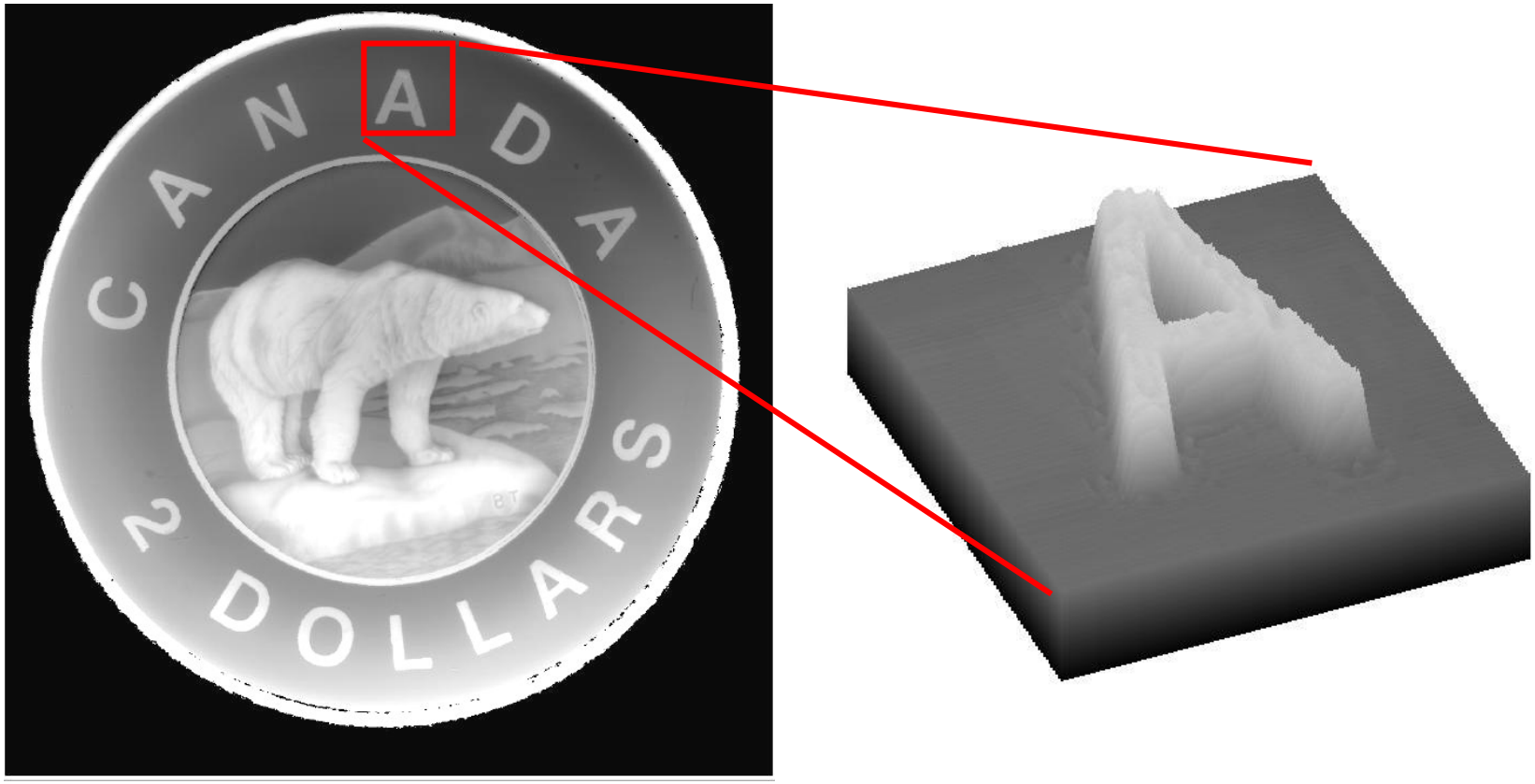
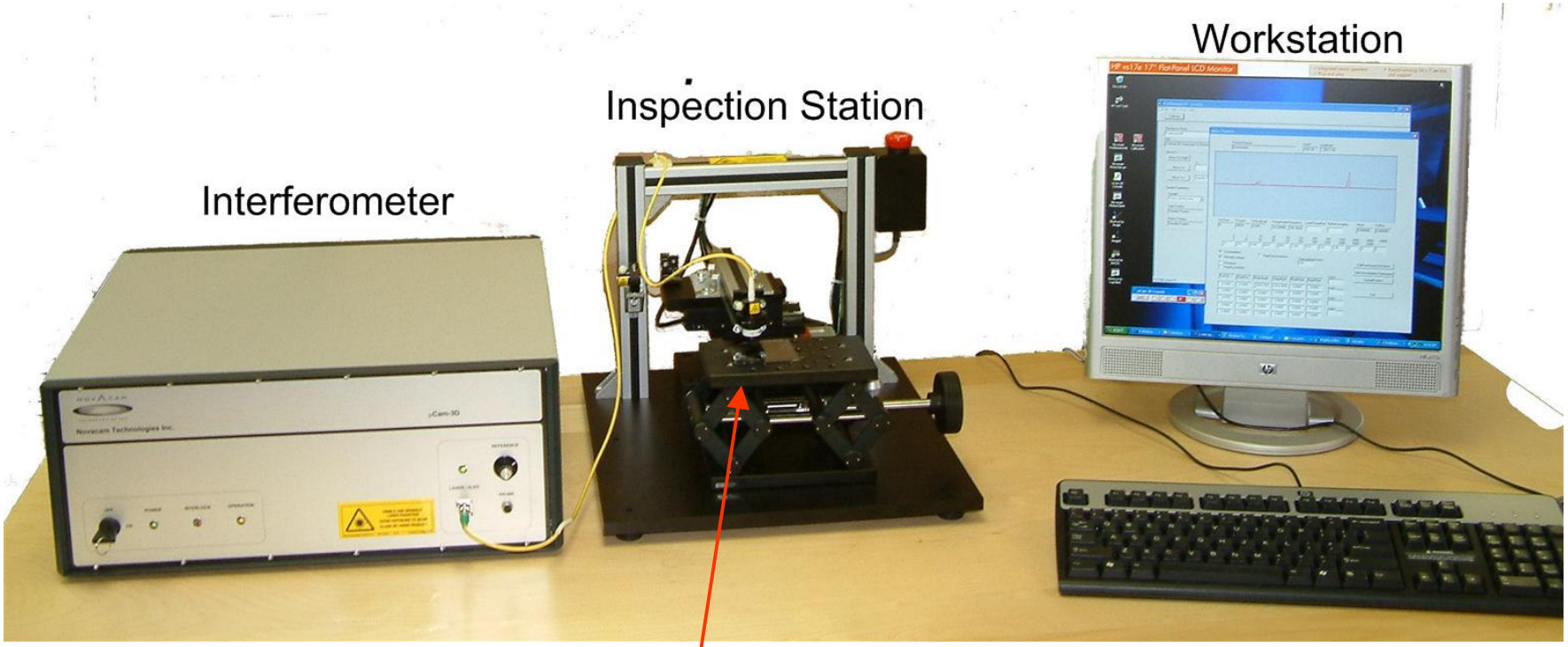
Fiber-Based Profilometers and Their Applications

Novacam Technologies Inc.

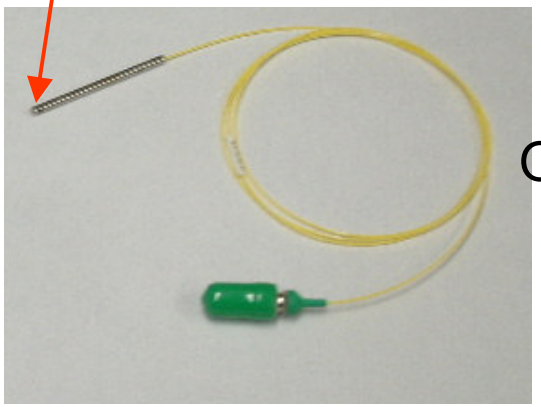
3D measurements with accuracy better then 1µm



What Is Fiber-Based Profilometry?



Probe tip



Optical fiber

Profilometry Applications

1) Profilometry

- Distance measurements => 3D surface map or profile
- Surface characterization - roughness
- Hard to reach surfaces
- Hostile environments (cryogenic, high temp., radioactive)
- Volume loss
- High aspect ratio imaging

2) Thickness measurements of film or coating

- Multi-layer film thickness measurements
- Measurement of the refraction index

3) Cross section imaging

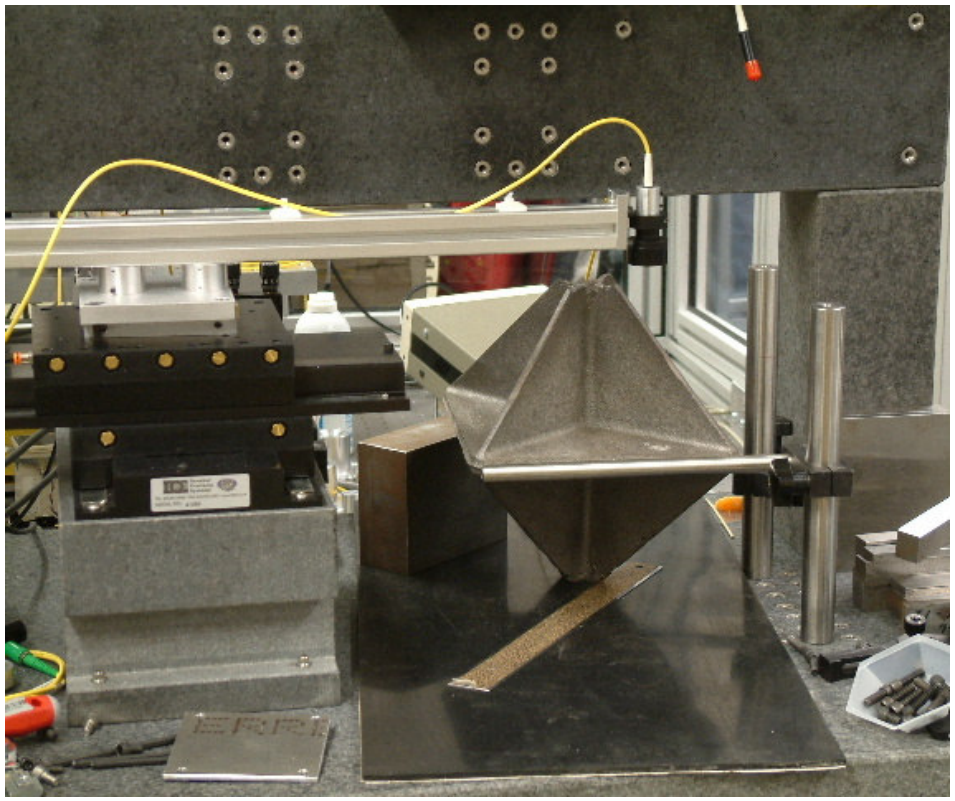
4) On-line industrial and lab applications

Profilometry: Industrial Applications

- **Semiconductor industry**
- **Aerospace industry**
- **Casting industry**
- **Optical industry**
  - etching and deposition measurements for waveguides
  - inspection of optical components
- **Forensic applications**
  - bullet shape, cartridge, gun barrel inspection
- **Fuel cell metrology**
- **Glass industries:** thickness measurements
- **Plastic industry:** rheometric measurements

…and many other industries

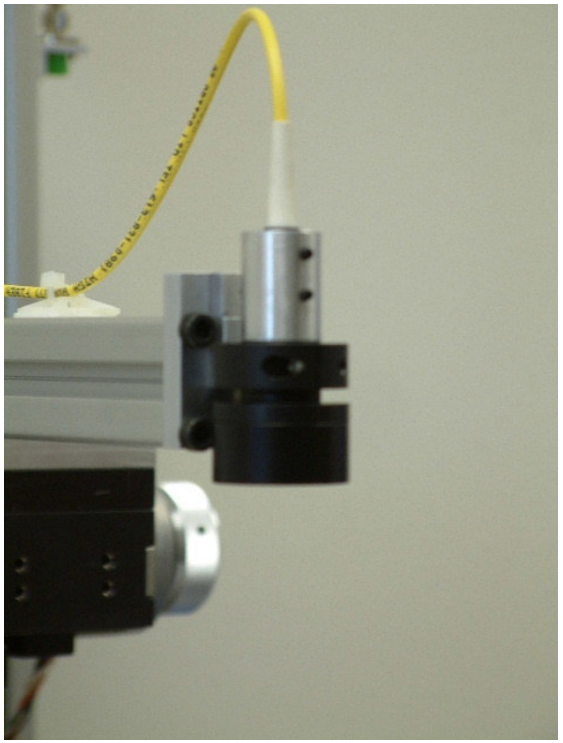
Typical Profilometry Setup With X-Y Slides



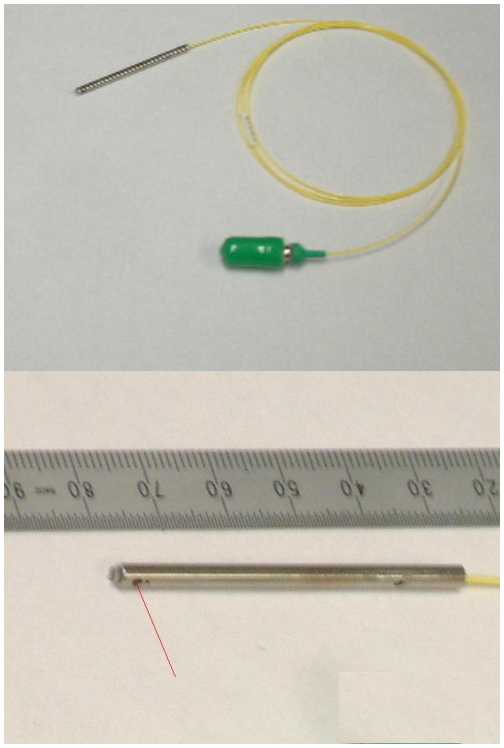
Standoff distance 150 mm or 6”

