Vacuum tribometer with in-situ wear measurement by DHM® (digital holography microscope)

Yves Emery and Etienne Cuche

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1999: 20 years ago !

The first Digital Holography Microscopes
for simultaneous single shot
phase and intensity contrast
measurements

E. Cuche et al:

1999: OPTICS LETTERS, Vol. 24, No. 5 Applied Optics, Vol. 38, No. 34

Simultaneous amplitude-contrast and quantitative phase-contrast microscopy by numerical reconstruction of Fresnel off-axis holograms

Etienne Cuche, Pierre Marquet, and Christian Depeursinge

Digital holography for quantitative phase-contrast imaging

Etienne Cuche, Frédéric Bevilacqua, and Christian Depeursinge

Institute of Applied Optics, Swiss Federal Institute of Technology, CH-1015 Lausanne, Switzerland

Received November 16, 1998

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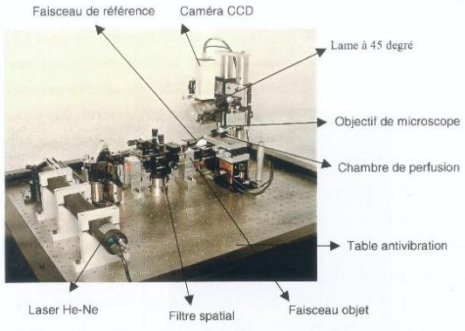
OCIS codes: 120.5050, 150.6910, 090.0090, 040.1520, 120.3940.



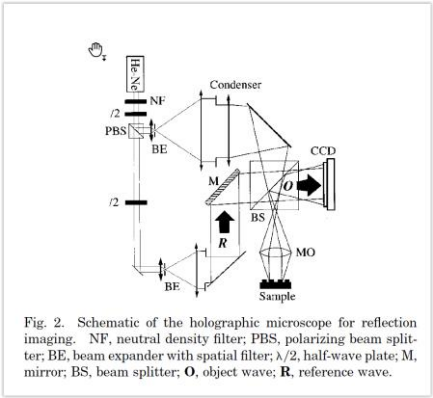


Fig. 2. Schematic of the holographic microscope for reflection imaging. NF, neutral density filter; PBS, polarizing beam splitter; BE, beam expander with spatial filter; λ/2, half-wave plate; M, mirror; BS, beam splitter; **O**, object wave; **R**, reference wave.

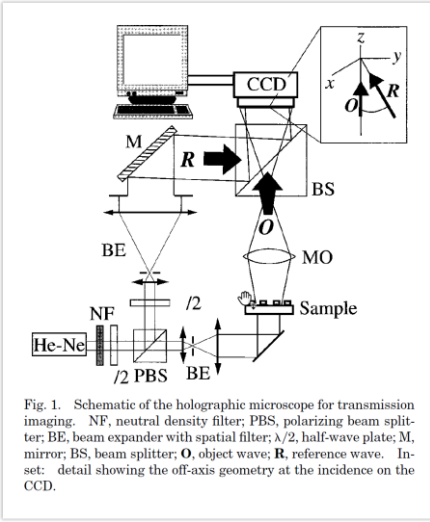
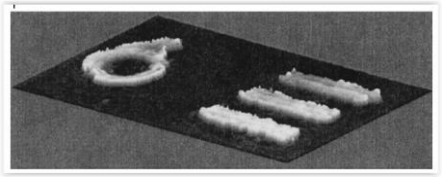
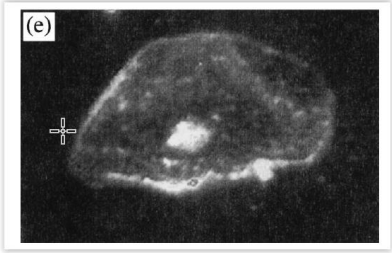


Fig. 1. Schematic of the holographic microscope for transmission imaging. NF, neutral density filter; PBS, polarizing beam splitter; BE, beam expander with spatial filter; λ/2, half-wave plate; M, mirror; BS, beam splitter; **O**, object wave; **R**, reference wave. Inset: detail showing the off-axis geometry at the incidence on the CCD.



Reflection DHM



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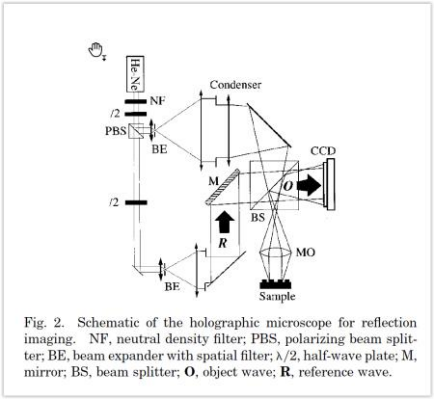
attractive feature of this instrument is that precise quantitative information about the three-dimensional structure of the sample can be obtained on the basis of only one hologram, which can be acquired at the video frequency. Applications in both biological and materials science microscopy are expected.

