**50 Years Laser (SSOM) &
3D Measuring (SLN)**

Leica Microsystems (Switzerland) Ltd.
Industry Division
Reto Züst (R&D)

3D MEASUREMENT-METHODS FOR MICROSTRUCTURES

Leica Microsystems Group (LMG)

OpCo*	Leica Biosystems (LBS)	Leica Microsystems (LMS)			
Divisions	Biosystems	Life Science	Medical	Industry	Invetech
					
Major Product Groups	▪ Core Histology Systems ▪ Core Histology Consumables ▪ Advanced Staining Systems ▪ Advanced Staining Reagents	▪ Imaging Solutions for Research & Clinical ▪ Specimen Preparation for Imaging at Nanoscale ▪ Screening & Picking Technology for Optical Imaging	▪ Surgical Microscopes ▪ Imaging Technologies ▪ Documentation Platform	▪ Imaging Solutions for Industry & Education ▪ Stereo and Compound Microscopes for Material and Geosciences ▪ Forensic Microscopes	▪ Contract R&D Services Company developing products, instruments & manufacturing systems

*) Operating Company

Industry Division

Microscopic Imaging & Analysis Solutions for Industrial, Educational & Forensic Applications

Materials Manufacturing & Processing

- Stereo Microscopes
- Compound Microscopes
- Digital Cameras
- Imaging Software Solutions
- Digital Microscopes

Microtechnology

- Confocal & Interfero-metry Instructments
- Compound Microscopes
- Stereo Microscopes
- Digital Cameras
- Imaging Software Solutions
- Digital Microscopes

Scientific Institutions

- Confocal & Interfero-metry Instructments
- Compound Microscopes
- Digital Microscopes
- Stereo Microscopes
- Polarization Microscopes
- Digital Cameras
- Imaging Software Solutions

Education

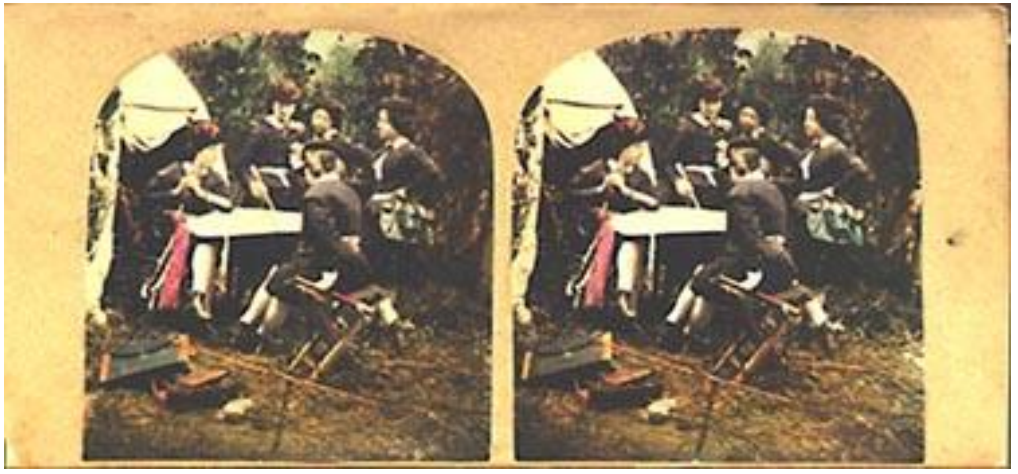
- Compound Microscopes
- Polarization Microscopes
- Stereo Microscopes
- Digital Cameras
- Annotation & Measure-ment software

Forensic

- Comparison Macroscopes
- Stereo Microscopes
- Polarization Microscopes
- Compound Microscopes
- Imaging Software Solutions
- Digital Microscopes

- Leading market position in Ergonomic Solutions and Stereo Microscopy
- Advanced Stereo and Compound Microscopes for Material & Geosciences
- Imaging Solutions including Imaging Analysis for Industrial and Educational Applications
- Market leader in Forensic Microscopy

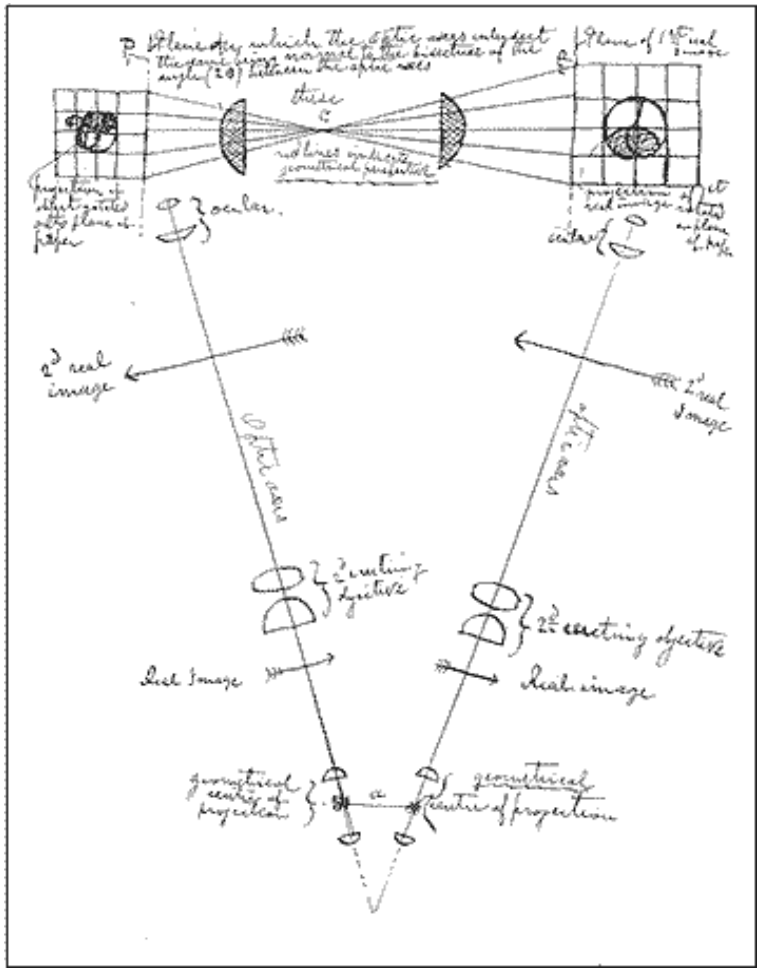
3D Measurement in microscopy: How this all started…



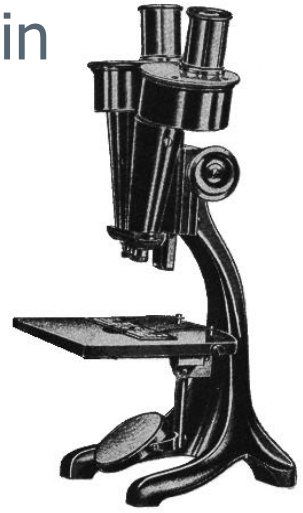
The stereograph is the card of introduction to make all mankind acquaintances

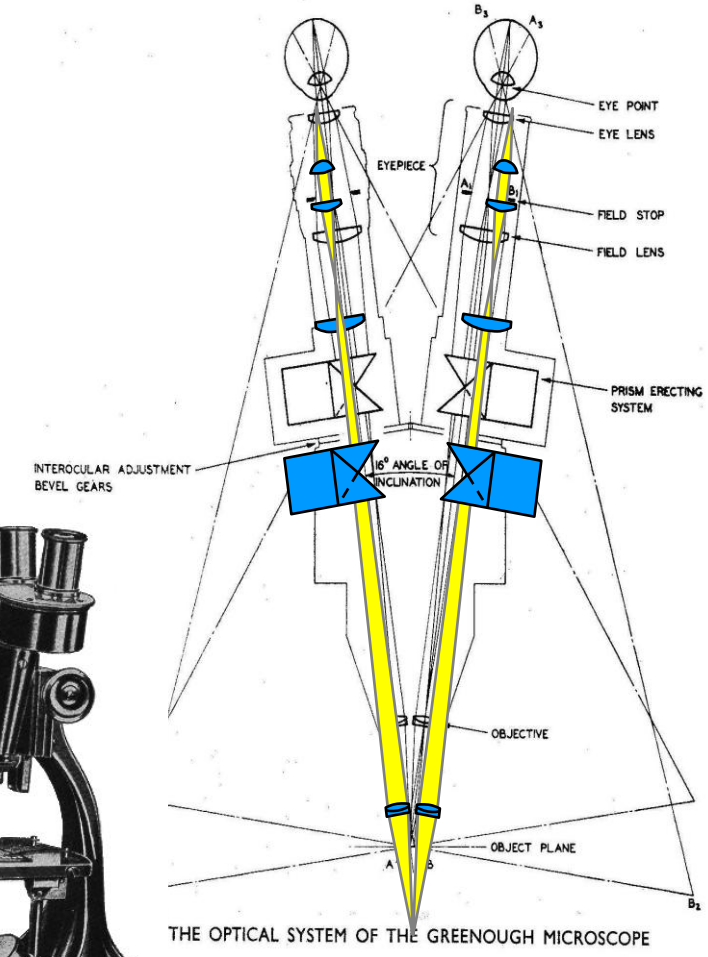
-- Oliver Wendell Holmes, 1859

Horatio S. Greenough (American zoologists)



