Part 6 - Measurement of Surface Microstructure

- Non-Contact Optical Profilers
- White Light Interferometry
- Vertical Scanning Optical Profilers

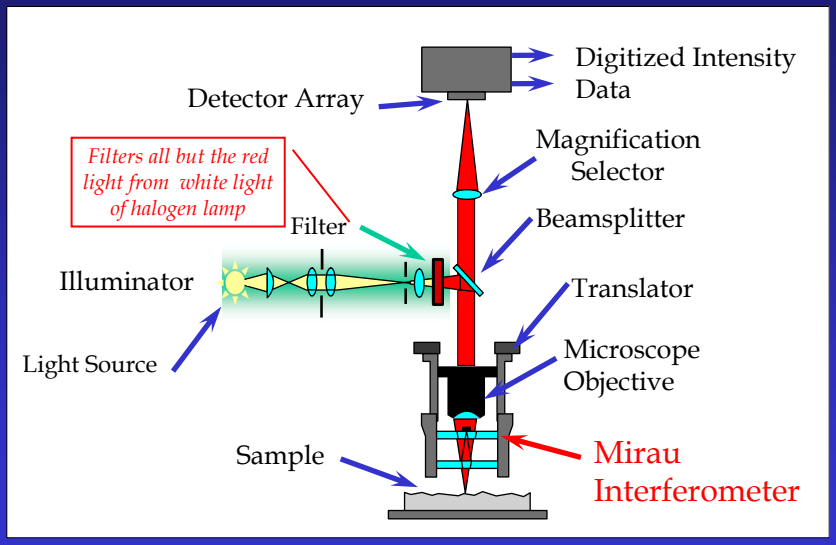
Non-Contact Optical Profilers for Measurement of Surface Microstructure

- Advantages
  - Non-contact measurement
  - 2D or 3D surface topography
  - Visual qualitative surface inspection
  - Vertical resolution suitable for super-polished optics
  - Fast measurement and analysis
- Disadvantages
  - Measures phase change as well as profile
  - Lateral resolution limited by optical resolution

Advantages of White Light over Laser Light

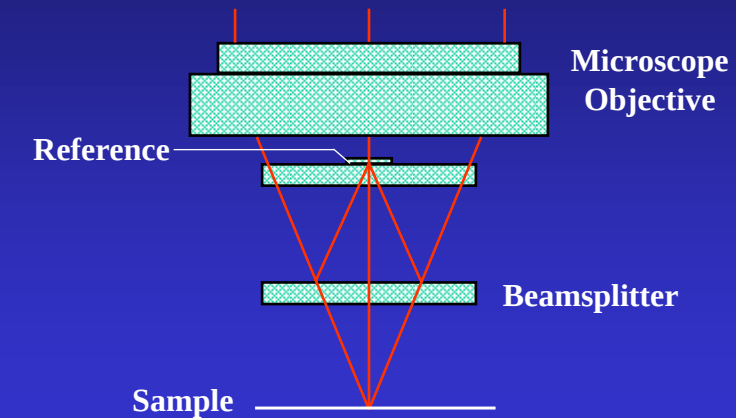
- Lower noise
  - No spurious fringes
- Multiple wavelength operation
  - Measure large steps
- Focus easy to determine

Interference Microscope Diagram



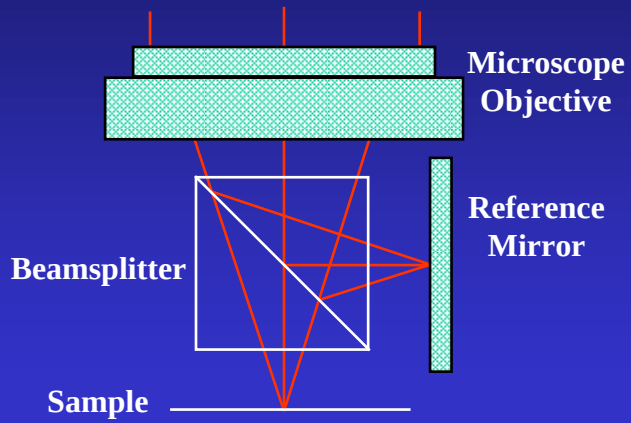
Mirau Interferometer

(10X, 20X, 50X)