This study was supported by Swiss National Fund



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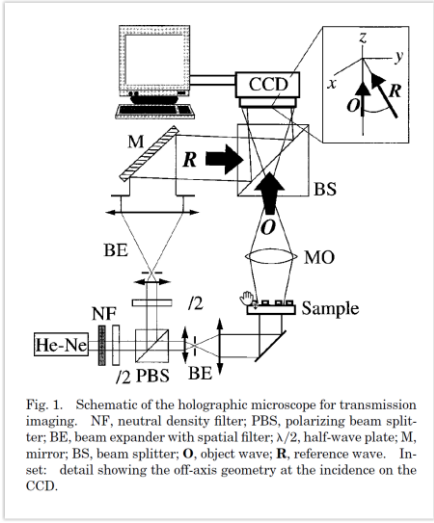

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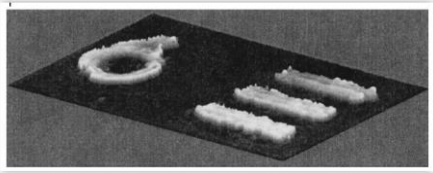
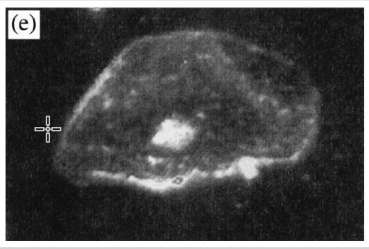


Reflection DHM



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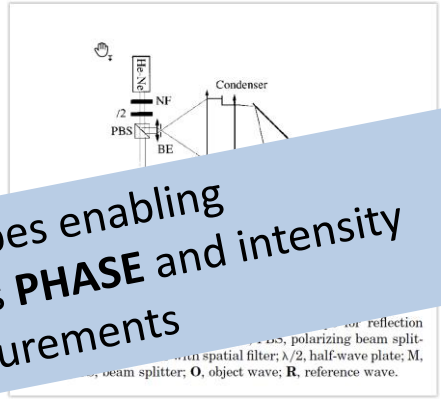
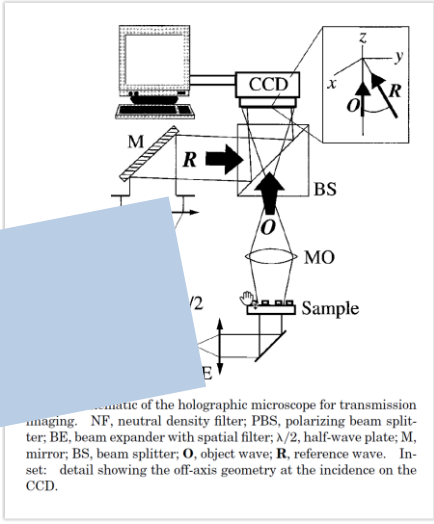
OCIS codes: [illegible]

The first Microscopes enabling **SINGLE SHOT** simultaneous **PHASE** and intensity contrast measurements



[illegible] reflection [illegible] polarizing beam splitter [illegible] spatial filter; λ/2, half-wave plate; M, [illegible] beam splitter; **O**, object wave; **R**, reference wave.



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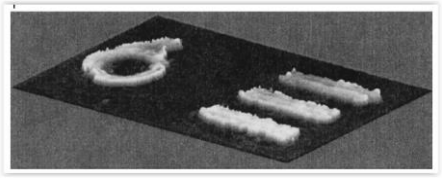
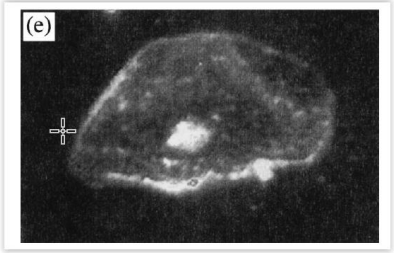
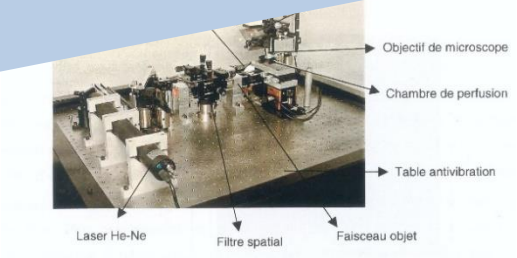






Reflection DHM

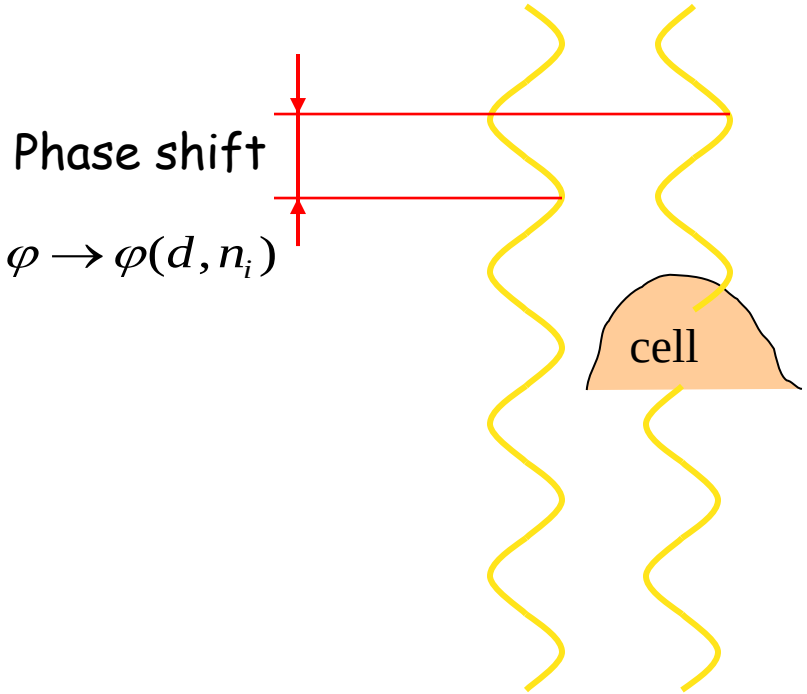
Transmission DHM

Why is the **PHASE** of the wave relevant ?