- 1892
- Two compound microscopes
- Convergence angle for 3D impression in human brain

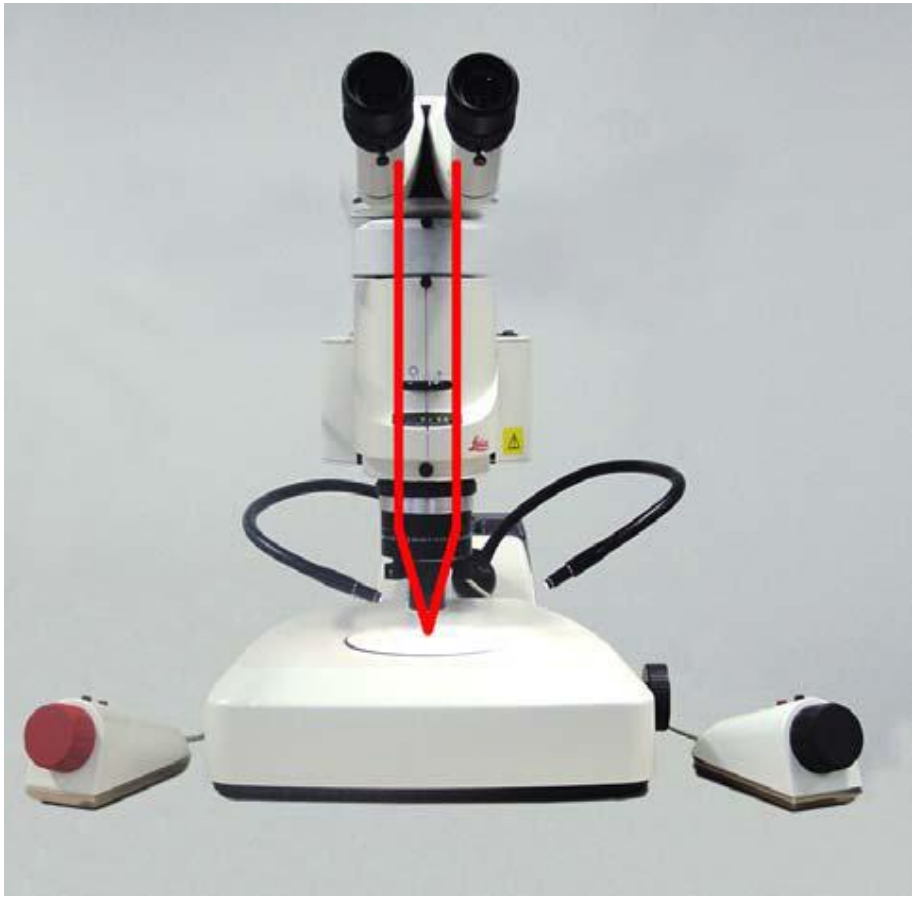




THE OPTICAL SYSTEM OF THE GREENOUGH MICROSCOPE

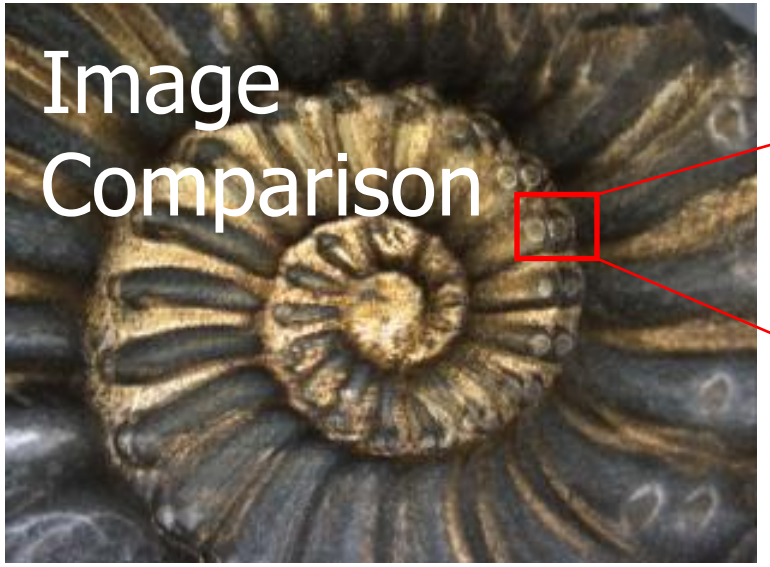
Stereoscopic 3D Reconstruction

- Used in Leica StereoExplorer
- Needs stereo image pair and parallax geometry
- 2-step approach
  - Find corresponding surface points in both camera images
  - Use triangulation to calculate relative height



