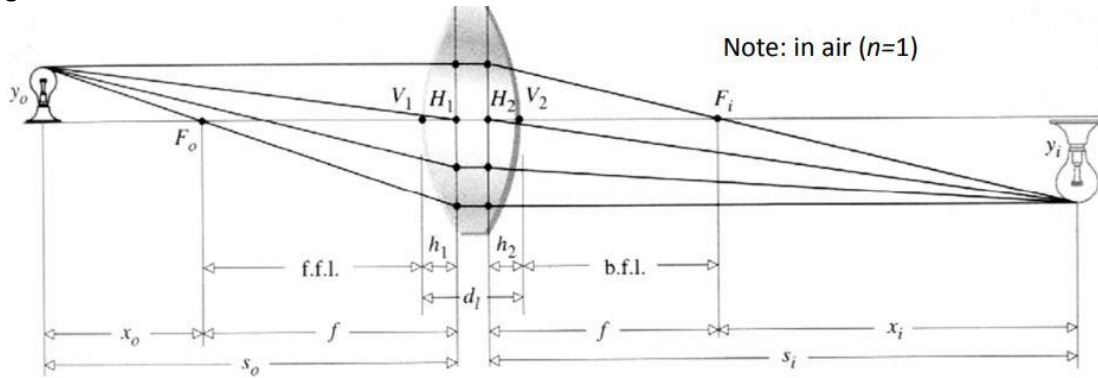


Singlet lens:



Consider a singlet lens of

Focal length - f

Power of lens - $\Phi = 1/f$

Radius of curvature of first surface R_1

Radius of curvature of second surface $R_2 = -R_1$

Thickness of lens = d_1

Refractive index $n=1.5168$

$$\Phi = (n-1)/R_1 + (1-n)/R_2 + ((d_1/n)*(n-1)^2/(R_1 R_2))$$

$$\Phi = 2(n-1)/R_1 - ((d_1/n)*(n-1)^2/(R_1^2))$$

$$\Phi = 1.03/R_1 - (0.18 d_1/R_1^2)$$

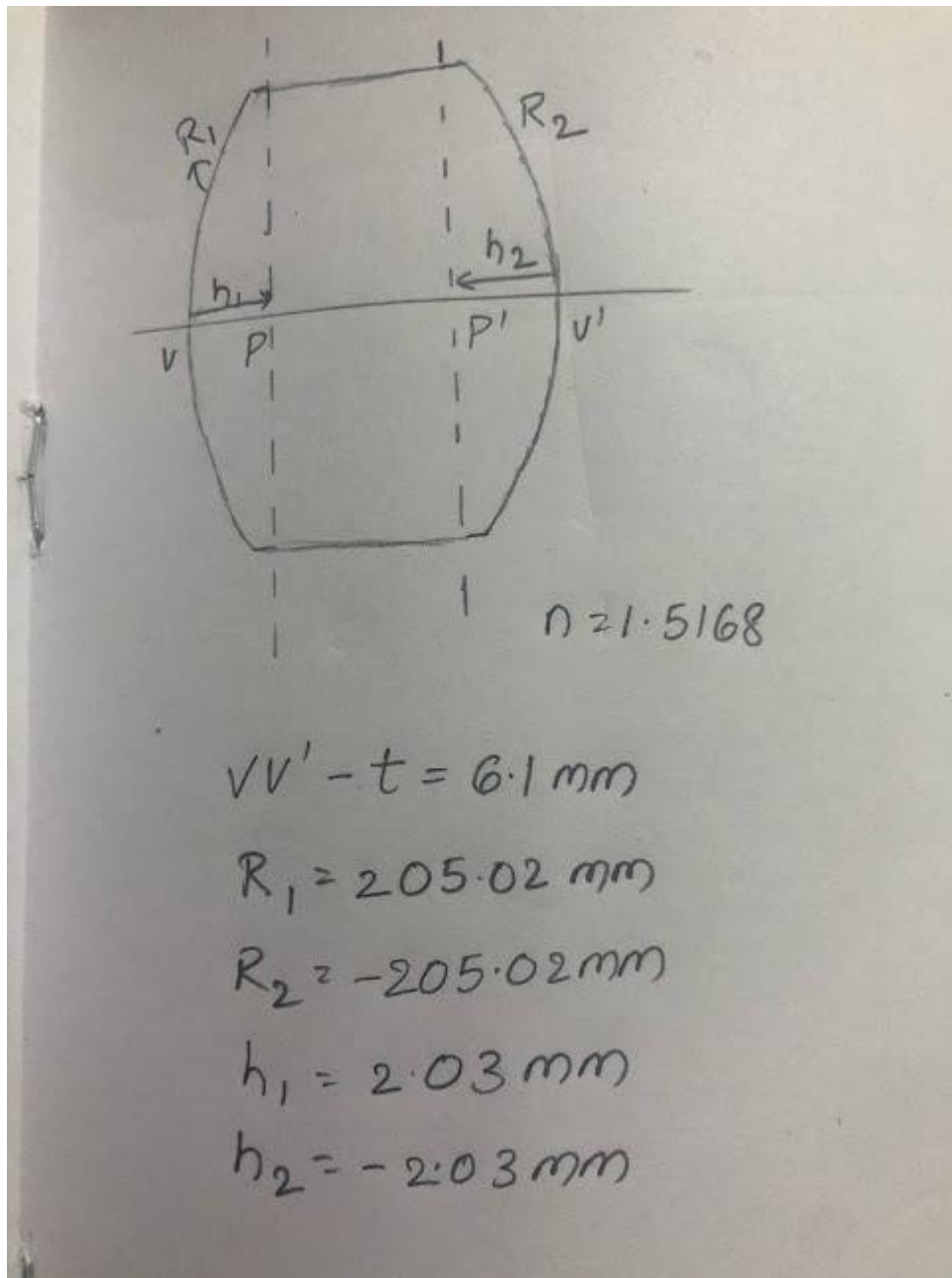
$$f.f.l = f(1 - [d_1 (n-1)/R_1])$$

$$b.f.l = f([d_1 (n-1)/R_1] - 1)$$

$$\text{Location of P : } h_1 = f d_1 (n-1)/R_1$$

$$\text{Location of P' : } h_2 = -f d_1 (n-1)/R_1$$

First lens $f = 200$



Assume $d_1 = 6.1 \text{ mm}$

$$\Phi = 1.03 / R_1 - (0.18 d_1 / R_1^2)$$

$$1/200 = 1.03 / R_1 - 1.01 / R_1^2$$

$$1.01 / R_1^2 - 1.03 / R_1 + 1/200 = 0$$

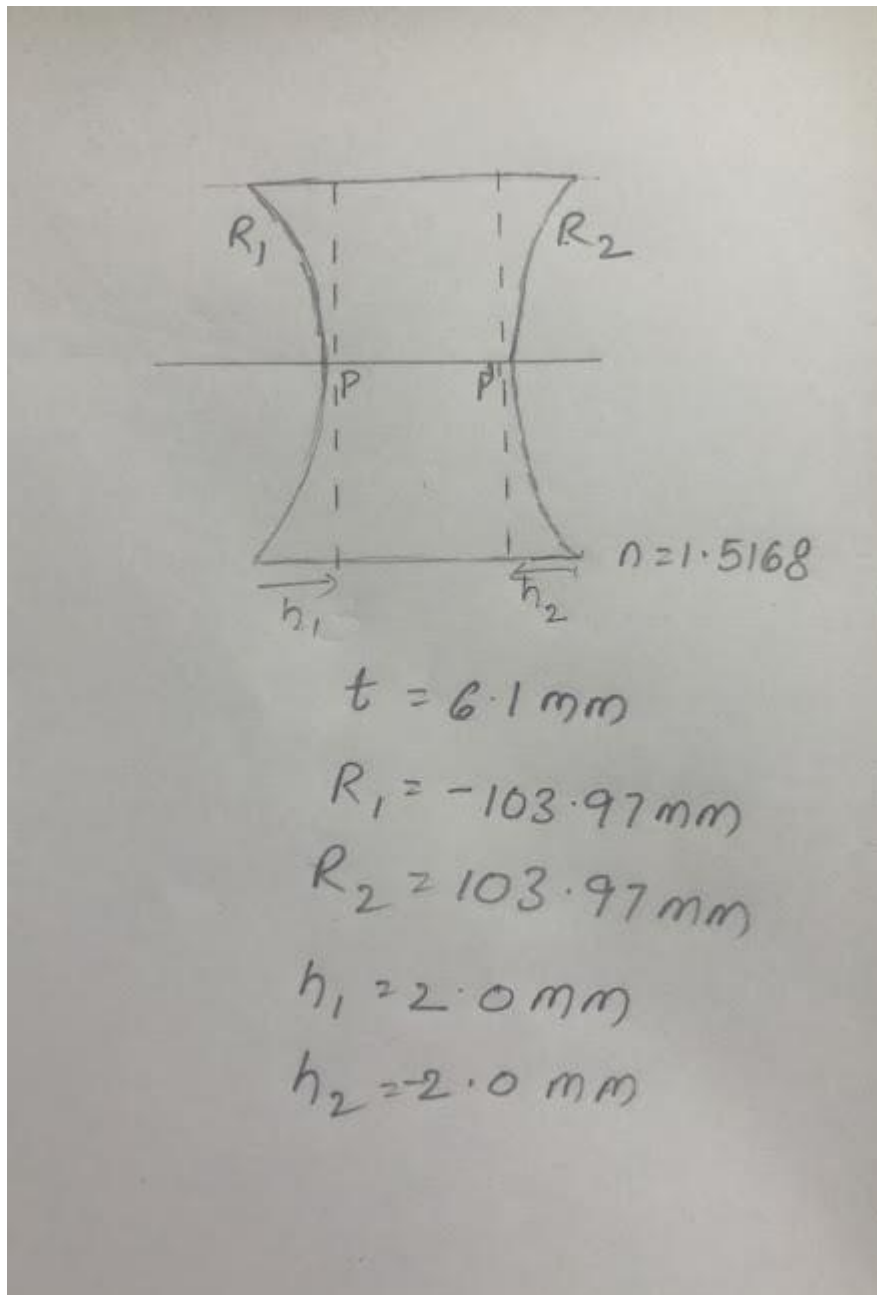
$$R_1 = 0.985 \text{ mm} \quad \text{Or} \quad R_1 = 205.02 \text{ mm}$$