- **Standoff distance, probe to object = few mm to 1m**
- **Accuracy of measurement still under 1µm**
- **Measuring one point at a time - probe must be scanned to map whole surface**
- **Acquisition speed up to 20,000 points per second**

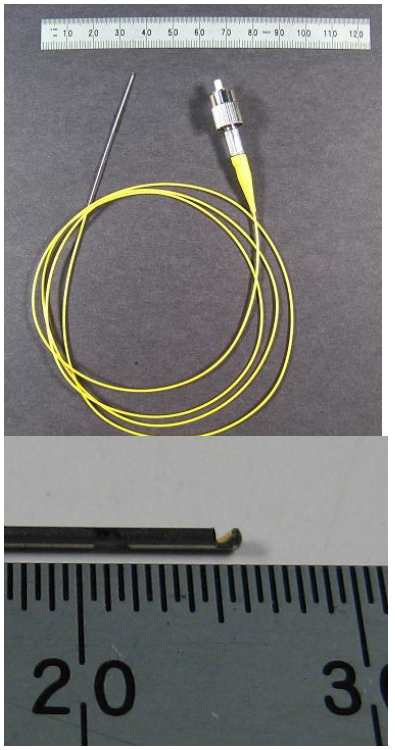
Fiber Probes



Φ 16mm probe (standard)

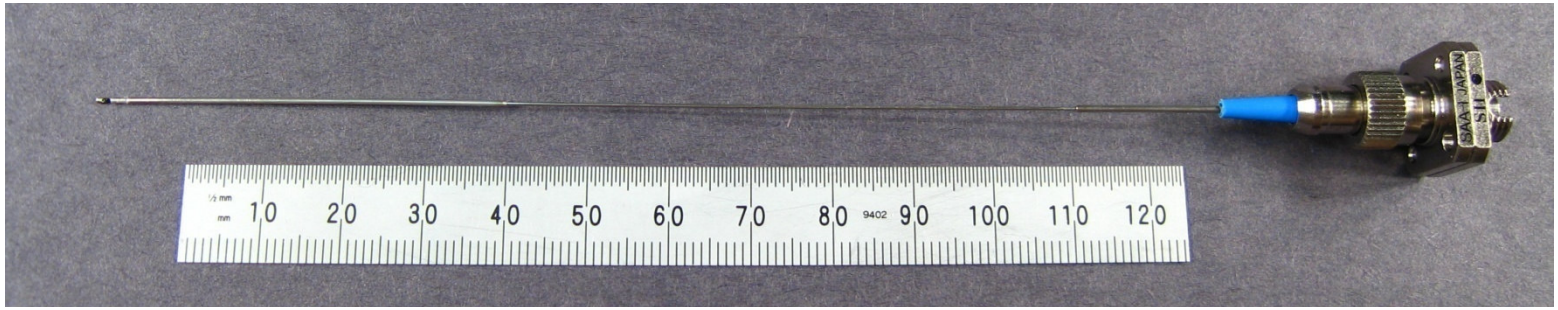


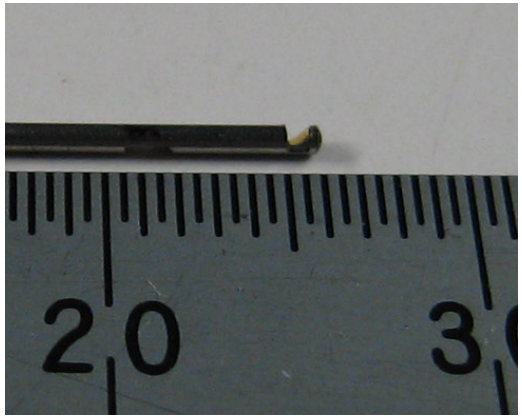
Φ 5mm probe



Φ 0.9mm probe

Small Diameter Fiber Probes





Profilometry Applications

1) Profilometry

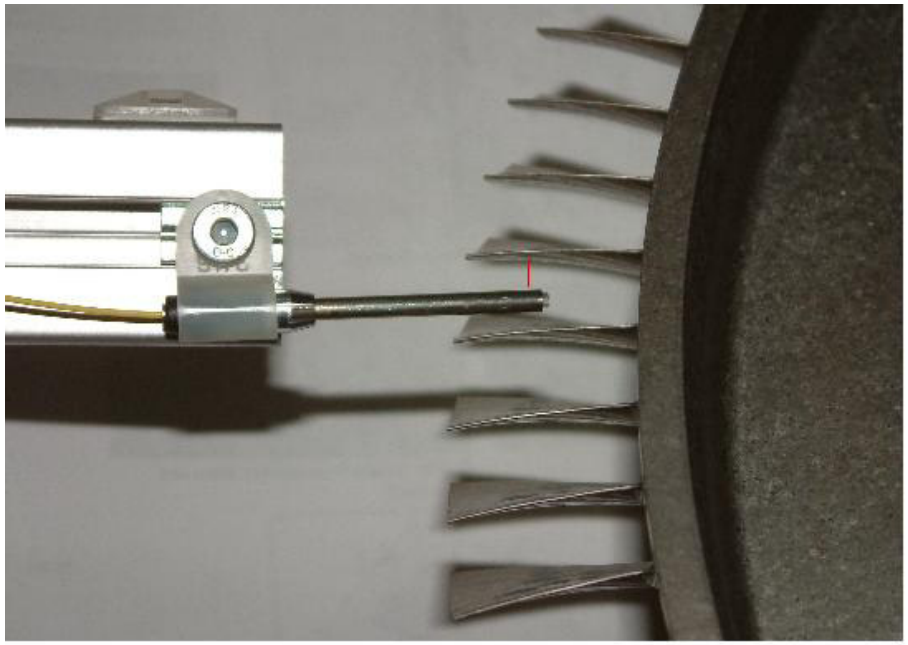
2) Thickness measurements of film or coating

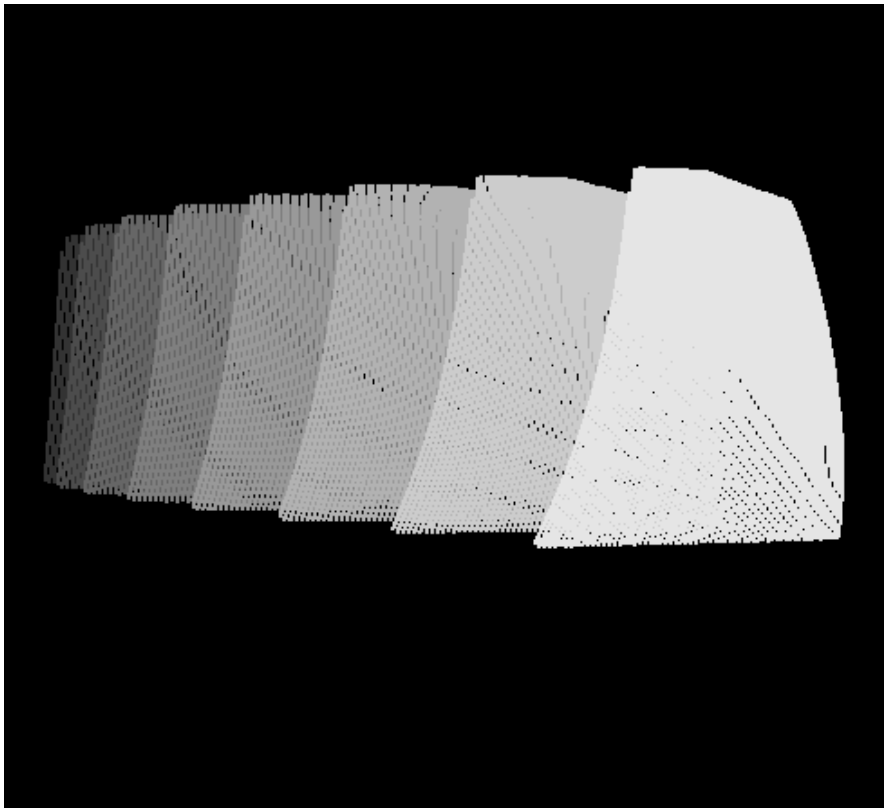
3) Cross section imaging

4) On-line industrial and lab applications

Profilometry in Aerospace Industry

Profiling turbine blades in blisk assembly

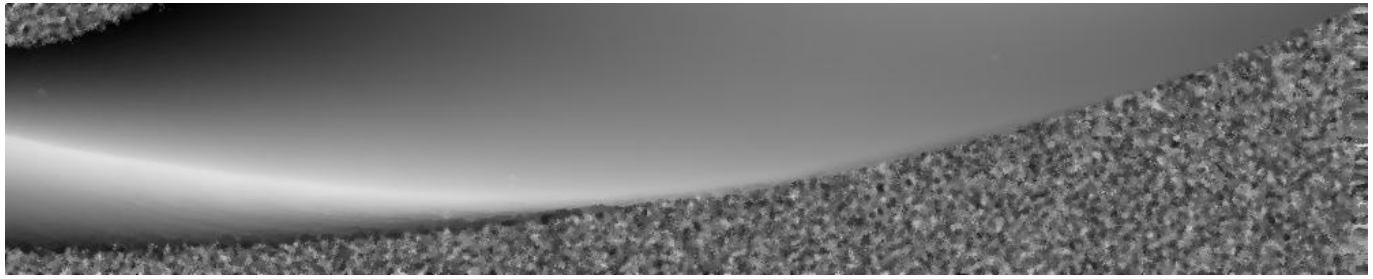




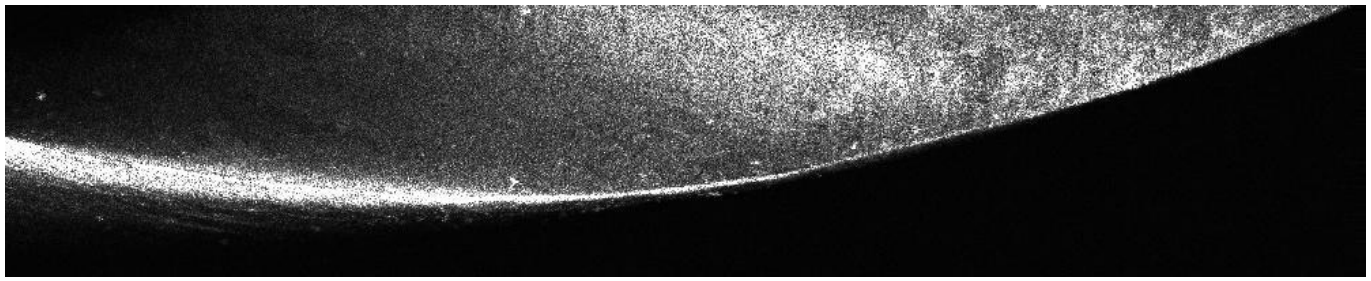
Small fiber probe can image in between blisk blades

Blade Profiling of Tools

Drill bit – high-aspect ration imaging



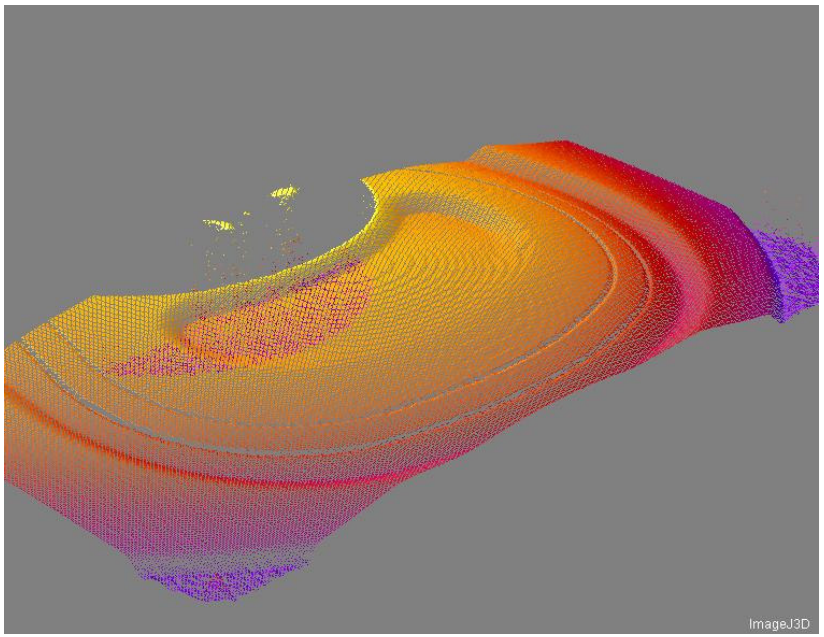
Height image

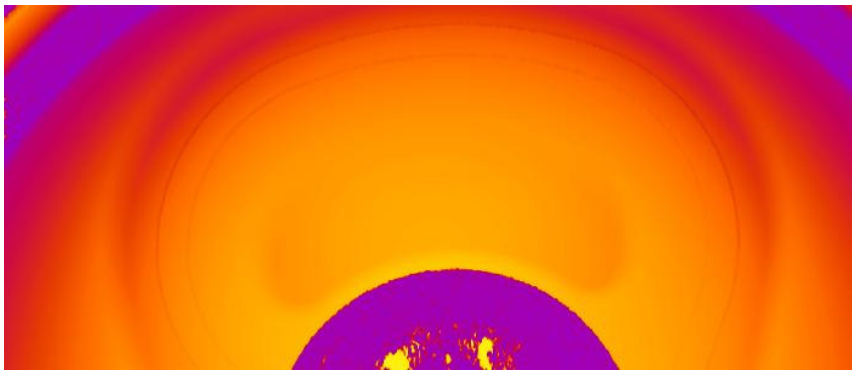


Intensity image

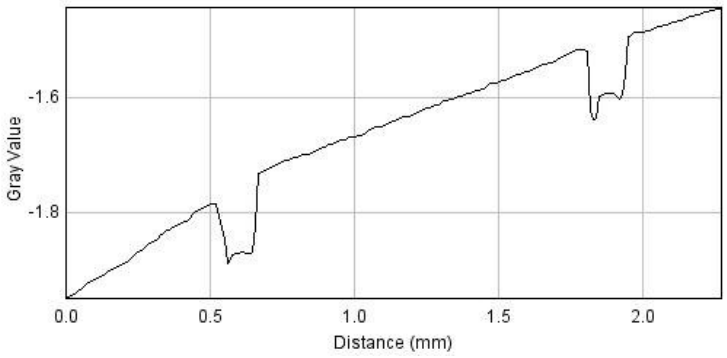
Profilometry of High Aspect Ratio Imaging Features