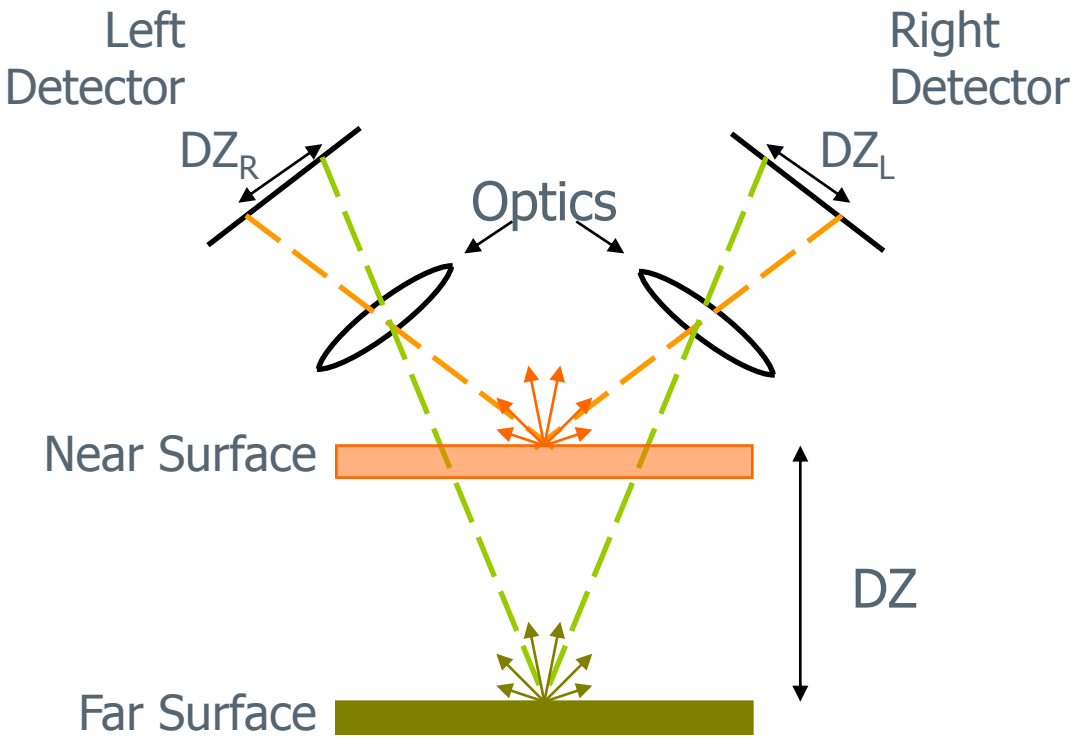
Stereoscopic 3D Reconstruction

- Step 1: Find corresponding surface points



Stereoscopic 3D Reconstruction

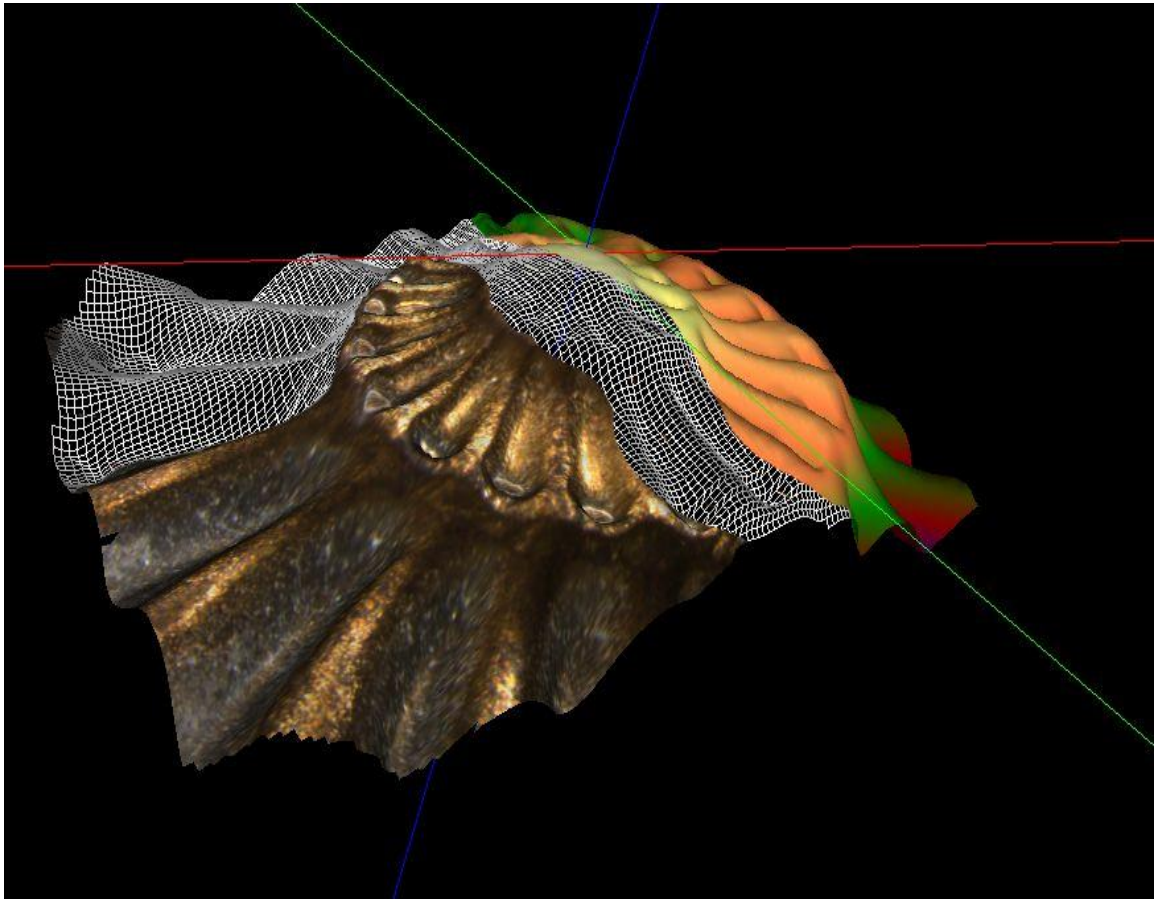
- Step 2: Triangulation



$$DZ_L + DZ_R \sim DZ$$

Stereoscopic 3D Reconstruction

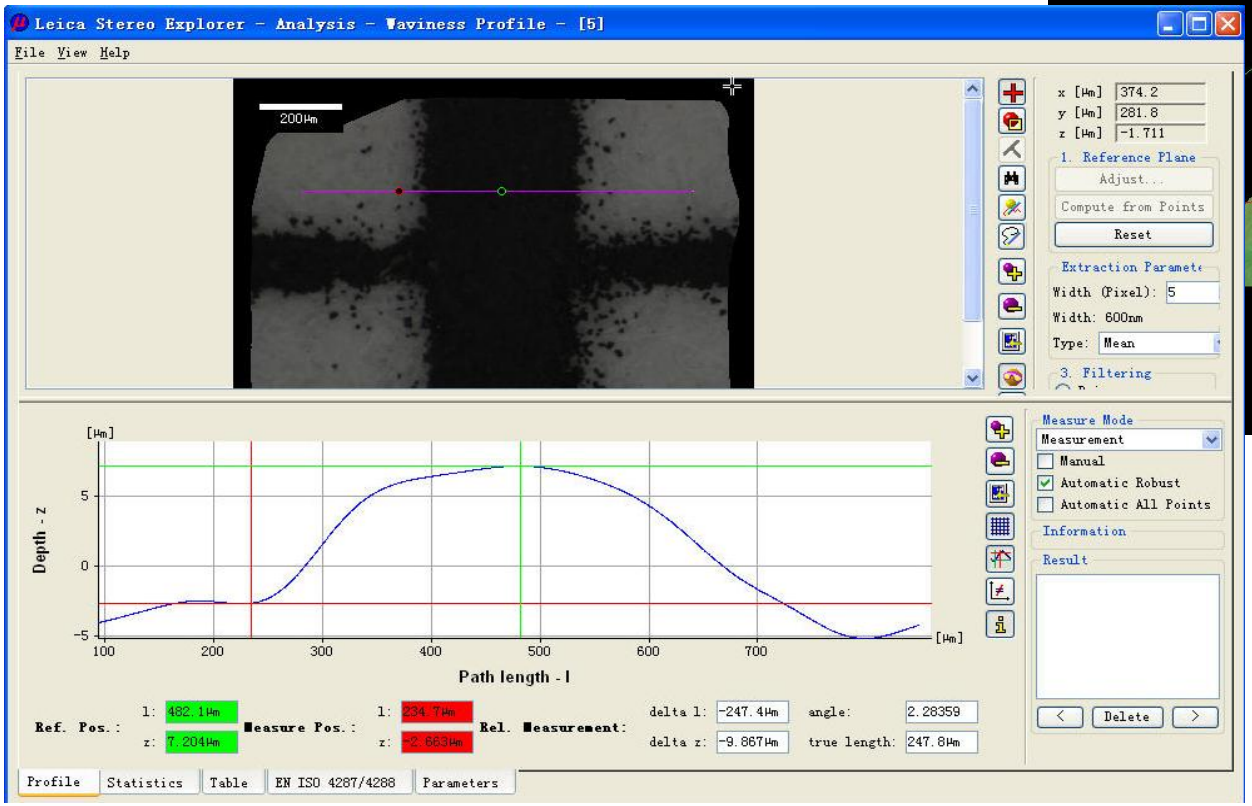
- Results:
  - Surface point co-ordinates
  - Texture of of surface points
  - Vertical resolution: ≥0.2µm
  - Lateral resolution: ≥2.5µm
  - Vertical range: ≤34mm
  - Lateral range: ≤31x23mm

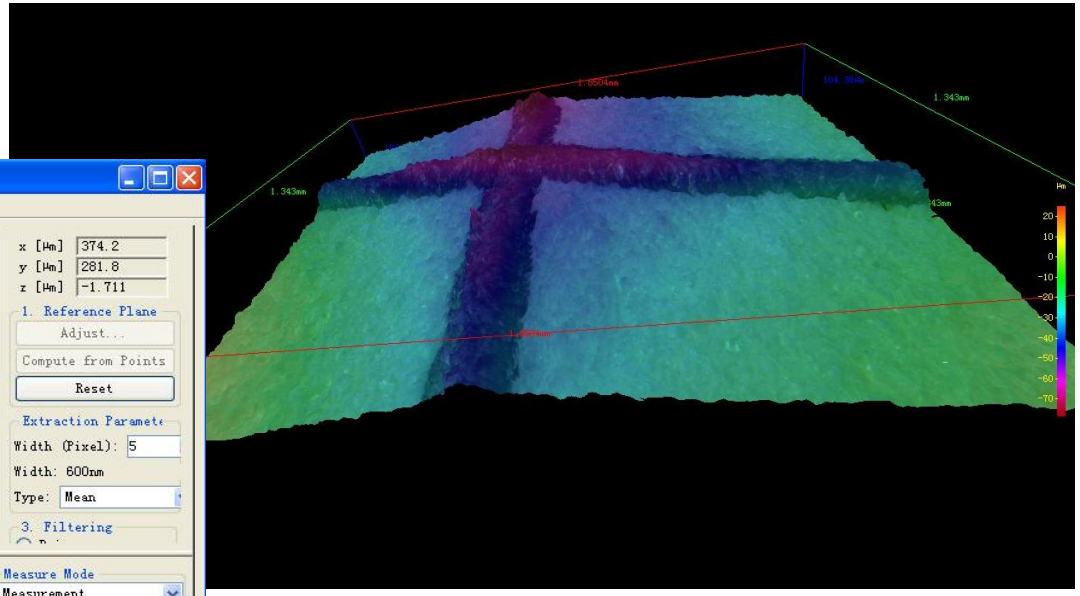


Stereoscopic 3D Reconstruction

- Conditions
  - Common surface regions in left and right image ➔ Object
  - Surface texture ➔ Object
  - Similar texture appearance in left and right image ➔ Illumination
  - Surface texture resolved ➔ Optics (resolution, depth of field)
- Benefits
  - Provides geometry and texture / color
  - Easy setup and calibration