Considering $R_1 = 205.02 \text{ mm}$

$$h_1 = f d_1 (n-1) / n R_1 = 2.03$$

$$h_2 = -f d_1 (n-1) / n R_1 = -2.03$$

Second lens $f = -100$



Assume $d_1 = 6.1 \text{ mm}$

$$\Phi = 1.03 / R_1 - (0.18 d_1 / R_1^2)$$

$$-1/100 = 1.03 / R_1 - 1.01 / R_1^2$$

$$1.01 / R_1^2 - 1.03 / R_1 - 1/100 = 0$$

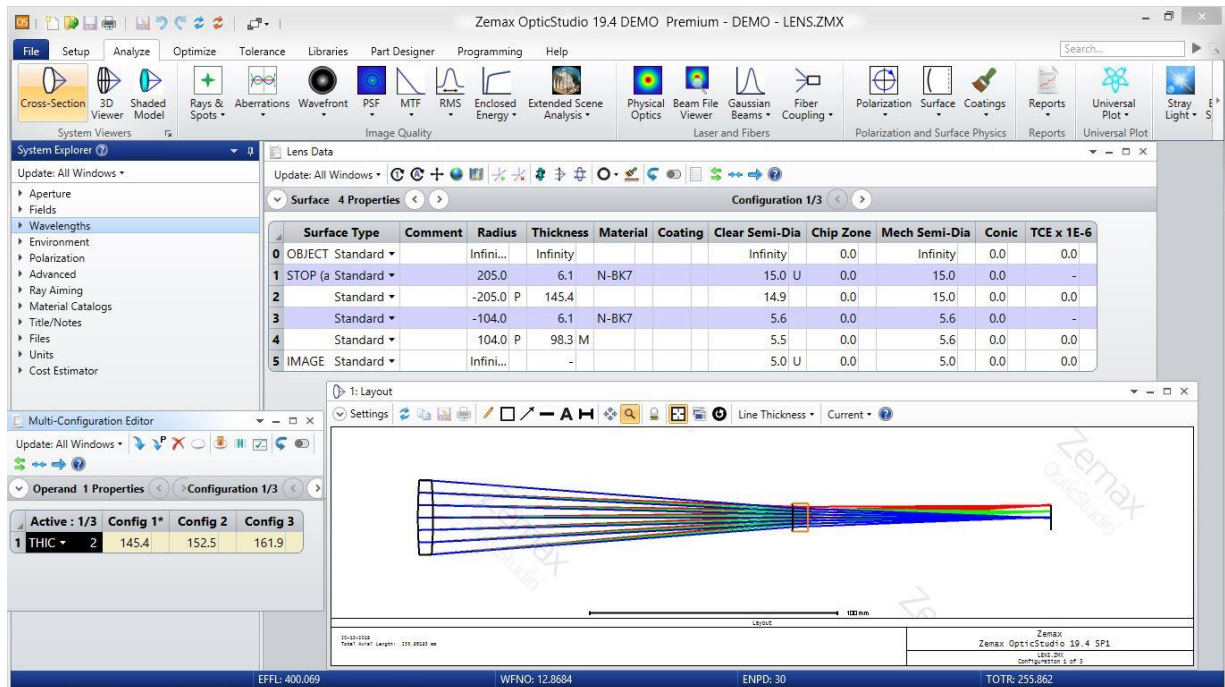
$$R_1 = 0.9714 \text{ mm} \quad \text{Or} \quad R_1 = -103.97 \text{ mm}$$

