EPIC European Photonics Industry Consortium

nano scribe A BICO COMPANY

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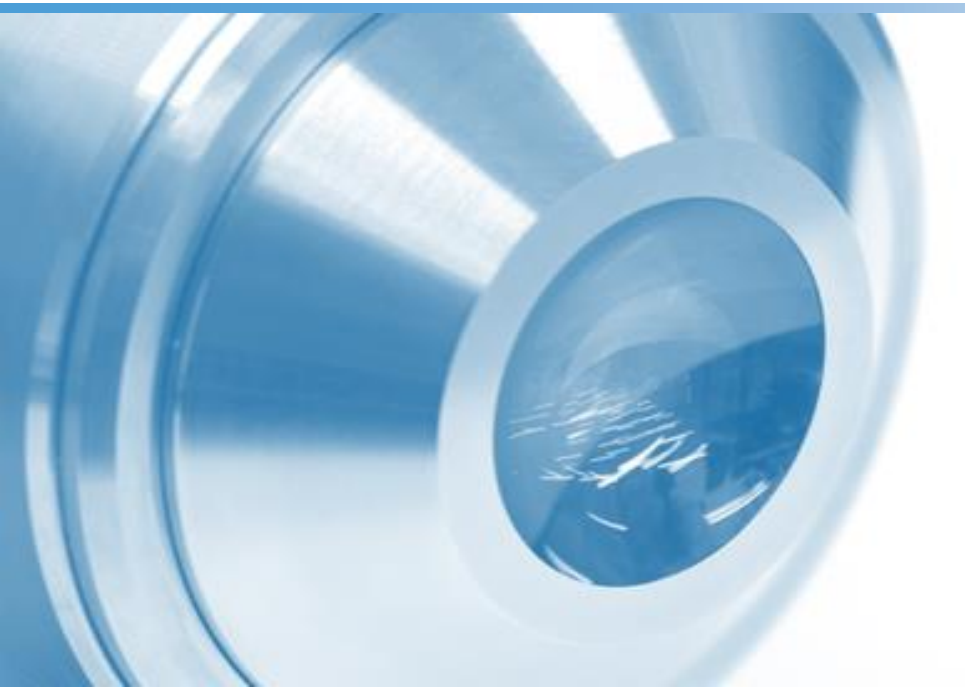


In-Process Metrology for Microlenses Using Confocal Microscopy

Jürgen Valentin
NanoFocus AG

11-12 May 2022

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

Karlsruhe, Germany

Contents

- Company & Products
- Technology
- Application: Microlenses
- Conclusion & Challenges

About me

- Jürgen Valentin

- **Co-Founder of NanoFocus AG**
- **1995 - 2001 Head of Software Development**
- **2001 - 2017 CTO**

- Current activities:
  - Innovation & Partner Management:
    - Microoptics & Semiconductor
    - Electromobility / H2
  - Standardization: ISO / VDI Standardization Groups
  - Networking: OPTECHNET, IVAM, VDMA, NMWP
  - Steering: VDMA Photonics / Industrial Steering Commitees

NanoFocus AG

- Company Profile

- **Development**, **production** & sales of **Optical 3D surface** measurement systems (micro/nano)
- Focus on **production metrology**
- Experienced supplier to the **automotive & semiconductor industry** (since 1996 >> 1500 systems wordwide)

