Symmetric system

In a symmetric system, all odd aberrations are completely corrected. This is demonstrated in this exercise.

a) Establish an incoming collimated beam with wavelength 500 nm and 10 mm diameter with the field angles 0°, 7° and 10°. It is focused by two lenses with material SF6, thickness 5 mm and distance 10 mm. The image is located in a distance of 100 mm, the stop lies 5 mm before the first lens vertex. Optimize the system by changing only the radii of curvature. Inspect the quality by calculating the spots, the Seidel aberration contributions, the distortion, and the Zernike coefficients for the outer field point.

b) Now double the system perfectly symmetric. Exchange the field definition from angle to the equivalent finite object height. What is the correction now? Change the position of the stop only by a slider option. What kind of changes are seen? Prepare a universal plot to see the change in coma as a function of the stop location between 0 and 10 mm.

c) Now re-optimize the system preserving the symmetry. Is the system now diffraction limited?
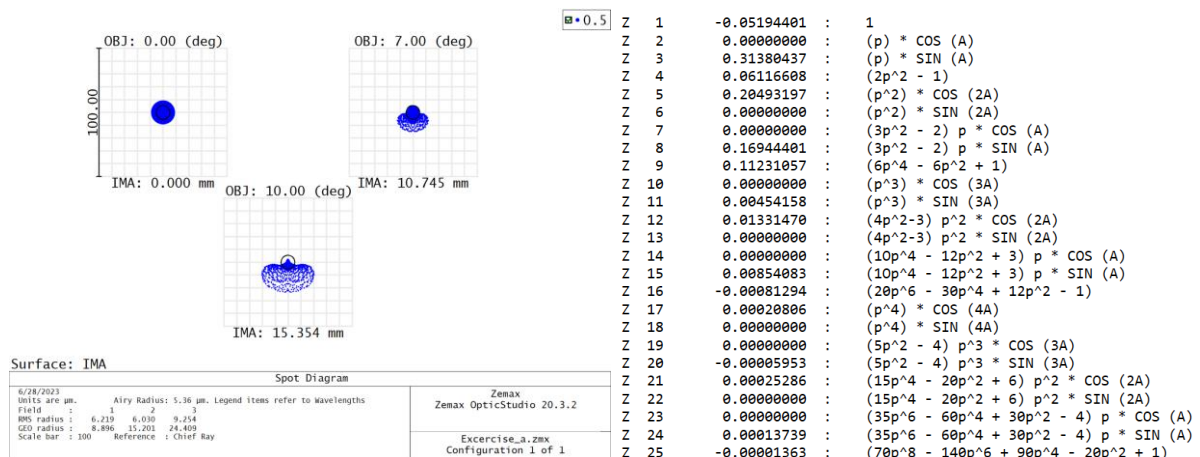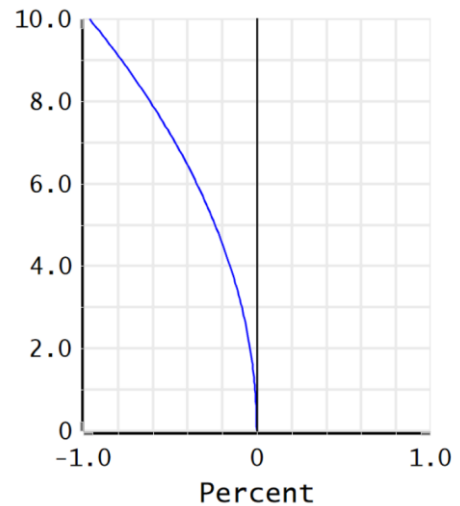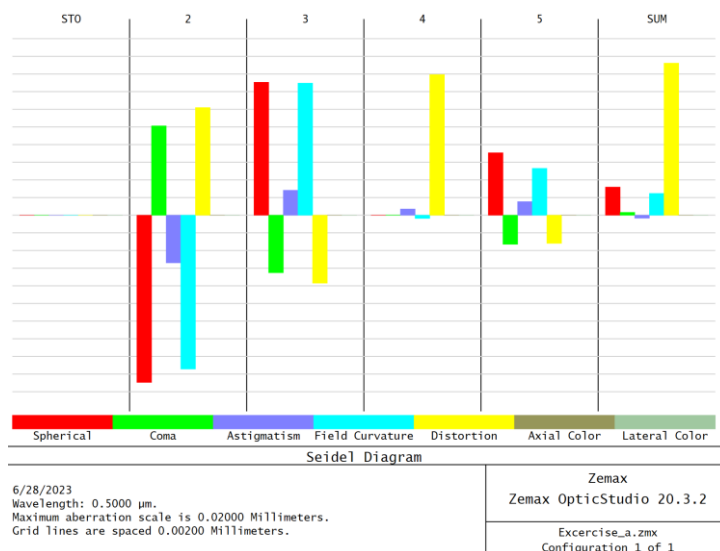
Solution:

a)

