Absolute Testing

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

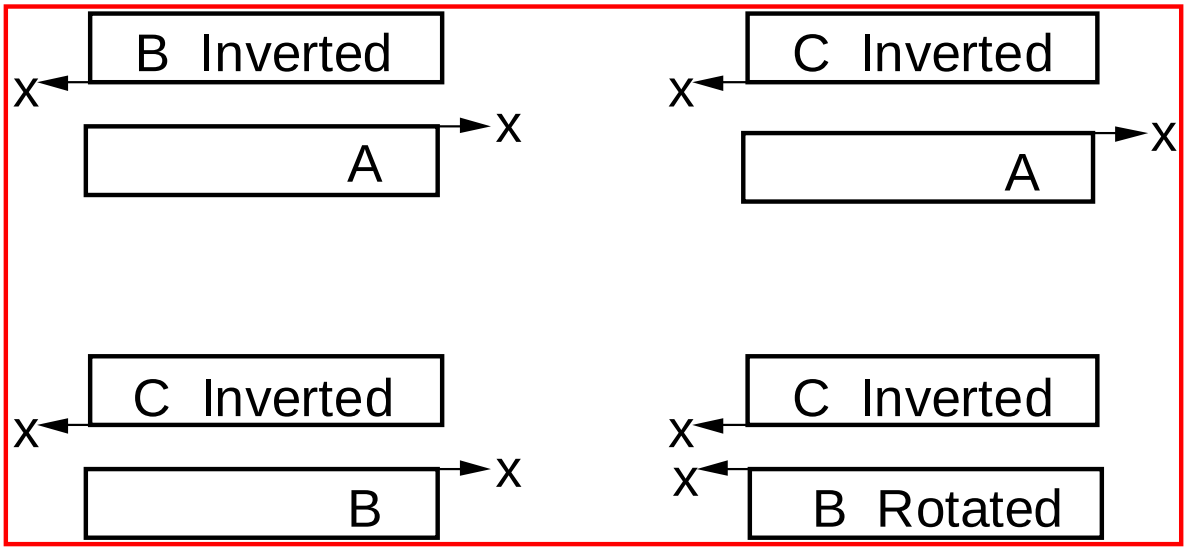
Absolute Surface Shape Measurement

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

Three-Flat Test

If we have only two flats and we get straight line fringes when we compare the two flats we do not know they are flat because one could be concave and the second could be convex so the two surfaces match. If we have three flats and we get straight line fringes when we compare flat A with flat B and when we compare flat A with flat C and again when we compare flat B with flat C then the surfaces must all be flat.

The following are the four measurements required to find an absolute measurement of the x and y profiles of the three flats.



- **From the 4 measurements we obtain**

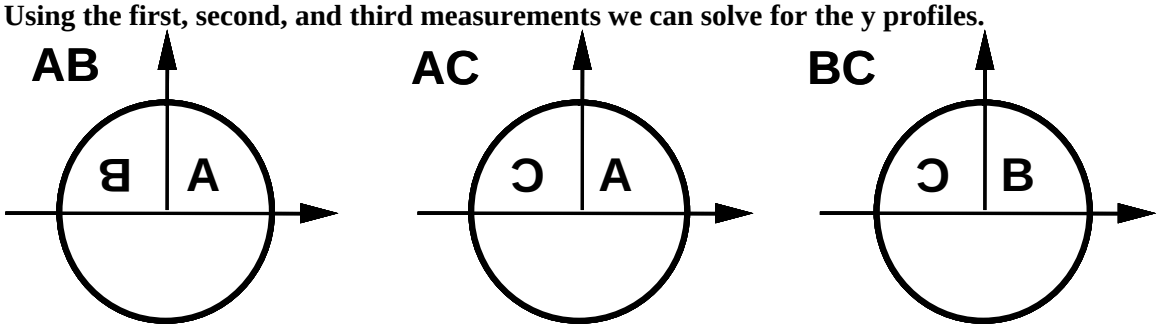
$G_{AB}[x\_, y\_] := f_A[x, y] + f_B[-x, y]$

$G_{AC}[x\_, y\_] := f_A[x, y] + f_C[-x, y]$

$G_{BC}[x\_, y\_] := f_B[x, y] + f_C[-x, y]$

$G_{BC'}[x\_, y\_] := f_B[-x, -y] + f_C[-x, y]$

- **Using the first, second, and third measurements we can solve for the y profiles.**

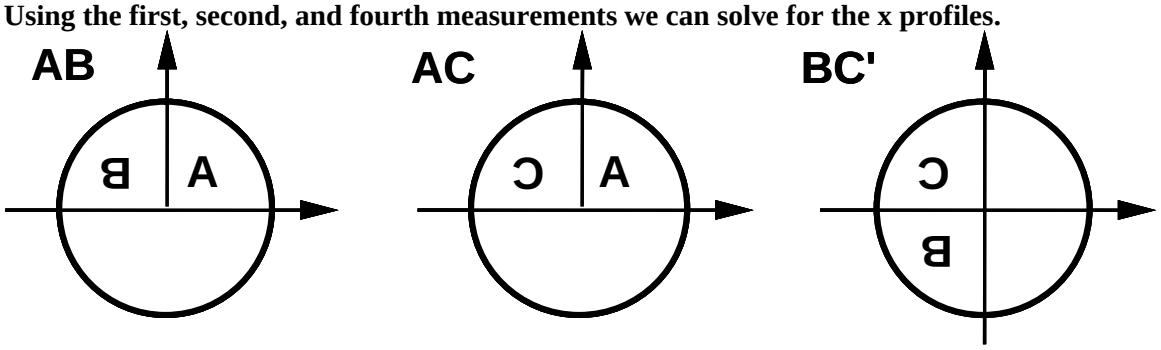


$$\frac{G_{AB}[0, y] + G_{AC}[0, y] - G_{BC}[0, y]}{2} = f_A[0, y]$$

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

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

- **Using the first, second, and fourth measurements we can solve for the x profiles.**



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

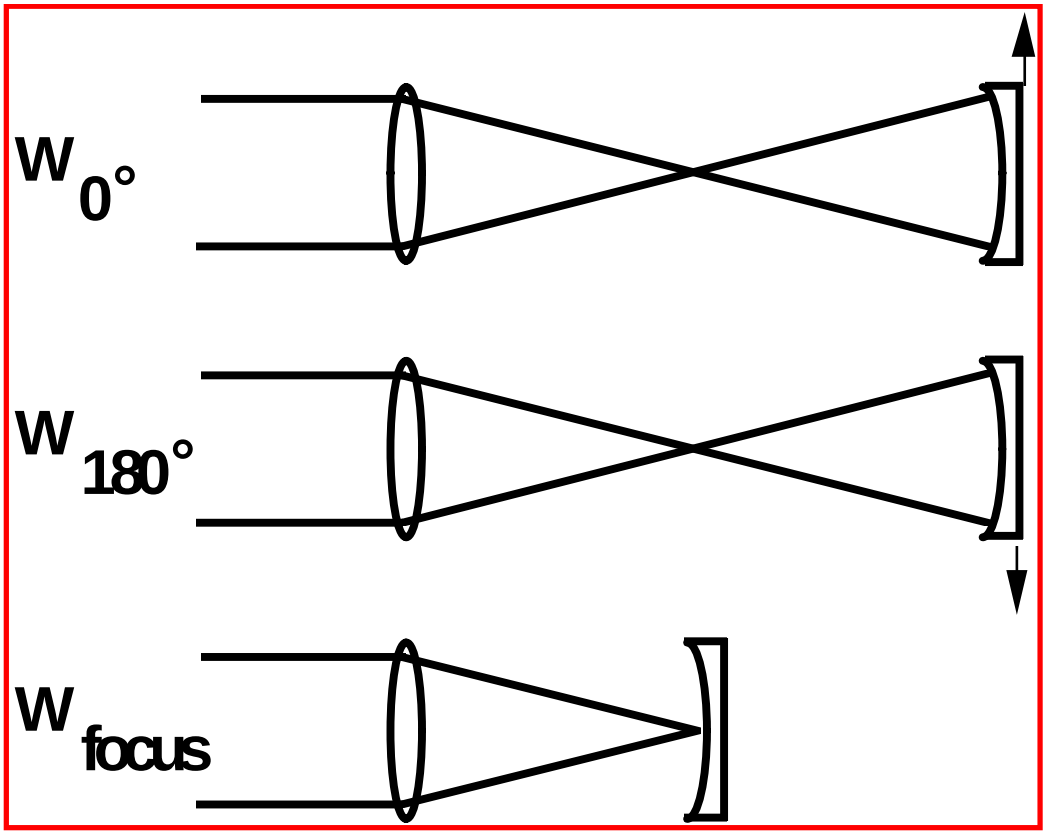
$$\frac{G_{AB}[x, 0] - G_{AC}[x, 0] + G_{BC'}[x, 0]}{2} = f_B[-x, 0]$$

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

We have obtained the x and y profiles of the three flats. The process can be repeated to obtain other profiles.

Absolute Sphere Testing

Using the following procedure it is possible to separate interferometer errors from errors in the spherical mirror being tested. The technique will work with both the Twyman-Green interferometer and the laser-based Fizeau interferometer. Three measurements are required.



The three measurements give

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W0[x_, y_] := 2 Wsurf[x, y] + Wref[x, y] + 2 Wdiv[x, y]
W180[x_, y_] := 2 Wsurf[-x, -y] + Wref[x, y] + 2 Wdiv[x, y]
Wfocus[x_, y_] := Wref[x, y] + Wdiv[x, y] + Wdiv[-x, -y]
```

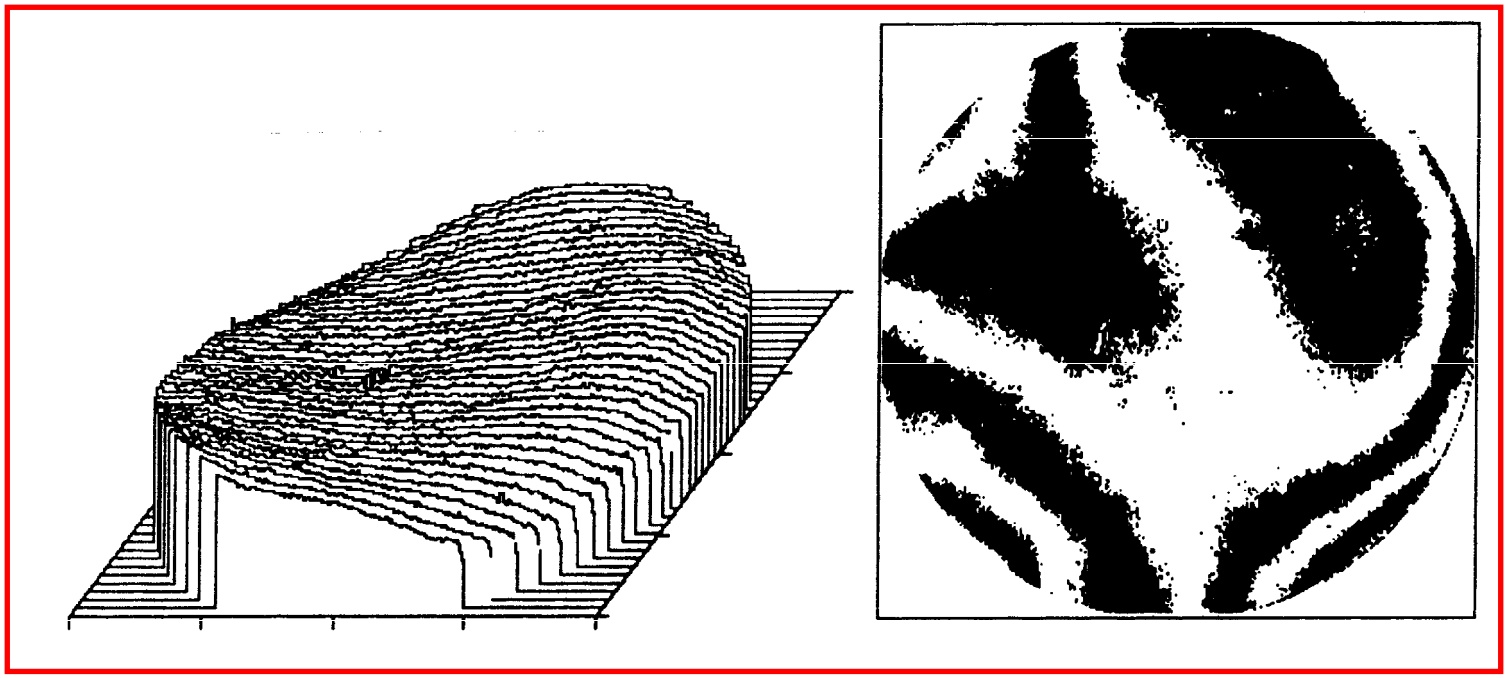
The mirror surface error is given by

$$\frac{1}{4}\left(W_0[x, y] + W_{180}[-x, -y] - W_{focus}[x, y] - W_{focus}[-x, -y]\right) = W_{surf}[x, y]$$

$[-x.-y]$ in the last equation means we are rotating the data 180° in the computer.

Single Measurement of Sphere

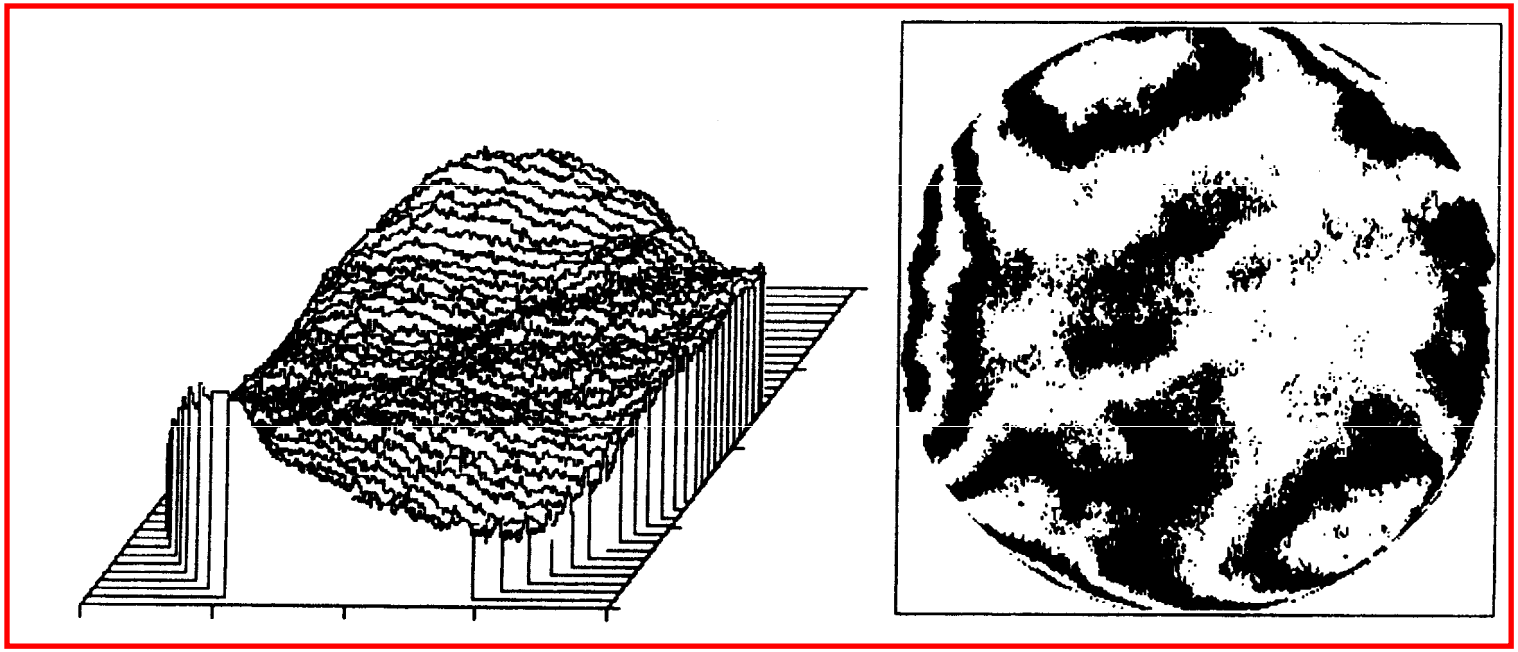
TILT, POWER REMOVED
INTERVAL = 0.025
RMS = 0.014 WAVES
P-V = 0.121 WAVES



FIZEAU INTERFEROMETER, F/1.1 REF. SPHERE

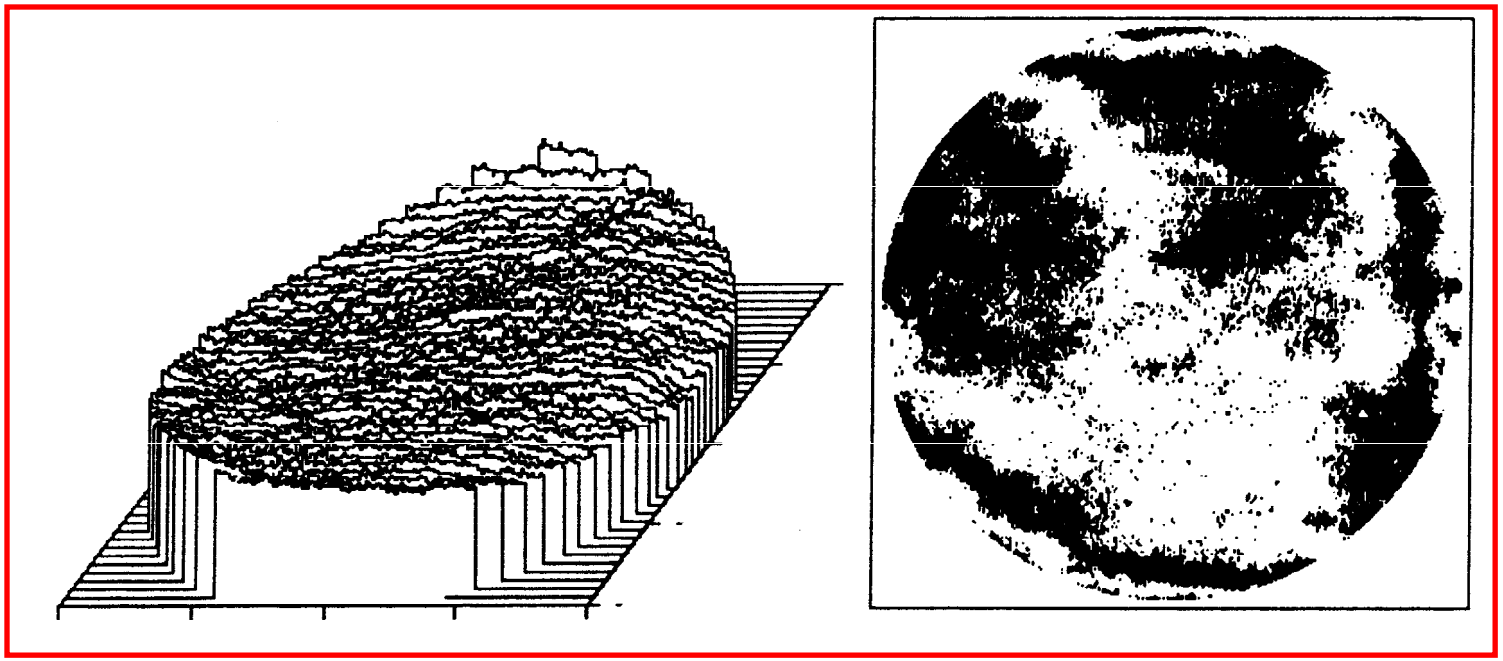
Flat at Focus f/1.1 Diverger

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



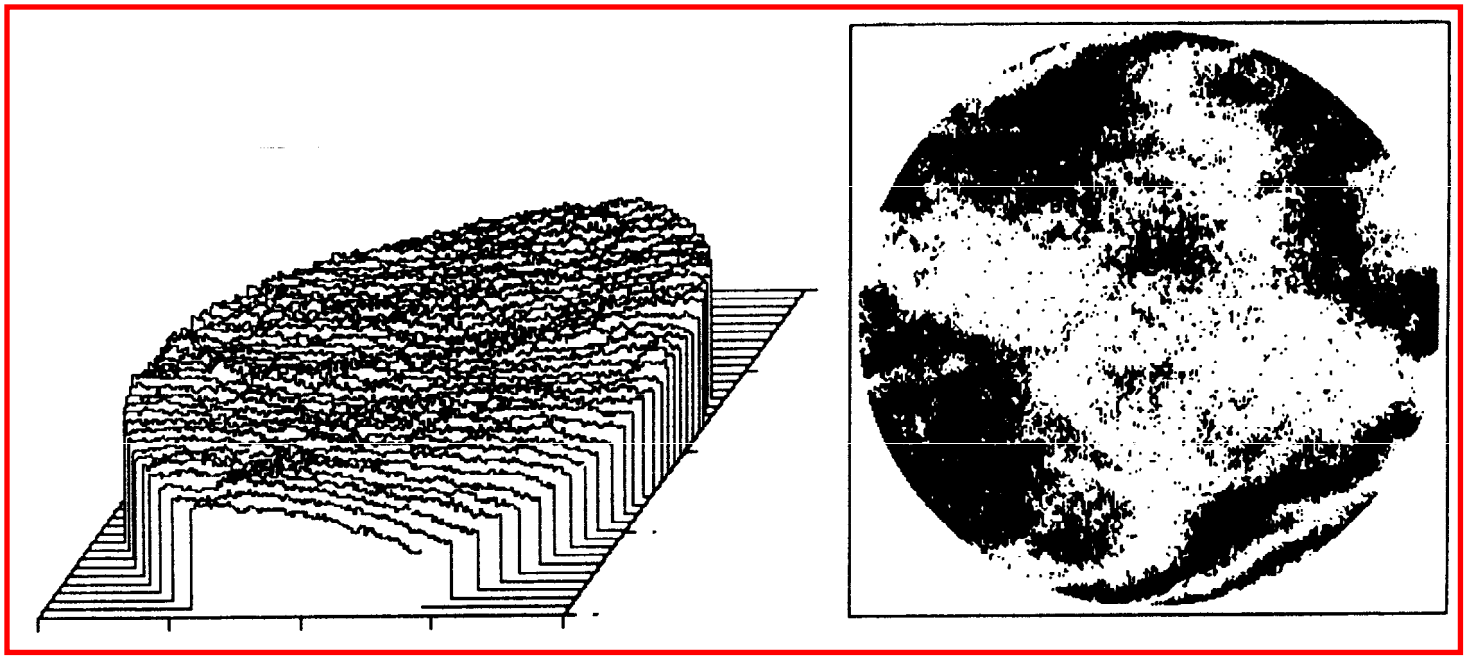
Absolute Reference

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

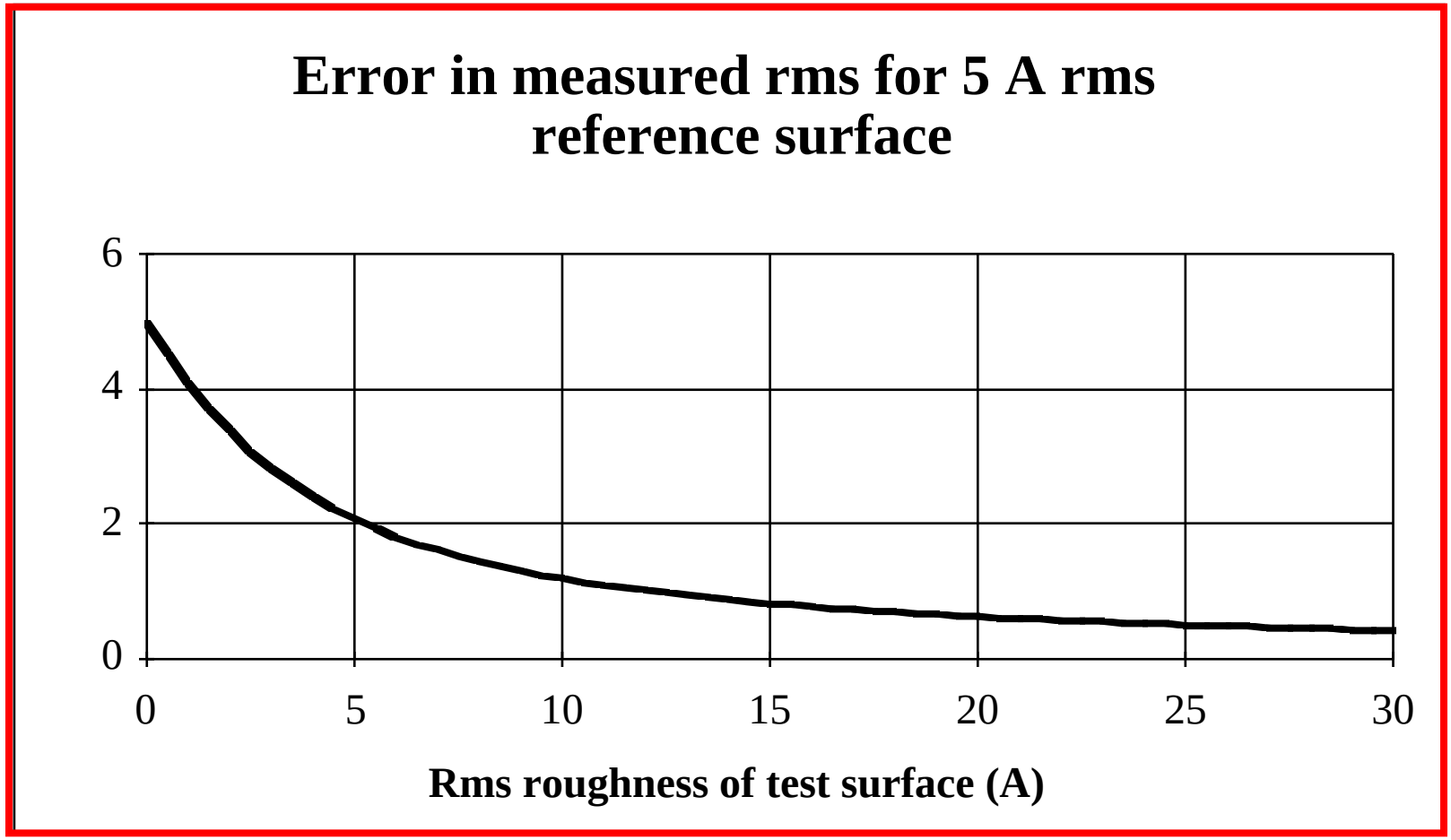


Absolute Surface Roughness Measurement Assumptions

- **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

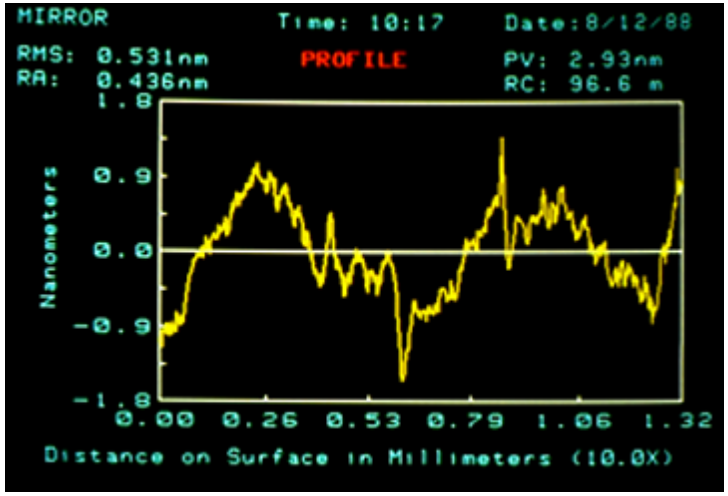
- **Perfect mirror**
- **Generate reference**
- **Absolute rms measurement**

Generate Reference

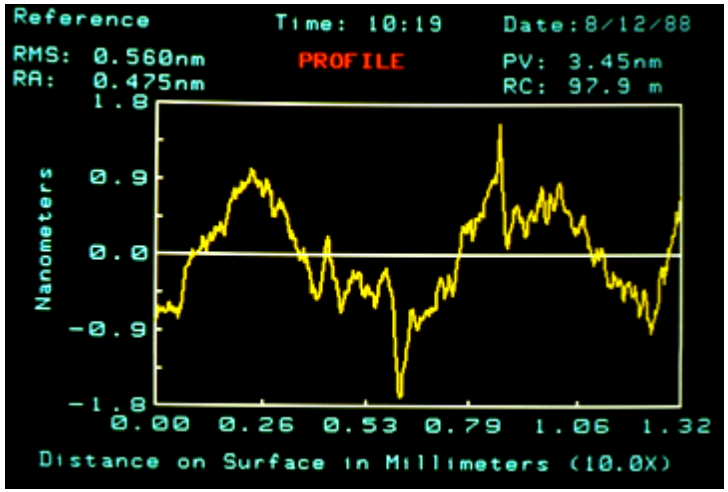
- **Average many measurements**
- **Move random surface > correlation length between measurements**
- **Effects of random surface reduce as square root of number of measurements**

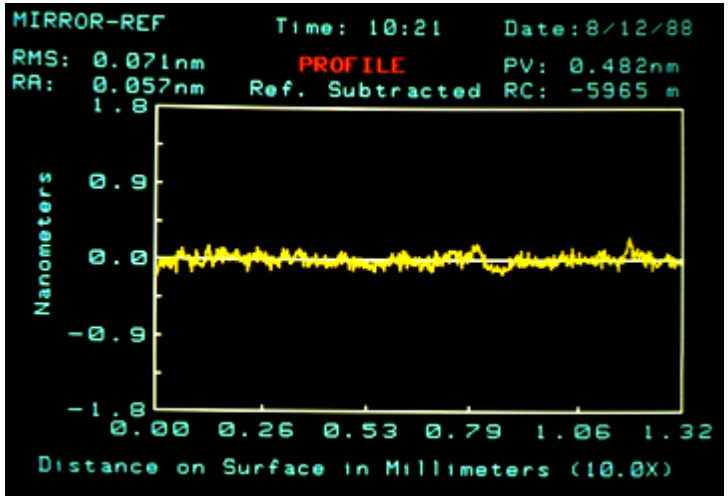
Generate Reference and Subtract

Surface + Reference



Reference





Surface (0.071 nm)

Absolute RMS Measurement

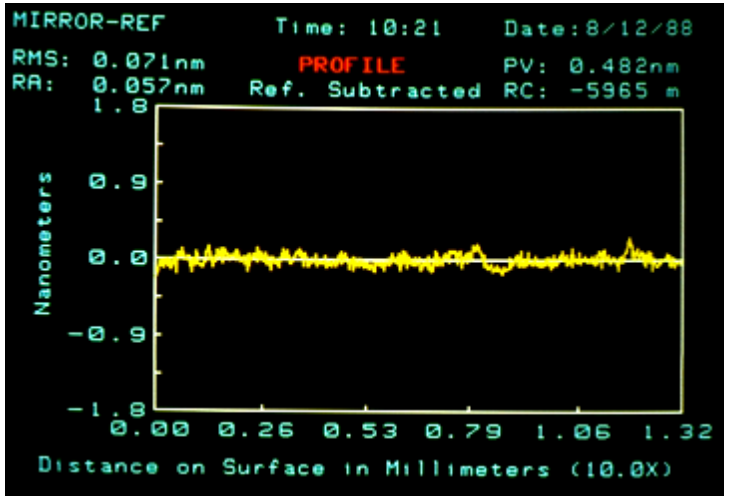
- **Make 2 measurements where surface moved > correlation length between measurements**
- **Subtract measurements and divide by square root of 2**
- **Reference cancels and obtain**
- **RMS of test surface**

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

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

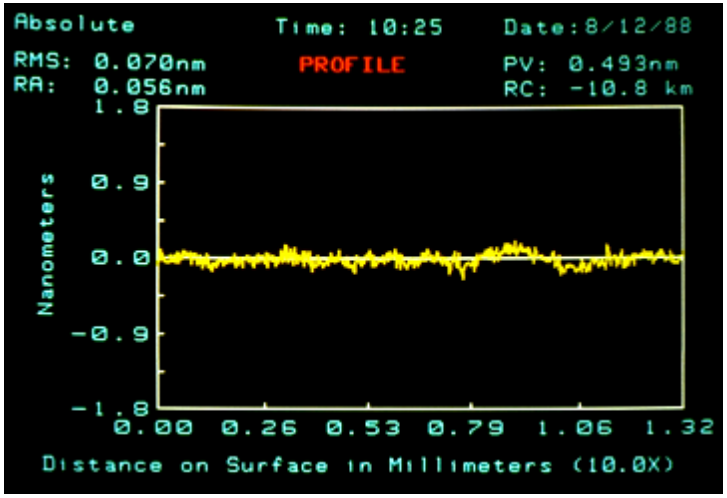
Generate Reference and Absolute RMS Comparison

Generate Reference



RMS = 0.071 nm

Absolute RMS



RMS = 0.070 nm