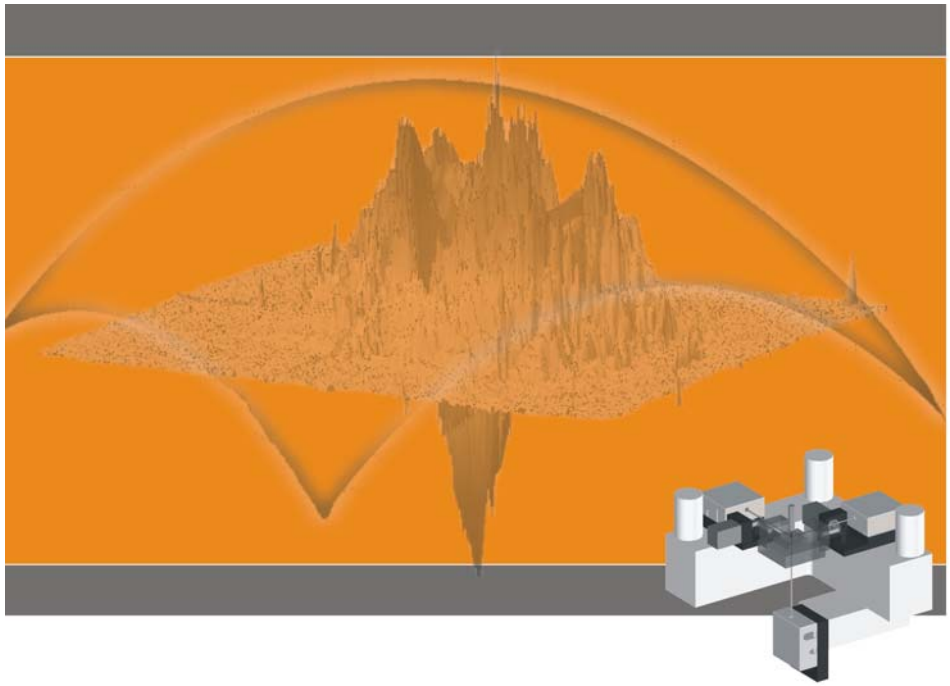
Application of NanoCMMs:
Current Status and Trends



Hannovermesse 2011
Forum “Innovations for Industry”

Institute of Process Measurement and Sensor Technology
Ilmenau University of Technology

Outline

1. Motivation
2. State of the art in nanocoordinate measuring machines
3. Typical measurement tasks
4. Future goals and challenges
5. Nanopositioning and Nanomeasuring Machine NPMM-200

Motivation

- Structures achieve atomic dimensions
- Multiple-scale measurement and positioning from sub-nanometres up to hundreds of millimetres
- Increasing demands for 3-D measurements

Application areas

- micro-/nanoelectronics
- micromechanics
- microsystems technology
- metrology
- precisions optics
- precision technology
- biology
- genetic engineering
- chemistry

Tasks

- measuring
- positioning
- sensing
- scanning
- treatment
- manipulation
- assembling

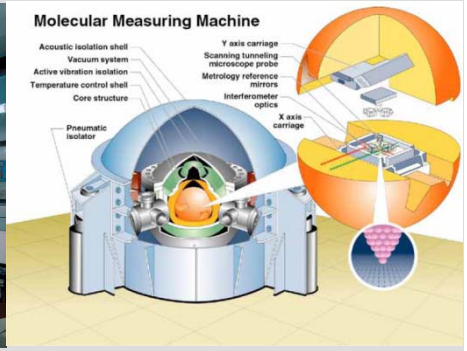
Challenges

- increasing measurement volume
- increasing resolution, reproducibility, accuracy
- high dynamics
- increasing complexity

SFB 622: Nanopositioning and Nanomeasuring Machines

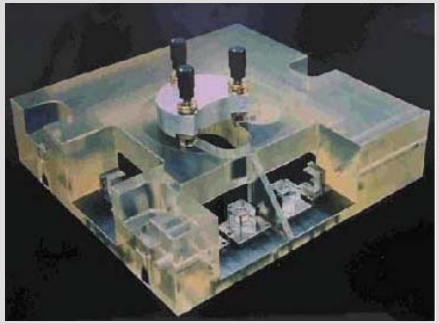
International research activities

Molecular Measuring Machine / NIST / USA



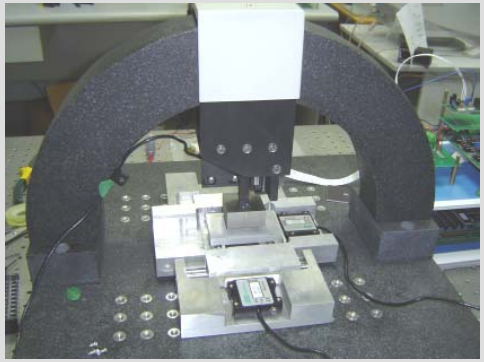
Source: http://www.nist.gov/mel/ped/upload/ped2009pta.pdf

Sub-Atomic Measuring Machine UNC at Charlotte / Prof. Hocken



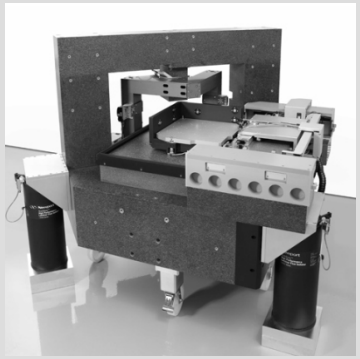
Source: Hocken, et al: Needs and advances in metrology for precise motion control in mechatronic. IMEKO 2006

Nano-CMM. National Taiwan University / Prof. Fan



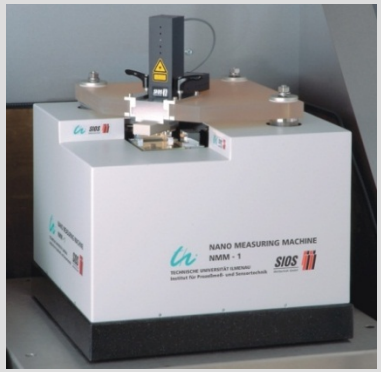
Source: SFB-Kolloquium 30.07.2004 Ilmenau

