Star Test & Classical Hartmann Test

Background: Read Wyant's Non-interferometric Testing section 8.2.11 on course website. Also see Chapter 10 Hartmann and other Screen Tests in Malacara's Optical Shop Testing (Available in the library).

Introduction: The first portion of this laboratory explores a technique called the Star Test. In this test, you essentially visualize the Point Spread Function (PSF) of the system under test. In the region of focus, it is often difficult to determine the dominant aberrations. However, by looking through focus, dominant aberrations emerge. The test is usually qualitative, but experience with different PSFs can enable some idea of system performance.

1. **Star Test** – Set up a laser, microscope objective, spatial filter and collimating lens to create a collimated beam. Place the plano-convex test lens in the beam with the convex side towards the laser. Set up the camera to record the spot pattern in the neighborhood of focus. You will need to add a neutral density filter to the source to reduce the brightness to keep the camera from saturating. Record several PSFs though focus. Reverse the orientation of the plano-convex lens and repeat. Also repeat for the astigmatism and coma cases examined in the previous lab. What are the relevant features of the various PSFs? How do the in focus PSFs compare between all the various aberrations? Use a translation stage when shifting the camera position to know exactly how far you moved. Measure the dimensions of the camera sensor to determine the size of each pixel.

The second portion laboratory explores a technique called the Classical Hartmann test. The test places a mask with a hole pattern over the test optic. A collimated beam is shone through the mask effectively creating a discrete number of "rays" passing through the system. The holes are large enough to minimize diffraction effects, but small enough create distinct paths through the test lens. Since the rays enter the lens collimated, they will converge to the rear focal point of the test lens. However, if we examine the regions on either side of focus, a discrete spot pattern will appear. This pattern is effectively the physical analog of the spot diagram provided in lens design code. By shifting the location of the observation plane by fixed amounts and tracking the movements of the spots, the trajectory of each ray can be determined. Different aberrations in the test lens will create different characteristic patterns in the spot pattern.

2. **Spherical Aberration** – Set up a laser, microscope objective, pinhole and collimating lens to create a collimated beam. Place the plano-convex test lens in the beam with the convex side towards the laser. Place the 5x5 Hartmann screen against the test lens. Using a piece of paper, observe the spot pattern following the test lens as you move the paper through focus. Set up the camera to record the spot pattern in the neighborhood of focus. You will need to add a neutral density filter to the source to reduce the brightness to keep the camera from saturating. Record the spot pattern well inside and well outside of focus. Use a translation stage when shifting the camera position to know exactly how far you moved. Use your previous measurements of the camera sensor to determine the spacing between the spots.

Determine which spots in the two images correspond to the same ray. What is the trajectory of each ray? Predict what the spot pattern will look like through focus based on the ray positions and trajectories. Reverse the test lens so the plano side is towards the laser and repeat the preceding testing.

3. **Astigmatism** – Replace the plano-convex lens with the spherical and cylindrical trial lenses. This lens combination will create astigmatism in the emerging beam. Repeat the Hartmann testing for this case. Note, you will need to look at the patterns outside the interval of Sturm to reliably connect the spots.

4. **Coma** – use a plano-convex and plano-concave lens for testing next. Place the plano sides of the two lenses against each other and laterally displace each lens. The decentration will create coma in the emerging beam. You may need a third lens to focus the beam as well depending on the power of the plano-convex lens. Repeat the Hartmann test for the coma case.