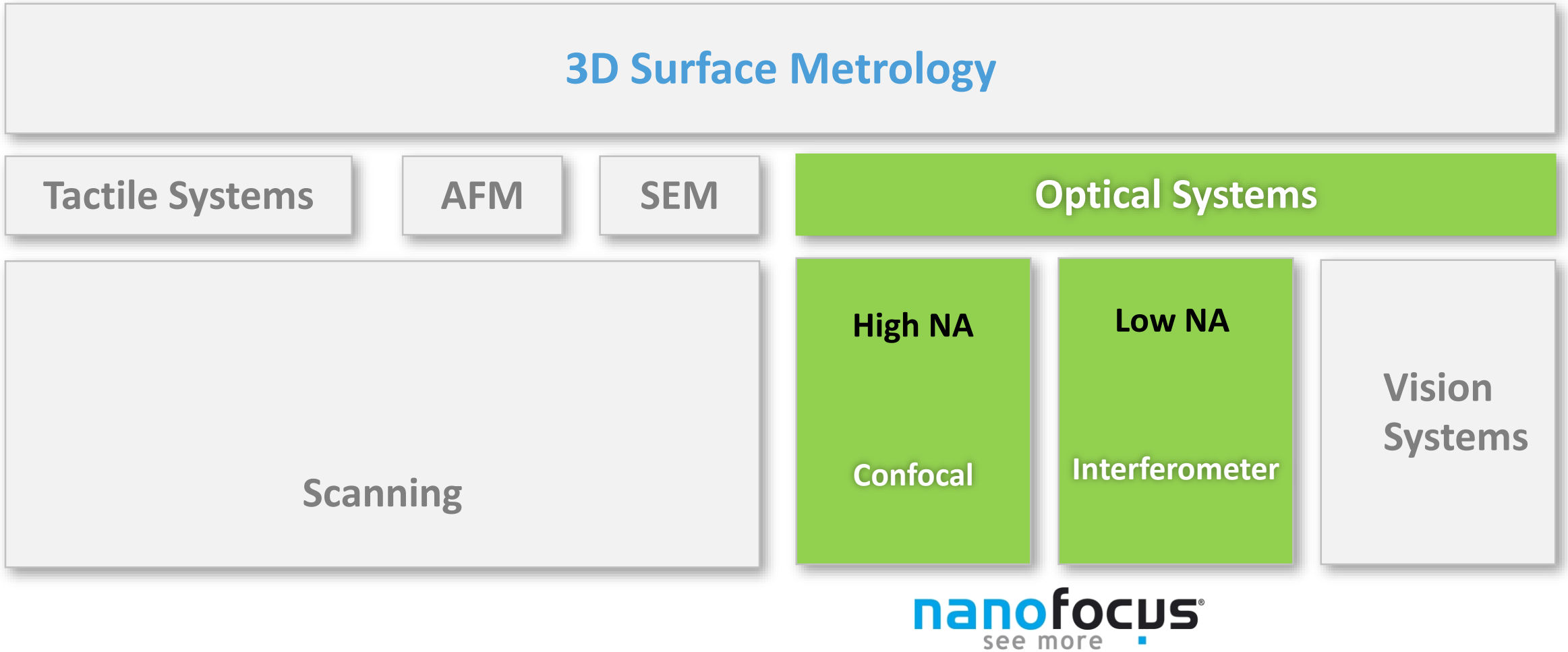
HQ Oberhausen, Germany

HQ Göttingen, Germany
Principal shareholder

Products

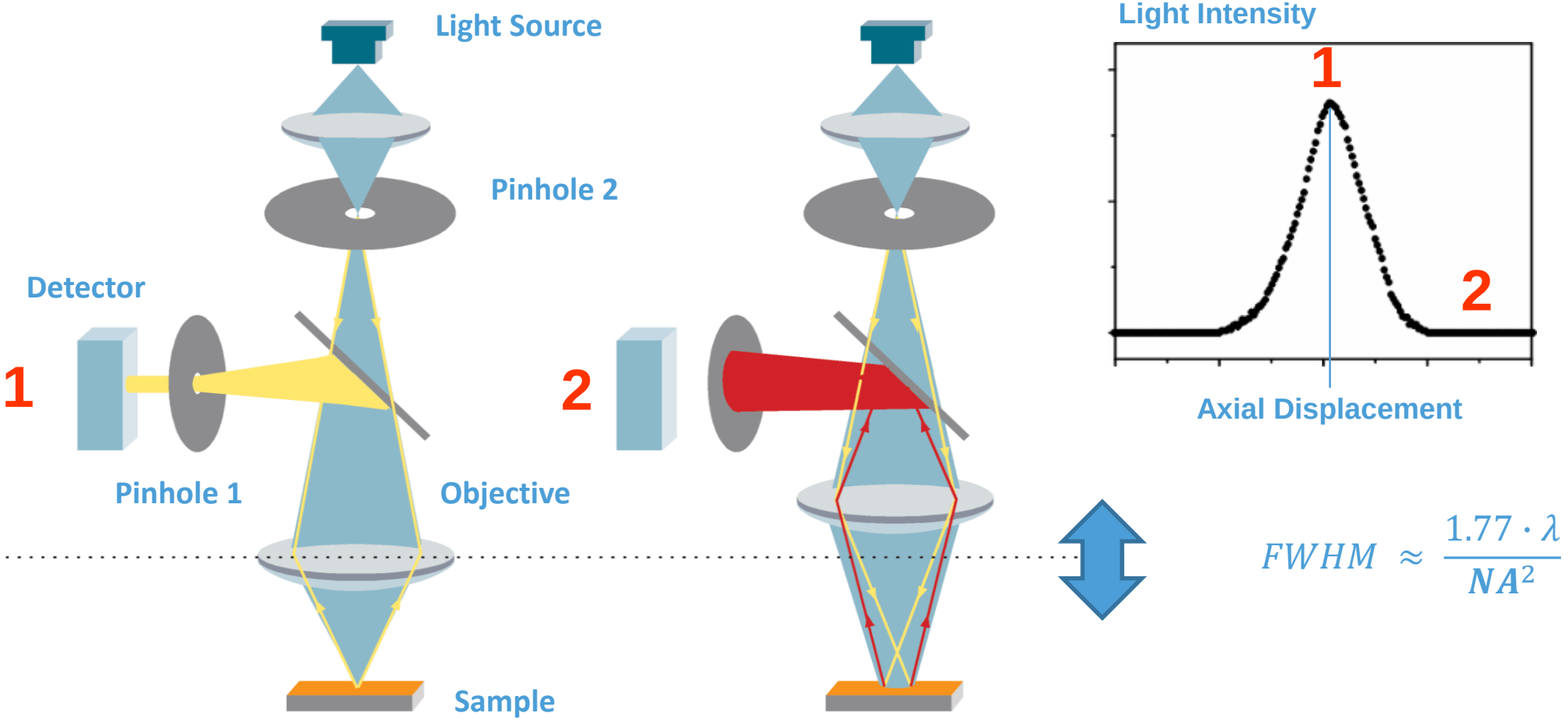
Special Solutions (Automation) & OEM Products

Laboratory Systems


3D Surface Metrology
Tactile Systems
AFM
SEM
Optical Systems
Scanning
High NA
Confocal
Low NA
Interferometer
Vision Systems