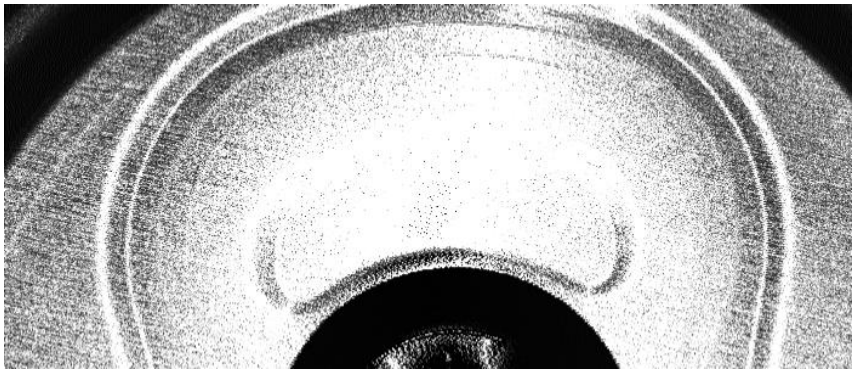
Profiling groove depth on cola can lid





Height image

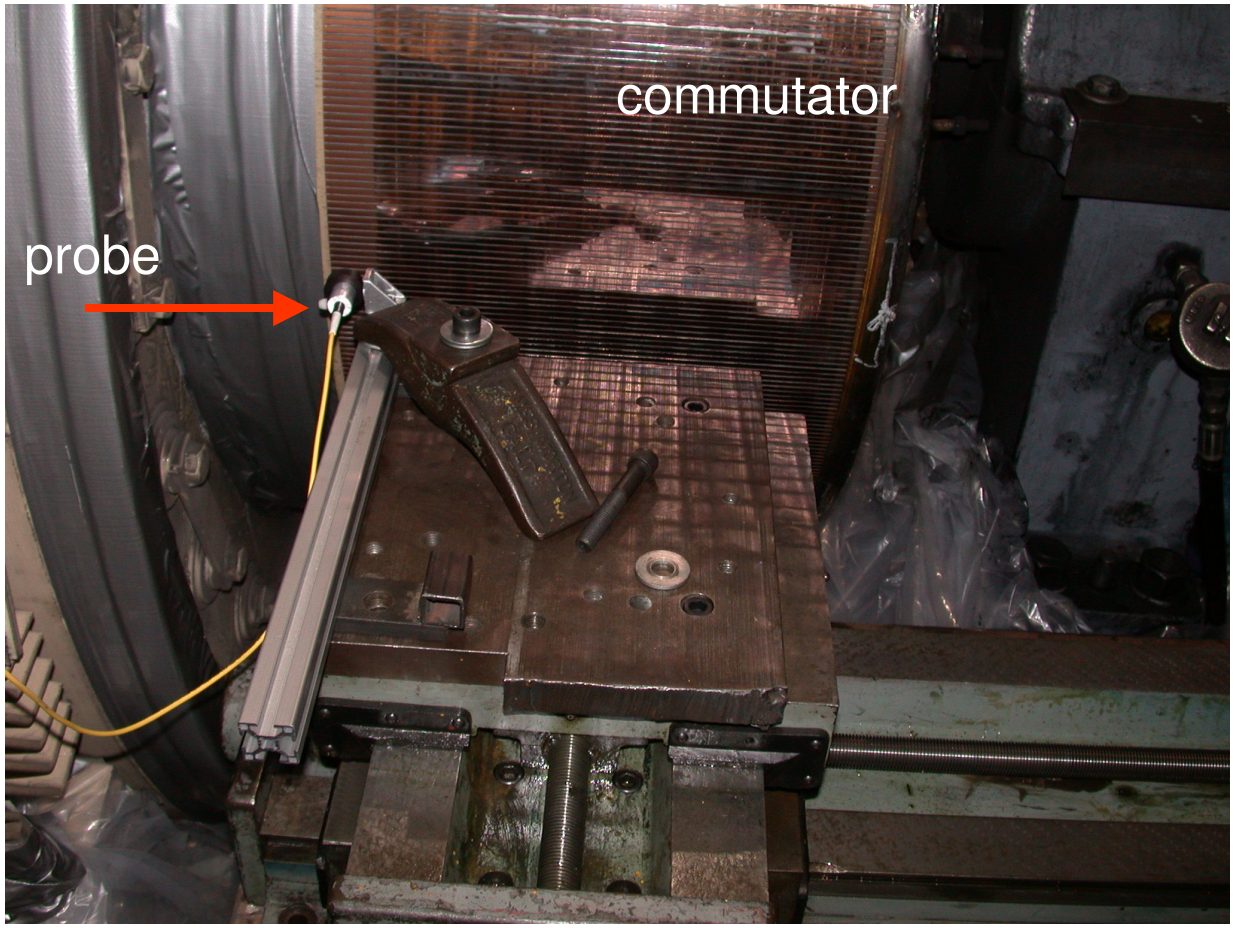




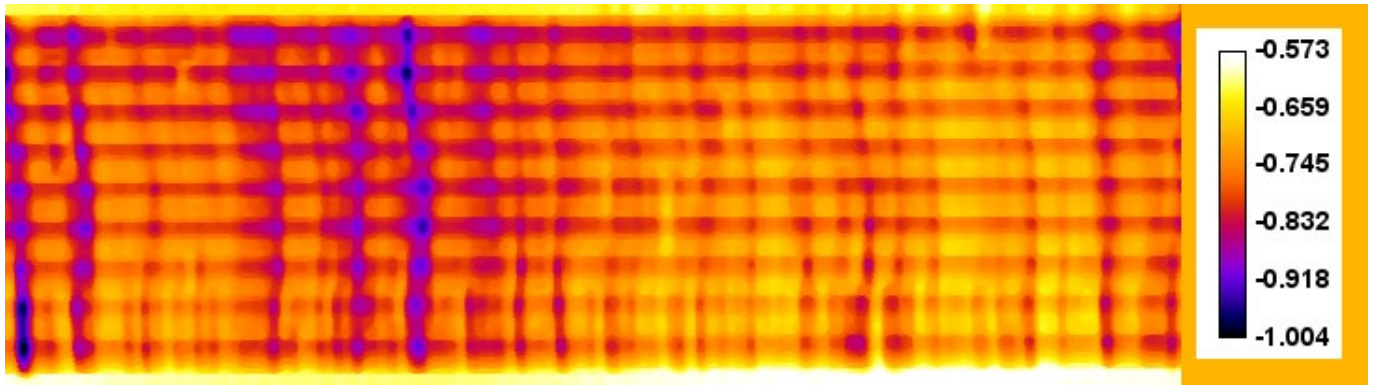
Intensity image

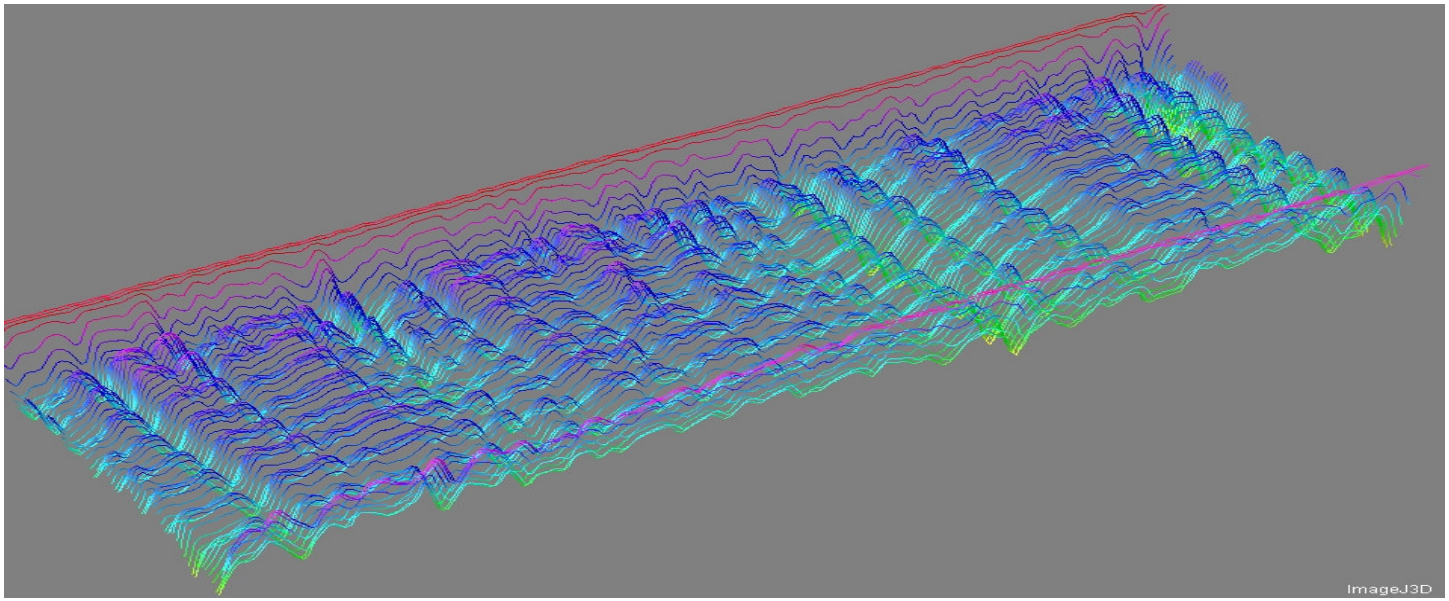
Profilometry of Cylinder or Drum-Shaped Objects

1.2m diameter motor commutator



Profilometry of Cylinder or Drum-Shaped Objects Cont.

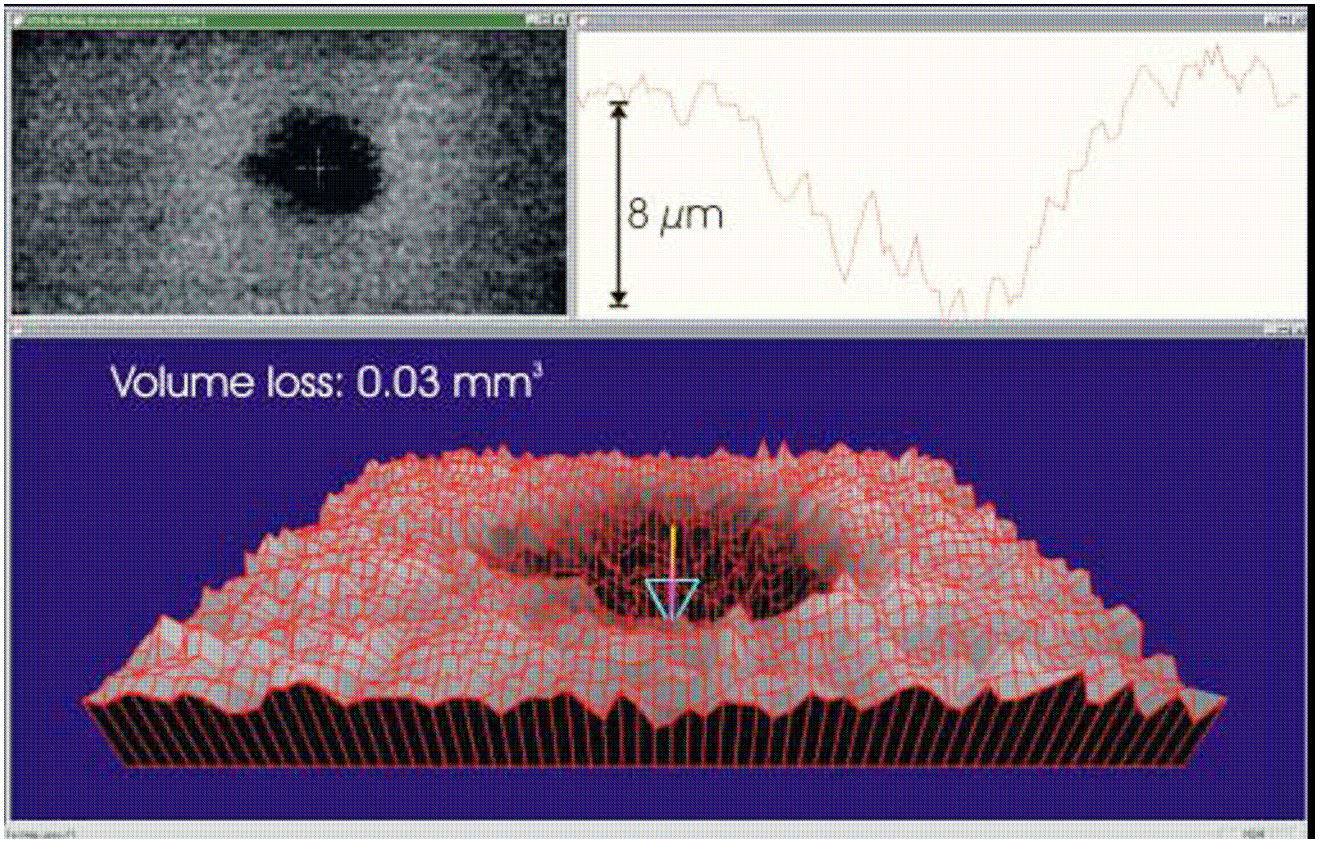




Flattened surface of a 1.2m-diameter motor commutator showing wear caused by contact of brushes

