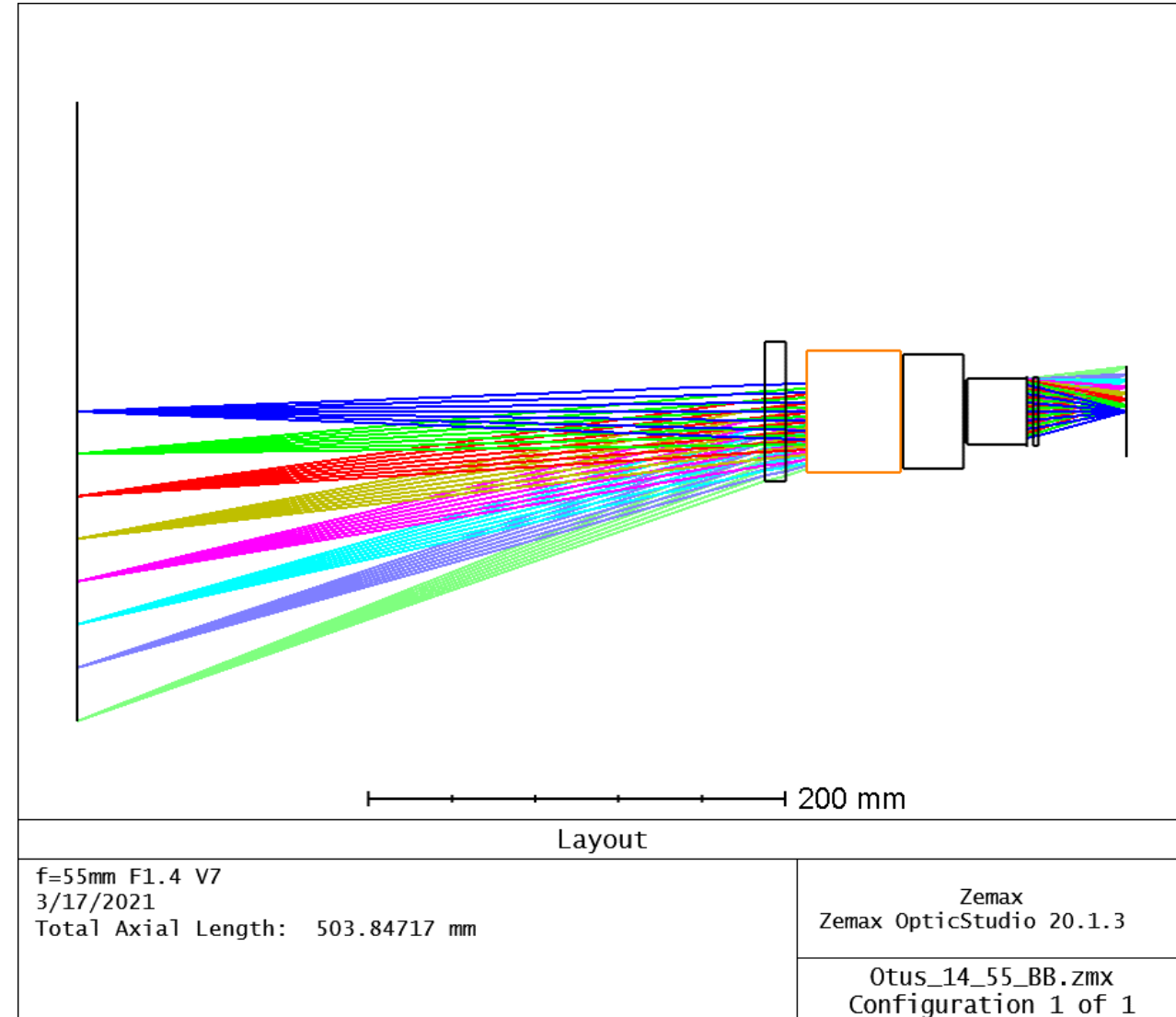
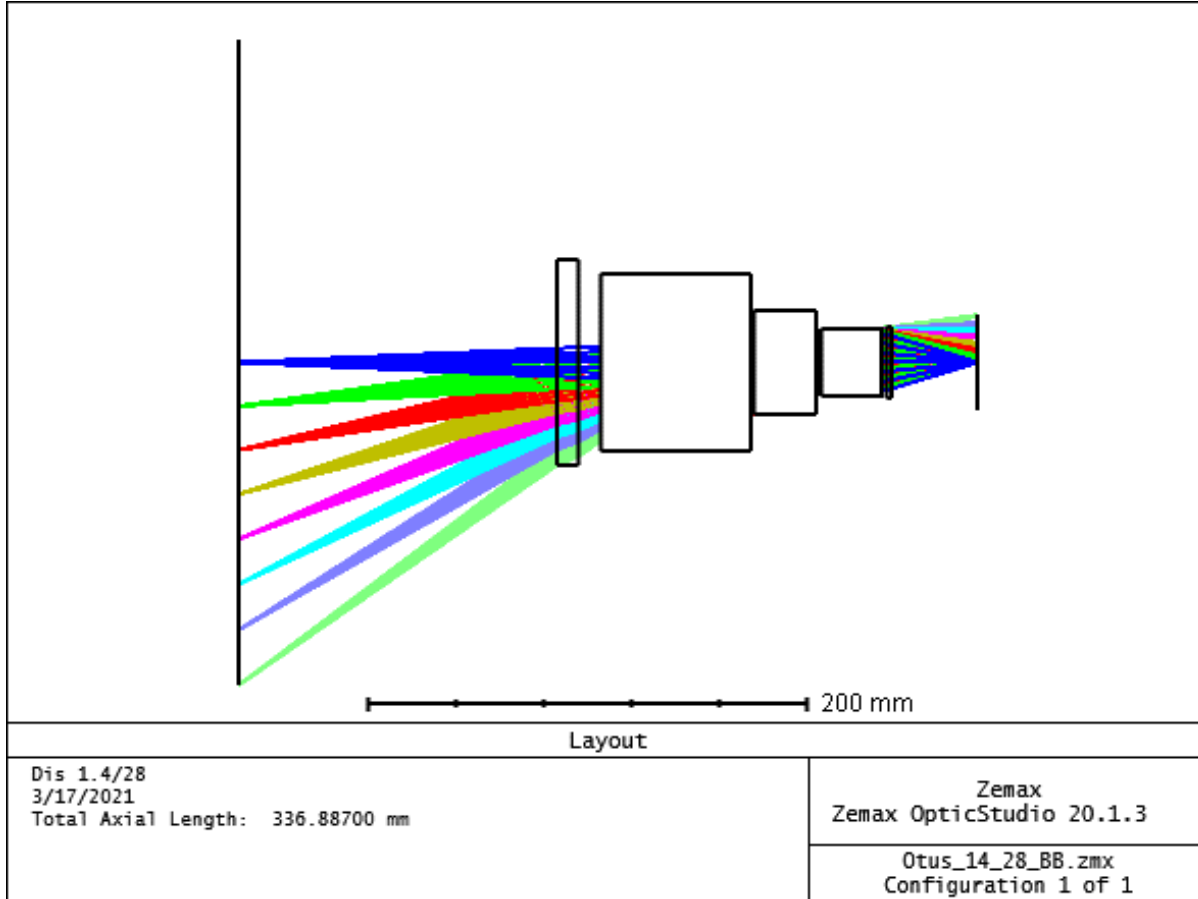


