OPTI 421/521 – Introductory Opto-Mechanical Engineering

Homework 3: Image quality, Tolerancing for alignment

Part 1) Short answer

1. For a circular aperture of 25 mm, 0.5 µm wavelength light, f/5 system
   a) for ideal system, sketch the diffraction PSF and MTF
   b) for 25 µm defocus, estimate PSF, SR
   c) for 250 µm defocus, estimate PSF, MTF

2. A wavefront with 1 µm P-V spherical aberration has a shape error described by the equation:
   $S(\rho) = (1\mu m)\left(4\rho^4 - 4\rho^2 + \frac{2}{3}\right)$ where ρ is the normalized pupil radial coordinate (ρ = 1 at the edge)

Write the integrals and evaluate to calculate the rms wavefront deviation for this case.

3. Use results from 2). calculate the Strehl ratio for a system with λ/4 P-V spherical aberration.

4. Consider an f/20 system with 500 nm light. Calculate the P-V wavefront error for 1 mm defocus.

5. Calculate the rms wavefront error and SR due to the 1 mm defocus above.

6. Derive the expression for rms spot size for defocus in the geometric limit.

Part 2) Rules of Thumb

Provide three rules of thumb using the format provided in HW2.

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).

The following optical system is used to focus a collimated HeNe laser beam onto a Position Sensing Detector (PSD).

The system requirements are:

- 20 mm entrance pupil diameter
- Nominal EFL = 100 mm
- Wavelength = 632.8 nm (HeNe)
- Diffraction limited operation, SR > 80%
  - (A fine focus adjustment can be made by moving the PSD.)
- The resolution for this adjustment is ±5 um

A nominal optical design has been supplied, see the following page. The design residual of this system is 0.002 λ rms.

A top level system budget has been performed in terms of rms wavefront error:.

Lenses	0.04 λ rms	:	This term covers errors from lenses themselves
Assembly tolerances	0.04 λ rms	:	This term includes lens positions errors
Operational changes	0.04 λ rms	:	Thermal changes, residual focus
RSS	**0.07 λ rms**		

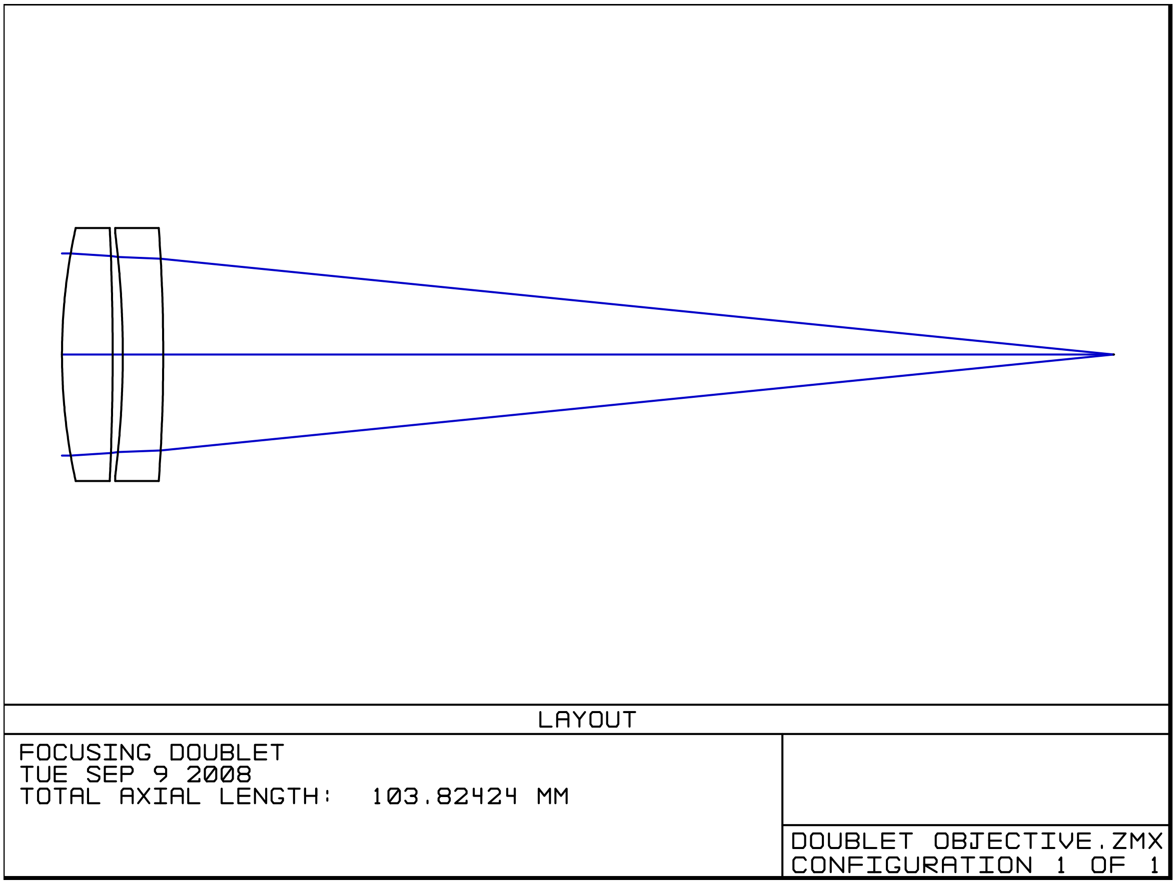
Your job is to perform an initial strawman budget for the assembly tolerances, adding up to 0.04 λ rms. You should include all degrees of freedom for mounting the lenses including tilt, decenter, and axial position. Assume focus compensation by moving the image plane.

You should use a ray trace program such as Zemax, CodeV, Oslo, to determine the sensitivities. Then create a spreadsheet to help set the tolerances to sensible values. (The sensitivities can be provided to you if you do not have access to such a program.)

You should write a report called "Mounting requirements for focusing doublet." Next week you will tolerance the lens elements themselves. Later in the term, you will design the support cells, including tolerances for thermal effects.

Do not simply push the "tolerance" button on Code V. If you insist on doing this, you must verify that CodeV has calculated the sensitivities appropriately.

Focusing Doublet



SURFACE DATA SUMMARY:

Surf	Type	Radius	Thickness	Glass	Diameter
OBJ	STANDARD	Infinity	Infinity		0
STO	STANDARD	Infinity	0		20
2	STANDARD	58.6	5.0	N-SK15	25
3	STANDARD	-277.0	1.0		25
4	STANDARD	-97.0	4.0	N-SK15	24
5	STANDARD	-174.0	93.824		25
IMA	STANDARD	Infinity			

INDEX OF REFRACTION DATA:
Index data is relative to air at the system temperature and pressure.
Index of refraction at 632.8 nm
N-SK15 1.620702