Profilometry of LIBS Holes

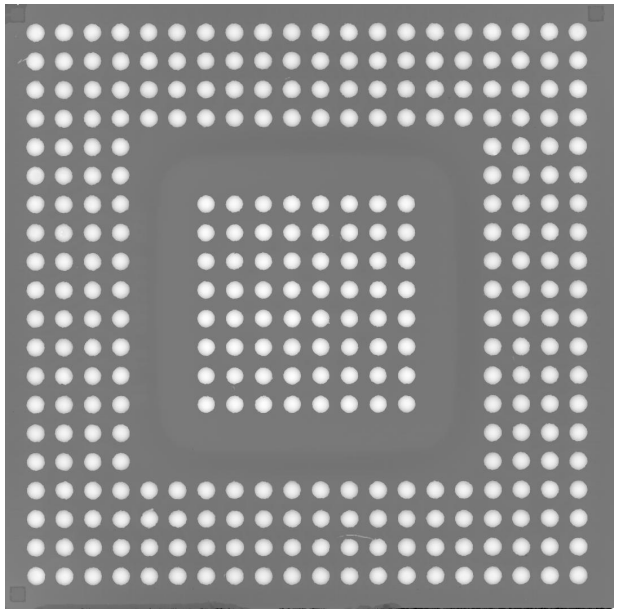
Very small hole created by Laser-Induced Breakdown Spectroscopy (LIBS) pulses

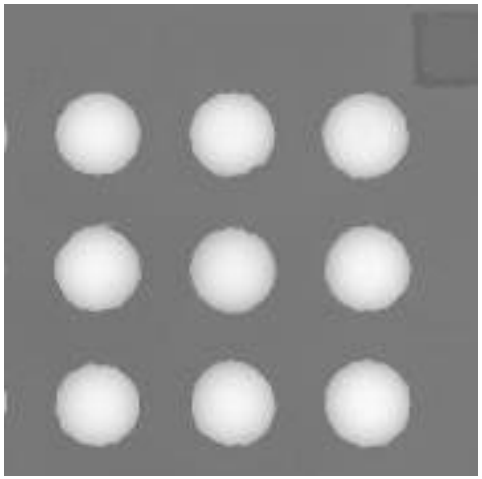


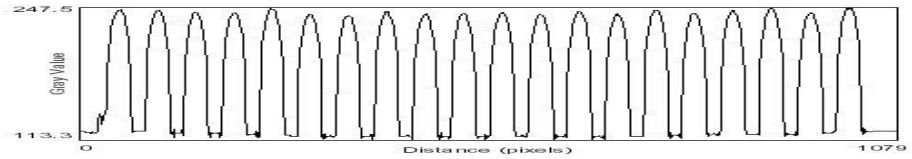
By combining LIBS and fiber profilometry, coatings in aerospace applications can be measured – e.g. in metal surfaces