Some updated info on Zeiss OTUS 55 & 28mm focal length lenses

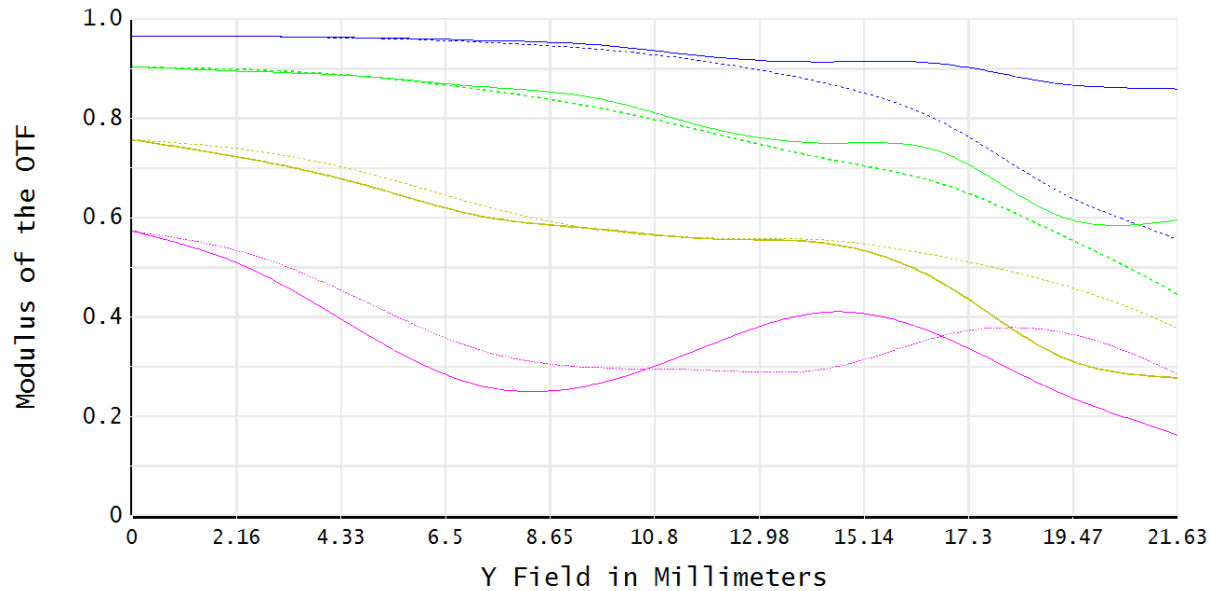
Andy Rasmussen Magis-100 mtg, 210318

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):

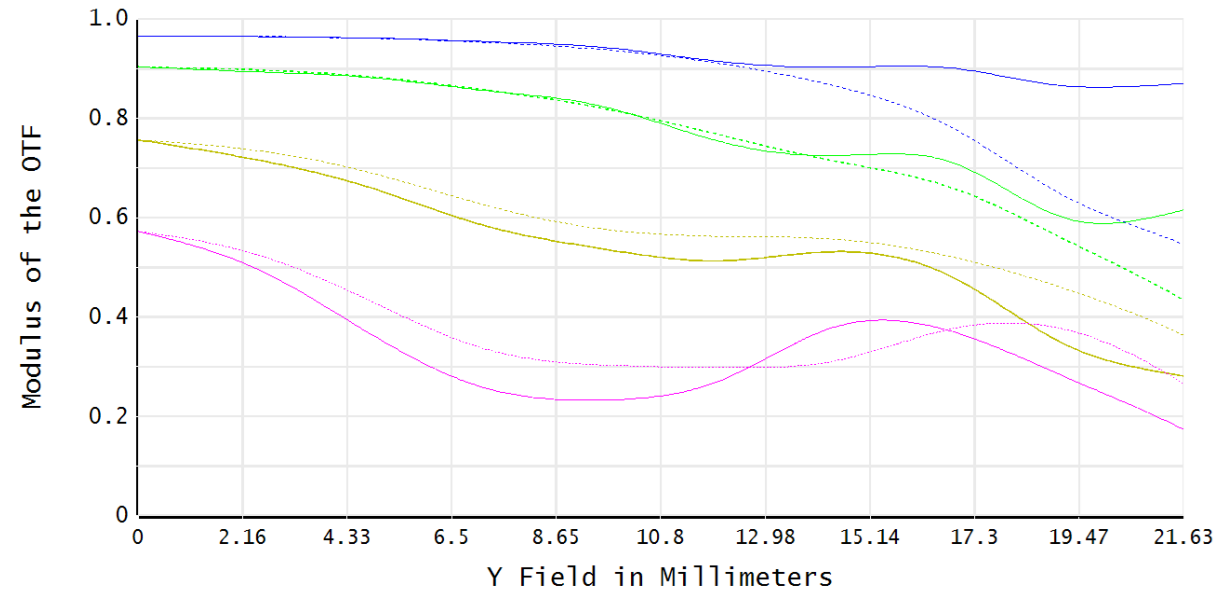


■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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



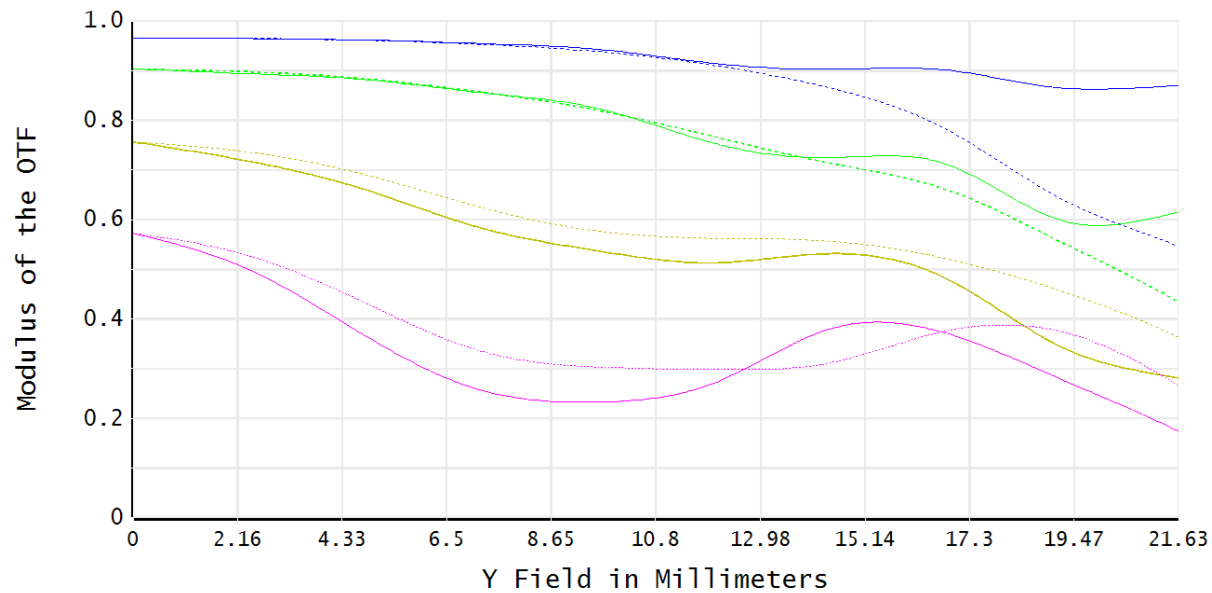
■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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

