Astronomical Telescopes and Instruments 2014: Exercises on Geometrical Optics 2 (Due on 1 October 2014 at 13:45)

C.U.Keller

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1 Spherical Aberration

For a single, biconvex lens that images an object at infinity on the optical axis, show that the transverse spherical aberration is about proportional to F^{-3}, where F is the f-number, and is independent of the field location. Use the optical design software and determine the rms spot size in the best focus for a number of different beam diameters illuminating a single lens with a fixed focal length. Note that the location of best focus depends on the beam diameter, even if the lens has a constant focal length.

2 Galileo and Kepler Telescopes

Design a refractor according to Galileo (positive and negative lens) and one according to Kepler (two positive lenses) with identical diameter and magnification. Determine the field of view and the chromatic aberration and compare the two telescopes with respect to these parameters. Use the rms spot diameter as the performance metric. Hint: use a single lens with a long focal length to simulate the eye; the long focal length will make sure that the aberrations induced by that lens can be neglected with respect to the aberrations of the telescopes that you design.

3 Distortion

A single lens made of fused silica (FS) with an aperture diameter of 60 mm and a focal length of 100 mm shows image distortion when imaging an object at infinity.

1. For a lens that has the optimum shape (minimizing the spherical aberration), determine the radii of curvature for the the sides of the lens.
2. Determine the type of distortion (barrel or pin-cushion) and the amount of distortion for a field angle of 10 degrees. Hint: determine the image location for a field of 1 degree and a field of 10 degrees and determine the relative change with respect to the expected ratio of 10.

4 Field Curvature

Make a simple Newtonian telescope (single parabolic primary mirror with 200 mm aperture diameter and 200 mm focal length) and use a flat secondary mirror to bring the focus behind the parabolic mirror (note that the code ignores the secondary mirror on the first path through the backside of the flat mirror). Design a single lens, located close to the focal plane, that improves the performance at an angle of 8 degrees away from the optical axis. What are the parameters of the lens? Hint: the average rms spot size can be improved by about a factor of 2.