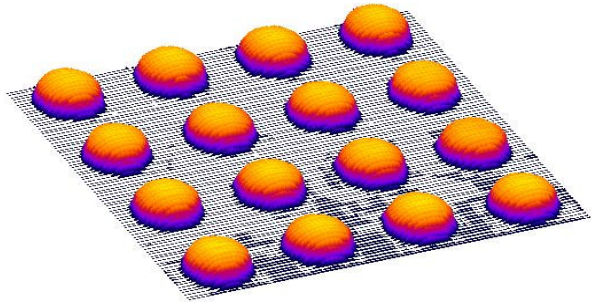
Profilometry in Semi-Conductor Industry

Profiling of bumps on BGA packaging



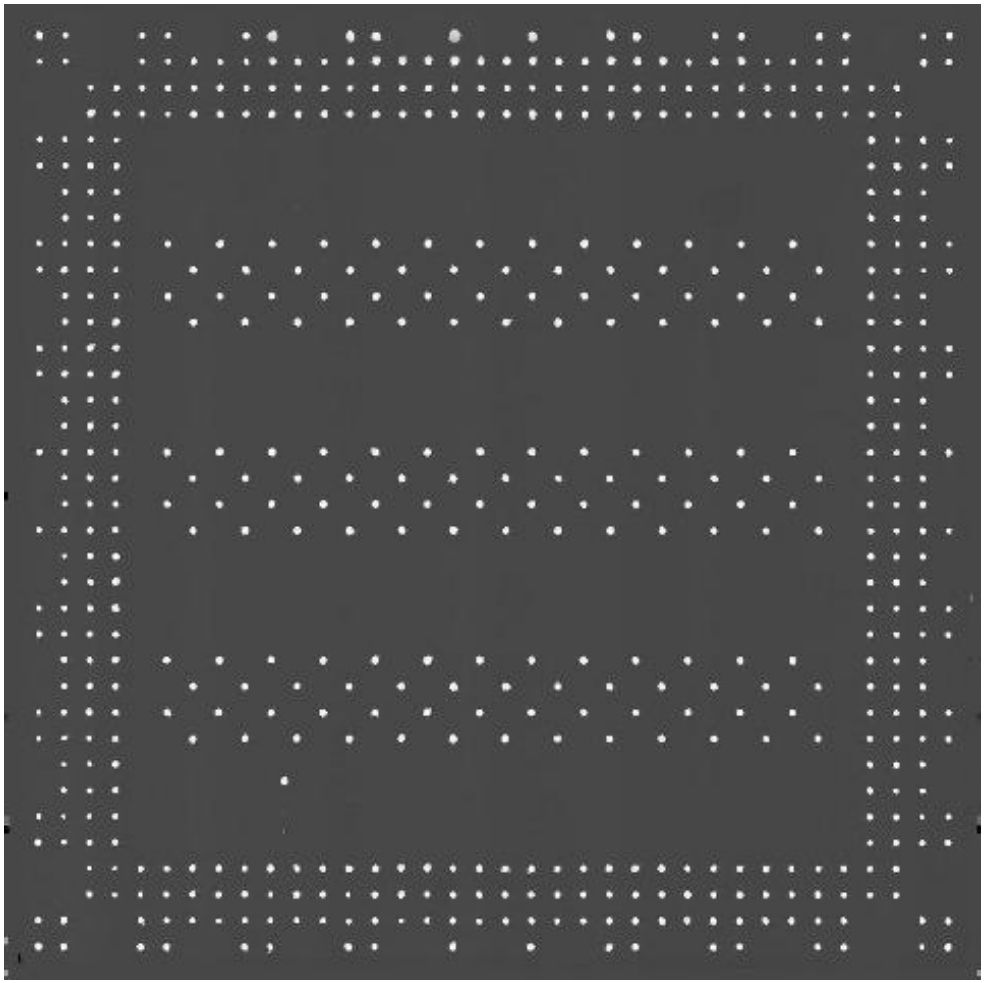




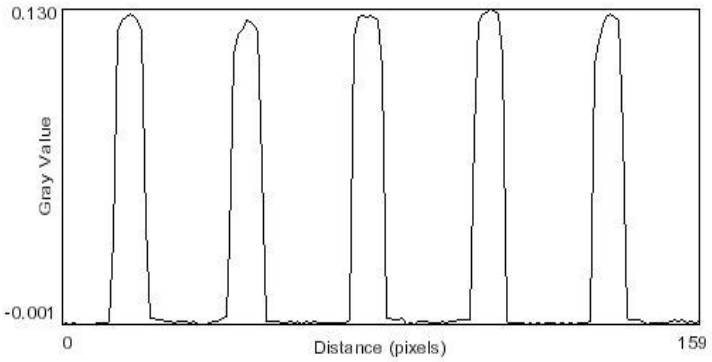


Profilometry in the Semi-Conductor Industry

Profiling of BGA flip chip

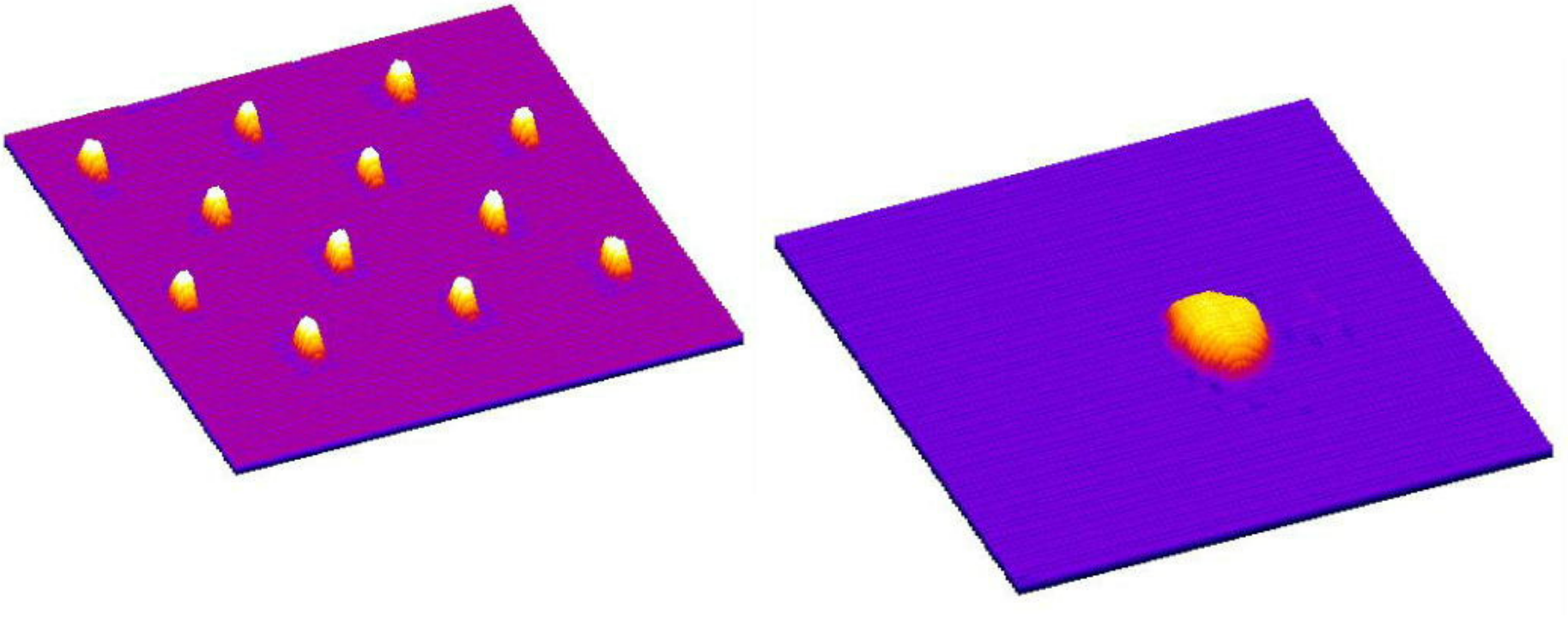


Ball height = 0.13mm or 130µm



Profilometry in the Semi-Conductor Industry

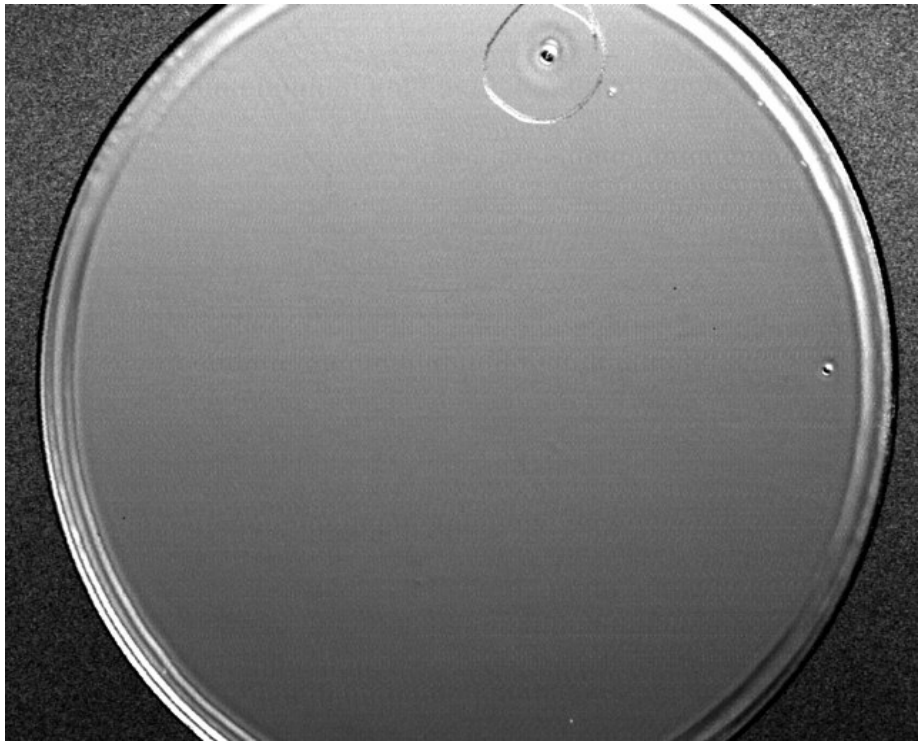
3D Rendering of flip chip

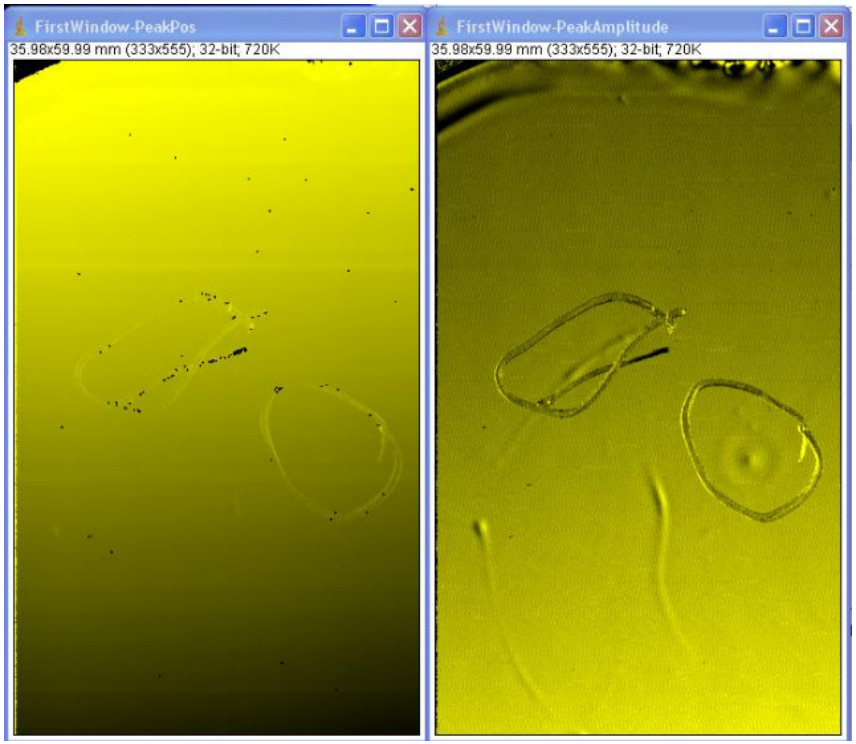


Ball height = 0.13mm or 130µm

Sub-Micron Surface Defects

Imaging surface defects in coatings of 4” wafers

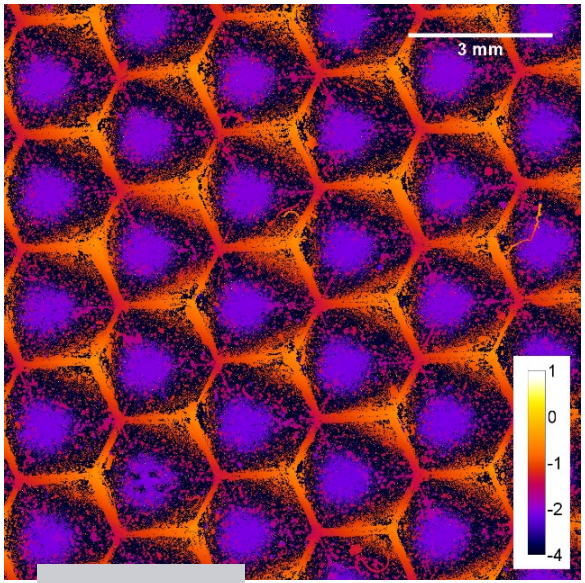




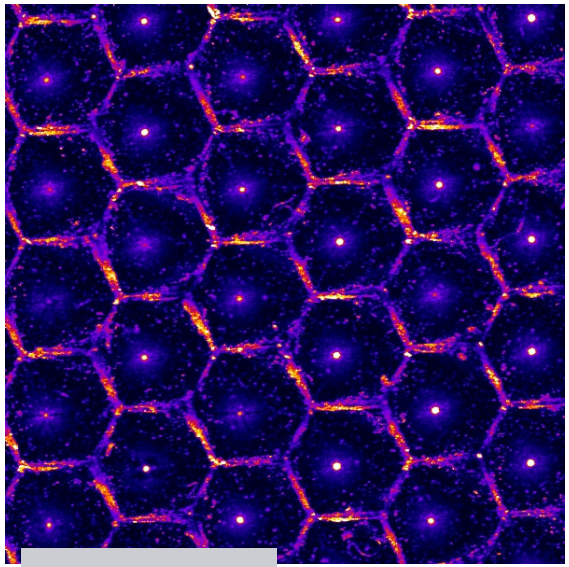
Profilometry of Optical Elements

Car industry:

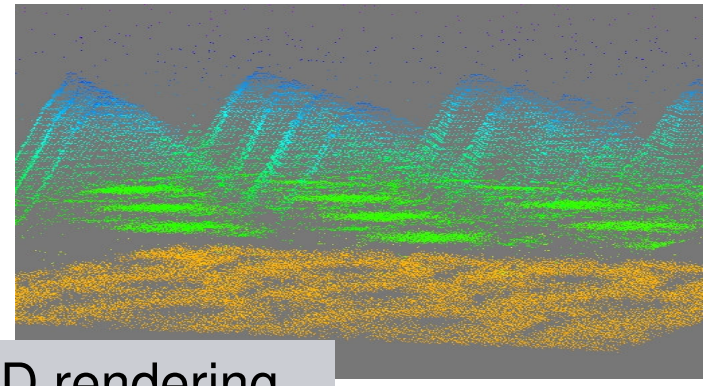
Imaging of metal mold for retro-reflector manufacture



Height



Intensity



3D rendering

High sensitivity for imaging highly reflective surfaces

Surface Mapping of Optical Elements

3D surface mapping of lens

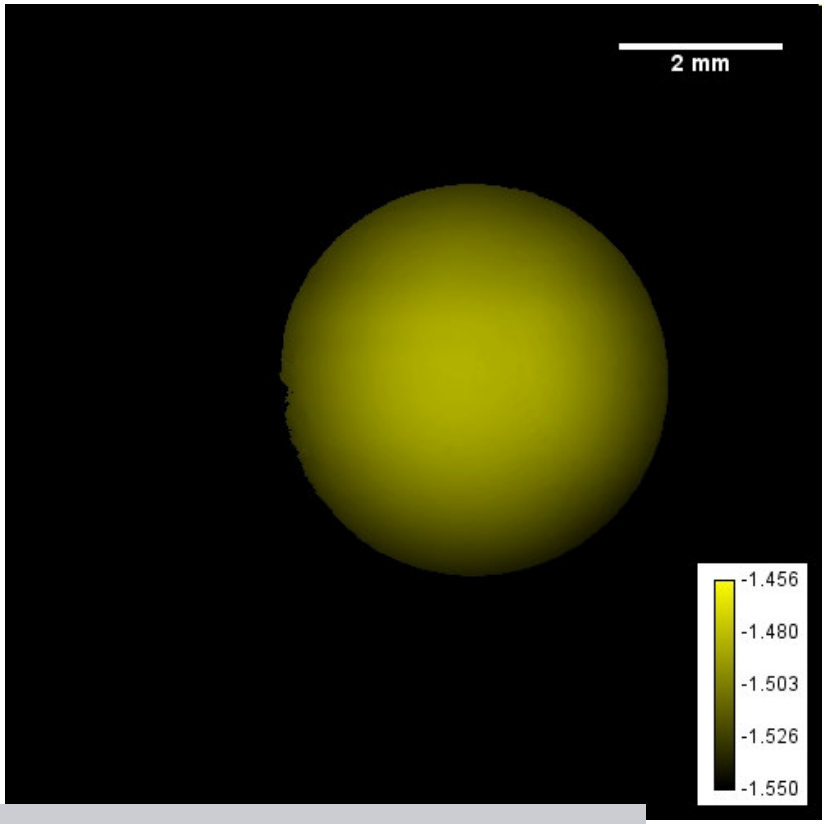
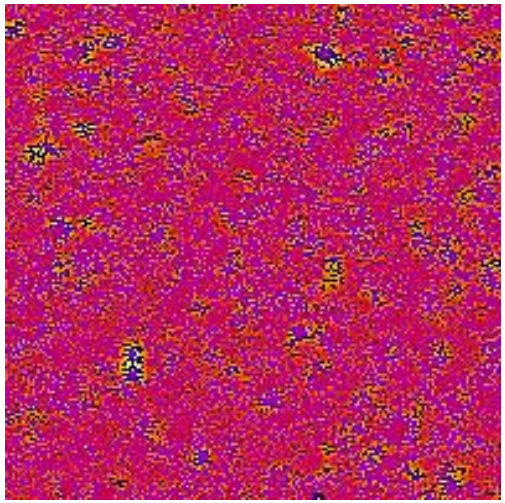


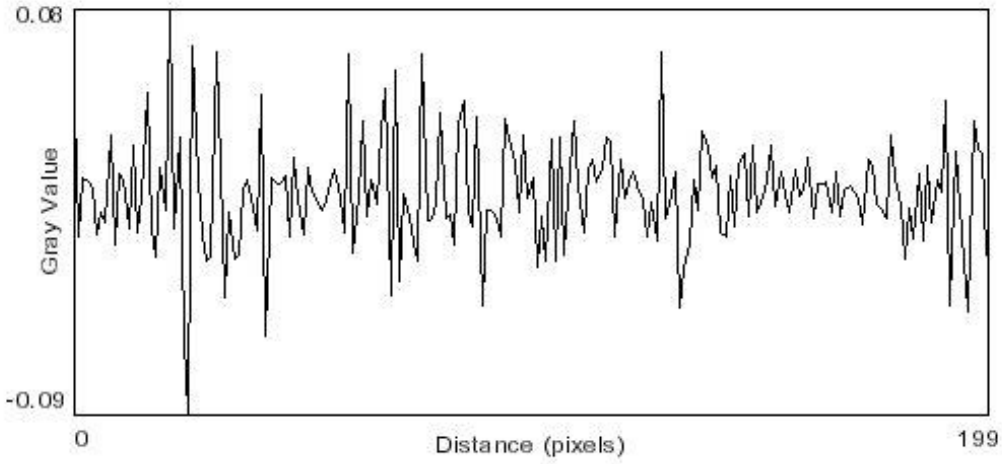
Image height represented by color intensity

Radius of lens measured from surface map

Surface Roughness Measurements

Plasma coated surface

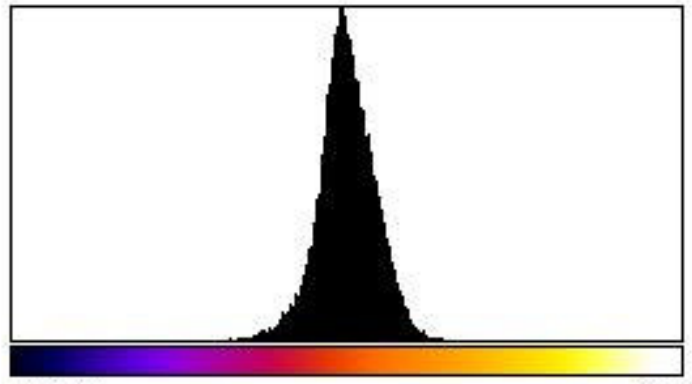




Surface Characterisation...

File Edit

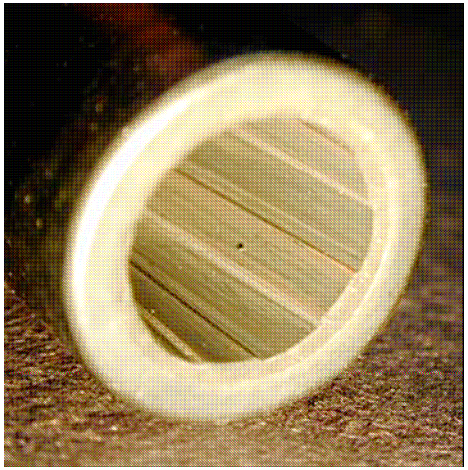
Slice	Rq	Ra	Rsk	Rku	Rv	Rp	Rt
1	0.046	0.034	0.121	20.571	-1.313	1.470	2.783