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



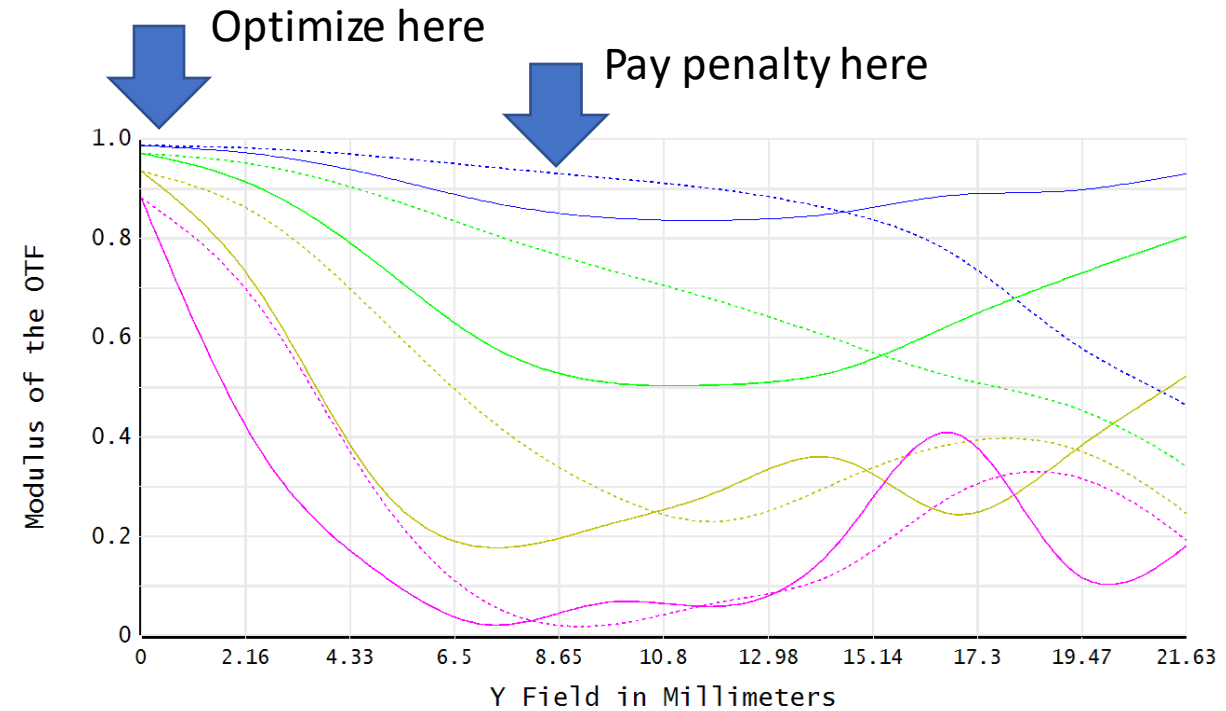
□—T1 □—S1 □—T2 □—S2 □—T4 □—S4 □—T5 □—S5

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/mm Freq 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



□—T1 □—S1 □—T2 □—S2 □—T4 □—S4 □—T5 □—S5

FFT MTF vs. Field

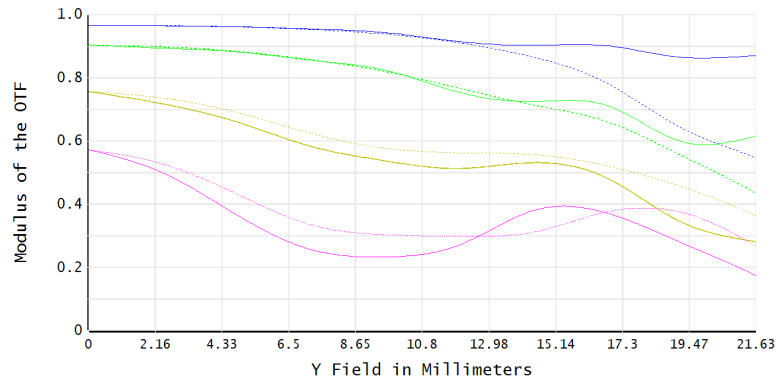
f=55mm F1.4 V7, 2/16/2021
 Data for 0.4500 to 0.4500 μm .
 Freq 1: 10.00 cyc/mm Freq 5: 67.50 cyc/mm
 Freq 2: 20.00 cyc/mm
 Freq 4: 40.00 cyc/mm
 Legend items refer to Tangential(T)/Sagittal(S) frequency

Zemax
 Zemax OpticStudio 16.5

Otus_14_55_BB.zmx
 Configuration 4 of 4

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:

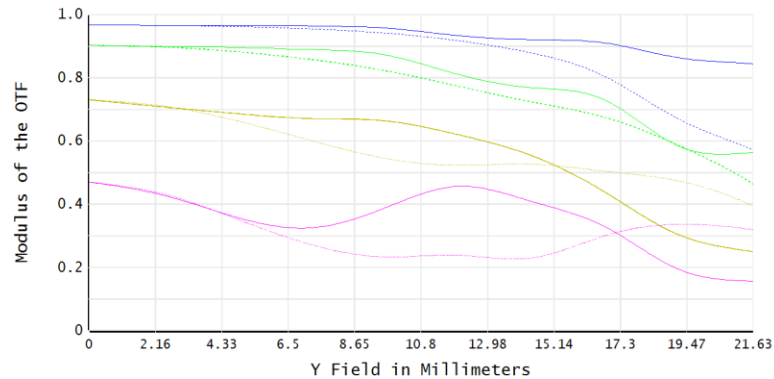


■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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

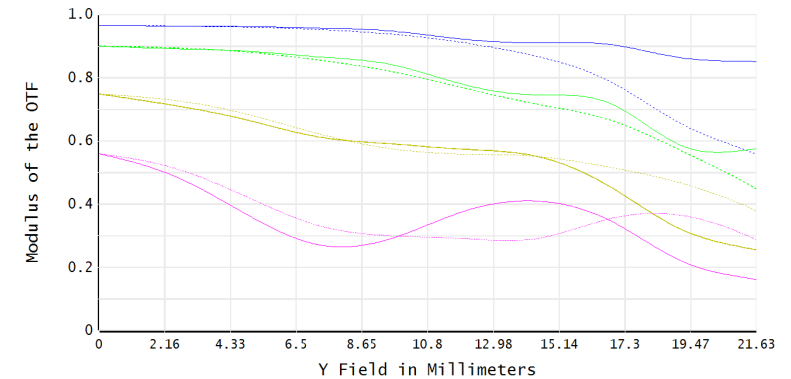


■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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