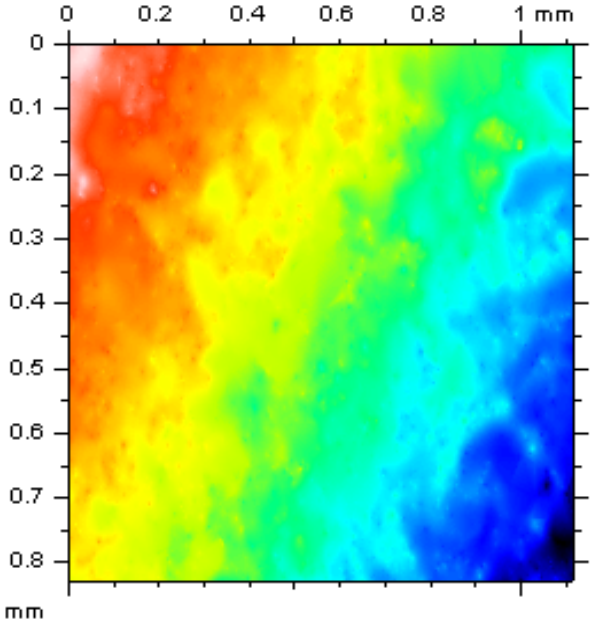
Application: Forensic, Document Analysis



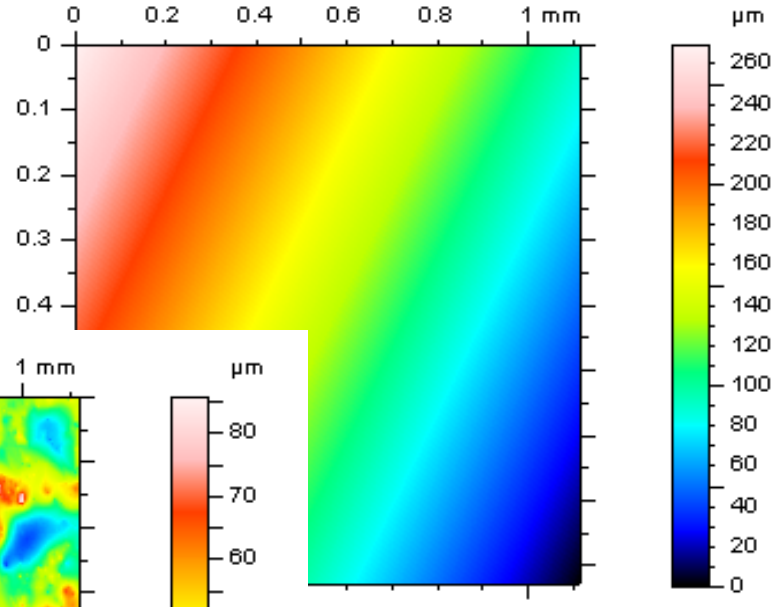


Application: Surface roughness (part 1/2)

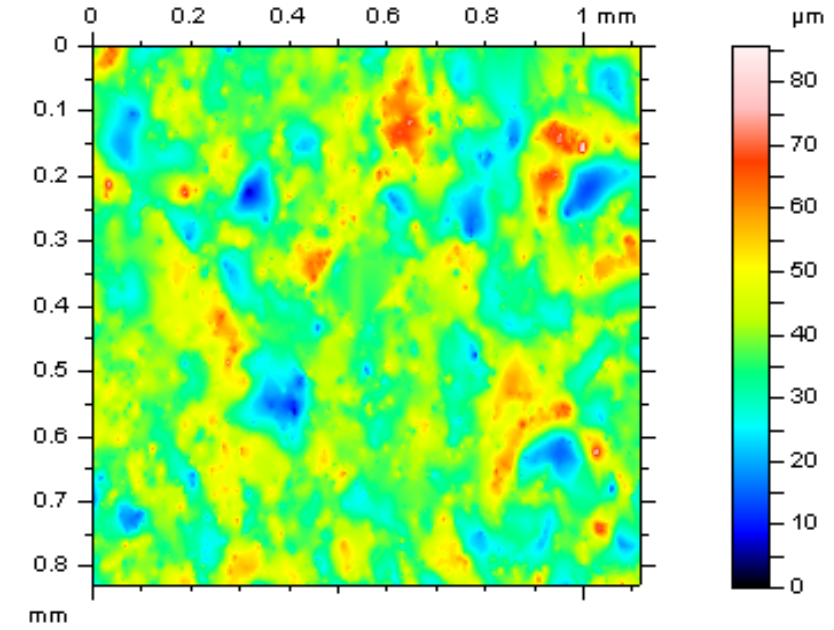
Raw Data



Reference Surface



Processed Data



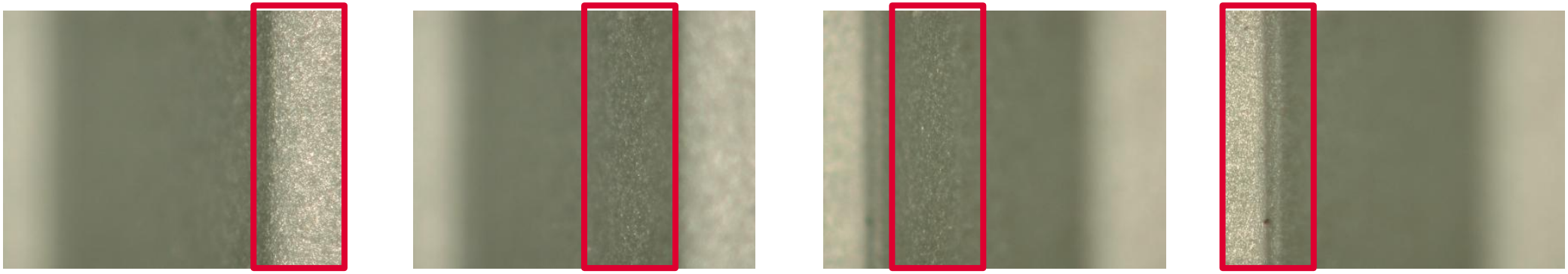
Sa = 6.46 µm

colaboration with:

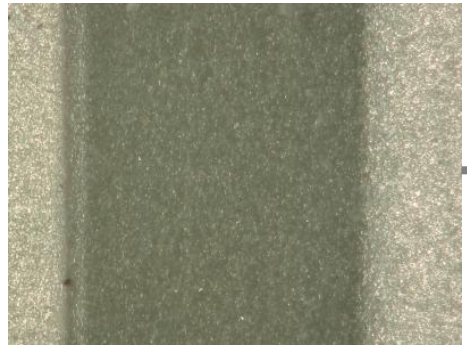
EMPA

Z-Stacking / Extended Depth of Field

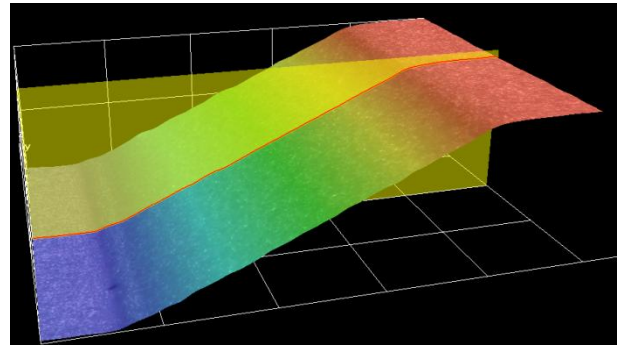
Top Focus Position → Bottom Focus Position



- Results:
  - Surface point co-ordinates
  - Texture of surface points
  - Vertical resolution: ≥0.5µm
  - Lateral resolution: ≥1.0µm

