Burge
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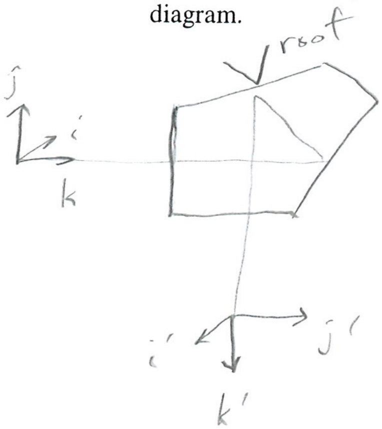
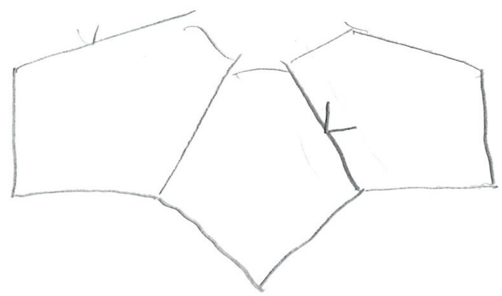
Introductory Optomechanical Engineering 421/521 – Fall 2009
Midterm 1 50 minutes, 1 page of notes is permitted, calculator is permitted

1.) (10) Sketch a roof penta prism. Define three axes and write the mirror matrix for this prism. Draw its tunnel diagram.



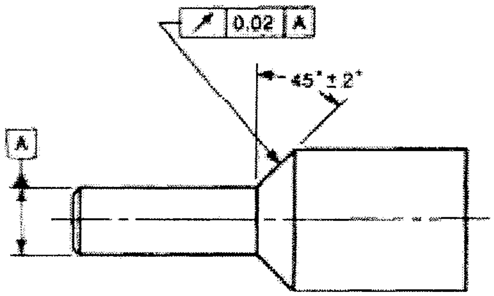


$$M = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

2.) (5) For the prism above, describe what happens to line of sight and image rotation if the prism is rotated by a small angle about each of the three axes. Define each axis clearly on your sketch.

about x, pitch — no effect
about y, yaw — LOS moves out of plane (about j')
about z, roll — " " " and image rotates

3.) (5) Explain the meaning of all 3 parts of the callout in the drawing below.



↗ TIR Total Indicator Runout

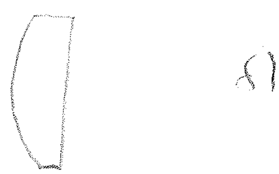
0.02 tolerance zone, maximum full excursion of indicator

A Datum: TIR must be within 0.02 as part is rotated about axis of cylinder A

4.) (15) A 25 mm diameter, 250 mm focal length plano-convex lens was made with 50 μm ETD. Assume $n = 1.5$, R = 125 mm.

Consider two cases, **make a sketch** for each:

A) Assume the lens is mounted using the outer mechanical surface. Determine the angular deviation of light due to the wedge in the lens.



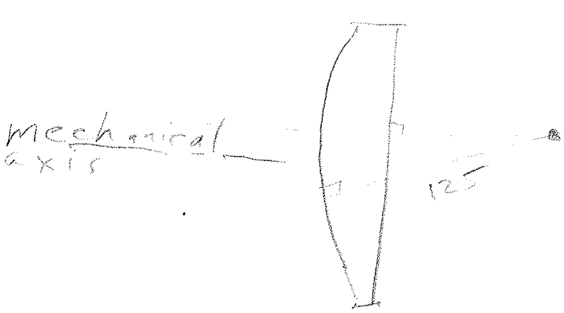
wedge is $\frac{50\,\mu m}{25\,mm} = 2$ mrad

$\delta = (\text{wedge})(n-1) \approx 1$ mrad

$\varepsilon = \delta\ 250 = 250\,\mu m$

image shift off axis

B) If the lens is mounted such that the optical axis (defined by the two optical surfaces) is placed on the system axis, then the deviation will be zero. Determine the lens decenter (as defined by the outer edge) for such alignment.