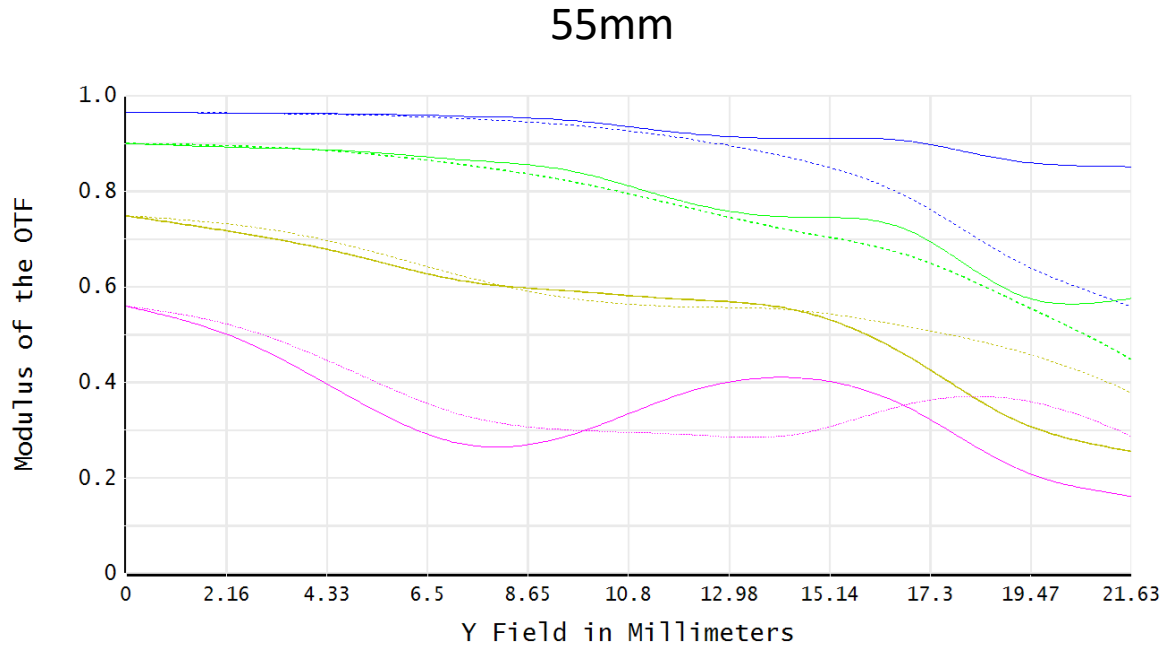
■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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

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



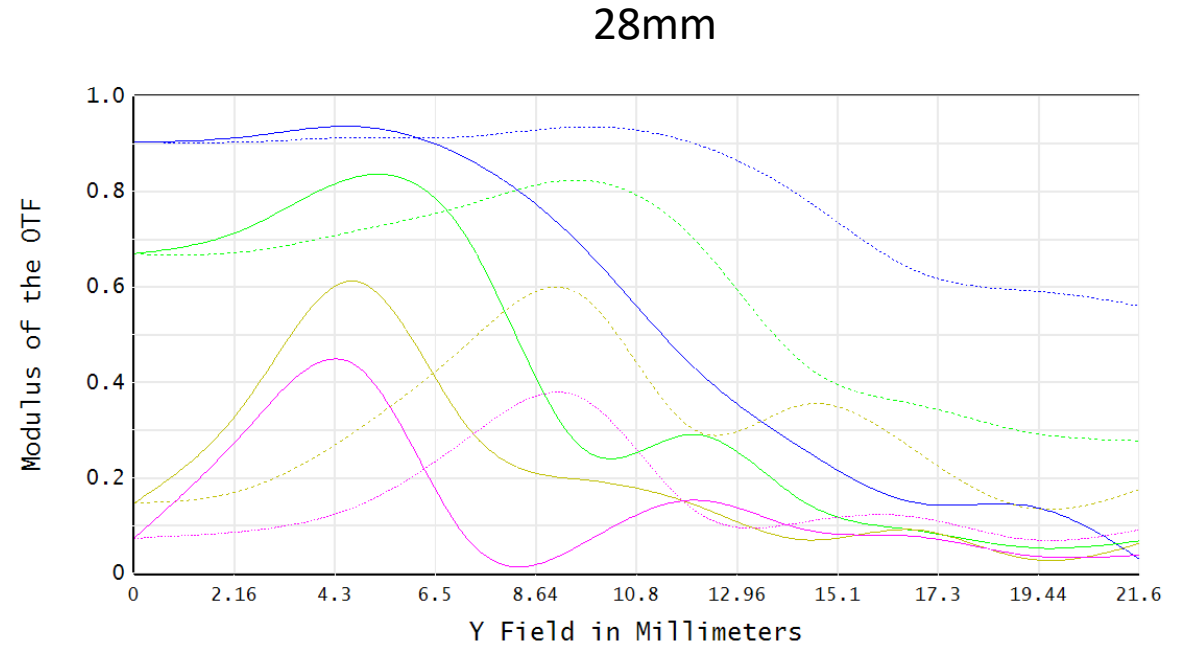
■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

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/mm Freq 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



■ T1 ■ S1 ■ T2 ■ S2 ■ T4 ■ S4 ■ T5 ■ S5

FFT MTF vs. Field

Dis 1.4/28, 2/19/2021
 Data for 0.4500 to 0.4500 μm .
 Freq 1: 10.00 cyc/mm Freq 5: 67.00 cyc/mm
 Freq 2: 20.00 cyc/mm
 Freq 4: 40.00 cyc/mm
 Legend items refer to Tangential(T)/Sagittal(S) frequency