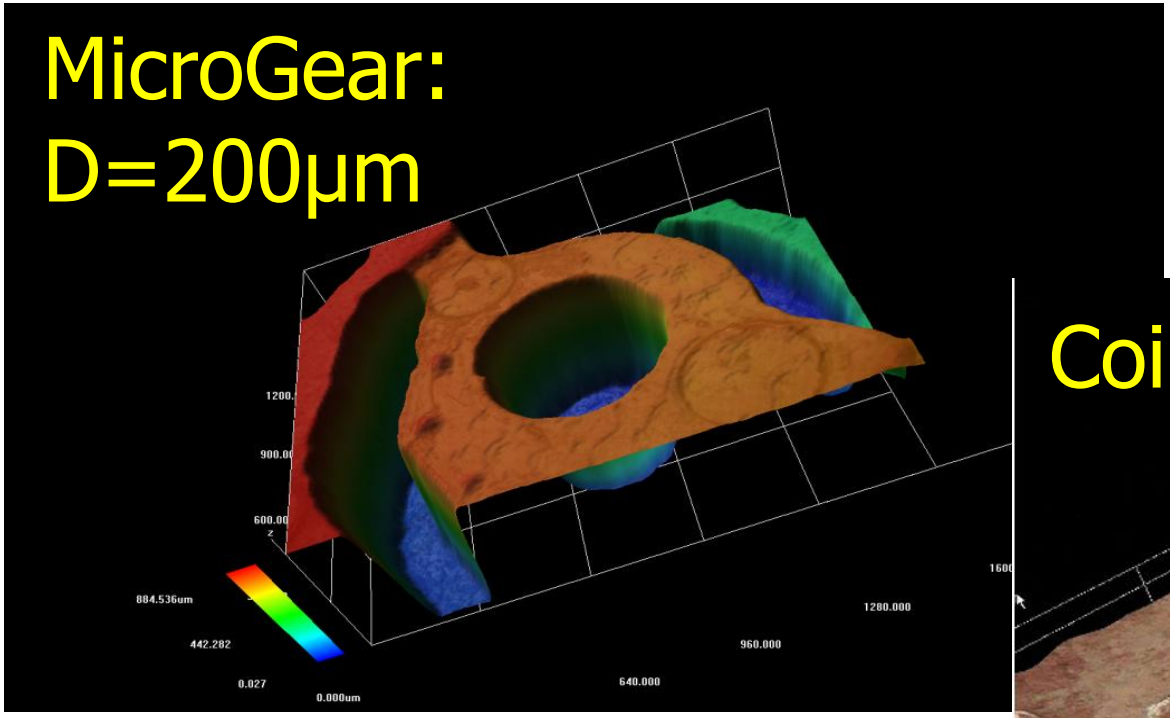


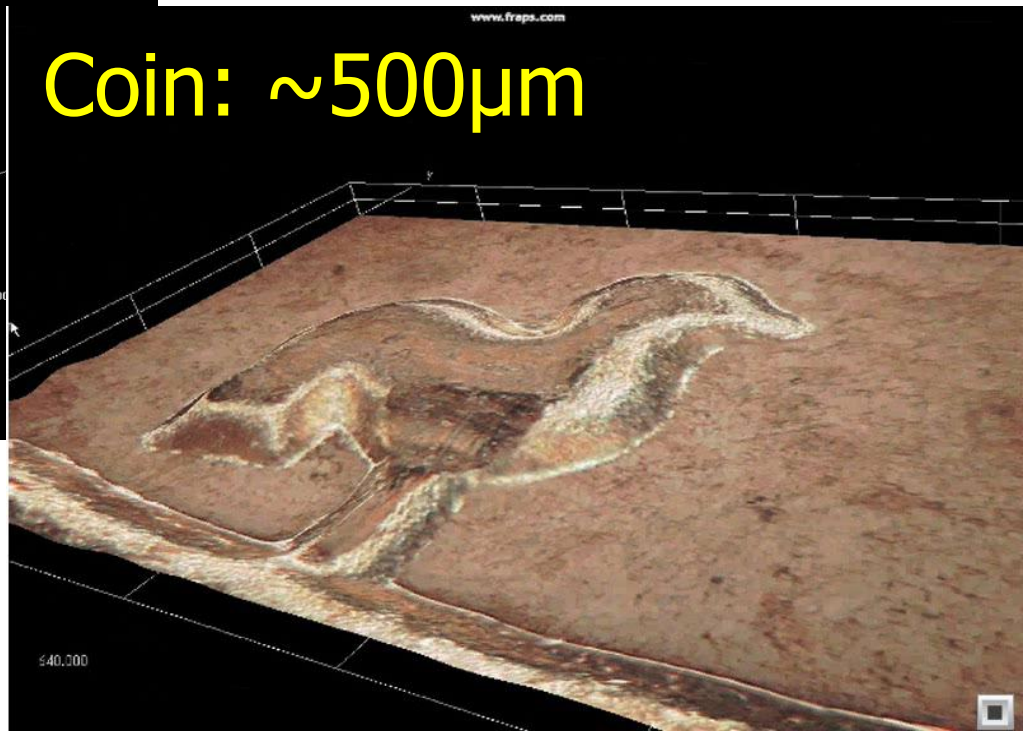
Extended Depth of Field Image



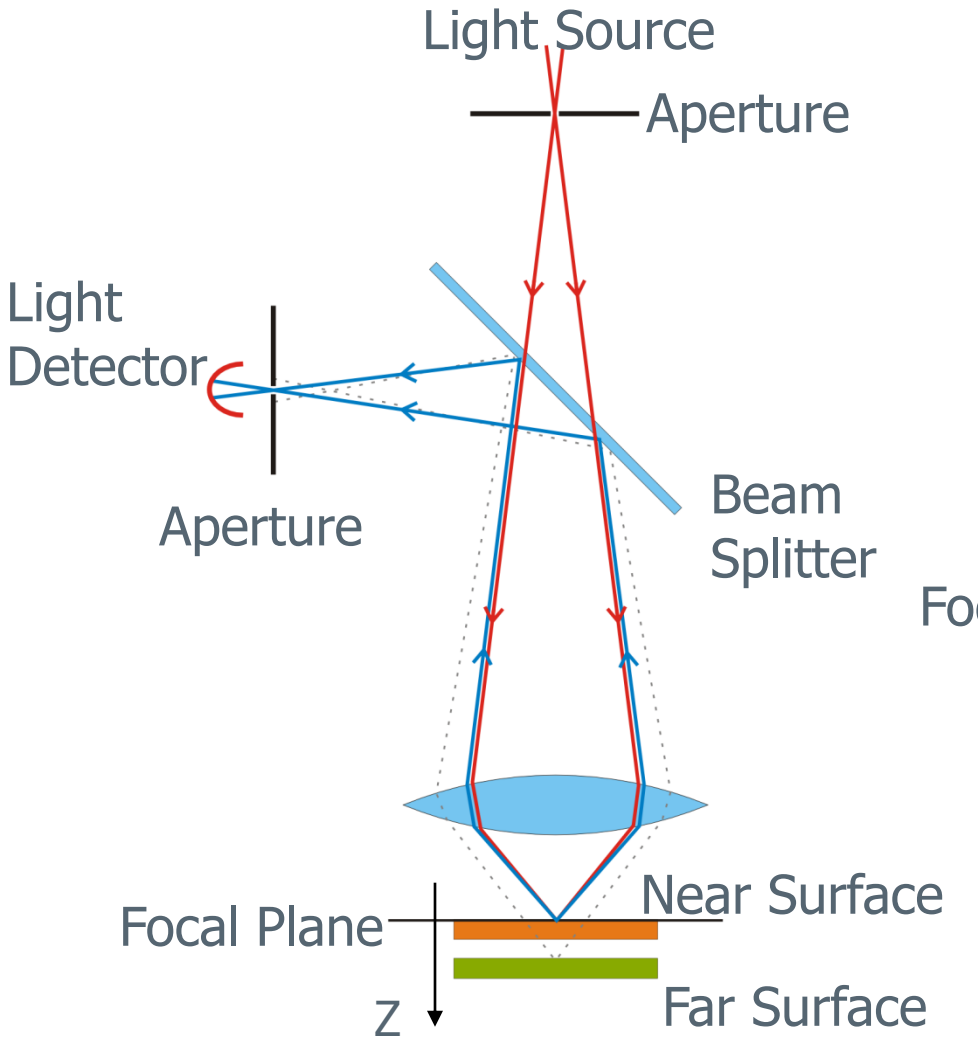
3D Topography

Applications

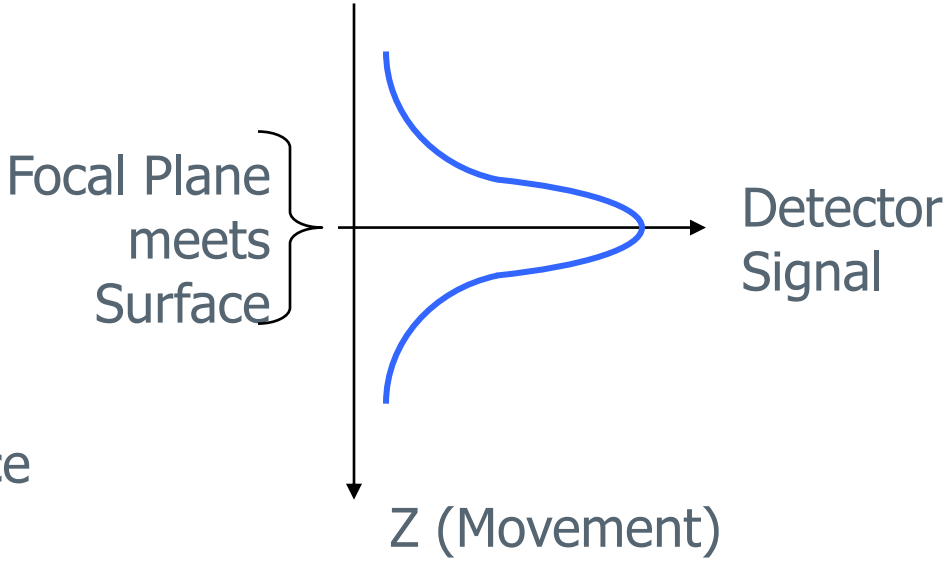




Confocal Microscopy (Basic principal)

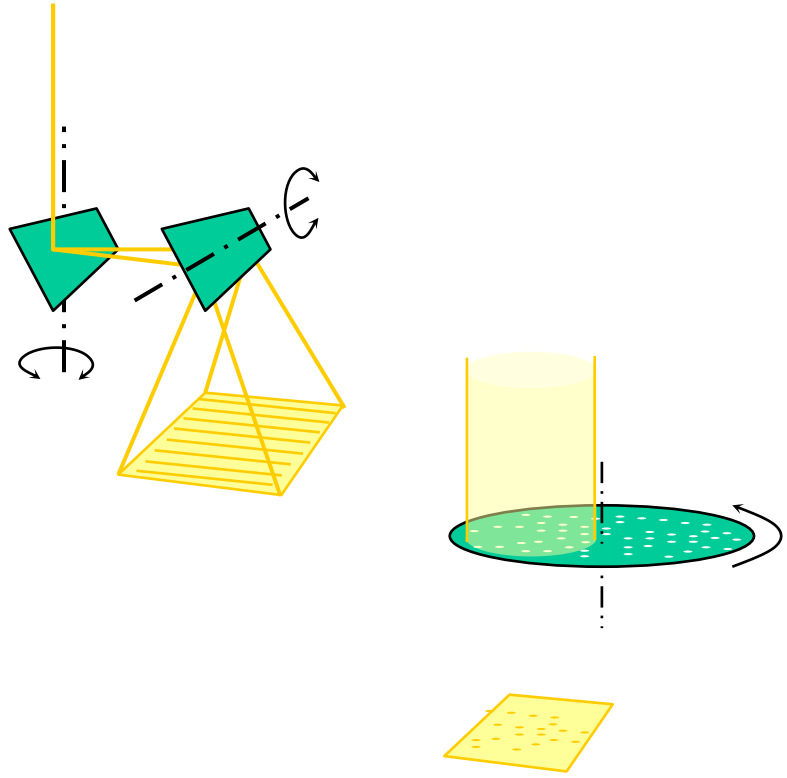


- Only the light near (at) the focal plane can be detected

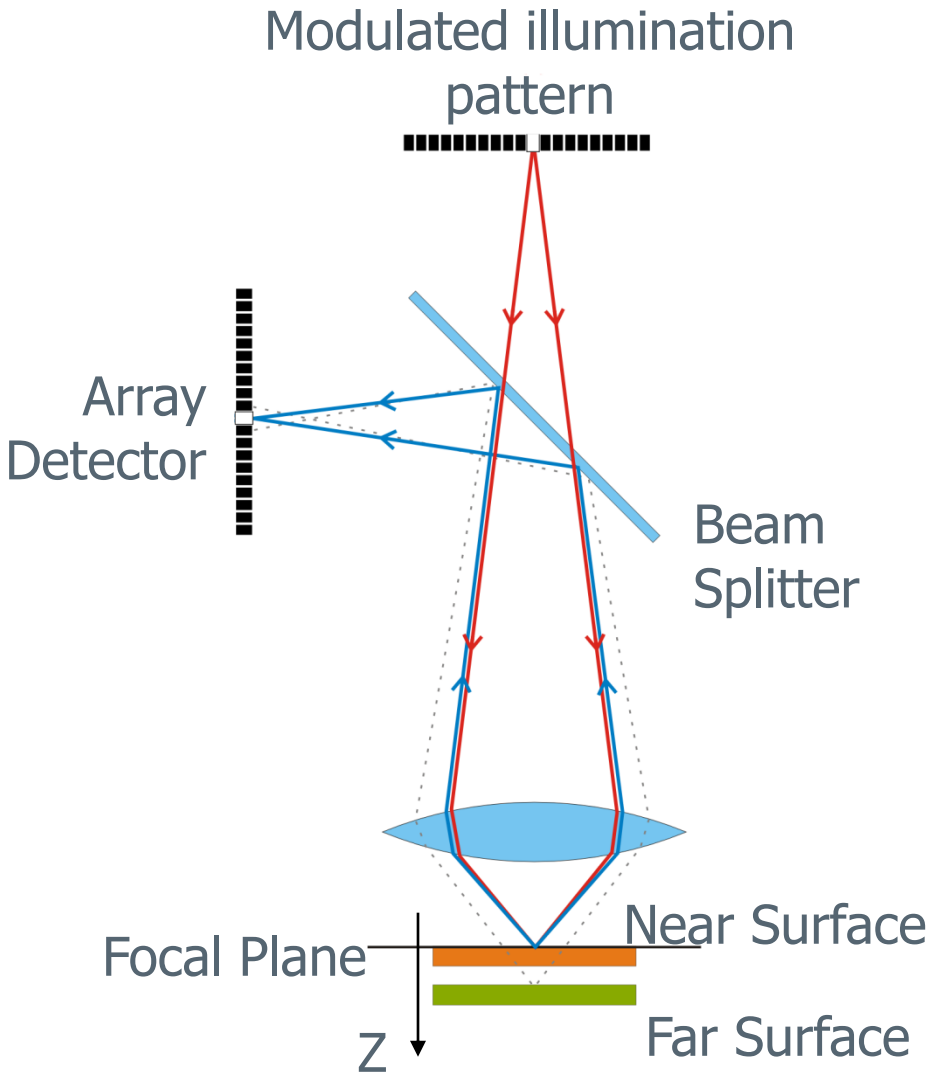


Traditional (Laser) Scanning Microscope