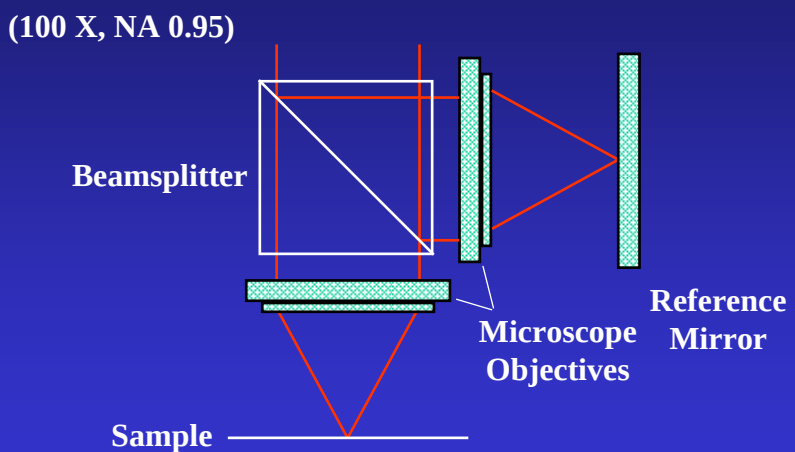


Michelson Interferometer

(1.5X, 2.5X, 5X)



Linnik Interferometer

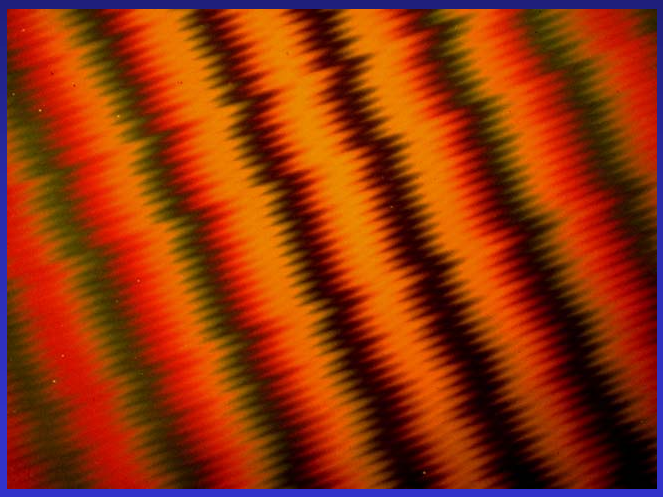


Interference Objectives

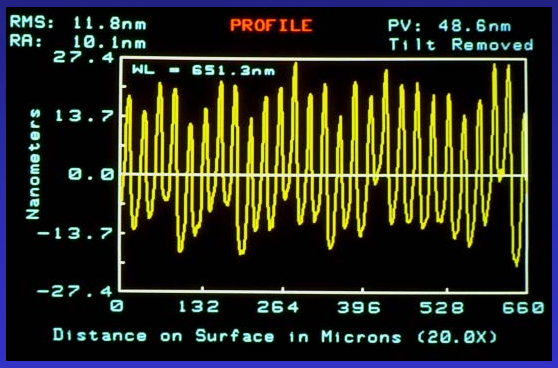
- Mirau
  - Medium magnification
  - Central obscuration
  - Limited numerical aperture
- Michelson
  - Low magnification, large field-of-view
  - Beamsplitter limits working distance
  - No central obscuration
- Linnik
  - Large numerical aperture, large magnification
  - Beamsplitter does not limit working distance
  - Expensive, matched objectives

