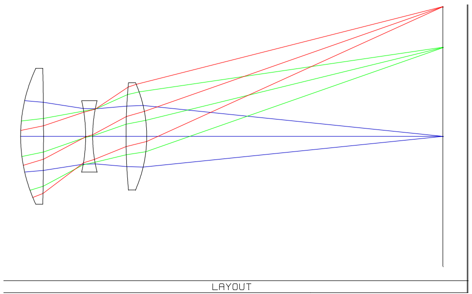
OPTI 421/521 – Introductory Opto-Mechanical Engineering

Homework 4: Image quality, Tolerancing for alignment : Hints

Part 1) Short answer

2. Consider the system from HW2 below with 10 mm entrance pupil diameter, 50 mm EFL, with object at infinity. (*Working F-number = 5*). Assume each lens surface is finished to 2 waves PV irregularity (at 587 nm).
   Determine the degradation to the rms image size due to the lens surface irregularity.



L1: 34 mm focal length
L2: -17 mm focal length
L3: 24 mm focal length

To get rms image, you need wavefront slope. Get this for each optical surface by:
2 waves PV surface irregularity
~ 2 wave/radius rms surface slope variation (from RoT on P 21.)
~1.2 um/radius rms surface slope variation for lambda = 0.6 um
Estimate the lens diameters D_i and the Beam diameters B_i for each of the lenses using the sketch above. (For lens 2 $D_2 = B_2 = 10$ mm).
Convert surface slope in um/radius to wavefront slope in radians using factor of (n-1) and using the lens radius = diameter/2.
You have 3 lenses – 6 surfaces. Each contributes to the rms spot blur as

$$\varepsilon_{rms} = \left(\nabla W\right)_{rms} B_i F_n$$

Calculate each one and find RSS

3. Consider the same optical design as 2), but use better lenses, finished to 0.1 waves P-V (at 587 nm). Estimate the contribution to rms wavefront error from the lens surfaces. Assume 587 nm operating wavelength.

This is easier. Convert to wavefront rms directly using relationship on P 22. Include the fact that the different lenses have different α. Take the RSS of all 6 contributions.

4. Consider a 25 mm beamsplitter with refractive index inhomogeneity of +/- 0.00001. Determine the P-V and rms wavefront variation due to the glass. For 0.5 µm wavelength, calculate the Strehl ratio assuming this is the only error in the system.

Use expression on P37.

5. A pitch polished aspheric mirror will typically have surface roughness of 20 angstroms rms. This causes wide angle scatter. Calculate the total amount of scatter from one of these mirrors at 400 nm light.

Use $\Delta W = \Delta S(n-1)\cos(\phi)$ where n-1 is -2 (ignore the sign.) 2 nm rms surface = 4 nm rms wavefront.
Scattered light = 1-SR.

Part 3) Tolerance Analysis

Undergraduate OPTI421 students can work in pairs for this assignment, jointly submitting one report per team.

The reports must be submitted separately from Parts 1) and 2).

For the doublet from HW 3, develop a tolerance analysis for the optical elements which contributes less than 0.04 rms to the system wavefront error budget. Errors should include:

- Surface radii of curvature
- Lens thickness
- Wedge
- Surface irregularity
- Refractive index error
- Refractive index variation (inhomogeneity)

Assume focus compensation as you did for HW3.

You should use a ray trace program such as Zemax, CodeV, Oslo, to determine the sensitivities for the geometric parameters. You can use rules of thumb and calculations to determine the affect of surface figure and index variations. Then create a spreadsheet to help set the tolerances to sensible values. If you do not have access to a ray trace program, Dr. Burge can provide the sensitivities.

Specify the tolerances so that the lenses could be manufactured. Specify the grade of glass so it could be purchased from Schott.

You should write a report called "Lens requirements for focusing doublet."

Hints:

For the following, perform perturbation analysis using CodeV or Zemax

- Surface radii of curvature
- Lens thickness
- Wedge
- Refractive index

For the following, calculate the effects directly, assuming lambda/10 surfaces, H2 quality glass

- Surface irregularity
- Refractive index variation (inhomogeneity)

Scale these as needed to get to a solution that allows 0.04 wave rms, and does not have any tolerances tighter than they need to be.

Look at the posting I already made on common problems with HW3. Don't make these mistakes.