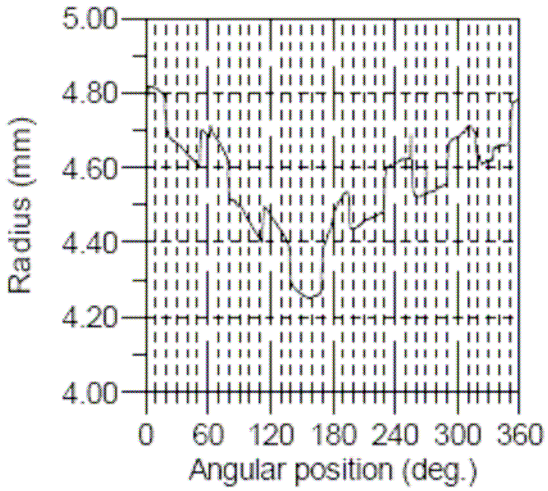


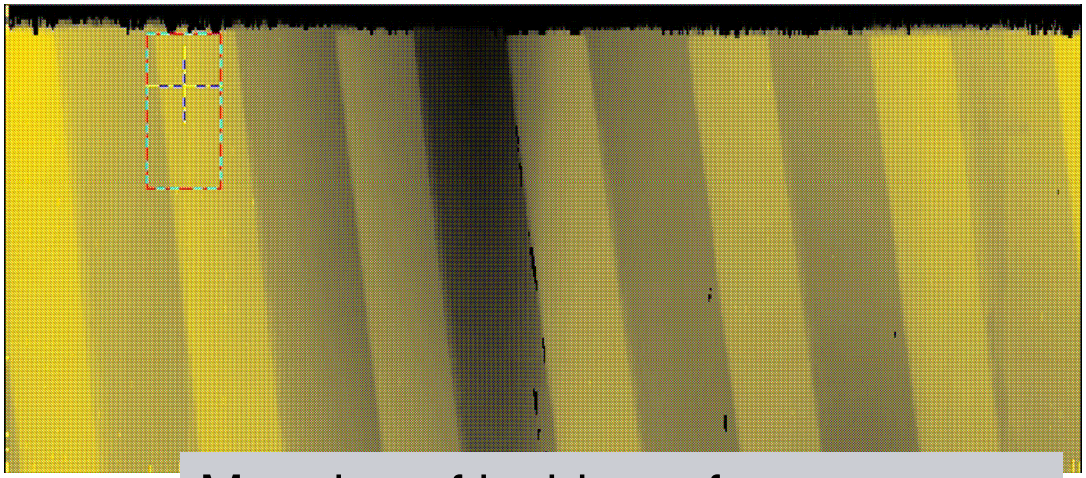
Count: 39999 Min: -0.362
Mean: -3.5450546E-5 Max: 0.500
StdDev: 0.045 Mode: -0.010 (1685)
Bins: 256 Bin Width: 0.004

Profilometry of Hard-to-Reach Surfaces

Profiling of inside wall of gun barrel



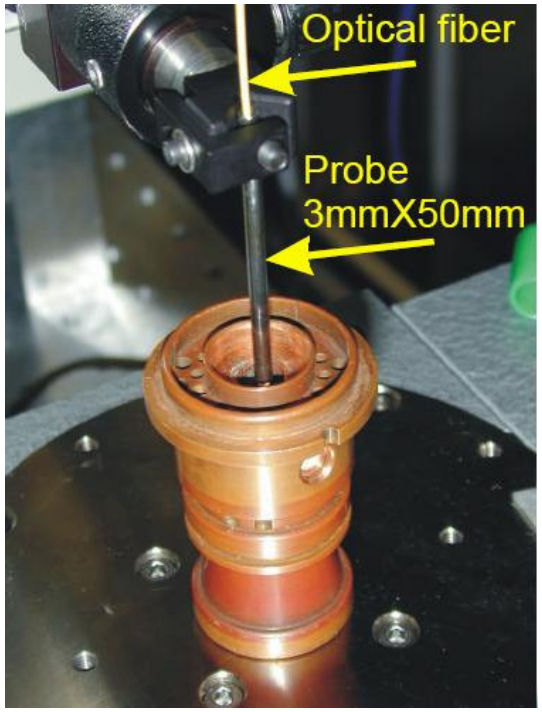


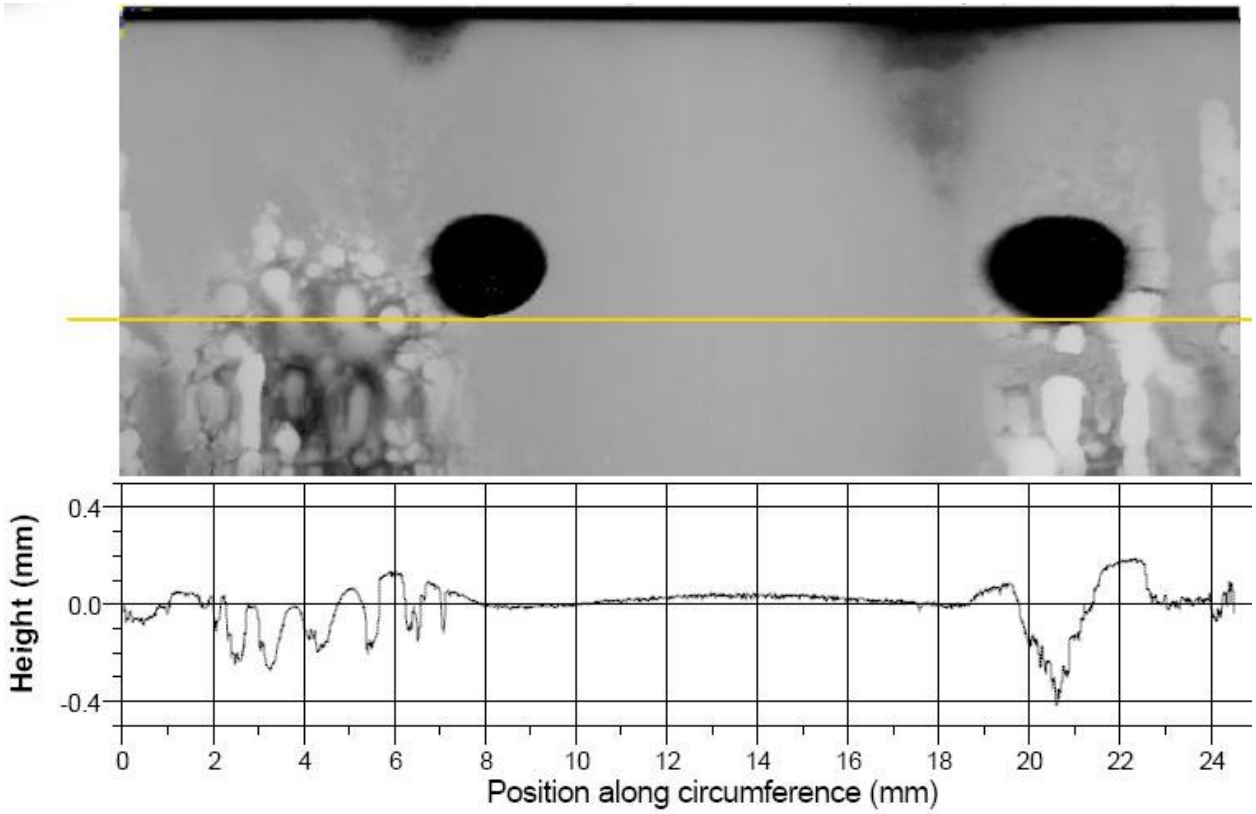


Mapping of inside surface,
depth represented by color intensity

Internal Wall Profiling of Small Diameter Tube

Plasma torch





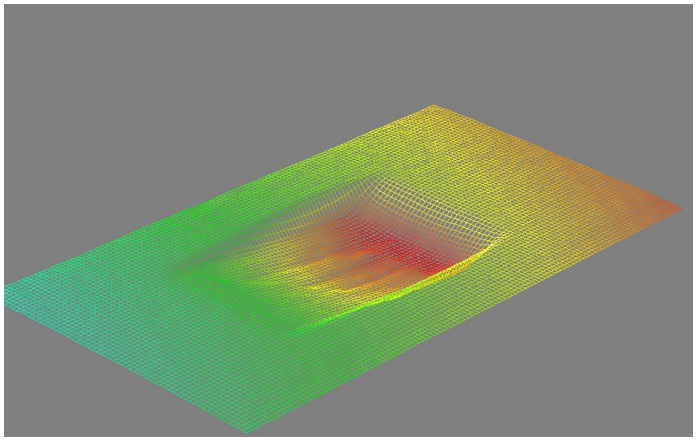
Mapping of inside wall surface

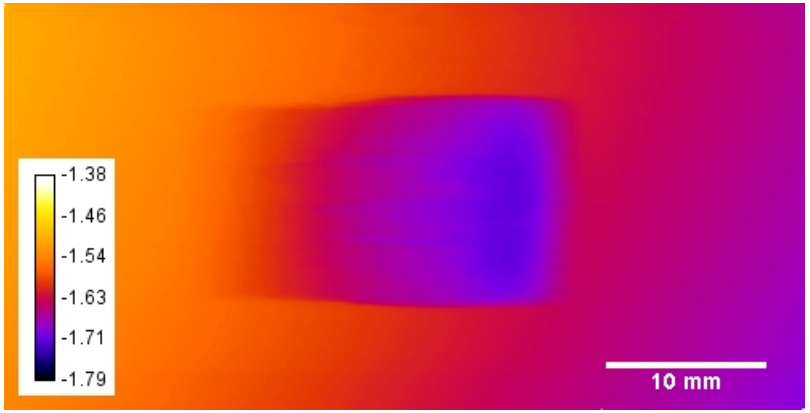
Measurements in Hostile Environments

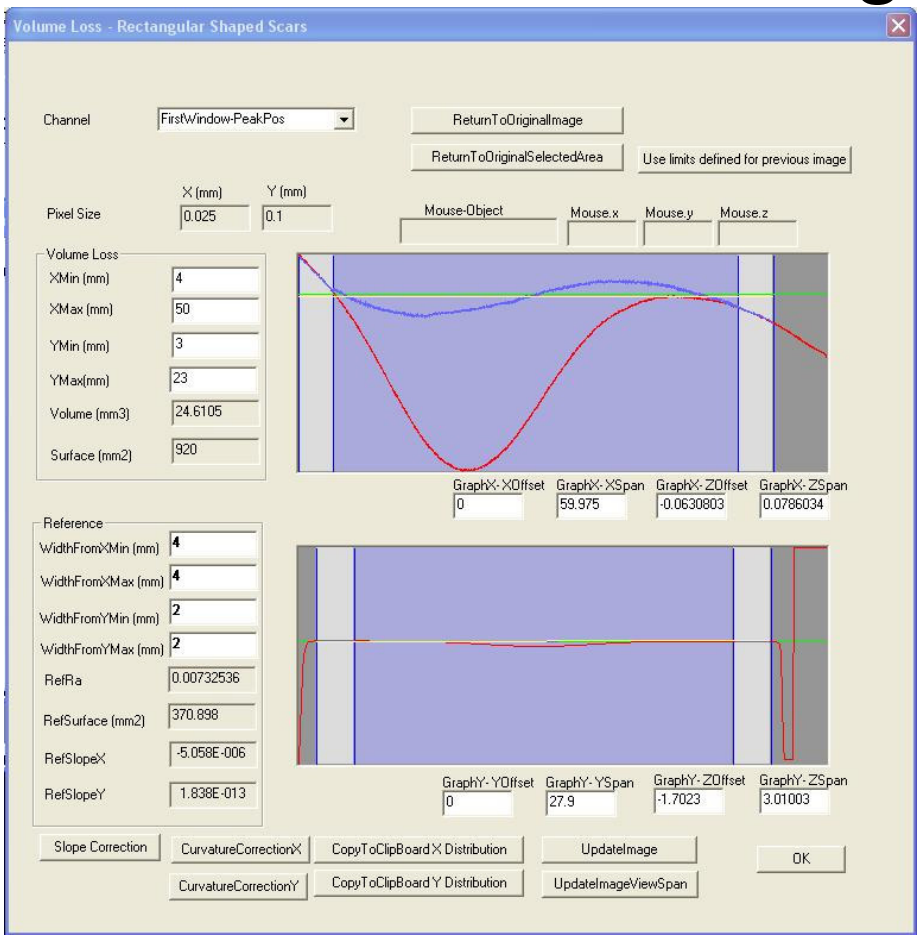
- **High temperature**
  - Proximity of red-hot steel
  - Proximity of plasma coating process
- **Cryogenic**
  - Cryogenic propulsion system
  - Liquid nitrogen level measurement in propulsion systems
- **Radioactive**
  - Inspection of pitting of accelerator targets
  - Crack inspection in nuclear facilities
- **High vacuum**
  - Evaporation chambers