Optical Profiler

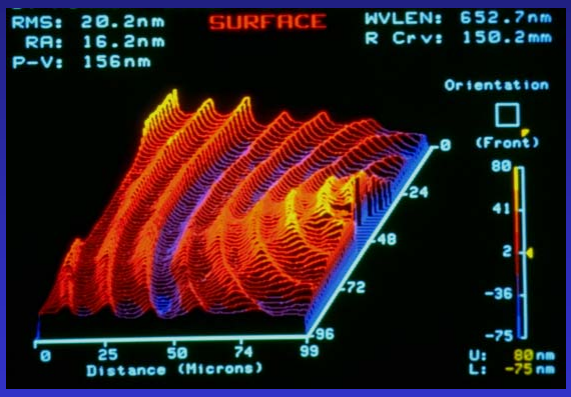
White Light Interferogram



Profile of Diamond Turned Mirror

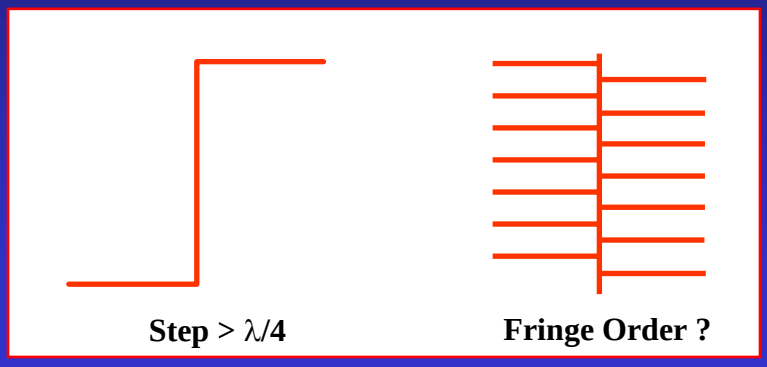


Diamond Turned Mirror



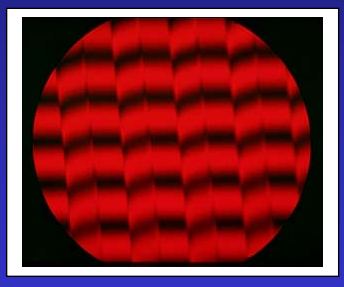
How High is the Step?

Steps > λ/4 between adjacent detector pixels introduce integer half-wavelength height ambiguities

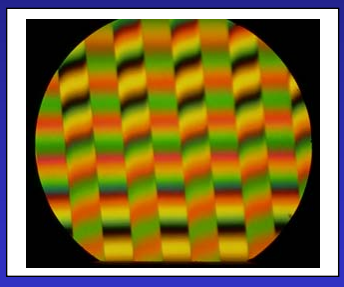


Interferograms of Diffraction Grating

Quasi-Monochromatic Light



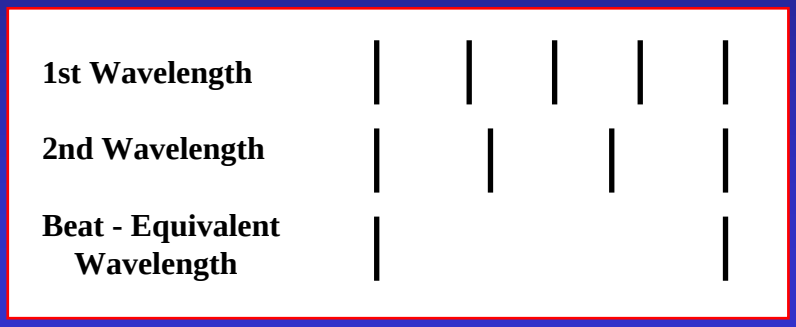
White Light



Profile

Two Wavelength Measurement

- Measure Beat Frequency
- Long Effective Wavelength



Two Wavelength Calculation

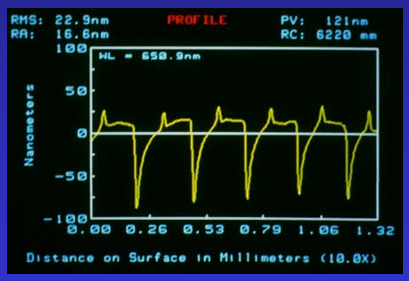
Equivalent Wavelength $\lambda_{eq} = \frac{\lambda_1 \lambda_2}{|\lambda_1 - \lambda_2|}$

