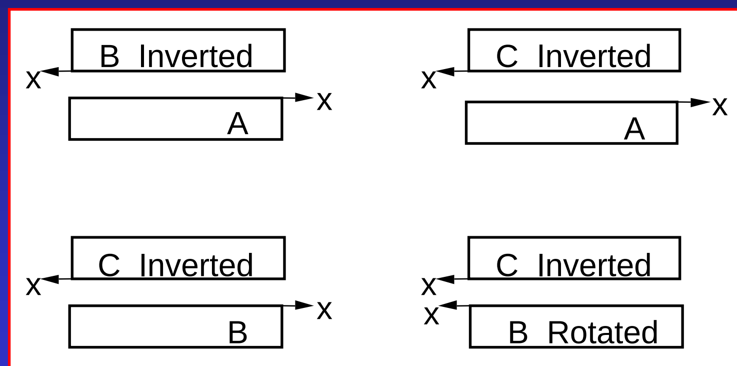
Part 7
Absolute Measurements

- Absolute measurement of flats
- Absolute measurement of spheres
- Absolute measurement of surface roughness

Absolute Surface Shape Measurement

- Removing system aberrations & reference surface effects
- Improves measurement accuracy
- Tests for
  - Flats
  - Spheres
  - Surface roughness

Measurements Required for Three-Flat Test



Three-Flat Test Equations

Make 4 Measurements

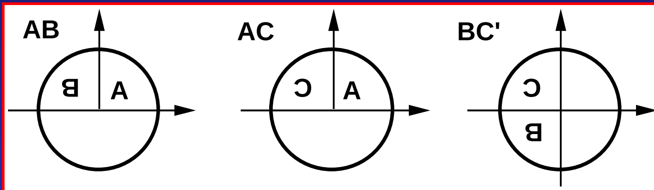
$$G_{AB}(x,y) = f_A(x,y) + f_B(-x,y)$$

$$G_{AC}(x,y) = f_A(x,y) + f_C(-x,y)$$

$$G_{BC}(x,y) = f_B(x,y) + f_C(-x,y)$$

$$G_{BC'}(x,y) = f_B(-x,-y) + f_C(-x,y)$$

Three-Flat Test - X Line

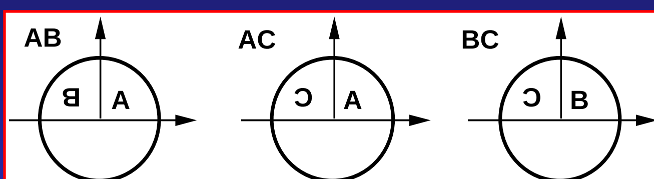


$$f_A(x,0) = \frac{G_{AB}(x,0) + G_{AC}(x,0) - G_{BC'}(x,0)}{2}$$