- Scanning whole image area
  - Using rotating mirrors
  - Using rotating pin-hole disk (Nipkow)
- Problem areas
  - Vibrations, Nonlinearity, Noise
  - Sensitive mechanics



Confocal Microscopy (PAM*-Type)

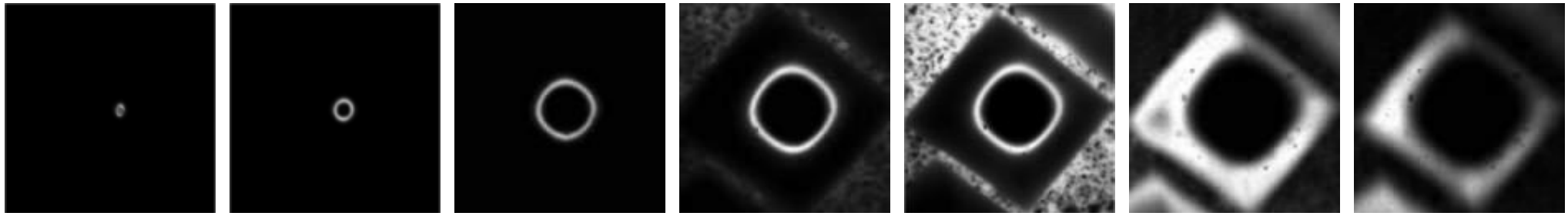


- Modulated illumination pattern combines light source and aperture (e.g. with LCOS** micro display and LED)
- Array detector combines detector and aperture (e.g. CCD array sensor)
- Modulation allows multi-point scanning