Equivalent Phase $\varphi_{eq} = \varphi_1 - \varphi_2$

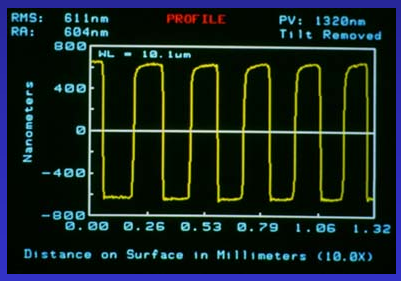
No height ambiguities as long as height difference between adjacent detector pixels < equivalent wavelength / 4

Diffraction Grating Measurement

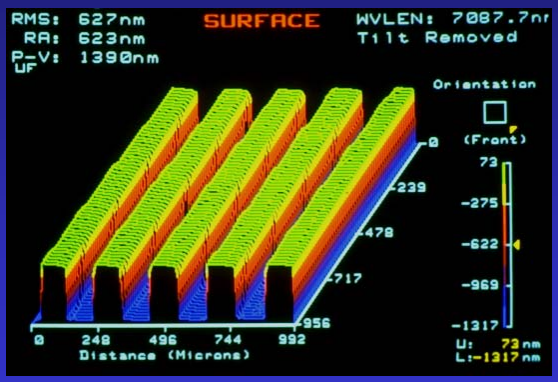
Single wavelength (650 nm)



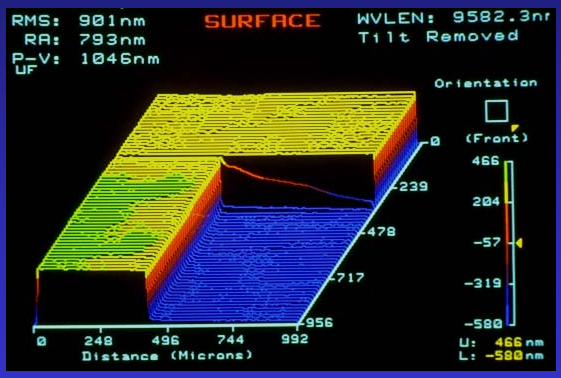
Equivalent wavelength (10.1 microns)



3-D Two-Wavelength Measurement (Equivalent Wavelength, 7 microns)



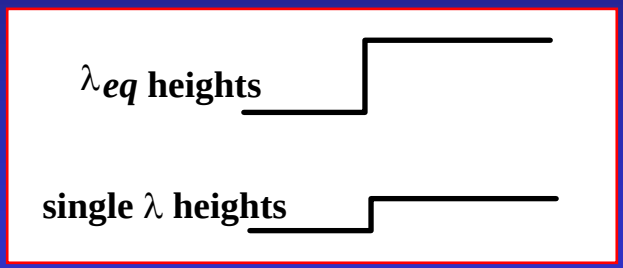
Two-Wavelength Measurement of Step



Wavelength Correction

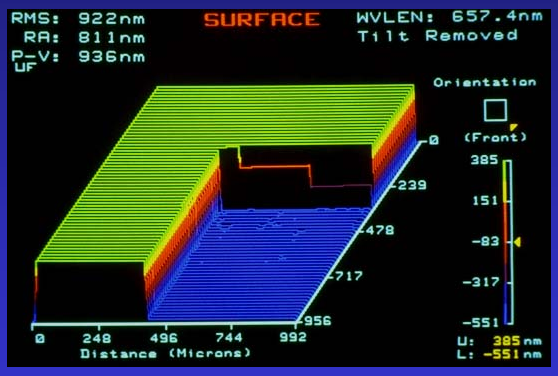
Compare

- **Heights calculated using equivalent wavelength**
- **Heights calculated using single wavelength**