Isara 400 / IBS Precision Engineering



Source: www.ibspe.com/ibs_precision_engineering_uk/ibs_isara_400.html

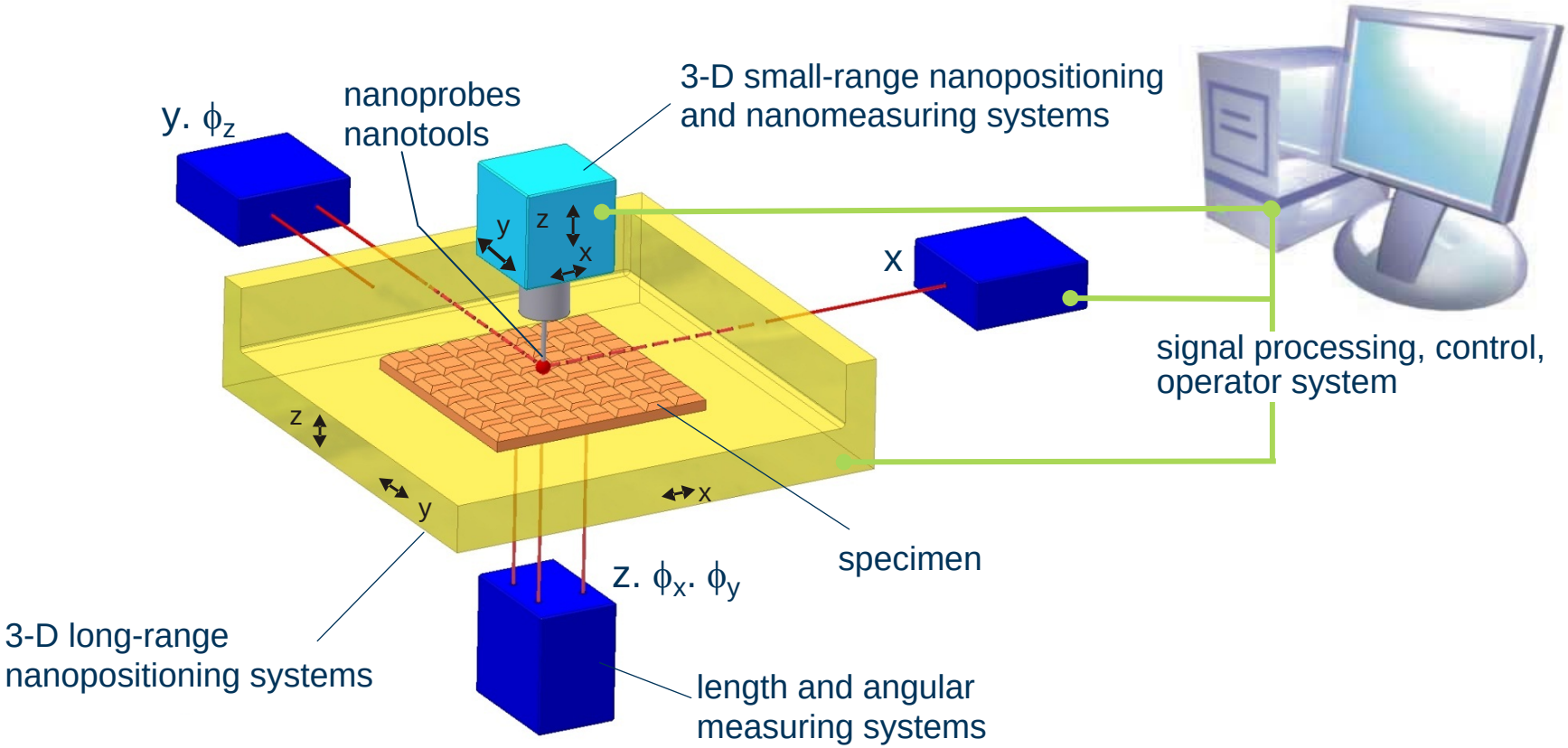
Nanopositioning and Nano-measuring Machine / TU Ilmenau, SIOS



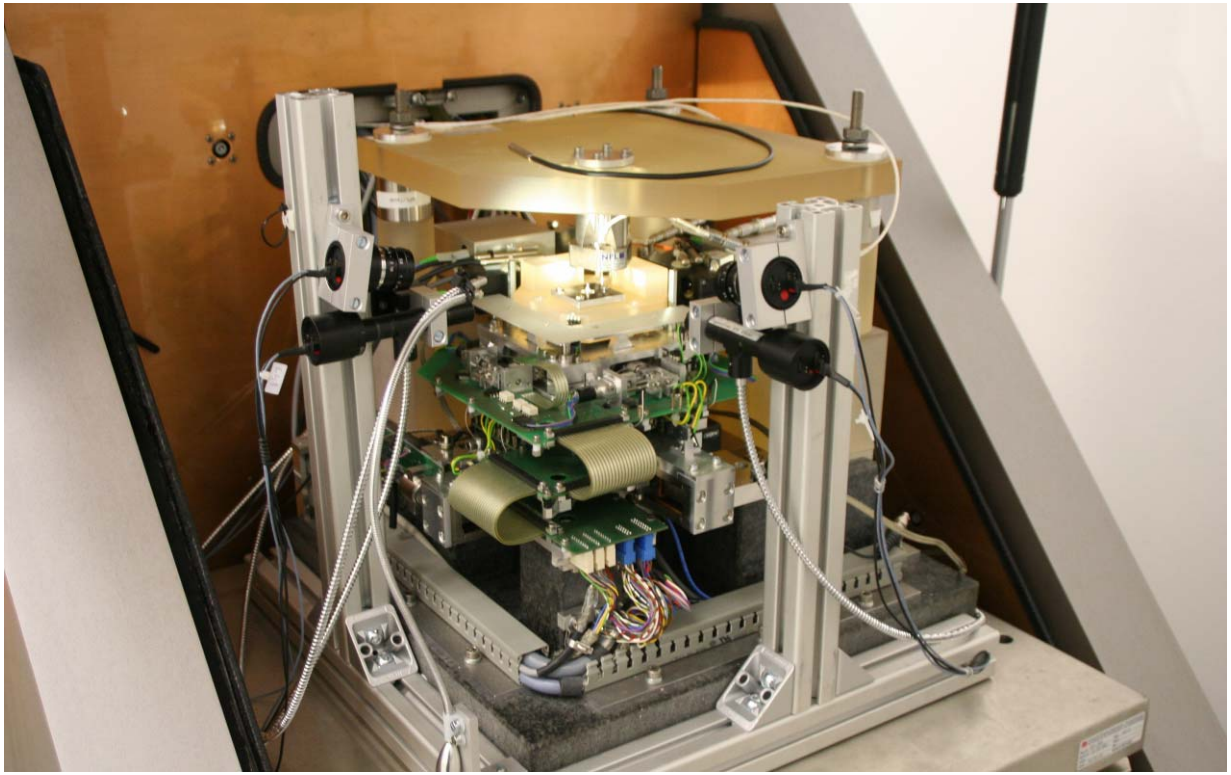
NMM-1

Basis concept of NPM machines

- Abbe-error-free measurement in all measurement axes over the entire measurement range
- permanent compensation of all guide errors (6-DOF compensation)
- nanoprobes acts as zero indicators