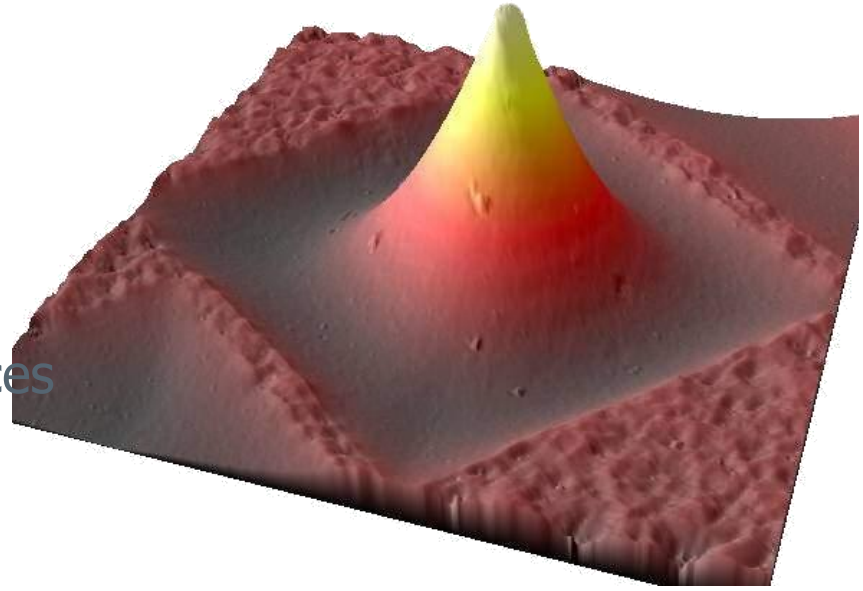
*PAM: Programmable Array Microscope
**LCOS: Liquid Cristall On Silicon

Z-stacking → 3D surface

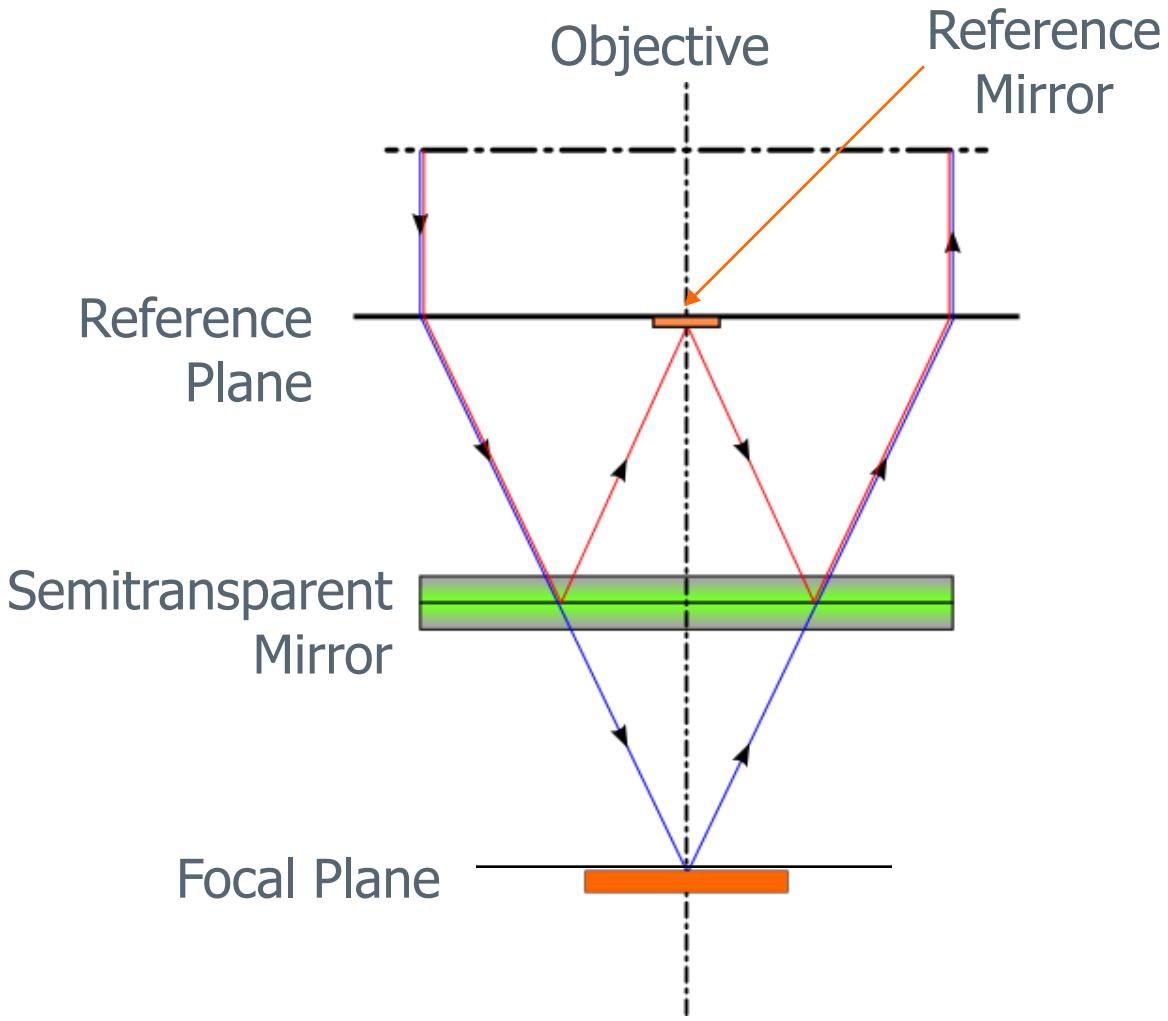
Top Focus Position → Bottom Focus Position



- Vertical resolution: ≥2 nm
- Lateral resolution: 0.15 µm
- Typical scan time: 5 s
- Local slopes on smooth surfaces up to 72º.
- From very rough to moderately smooth surfaces



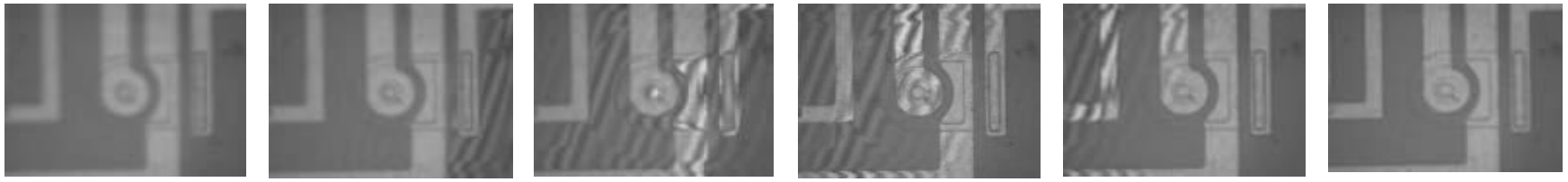
Interferometrical Microscopy (Mirau)



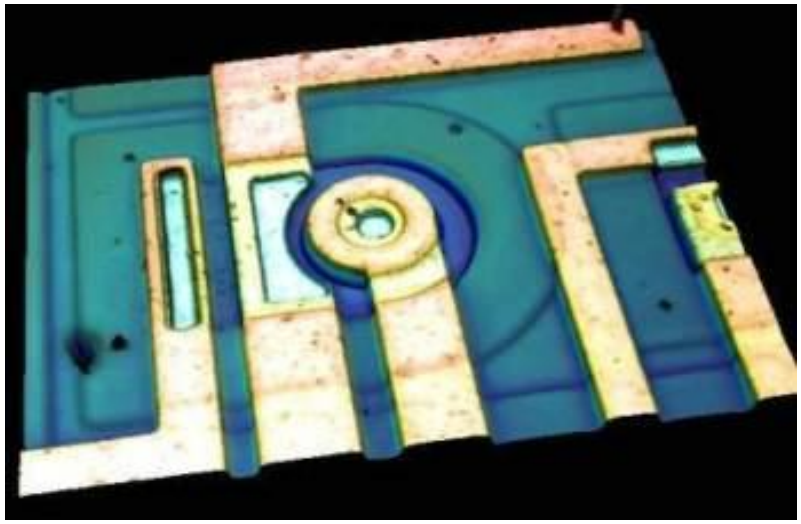
- Additive interference if object in focal plane (length of red and blue beam path identical)
- Vertical scanning interferometry (VSI) with white light for rough surface / steps
- Phase shift interferometry (PSI) for smooth surface (nm-resolution)

