2013-02-04

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Exercise Solution
Lecture Optical design with Zemax– Part 8

8 Correction

8.1 Correction with Buried Surface

Select an achromatic system with focal length f = 50 mm out of a vendor catalog. For an incoming collimated beam diameter of 10 mm this gives a nearly diffraction limited imaging quality for λ = 546 nm. Now increase the numerical aperture by inserting a aplanatic concentric lens with thickness 3 mm and made of the glass F9. Now a broadband spectrum is considered, which is characterized by the wavelengths e F' C'. Show, that the performance for blue and red is not diffraction limited.
In the next step, the meniscus lens is splitted into a cemented component, where the second lens is made of the glass SK16. This gives a burierd surface lens. Show, that the correction for green is not perturbed. Is the spot better or unchanged ? Improve now the chromatic correction by optimizing the cemented surface of the burier component. Is the performance diffraction limited over the complete spectral range ? Now re-optimize the first achromatic component only with the radii. What is the overall performance now ?
In a last step, combine the system with a the reversed version to get a perfect symmetrical system. The distance between the two parts should be 2 mm. Show that for a finite field of height 3 mm the asymmetrical aberrations vanish completly. What is the remaining and dominating aberration ?

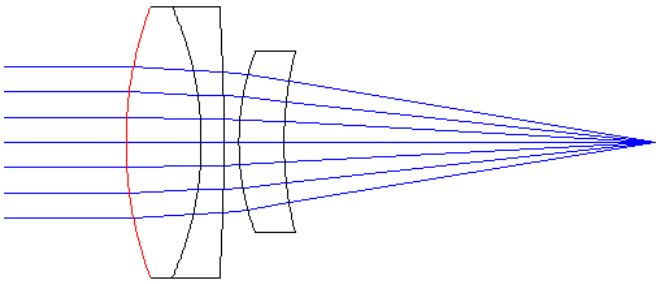
Solution:

We select the achromate with the number 322265000 from Linois Photonics. The wavelength e is chosen and the incoming beam aperture 10 mm is selected. Now the aplanatic concentric meniscus lens is added with a distance of 1 mm and a thickness of 3 mm of F9. After calculating the quick focus, the following system is obtained:

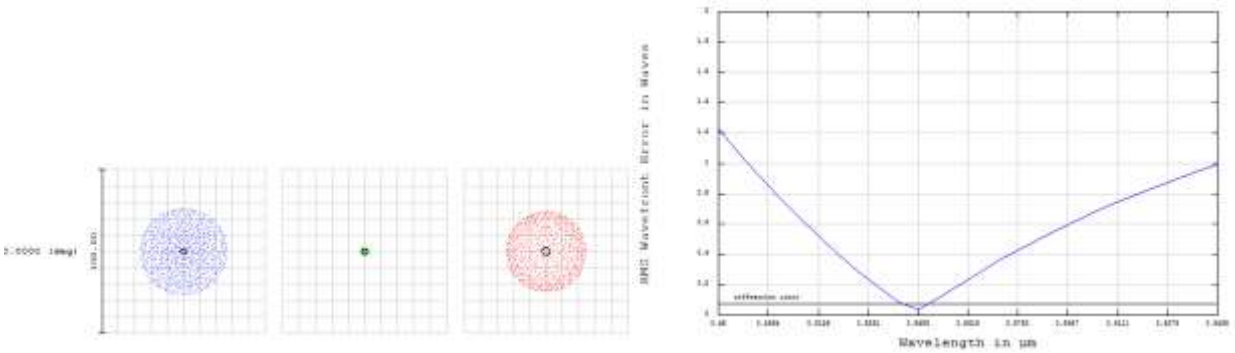
Lens Data Editor

Edit Solves View Help

Surf:Type		Comment	Radius		Thickness		Glass		Semi-Diameter	
OBJ	Standard		Infinity		Infinity				0.0000000	
1	Standard		Infinity		10.0000000				5.0000000	
*	Standard	322265000	25.4830000		5.0000000		N-BK7		9.0000000	U
3*	Standard		-21.9090000		1.5000000		N-F2		9.0000000	U
4*	Standard		-139.240000		1.0000000				9.0000000	U
5*	Standard		17.1286603	A	3.0000000		F9		6.0000000	U
6*	Standard		24.6738333	N	24.6520554				6.0000000	U
IMA	Standard		Infinity		-				0.0265405	



The wavelength combination e F' C' is selected. It is seen, that the system is diffraction limited only near the green line. Spot rms value for the e-line is D = 0.858 μm.