Considering $R_1 = -103.97 \text{ mm}$

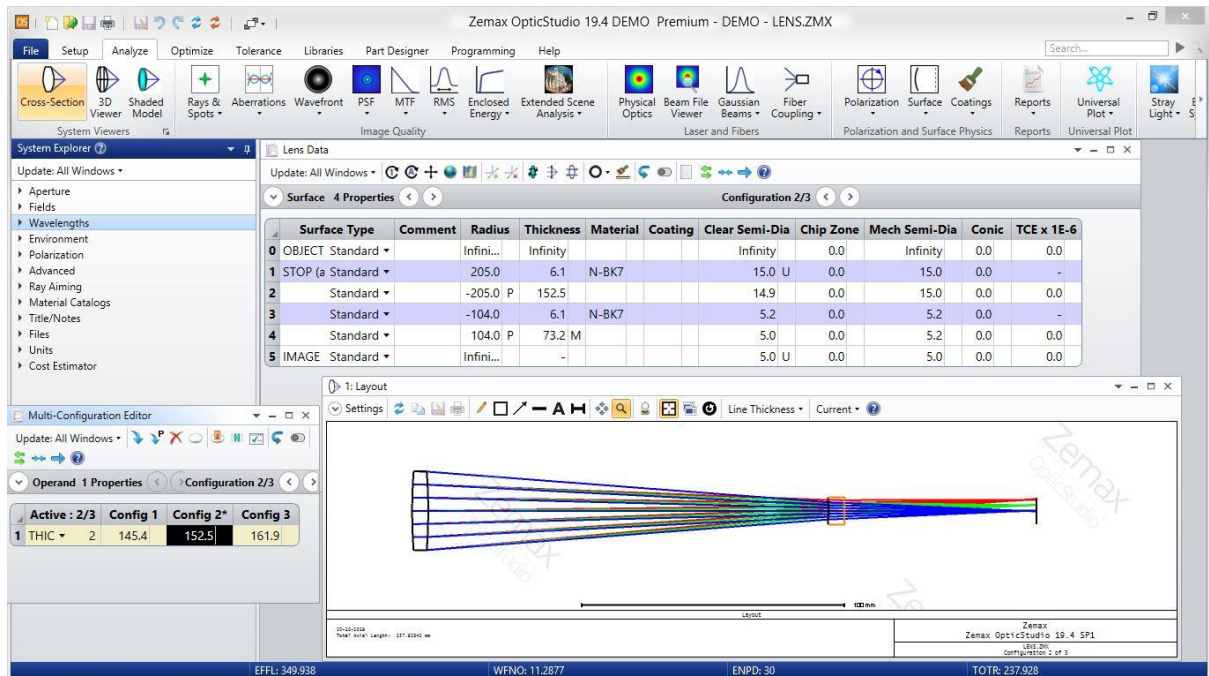
$$h_1 = f d_1 (n-1) / R_1 = 2.0$$

$$h_2 = -f d_1 (n-1) / R_1 = -2.0$$

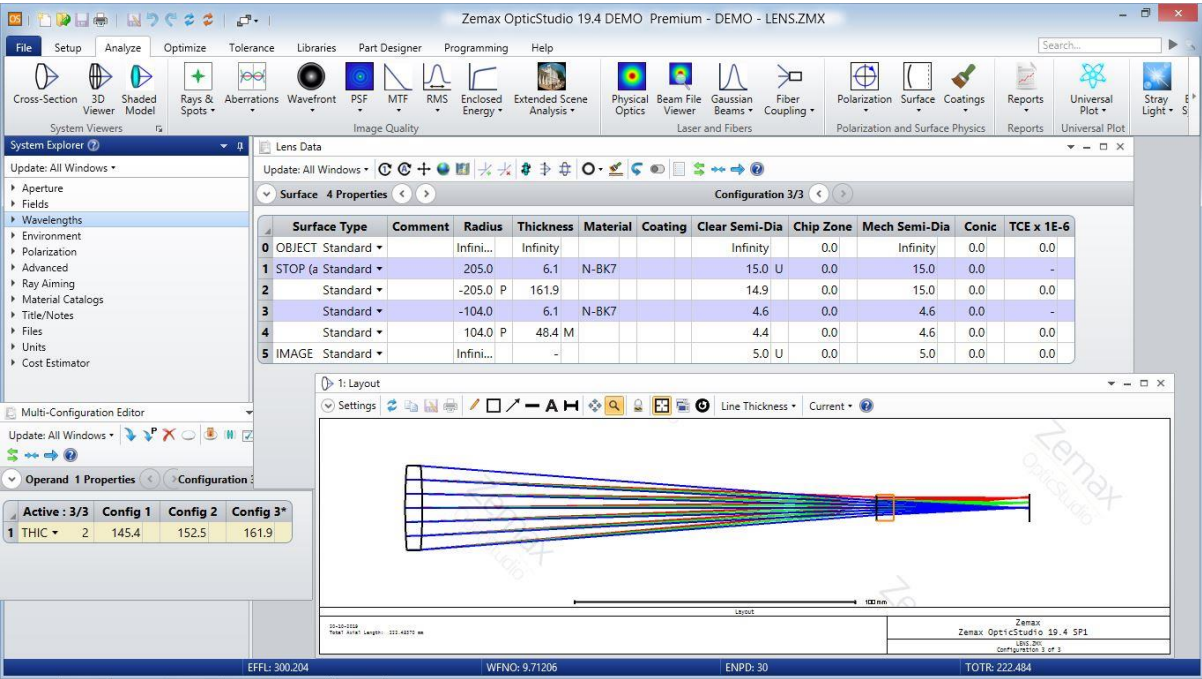
Config1 (F=400mm):



Config2(F=350mm):



Config (F=300mm)



Optimized Singlet Lens Design

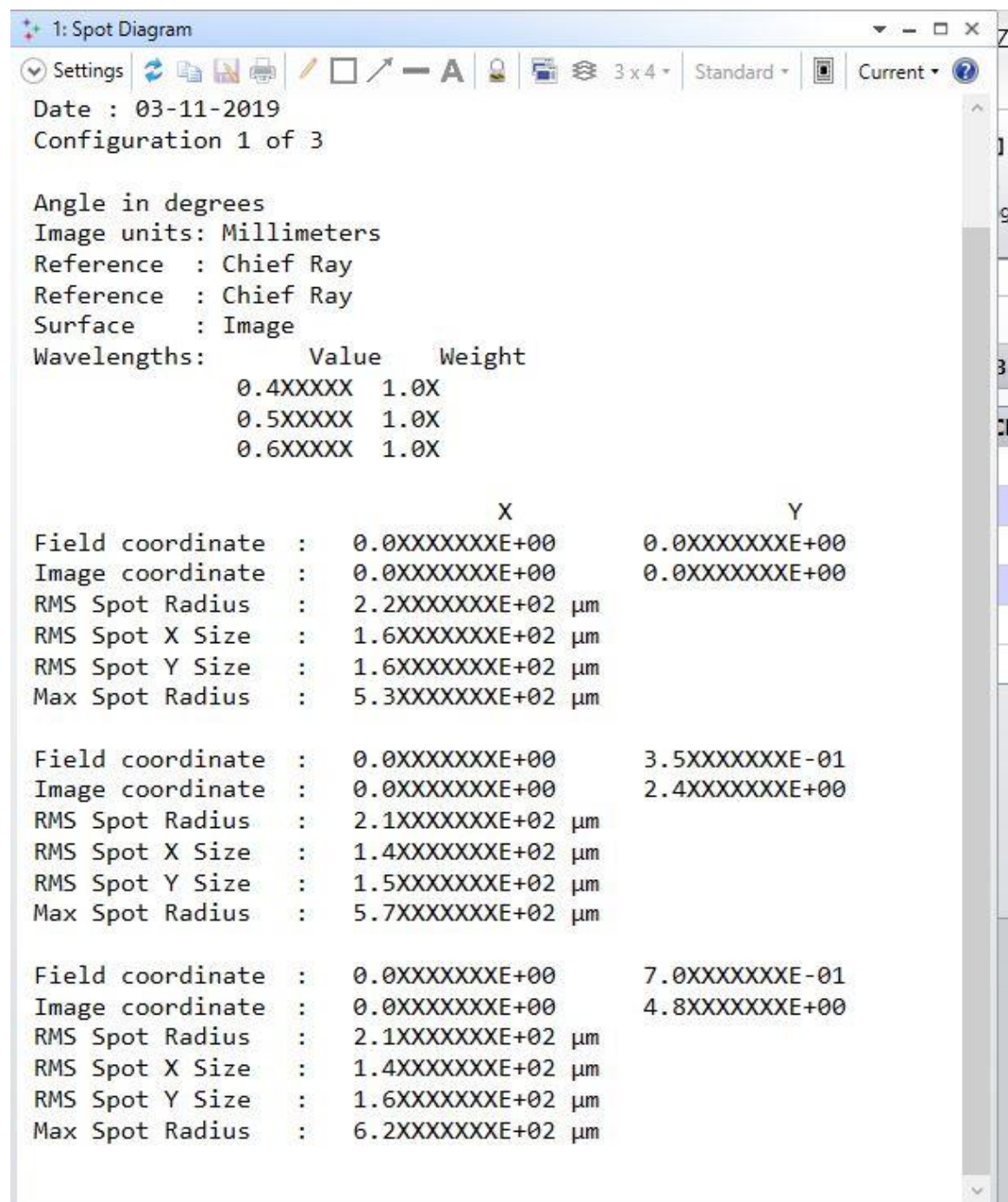
Initial Merit Function: 6.237

Merit Function Editor

Wizards and Operands Merit Function: 6.23747804488397

Type	Cfg#								
1 CONF ▾	1								
2 EFFL ▾	1				400.0	1.0	383.5	39.0	
3 TOTR ▾					255.8	1.0	255.8	1.4E-04	
4 CONF ▾	1								
5 EFFL ▾	2				400.0	1.0	400.0	2.0E-05	
6 TOTR ▾					255.8	1.0	255.8	1.4E-04	
7 CONF ▾	1								
8 EFFL ▾	3				400.0	1.0	407.7	8.5	
9 TOTR ▾					255.8	1.0	255.8	1.4E-04	
10 CONF ▾	2								
11 EFFL ▾	1				350.0	1.0	336.4	26.6	
12 TOTR ▾					237.9	1.0	237.9	1.2E-04	
13 CONF ▾	2								
14 EFFL ▾	2				350.0	1.0	349.9	5.6E-04	
15 TOTR ▾					237.9	1.0	237.9	1.2E-04	
16 CONF ▾	2								
17 EFFL ▾	3				350.0	1.0	356.3	5.6	
18 TOTR ▾					237.9	1.0	237.9	1.2E-04	
19 CONF ▾	3								
20 EFFL ▾	1				300.0	1.0	289.3	16.4	
21 TOTR ▾					222.5	1.0	222.5	3.8E-05	
22 CONF ▾	3								
23 EFFL ▾	2				300.0	1.0	300.2	6.0E-03	
24 TOTR ▾					222.5	1.0	222.5	3.8E-05	
25 CONF ▾	3								
26 EFFL ▾	3				300.0	1.0	305.3	4.0	
27 TOTR ▾					222.5	1.0	222.5	3.8E-05	

Spot Diagram:



Merit function: 5.971

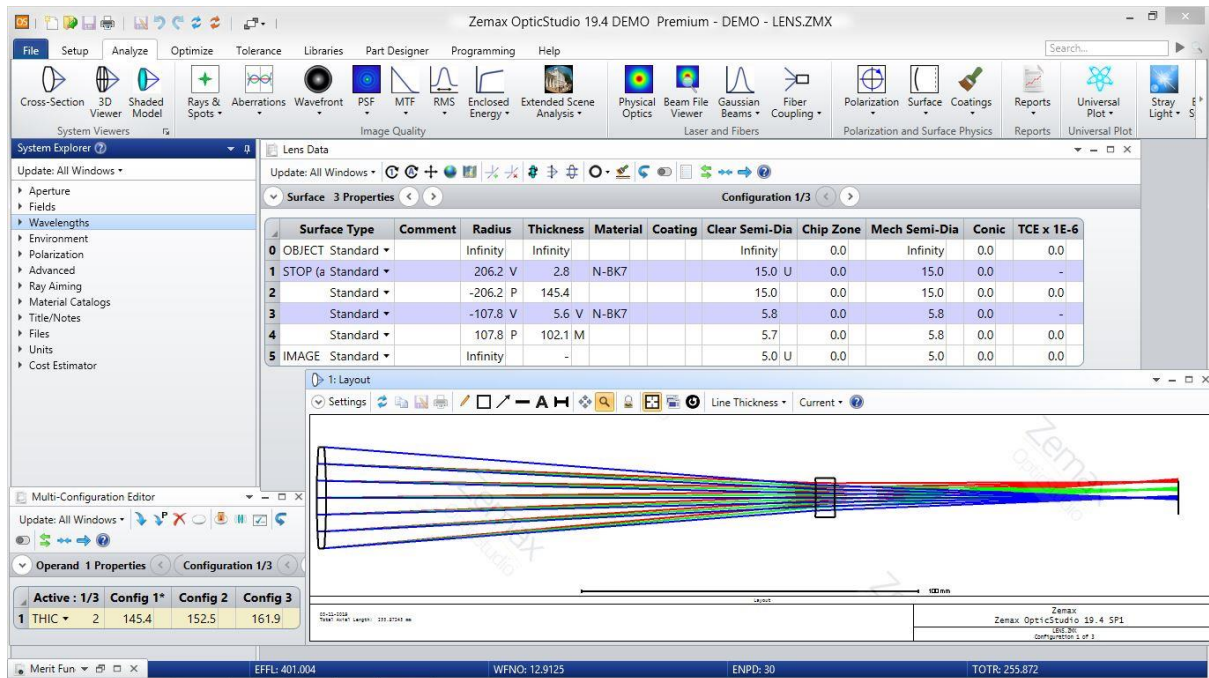
[illegible]

Spot Diagram: RMS Spot Radius has also been reduced by 40 for all the 3 field angles

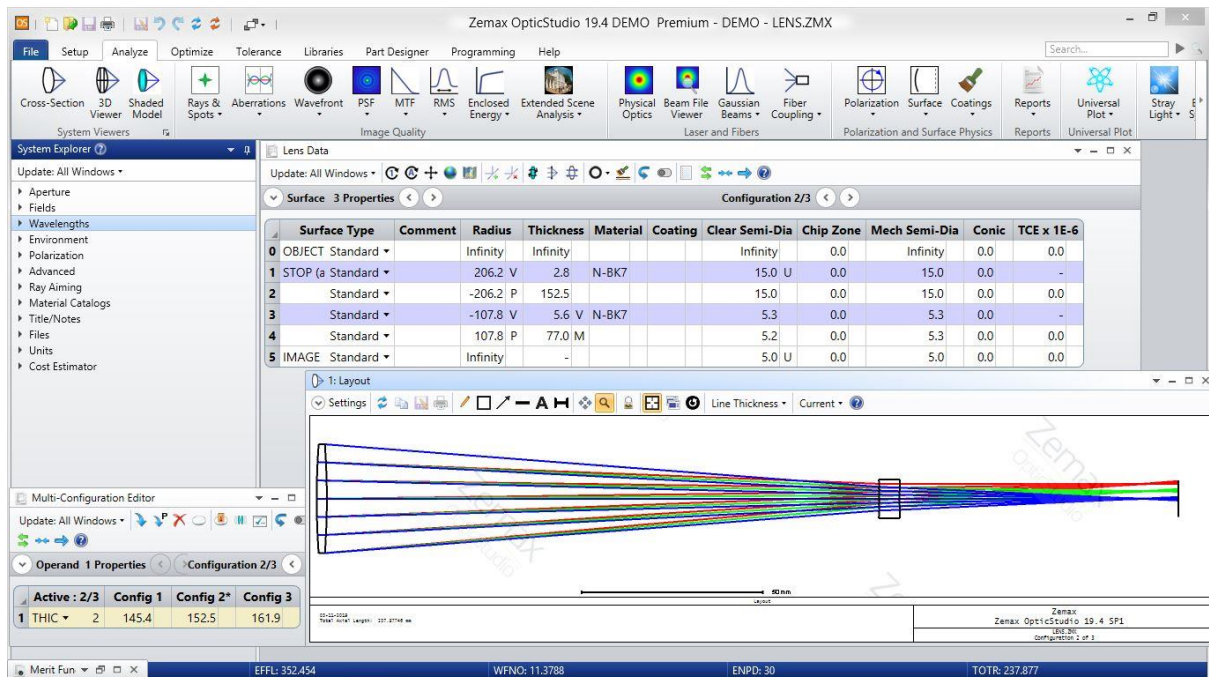
Angle in degrees		
Image units: Millimeters		
Reference : Chief Ray		
Reference : Chief Ray		
Surface : Image		
Wavelengths:	Value	Weight
	0.4XXXXX	1.0X
	0.5XXXXX	1.0X
	0.6XXXXX	1.0X
	X	Y
Field coordinate :	0.0XXXXXXXXXE+00	0.0XXXXXXXXXE+00
Image coordinate :	0.0XXXXXXXXXE+00	0.0XXXXXXXXXE+00
RMS Spot Radius :	1.8XXXXXXXXXE+02 μm	
RMS Spot X Size :	1.3XXXXXXXXXE+02 μm	
RMS Spot Y Size :	1.3XXXXXXXXXE+02 μm	
Max Spot Radius :	4.3XXXXXXXXXE+02 μm	
Field coordinate :	0.0XXXXXXXXXE+00	3.5XXXXXXXXXE-01
Image coordinate :	0.0XXXXXXXXXE+00	1.8XXXXXXXXXE+00
RMS Spot Radius :	1.7XXXXXXXXXE+02 μm	
RMS Spot X Size :	1.1XXXXXXXXXE+02 μm	
RMS Spot Y Size :	1.2XXXXXXXXXE+02 μm	
Max Spot Radius :	4.6XXXXXXXXXE+02 μm	
Field coordinate :	0.0XXXXXXXXXE+00	7.0XXXXXXXXXE-01
Image coordinate :	0.0XXXXXXXXXE+00	3.7XXXXXXXXXE+00
RMS Spot Radius :	1.7XXXXXXXXXE+02 μm	
RMS Spot X Size :	1.1XXXXXXXXXE+02 μm	
RMS Spot Y Size :	1.3XXXXXXXXXE+02 μm	
Max Spot Radius :	4.9XXXXXXXXXE+02 μm	

After optimization,

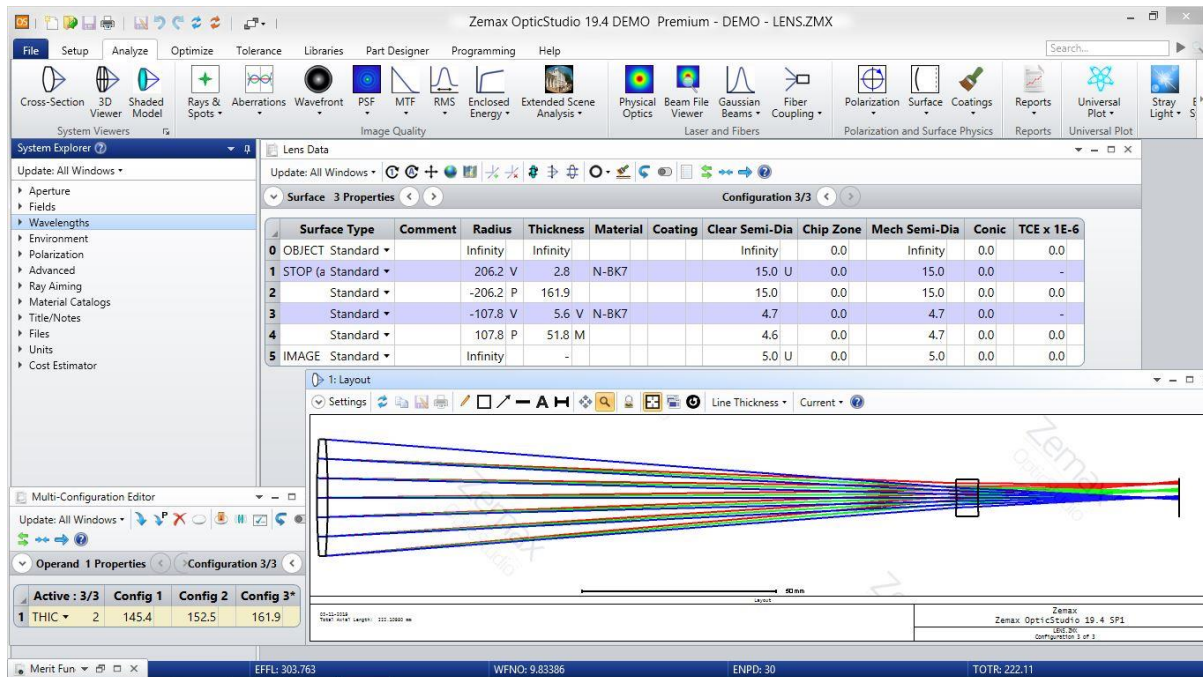
Config1 (F=400mm)