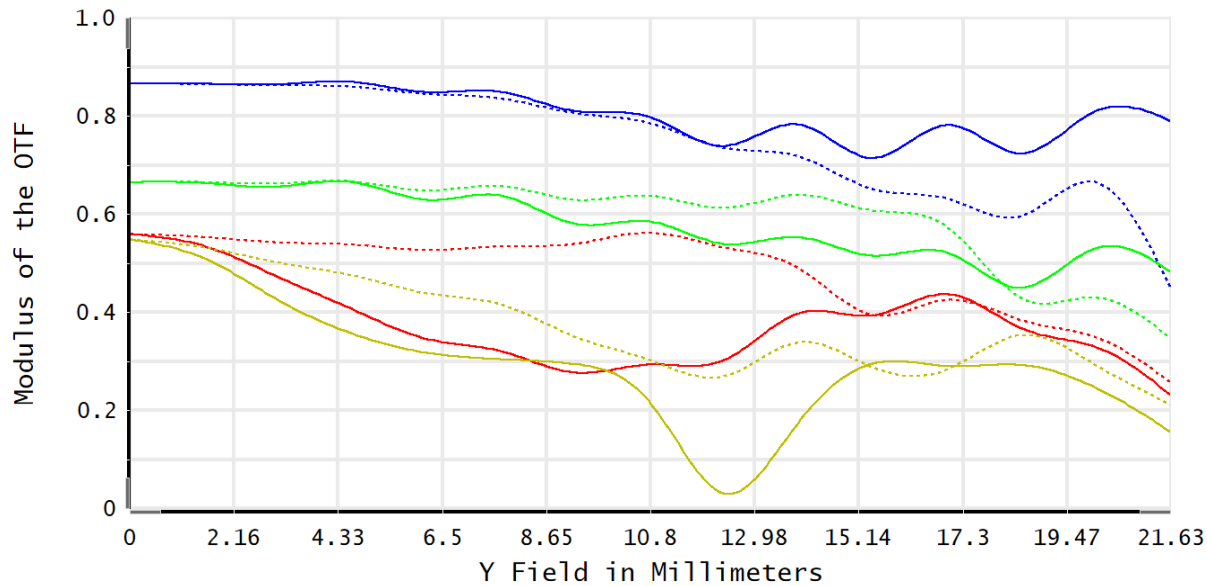
Zemax
 Zemax OpticStudio 16.5

Otus_14_28_BB.zmx
 Configuration 5 of 6

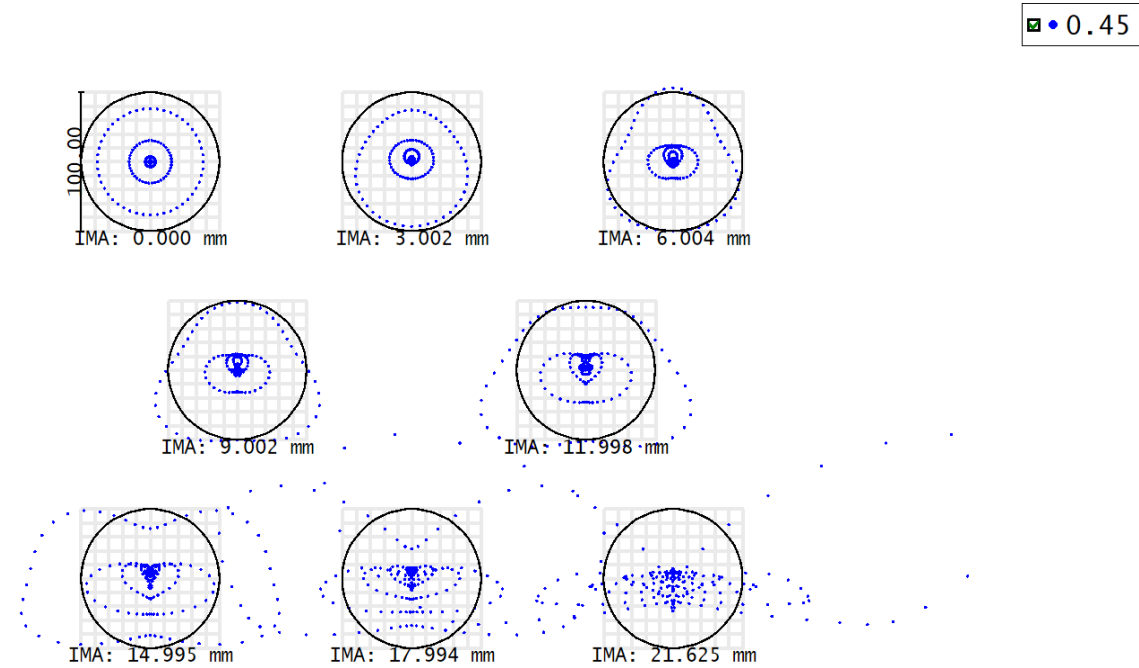
28mm lens doesn't offer as much imaging resolution as 55mm but probably has significantly more light for the same image space F/#.

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.



Legend: T1 (solid blue), S1 (dashed blue), T2 (solid green), S2 (dashed green), T3 (solid red), S3 (dashed red), T4 (solid yellow), S4 (dashed yellow)



Surface: IMA

Spot Diagram

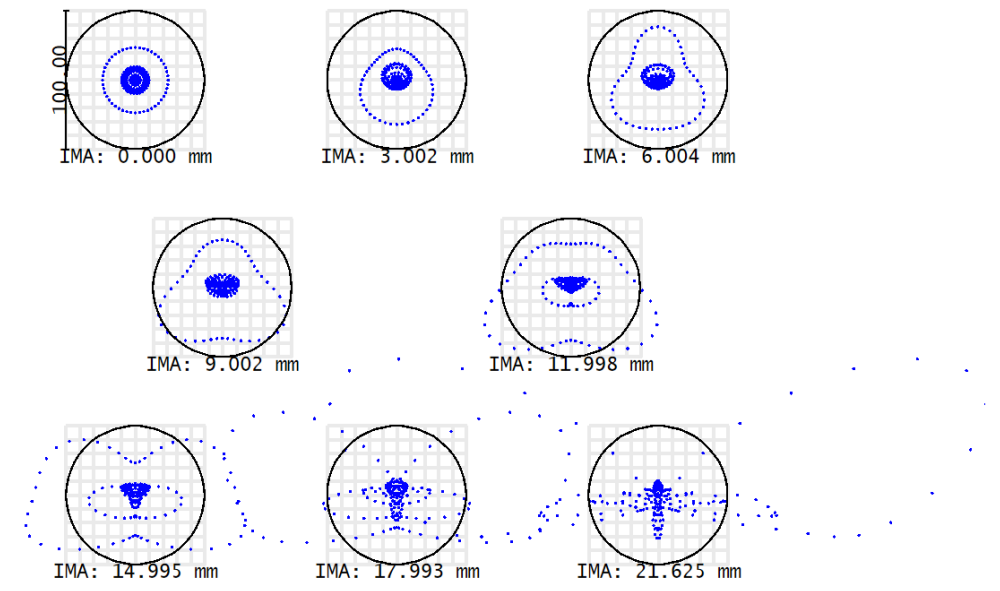
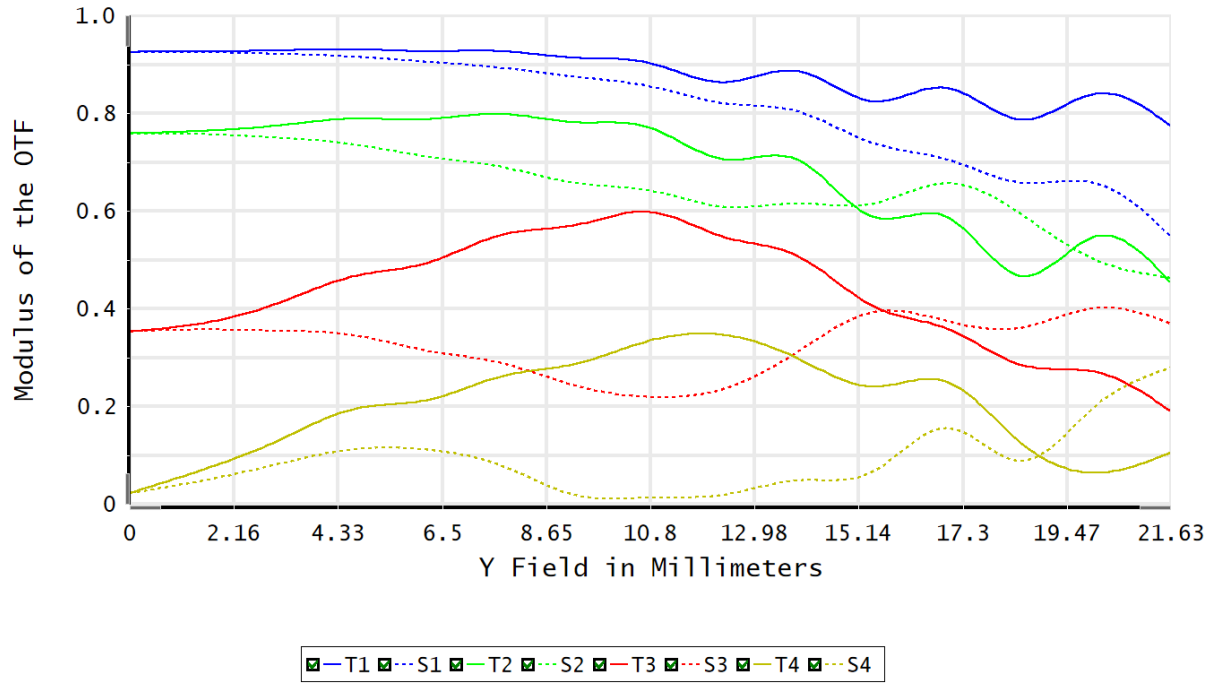
FFT MTF vs. Field		Zemax	
f=55mm F1.4 V7, 3/18/2021 Data for 0.4500 to 0.4500 μm .		Zemax OpticStudio 20.1.3	
Freq 1: 10.00 cyc/mm	Freq 4: 67.00 cyc/mm	Otus_14_55_BB.zmx Configuration 4 of 5	
Freq 2: 20.00 cyc/mm			
Freq 3: 40.00 cyc/mm			
Legend items refer to Tangential(T)/Sagittal(S) frequency			

Spot Diagram								Zemax	
f=55mm F1.4 V7, 3/18/2021								Zemax OpticStudio 20.1.3	
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
								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.

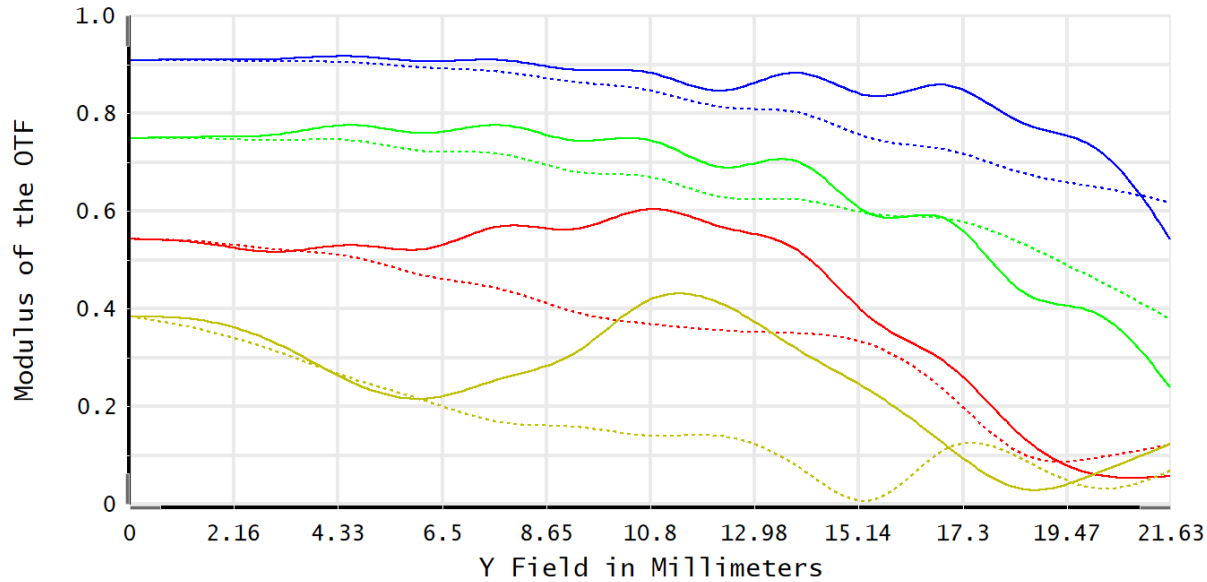
0.45



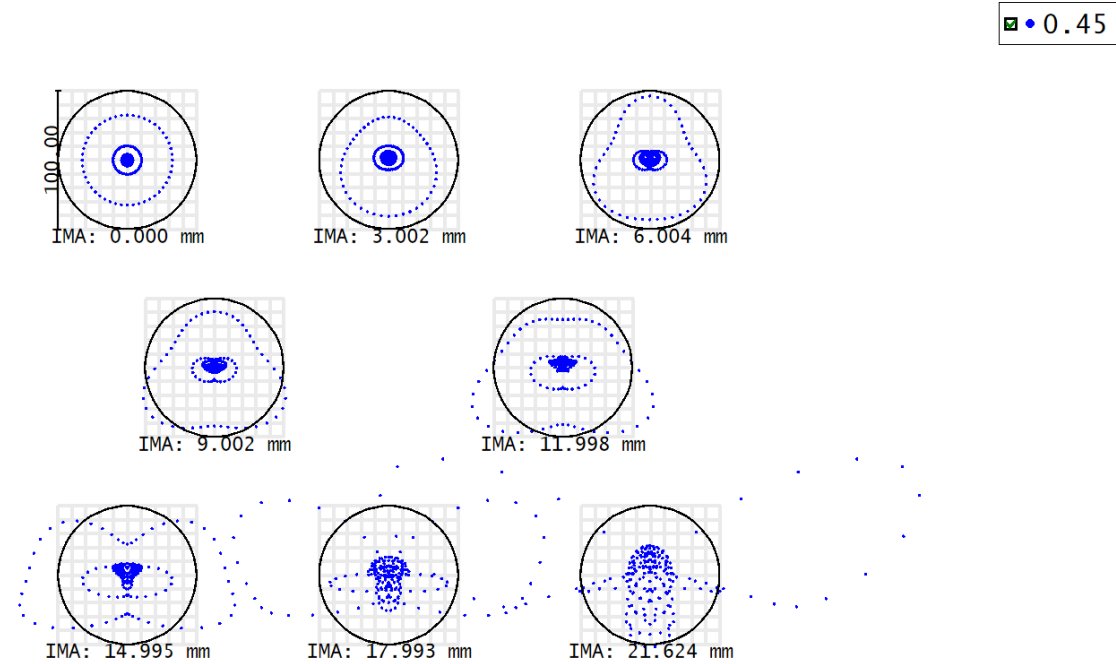
FFT MTF vs. Field		Zemax	
f=55mm F1.4 V7, 3/18/2021 Data for 0.4500 to 0.4500 μm .		Zemax OpticStudio 20.1.3	
Freq 1: 10.00 cyc/mm	Freq 4: 67.00 cyc/mm	Otus_14_55_BB.zmx	
Freq 2: 20.00 cyc/mm		Configuration 5 of 5	
Freq 3: 40.00 cyc/mm			
Legend items refer to Tangential(T)/Sagittal(S) frequency			

Surface: IMA								Spot Diagram								Zemax	
f=55mm F1.4 V7, 3/18/2021								Units are μm . Legend items refer to Wavelengths								Zemax OpticStudio 20.1.3	
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								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.



Legend: T1, S1, T2, S2, T3, S3, T4, S4



Surface: IMA

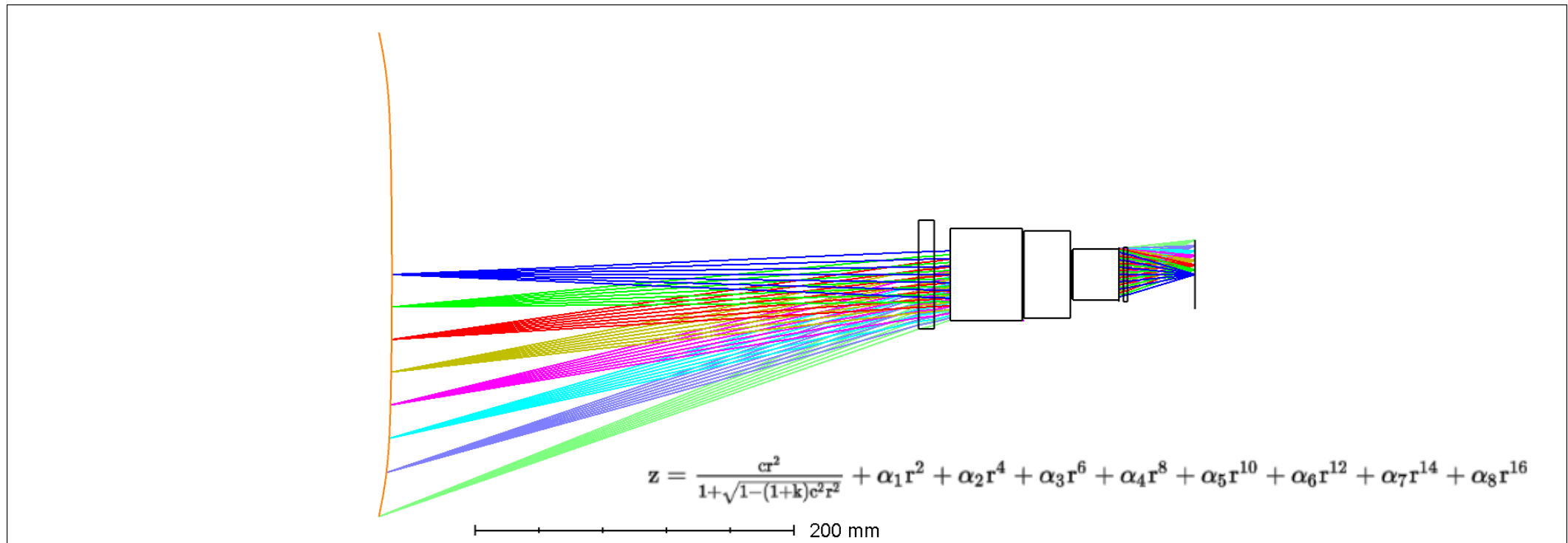
Spot Diagram

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

Spot Diagram								Zemax	
f=55mm F1.4 V7, 3/18/2021								Zemax OpticStudio 20.1.3	
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					
								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	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	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

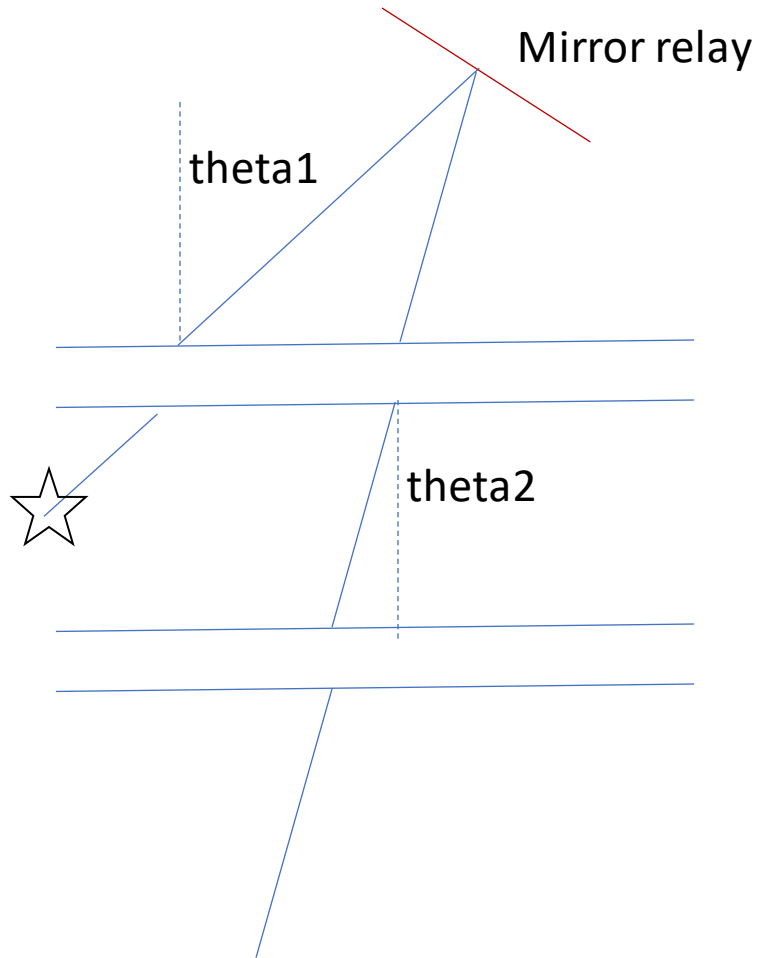
Zemax
 Zemax OpticStudio 20.1.3

Otus_14_55_BB.zmx
 Configuration 6 of 6

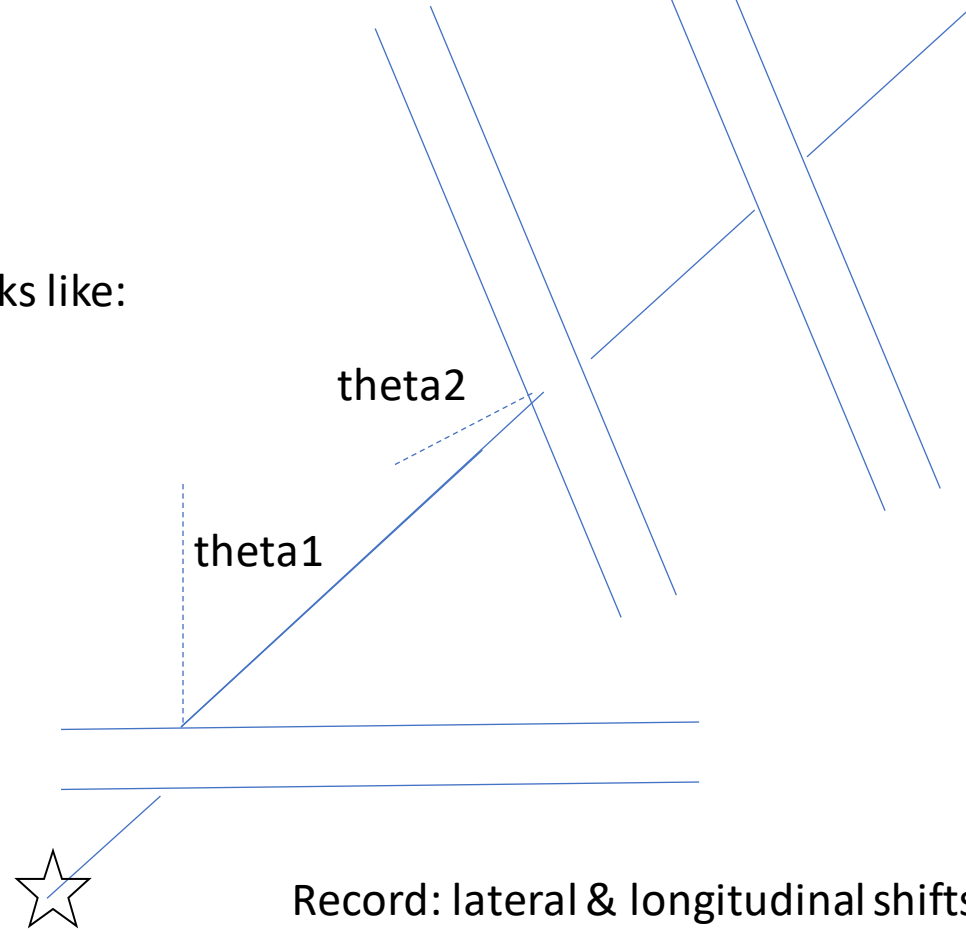
The above zemax studies using OTUS 55mm black box lens included a 10mm plano-plano vacuum barrier.

