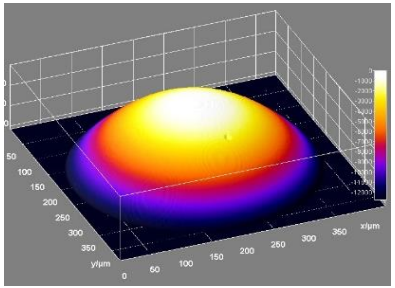
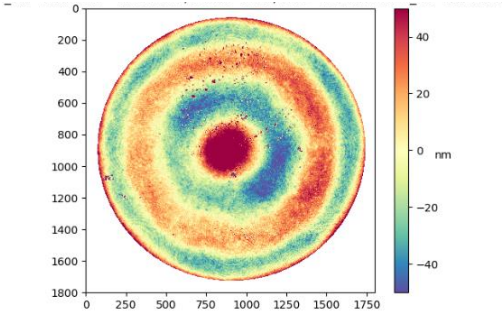
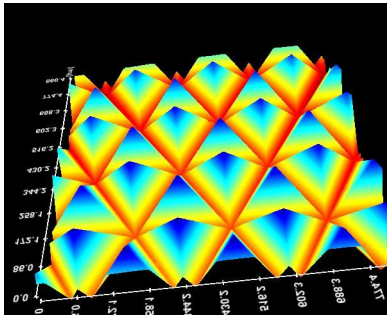
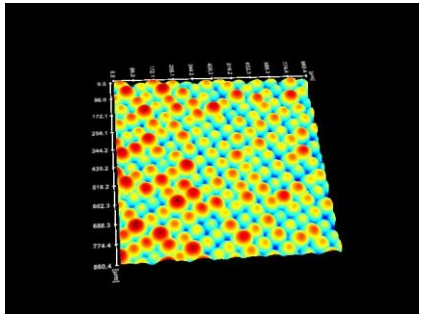
On-Flight, In-Line, and In-Situ during Manufacturing Process Micro-Optic Characterization by Digital Holography Microscopy (DHM®)

Yves Emery, CEO Lyncée Tec SA, Switzerland









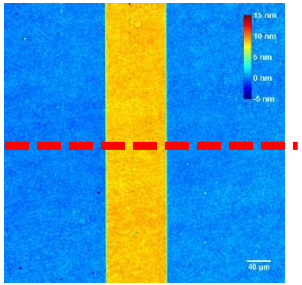
EPIC European Photonics Industry Consortium

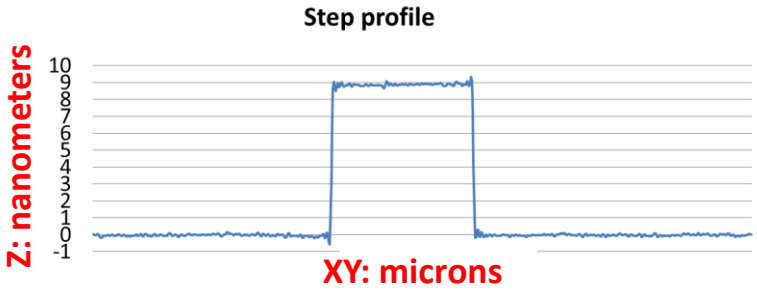
11-12 May 2022, Karlsruhe, Germany

EPIC Meeting on Advanced Microoptics: Simulation, Fabrication & Characterization at Nanoscribe

What is a DHM® ?

- a 3D optical profilometer with interferometric resolution …

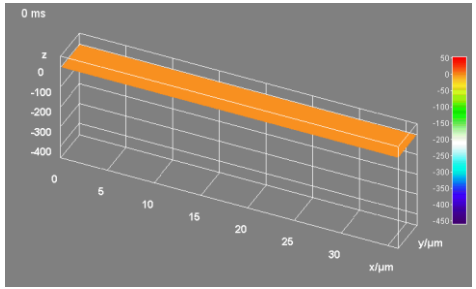


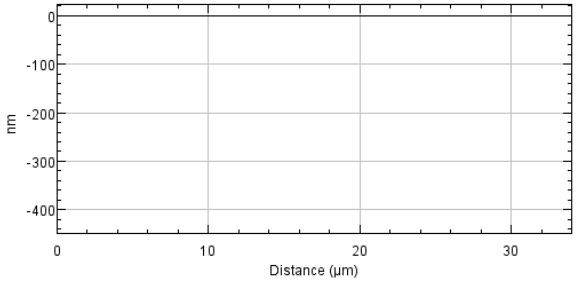


Certified 9 nm step

- … enabling time-resolved measurements, i.e. 4D

Timescale: milliseconds

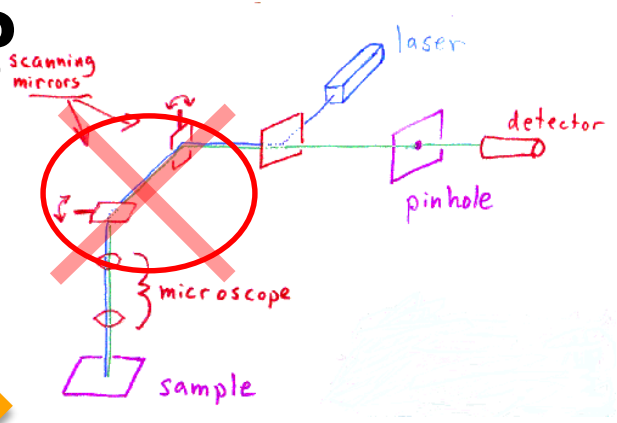




Graphene membrane deformation by pressure

What is different with a DHM® ?

- 3D topography is measured “instantaneously” at camera rate
  - DHM® does not necessitate a scanning mechanism for acquiring the 3D information over the full field of view



No blur during exposure sensitive measurements
- Acquisition time, down to 10 µs

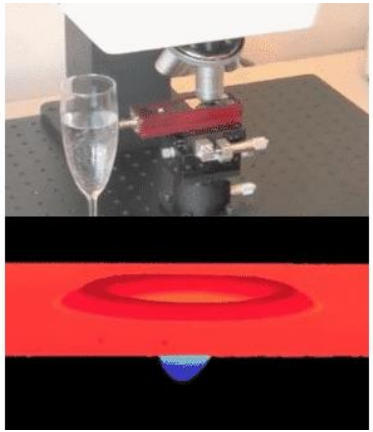
4D: Time-resolved 3D measurements (real-time)
- Acquisition rate up to 100’000 fps (full field)

Full field of view (Megapixels) MEMS characterization
- Stroboscopic synchronization up to 25MHz

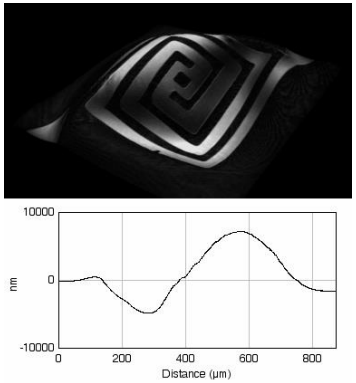
OPENS UNIQUE 4D applications, FROM STATIC TO 25MHZ