Config2 (F=350mm)



Config3 (F=300mm)

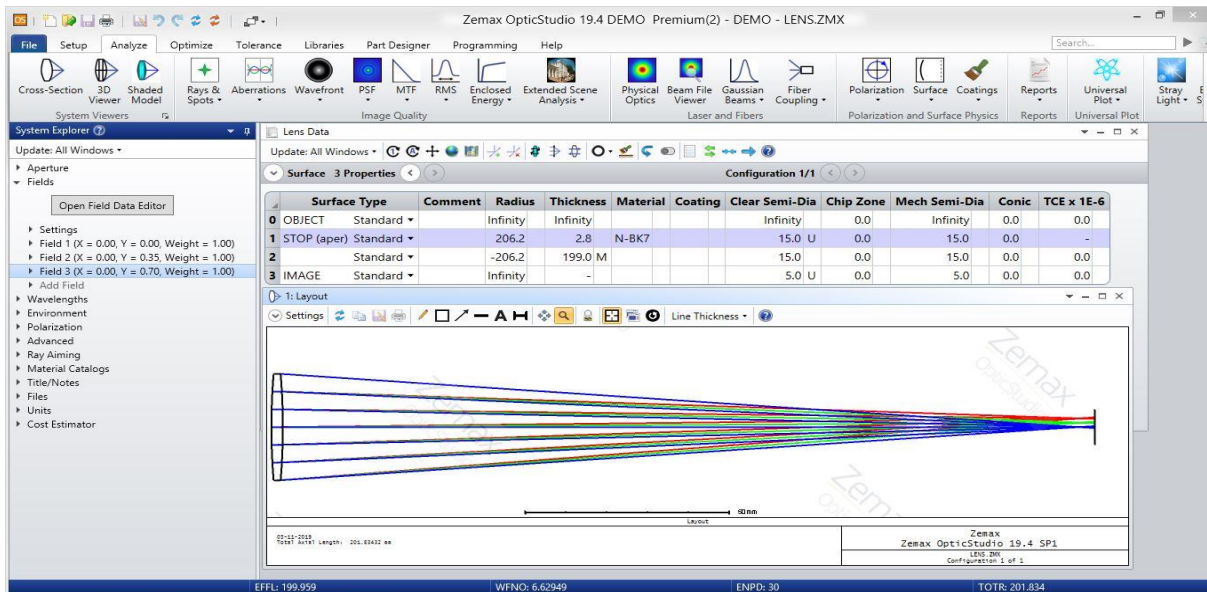


All the configurations meet the constraint of throw < 300mm while attaining effective focal length.

Optimized Multi-Element Lens Design

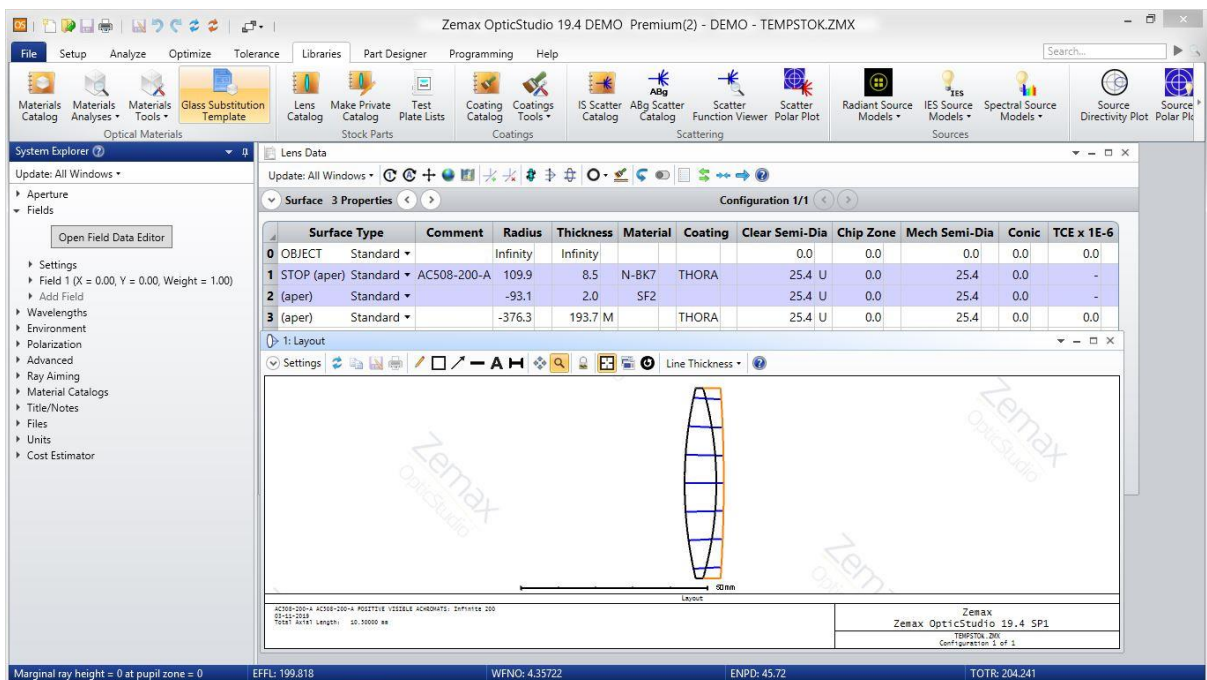
In the optimized singlet design,

Focal length of first singlet lens = 200

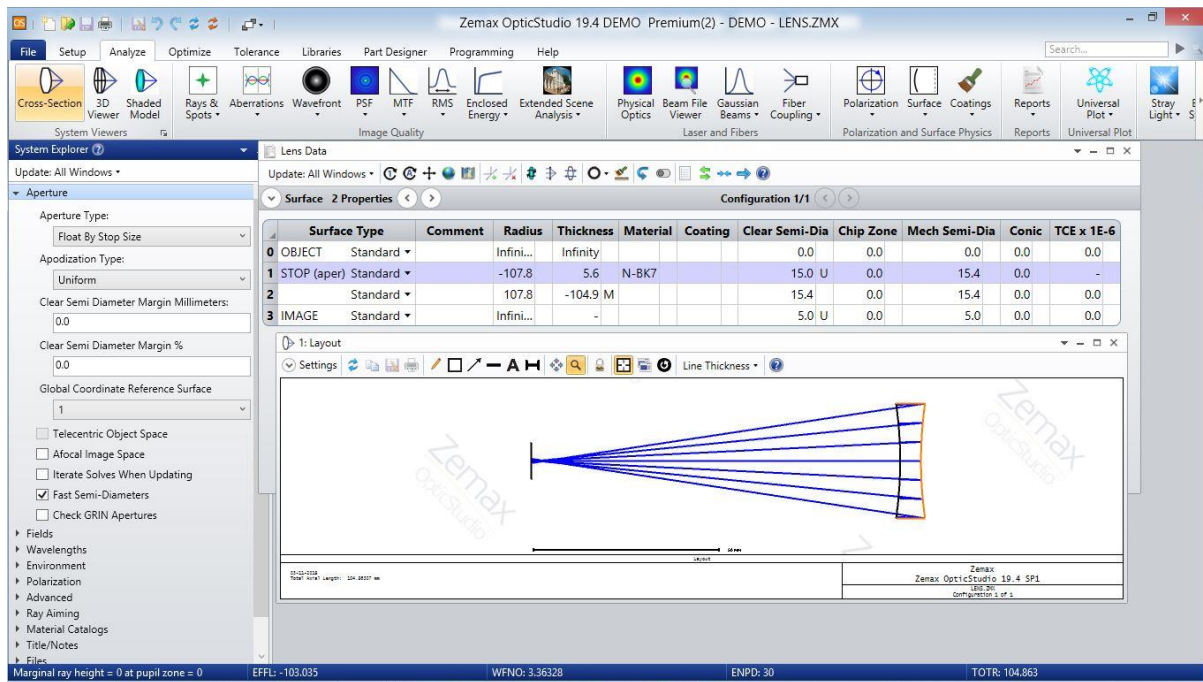


I have replaced first singlet lens with I have replaced second singlet lens with Doublet lens :

