Introductory Optomechanical Engineering 421/521 – Fall 2009: Final Exam
Closed Book, closed notes, One page of notes and calculators are permitted.
110 minutes.

1.) (5) Image rotation is performed using a dove prism.
  a) Sketch the layout for such a system
  b) Sketch the tunnel diagram
  c) Write the mirror matrix
  d) For small angles of rotation about each axis, determine the change in line of sight. Make sure to clearly define the axes!
  e) Use the tunnel diagram to show that the angular deviation is not wavelength dependent

2.) (5) Consider a 1/4 – 20 socket head cap screw
  a) Give the critical dimensions of the screw (outer diameter, thread pitch)

  b) Give the approximate root diameter and minimum cross sectional area

  c) Assume SAE grade 5 with 85 ksi material strength (proof load), calculate the load that can be carried safely by the screw.

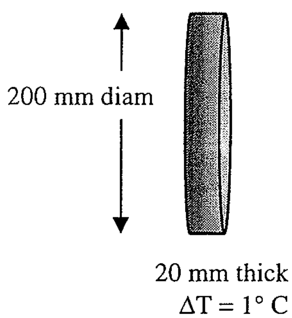
  d) What is the rule of thumb for the appropriate depth of the threaded hole?

3.) (10) Consider a 200 mm diameter, 20 mm thick plano-plano window made from BK7 with an axial thermal gradient of 1°C across the 20 mm thickness:

a) Provide the thermal conductivity, CTE, and dn/dT for BK7

b) Calculate the power in Watts required to maintain this thermal gradient

c) This gradient causes the window distort. Determine the radius of curvature of the distorted window.



4.) (15) Design a mount for the window in problem 3, used as a vacuum window.
200 mm diameter, 20 mm thick BK7

a) Sketch a design of a mount for this window.

b) Calculate the maximum tensile stress in the glass due to the pressure. In your sketch show where this maximum occurs.

c) For the case where the window is pointed vertically, calculate the approximate ~~self-weight~~ deflection. due to the pressure.
(If you have a relationship for self weight deflection, you can apply a scaling factor which replaces (weight/area) with applied pressure.)

5) (10) Define each of the following, using a simple sketch, and give approximate values of the material properties for aluminum.

Normal stress and strain, Young's modulus (elastic modulus)

Shear stress and strain, shear modulus

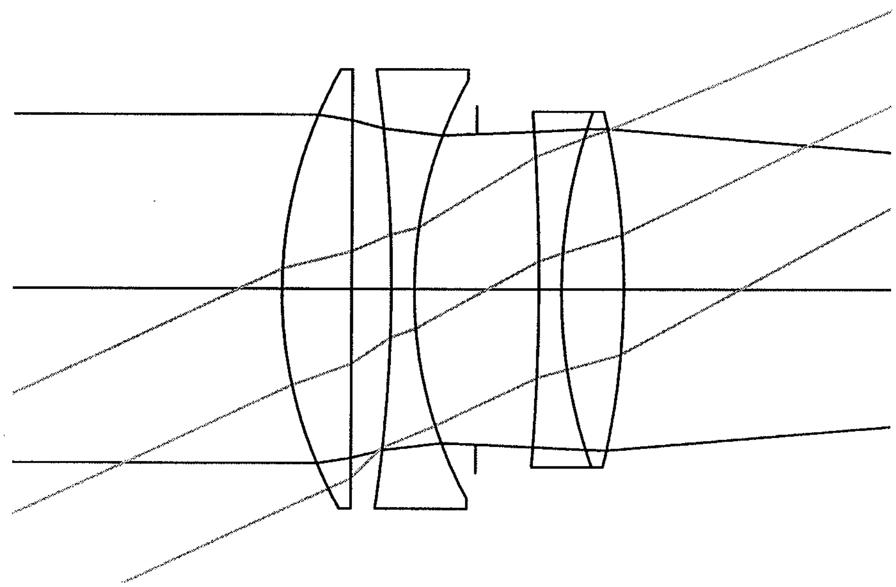
Poisson effect, Poisson ratio

Isostatic pressure, Bulk modulus

6) (15) Design a method for mounting the following lenses which range from 21 to 17 mm diameter. The tilt, decenter, and axial position must be maintained to 50 μm accuracy. Assume the lenses must survive 100 G shock load and +/- 30 C temperature changes.

Describe engineering choices made and issues to consider for assembly, performance and survivability.

Sketch the layout for the mechanical constraints here. You can specify custom edging of the lens elements as well as the other mechanical components



7) (15) Provide a design for flat mirror that folds a 10 mm diameter collimated beam by 90°. Specify the mirror and the mounting technique. Show how it will meet the requirements.

Requirements:

> 95% reflectivity for 400 – 700 nm light

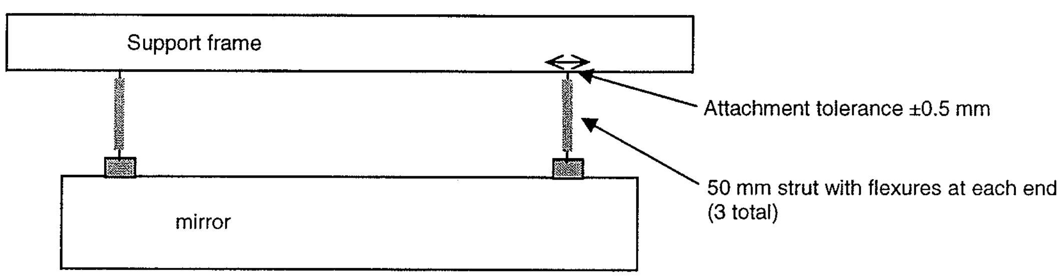
< 100 nm PV wavefront error due to mirror surface errors

Operational environment: +15° to + 25°C

Survival requirements: T = -20°C to 50°C, 50 G shock

8) (5) Describe a hexapod positioner. List the two key features that make this design attractive. List the one key limitation or difficulty.

9) (5) We use flexures to define connections to sensitive optics, such as mirrors. A particular hinge flexure has axial stiffness of 100,000 N/mm and bending stiffness of 0.01 N-m/mrad. This is attached rigidly to metal pucks that are bonded to the back of a mirror. Finite element modeling predicts 100 nm rms surface deflection for a 1 N-m moment at each puck. The attachment to the flexure is made through 50 mm long struts. Assembly tolerances allow 0.5 mm for the attachment of the strut. Determine the contribution to the mirror surface error from the all 3 struts assuming the 0.5 mm alignment errors are uncorrelated.



10) (5) Pure kinematic interfaces require point contacts. These have peculiar issues which depend on the preload. Sketch a graph that shows the stiffness as a function of preload for a 0.2" diameter steel ball on a flat surface. For the case of 1 pound preload, give the approximate stiffness, static frictional force (assume lubrication, μ=0.15), and stress.