$$f_B(x,0) = \frac{G_{AB}(x,0) - G_{AC}(x,0) + G_{BC'}(x,0)}{2}$$

$$f_C(x,0) = \frac{- G_{AB}(x,0) + G_{AC}(x,0) + G_{BC'}(x,0)}{2}$$

Three-Flat Test - Y Line

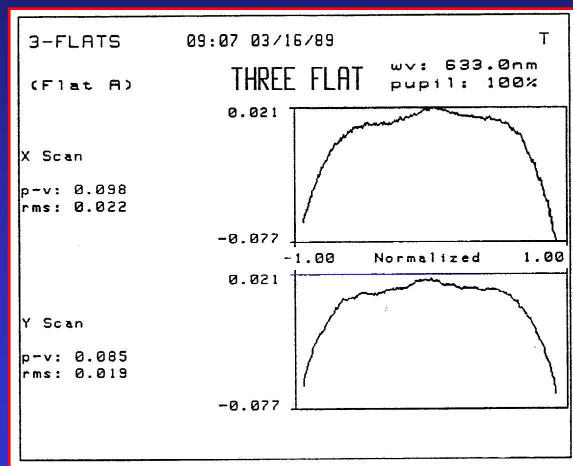


$$f_A(0,y) = \frac{G_{AB}(0,y) + G_{AC}(0,y) - G_{BC}(0,y)}{2}$$

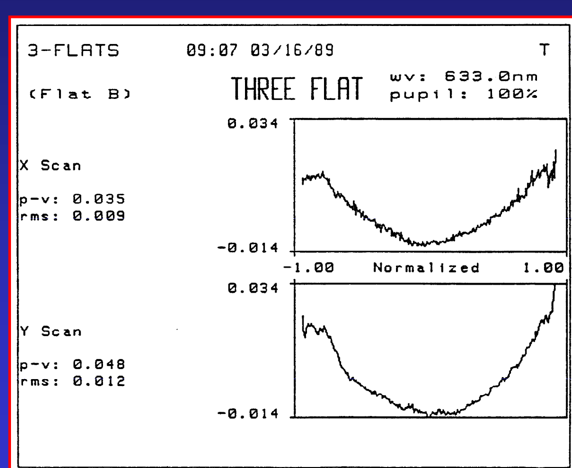
$$f_B(0,y) = \frac{G_{AB}(0,y) - G_{AC}(0,y) + G_{BC}(0,y)}{2}$$

$$f_C(0,y) = \frac{- G_{AB}(0,y) + G_{AC}(0,y) + G_{BC}(0,y)}{2}$$

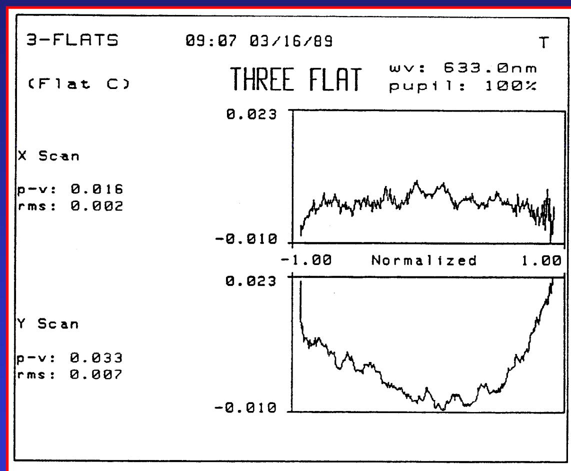
Three-Flat Test - Flat A



Three-Flat Test - Flat B



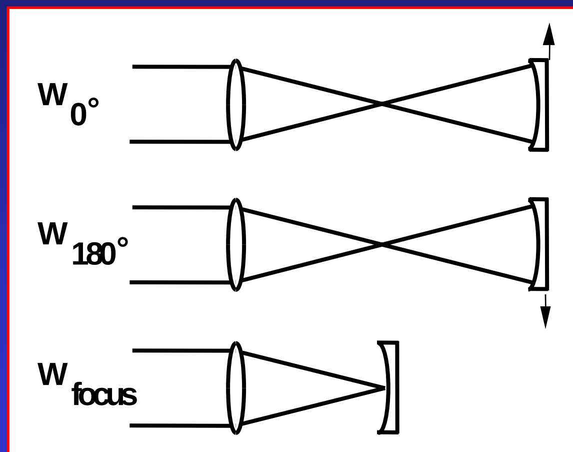
Three-Flat Test - Flat C



Absolute Sphere Testing

- Separate interferometer errors from errors in spherical mirror being tested.
- Three measurements required.