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone
0	OBJECT Standard ▾		Infinity	Infinity			Infinity	0.000000
1	STOP Standard ▾		Infinity	5.000000			5.000000	0.000000
2	Standard ▾		-20.140924 V	5.000000	SF6		5.734639	0.000000
3	Standard ▾		-23.462288 V	10.000000			6.842470	0.000000
4	Standard ▾		-941.689105 V	5.000000	SF6		8.710481	0.000000
5	Standard ▾		-66.141045 V	100.000000			9.136237	0.000000
6	IMAGE Standard ▾		Infinity	-			15.348700	0.000000
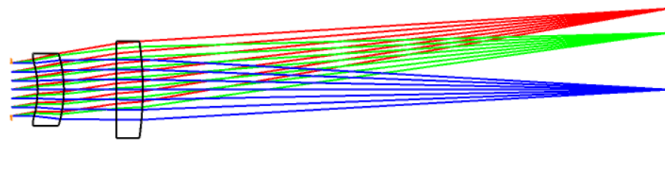
It is seen, that the system is not diffraction limited and there is a larger contribution of coma (c8) and 1% distortion.

Z	1	-0.05194401	:	1
Z	2	0.00000000	:	(p) * COS (A)
Z	3	0.31380437	:	(p) * SIN (A)
Z	4	0.06116608	:	(2p^2 - 1)
Z	5	0.20493197	:	(p^2) * COS (2A)
Z	6	0.00000000	:	(p^2) * SIN (2A)
Z	7	0.00000000	:	(3p^2 - 2) p * COS (A)
Z	8	0.16944401	:	(3p^2 - 2) p * SIN (A)
Z	9	0.11231057	:	(6p^4 - 6p^2 + 1)
Z	10	0.00000000	:	(p^3) * COS (3A)
Z	11	0.00454158	:	(p^3) * SIN (3A)
Z	12	0.01331470	:	(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 * COS (A)
Z	15	0.00854083	:	(10p^4 - 12p^2 + 3) p * SIN (A)
Z	16	-0.00081294	:	(20p^6 - 30p^4 + 12p^2 - 1)
Z	17	0.00020806	:	(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	-0.00005953	:	(5p^2 - 4) p^3 * SIN (3A)
Z	21	0.00025286	:	(15p^4 - 20p^2 + 6) p^2 * COS (2A)
Z	22	0.00000000	:	(15p^4 - 20p^2 + 6) p^2 * SIN (2A)
Z	23	0.00000000	:	(35p^6 - 60p^4 + 30p^2 - 4) p * COS (A)
Z	24	0.00013739	:	(35p^6 - 60p^4 + 30p^2 - 4) p * SIN (A)
Z	25	-0.00001363	:	(70p^8 - 140p^6 + 90p^4 - 20p^2 + 1)

b) The image heights are 0 / 10.5 mm and 15.5 mm.

	Surface Type	Comment	Radius		Thickness	Material	Coating	Clear Semi-Dia	Chip Zone
0	OBJECT Standard ▾		Infinity		100.000000			15.500000	0.000000
1	Standard ▾		66.141045	V	5.000000	SF6		7.352443	0.000000
2	Standard ▾		941.689105	V	10.000000			6.914002	0.000000
3	Standard ▾		23.462288	V	5.000000	SF6		5.135077	0.000000
4	Standard ▾		20.140924	V	5.000000			4.191388	0.000000
5	STOP Standard ▾		Infinity		5.000000			3.395794	0.000000
6	Standard ▾		-20.140924	V	5.000000	SF6		4.192951	0.000000
7	Standard ▾		-23.462288	V	10.000000			5.136910	0.000000
8	Standard ▾		-941.689105	V	5.000000	SF6		6.916303	0.000000
9	Standard ▾		-66.141045	V	100.000000			7.354820	0.000000
10	IMAGE Standard ▾		Infinity		-			15.503302	0.000000
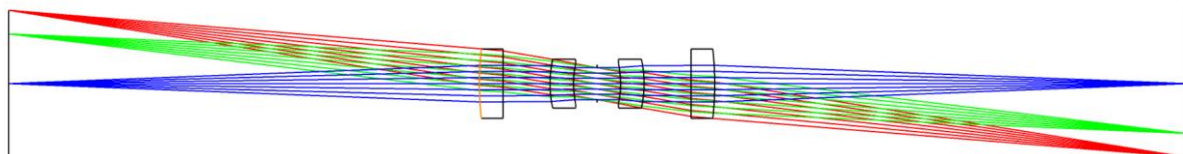
The spot is now on axis larger than in the field, the distortion and the coma is gone, the even aberrations are increased.