VSI: Vertical Scanning Interferometry

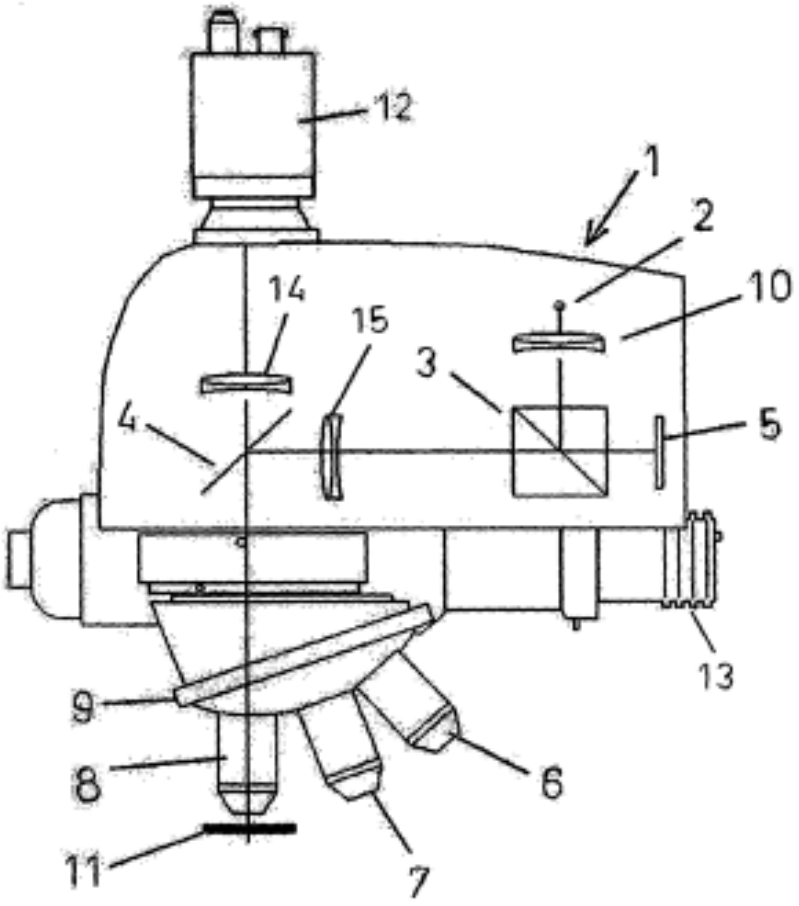
Top Focus Position → Bottom Focus Position



- Vertical resolution: ≥4 nm
- Lateral resolution: ≥0.28 µm
- Measurement range: ≤10 mm
- Typical scan time: <10 s
- Smooth to rough surfaces



Confocal + Interferometry = Dual Core

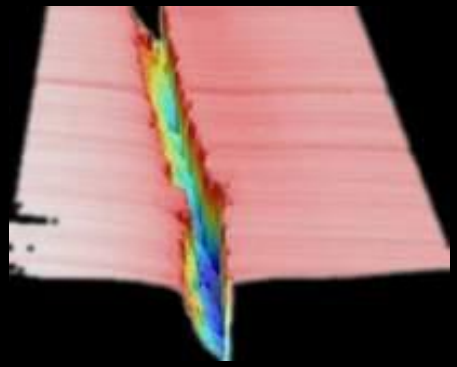


- Setup
  - 2: LED light source
  - 4: Beam splitter
  - 5: Micro display
  - 6: Conventional objective
  - 8: Interferometry objective
  - 11: Sample
  - 12: Camera
- Confocal: Use micro display for illumination pattern
- Interferometry: Use micro display for plane illumination

Image from LAGUARTA BERTRAN, Ferran et. al.

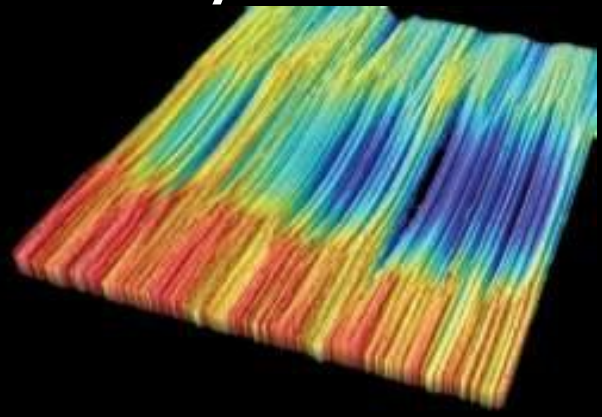
Applications

Crack Analysis

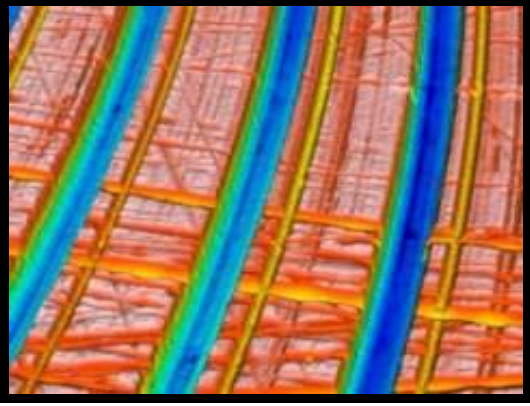


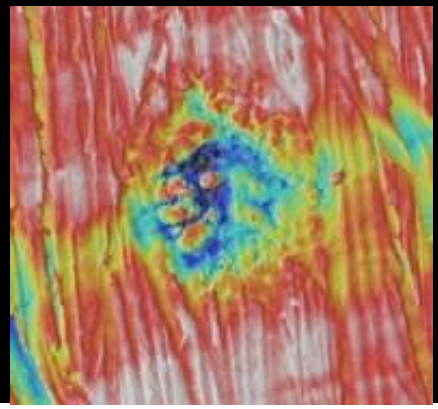
Large surface

Roughness analysis

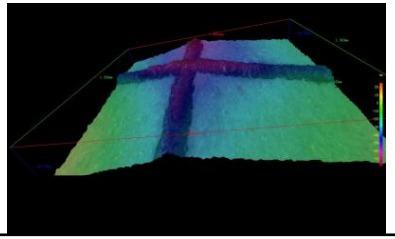
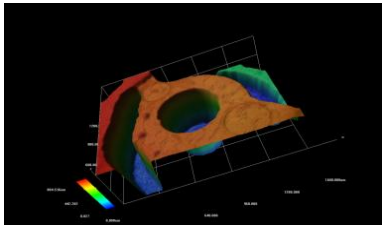
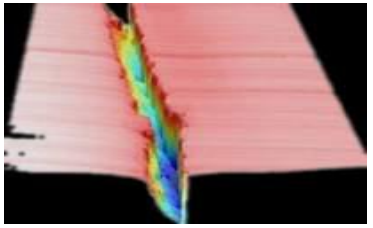
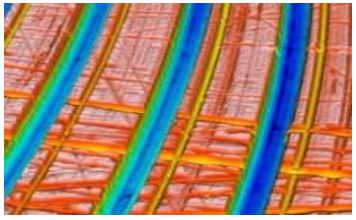


Wear analysis





Comparison of Methods

	Stereoscopic	Z-Stack	PAM Confocal	Interfero-metry
Lateral resolution	≥2.5µm	≥1.0µm	≥0.15µm	VSI:≥0.3µm PSI:≥0.3µm
Vertical resolution	≥0.2µm	≥0.5µm	≥2nm	VSI: ≥4nm PSI:≥0.1nm
Image capture	Image pair	Image stack	Image Stack	Image Stack
Time	≈ 2-5min	≈ 2min	≈ 30s	≈ 5-20s
Samples	Macroscopic, Microscopic 	Macroscopic, Microscopic 	Microscopic 	Microscopic 

Leica
MICROSYSTEMS

Living up to Life