In both bio imaging and material sciences …

DHM® for life sciences applications

Cells are “phase objects”

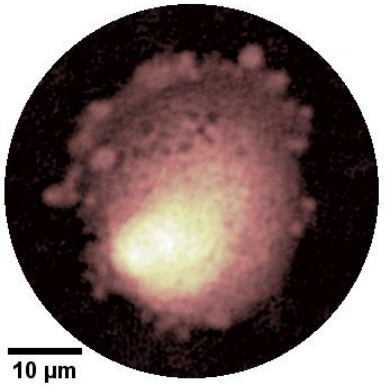


$$\varphi = \frac{2\pi}{\lambda}(n_c - n_m)d$$

living cells = transparent object
= **phase** object

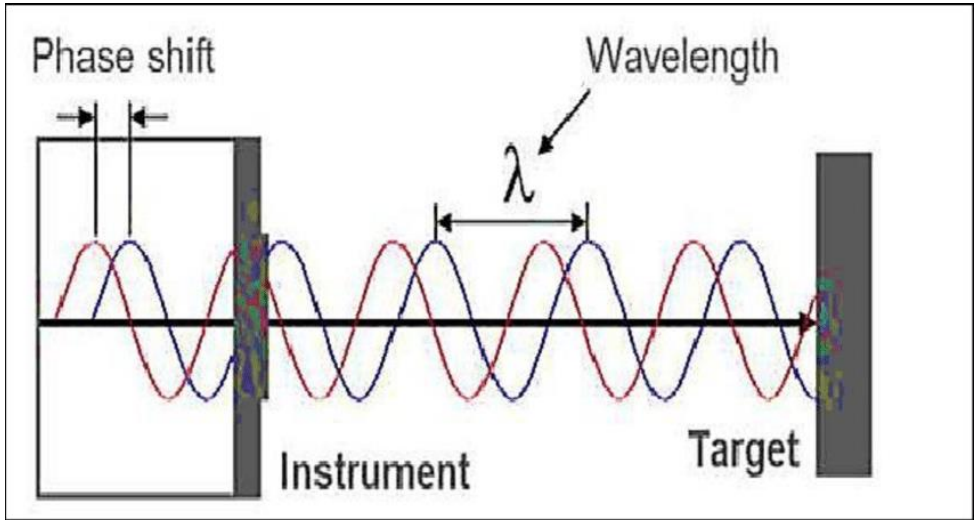
DHM® for life sciences applications

- ✓ **Label-free non-invasive imaging technique (non-perturbing measurements)**
- ✓ **Quantitative information about morphology and intracellular content**
- ✓ **Millisecond to multi-days continuous recording**



DHM® for life sciences applications

- PHASE shift images enables to measure distances for each pixel of the field of view !



- ✓ **Interferometric resolution**
- ✓ **Laser metrology**
- ✓ **Multi wavelengths for large distances**

PHASE of the wave is relevant
for both
bio imaging and material sciences

Why is **SINGLE-SHOT** a key ?

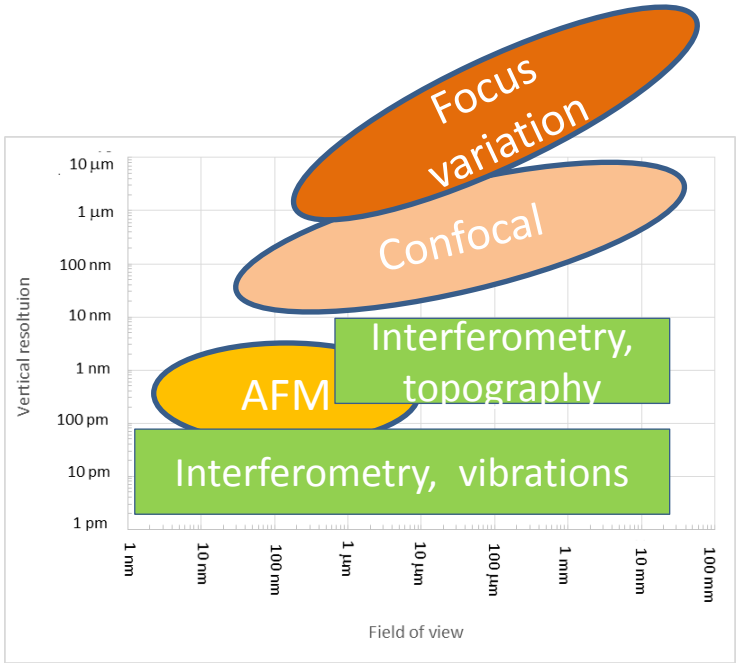
DHM® in material sciences

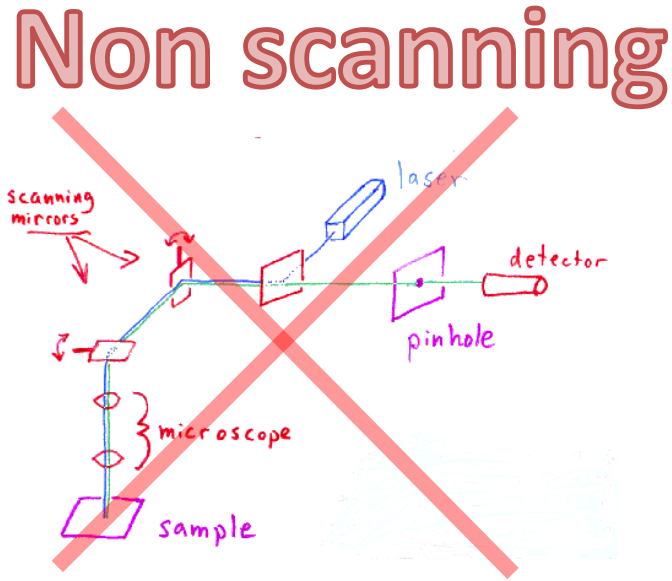
A 3D optical profilometer

- with an interferometric resolution
- capturing the full field of view in a **single shot**, without any vertical or lateral scanning

Reflection

Transmissions

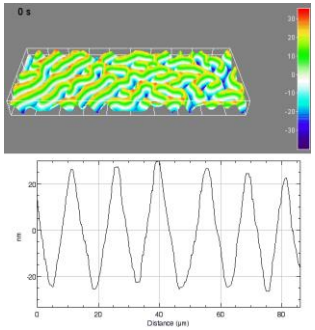




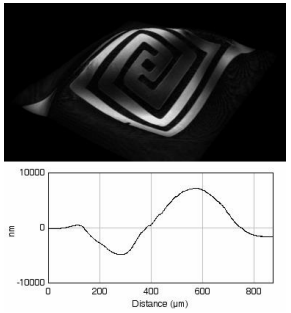
DHM®: Time-resolved optical profilometry

Sample 3D topography changes with temperature, chemical action, light irradiance, mechanical, electrical, magnetic forces, ….

