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Johannes Stock

Friedrich Schiller University Jena
Institute of Applied Physics
Albert-Einstein-Str. 15
07745 Jena

# Imaging and Aberration Theory – Seminar 3

## Exercise 3-1: Aberrations of a Plane Plate

Derive the axial spherical aberration, which corresponds to the difference between the real and the paraxial image location of a plane parallel plate with index n and thickness d. Calculate the lowest order of the aberration as a function of a small value of sin u. If the diameter in the Gaussian image plane should not be larger than 10 µm, calculate the greatest possible thickness of a plate in this approximation with a refractive index of n = 1.48 for a numerical aperture of sin u = 0.8.

## Exercise 3-2: Ray-fan Plots for Primary Aberrations

Beside spot diagrams, ray-fan plots are often used to visualize aberrations in a system. For a fixed field point at height y, the wavefront error, the transverse, or the longitudinal ray error are plotted against the tangential or sagittal pupil coordinate $y_p$ and $x_p$, respectively.

a) For each of the following aberrations, sketch the wavefront error and the corresponding transverse aberrations for a tangential and sagittal ray fan starting from an on-axis point y=0 and an off-axis point at the maximum normalized field height y=1: defocus, wavefront tilt, spherical aberration, coma, field curvature, astigmatism, and distortion (use the Seidel definition of the primary aberrations).

b) Sketch the spot diagram for these aberrations by considering transverse ray errors $\Delta x', \Delta y'$ in the image plane for rays with different, fixed pupil radius $r_p$ (ray cones).

## Exercise 3-3: Spherical Aberrations of a Thin Lens

A thin plano-convex lens with focal length f' = 100 mm is used to focus a collimated beam with diameter D = 10 mm and wavelength $\lambda$ = 560 nm that is parallel to the optical axis.

a) Which orientation of the lens is optimal? Why?
b) Calculate the magnification parameter M and the bending parameter X for the lens.
c) Calculate the primary spherical wave aberration $A_s$ for a single lens of refractive index n=1.5 and n=1.9. Which choice is more advantageous?
d) Calculate the transverse aberration $\Delta$y' in the image plane for both indices. Is the system diffraction limited? Compare the geometrical spot size and the diffraction Airy diameter.
e) How much can the spherical aberration be reduced by bending the lens?