Technology

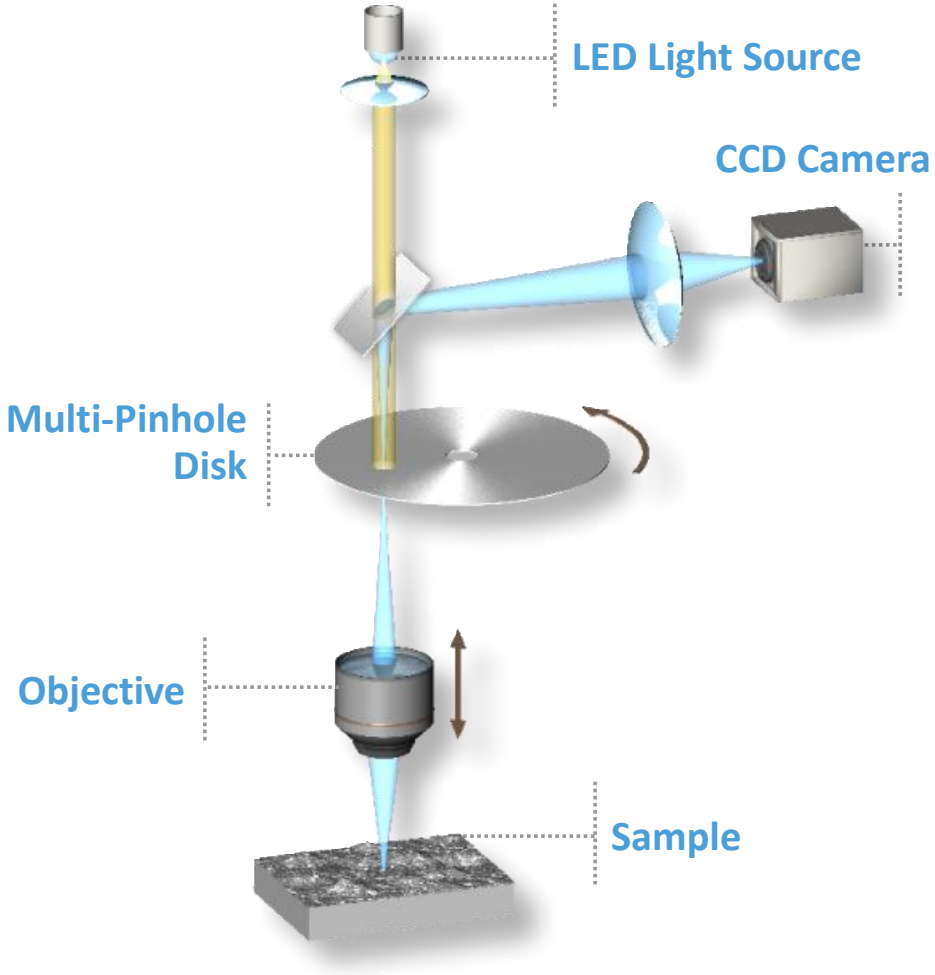
- Confocal measuring principle

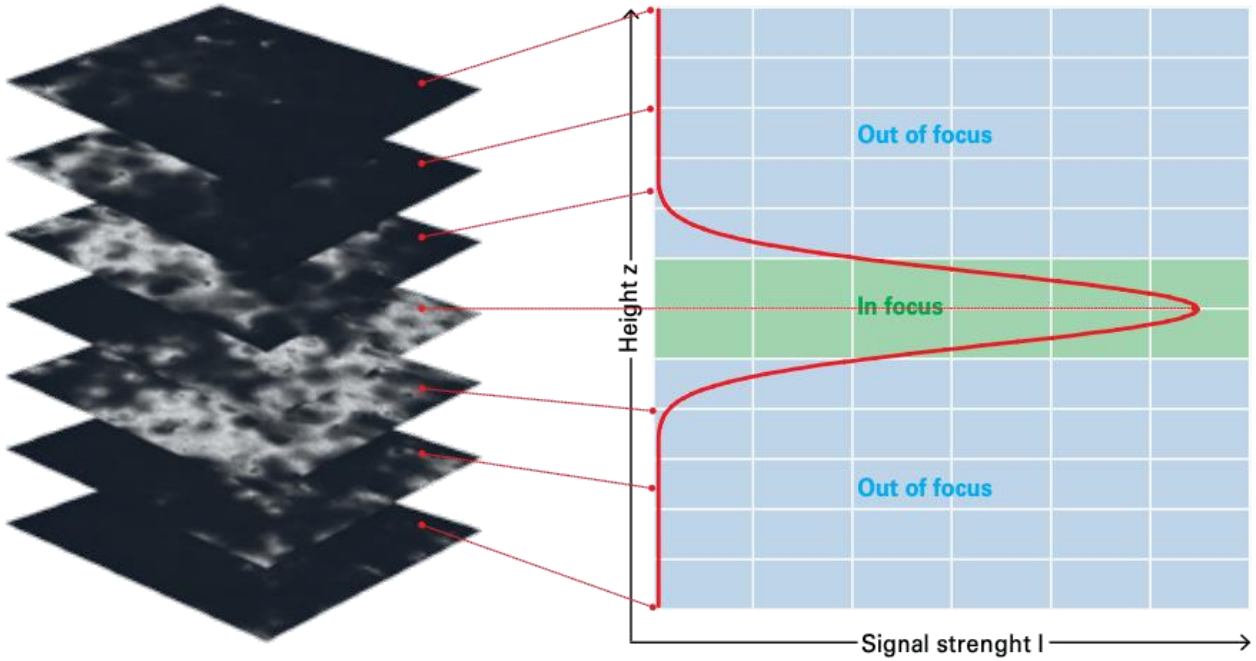


$$FWHM \approx \frac{1.77 \cdot \lambda}{NA^2}$$

Technology