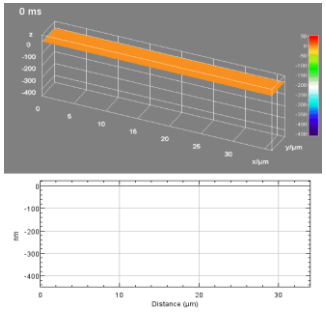
- Up to 100’000 fps (standard 190 fps)
- In liquid, vacuum, high temperature, …
- Nanometer vertical resolution for an choice of objective



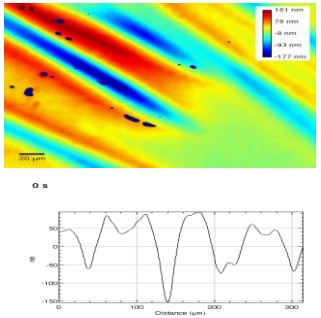
Smart coating sensitive to UV



Micro hot-plate temperature deformation



Graphene membrane deformation by pressure

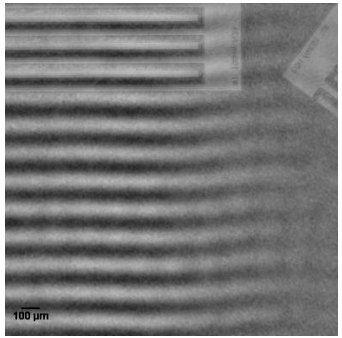


Self-recovery surface from mechanical scraches

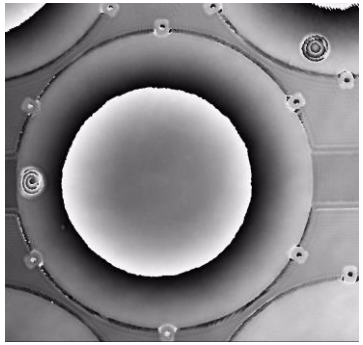
DHM®: 3D MEMS analyzer

MEMS probing, driving and time-resolved 3D topography up to 25 MHz.

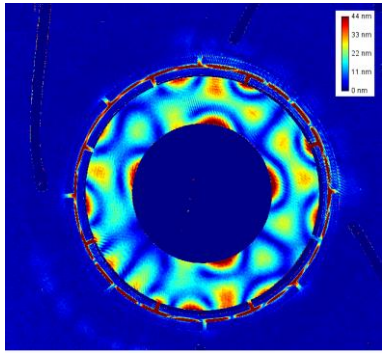
- In liquid, vacuum, high temperature, …
- Picometer out-of-plane and nanometers in-plane vibrations resolution
- Electrical, in- out-of-plane vibration and frequency analysis



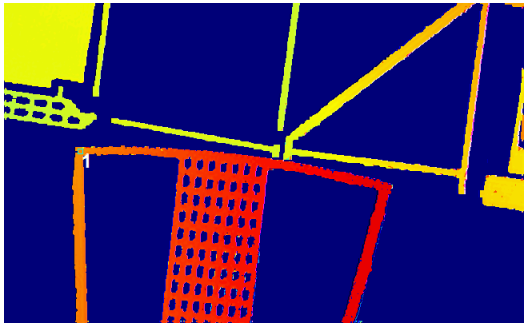
Full field of view measurements up to 25 MHz



Measurements in vacuum, in liquid, …

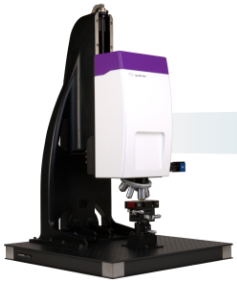


Vibration maps with Unrivalled spatial resolution



3D time sequence for in- & out-of plane analysis

DHM® for material sciences applications



STATIC | EXPOSURE SENSITIVE | TIME-RESOLVED | VIBRATIONS

DHM® : 3D MEASUREMENTS FROM STATIC TO 25 MHz

No alternative systems

EXPOSURE TIME SENSITIVE
- Suspended structures
- Liquid interfaces
- Air turbulences (warm/cold)
- Moving samples
- Environmental vibrations

No blurred or altered measurement

TIME-RESOLVED 3D measurements
- Large surface scanning
- Fast and on-flight quality control
- MEMS
- Energy harvesters
- Liquid interfaces
- Samples deformation due to:
  - temperature or pressure
  - light irradiance
  - mechanical force
  - electromagnetic fields
  - ...