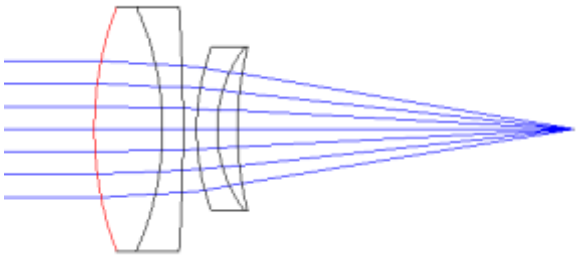


Now the second lens is splitted and a default merit function is established. After optimizing the buried surface and re-optimizing the image distance by quick focus, we get the following data:

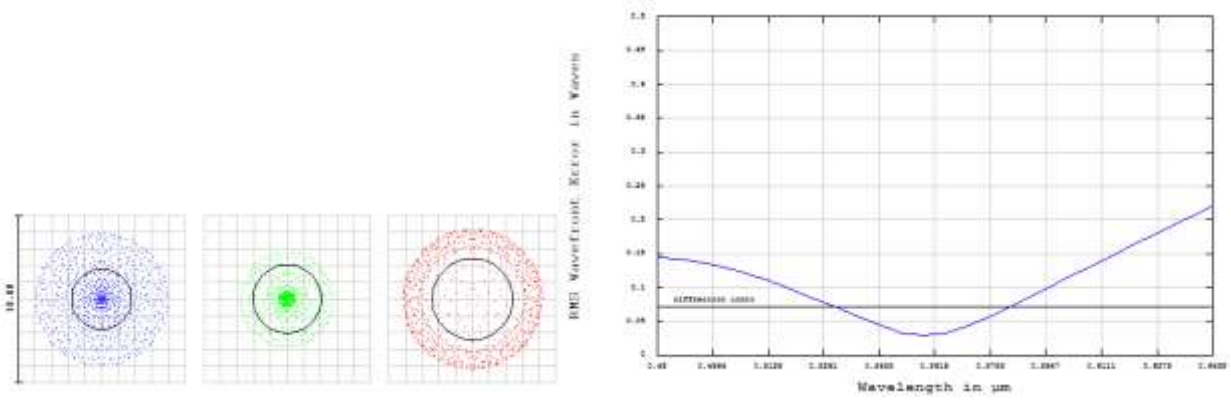
Lens Data Editor

Edit Solves View Help

	Surf:Type	Comment	Radius		Thickness		Glass		Semi-Diameter	
OBJ	Standard		Infinity		Infinity				0.0000000	
1	Standard		Infinity		10.0000000				5.0000000	
*	Standard	322265000	25.4830000		5.0000000		N-BK7		9.0000000	U
3*	Standard		-21.9090000		1.5000000		N-F2		9.0000000	U
4*	Standard		-139.240000		1.0000000				9.0000000	U
5*	Standard		17.1286603	A	1.5000000		F9		6.0000000	U
6*	Standard		9.9215270	V	1.5000000		SK16		6.0000000	U
7*	Standard		24.7121936	M	24.6988925				6.0000000	U
IMA	Standard		Infinity		-				4.0023E-003	



The spot for green now is 0.799 μm, if a quick focus is performed for only green. If all wavelengths are used, the spot is 1.425 μm and the quality is more smooth over the wavelengths. The diffraction limit is not fulfilled for blue and red.

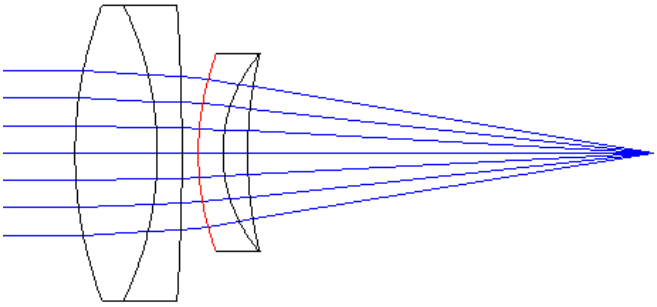


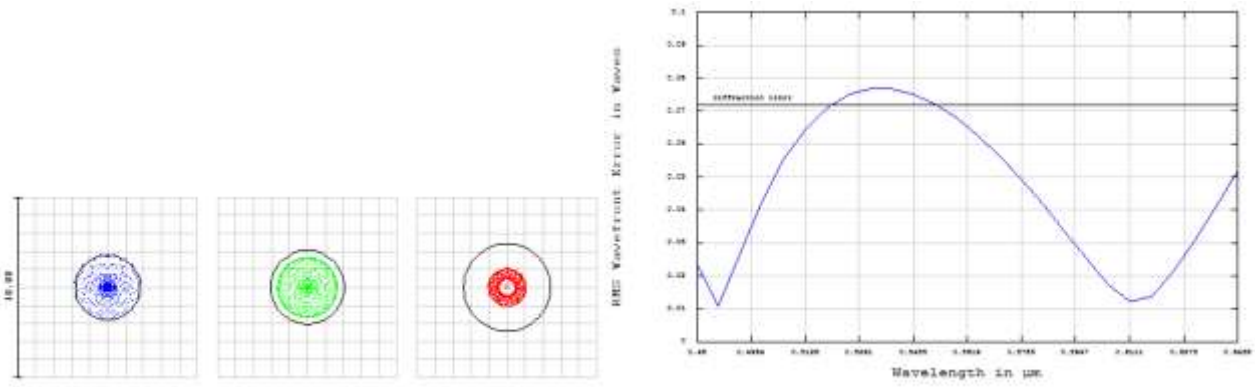
If we now also optimize the three radii of the achromate, we get a diffraction limited performance nearly over the complete spectrum.

Lens Data Editor

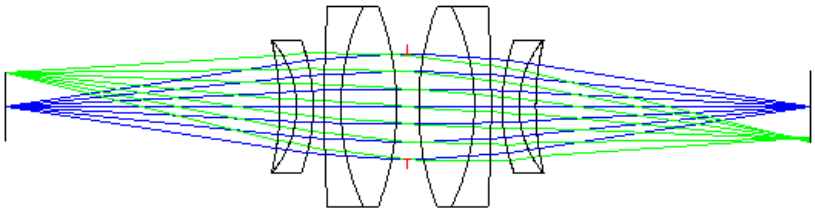
Edit Solves View Help

	Surf:Type	Comment	Radius		Thickness	Glass	Semi-Diameter	
OBJ	Standard		Infinity		Infinity		0.0000000	
1	Standard		Infinity		10.0000000		5.0000000	
*	Standard	322265000	25.2540589	V	5.0000000	N-BK7	9.0000000	U
3*	Standard		-20.8098766	V	1.5000000	N-F2	9.0000000	U
4*	Standard		-137.371490	V	1.0000000		9.0000000	U
5*	Standard		17.1143834	A	1.5000000	F9	6.0000000	U
6*	Standard		9.2141000	V	1.5000000	SK16	6.0000000	U
7*	Standard		24.6937815	M	24.6988925		6.0000000	U
IMA	Standard		Infinity		-		1.6914E-003	

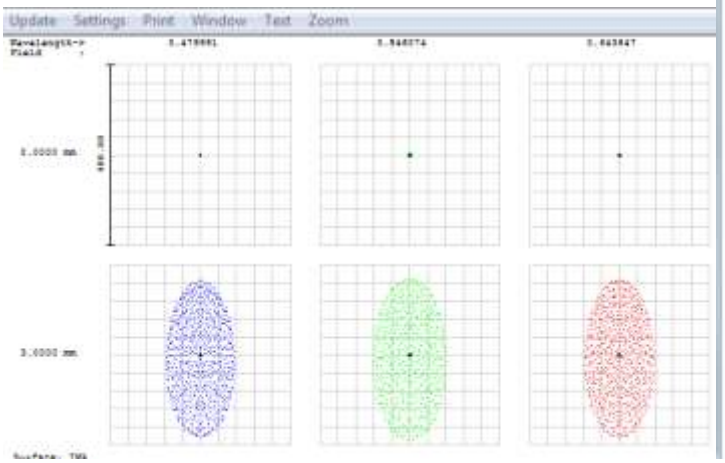




If the system is symmetrized and a field height of 3 mm is introduced, we get the following layout with the stop in the center:



Due to theory, only astigmatism and field curvature are remaining. This can be seen at the Zernike coefficients and the spot diagram, which contains elliptical shapes in the field.