Volume Loss Measurements

Measuring material wear
for hardness measurements and scratch testing

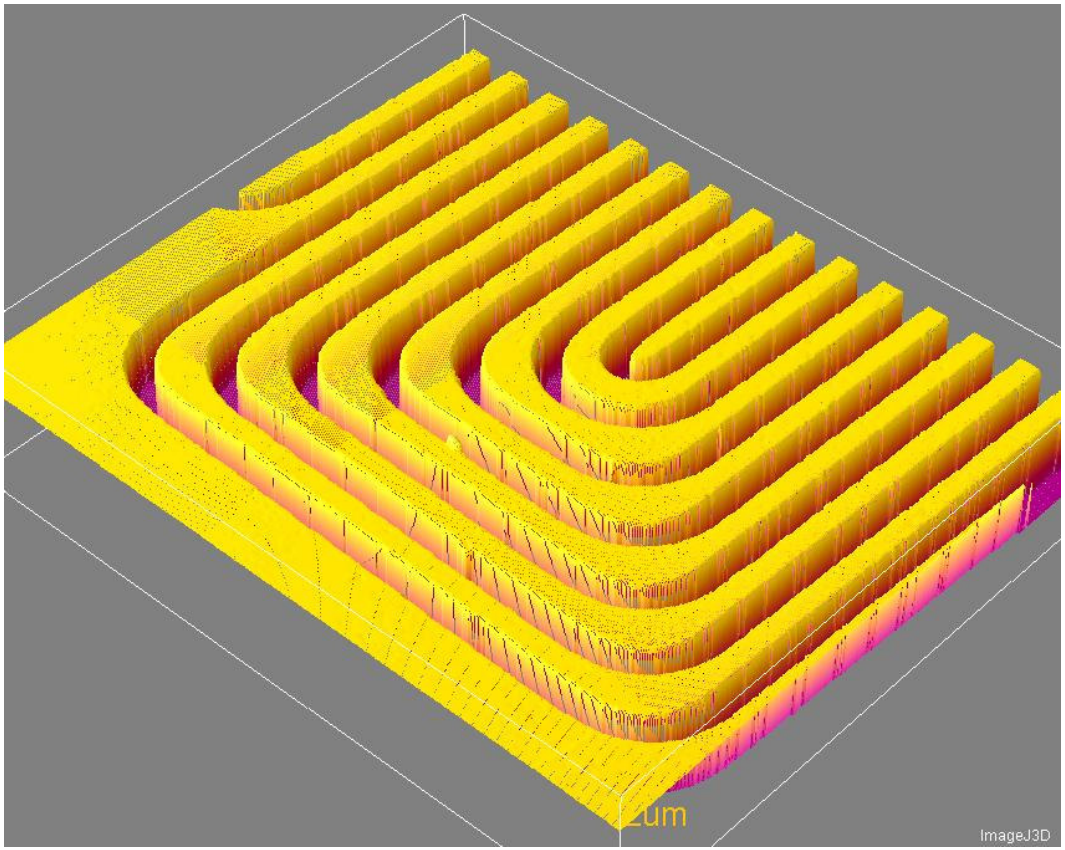






Profiling High-Aspect Ratio Surfaces

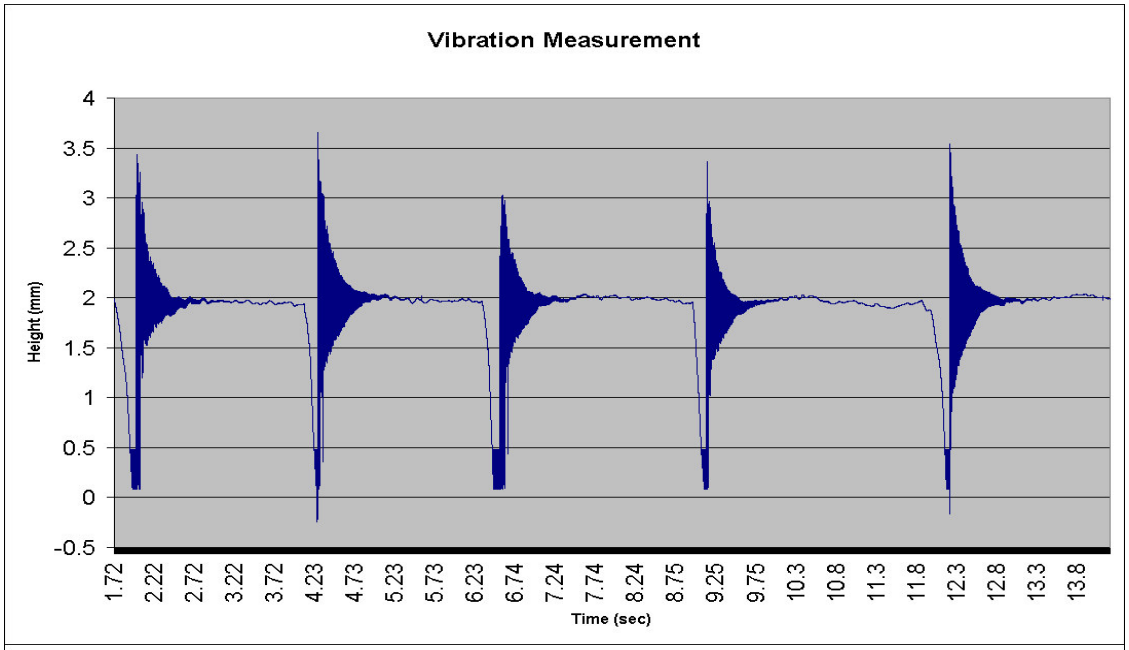
Profiling of bipolar plates in fuel cell

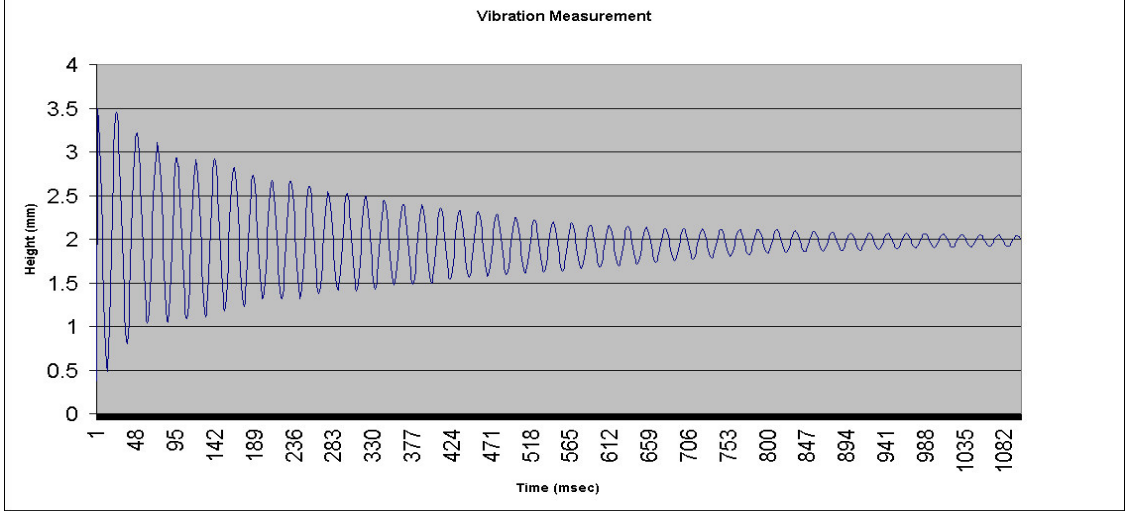


Advantage over triangulation sensors –does not need angle between sensor and light projection

Light emitted and picked up with same probe

Vibration Measurements





- **Vibration frequency and intensity and shaft eccentricity can be measured with one or two probes mounted perpendicularly**

- **Multiple probes can be selected with optical switch (one at the time)**

Profilometry Applications

1) Profilometry

2) Thickness measurements of film or coating

3) Cross section imaging

4) On-line industrial and lab applications

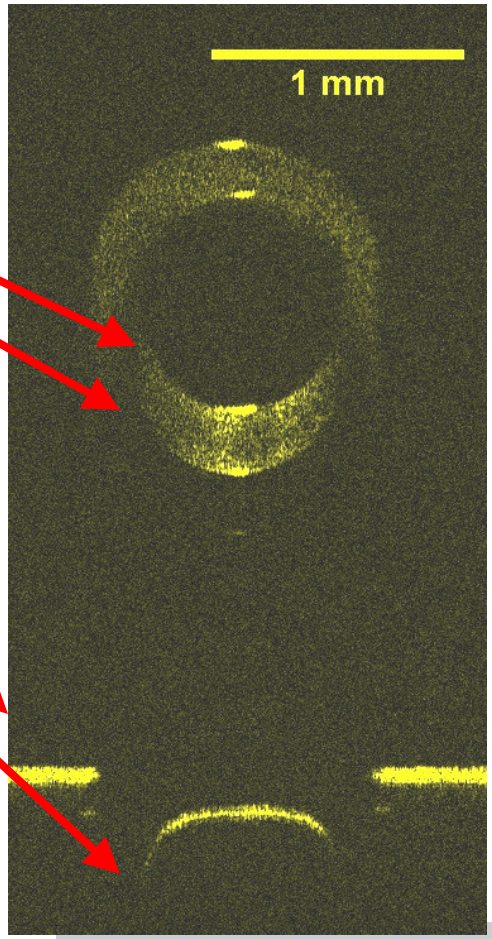
Polymer Wall Thickness Measurements

Measuring wall thickness of polymer tube

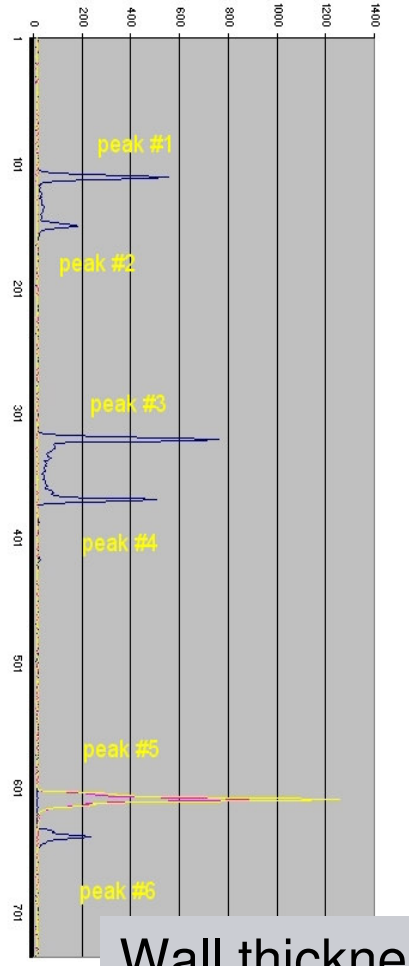
Inside diameter (ID)
Outside diameter (OD)

Reference plane

Index of refraction calculated from change in distance of reference plane



Tube cross-section



Wall thickness measurement

Thickness Measurements

Photo-resist coating on semi-conductor wafer

6” diameter wafer with ~300 micron coating

Profilometry Applications

1) Profilometry

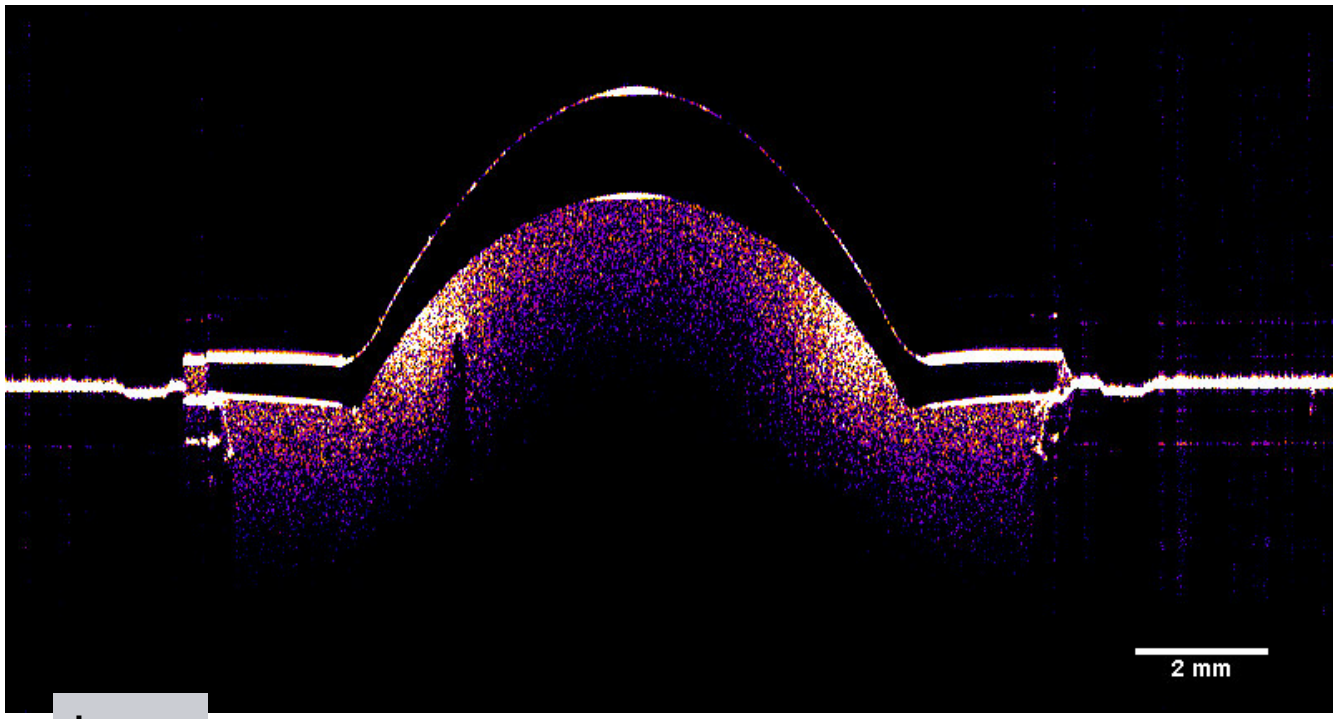
2) Thickness measurements of film or coating

3) Cross-section imaging

4) On-line industrial and lab applications

Cross-Section Imaging

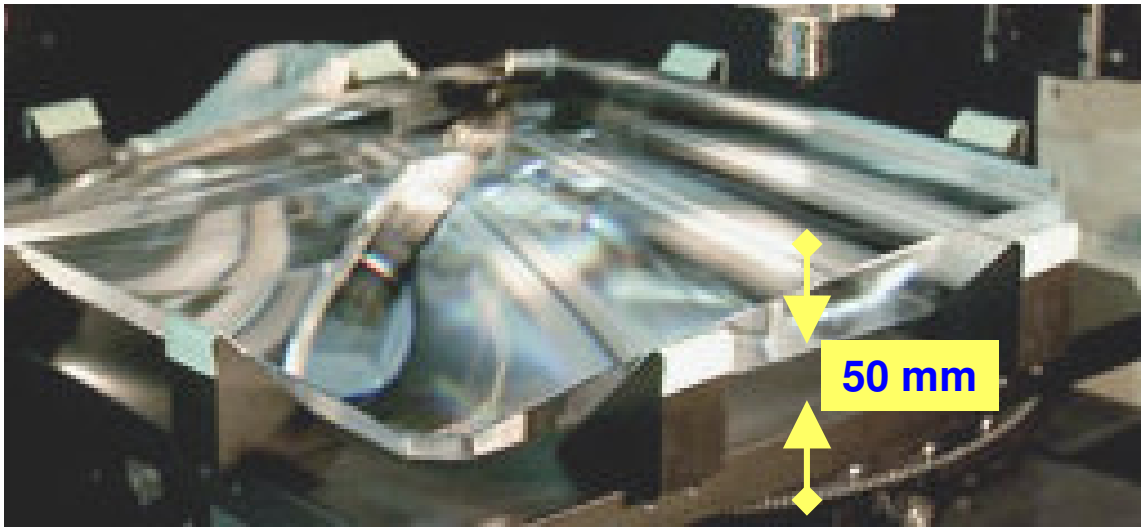
Radius measurements of transparent optical elements