wedge = 2 mrad

shifts CofC by

(2 mrad)(125 mm)

= 250 μm

5.) (5) A 20 mm diameter lens has a spherical surface with requirements of R = 500 +/- 5 mm. Calculate the tolerance in terms of the sag of the surface. Is this tight?

$$\text{Sag} = \frac{r^2}{2R^2} \qquad \Delta\text{Sag} = -\frac{r^2}{2R^2}\Delta R = \frac{D^2}{8R^2}\Delta R = \frac{1}{8(R/D)^2}\Delta R$$

$$R/D = 500/20 = 25$$

$$8(R/D)^2 = 8 \cdot 625 = 5000$$

$$\Delta S = 5\text{mm}/5000 = 1\mu\text{m}$$ yes, this is tight

6.) (5) A polished optic may have a scratch/dig specification of 20/10. Explain briefly what this means. Is 20/10 tight?

20 = scratch number, compared with standard

10 = dig #, no dig > 100 μm

20/10 is very tight

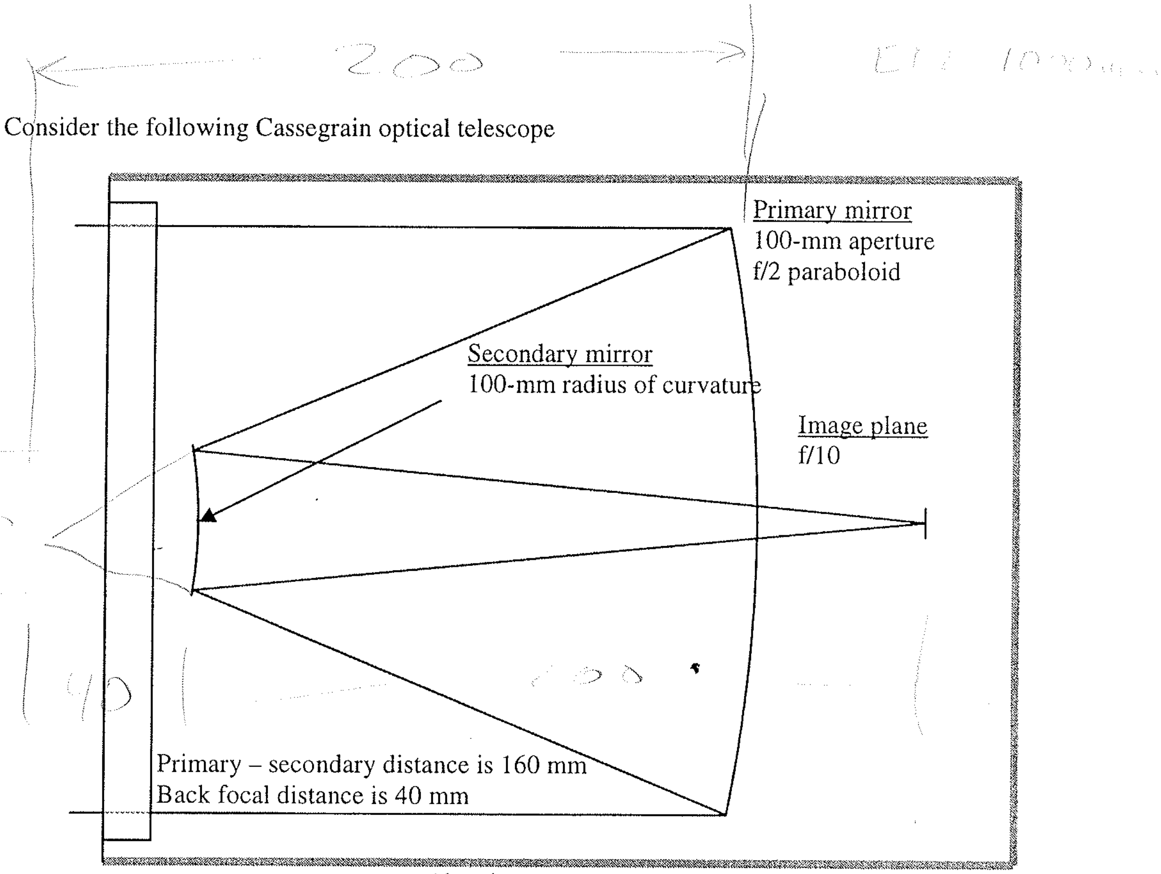
7.) (5) What is the name of the machine that is used for shaping most metal parts.

