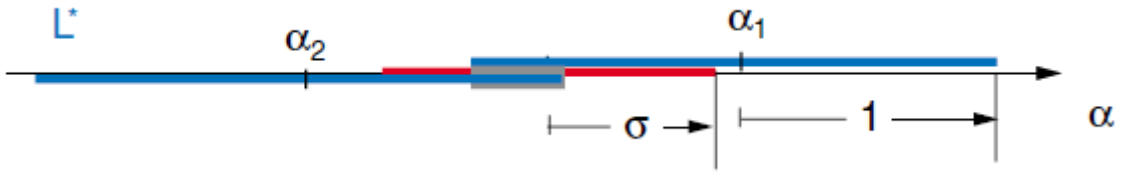
Exercise sheet 4; due: June 18th 2024 OSDF Seminar

Exercise 10: Ideal Hopkins Transfer function: 1D case

a) Give an analytical expression for the ideal Hopkins Transfer function in 1D for a homogeneous illumination of "radius" σ and an ideal pupil of radius 1. Normalize your result, such that HTF(0,0)=1.



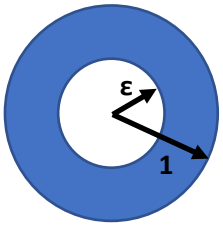
b) For the result of a) plot the quasi-coherent Hopkins Transfer Function HTF(α,0) for σ=0, σ=0.5, σ=1, and σ=2.

c) Give an analytical expression for the defocus 1D HTF as above, by incorporating following wavefront deformation in the pupil function:

$$W(\alpha) = c_2\alpha^2$$

Exercise 11: PSF and OTF of ideal pupil with central obscuration

Given a circular pupil L(α,β) with normalized radius 1, and with central obscuration of radius ε.



a) Compute the amplitude point spread function $K(x - m\xi, y - m\eta) = \iint L(\alpha,\beta) exp\left(i2\pi \frac{NA'}{\lambda}\left(\alpha\,(x - m\xi) + \beta(y - m\eta)\right)\right) d\alpha\, d\beta$ (use polar coordinates to keep the calculation as simple as possible).

b) Give the expression of the (intensity) PSF and plot the normalized PSF´s (meaning PSF(0)=1) for the following inner radii: ε=0, ε=0.25, ε=0.5, ε=0.75, ε=0.99. Also compute the relative intensity compared to the unobscured pupil (ε=0) for all these particular obscuration sizes

c) Give the analytical expression for the MTF for the general case (any ε<1). [Consider whether the solution can be given as a combination of solutions for a circular pupil (radii 1 and ε respectively)]

d) What is the largest spatial frequency just transferred for f/2 ("f-number equal to 2") and a wavelength of λ =0.5µm?

Exercise 12: Data of a mobile phone camera

A mobile phone supplier published following data on the camera system:

Advanced dual-camera system

48MP Main: 26 mm, ƒ/1.6 aperture, sensor-shift optical image stabilization, 100% Focus Pixels, support for super-high-resolution photos (24MP and 48MP)

12MP Ultra Wide: 13 mm, ƒ/2.4 aperture and 120° field of view

12MP 2x Telephoto (enabled by quad-pixel sensor): 52 mm, ƒ/1.6 aperture, sensor-shift optical image stabilization, 100% Focus Pixels

Assume that the given focal length data are not actual focal lengths, but referred to the 35mm standard format (36mm x 24mm).

a) What is the diagonal field-of-view of each of the mentioned cameras?
b) What is the number of pixels along horizonal and vertical direction of each image sensor assuming a 4:3 aspect ratio?

For the “48MP Main: 26mm, f/1.6” assume a full diagonal sensor size of 13mm.

c) What is the pixel pitch and the diameter of the lens Airy disk of the Main Camera? Is resolution limited rather by sensor or lens? Assume that the photo sensitive area is over the complete pixel. For simplicity first consider a gray-scale sensor and discuss how the requirement changes for an RGB-Bayer pattern sensor. Also discuss whether a quad-cell sensor would be rather limited in resolution by sensor or by lens.
d) For c) what is the highest spatial frequency you should consider for specification of the lens?
e) According to the equation of the MTF for an ideal lens with circular pupil what would be the best achievable contrast at the spatial frequency of d)? [for simplicity assume a monochromatic transfer at wavelength $\lambda = 0.5\mu m$]