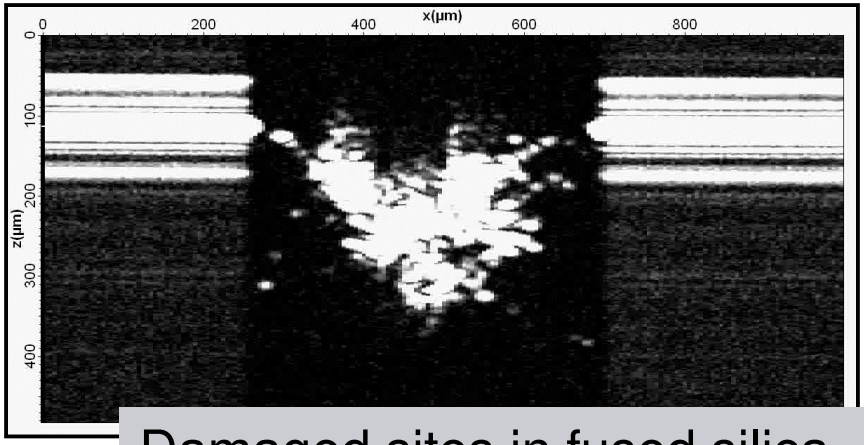


Lens

Cross-Section Imaging of Glass

Sub-surface imaging of damage sites



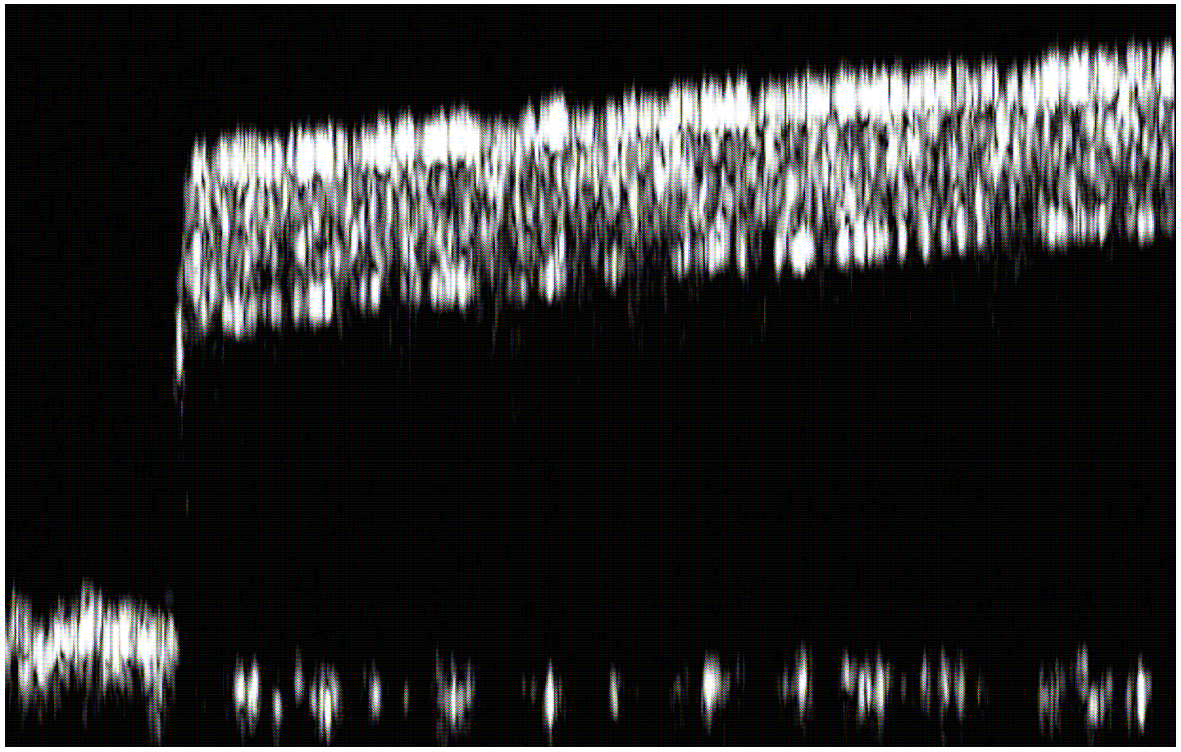


Damaged sites in fused silica

large optics 400mm x 400mm imaged through 50mm of glass

Cross-section Imaging of Paper

Wax paper



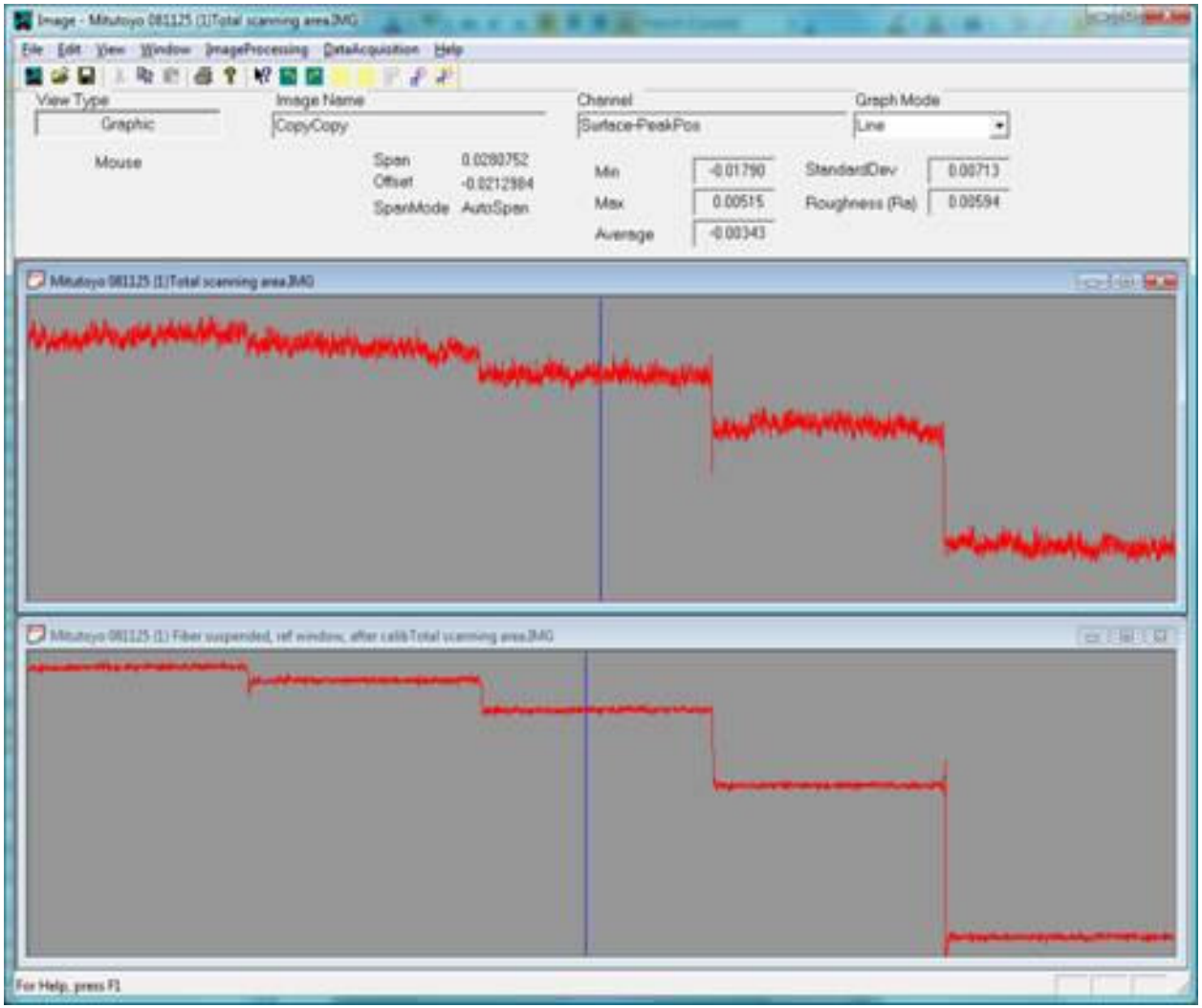
thickness = 50µm

Comparative Advantages

- Small thin (1-12mm diameter) fiber-based probe
- Insensitive to environment lighting
- High-aspect ratio measurements
- High sensitivity and high resolution
- Ability to use multiple multiplexed probes
- Inhospitable environments
- Possible large standoff distance from probe
- Measurements possible far from detector enclosure
- Advantage over triangulation sensors
- Same probe can pick up IR ~900nm light of molten steel

Accuracy Better Than 1µm

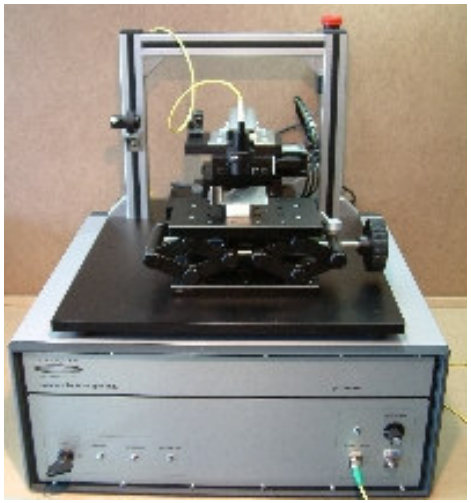
Profiling Mitutoyo step gage with steps of 1, 2, 5 and 10µm



Without reference

With reference optical flat

System Specifications

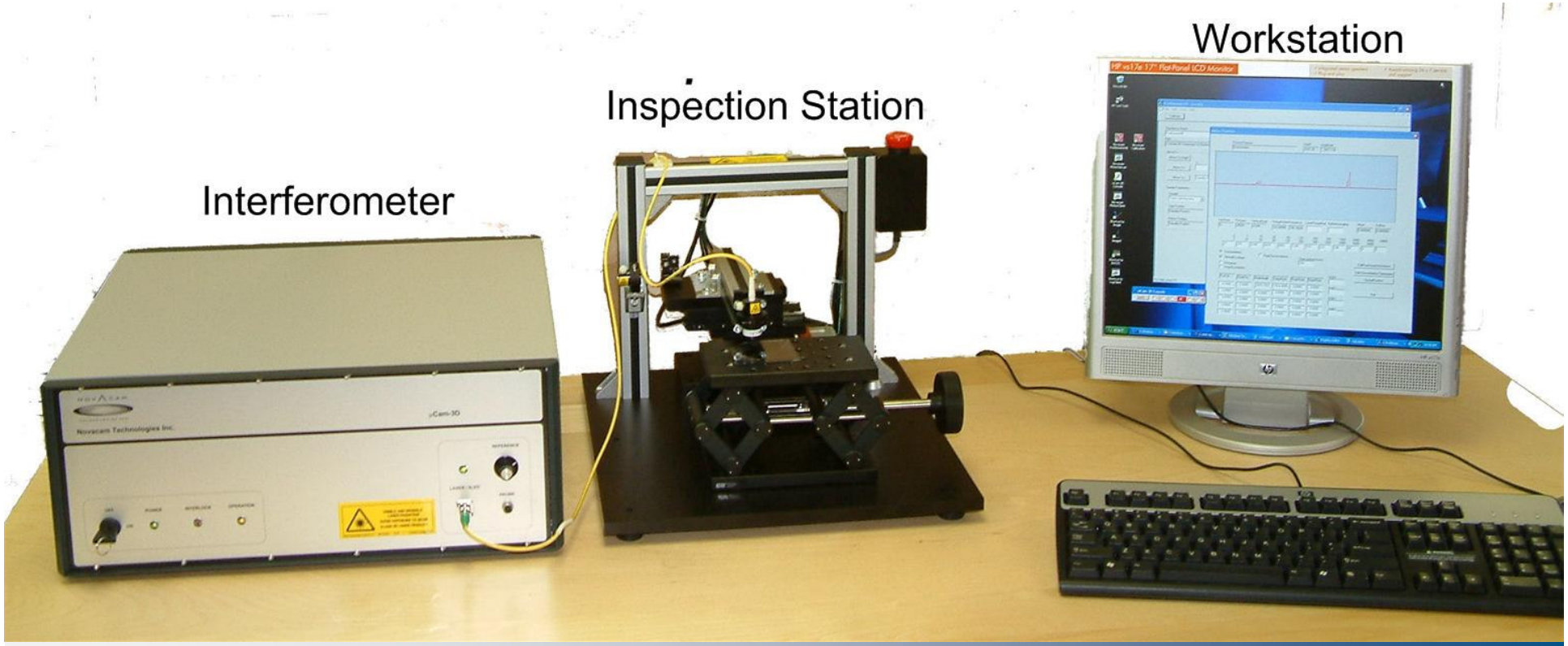


- **Wavelength: 1,310 nm**
- **Acquisition rate: 1,000 - 20,000 points/second**
- **Depth range scanned : < 8mm**
- **Standoff distance: from few mm up to 1m**
- **Axial resolution: <1μm**
- **Lateral resolution: 8-25 μm**
- **Distance of probe from detector enclosure < 1km**

Fiber-Based Profilometer

Typical lab setup

Larger X-Y tables used for long stroke profilometry



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