

Absolute Testing

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

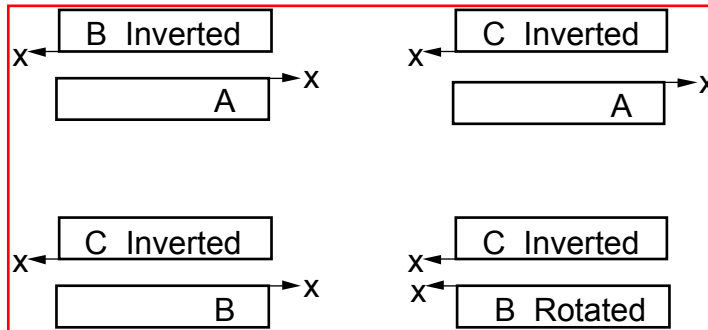
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Absolute Surface Shape Measurement

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

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Measurements Required for Three-Flat Test



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Three-Flat Test Equations

Make 4 Measurements

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

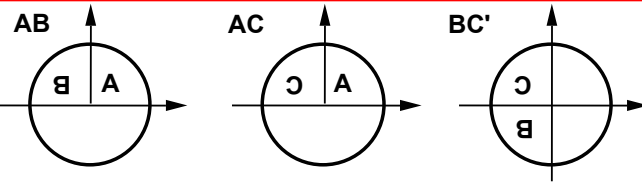
$$G_{AC}(x,y) = f_A(x,y) + f_C(-x,y)$$

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

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

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Three-Flat Test - X Line



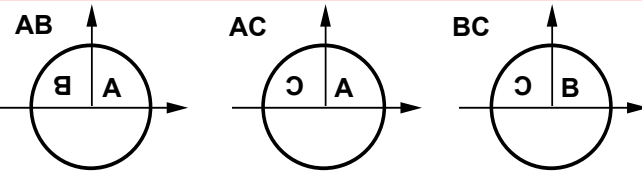
$$f_A(x,0) = \frac{G_{AB}(x,0) + G_{AC}(x,0) - G_{BC'}(x,0)}{2}$$

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

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

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Three-Flat Test - Y Line



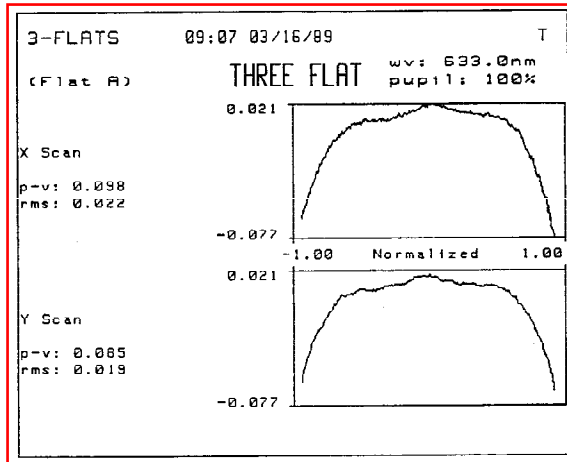
$$f_A(0,y) = \frac{G_{AB}(0,y) + G_{AC}(0,y) - G_{BC}(0,y)}{2}$$

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

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

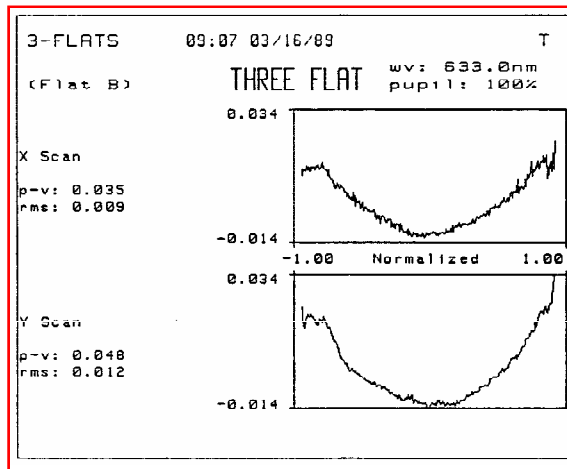
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Three-Flat Test - Flat A



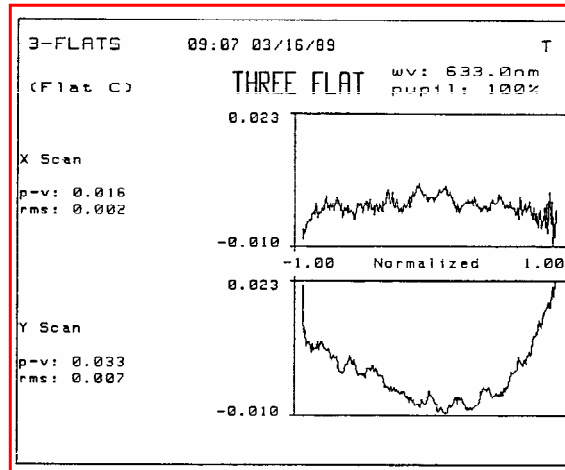
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Three-Flat Test - Flat B



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Three-Flat Test - Flat C



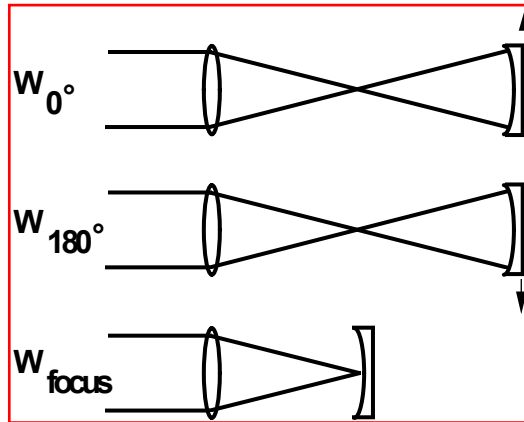
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Absolute Sphere Testing

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

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Absolute Sphere Testing (Measurements Required)



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Absolute Sphere Testing (Equations)

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

$$W_{0^\circ} = W_{\text{surf}} + W_{\text{ref}} + W_{\text{div}}$$

$$W_{180^\circ} = \overline{W}_{\text{surf}} + W_{\text{ref}} + W_{\text{div}}$$

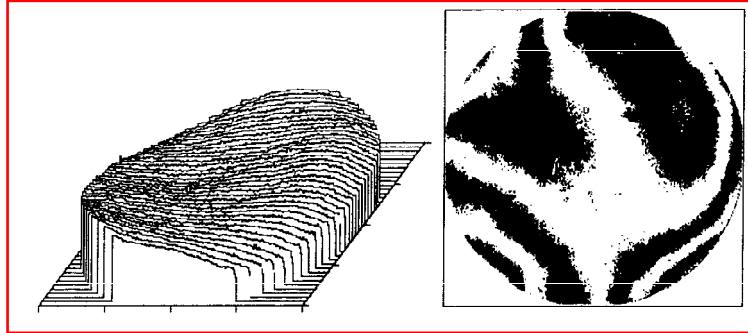
COMBINE 3 MEASUREMENTS

$$W_{\text{surf}} = \frac{1}{2} [W_{0^\circ} + \overline{W}_{180^\circ} - W_{\text{focus}} - \overline{W}_{\text{focus}}]$$

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Single Measurement of Sphere

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

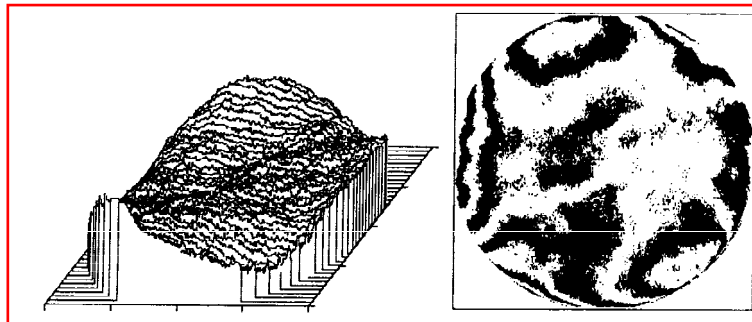


FIZEAU INTERFEROMETER, F/1.1 REF. SPHERE

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Flat at Focus f/1.1 Diverger

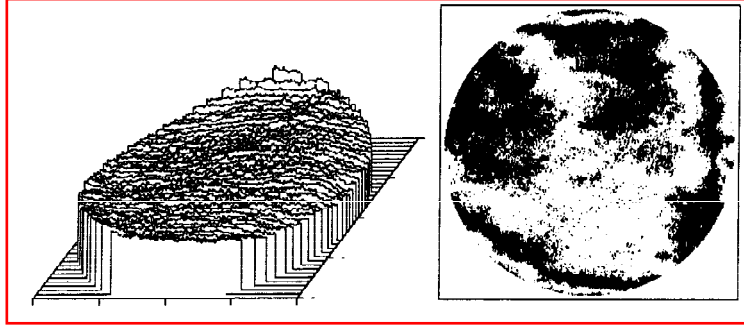
TILT, POWER, COMA REMOVED
INTERVAL = 0.05
RMS = 0.027 WAVES
P-V = 0.243 WAVES



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Absolute Reference

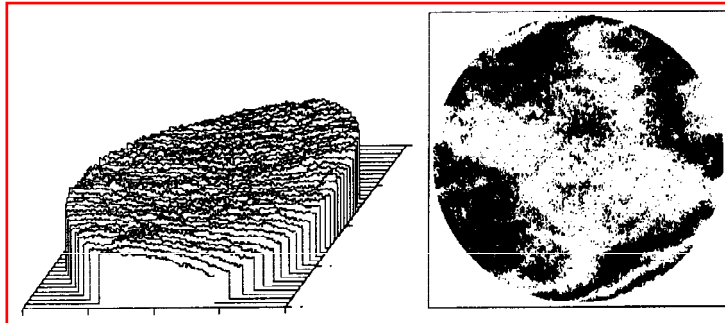
TILT, POWER REMOVED
INTERVAL = 0.025
RMS = 0.010 WAVES
P-V = 0.084 WAVES



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Absolute Measurement of Sphere

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



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Absolute Surface Roughness Measurement Assumptions

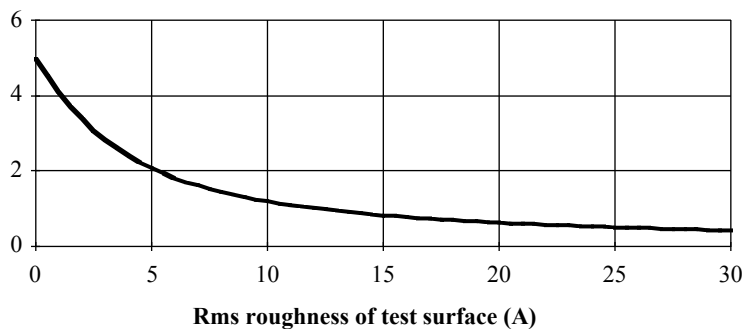
- Surface height is random
- Statistics do not vary over surface
- Each measurement = Test + Reference
- Test and reference uncorrelated

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

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Effect of Reference Surface on Measurement

Error in measured rms for 5 Å rms reference surface



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Subtraction of Errors due to Reference Surface

- **Perfect mirror**
- **Generate reference**
- **Absolute rms measurement**

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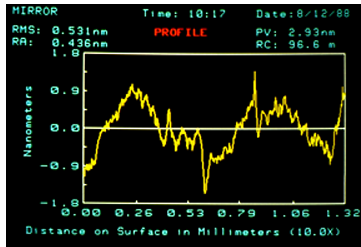
Generate Reference

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

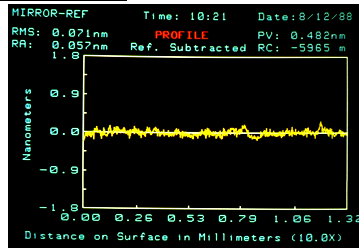
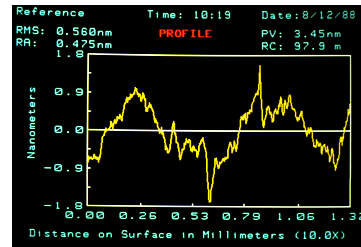
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Generate Reference and Subtract

Surface + Reference



Reference



Surface
(0.071 nm)

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Absolute RMS Measurement

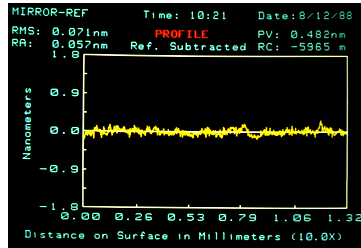
- Make 2 measurements where surface moved > correlation length between measurements
- Subtract measurements and divide by square root of 2
- Reference cancels and obtain
- RMS of test surface

$$Diff = Test_1 + (-Test_2)$$
$$RMS_{Test} = \frac{1}{\sqrt{2}} RMS_{Diff}$$

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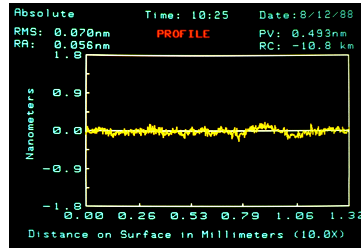
Generate Reference and Absolute RMS Comparison

Generate Reference



RMS = 0.071 nm

Absolute RMS



RMS = 0.070 nm