Homework #3

Thursday, September 17, 2009
2:48 PM

1 a) We define a wavefront as the sum of the reference + the surface.

$$W = r_n^m + s_n^m$$

A reflective surface, like those used in a Fizeau, have twice the OPD.

$$\therefore \quad s_n^m = \frac{W_n^m - r_n^m}{2}$$

b) $Z_2 = 4$, $Z_3 = 3$

These correspond to

$$Z_2 = \rho \cos\theta$$
$$Z_3 = \rho \sin\theta$$

Using the trig relation

$$a\cos\theta + b\sin\theta = \sqrt{a^2+b^2}\cos\left(\theta - \tan^{-1}\frac{b}{a}\right)$$

we get

$\Rightarrow \sqrt{3^2+4^2}\,\rho\cos(\theta - \tan^{-1}\tfrac{3}{4})$

Thus as $\rho \to 1$

Magnitude $\Rightarrow \sqrt{3^2+4^2} = 5$ or 10 if using standard Zernikes.

Angle $\Rightarrow \tan^{-1}\tfrac{3}{4}$

c) $Z_5 = 1$, $Z_6 = 1$ these correspond to

$Z_5 = \rho^2\cos 2\theta$, $Z_6 = \rho^2 \sin 2\theta$

Using the relation from 16,

$W = \rho^2\cos 2\theta + \rho^2 \sin 2\theta$

$= \sqrt{1^2+1^2}\,\rho^2\cos(2\theta - \tan^{-1}\tfrac{1}{1})$

but $\cos 2\theta = 2\cos^2\theta - 1$ ← this is a defocus term not astig.

so $2\sqrt{2}\,\rho^2\cos^2(\theta - \tfrac{1}{2}(\pi/4))$

Mag: $2\sqrt{2}$ (or $2\sqrt{12}$)

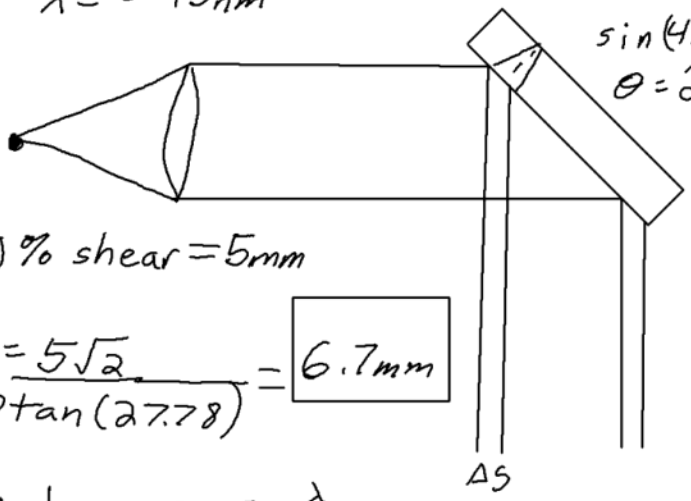
Angle: $\pi/8$

See J. Wyant notes on Zernikes for more details

Start here Page 2

2) LSI N-BK7 ($n = 1.517$), $D = 50\,mm$

$\lambda = 543\,nm$



10% shear = 5mm

$$t = \frac{5\sqrt{2}}{2\tan(27.78)} = \boxed{6.7\,mm}$$

Wedge $\alpha = \frac{\lambda}{2nd_s}$

We want 10 fringes so $d_s = \frac{50-5}{10} = 4.5\,mm$

$$\alpha = \frac{.543\,\mu m}{2(1.517)\,4500\,\mu m} \simeq \boxed{40\,\mu rad}$$

Focus error causes rotation in the system due to the tilt

$$R = \frac{s d_s}{\lambda \Delta\phi} \qquad \Delta\phi \simeq 2° = 35\,mrad$$

$$R = \frac{5 \cdot (4.5)\,mm^2}{.543\,\mu m \;\; 35\,mrad} = 1193\,m$$

very sensitive!

3) a) 1) Place ball at focus of PSM such that a point is present to determine the center of the bearing.
2) Remove ball and align spherical mirror to return spot.
3) Replace tooling ball. Mirror CC and ball CC are coincident.

b) WD must be longer than 6.35mm
EP must be $\geq$ 7mm
Largest NA to reduce DOF error.

ex. Mitutoyo NT59-879 50x

c) DOF of objective is $\pm$ B' S/#

$DOF = \pm 2 [redacted] \lambda \, S/\#^2 \simeq \boxed{2\mu m}$

can see 1/2 pixel movement

$$\Delta x_i = m_v \Delta x_o \Rightarrow \Delta x_o = \frac{dp}{2}\left(\frac{S_{obj}}{S_{tube}}\right)$$

$$\Rightarrow \left(\frac{4.45}{2}\right)\left(\frac{4}{100}\right) = \boxed{0.089\mu m}$$