Interferometric resolution up to 25 MHz

VIBRATION chracterization
- Amplitude and phase maps
- Resonance and spurious modes
- Frequency and time analysis
- Picometer range vertical resolution

Unbeatable lateral resolution

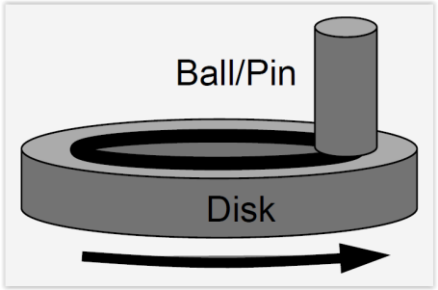
PAPER

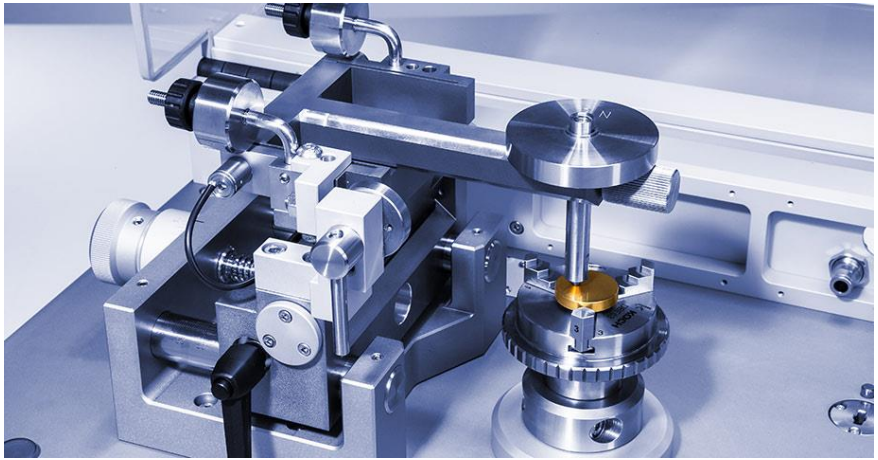
A new ball-on-disk vacuum tribometer with *in situ* measurement of the wear track by digital holographic microscopy

B Meylan[1], D Ciani[2], B Zhang[2], E Cuche[3] and K Wasmer[1]

Published 9 November 2017 • © 2017 IOP Publishing Ltd
Surface Topography: Metrology and Properties, Volume 5, Number 4
In-situ Measurement

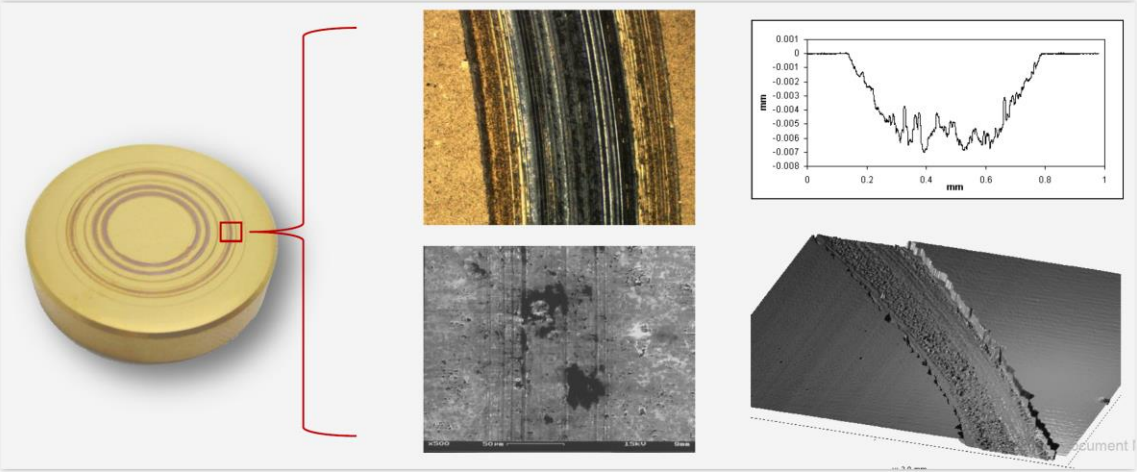
Ball/Pin-on-Disk tribometer





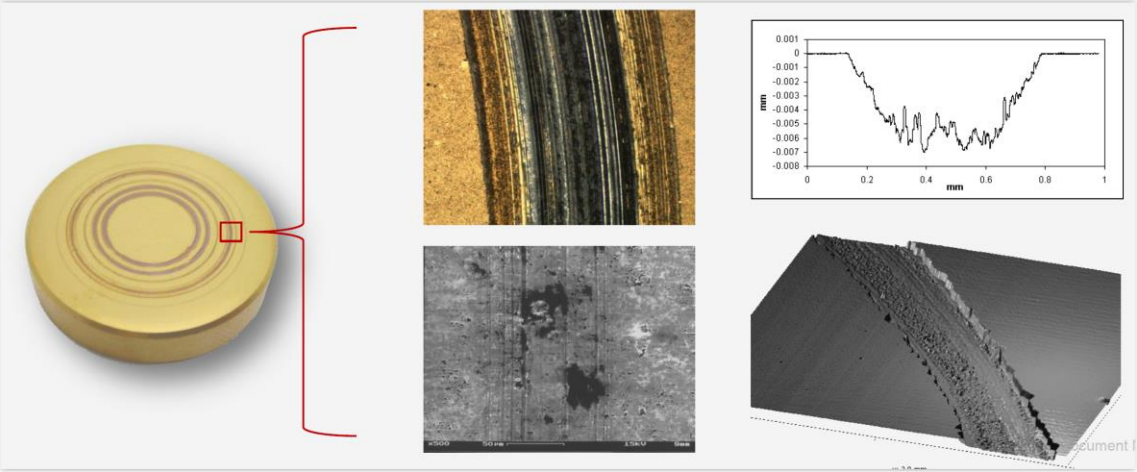
- “Simple” system and highly reproducible measurement
- Simulation of real frictional condition
  - Contact pressure
  - Movement mode
  - Sliding speed
  - Static partner (size, geometry, mechanical properties, etc.)
  - Lubrication
  - Environmental condition (temperature, vacuum, humidity, etc.)

