Exercise I: Lens bending

Most of the aberrations change with the bending of a lens. This is demonstrated in this exercise.

a) Establish a lens with focal length f = 100 mm made of BK7 with thickness 5 mm for 587.6 nm for an object space numerical aperture of NA = 0.07. The object distance is 170 mm. The object field has a diameter of 30 mm. The stop is located at the lens

b) Generate a universal plot for coma, spherical aberration, astigmatism and Petzval curvature, if the curvature of the first lens surface is varied between -0.03 ... +0.05. Explain the results.

c) Now modify the setup by placing the system stop 30 mm in front of the lens. What is changing?

d) It is obvious that the stop position and the bending have influence on the aberrations. Therefore it makes sense to look at the combined effect. For getting this, generate a 2D universal plot, where the stop position and the bending are changed. Formulate the second thickness as a pickup to keep the object distance constant and change the distance between object and stop from 100 ...170 mm. Plot the 2D-dependence for spherical aberration, coma and astigmatism. Interpret the results. What is the optimal bending for a distance of 100 mm? Is it possible to correct all three aberrations simultaneously?

Solution:

a) The data are as follows, the second lens surface is fixed as a solve with the power of 0.01.

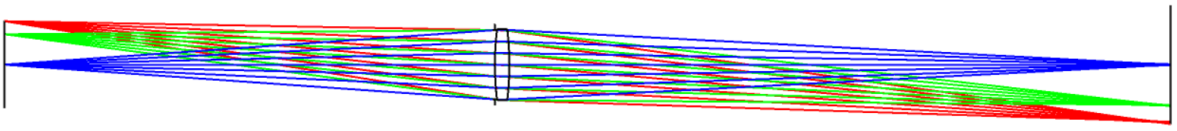
Lens Data

Update: All Windows

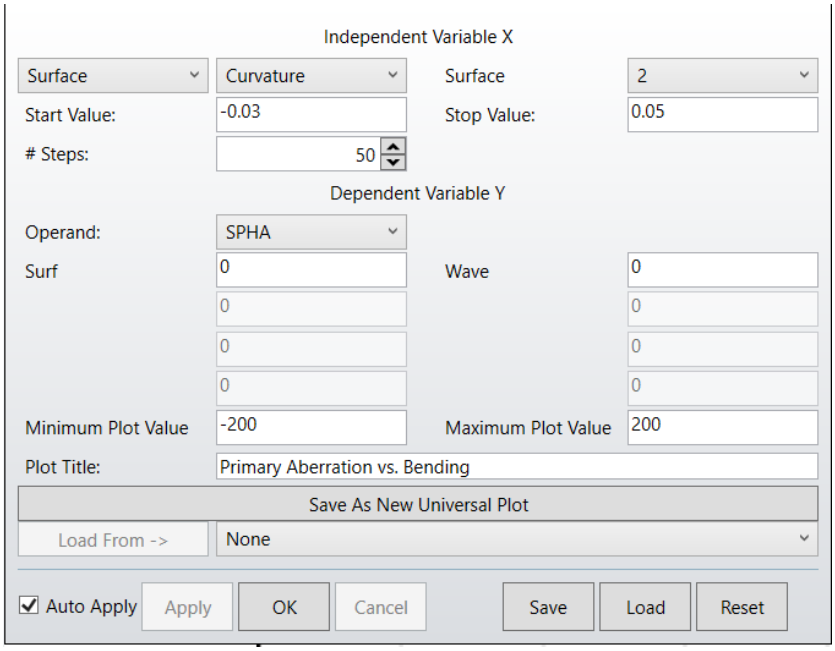
Surface 3 Properties

Configuration 1/1

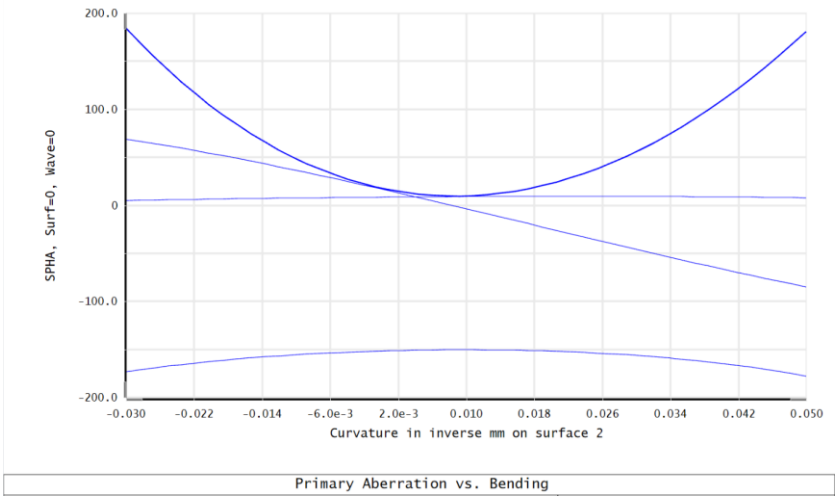
	Surface Type	Comment	Radius		Thickness	Material	Coating	Clear Semi-Dia
0	OBJECT Standard		Infinity		170.000000			15.000000
1	STOP Standard		Infinity		0.000000			11.929263
2	Standard		100.000000		5.000000	BK7		12.044585
3	Standard		-105.130941	X	229.154334			12.261995
4	IMAGE Standard		Infinity		-			20.460953