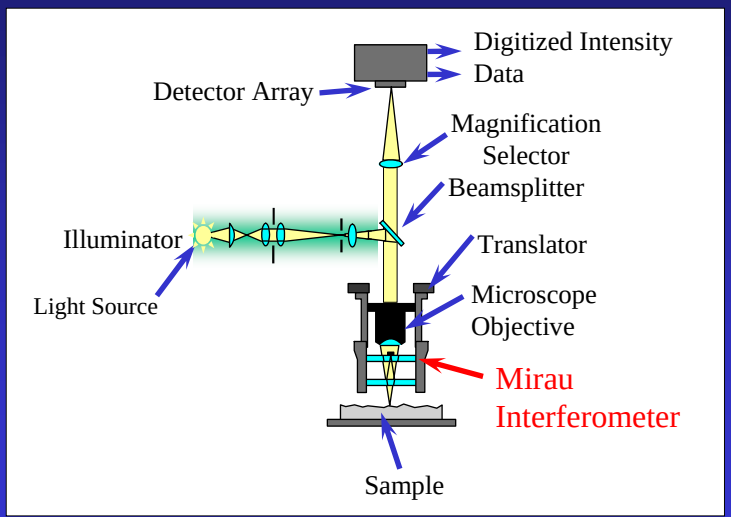


Add N x λ/2 to heights calculated using single wavelength so difference < λ/4

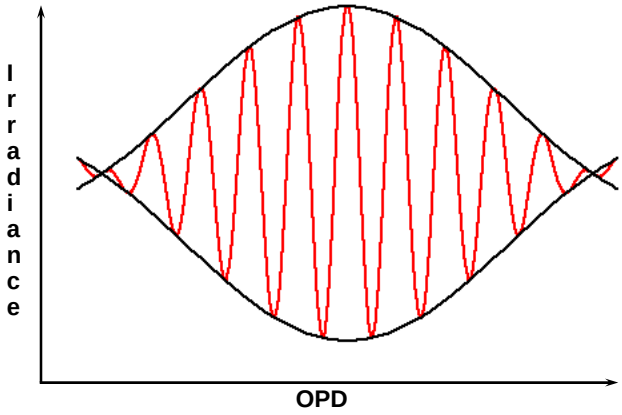
Wavelength Correction Measurement of Step



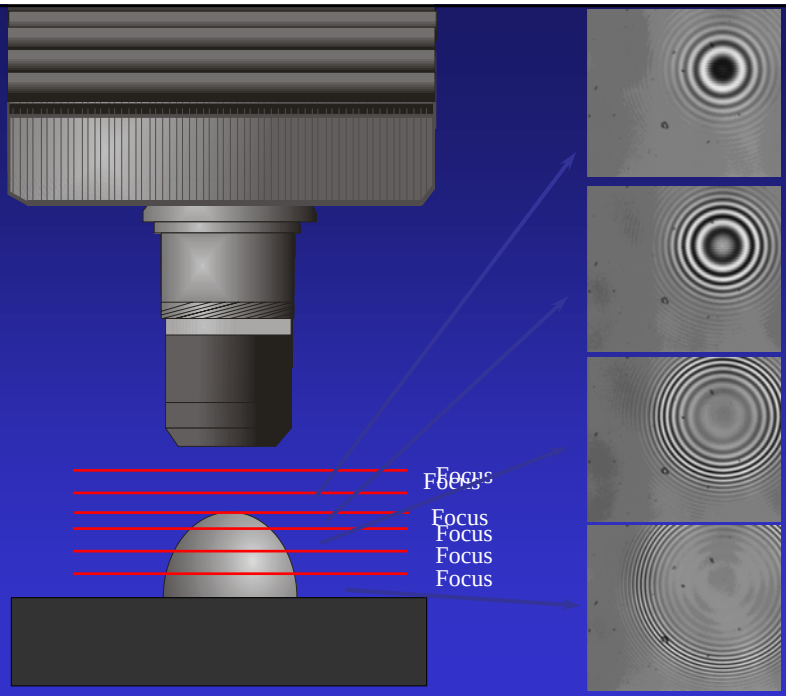
Interference Microscope Diagram (White Light – Vertical Scanning)