Ball/Pin-on-Disk tribometer



- Up to now, wear only measured ex situ and post-mortem
  - Common workaround to get wear evolution
  - Several experiments stopped at different duration
  - One experiment stopped various times

Ball/Pin-on-Disk tribometer



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Anton Paar
Empa
Materials Science and Technology

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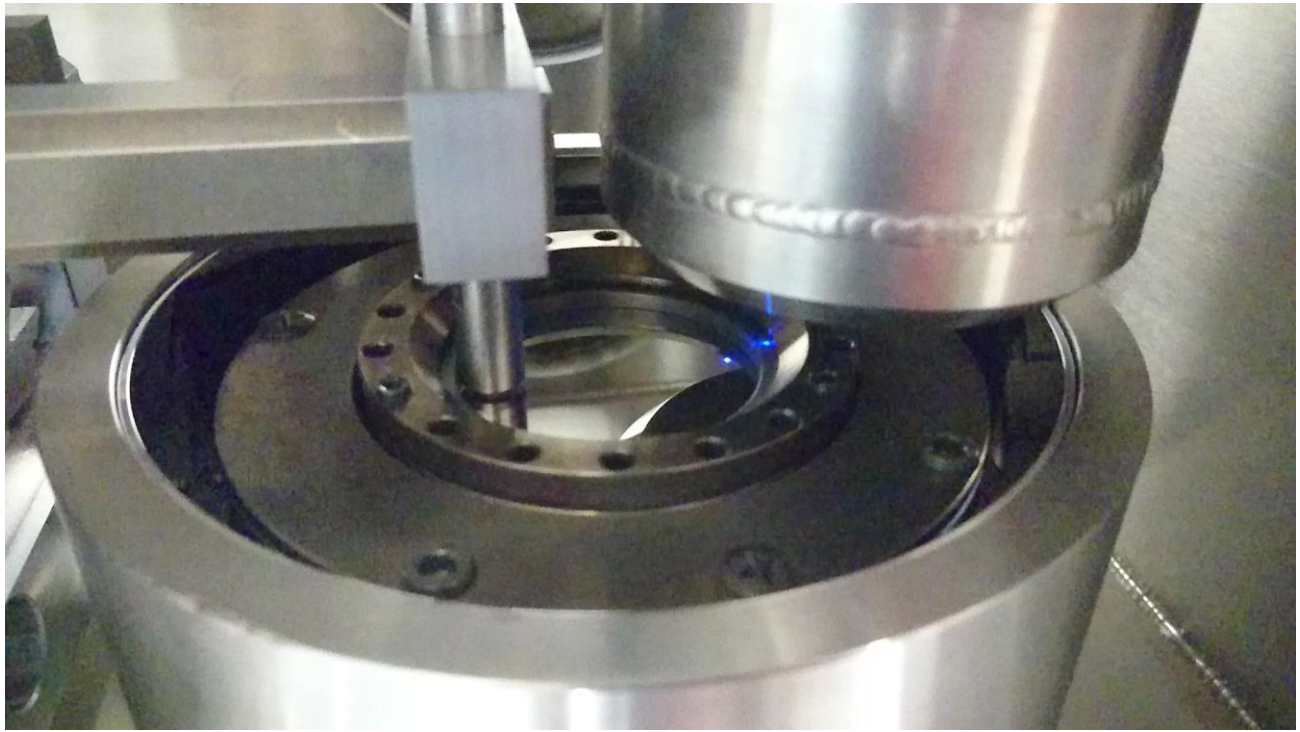

On site Ball/Pin-on-Disk tribometer

Surface Topography: Metrology and Properties

PAPER

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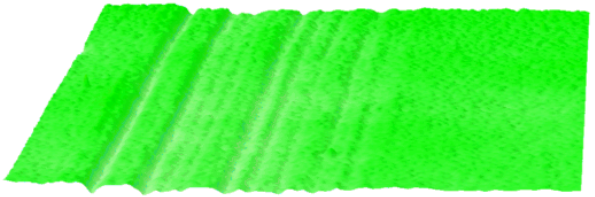
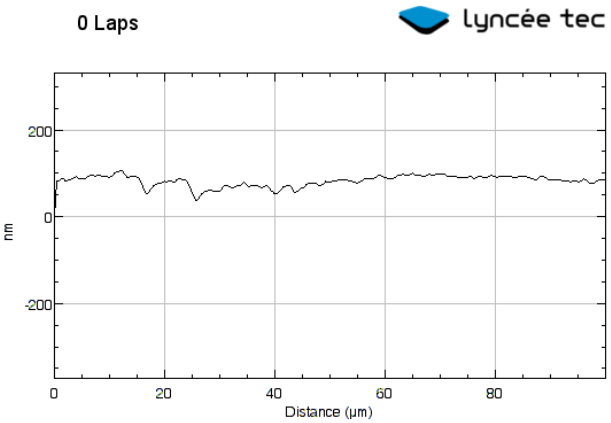
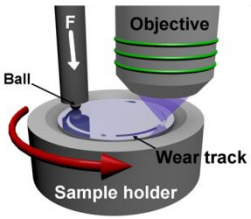
Surface Topography: Metrology and Properties, Volume 5, Number 4