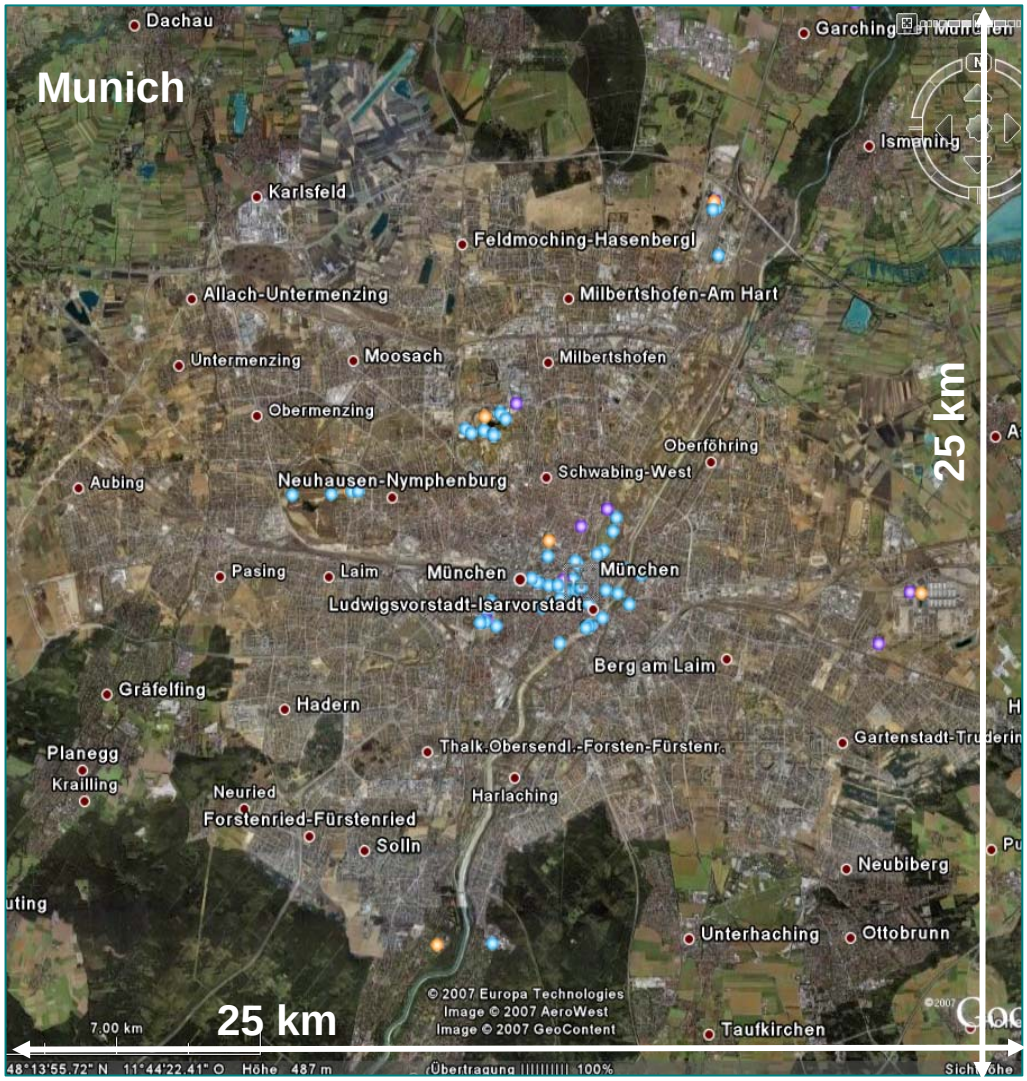
Nanopositioning & Nanomeasuring Machine NMM-1



developed at the Ilmenau University of Technology and manufactured by SIOS Meßtechnik GmbH

- Measuring range: 25 mm x 25 mm x 5 mm
- Resolution: less than 0.1 nm
- Highest accuracy and measuring uncertainties of less than 10 nm
- Possibility to apply surface-sensing probes and 3-D-probes

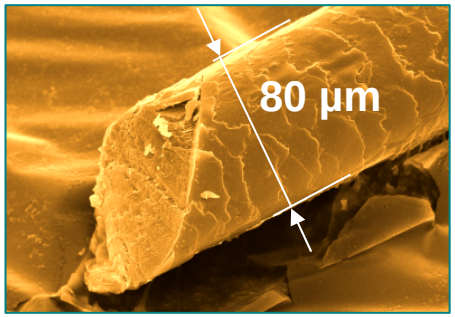
Comparison of capability of the NMM-1



Measuring range: 25x25x5 mm^3
Resolution: 0.08 nm
Scanning speed: 10 µm/s (AFM)
1 mm/s (focus sensor)

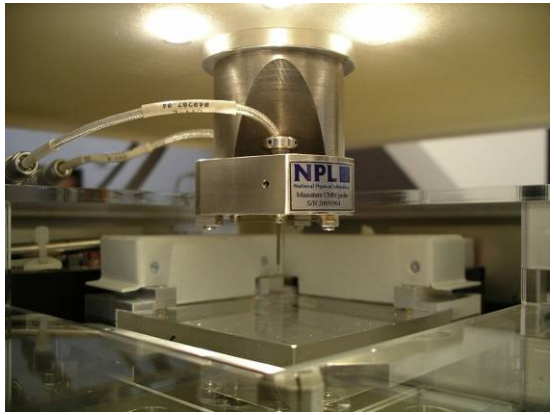
Find a human hair (80µm) in the area of Munich: 25x25x5 km^3 with a speed of 36 km/h (by car) 3600 km/h (by jet)