Absolute Sphere Testing (Measurements Required)



Absolute Sphere Testing (Equations)

$$W_{focus} = W_{ref} + \frac{1}{2}\left[W_{div} + \overline{W}_{div}\right]$$

$$W_{0°} = W_{surf} + W_{ref} + W_{div}$$

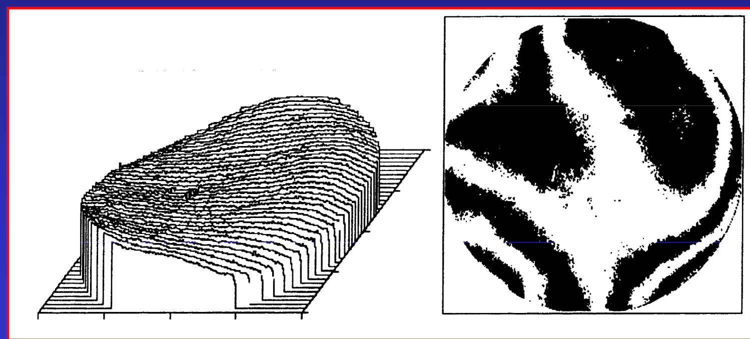
$$W_{180°} = \overline{W}_{surf} + W_{ref} + W_{div}$$

COMBINE 3 MEASUREMENTS

$$W_{surf} = \frac{1}{2}\left[W_{0°} + \overline{W}_{180°} - W_{focus} - \overline{W}_{focus}\right]$$

Single Measurement of Sphere

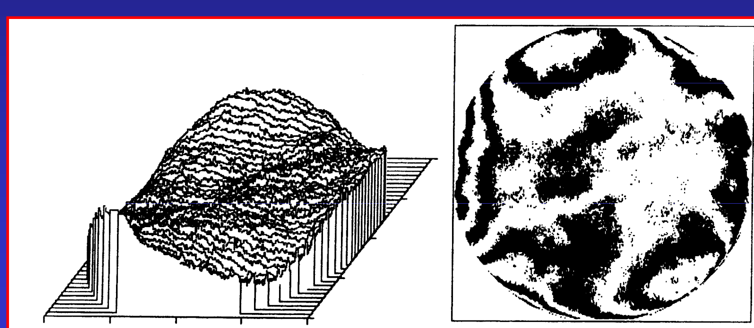
TILT, POWER REMOVED
INTERVAL = 0.025
RMS = 0.014 WAVES
P-V = 0.121 WAVES