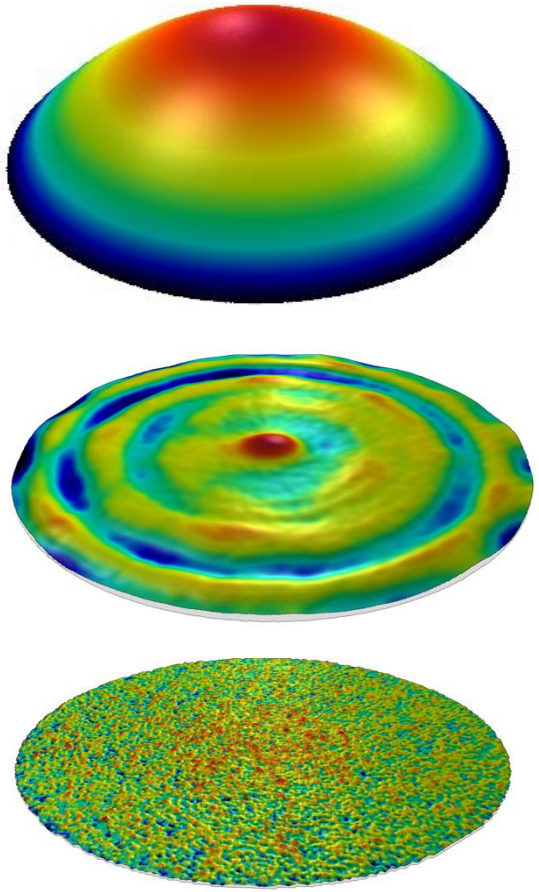
- Confocal microscope (Nipkow Disk)

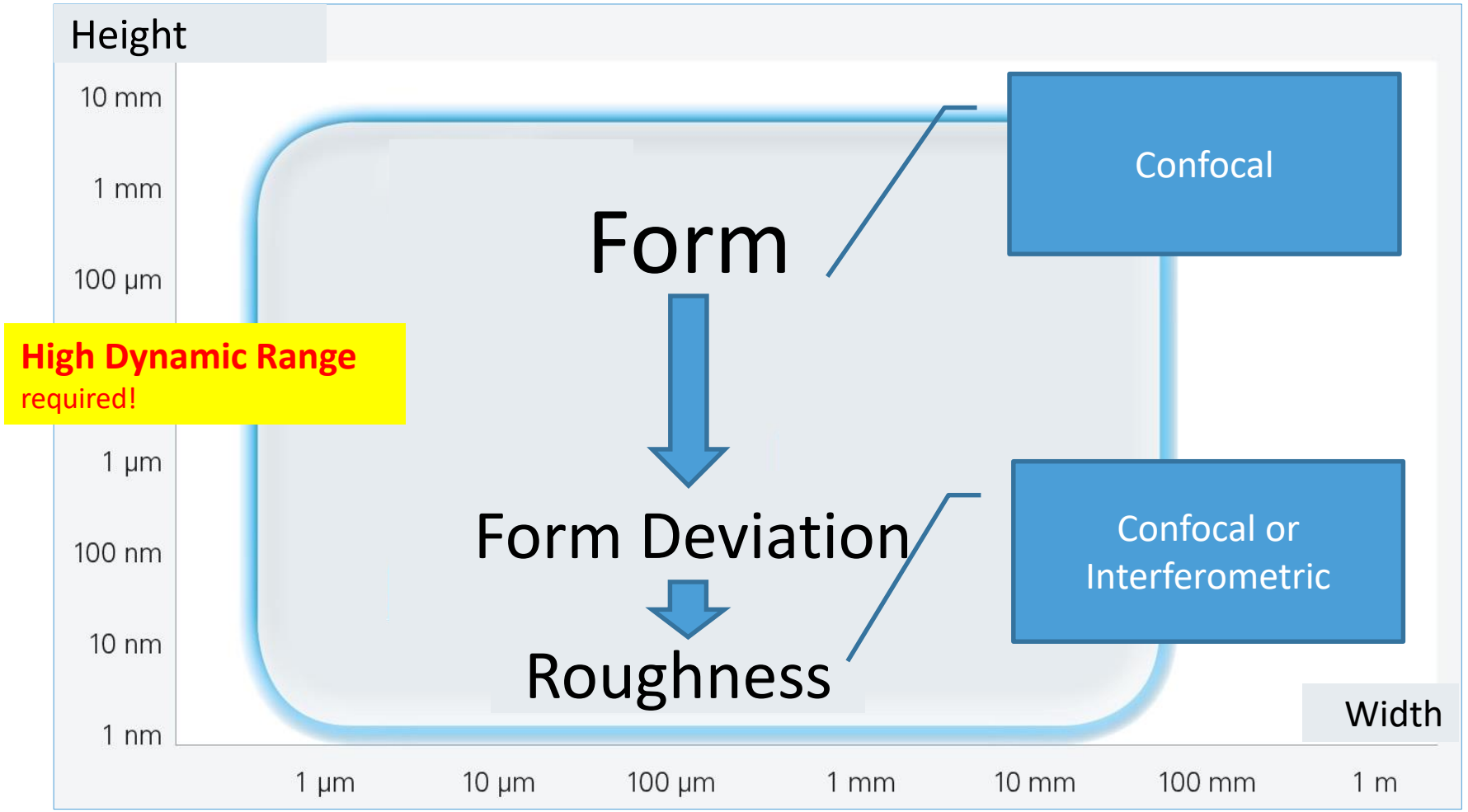




Application area

- Scope of microoptic applications





High Dynamic Range required!