4

Start here Page 5

d) The erros in c will be present, It will have a DOF from the mirror as well.

e) see Newport catalog

f) The sensitivity is $\frac{\lambda}{300}$

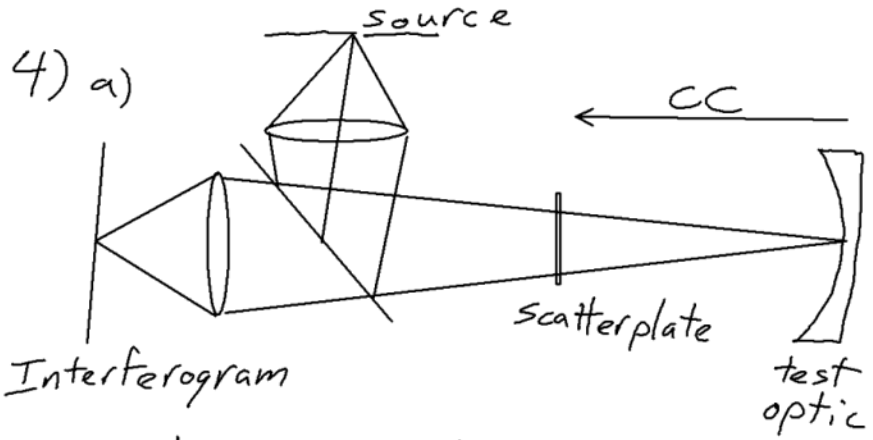
$$\Delta W = \frac{\varepsilon_z}{8(f/\#)^2} \Rightarrow \varepsilon_z = 8(3.3)^2\left(\frac{.633\mu m}{300}\right)$$

$$= .184\mu m$$

g) The Sizeau is far more sensitive.

Start here Page 6

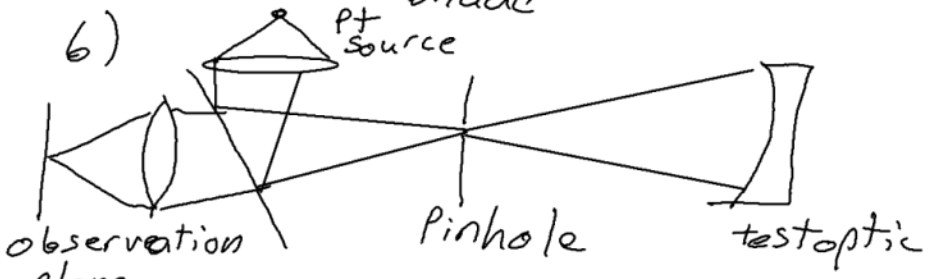
4) a)



Good to use when unsure of system optical quality. The scatter plate must have inversion symmetry

Pros: simple, can use white light
Cons: plate must be carefully made

6)

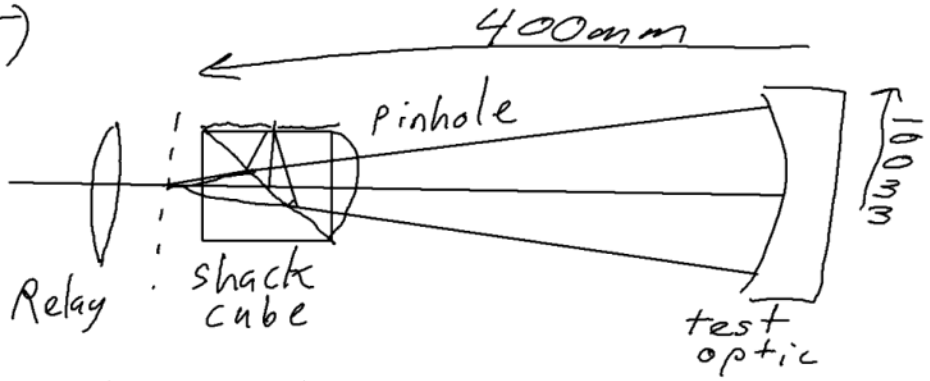


Pros: common path, can phase shift easily
Cons: very sensitive to pinhole alignment
Pinhole should be size of Airy Disk.

Start here Page 7

4c) Works well with optics that do not change polarization. If an element changes to say linear polarization, no interference can be seen as vis → 0

5)



a) The point source is at the center of curvature for the test optic and cube lens, ideally at the cube. This is so the spherical wavefront is ⊥ to both, and minimizes 3rd order aberrations from hitting the cube at an angle

b) A lens is not needed as the cube lens already images the surface (and fringes). The extra lens helps to magnify the spot to reasonable size.

Start here Page 8

c) can be phase shifted by moving the mirror (slightly) using piezos

Start here Page 9