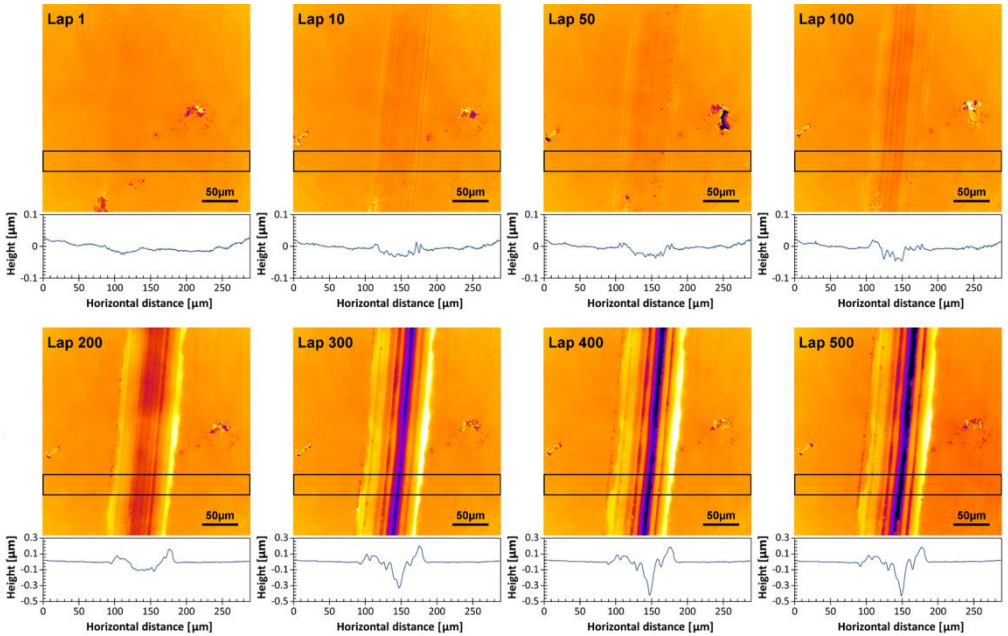
Invite Measurement







- Synchronized with rotation speed of the tribometer



Dual wavelengths DHM, measurement rate 200 Hz

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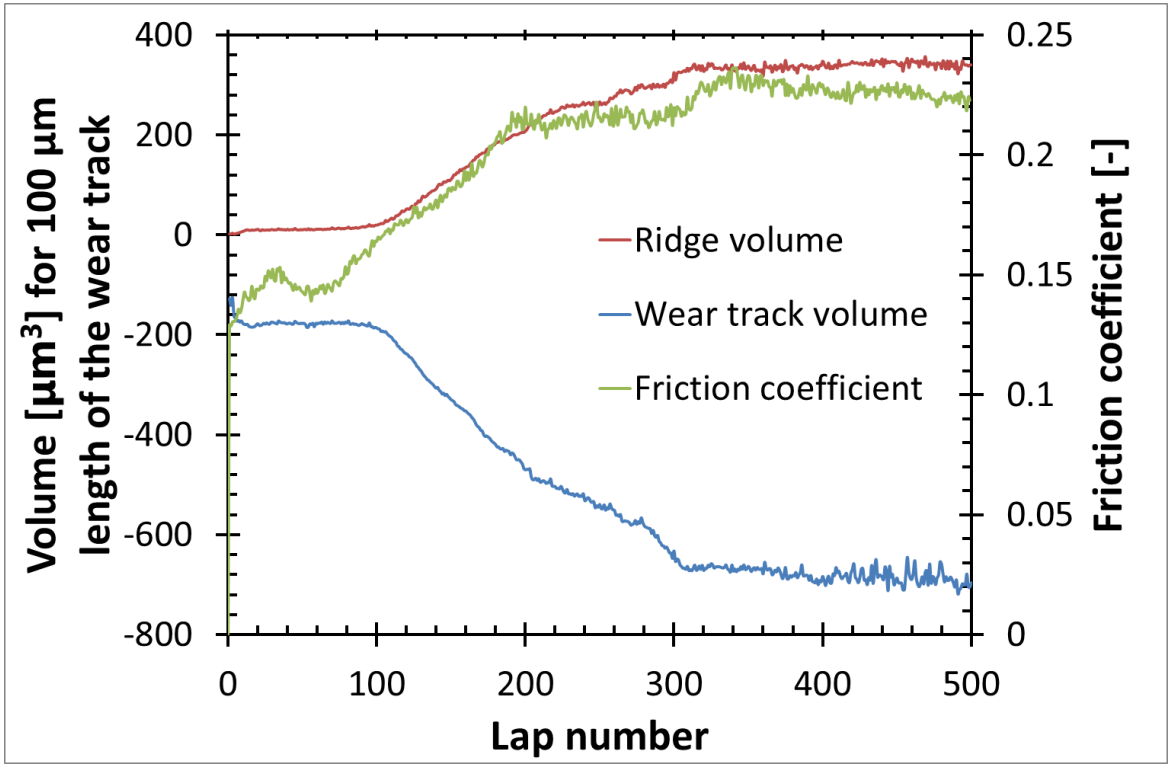
On site Ball/Pin-on-Disk tribometer



Friction coefficient , ridge volume and wear track volume versus the lap number

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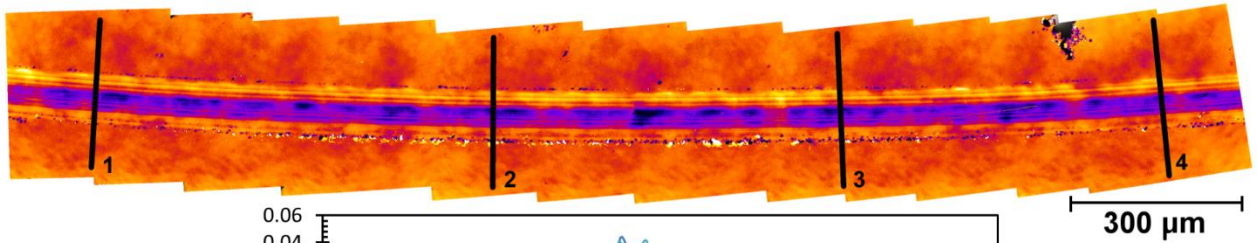
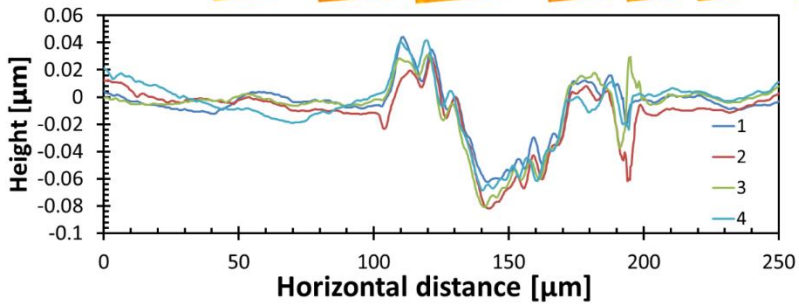
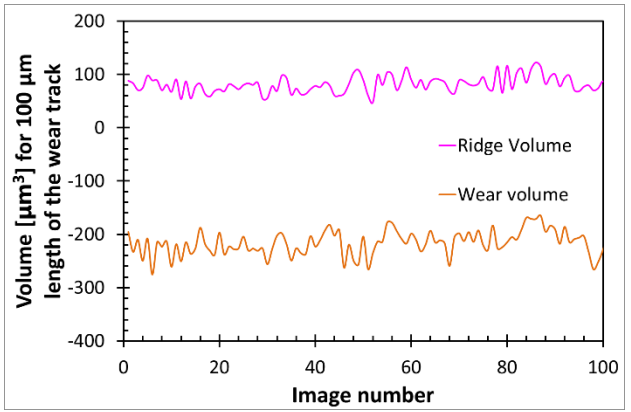
On site Ball/Pin-on-Disk tribometer