4: Zernike Fringe Coefficients

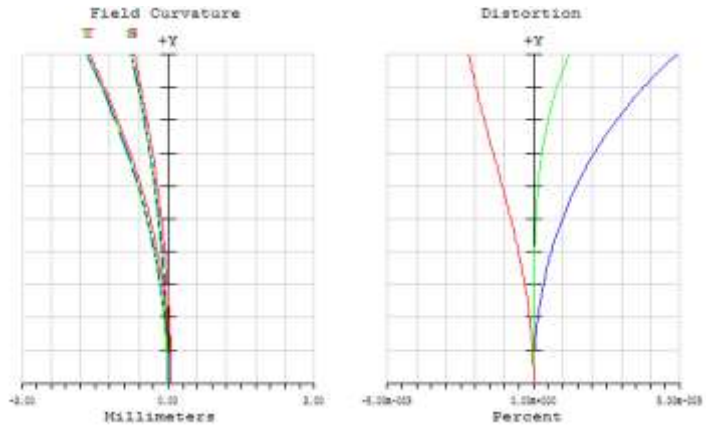
Update Settings Print Window

```
Peak to Valley (to chief)     :    24.85477997 wav
Peak to Valley (to centroid)  :    24.58377965 wav
RMS (to chief)                :     5.77967334 wav
RMS (to centroid)             :     5.77809427 wav
Variance                      :    33.38637337 wav
Strehl Ratio (Est)            :     0.00000000

RMS fit error                 :     0.00000004 wav
Maximum fit error             :     0.00000028 wav

Z  1      8.92498253 :  1
Z  2      0.00000000 :  (p) * COS (A)
Z  3     -0.27272916 :  (p) * SIN (A)
Z  4      8.91065510 :  (2p^2 - 1)
Z  5     -6.64502212 :  (p^2) * COS (2A)
Z  6      0.00000000 :  (p^2) * SIN (2A)
Z  7      0.00000000 :  (3p^2 - 2) p * COS (A)
Z  8     -0.13802210 :  (3p^2 - 2) p * SIN (A)
Z  9     -0.02282145 :  (6p^4 - 6p^2 + 1)
Z  10     0.00000000 :  (p^3) * COS (3A)
Z  11     0.01813571 :  (p^3) * SIN (3A)
Z  12     0.02496537 :  (4p^2-3) p^2 * COS (2A)
Z  13     0.00000000 :  (4p^2-3) p^2 * SIN (2A)
Z  14     0.00000000 :  (10p^4 - 12p^2 + 3) p *
Z  15    -0.00076732 :  (10p^4 - 12p^2 + 3) p *
Z  16    -0.00567417 :  (20p^6 - 30p^4 + 12p^2 -
Z  17     0.00020417 :  (p^4) * COS (4A)
Z  18     0.00000000 :  (p^4) * SIN (4A)
Z  19     0.00000000 :  (5p^2 - 4) p^3 * COS (3A
Z  20     0.00042431 :  (5p^2 - 4) p^3 * SIN (3A
Z  21    -0.00034195 :  (15p^4 - 20p^2 + 6) p^2
Z  22     0.00000000 :  (15p^4 - 20p^2 + 6) p^2
Z  23     0.00000000 :  (35p^6 - 60p^4 + 30p^2 -
```

Also the distortion vanishes nearly completely:



If now the system is kept exact symmetrical and the first group is optimized by radii only it is assumed, that astigmatism and field curvature shoulkd be corrected. Thick meniscus lenses and a smaller beam diameter in the middle part solves this requirement best. Exactly this is obtained by numerical optimization. The system is now nearly diffraction limited. The spots show no asymmetrical contribution due to the fact, that the coma is zero.

Lens Data Editor

Edit Solves View Help

	Surf:Type	Comment	Radius		Thickness		Glass		Semi-Diameter
OBJ	Standard		Infinity		24.6988900				3.0000000
1	Standard		14.0992085	V	1.5000000		SK16		4.0554537
2	Standard		-13.9726976	V	1.5000000		F9		4.0280081
3	Standard		-46.5326749	V	1.0000000				3.8567441
4	Standard		7.8013285	V	1.5000000		N-F2		3.4647625
5	Standard		3.9817338	V	5.0000000		N-BK7		2.8760668
6	Standard		4.7343646	V	1.0000000				1.7788260
STO	Standard		Infinity		1.0000000				1.6546158
8	Standard		-4.7343646	P	5.0000000		N-BK7		1.7679864
9	Standard		-3.9817338	P	1.5000000		N-F2		2.8641910
10	Standard		-7.8013285	P	1.0000000				3.4541535
11	Standard		46.5326749	P	1.5000000		F9		3.8505172
12	Standard		13.9726976	P	1.5000000		SK16		4.0214960
13	Standard		-14.0992085	P	24.6988925				4.0497199
IMA	Standard		Infinity		-				3.0066338