No blur during exposure sensitive measurements

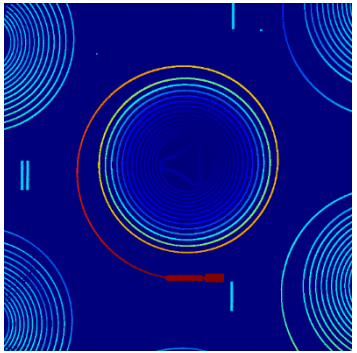
- Acquisition time, down to 10 µs



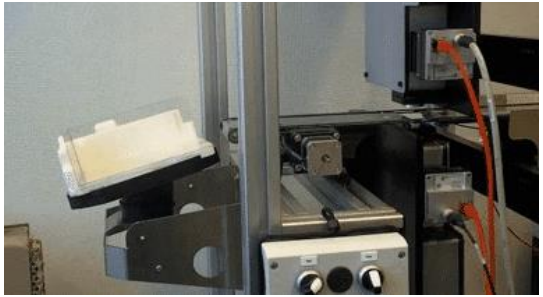
Non sensitivity to surrounding vibrations

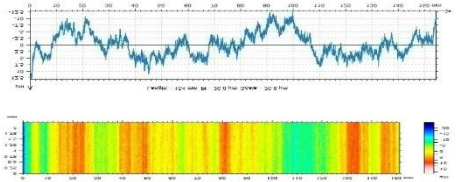


Measurements in presence of turbulent air.
Micro hot plate varying from 20°C to 800°C
DHM® applications from -196°C to 1500°C



“Never static” suspended structure:
Watch spiral spring





“On flight & in-line “ measurement
of moving samples for fast quality control and screening

4D: Time-resolved 3D measurements (real-time)

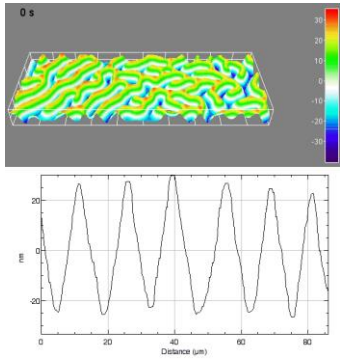
- Acquisition rate up to 100’000 fps (full field)

And also

- Evaporation, melting, …
- Dissolution
- Electro - magnetic force
- …

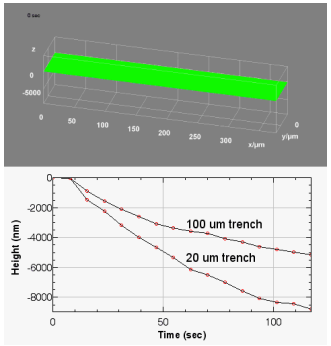
Investigate response of your sample to:

Light irradiance



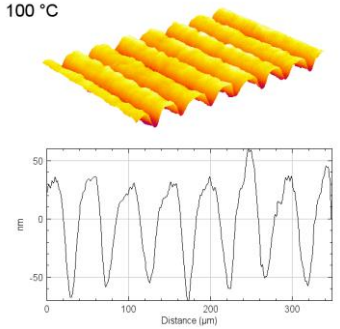
Smart polymer response to UV light excitation

Chemical action



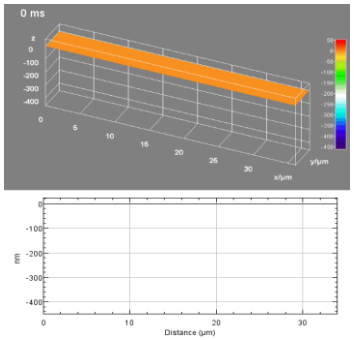
End-point in-situ measurement during Electrochemical etching

Temperature



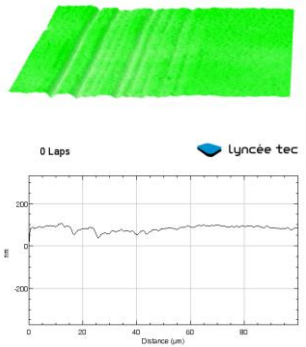
Programmed Liquid Cristal elastomer temperature response

Pressure



Investigation of mechnical properties of graphene membranes

Mechanical wear



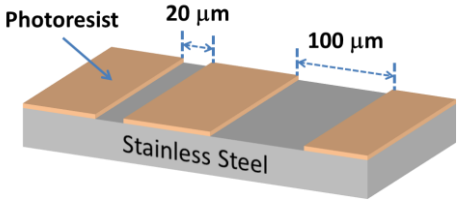
Wear track by ball-on-disk vacuum tribometer measured in-situ

4D: Time-resolved 3D measurements (real-time)

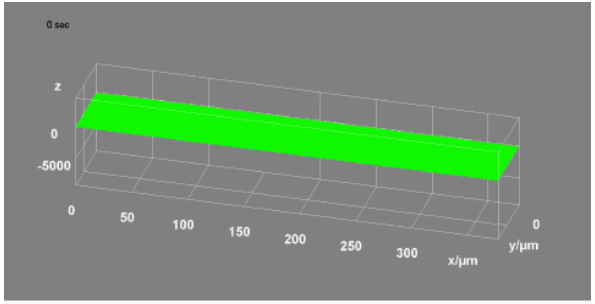
- Acquisition rate up to 100’000 fps (full field)

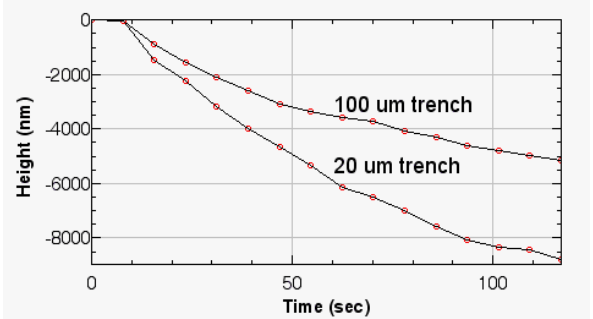
Measure as you manufacture

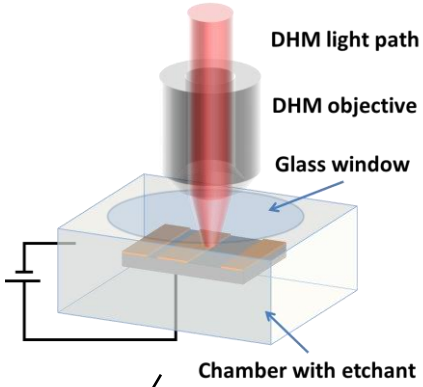
DHM® controlled wet chemical etching



Timescale: 2 minutes







Courtesy of Micropat (Switzerland)

In-situ

4D: Time-resolved 3D measurements (real-time)

- Acquisition rate up to 100’000 fps (full field)

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Article | Open Access | Published: 12 November 2020