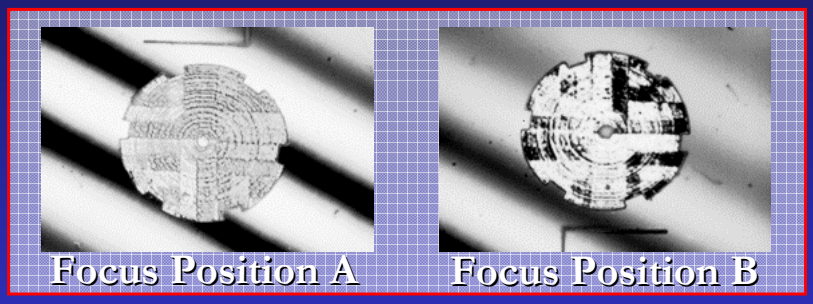
Irradiance Signal Through Focus



$$I = I_o\left[1 + \gamma\cos(\phi + \alpha)\right]$$

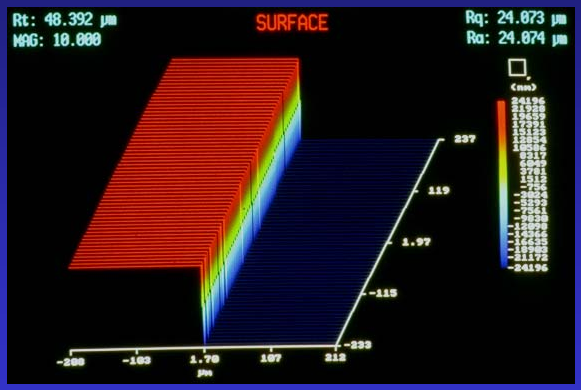


White Light Interferograms



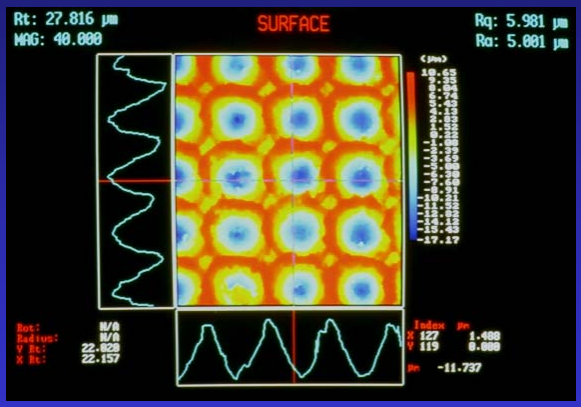
As the scan moves different areas of the part being measured come into focus (have zero OPD or maximum contrast between fringes). A determination of the point of maximum contrast and knowledge of the scan position allows a reconstruction of the surface shape.