Human Hair

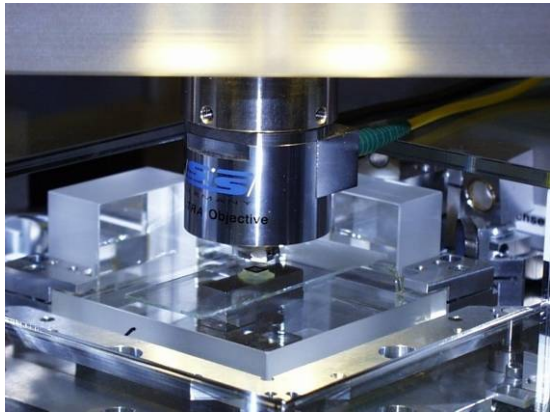


Using the Nanomeasuring Machine NMM-1 as

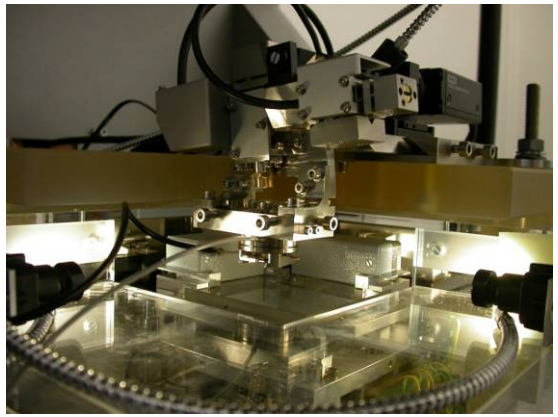
Coordinate Measuring Machine



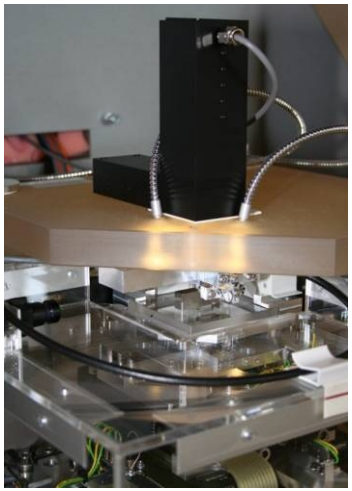
Atomic Force Microscope



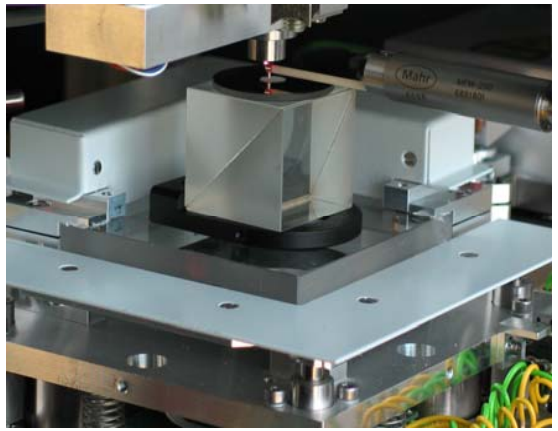
Interference microscope



Scanning Tunnelling Microscope

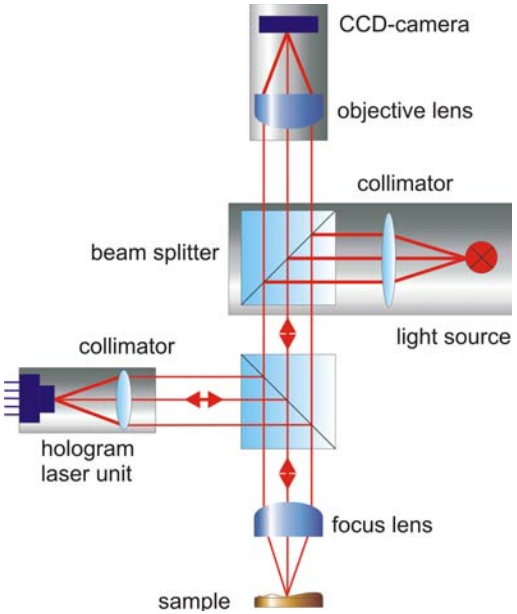


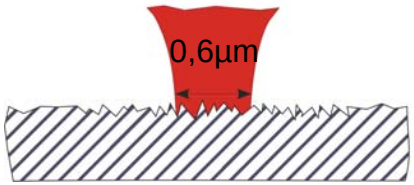
Optical Surface Profiler



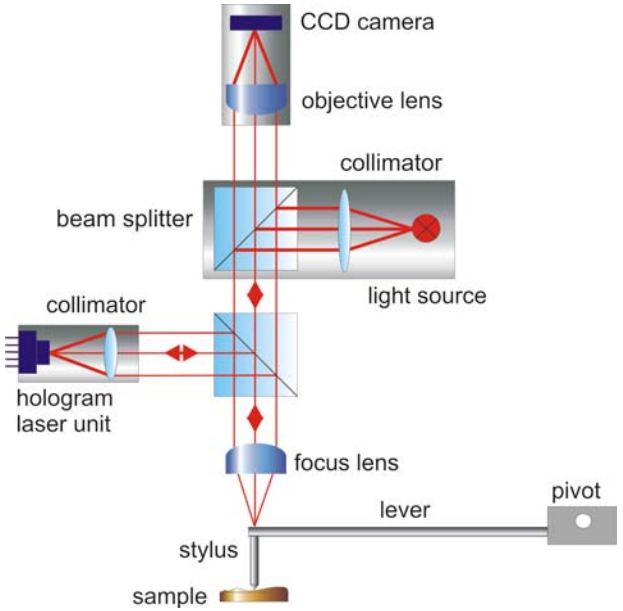
Tactile Surface Profiler

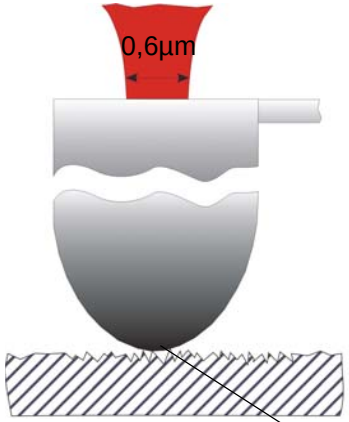
Focus sensor for various applications



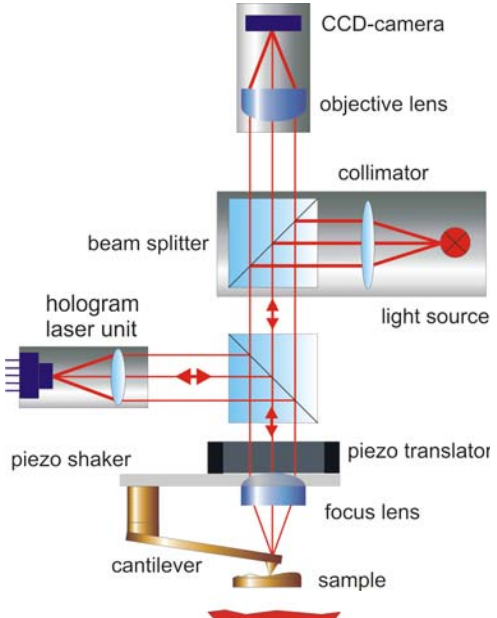


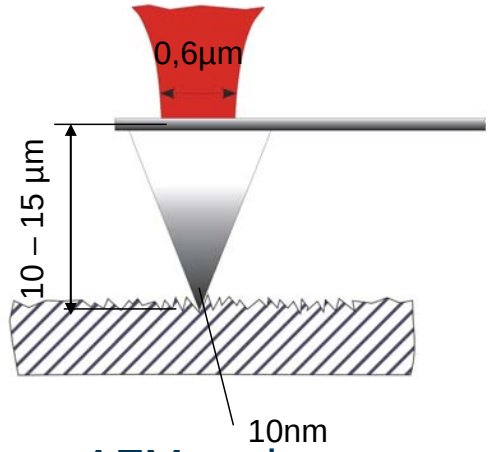
Focus probe





Stylus probe



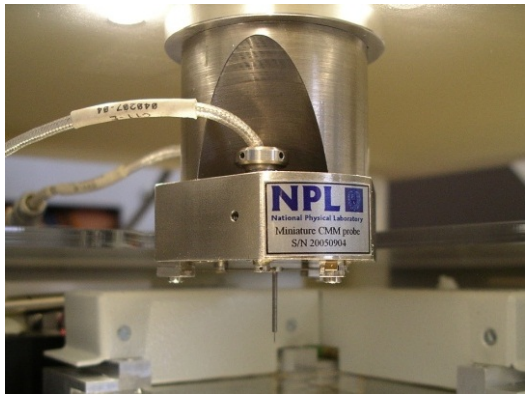


AFM probe

3-D Microprobes integrated into the NMM-1

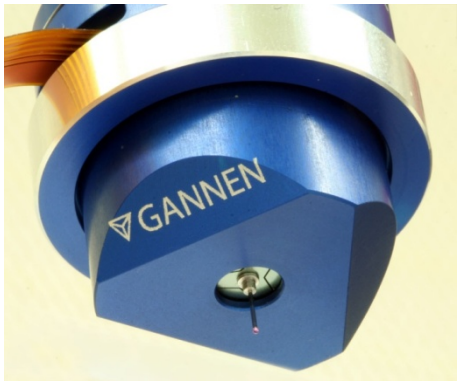
- Ball diameter: 300 µm
- Measuring forces below 0.3 mN

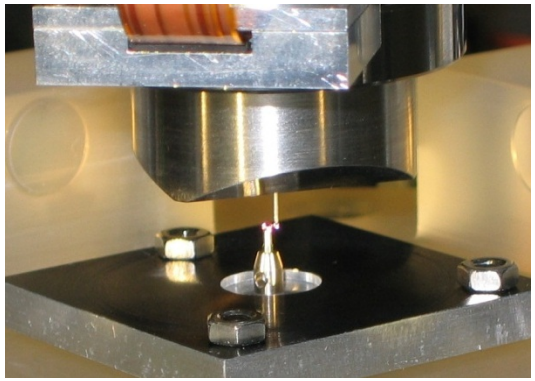
NPL probe (IBS Eindhoven)



3 copper beryllium flexures
3 capacitive sensors
Stiffness: 10 N/m (isotropic)
Reproducibility: 4.3 nm