AC-508-200-A EFL=199.80 EPD=45.72 (?,S,2) from THORLABS

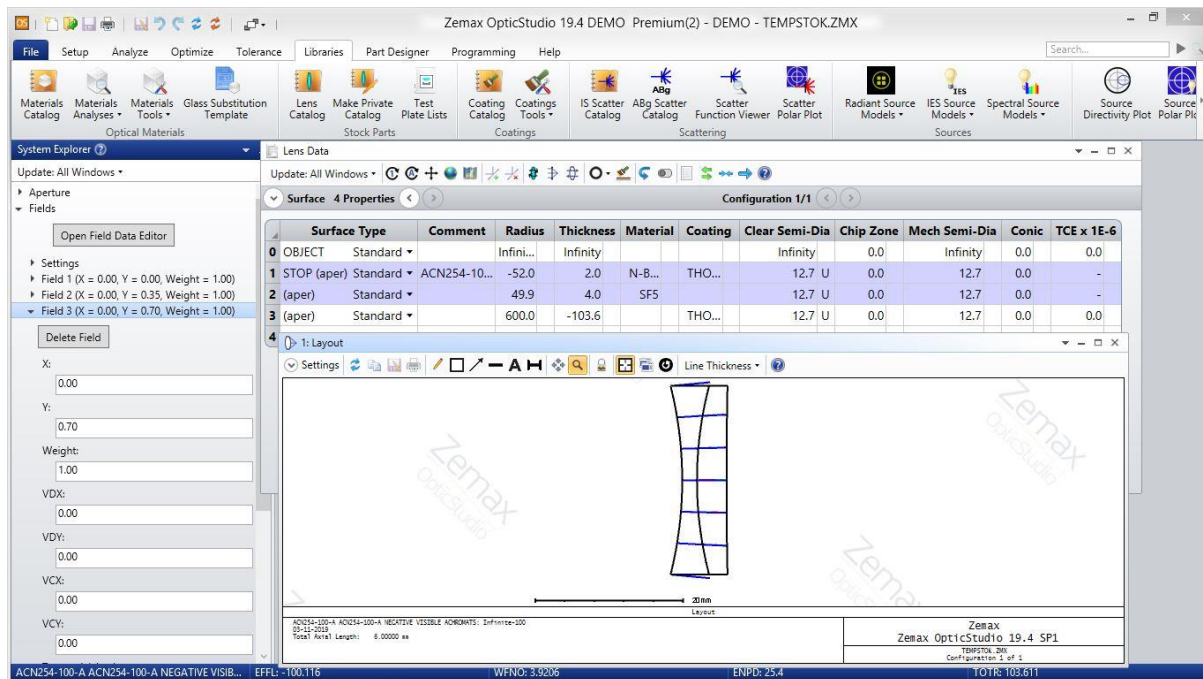


Focal length of second singlet lens = -100

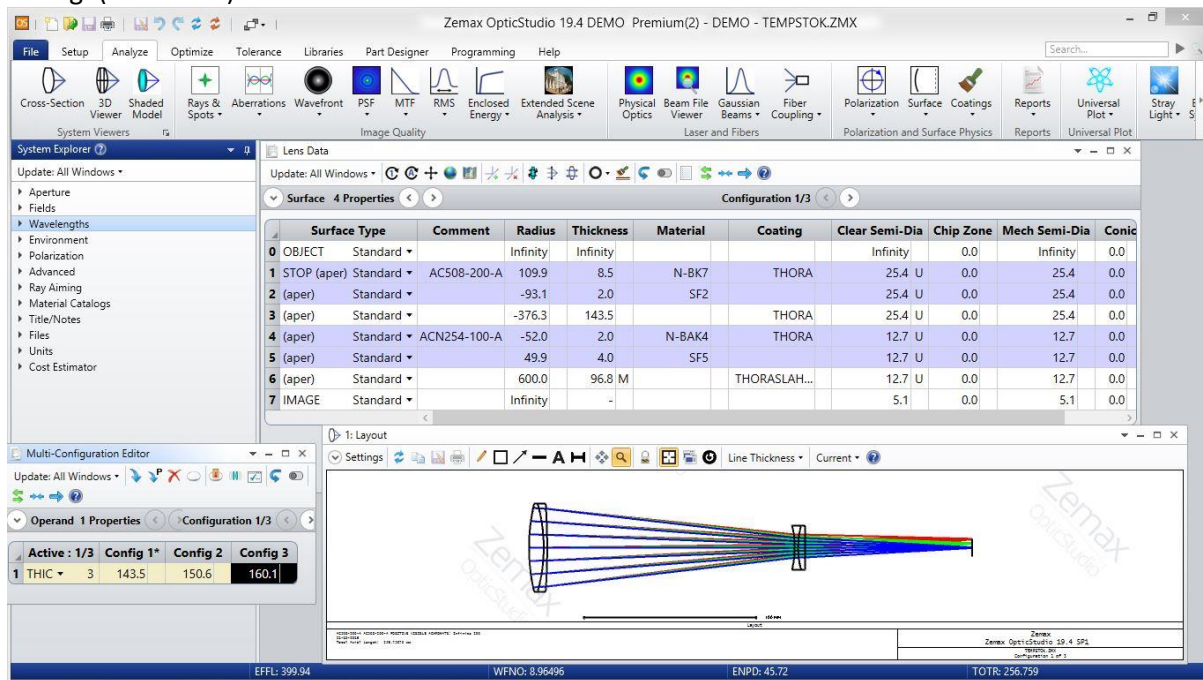


I have replaced second singlet lens with I have replaced second singlet lens with Doublet lens :

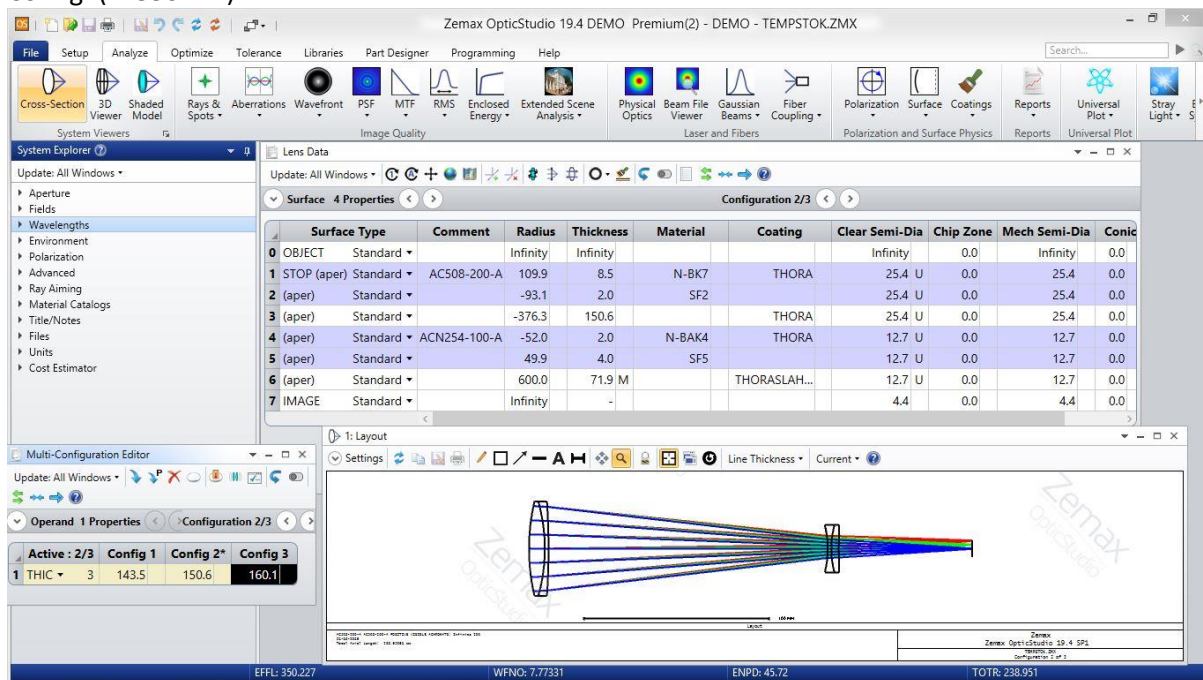
ACN254-100-A EFL=-100.10 EPD=21.84 (?,S,2) from THORLABS



Config1(F=400mm):



Config2(F=350mm):



Config3(F=300mm):

Zemax OpticStudio 19.4 DEMO Premium(2) - DEMO - TEMPSTOK.ZMX

File Setup Analyze Optimize Tolerance Libraries Part Designer Programming Help

Cross-Section 3D Shaded Model Rays & Spots Aberrations Wavefront PSF MTF RMS Enclosed Energy Extended Scene Analysis Physical Optics Beam File Viewer Gaussian Beams Fiber Coupling Polarization Surface Coatings Reports Universal Plot Stray Light

System Explorer

Update: All Windows

- Aperture
- Fields
- Wavelengths
- Environment
- Polarization
- Advanced
- Ray Aiming
- Material Catalogs
- Title/Notes
- Files
- Units
- Cost Estimator

System Views

Update: All Windows

Surface 4 Properties

Configuration 3/3

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone	Mech Semi-Dia	Conic	
0	OBJECT	Standard	Infinity	Infinity			Infinity	0.0	Infinity	0.0	
1	STOP (aper)	Standard	AC508-200-A	109.9	8.5	N-BK7	THORA	25.4 U	0.0	25.4	0.0
2	(aper)	Standard		-93.1	2.0	SF2		25.4 U	0.0	25.4	0.0
3	(aper)	Standard		-376.3	160.1		THORA	25.4 U	0.0	25.4	0.0
4	(aper)	Standard	ACN254-100-A	-52.0	2.0	N-BAK4	THORA	12.7 U	0.0	12.7	0.0
5	(aper)	Standard		49.9	4.0	SF5		12.7 U	0.0	12.7	0.0
6	(aper)	Standard		600.0	46.8 M		THORASLAH...	12.7 U	0.0	12.7	0.0
7	IMAGE	Standard		Infinity			3.7	0.0	3.7	0.0	

Multi-Configuration Editor

Update: All Windows

Operand 1 Properties

Configuration 3/3

Active : 3/3 Config 1 Config 2 Config 3*

1 THIC 3 143.5 150.6 160.1

1: Layout

Settings

Line Thickness Current

AC508-200-A AC508-200-A POSITIVE VISIBLE A... EFFL: 300.285 WFNO: 6.60694 ENPD: 45.72 TOTR: 223.428

Merit Function: Using doublet lenses in the place of singlet lens has drastically reduced the merit function from 5.971 to 0.909

[illegible]

Spot Diagram: RMS Spot Radius has reduced from 180 to 28 by replacing singlet with doublet lens

```
Angle in degrees
Image units: Millimeters
Reference   : Chief Ray
Reference   : Chief Ray
Surface     : Image
Wavelengths:      Value      Weight
                0.4XXXXXX  1.0X
                0.5XXXXXX  1.0X
                0.6XXXXXX  1.0X

Field coordinate :      X      Y
Image coordinate :      X      Y
RMS Spot Radius  : 2.8XXXXXXXE+01 µm
RMS Spot X Size  : 1.9XXXXXXXE+01 µm
RMS Spot Y Size  : 1.9XXXXXXXE+01 µm
Max Spot Radius  : 5.4XXXXXXXE+01 µm

Field coordinate :      X      Y
Image coordinate :      X      Y
RMS Spot Radius  : 2.8XXXXXXXE+01 µm
RMS Spot X Size  : 1.9XXXXXXXE+01 µm
RMS Spot Y Size  : 1.9XXXXXXXE+01 µm
Max Spot Radius  : 6.2XXXXXXXE+01 µm

Field coordinate :      X      Y
Image coordinate :      X      Y
RMS Spot Radius  : 2.8XXXXXXXE+01 µm
RMS Spot X Size  : 1.9XXXXXXXE+01 µm
RMS Spot Y Size  : 1.9XXXXXXXE+01 µm
Max Spot Radius  : 6.7XXXXXXXE+01 µm
```

Graph

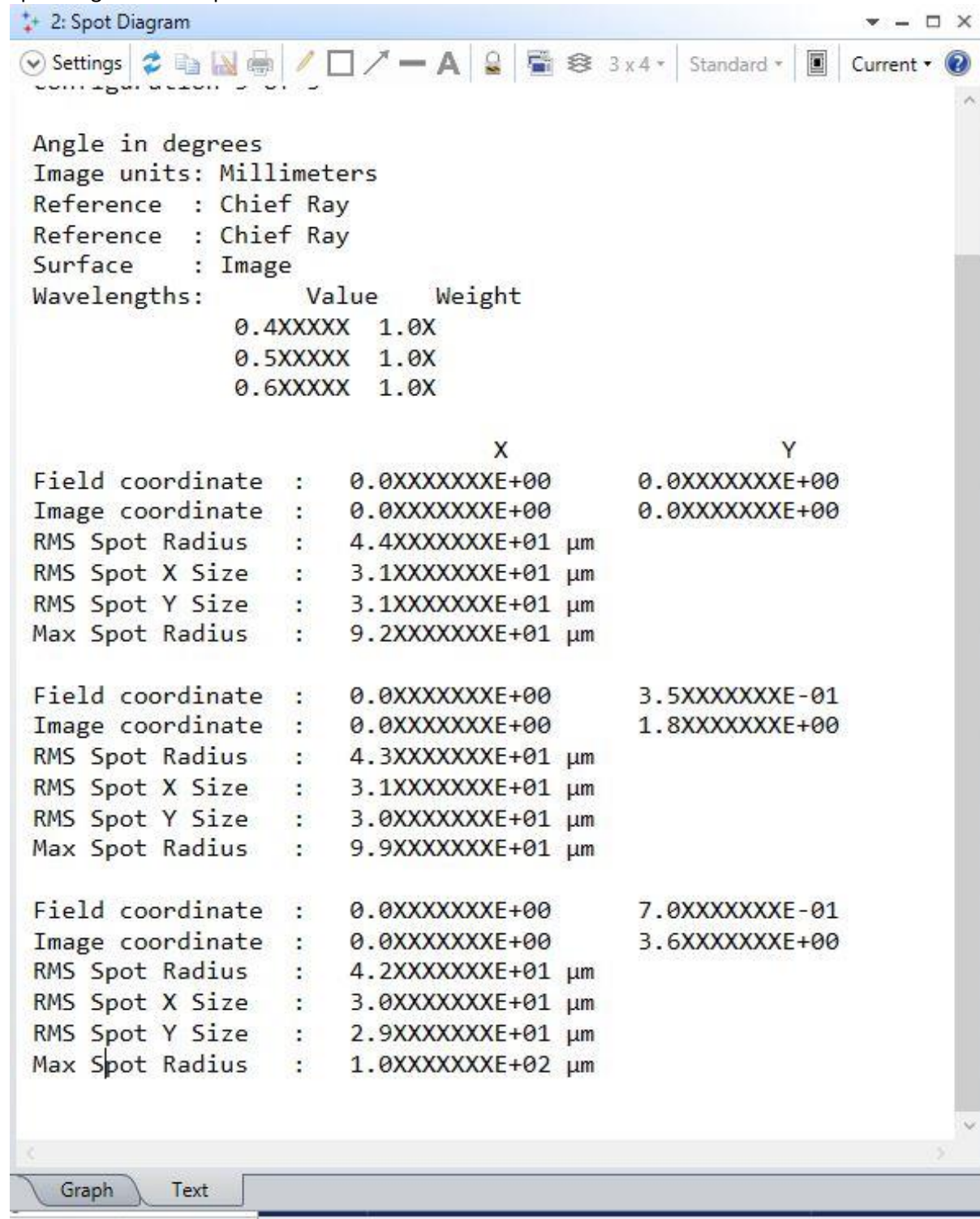
Text

Optimized merit function: On optimizing the doublet lens system, the merit function reduced from

0.909 to 0.293

Merit Function Editor										
Wizards and Operands										
Merit Function: 0.293337282274687										
	Type	Cfg#								
1	CONF	1								
2	EFFL		1				400.0	1.0	400.1	0.7
3	TOTR						256.8	1.0	256.6	3.8
4	CONF	1								
5	EFFL		2				400.0	1.0	399.4	26.8
6	TOTR						256.8	1.0	256.6	3.8
7	CONF	1								
8	EFFL		3				400.0	1.0	400.2	2.0
9	TOTR						256.8	1.0	256.6	3.8
10	CONF	2								
11	EFFL		1				350.0	1.0	350.2	2.6
12	TOTR						239.0	1.0	238.8	2.3
13	CONF	2								
14	EFFL		2				350.0	1.0	349.8	2.9
15	TOTR						239.0	1.0	238.8	2.3
16	CONF	2								
17	EFFL		3				350.0	1.0	350.5	18.6
18	TOTR						239.0	1.0	238.8	2.3
19	CONF	3								
20	EFFL		1				300.0	1.0	300.1	0.9
21	TOTR						223.4	1.0	223.3	0.2
22	CONF	3								
23	EFFL		2				300.0	1.0	300.0	0.1
24	TOTR						223.4	1.0	223.3	0.2
25	CONF	3								
26	EFFL		3				300.0	1.0	300.6	26.3
27	TOTR						223.4	1.0	223.3	0.2
28	DMFS									
29	CONF	1								

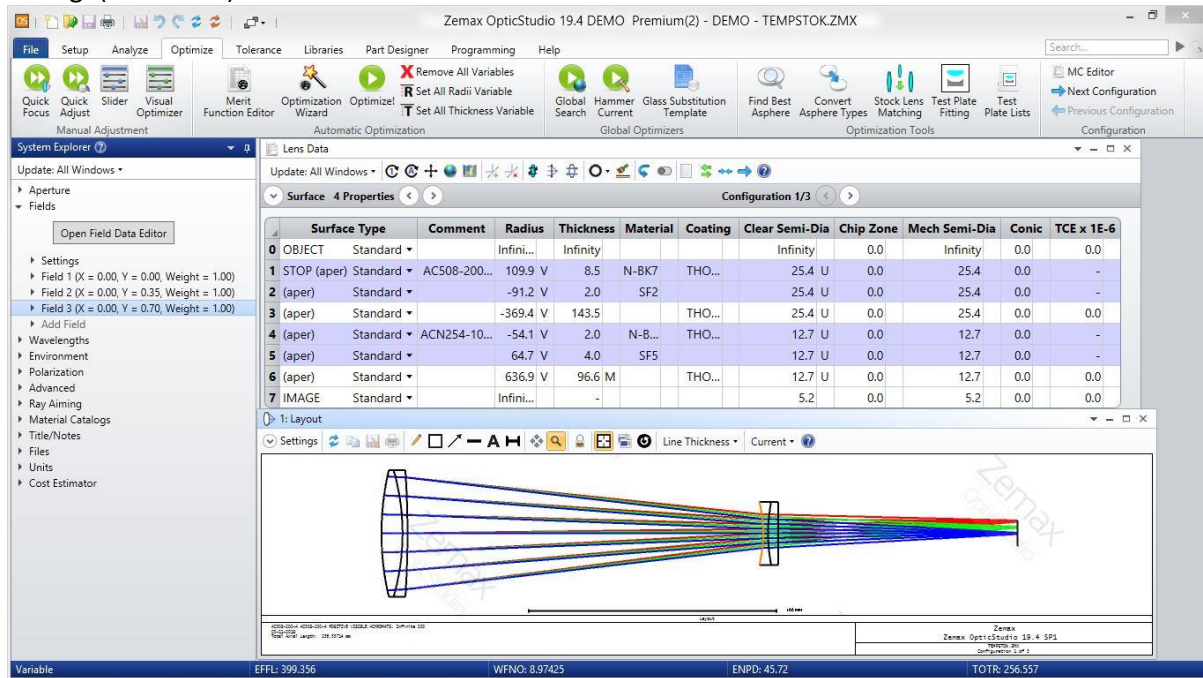
Spot Diagram: RMS Spot radius



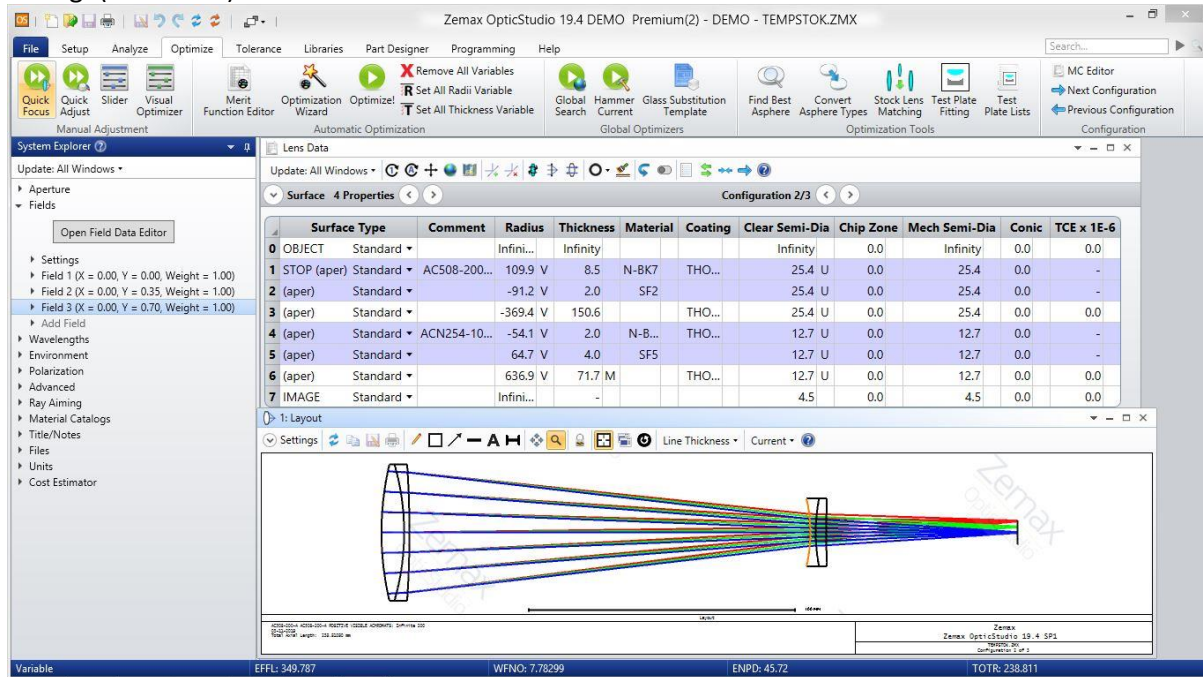
Starting from initial singlet design to optimized doublet system,

The merit function reduced from 6.237 to 0.293. RMS Spot radius reduced from 220 to 44

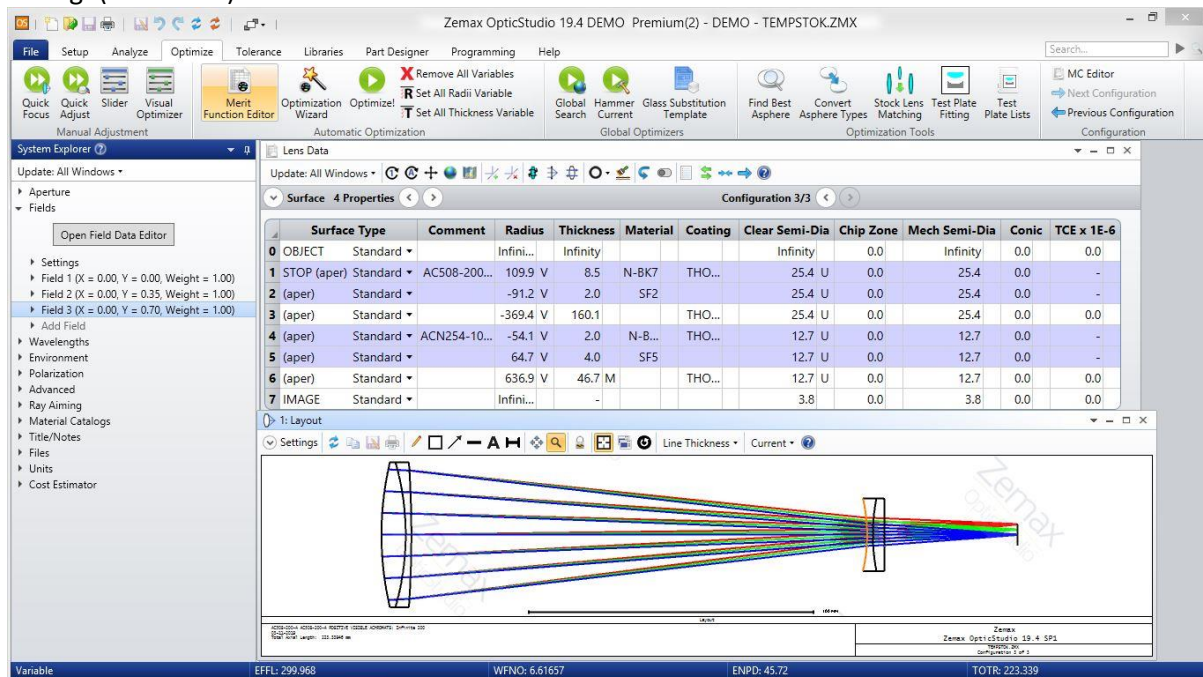
Config1(F=400mm)



Config2(F=350mm)



Config3(F=300mm)



After optimizing the doublet lens system, all the 3 configurations attain the focal length specified with throw < 300mm