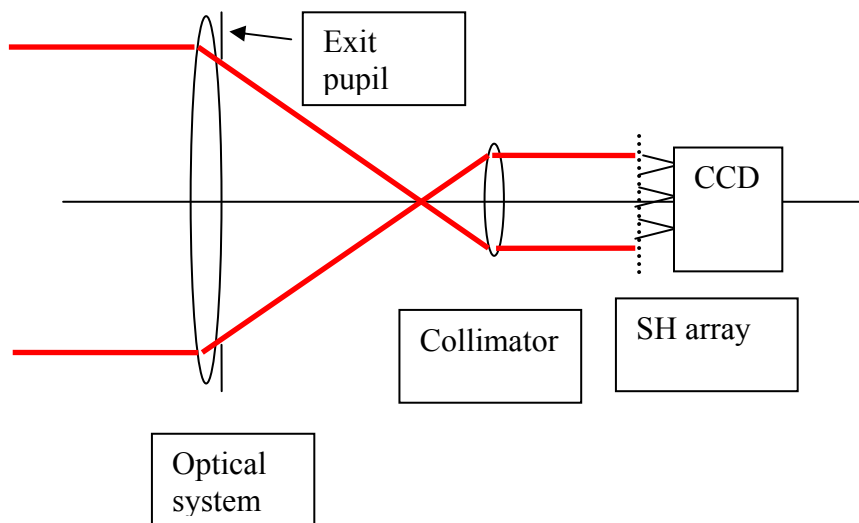


Opti 415/515 Homework #4

#1) A 20 mm diameter lens has a spherical surface with a nominal radius of curvature $R = 250 \text{ mm} \pm 1 \text{ mm}$. Calculate the tolerance in terms of the sag of the surface. Is this tight?

#2) An optical system, represented in the figure below by a single lens, is to be tested using a Shack-Hartmann (SH) array using a collimated source. The optical system has an $F/4$ output cone, 400 mm focal length and the exit pupil is at the second principal plane location. The test will be performed using a $\sim 500 \text{ nm}$ wavelength source. The collimator lens is used to 1) recollimate the light focused by the optical system, and 2) produce an image of the exit pupil of the optical system on the SH array.



- The collimator lens needs to produce a 10 mm diameter output beam, what should its focal length be?
- Using the exit pupil as the reference location, where is the focus of the optical system, collimator lens (model as a thin lens), and SH array?

- c) The SH array elements are 200 μm in diameter, and have a 5 mm EFL. The CCD is in the focal plane of the SH array elements. The CCD has 10 μm x 10 μm pixels. What is the Airy disk diameter of a single SH element in microns and pixels?
- d) What is the peak slope error in radians in the exit pupil of the optical system if the only aberration is $z_2^0 = 0.1 \mu\text{m}$? How much displacement of the focused spot for a single SH lenslet in microns and pixels does this slope error (aberration) produce at the detector?

$$\text{Zernike focus} = z_2^0 \sqrt{3} (2\rho^2 - 1)$$

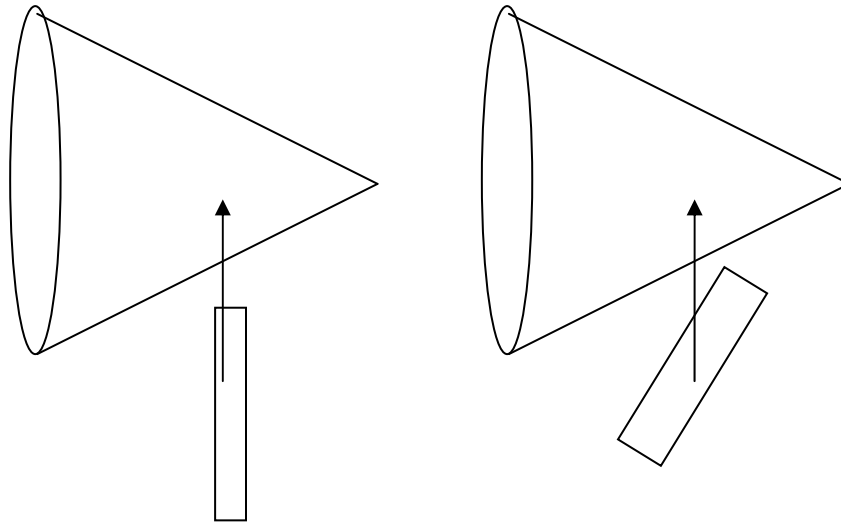
$$\text{Zernike spherical} = z_4^0 \sqrt{5} (6\rho^4 - 6\rho^2 + 1)$$

Note that Zernike focus has a quadratic term + constant to make it *orthogonal* (on the unit circle) to the constant term. Similarly, Zernike spherical has enough focus (quadratic term) and constant to be orthogonal to both.

- e) Repeat **d)** for $z_4^0 = 0.1 \mu\text{m}$.

3) Derive an expression for depth-of-focus based upon the requirement that the PV OPD error is less than $1/10$ wave PV. What Strehl ratio does this correspond to?

4) A plane parallel plate with a thickness $t = 5$ mm, index = 1.5 is placed in a converging F/10 cone of light, normal to the optical axis (left) as indicated below and tilted at 45 deg (right). How much does the image move axially and laterally? Name the aberrations that result from the plane parallel plate.



5a) Describe the requirements on the optical elements for a rotationally symmetric optical system to be aligned.

5b) When aligning an optical system, the functional requirements of the system may be broken down into two primary steps. What are the goals of the two steps?