FIZEAU INTERFEROMETER, F/1.1 REF. SPHERE

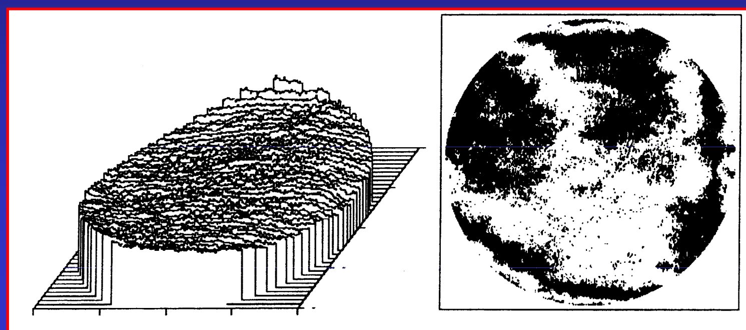
Flat at Focus f/1.1 Diverger

TILT, POWER, COMA REMOVED
INTERVAL = 0.05
RMS = 0.027 WAVES
P-V = 0.243 WAVES



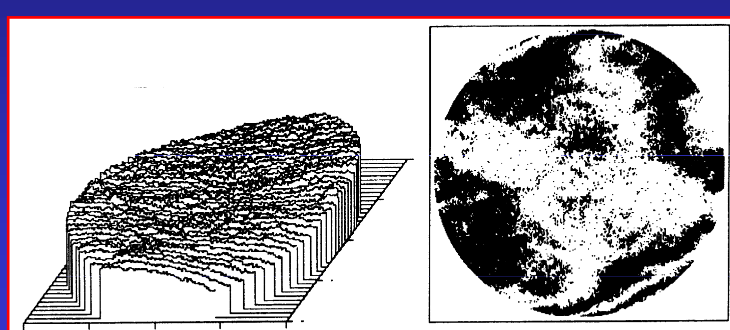
Absolute Reference

TILT, POWER REMOVED
INTERVAL = 0.025
RMS = 0.010 WAVES
P-V = 0.084 WAVES



Absolute Measurement of Sphere

TILT,POWER REMOVED
INTERVAL = 0.025
RMS = 0.011 WAVES
P-V = 0.081 WAVES

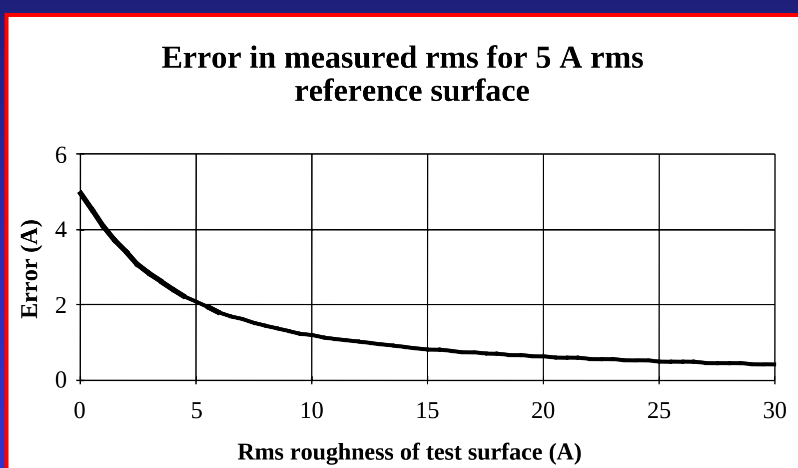


Absolute Surface Roughness Measurement Assumptions

- Surface height is random
- Statistics do not vary over surface
- Each measurement = Test + Reference
- Test and reference uncorrelated

$$RMS_{meas} = \sqrt{RMS_{test}^2 + RMS_{ref}^2}$$

Effect of Reference Surface on Measurement



Subtraction of Errors due to Reference Surface

- Perfect mirror
- Generate reference
- Absolute rms measurement

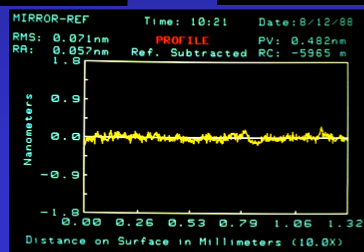
Generate Reference

- Average many measurements
- Move random surface > correlation length between measurements
- Effects of random surface reduce as square root of number of measurements

Generate Reference and Subtract

Surface + Reference

Reference



Surface
(0.071 nm)

Absolute RMS Measurement

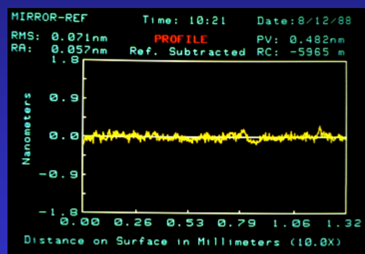
- Make 2 measurements where surface moved > correlation length between measurements
- Subtract measurements and divide by square root of 2
- Reference cancels and obtain
- RMS of test surface

$$Diff = Test_1 + (-Test_2)$$

$$RMS_{Test} = \frac{1}{\sqrt{2}} RMS_{Diff}$$

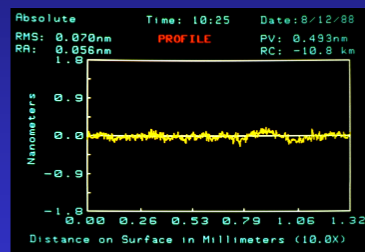
Generate Reference and Absolute RMS Comparison

Generate Reference



RMS = 0.071 nm

Absolute RMS



RMS = 0.070 nm