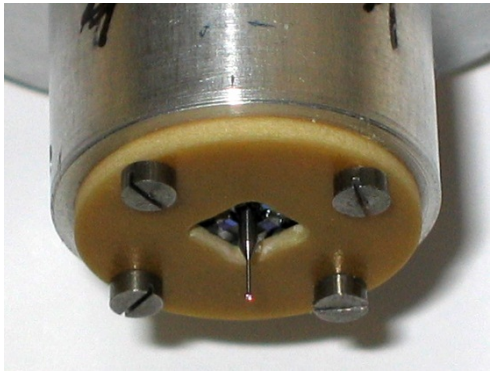
GannenXP probe

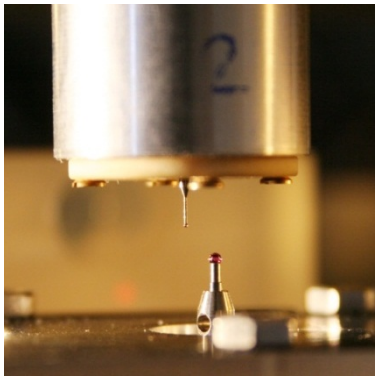




Silicon suspension system
3 piezoresistive sensors
Stiffness: 280 N/m (isotropic)
Reproducibility: 3.8 nm

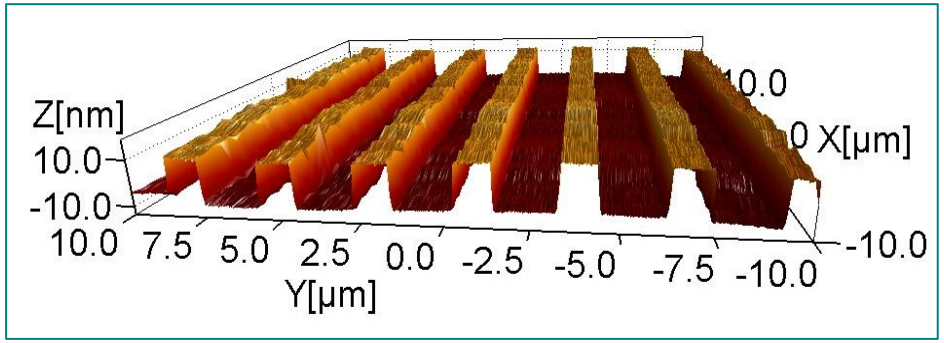
IMT probe



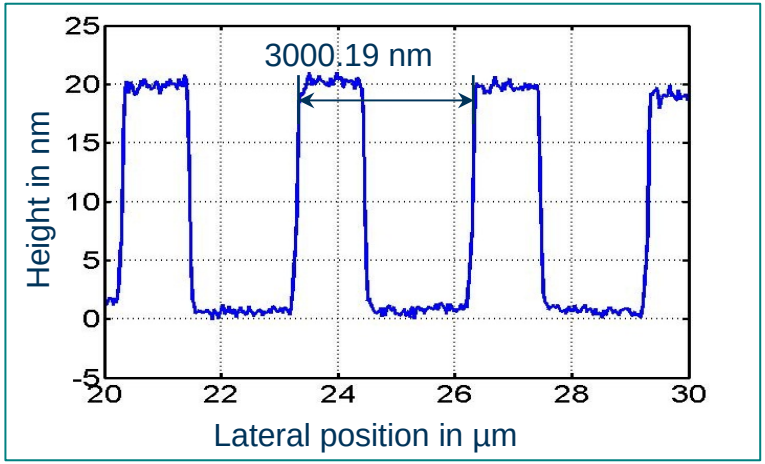


Silicon suspension system
4 piezoresistive sensors
Stiffness: nonisotropic
Reproducibility: 7.7 nm

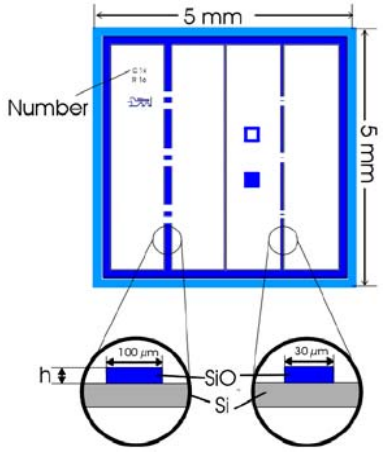
Examples of typical measurement tasks

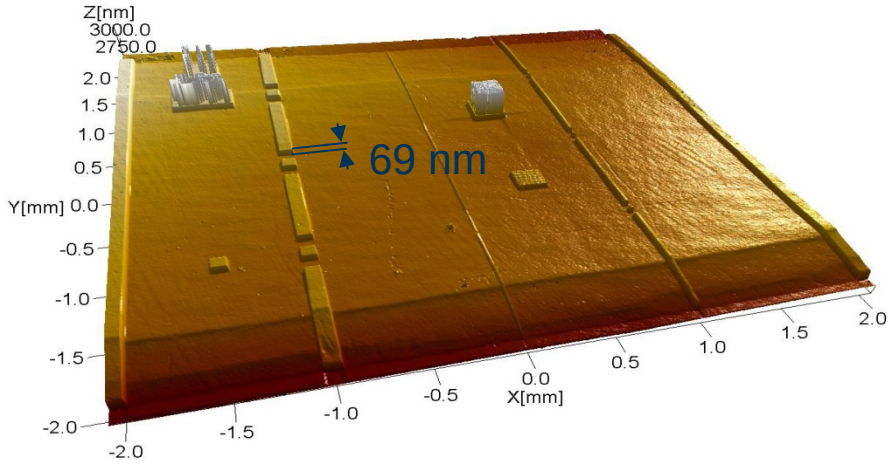


Grating TGZ1 manufactured by ATOS GmbH



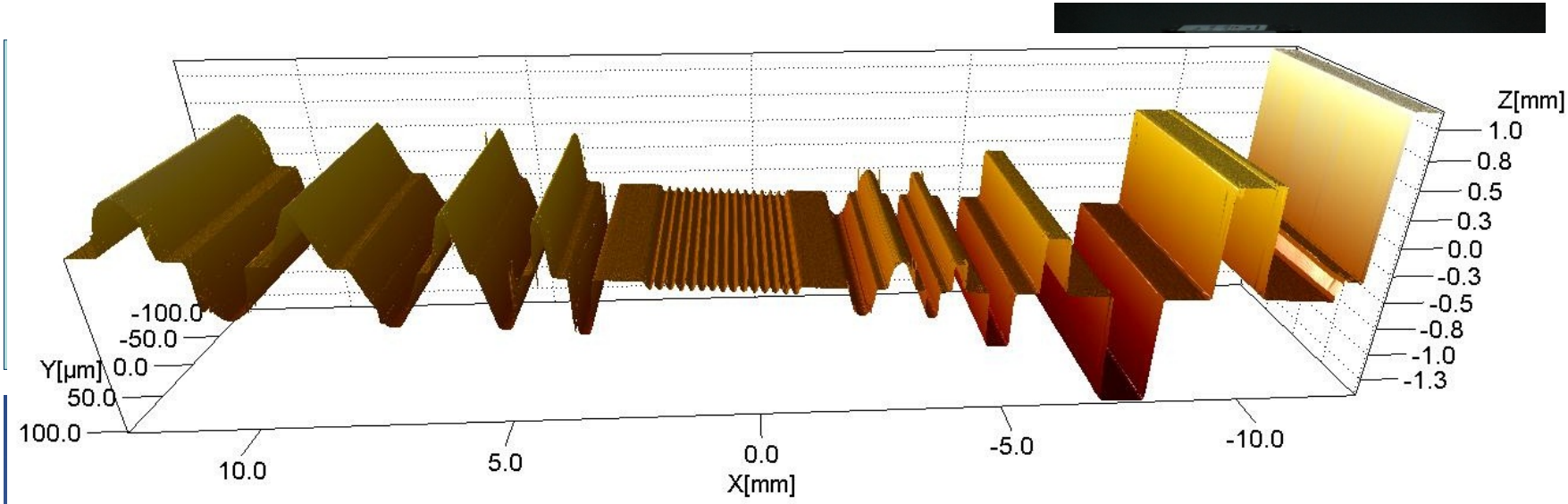
Step height standards

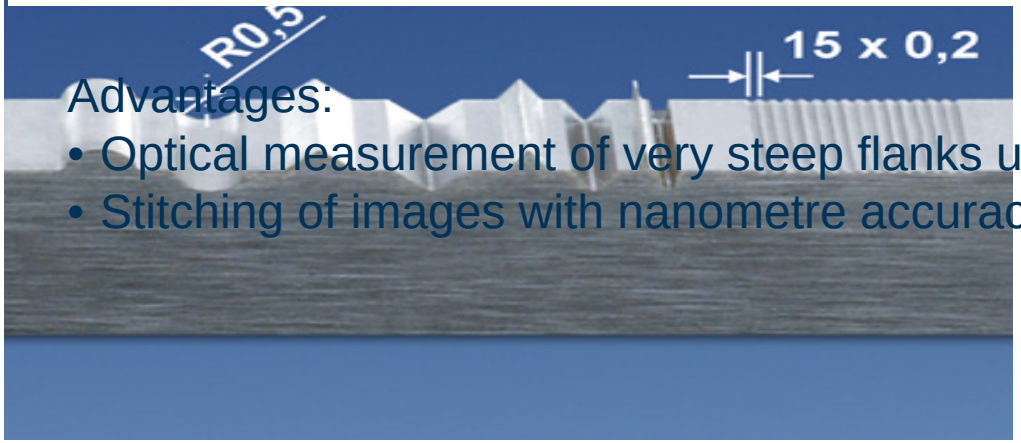




Examples of typical measurement tasks

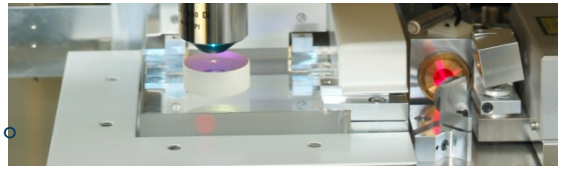
Depth From Focus (DFF) method





Advantages:

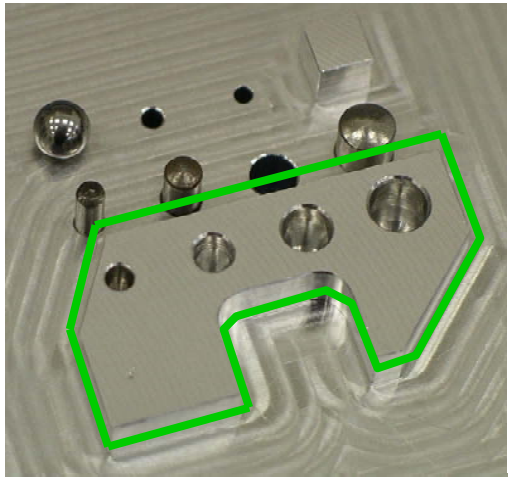
- Optical measurement of very steep flanks up to 80°
- Stitching of images with nanometre accuracy

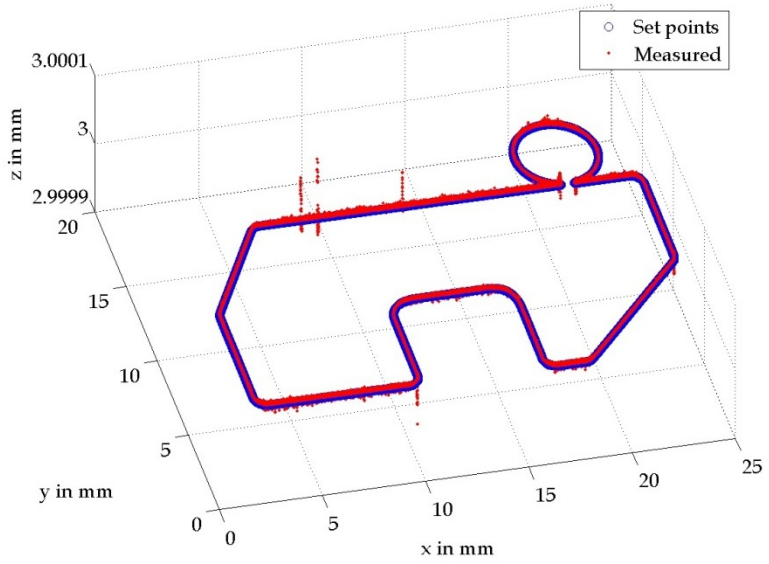


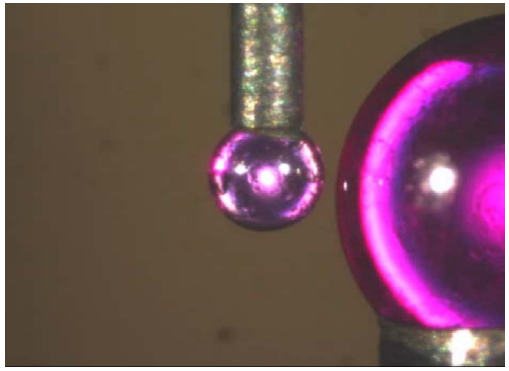
Microscope arrangement in the NPMM
(50x long-distance objective)

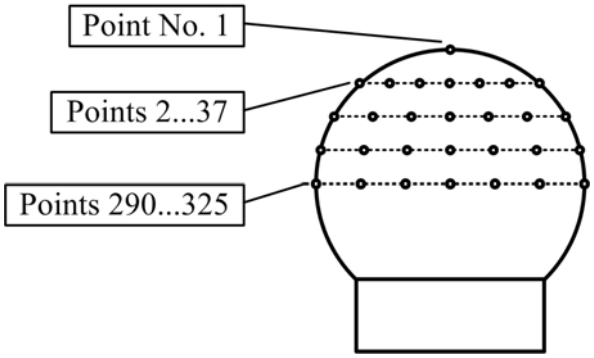
Real 3-D scanning according to I++ DME

Freeform scan: ScanInPlane





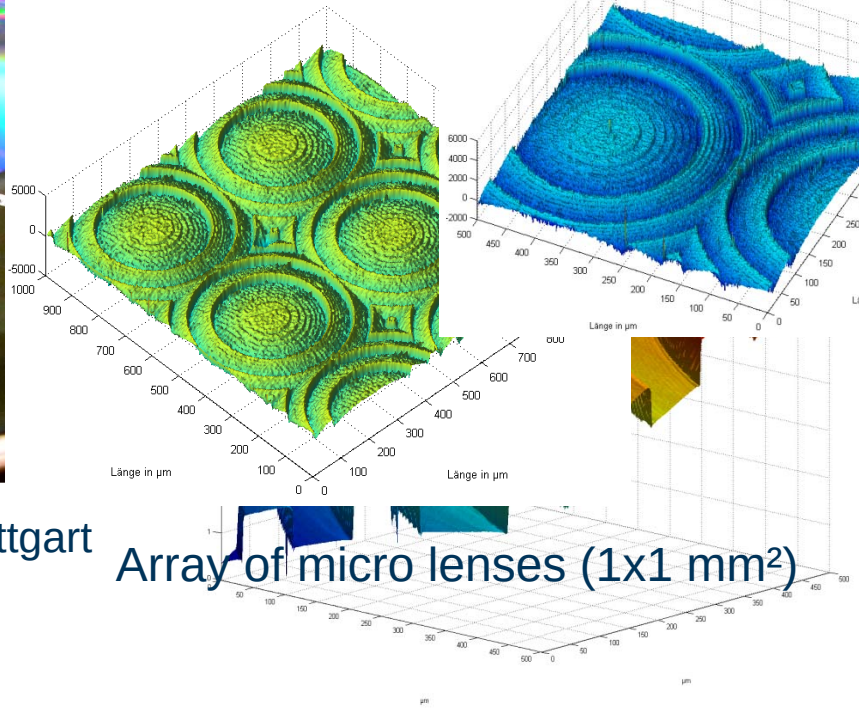




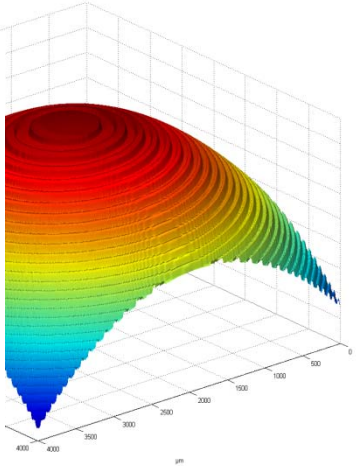
Challenges in optical micro-metrology

- Measurement of spheres, aspheres and freeforms (slope angle up to 80°)
- Superposition of macrogeometry with micro- and nanogeometries
- High-precision measurement of small up to large precision parts with 3-D nano probes

produced by ITO Stuttgart



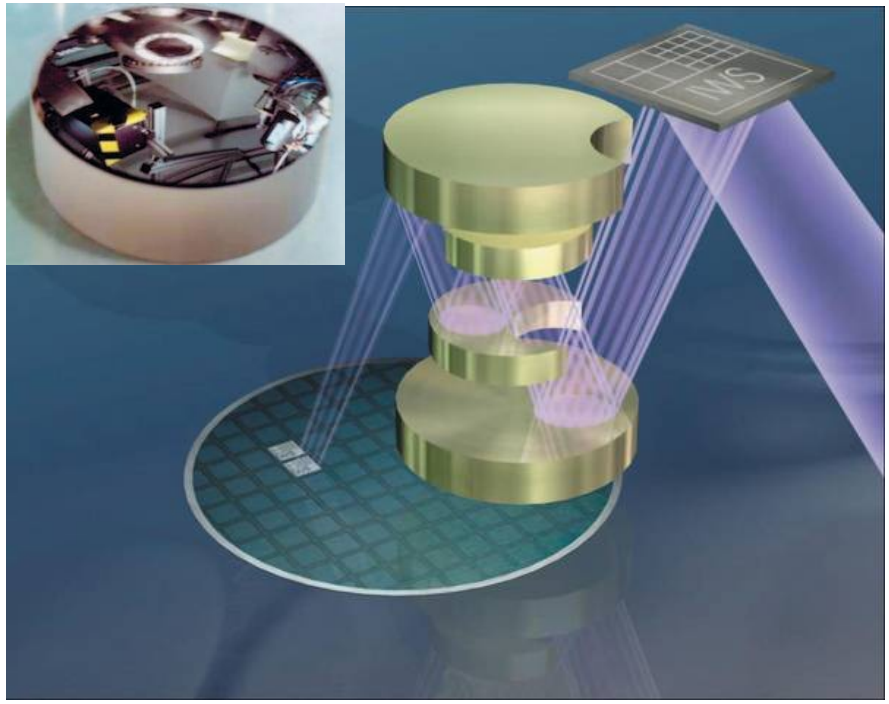
Array of micro lenses (1x1 mm²)



measured at TU Ilmenau

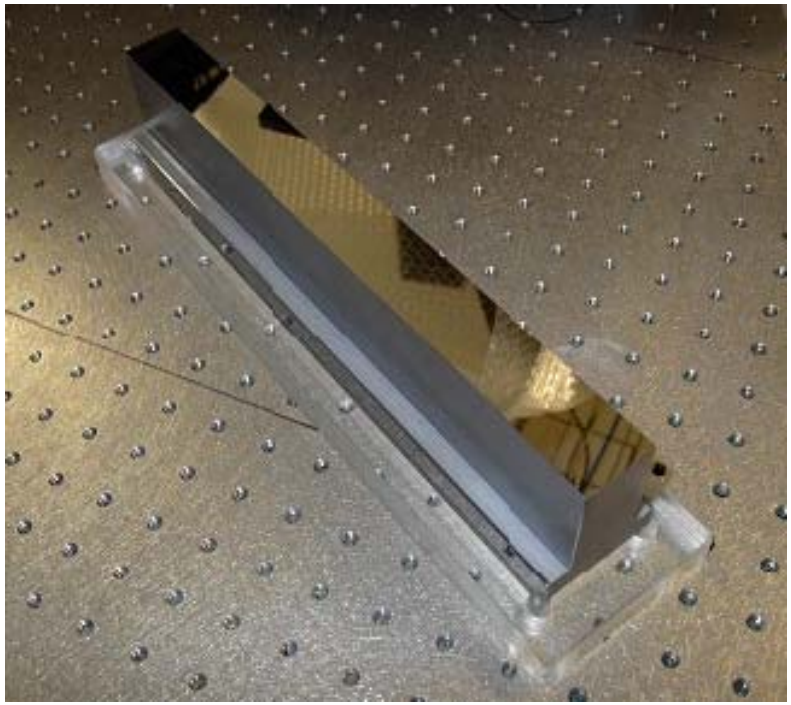
Challenges in large-area surface measurement

Form accuracy and roughness of flats up to curved surfaces with “atomic precision” (< 0.15 nm)
(e.g. mirrors for EUV technology and synchrotron)



Mirror for EUV lithography

source: Tilmann. Lowisch: EUV-Lithographie – die Chipfertigung der Zukunft. In: Photonik 2/2008. S. 44-47



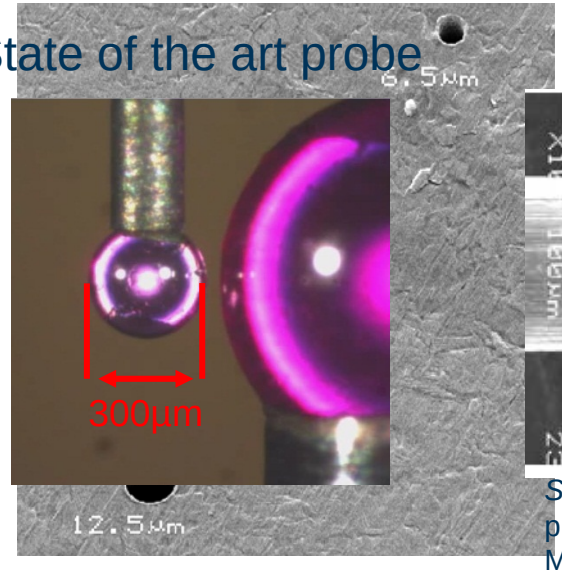
Bessy synchrotron mirror

source: Siewert, Bessy

Challenges in tactile micrometrology

- Developement of tactile probes:
  - Measurement in micro-holes (<100 µm)
  - high aspect ratios (1:100) → increasing stylus length
  - “Side wall” measurements, undercuts
- Smaller probing spheres and calibration of their form deviations (u < 10 nm)

