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Exercises
Lecture Optical design with Zemax– Part 5

4 Aberrations

4.1 Multi configuration, universal plot and slider

Load a classical achromate with a focal length of f = 100 mm, no field and numerical aperture NA = 0.1 from one of the vendor catalogs. Fix the wavelength to λ = 546.07 nm.
a) Add a thin mensicus shaped lens behind the system with an arteficial refractive index of n = 2 to enlarge the numerical aperture by a factor of 2 without introducing spherical aberration. To achieve this, the surfaces must be aplanatic and concentric.
b) Now reduce the numerical aperture to a diameter of 2 mm and set a folding mirror in the front focal plane of the system. The incoming beam should be come from below and is deflected to the right side.
c) Generate a multi-configuration system for a scan system by rotating the mirror. The first coordinate break angle can take the values -50°, -47.5°, -45°, -42.5° and -40°. The second coordinate break should be defined by a pick up with a resulting bending angle of the system axis of -90°.
d) The chief ray of the scan system is telecentric in the paraxial approximation. Due to the residual aberrations of the system, there is a deviation from the telecentricity in the real system. Show this by a correponding universal plot.
e) Show the variation of the spot in the image plane by using the slider.

4.2 Singlet optimization

Optimize a single lens with the data λ = 546.07 nm, object in the distance 100 mm from the lens on axis only, focal length f = 45 mm and numerical aperture NA = 0.07 in the object space. The lens should be made of the Schott glass N-K5 and has a thickness of 5 mm.
a) Try to start from a plane plate approach to find the best lens bending solution.
b) Now start the optimization with a lens and an image distance, which is near to the solution. Is the optimized lens diffraction limited in its performance ?
c) One possibility to improve the result is to use an aspherical lens. The first approach is to use the rear surface with a conic constant to allow the program a conic section as solution. Is this sufficient to get a diffraction limited solution ?

d) Now enlarge the numerical aperture by a factor of two. Re-optimize the system. What about the diffraction limited performance ? Use an aspherical coefficnet of 4th order to improve the system. What is the result ?
e) Now introduce a finite object size of diameter 10 mm. What is the dominant aberration for the off-axis field points ? Can the system by made diffraction limited by re-optimization, for example with more aspherical constants ? What can be done to get a better performance ?

4.3 Achromate

a) Calculate a classical achromate with the basic data:
- object at infinity
- focal length f = 10 mm
- image side numerical aperture NA' = 0.05
- glass materials BK7 and SF6
- wavelength used: d, F, C
- Performance:
  1. spherical correction at the aperture boundary zero
  2. achromatic correction with identical image position for F and C

Is the system diffraction limited on axis ?
b) Describe the performance for a finite field angle of 2°.
c) If the glass SF6 is used instead of SF12, can a system with equivalent quality be obtained ?