Step Measurement

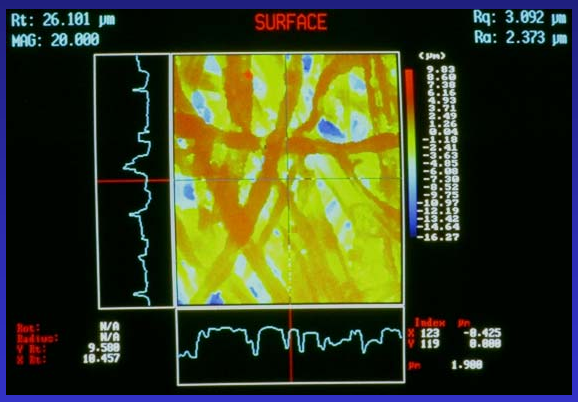


Print Roller

Print Roller Measurement



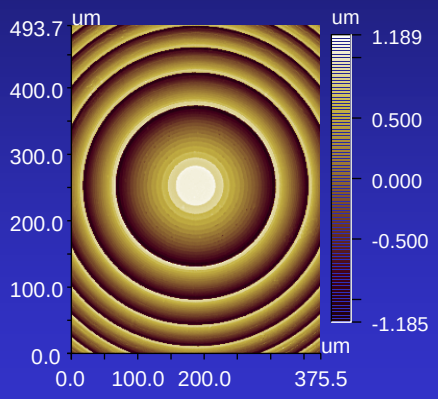
Paper Measurement



Micromachined Silicon Measurement

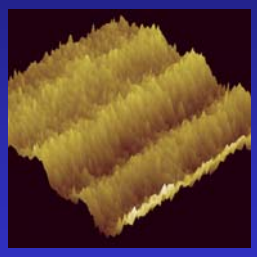
Binary Optic Lens

Surface Stats:
RMS: 561.30 nm
PV: 2.37 um

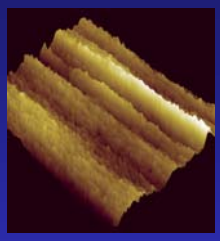


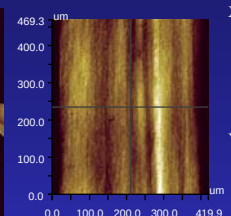
Chatter Seen on Camshaft

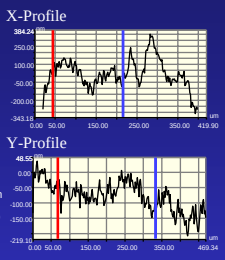
Surface Stats:
Rq: 872.06 nm
Ra: 693.90 nm
Rt: 7.47 um
Terms Removed:
Cylinder & Tilt



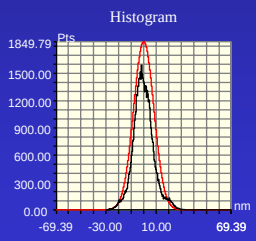
Heart Valve

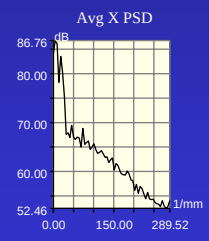






Data Statistics
Rt: 1.419 um
Ra: 87.391 nm
Rq: 113.942 nm



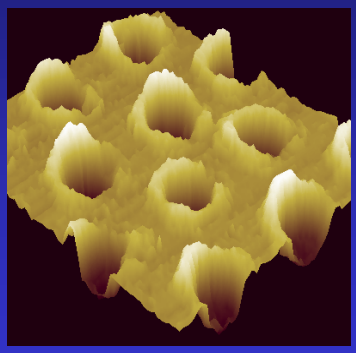


Pits in Metal

Size: 248 X 239
Sampling: 1.70 um

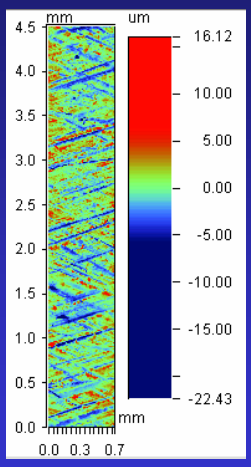
Surface Stats:
Rq: 5.07 um
Ra: 3.44 um
Rt: 31.05 um

Terms Removed:
Tilt



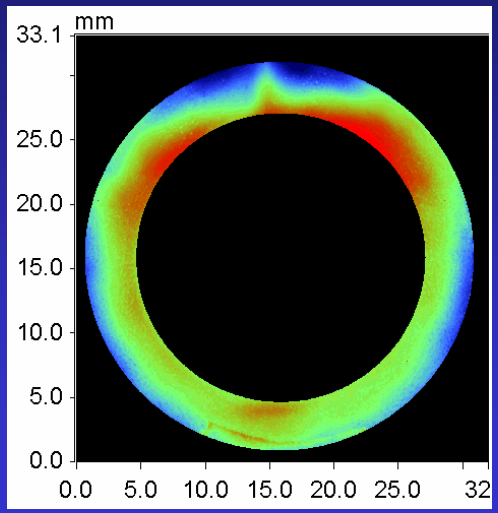
Six Stitched Data Sets of Inside of Engine Bore

Insight 2000 measuring inside of engine bore



Ra = 1.69 µm, Rz = 27.87 µm, and Rt = 38.54 µm

Stitched Measurement - Fuel Cap



VSI mode

Surface statistic

Ra=26.32 microns
Rq=32.72 microns
Rt=246.42 microns

array size 1251x1107
sampling 25.5 microns

Sub-Region of Stitched - Fuel Cap