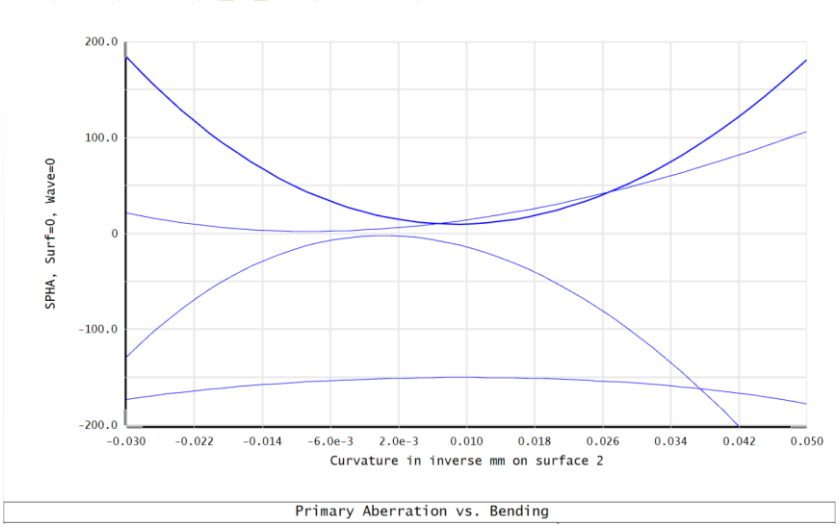
b) In the merit function, the lines with SPHA, COMA, ASTI, PETZ are established.



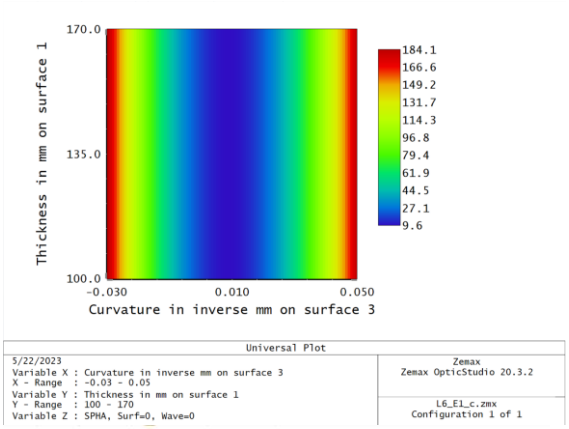
The universal plot with the various lines are generated with constant y-interval, then all the 4 plots are overlayed. As expected, the spherical aberration changes quadratically, the coma nearly linear, the astigmatism nearly not and the petzval curvature also very weak.

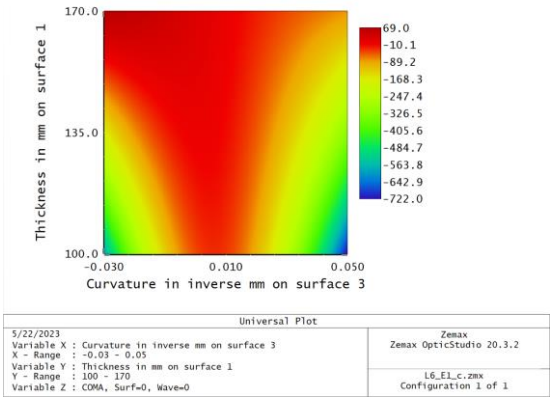


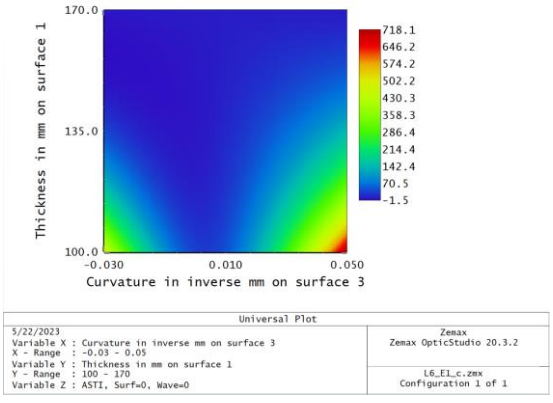
c) As can be seen, the spherical aberration and the Petzval curvature are not changing. The variation of the coma now is also quadratic and the astigmatism is now stronger changed.



d) The corresponding plots look as follows.







It is seen in the diagrams:

1. spherical aberration does not depend on the stop position
2. the minima for all 3 aberrations are at different bending values
3. coma and astigmatism become large, of large stop distances produce large chief ray heights
4. coma and astigmatism has a zero correction option for a certain stop distance, these are lying at different values

Minima of the bending / first surface curvature of the quadratic dependencies for the distance 100:

SPH	0.0084
Coma	0.0060
Astigmatism	0.0036

No of the aberrations can be corrected to zero, the minima occur at different bendings and therefor only a compromise is possible.