PANORAMA MODE – One exemple







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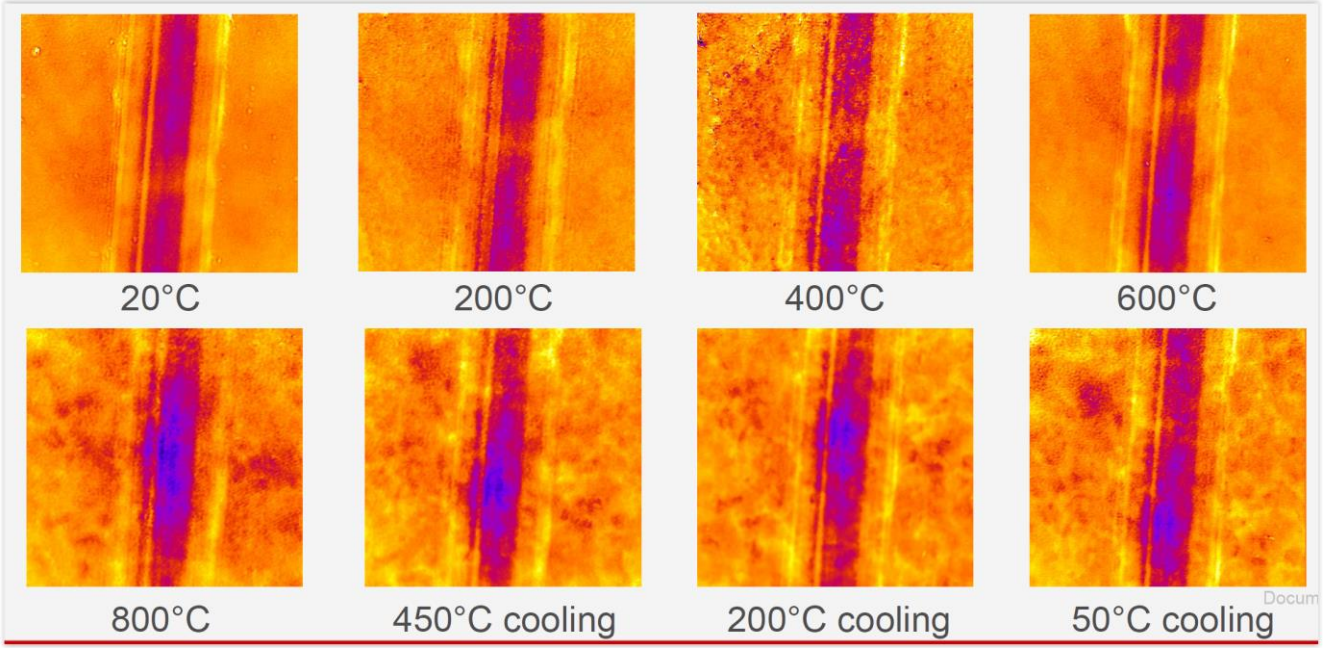
Materials Science and Technology

On site Ball/Pin-on-Disk tribometer



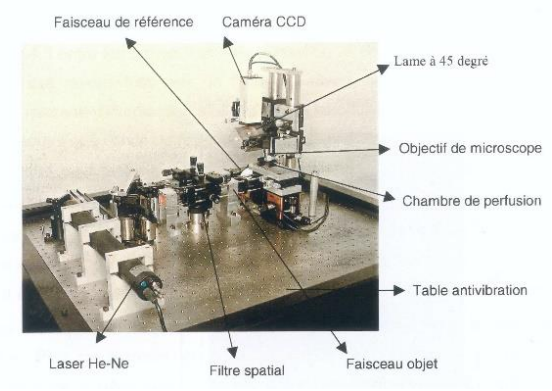
On site Ball/Pin-on-Disk tribometer - conclusions

- New vacuum tribometer with in situ wear measurement
  - Replaces common workaround to get wear evolution
    - Wear only measured ex situ and post-mortem
    - Several experiments stopped at different duration
    - One experiment stopped various times
- New measurement possibilities
  - Can be operated at high temperature
  - In presence of other gases
- Instrument
  - Validated by EMPA
  - Sold to other research institute

Empa
Materials Science and Technology
Anton Paar

20 years of DHM applications !

- Lyncée Tec has been founded on 2003
- **SINGLE SHOT** and **PHASE** are **KEYS** !
- Many applications demonstrated: DHM used daily for research and QC
- A full range of products and accessories tailored for both material and life sciences



Reflection

Transmission

Macroscope

Lensless

Holographic Camera

Many thanks for your attention

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