- 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 through window



Looks like:

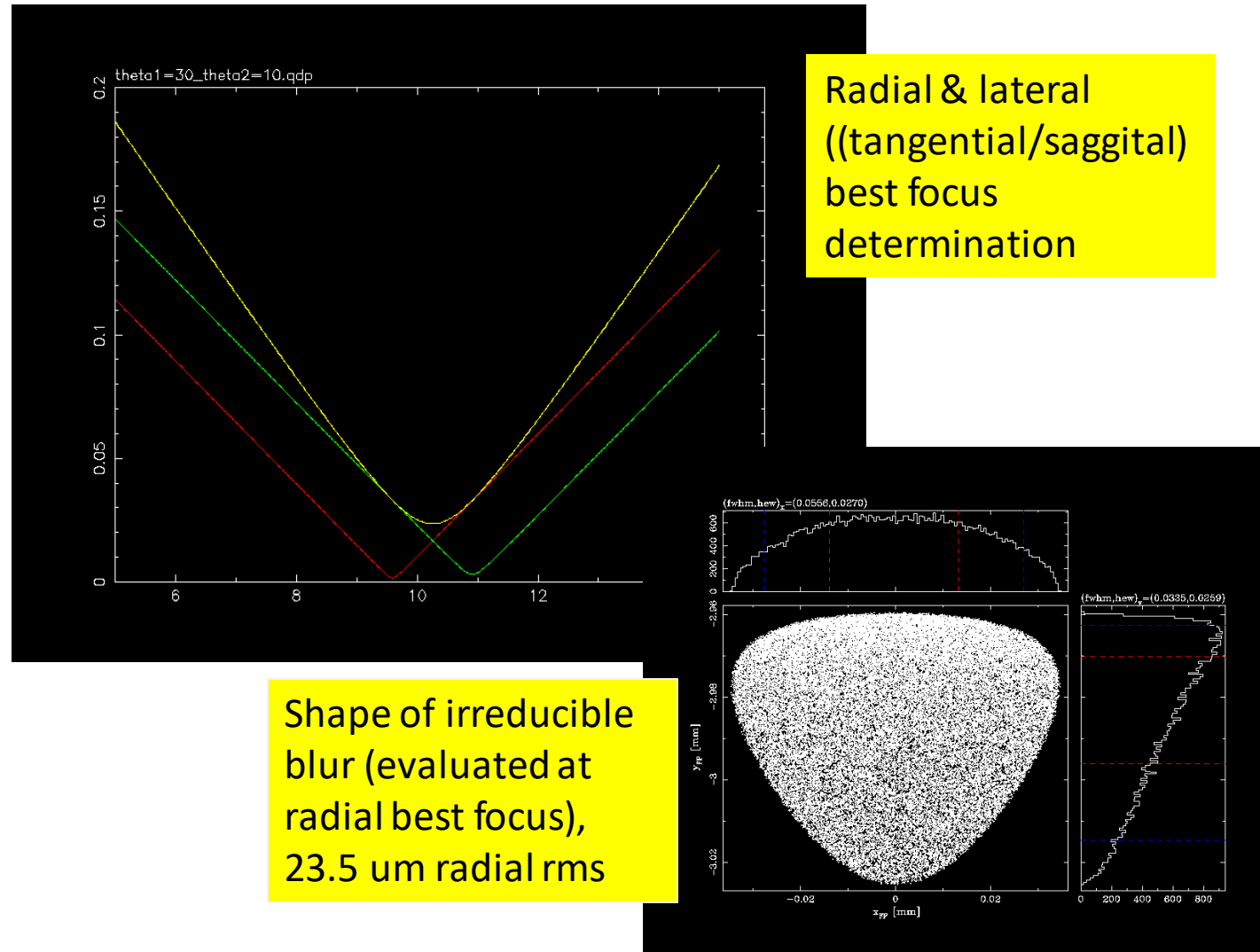
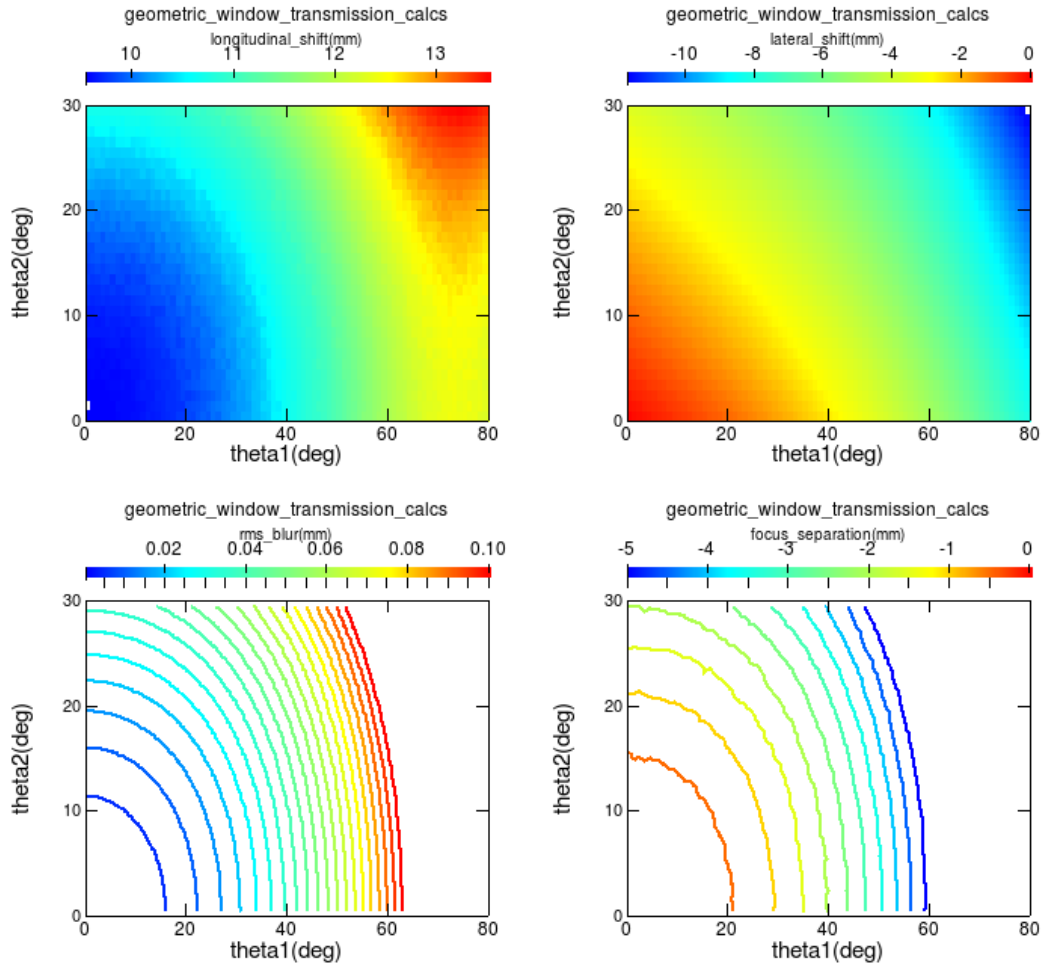


Record: lateral & longitudinal shifts of the apparent source, separation between orthogonal best focus, and minimum blur size.

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.



Radial & lateral ((tangential/sagittal) best focus determination

Shape of irreducible blur (evaluated at radial best focus), 23.5 um radial rms