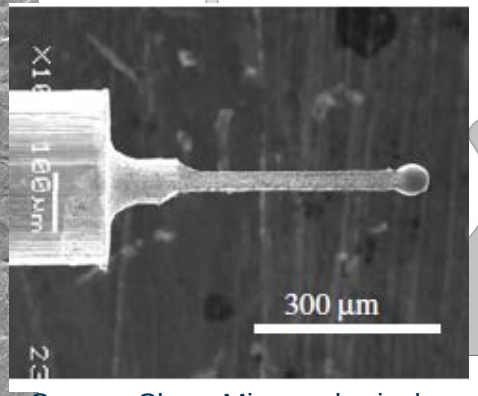
State of the art probe



Micro-holes

(http://www.mikrotools.com)

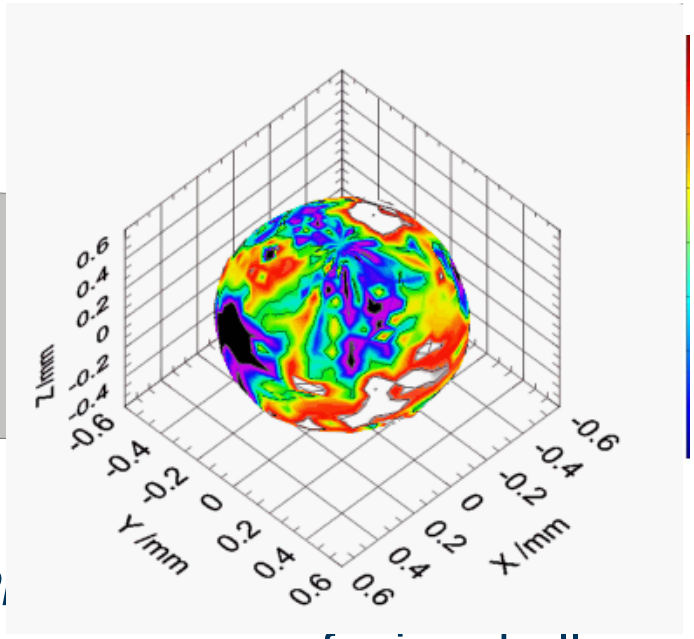
EDM probe



Source: Sheu, Micro-spherical probes machining by EDM, J. Micromech. Microeng., 2005

Undercuts

(EU NanoCMM P

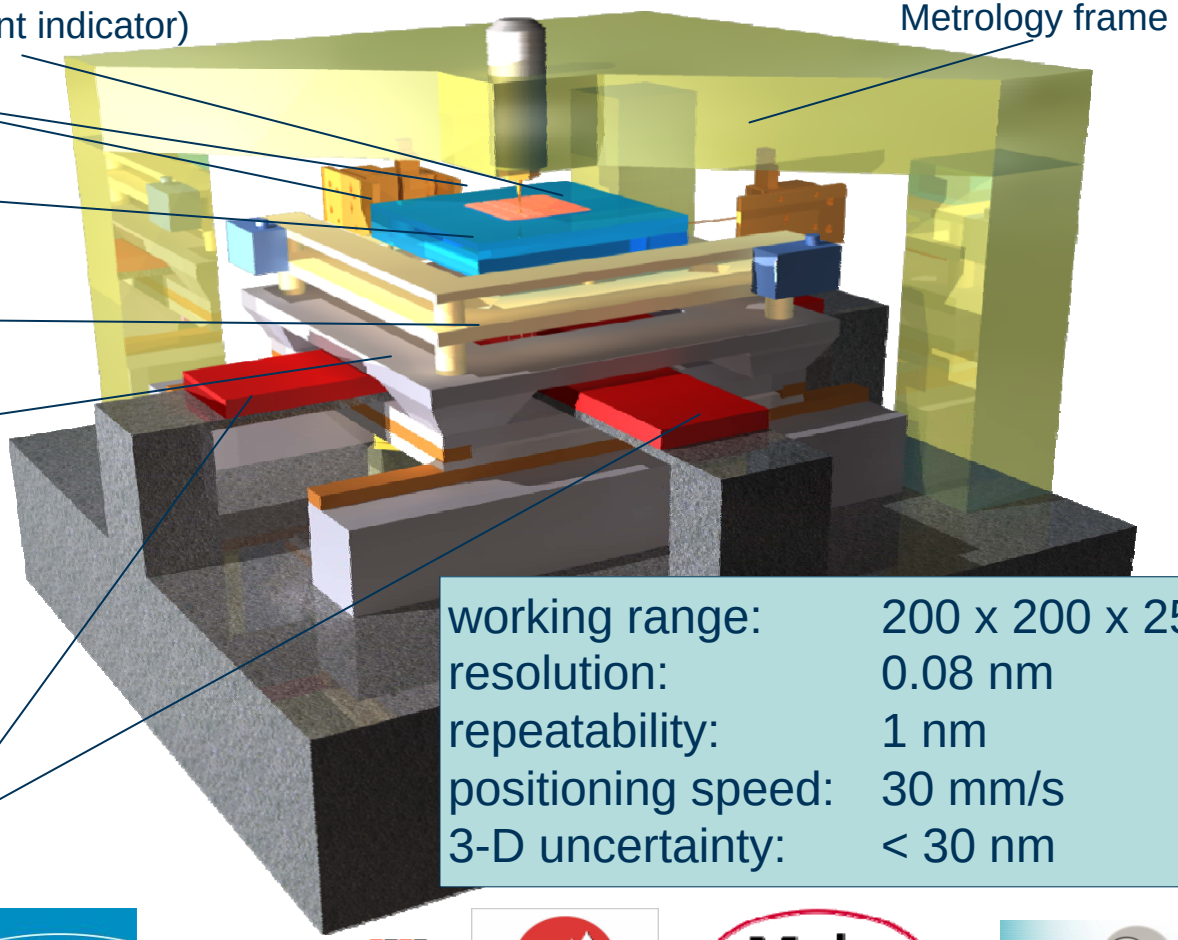


METAS Switzerland:

Absolute diameter and sphericity calibration of three sapphire spheres

of micro-balls

Nanopositioning and Nanomeasuring Machine NPMM-200



working range:	200 x 200 x 25 mm³
resolution:	0.08 nm
repeatability:	1 nm
positioning speed:	30 mm/s
3-D uncertainty:	< 30 nm

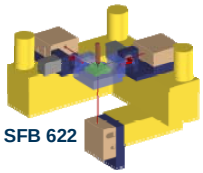
Acknowledgements

DFG: Collaborative Research Centre SFB 622:
Nanopositioning and Nanomeasuring Machines

EU FP6 Project: NanoCMM

SIOS Meßtechnik GmbH

all colleagues at the Ilmenau University of Technology



Thank you for your attention!