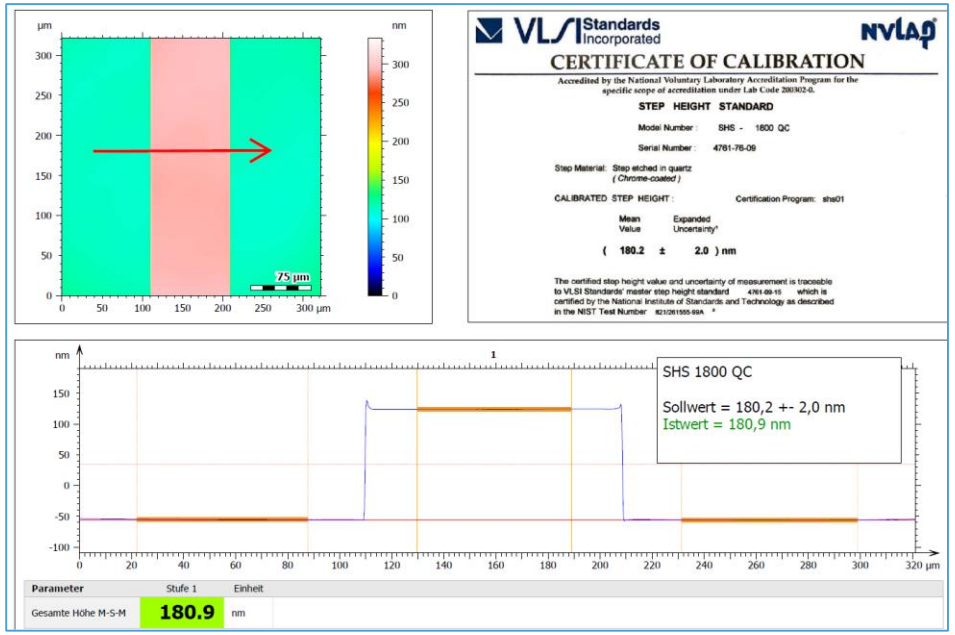
Requirements & Correspondences

- **Traceability of the results**
  - Acceptance Tests acc. **VDI 2655**
  - Special calibration, e.g. with **VLSI standards**
  - Use of **calibrated reference spheres** (METAS certificate)

- **Large Measuring angles**
  - Angles > 70° (Objective 160 XS, 320 XS, **NA 0.95**)

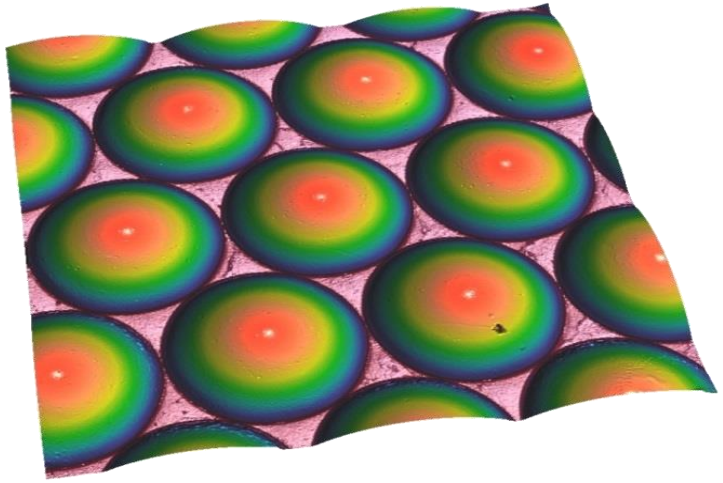
- Measurement of **small lens diameters** (D < 0,1 mm)

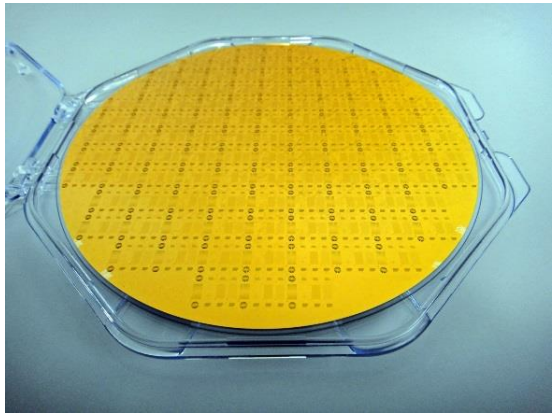
- High measurement **speed** (up to 20µm/s)
- High shape **accuracy and repeatability**
  (Radius deviation < 0,2% , RMS < 20 nm @ D=1 mm)