Z	1	-0.15342825	:	1
Z	2	0.00000000	:	(p) * COS (A)
Z	3	-0.00635243	:	(p) * SIN (A)
Z	4	-0.10520619	:	(2p^2 - 1)
Z	5	0.17145155	:	(p^2) * COS (2A)
Z	6	0.00000000	:	(p^2) * SIN (2A)
Z	7	0.00000000	:	(3p^2 - 2) p * COS (A)
Z	8	-0.00210785	:	(3p^2 - 2) p * SIN (A)
Z	9	0.04802758	:	(6p^4 - 6p^2 + 1)
Z	10	0.00000000	:	(p^3) * COS (3A)
Z	11	0.00080172	:	(p^3) * SIN (3A)
Z	12	0.00574970	:	(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 * COS (A)
Z	15	0.00070835	:	(10p^4 - 12p^2 + 3) p * SIN (A)
Z	16	-0.00019550	:	(20p^6 - 30p^4 + 12p^2 - 1)
Z	17	0.00011577	:	(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	0.00005307	:	(5p^2 - 4) p^3 * SIN (3A)
Z	21	0.00003675	:	(15p^4 - 20p^2 + 6) p^2 * COS (2A)
Z	22	0.00000000	:	(15p^4 - 20p^2 + 6) p^2 * SIN (2A)
Z	23	0.00000000	:	(35p^6 - 60p^4 + 30p^2 - 4) p * COS (A)
Z	24	-0.00000296	:	(35p^6 - 60p^4 + 30p^2 - 4) p * SIN (A)
Z	25	-0.00000102	:	(70p^8 - 140p^6 + 90p^4 - 20p^2 + 1)

If the slider is established for a stops location between 0 and 10 mm between the inner lenses, the symmetry is perturbed and coma is growing. The vanishing coma for the middle position can also be demonstrated by a universal plot.
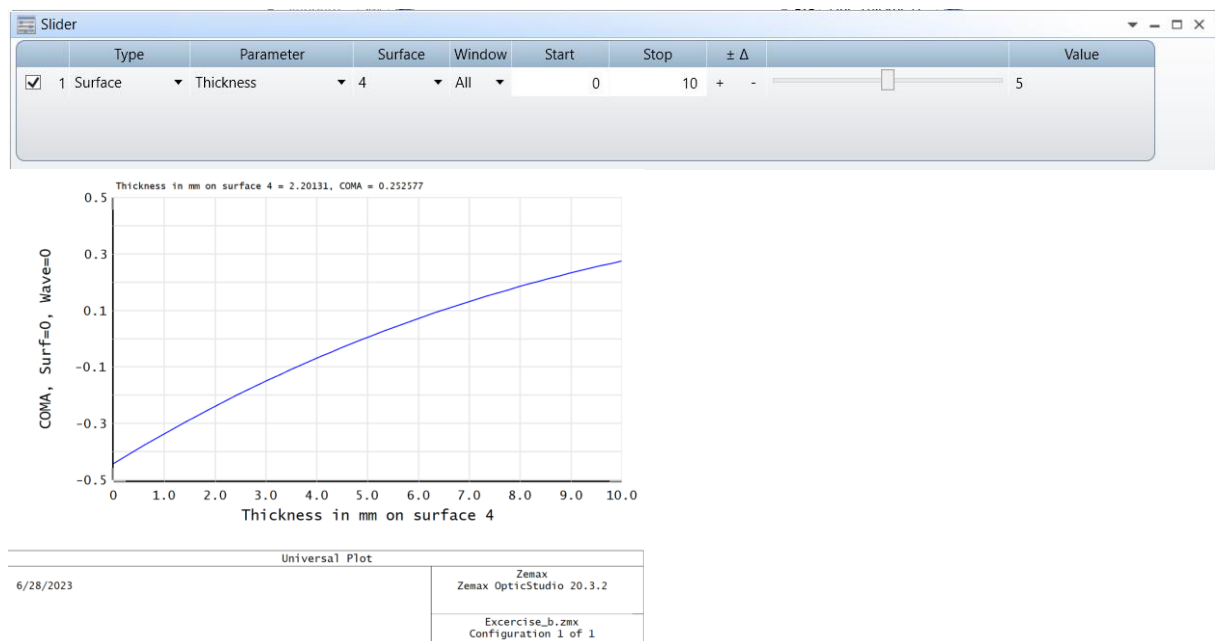
c) The system is reoptimized by fixing the radii in the second lens group via pick-up. The result gives a quite better performance. Due to the automatic correction of coma, the optimization allows to correct the even aberration better.

	Surface Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Dia	Chip Zone
0	OBJECT Standard ▾		Infinity	100.000000			15.500000	0.0000...
1	Standard ▾		97.079085 V	5.000000	SF6		7.403728	0.0000...
2	Standard ▾		-266.585465 V	10.000000			7.039258	0.0000...
3	Standard ▾		15.965580 V	5.000000	SF6		5.202044	0.0000...
4	Standard ▾		13.224172 V	5.000000			4.031431	0.0000...
5	STOP Standard ▾		Infinity	5.000000 P			3.237936	0.0000...
6	Standard ▾		-13.224172 P	5.000000	SF6		4.041650	0.0000...
7	Standard ▾		-15.965580 P	10.000000			5.214057	0.0000...
8	Standard ▾		266.585465 P	5.000000	SF6		7.052737	0.0000...
9	Standard ▾		-97.079085 P	100.000000			7.417149	0.0000...
10	IMAGE Standard ▾		Infinity	-			15.503991	0.0000...

	Z		value		
■•0.5	Z	1	0.03504327	:	1
	Z	2	0.00000000	:	(p) * COS (A)
	Z	3	0.00319208	:	(p) * SIN (A)
	Z	4	0.01946049	:	(2p^2 - 1)
	Z	5	-0.01655688	:	(p^2) * COS (2A)
	Z	6	0.00000000	:	(p^2) * SIN (2A)
	Z	7	0.00000000	:	(3p^2 - 2) p * COS (A)
	Z	8	0.00105279	:	(3p^2 - 2) p * SIN (A)
	Z	9	-0.01566736	:	(6p^4 - 6p^2 + 1)
	Z	10	0.00000000	:	(p^3) * COS (3A)
	Z	11	-0.00030006	:	(p^3) * SIN (3A)
	Z	12	0.02135674	:	(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 * COS (A)
	Z	15	-0.00037345	:	(10p^4 - 12p^2 + 3) p * SIN (A)
	Z	16	-0.00008211	:	(20p^6 - 30p^4 + 12p^2 - 1)
	Z	17	0.00064693	:	(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	0.00018071	:	(5p^2 - 4) p^3 * SIN (3A)
	Z	21	0.00030820	:	(15p^4 - 20p^2 + 6) p^2 * COS (2A)
	Z	22	0.00000000	:	(15p^4 - 20p^2 + 6) p^2 * SIN (2A)
	Z	23	0.00000000	:	(35p^6 - 60p^4 + 30p^2 - 4) p * COS (A)
	Z	24	-0.00000855	:	(35p^6 - 60p^4 + 30p^2 - 4) p * SIN (A)
	Z	25	0.00000252	:	(70p^8 - 140p^6 + 90p^4 - 20p^2 + 1)

Surface: IMA

Spot Diagram

6/28/2023
Field : 1 2 3
Units are µm. Airy Radius: 7.937 µm. Legend items refer to Wavelengths
RMS radius : 0.816 0.513 1.236
GEO radius : 1.487 1.482 3.963
Scale bar : 20   Reference : Chief Ray

Zemax
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Excercise_b.zmx
Configuration 1 of 1

Seidel Diagram

6/28/2023
Wavelength: 0.5000 µm.
Maximum aberration scale is 0.02000 Millimeters.
Grid lines are spaced 0.00200 Millimeters.

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Zemax OpticStudio 20.3.2

Excercise_b.zmx
Configuration 1 of 1