The milling machine

AKA the mill

AKA Bridgeport

8.) (20) Consider the following Cassegrain optical telescope



(drawing not to scale)

Find the effect of each mirror's rotation and lateral translation on system line-of-sight. Report the image motion due to the mirror motion as given below.

Mirror	Mirror motion	Resulting image shift
Primary Mirror	20 µm lateral motion	100 µm
	0.1 mrad tilt	200 µm
Secondary Mirror	20 µm lateral motion	80 µm
	0.1mrad tilt	40 µm

m = 5. 20 µm from PM → 100 µm at f/10

.1 mrad PM → 2 · (0.1 mrad)(200 mm)

PM EFL = 200 mm

40 µm at PM focus ×5 = 200 µm

SM f = 50 Δy = 20 µm $\Delta\theta = \frac{20\,\mu m}{50\,mm} = 0.4$ mrad

0.4 mrad × 200 mm = 80 µm

.1 mrad θ = 2 × .1 = 0.2 mrad

ε = .2 × 200 = 40 µm

9.) (10) Consider the same system above. Assume all four optical surfaces are polished to 0.1 wave **P-V** (primary mirror, secondary mirror, and each side of the window.) The effects of mounting and alignment are allotted additional 0.03 wave rms wavefront error. Calculate the expected the rms wavefront error for the as-built telescope and calculate the Strehl ratio.

each mirror 0.1λ P-V $\cong$ 0.025λ rms surface
$\times 2$ for reflection
$.05\lambda$ rms WF

each surface of window
0.1λ P-V $= 0.025\lambda$ rms surface
$\times n-1$
$= 0.0125\lambda$ rms WF

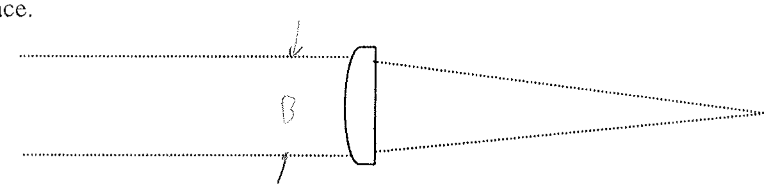
	rms WFE
W1	.0125
W2	.0125
M1	.05
M2	.05
align	.03

RSS = 0.079 λ rms

$SR \cong 1-\sigma^2 = 1-(2\pi(.079))^2$

$\cong 0.75$

10.) (5) Consider a single plano-convex lens, creating an image at f/8. The optical surfaces are manufactured to 4 fringes irregularity (P-V). Estimate the contribution to the rms spot size due to the figure errors of each optical surface.



4 fringes = 2λ P-V surface
$\times(n-1) = 1\lambda$ P-V WF

RoT $\rightarrow$ 1λ/rad rms WF slope

$\lambda = 500$ nm $\theta = 1\lambda/\text{rad} \cdot \frac{0.50\mu m}{1\lambda} \cdot \frac{\text{rad}}{B/2}$
$= 1\mu m/B$

$\varepsilon = \theta B F^\#$
$= \frac{1\mu m}{B} \cdot B \cdot 8 = 8\mu m$ rms / surface

total $= \sqrt{2} \cdot 8 = 11.3\mu m$ rms

11.) (15) Sketch a 3-view orthographic pro[illegible]tion of the followin[illegible] (You do not need to include dimensions.)