Example: Wafer-based microlenses

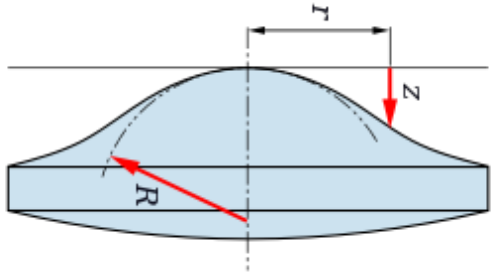
- Determination of shape and roughness

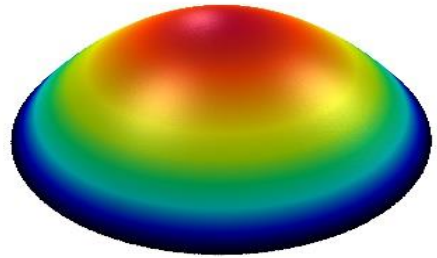


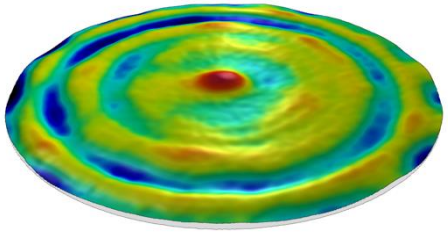


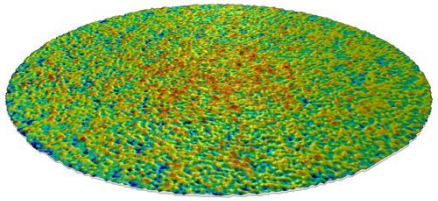
- **3D Asphere measurement & curve fitting**
  - **Calculation of R, k**
  - **Determination of RMS, PV**
- **Measurement of Sq**
- **Lens Position / Inclination measurement**