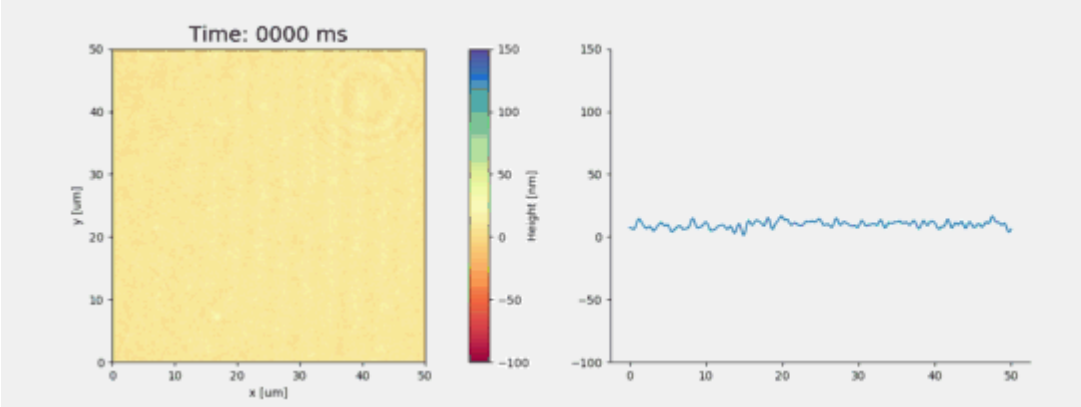
Digital holographic microscopy for real-time observation of surface-relief grating formation on azobenzene-containing films

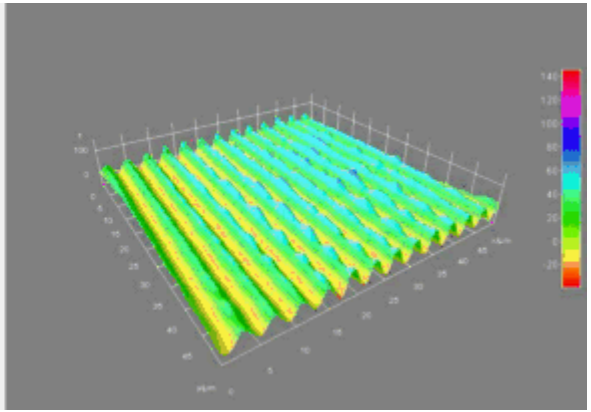
Heikki Rekola, Alex Berdin, Chiara Fedele, Matti Virkki & Arri Priimagi

Scientific Reports **10**, Article number: 19642 (2020) | Cite this article

Measure as you manufacture

DHM® controlled interference lithography





- Surface topography is measured simultaneously to laser texturing of a light sensitive film
- DHM® information is exploited to control in real time during the process the exact structure topography

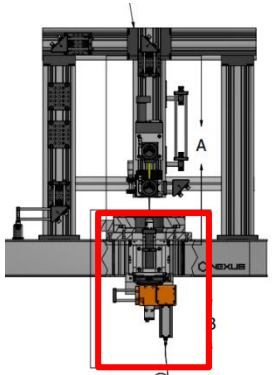
In-situ

4D: Time-resolved 3D measurements (real-time)

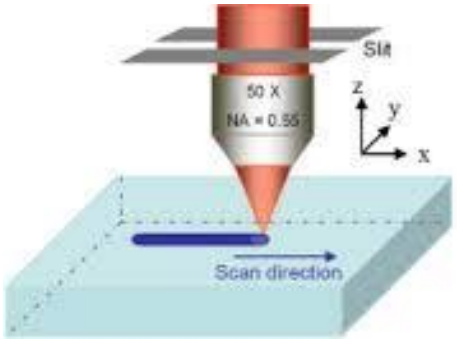
- Acquisition rate up to 100’000 fps (full field)

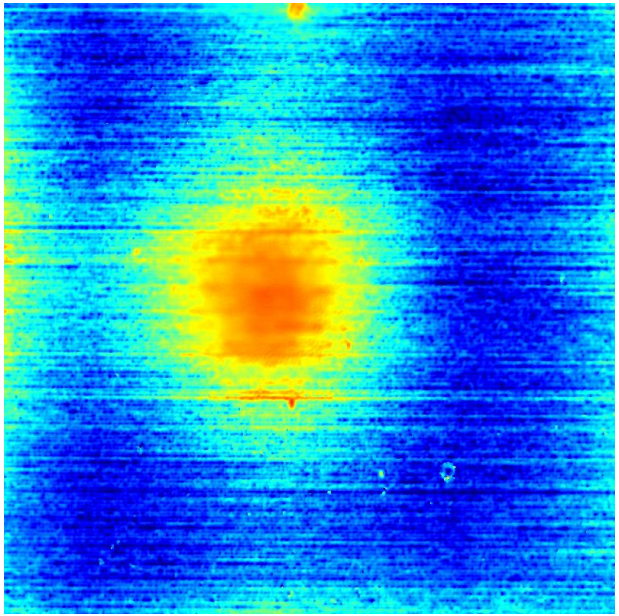
Measure as you manufacture

DHM® real time laser polishing



Integrated DHM® fibered module





- Surface topography is measured simultaneously to laser polishing
- DHM® information is exploited to control the laser beam parameter

On-flight

4D: Time-resolved 3D measurements (real-time)
- Acquisition rate up to 100’000 fps (full field)

JPhys Photonics

PAPER • OPEN ACCESS

On the use of a digital twin to enhance femtosecond laser inscription of arbitrary phase patterns

Olivier Bernard[2,1] and Yves Bellouard[1]

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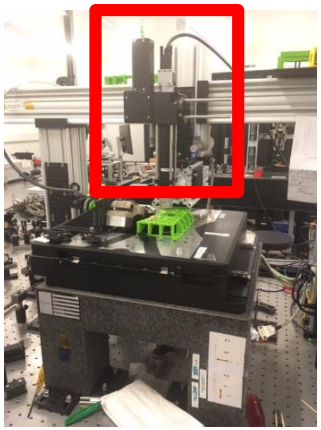
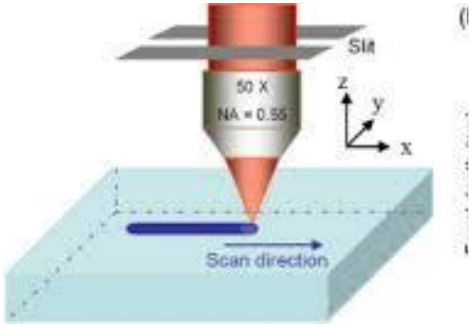
Journal of Physics: Photonics, Volume 3, Number 3