$$z(r) = \frac{\rho r^2}{1 + \sqrt{1 - (1+k)(\rho r)^2}} \qquad R = 1/\rho$$









Microlenses

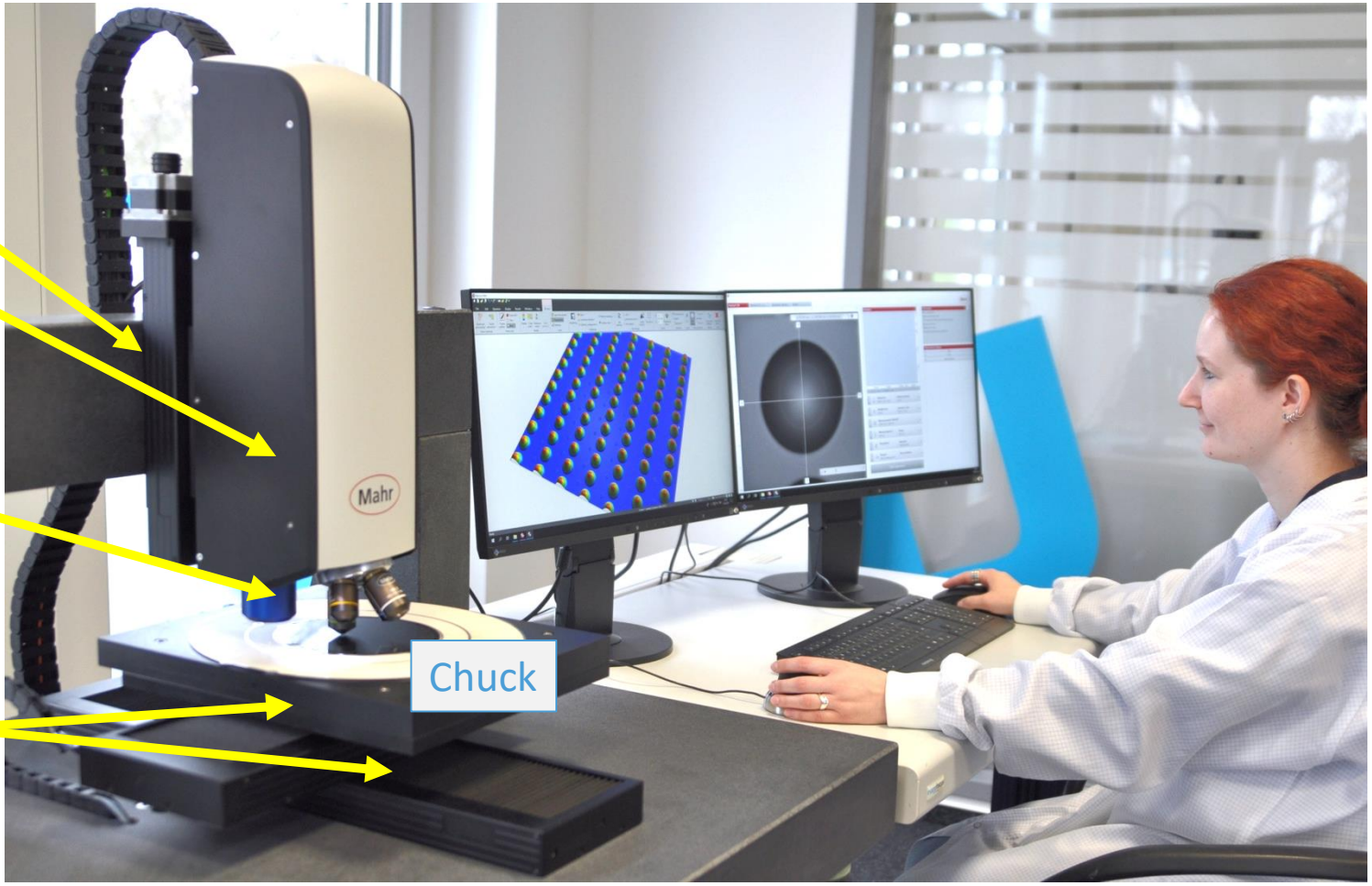
- Basic system design

- Robust portal design with **active damping**

- **Confocal** measuring head
  - 1200 X 1200 Pixel, **HDR**, **Binning** option, **100 fps**
  - Integrated Piezo Drive 350 µm z-Range

- Overview Camera (**Fiducial** Recognition)

- Positioning axes
  - Z: Range 100 mm
  - **XY:** **Range 300 X 300 mm**
    Mounting Area > Range
    Resolution (XYZ): 0,1 µm



Automation

- In-line production system

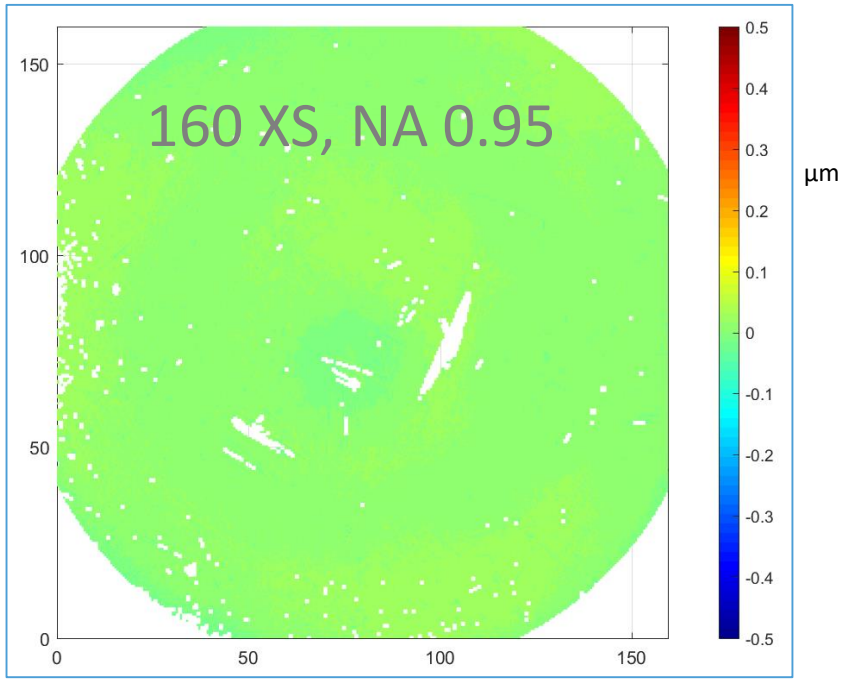
- Automated **Waferhandling** and Software Mapping
- **Clean room** compatible
- **Automation** software (rights management)
- Several **data interfaces**
  (z.B. SECS GEM,..)
- Automated **Measurement & Analysis**
- Interfaces for further data processing
  (**Python, MATLAB**, Mountains,..)

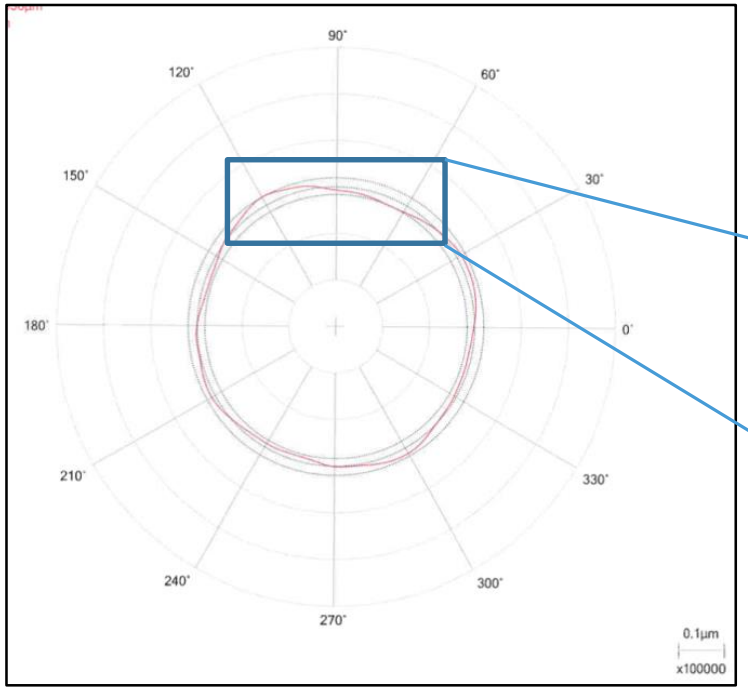
Calibration

- Measurement on calibrated spheres

Results (ROI 160 µm, 21.1° max angle):

Diameter: **0,5006 mm**
RMS: **13 nm**
PV (95%) **38 nm**





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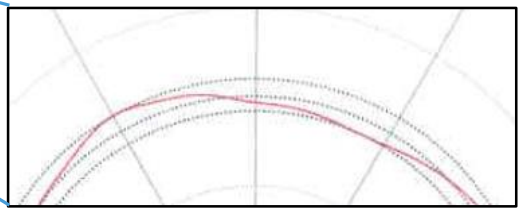
Confederaziun svizra

Eidgenössisches Institut für Metrologie METAS

Kalibrierzertifikat Nr. 111-15587



Problem: Real calibration balls often show local inhomogeneities (**roundness deviations, scratches** etc.)