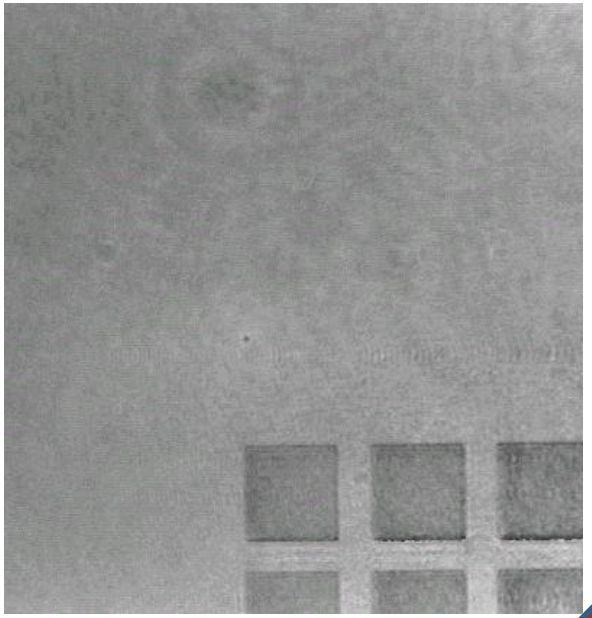
Citation Olivier Bernard and Yves Bellouard 2021 *J. Phys. Photonics* **3** 035003

Measure as you manufacture

DHM® feedback to femtosecond laser engraving







On-flight

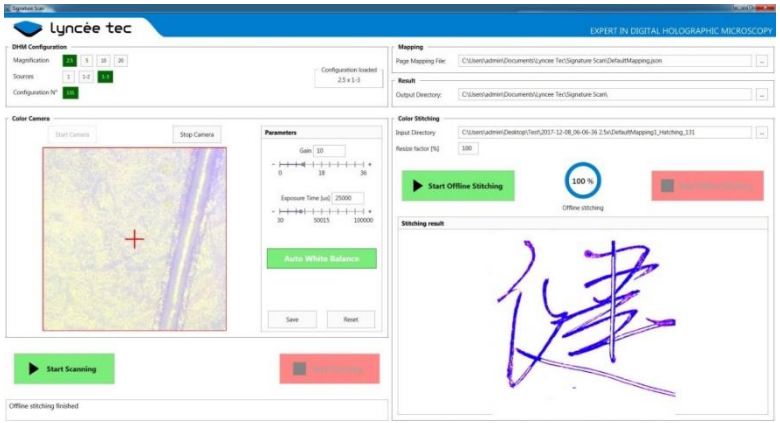
- Phase patterns are measured simultaneously to laser engraving
- DHM® information is exploited to control the laser beam parameter

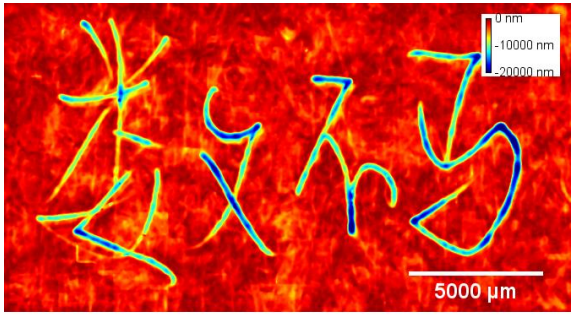
4D: Time-resolved 3D measurements (real-time)

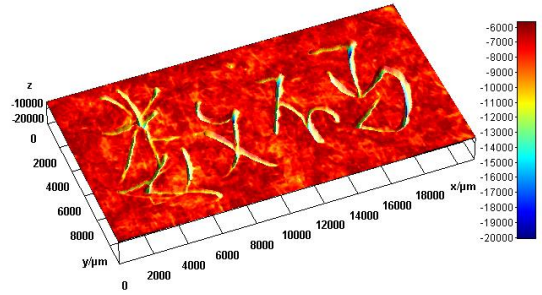
- Acquisition rate up to 100’000 fps (full field)

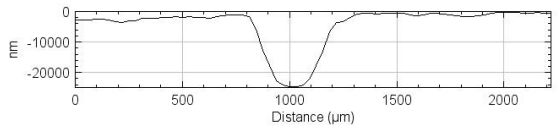
Characterize large surfaces

Forensic: automated signature 3D mapping









- Fast scanning of a large area of paper (2 cm x 5 cm) (3000 images, <60 s)
- Customized UI for simultaneous white light & DHM image acquisition

Full field of view (Megapixels) MEMS characterization

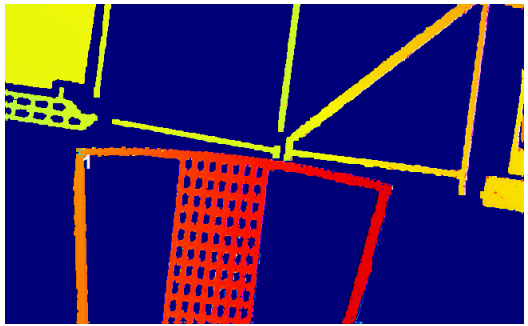
- Stroboscopic synchronization up to 25MHz

And also

- Microphones & resonators
- Micro-mirror & DMD
- LCOS
- SAW
- …

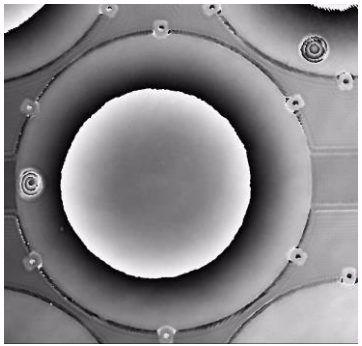
4D topography, vibrations maps, in- & and out-of-plane, frequency response of:

Actuators & micro motors



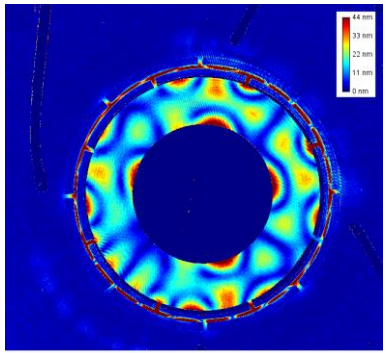
3D time-sequence wealth of information enables rigorous decorrelation of in- & out-of-plane components

Ultrasonic transducers

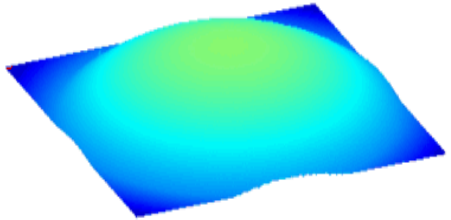


Measurements in liquid of the membrane response to burst signal excitation

Gyroscopes & accelerometers

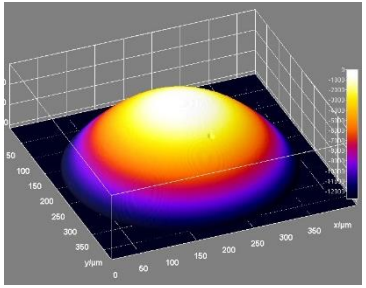


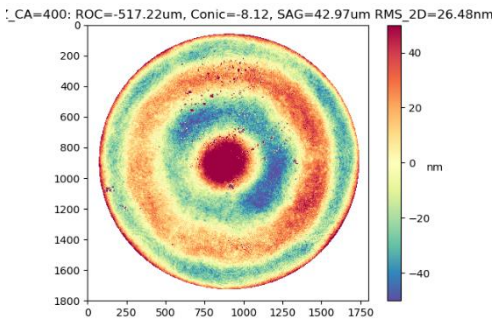
Vibration maps with Unrivalled spatial resolution

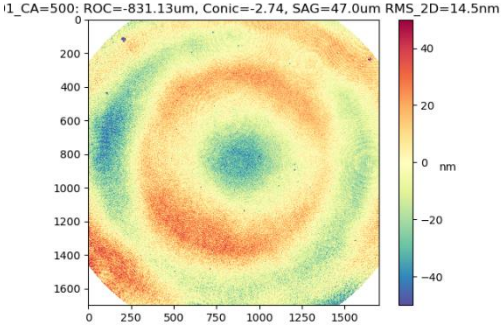


Tunable micro-lens
Ringing transients

Reflection DHM®

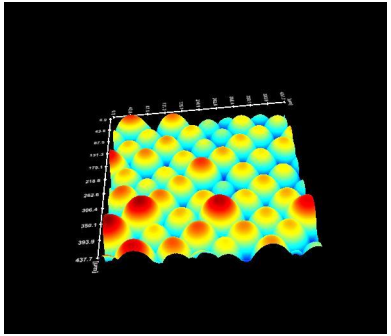


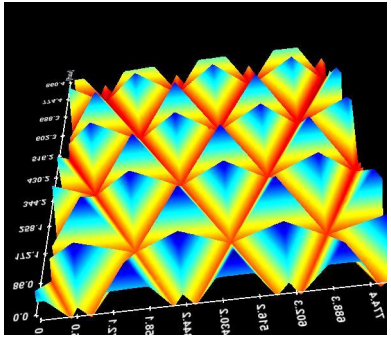


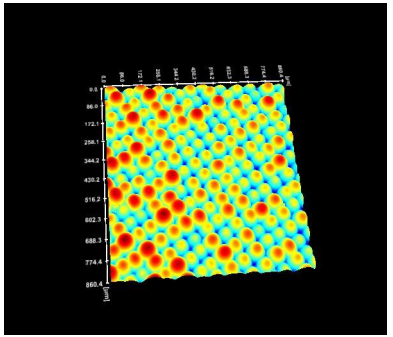


MICRO OPTICAL COMPONENTS CHARACTERIZATION

Transmission DHM®

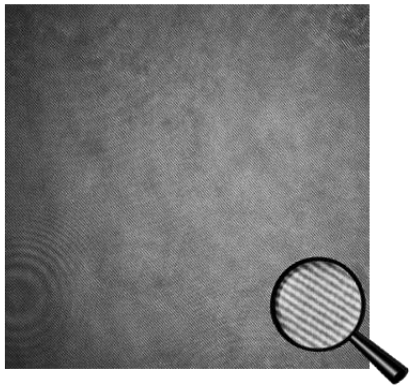




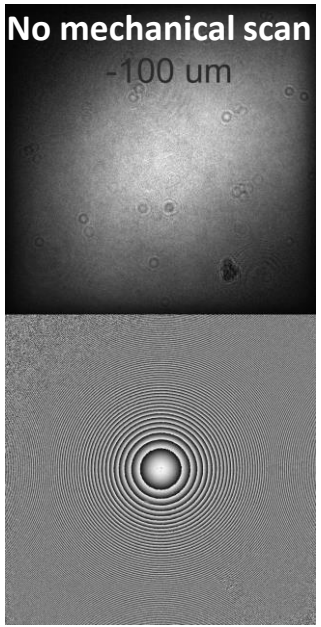


DHM®: micro-optics characterization

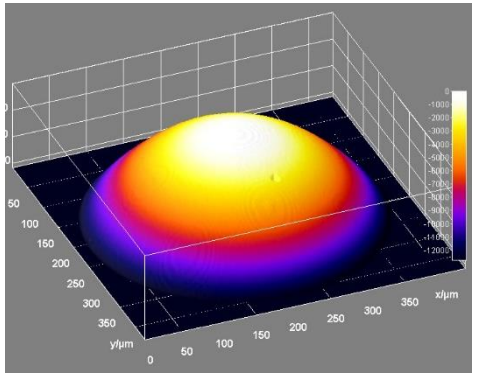
1. A single hologram records the complex wavefront reflected or transmitted by the sample
i.e. **phase + amplitude**



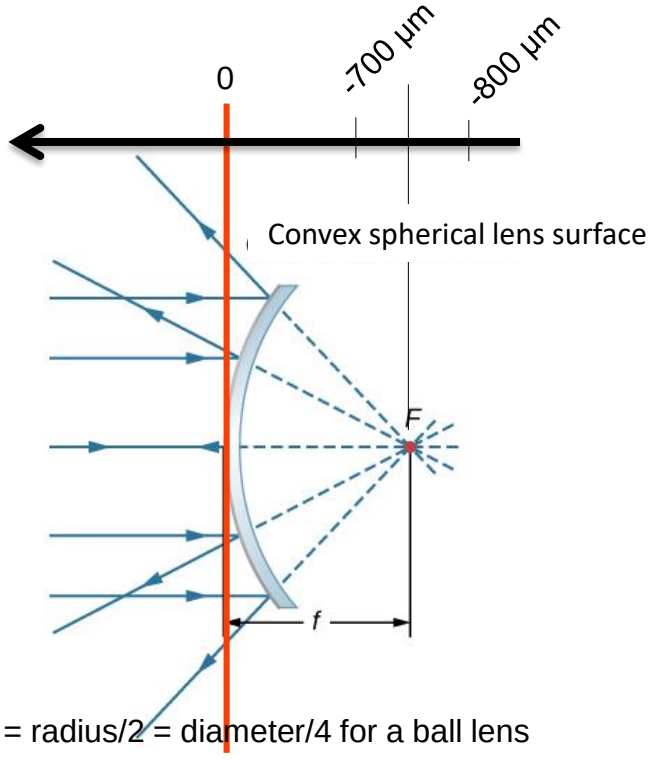
2. Wavefront is numerically propagated



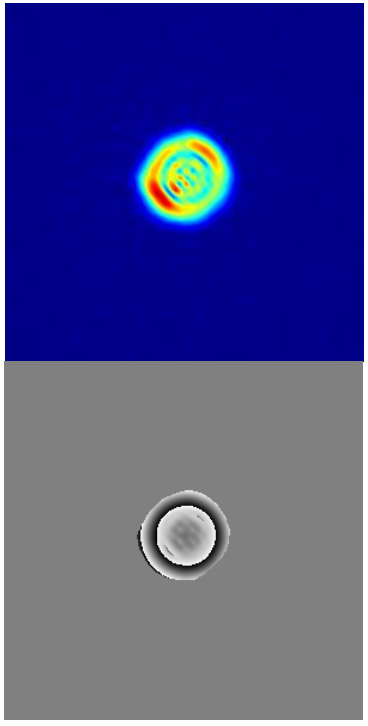
3. All-in-focus topography is calculated

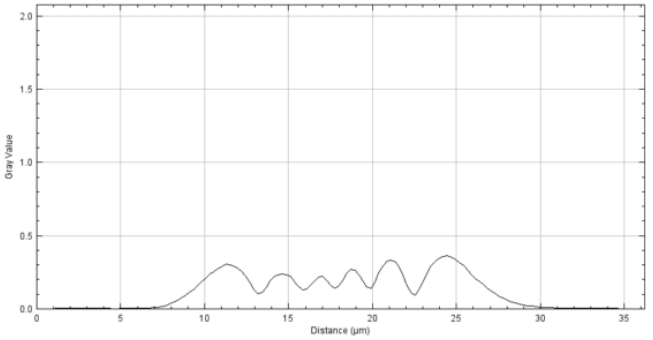


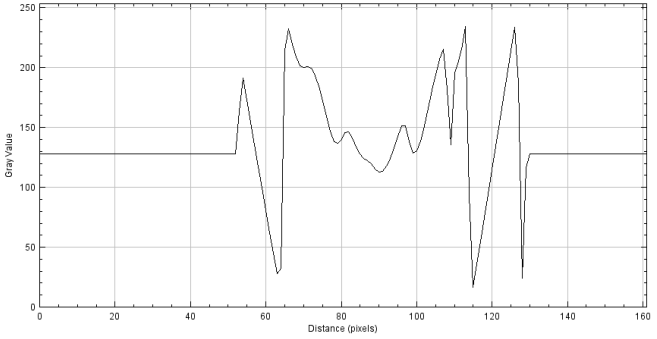
Numerical propagation of the wavefront



f = radius/2 = diameter/4 for a ball lens



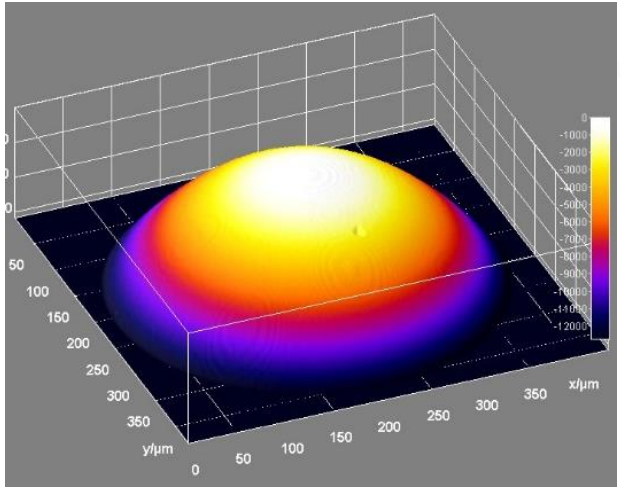




Propagation distance varying between -800 µm and -700 µm

DHM®: Ball lens shape measurement

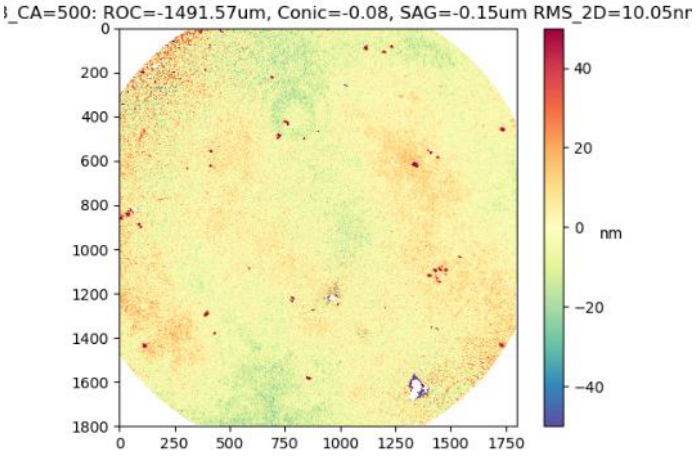
All in-focus Topography
- Diameter 3mm
- R = 1500um
- F = R/2 = 750um



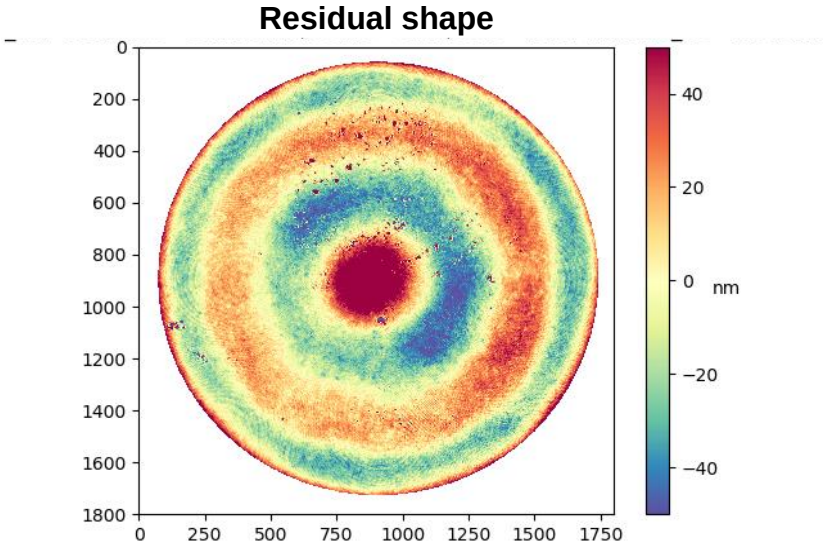
Aspherical lens fit

$$z(r) = \frac{r^2}{R\left(1+\sqrt{1-(1+K)\frac{r^2}{R^2}}\right)} + SAG$$

Residual shape
- R = 1492um
- Conic = 0.08
- RMS = 10nm



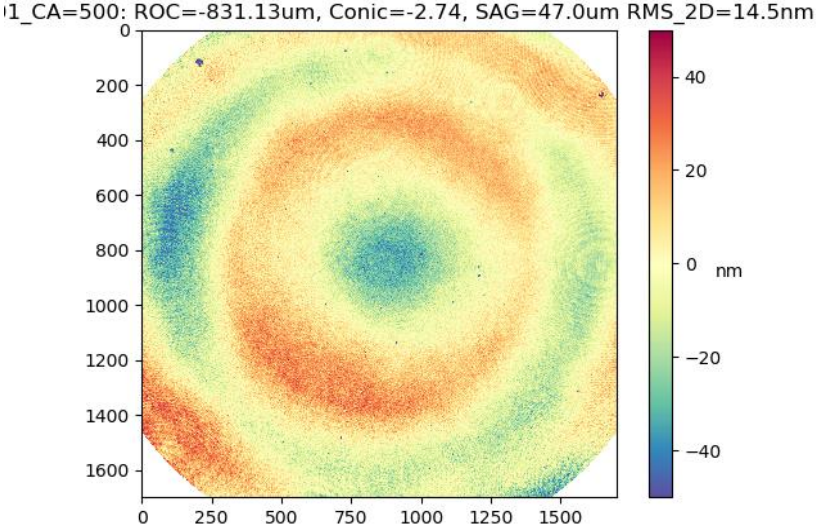
DHM® in reflection mode
Quartz reference lens



	Zygo	DHM®
Radius [µm]	516	517
Conic	-8.4	-8.12
RMS [nm]	NA	26.48

DHM® in reflection mode
Reference lens 1

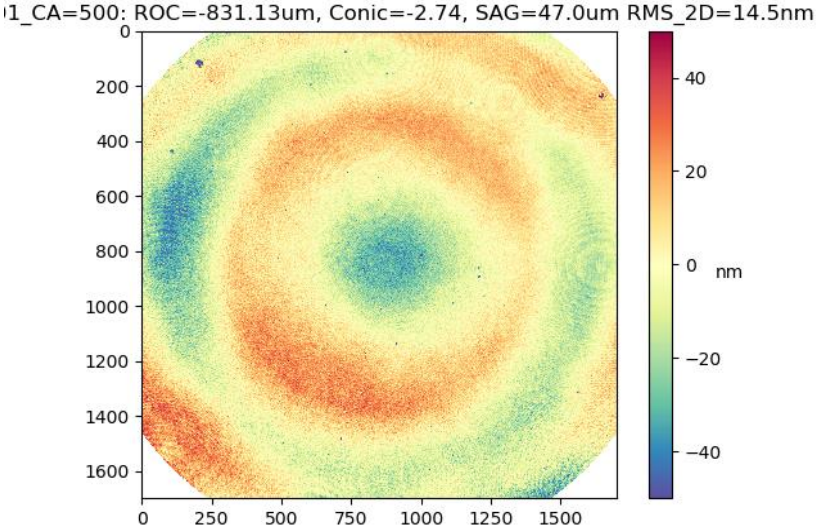
Residual shape



	Zygo	DHM®
Radius [µm]	827	831
Conic	-2.9	-2.74
RMS [nm]	NA	14.5

DHM® in reflection mode
Reference lens 2

Residual shape

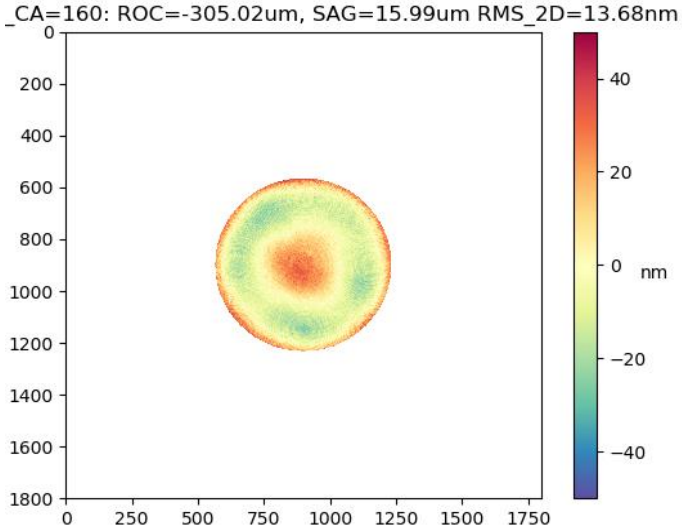


	Zygo	DHM®
Radius [µm]	3952	3960
Conic	0	0
RMS [nm]	NA	8.72

(spherical fit)

DHM® in reflection mode
Reference lens 3

Residual shape

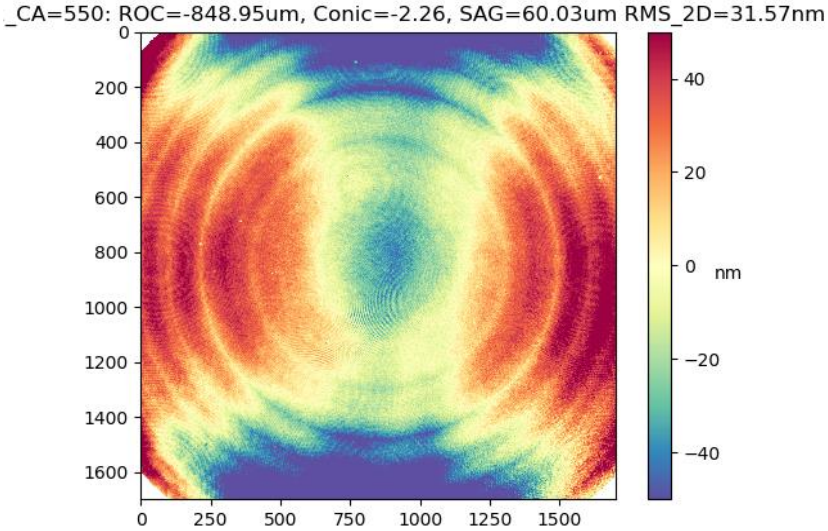


	Zygo	DHM®
Radius [µm]	303	305
Conic	0	0
RMS [nm]	NA	13.68

(spherical fit)

DHM® in reflection mode
Reference lens 4

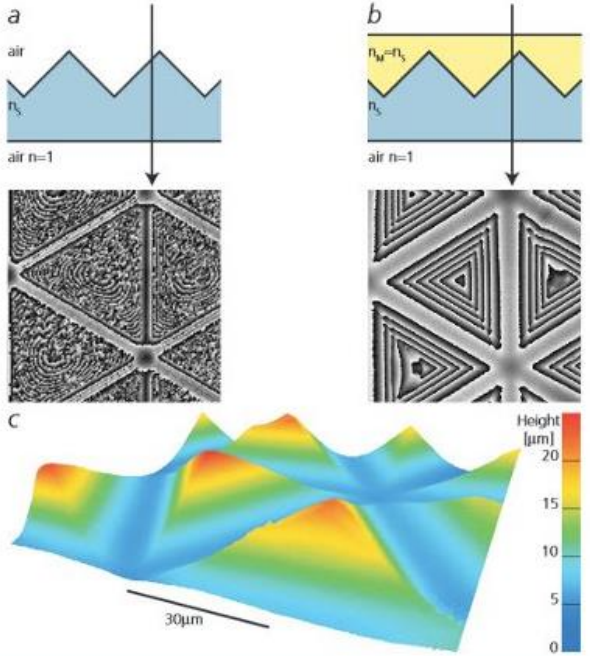
Residual shape



	Zygo	DHM®
Radius [µm]	841	848.95
Conic	-2.3	-2.26
RMS [nm]	NA	31.57

DHM in transmission configuration

- Refraction measured, rather then reflection
- Refraction angle depends on the surrounding medium
- Measurement of High NA components using immersion, over large Fields Of View
- Measurement of the “function of the lens”, not only of its topography



DHM measurement on 25µm base corner cube with high aspect-ratio: (a) without immersion liquid, (b) with immersion liquid with refractive index close to that sample, and (c) its resulting 3D view

Measurements of corner cubes microstructures by high-magnification digital holographic microscopy

Jonas Kühn, Etienne Cuche, Yves Emery, Tristan Colomb, Florian Charrière, Frédéric Montfort, Mikhail Botkine, Nicolas Aspert, Christian Depeursinge

Author Affiliations +

Proceedings Volume 6188, Optical Micro- and Nanometrology in Microsystems Technology; 618804 (2006) https://doi.org/10.1117/12.662030

Event: SPIE Photonics Europe, 2006, Strasbourg, France

Digital holographic microscopy for nanometric quality control of micro-optical components

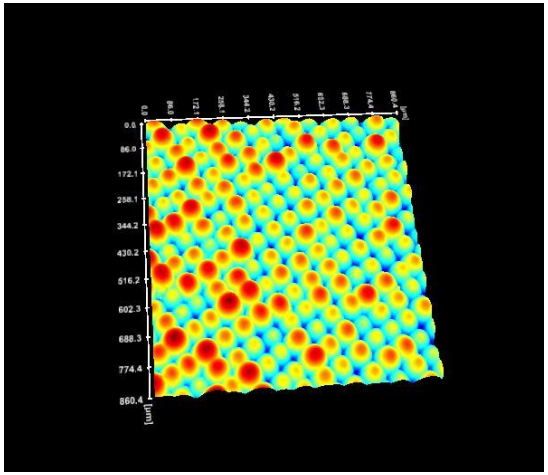
Jonas Kühn, Florian Charrière, Tristan Colomb, Etienne Cuche, Yves Emery, Christian Depeursinge

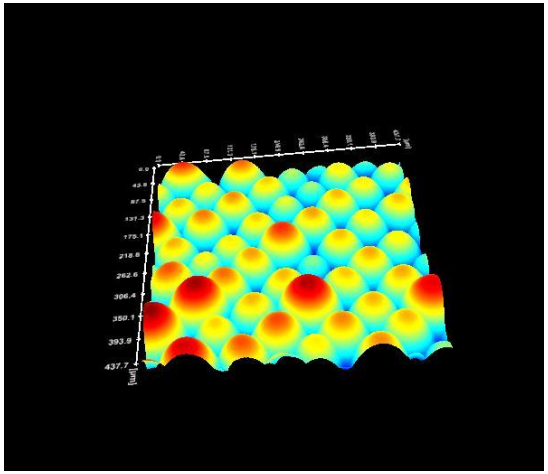
Author Affiliations +

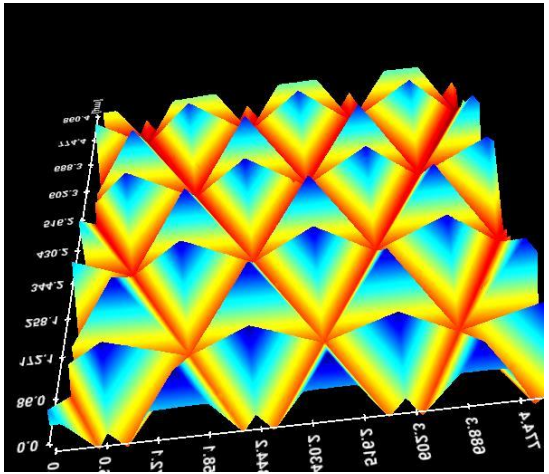
Proceedings Volume 6475, Integrated Optics: Devices, Materials, and Technologies XI; 64750V (2007) https://doi.org/10.1117/12.700523

Event: Integrated Optoelectronic Devices 2007, 2007, San Jose, California, United States

DHM in transmission configuration







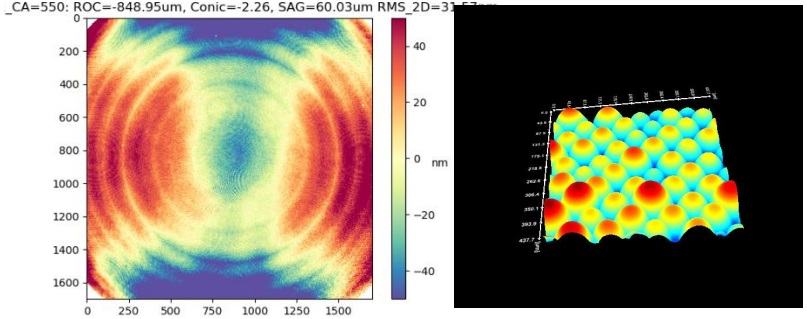
- High-NA diffusers and retroreflectors
- Large slopes & Large fields of view measured
- Measurement frame-rate: 190 fps

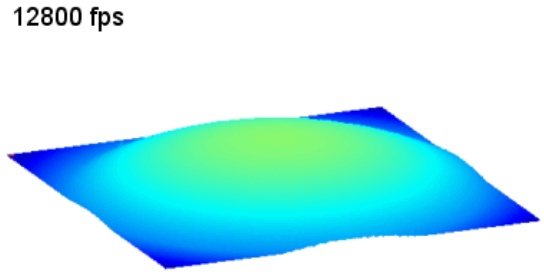
Summary: Digital Holography Microscopy (DHM®)

- **On-Flight, In-Line, and In-Situ**
- **High throughput Micro-Optic Topography and Wavefront Characterization with interferometric resolution**
  - Reflection:
    - Same results as with Zygo systems
  - Transmission:
    - High NA optical components
    - Large field of view

DHM® R 2100

DHM® T1000





Tunable micro lens

Thanks for your attention

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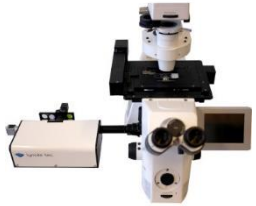
Lyncée Tec SA

DHM®: a complete range of stand-alone system and add-on modules

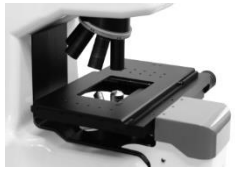


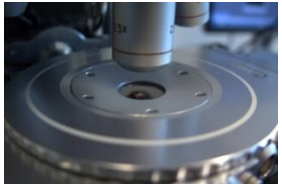

Reflection | Transmission | High Speed | Camera modules | Lensless | Industrial | Macro systems

2003 — From sample handling to data analysis — 2021

Options and accessories

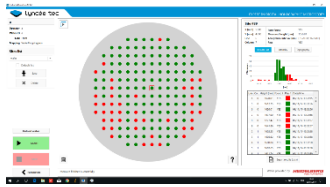


Motorized stages for automation

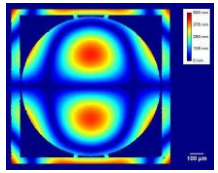


Environmental control (vacuum, T, …)

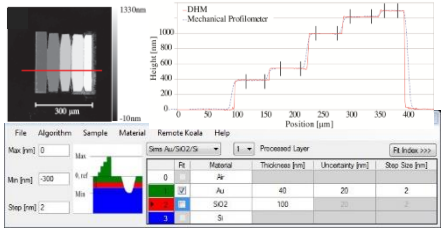
Software: acquisition, automation, data analysis, SDK



Automated QC



Vibration analysis



Spectral reflectometry