Messresultate

Identifikation	Nennwert	Gemessener Durchmesser	*RONt*
508893, 000001087673	0.5 mm	0.50044 mm	0.04 µm

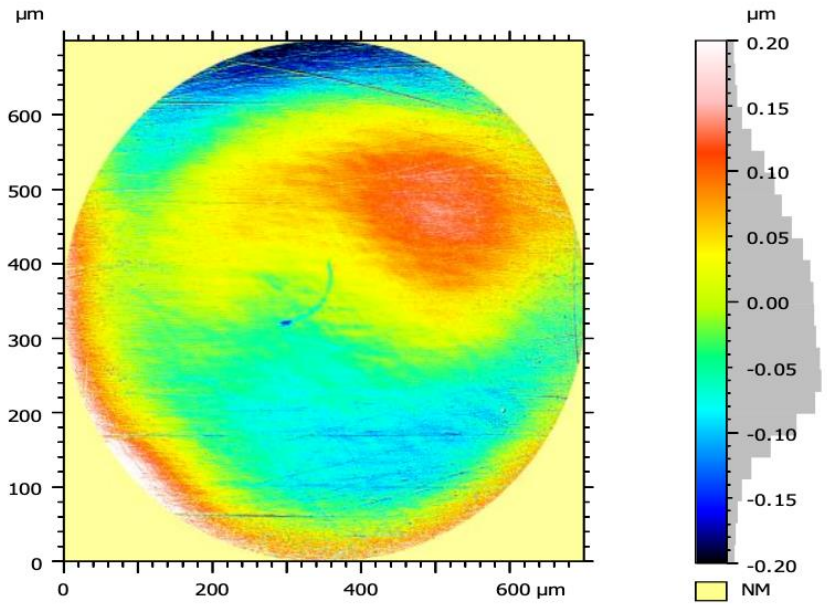
Messunsicherheit

Durchmesser: U = 0.20 µm
RONt: U = 0.08 µm

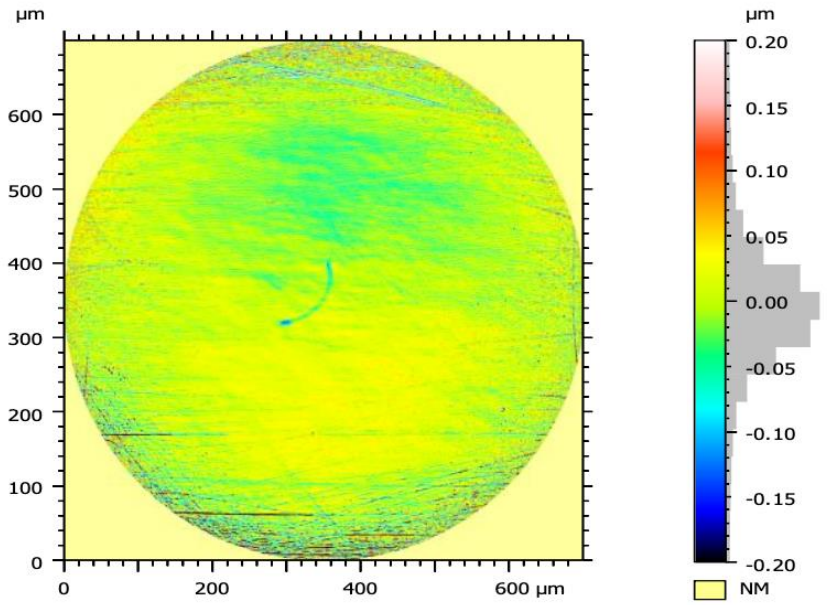
Lens abberation reduction

- Abberations of **low NA lenses**

raw



corrected



- **Abberations depend on**
  - Principal lens **design** (**Numerical Aperture**)
  - **Local** 3D **Surface Angle (1st order)**
  - **Individual properties of the objective (quality)**

- **Numerical correction by**
  - **Mapping** of angular deviation with calibrated spheres with different **diameters and orientations/rotations**
  - **Application of On-the-fly correction of raw data after measurement**

Conclusion

- **Benefits**:
  - Optical metrology is ideal for **fast and accurate** measurement of a **wide range** of microlenses
  - Measurements can be performed both fully **automated and manually**
  - Both **confocal and interferometric** measuring heads can be used & combined
  - The procedures comply with international **traceable quality standards**
  - Individual analysis receipts can be realized by **Python / MatLab** scripts

- **Challenges / Work in progress**:
  - **Low NA** Lenses (larger measurement area) require **correction methods**
  - Confocal **roughness** measurements **require high NA lenses and small working distances**
  - Traceability of lens measurements to **calibration spheres is technically difficult** **(only a small section of the sphere is measured) -> New Standards / Procedures?**

Thank you for your attention!

Special Thanks to the Support of: