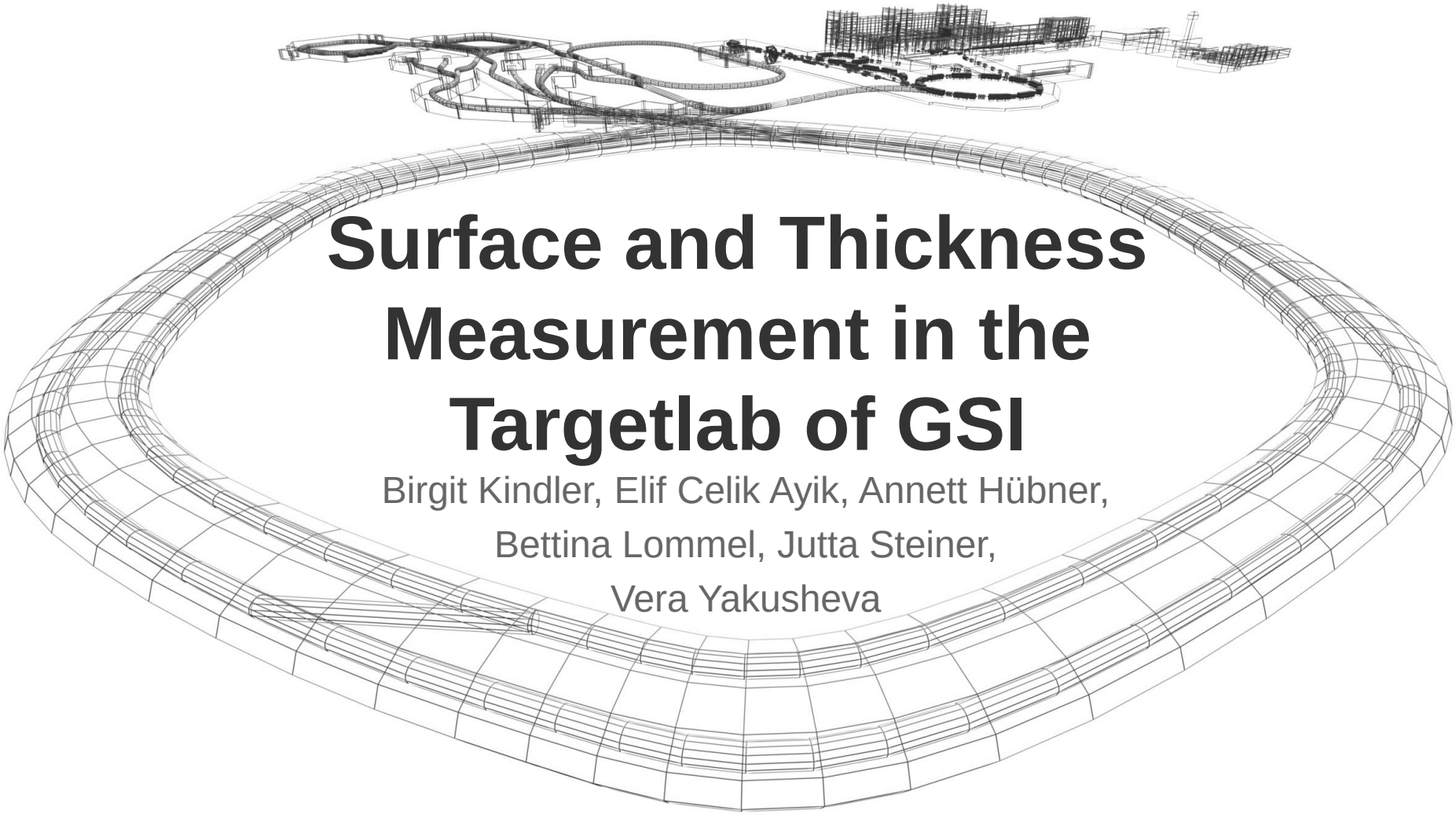
GSI Helmholtzzentrum für Schwerionenforschung GmbH



Surface and Thickness Measurement in the Targetlab of GSI

Birgit Kindler, Elif Celik Ayik, Annett Hübner,
Bettina Lommel, Jutta Steiner,
Vera Yakusheva

Outline

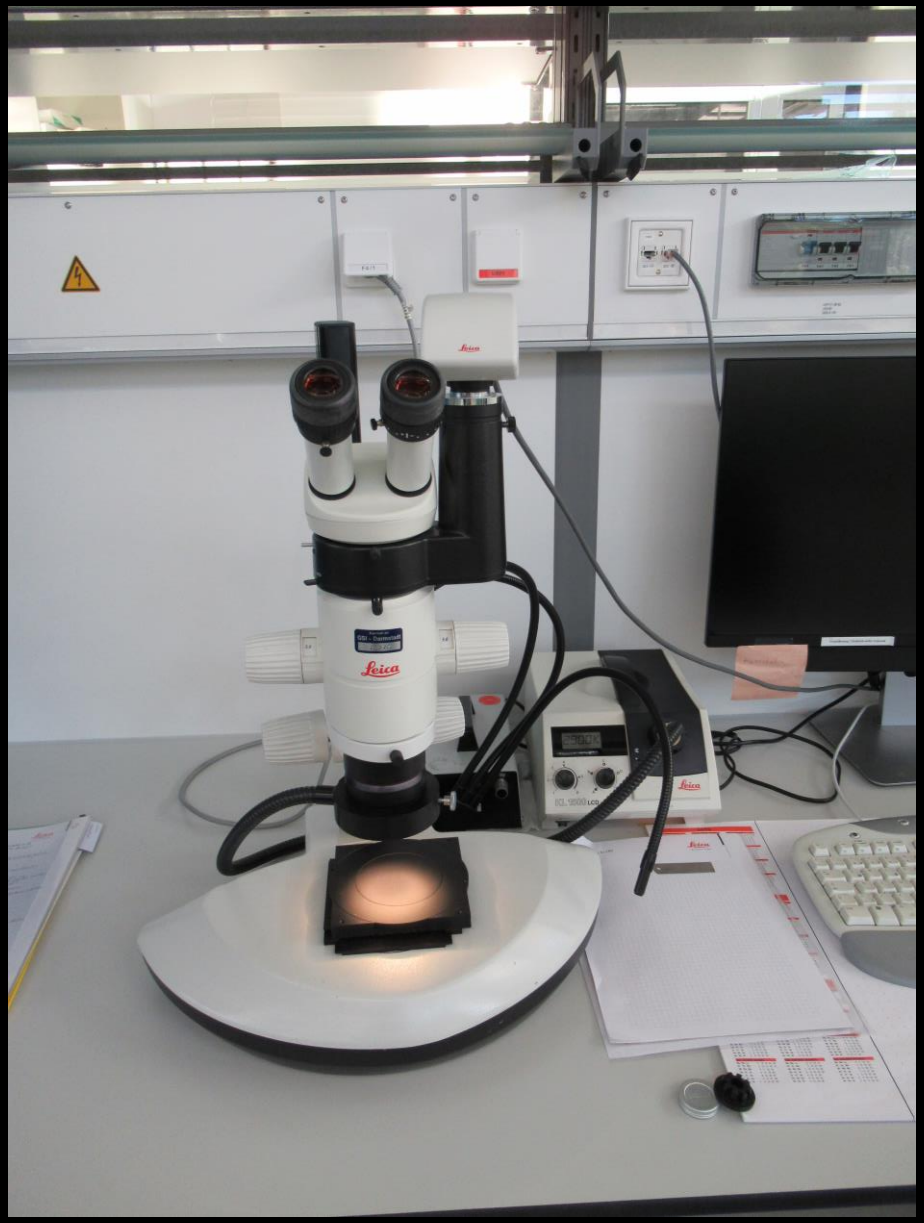
- Introduction
- Analytical Tools
- MicroProf®
  - System features
  - Measuring principle
- Examples of Applications
- Future Perspectives

Introduction

- Role of Analytics at GSI Targetlab
  - Quality control of samples produced in the lab
    - Weight
    - Thickness
    - Surfaces
      - Topology
      - Roughness
    - Composition
    - Impurities
  - Documentation of sample parameters
  - Analytics for internal and external customers

Analytical Tools

- Optical Microscopes with image acquisition software
  - Leitz and Leica



Stereo Zoom-Microscope
Magnifcation 6.3x – 50x

Orthoplan Largefield Microscope
Magnifcation 25.6x – 640x

Analytical Tools

- Optical Microscopes with image acquisition software
  - Leitz and Leica
- Balances
  - Mettler Toledo: Several analytical balances in different ranges and one microbalance

Microbalance UMX2
Readability 0.1 µg / reproducibility ± 0.25 µg

Analytical Balance XPE206DR
Readability 0.01 mg / reproducibility ± 0.015 mg

Analytical Tools

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- Length Gauges
  - Heidenhain: Two with 60 mm, two with 10 mm travel; ± 0.5 µm accuracy each

10 mm travel; ± 0.5 µm accuracy

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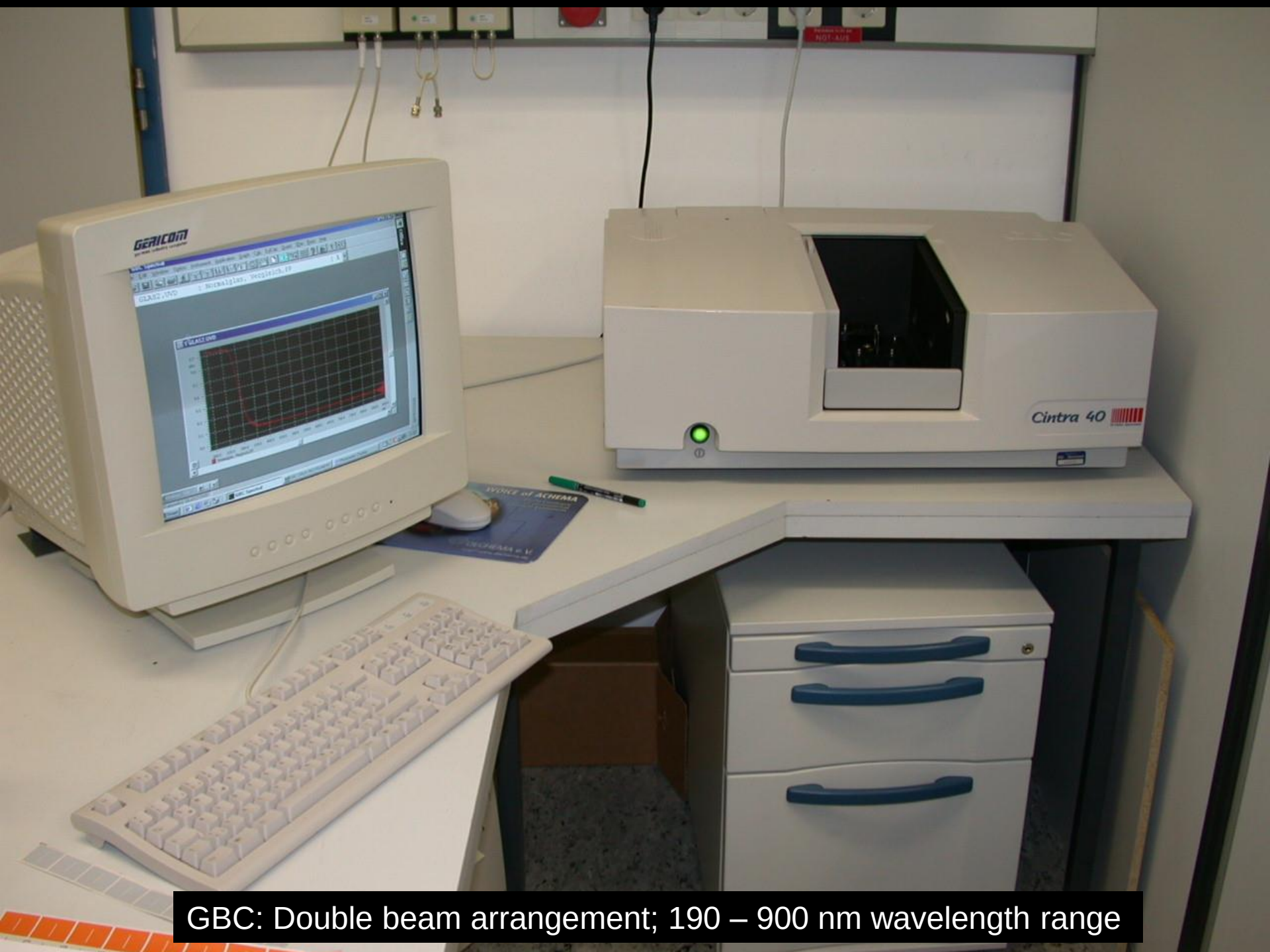
- UV-vis Spectralphotometer
  - GBC: Double beam arrangement; 190 – 900 nm wavelength range



GBC: Double beam arrangement; 190 – 900 nm wavelength range

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  - Philips: upgrade of detector and control software

PHILIPS
EDAX
UNLOCK
CHERRY

Analytical Tools

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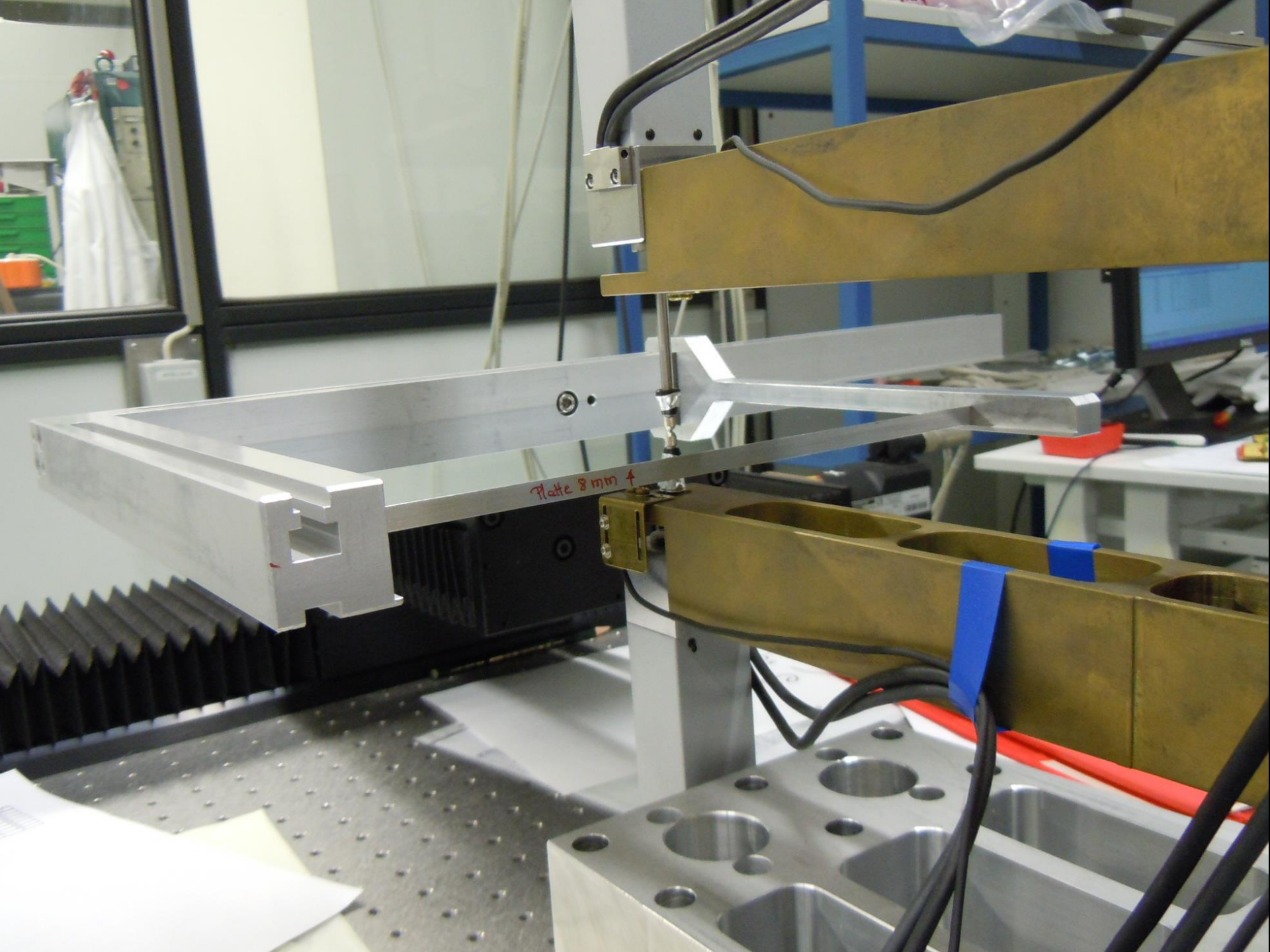
- Target Scanner
  - Self-construction from scratch for surface and thickness measurement

Newport
Newport


Platte 8mm

Analytical Tools

- Optical Microscopes with image acquisition software
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- Target Scanner
  - Self-construction from scratch: Surface and thickness measurement, mechanical sensors
- MicroProf®
  - FRT: Surface and thickness measurement, optical sensors

Der chromatische Sensor
Chromatischer Sensorem: Funktionsweise
Probenträger 2 PT2
acer

MicroProf® - System Features - Hardware

- Multi-sensor concept by FRT GmbH
- xy-table with 420 mm x 310 mm travel
  - defines measurable sample area
  - mounted on pneumomechanical isolation system for stability
- z-axis: 160 mm travel
  - defines maximum sample height
- CCD positioning camera
- Chromatic point sensors
  - 600 µm measuring range
    - working distance 6.5 mm
    - max. z-resolution 200 nm, xy-resolution 1-2 µm
    - measuring angle ~ 90° ± 30° (more for scattering surfaces)
    - 2 vertically aligned in TTV arrangement for thickness measurement
  - 25 mm measuring range (only surface measurement)
    - working distance 80 mm
    - max. z-resolution 8 µm, xy-resolution 14 µm
    - measuring angle ~ 90° ± 15° (more for scattering surfaces)

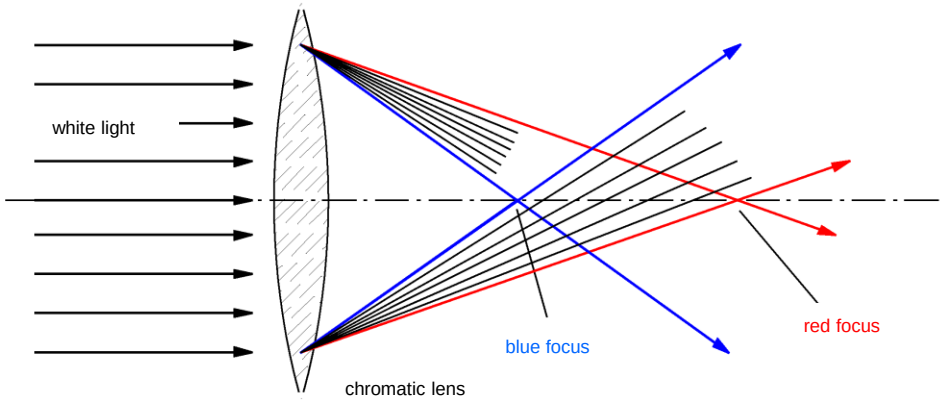
MicroProf® - System Features - Software

- Acquire
  - Controls metrology tools and all sensors
  - Allows fast and easy manual measurements
  - Measurements in 1D (line) or 2D (area)
  - Quick impression of measurement data of both surfaces and of thickness for Total Thickness Variation (TTV) setup

- Mark III
  - Analysis software for the evaluation of surface and profile measurements
  - Allows the easy and efficient evaluation of surface structures and parameters
  - Versatile 3D view represents the surface data in realistic detail

MicroProf® - Measuring Principle

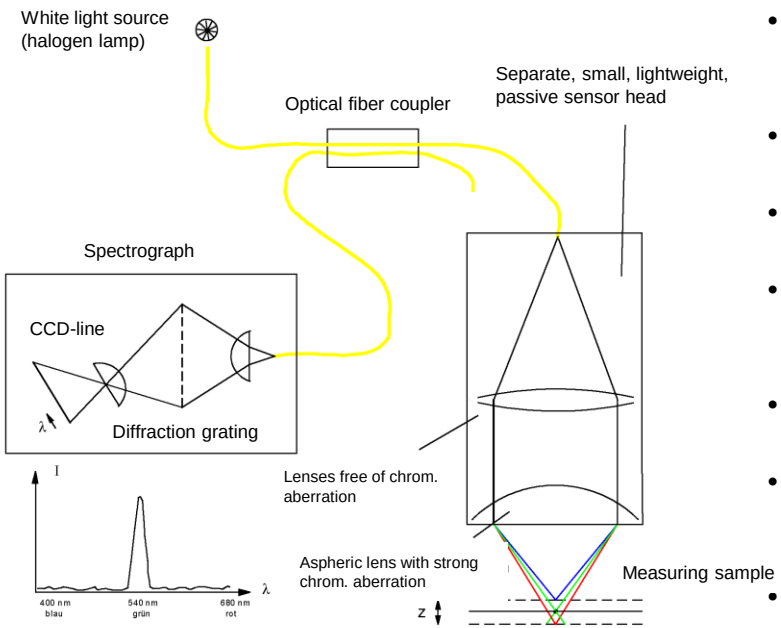
The Chromatic Sensor



- Principle: Confocal point sensor without a moveable lens
- Taking advantage of the wavelength dependence of the diffraction index n of the lens material: chromatic aberration

MicroProf® - Measuring Principle

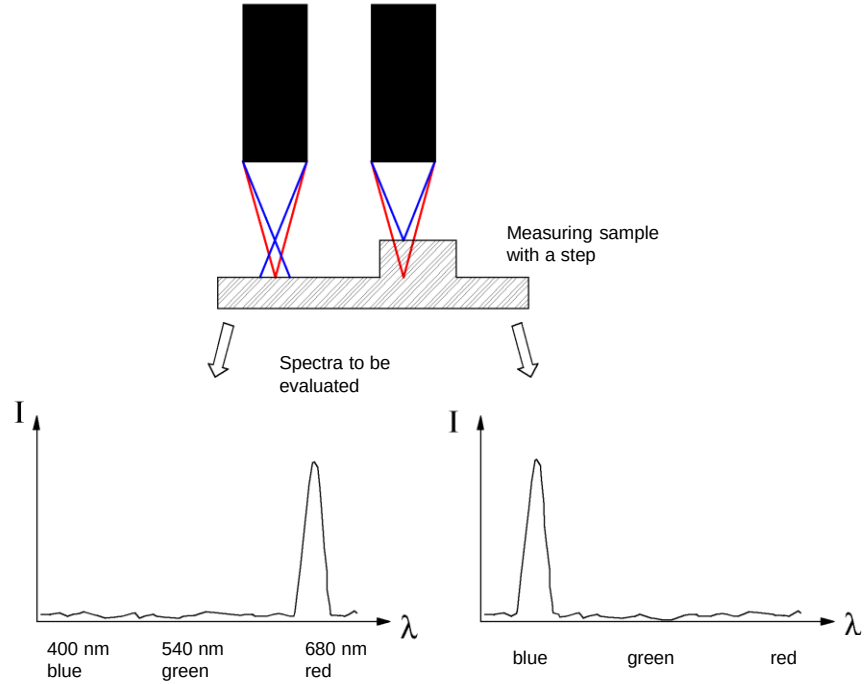
Chromatic sensors: Measuring principle



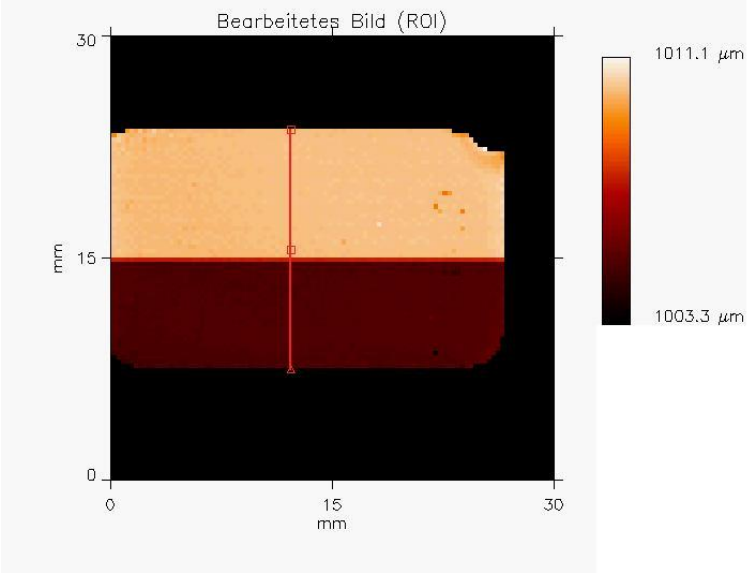
- Fibre transfers light from source of white light to measuring head
- End face of fibre serves as aperture (pin hole)
- One focus for each wavelength
- Confocal imaging is fulfilled for only one wavelength
- Peak in spectrum
- Evaluation of the signal hight at peak wavelength
- 3D-measurement by scanning in x- and y-direction

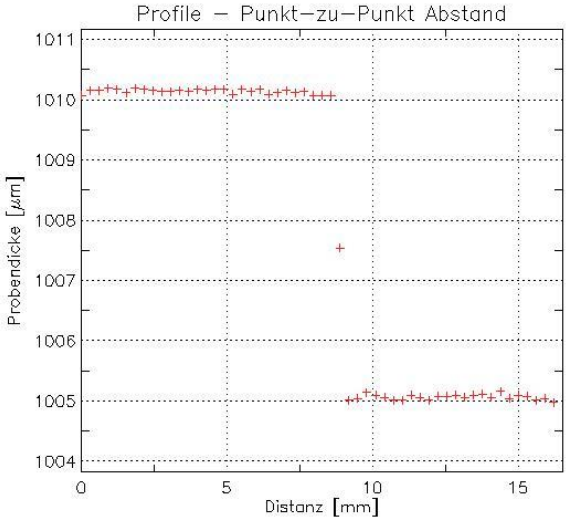
MicroProf® - Measuring Principle

Chromatic sensors: Measuring principle



Examples of Applications – System Test

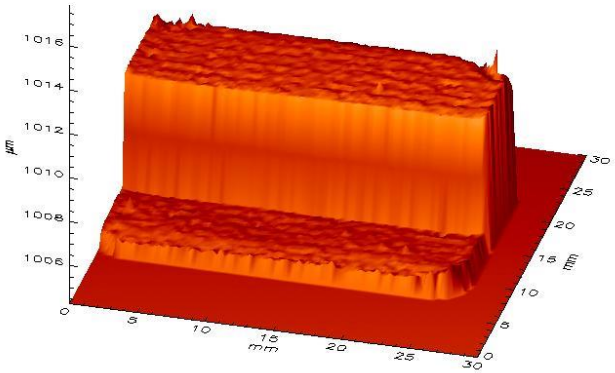




2D-plot of color-coded thickness with a profile line (red vertical line)

Thickness values along the red profile line normal to the edge

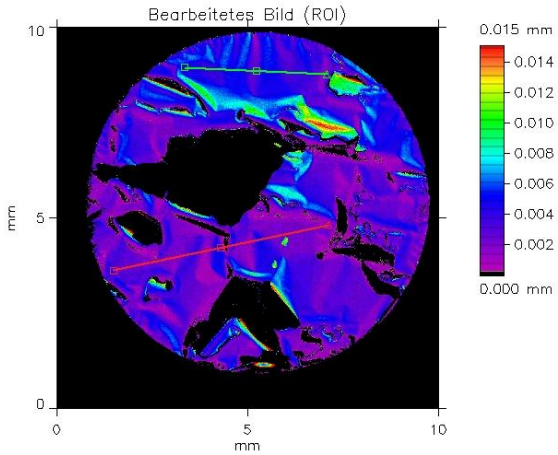
Test step with two standard stainless steel measures of 1.01 mm and 1.005 mm thickness



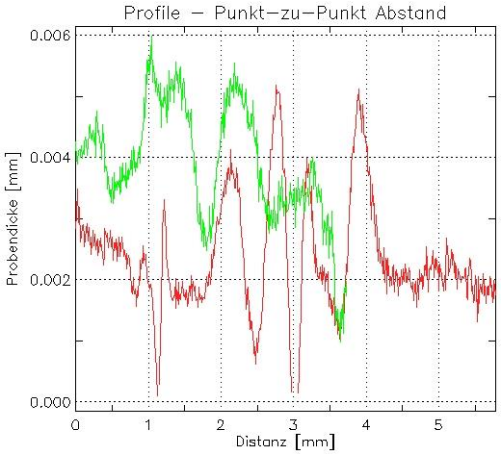
3D-plot of measured thickness

Examples of Applications – Inspection and Characterization of Targets

Fotorealistic view



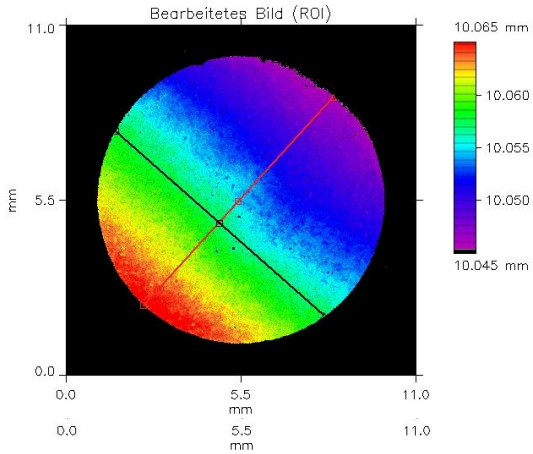
Color-coded thickness

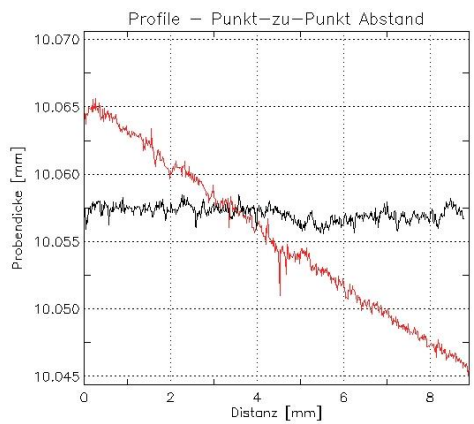


Thickness along profile lines

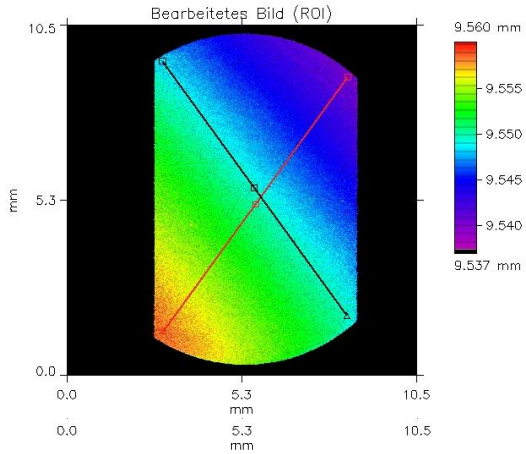
PbS-target on C-backing (~ 400 µg/cm²). Even qualitative characterization of nearly destroyed thin targets is possible.
Absolute thickness determination of such thin films not reliable!

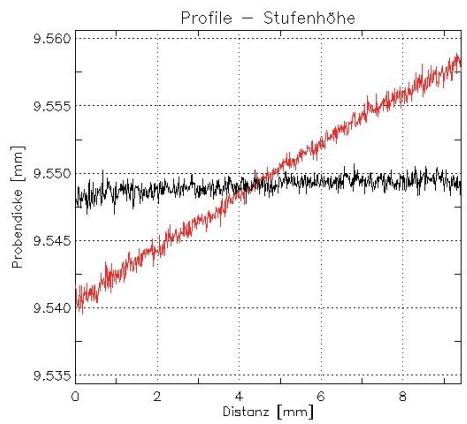
Examples of Applications – Monitoring Sample Preparation Steps



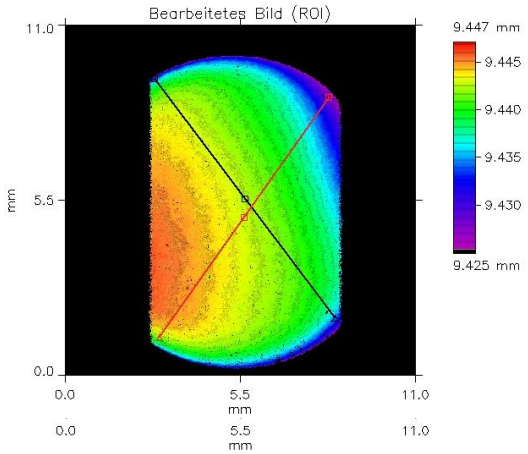


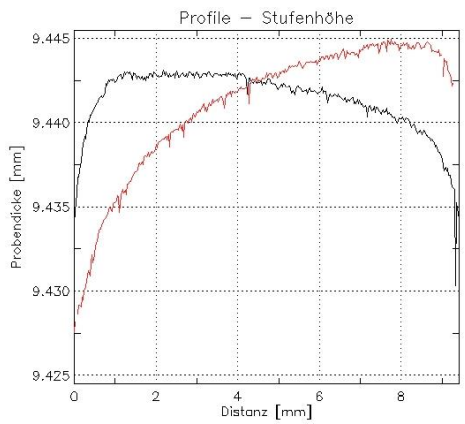
Unmachined, as cut





Both surfaces lapped

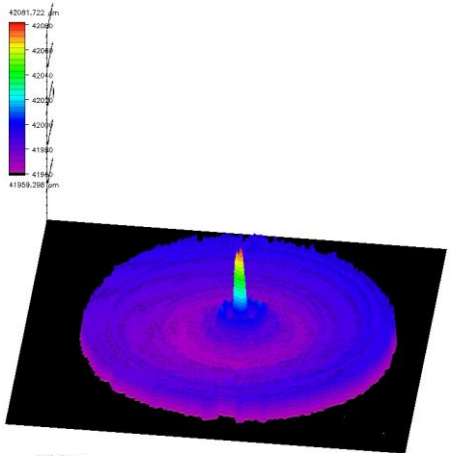


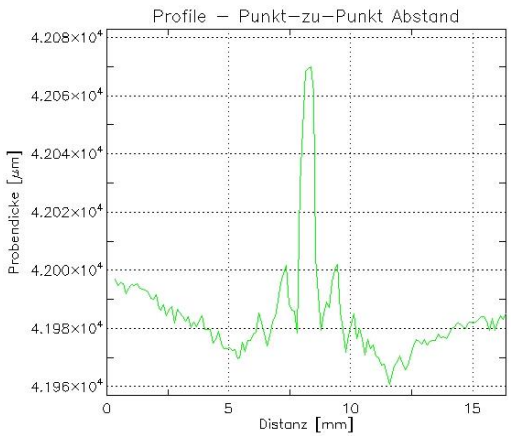


Both surfaces polished

Carbon sample with 10 mm thickness measured in different preparation steps

Examples of Applications – Monitoring Sample Preparation Steps

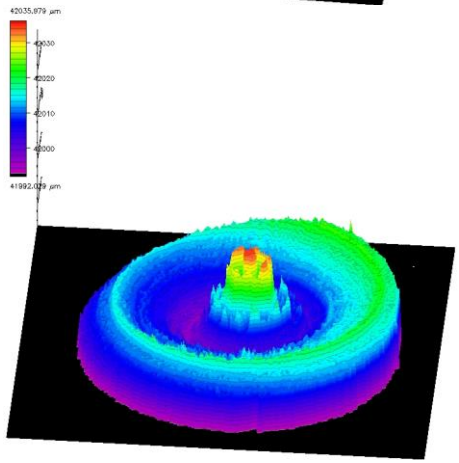


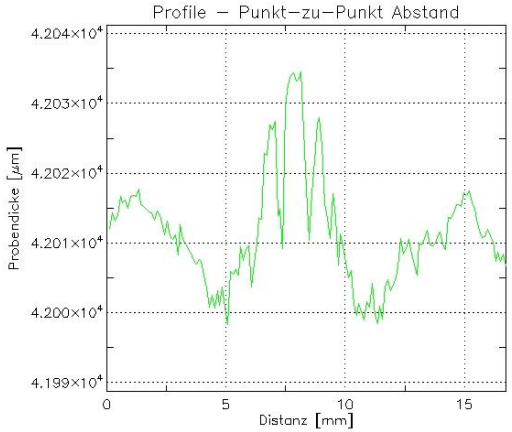


Lathed in workshop from a rod

Statistical evaluation

Mean thickness:	41982.240 µm
Minimum:	41961.227 µm
Maximum:	42071.490 µm
Standarddev:	**7.741 µm**





Polished by hand in a next step

Statistical evaluation

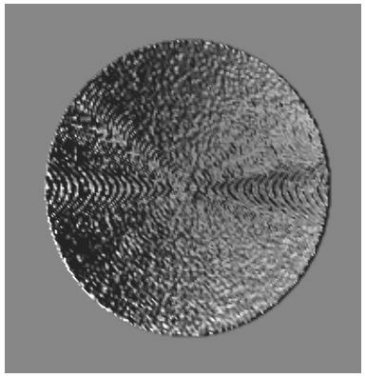
Mean thickness:	42010.312 µm
Minimum:	41993.444 µm
Maximum:	42034.511 µm
Standarddev.:	**5.954 µm**

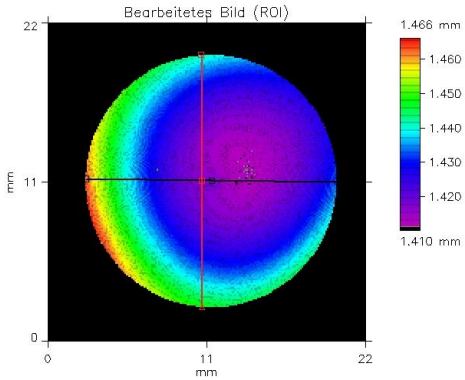
Color-coded thickness 3D-view

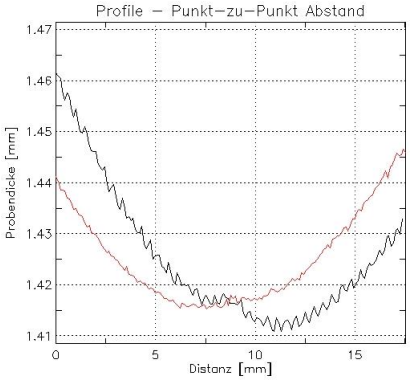
Thickness values along a line through the centre

PE-targets with 4 g/cm² equivalent to ~ 42 mm thickness

Examples of Applications – Qualitiy Control of Purchased Targets



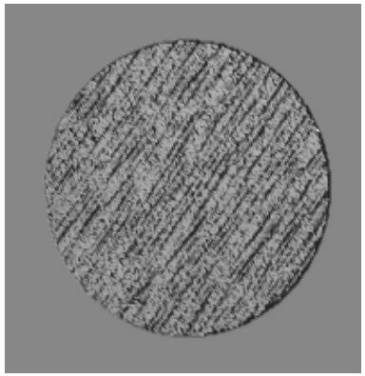


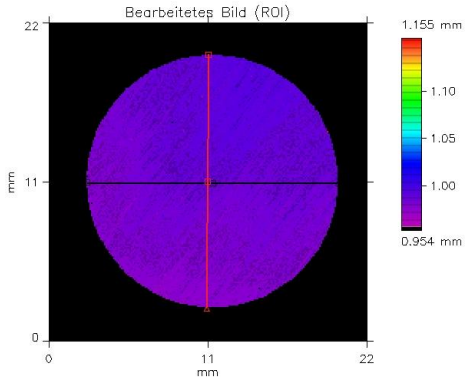


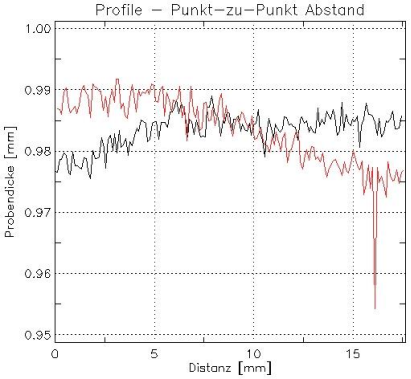
Nominal thickness 1.46 mm

Statistical evaluation

Mean thickness	**1.429 mm**
Minimum:	1.411 mm
Maximum:	1.464 mm
Standarddeviat.:	**0.012 mm**







Nominal thickness 1.0 mm

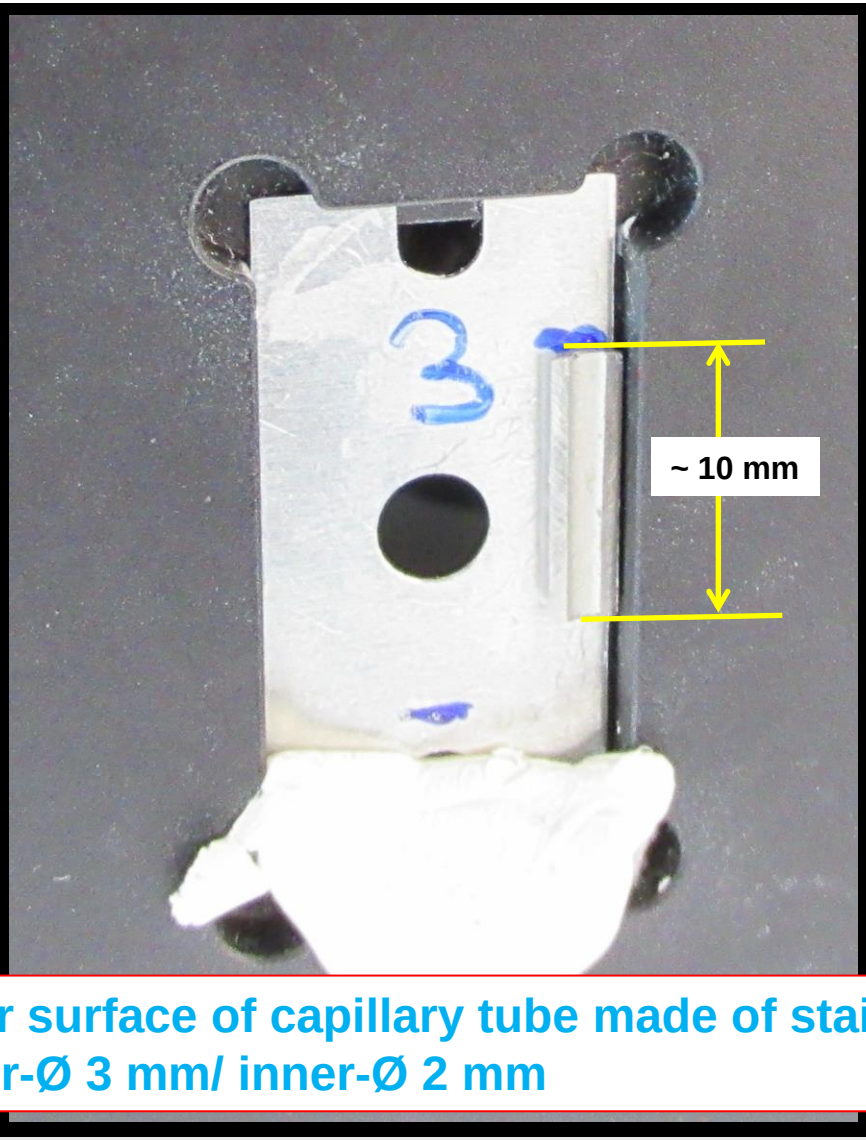
Statistical evaluation

Mean thickness	**0.983 mm**
Minimum:	0.970 mm
Maximum:	0.994 mm
Standarddeviat.:	**0.004 mm**

Foto-realistic view **Color-coded thickness** **Thickness values along the profile lines**

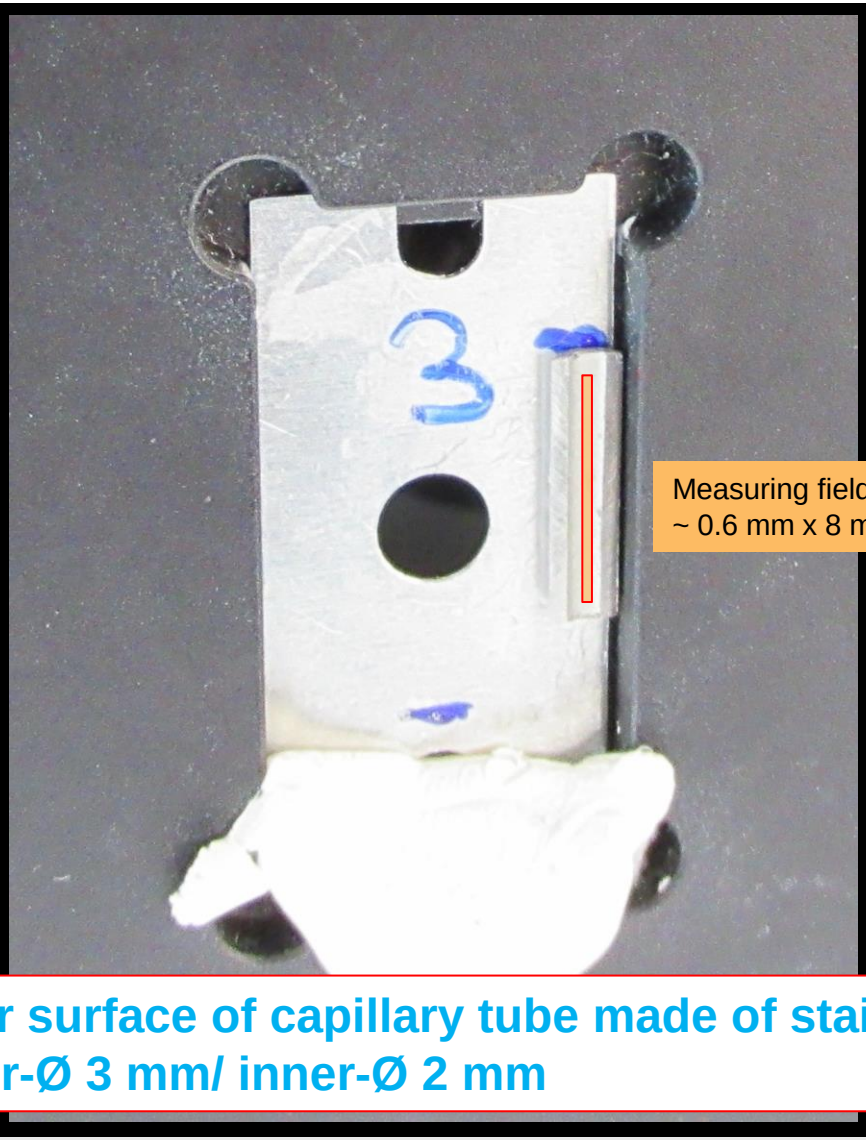
Quality control of bought Beryllium targets with thickness ~ 1 mm

Examples of Applications – Rougness Determination of Tube Wall



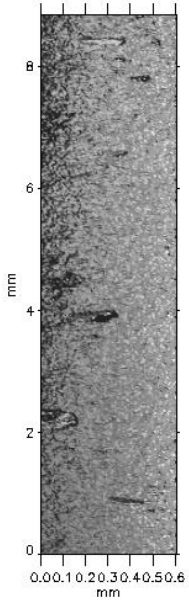
Roughness of inner surface of capillary tube made of stainless steel, length 10 mm, outer-Ø 3 mm/ inner-Ø 2 mm

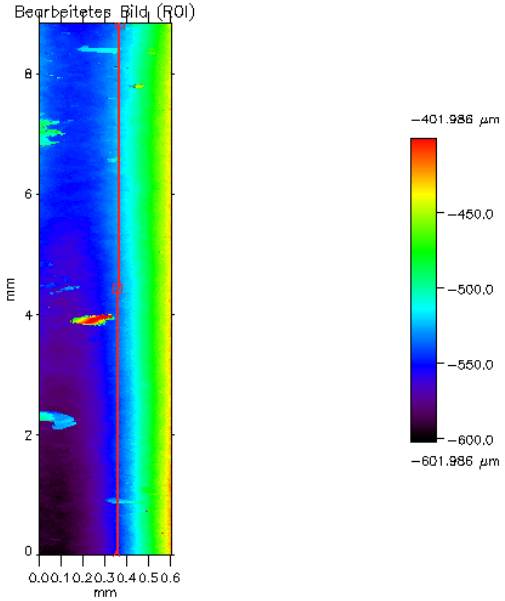
Examples of Applications – Rougness Determination of Tube Wall



Roughness of inner surface of capillary tube made of stainless steel, length 10 mm, outer-Ø 3 mm/ inner-Ø 2 mm

Examples of Applications – Rougness Determination of Tube Wall





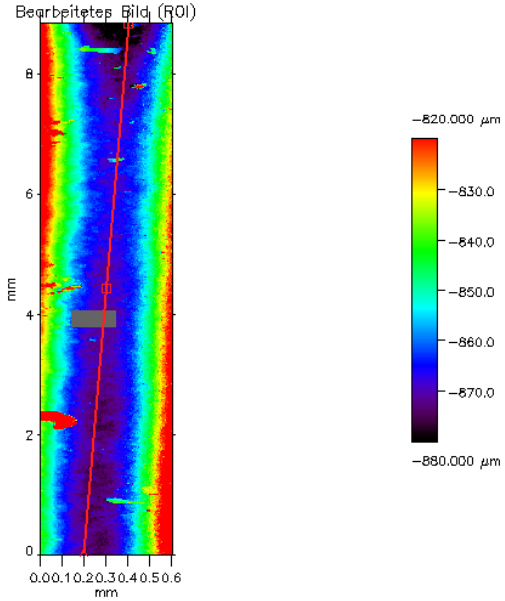
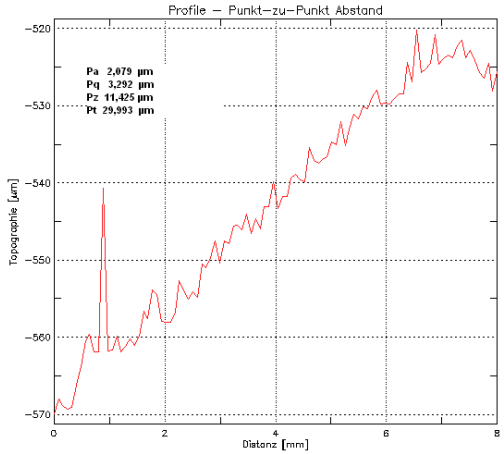


Foto-realistic view

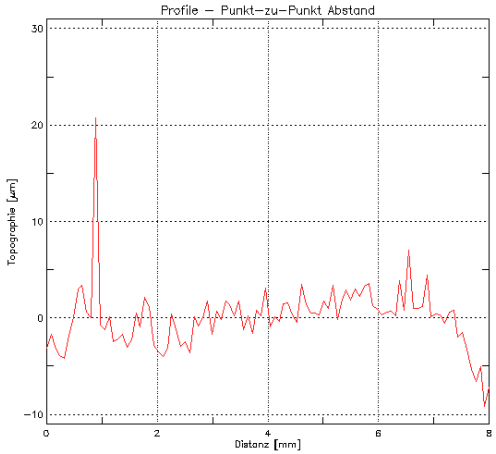
Color-coded thickness with profile line along the „valley plane“ (red line) as measured

after level substraction and masking

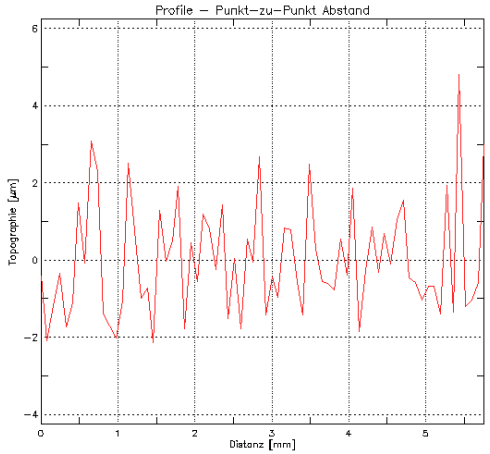
Examples of Applications – Rougness Determination



Suface profile as measured



... after level substraction

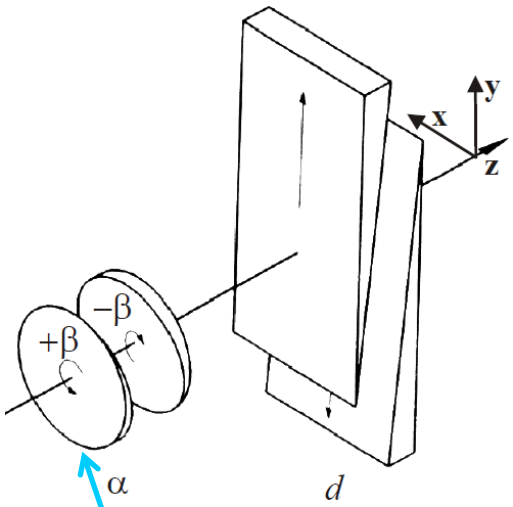


... after applying roughness evaluation

Surface parameter evaluated according to DIN EN ISO 4287:
Ls = 0.000 µm, Lc = 1.143 mm
x = [1.143 mm, 6.858 mm]

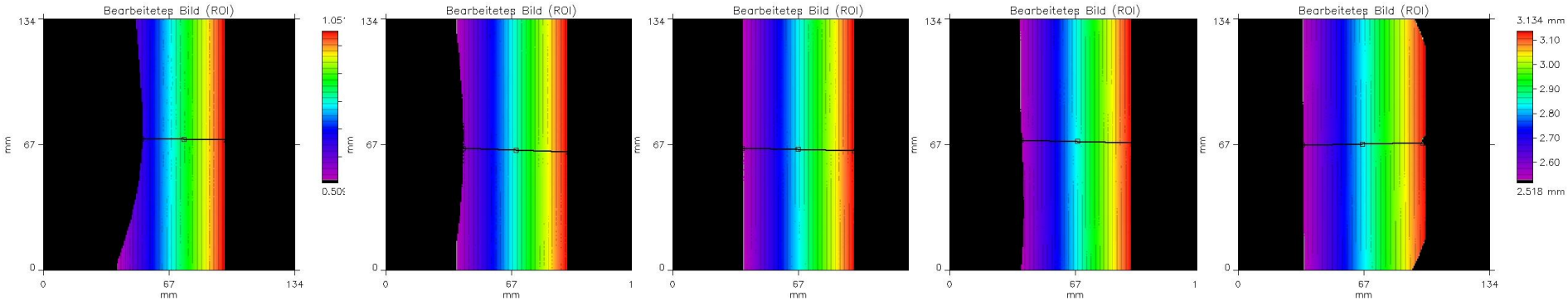
Ra:	**1.159 µm**
Rq:	**1.423 µm**
Rz(ISO):	**5.076 µm**
Rz(DIN):	**4.955 µm**
Rmax:	**6.184 µm**
Rsk:	**0.843**
Rku:	**3.185**

Examples of Applications – Quality Control of large complicated Devices

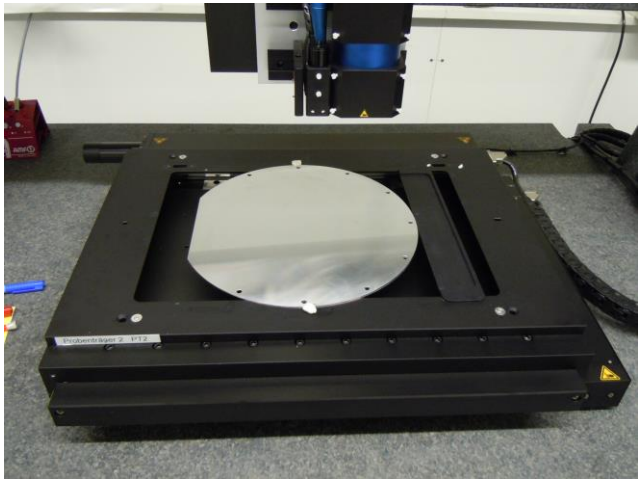


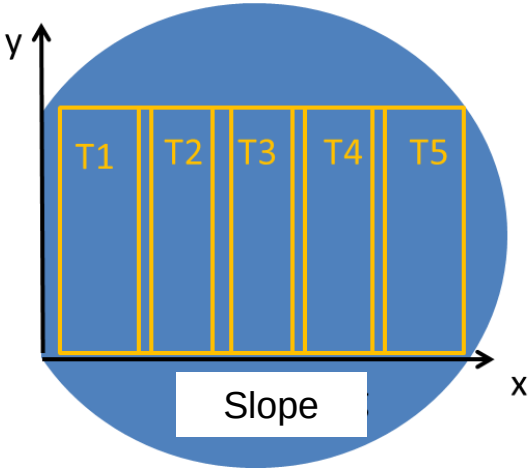
Thickness of <u>Al-wedge disk degrader</u> (Ø 330 mm, 0.5 mm – 3.2 mm specified) – Ion-optical elements for the Fragment Separator

Examples of Applications – Wedge Degrader



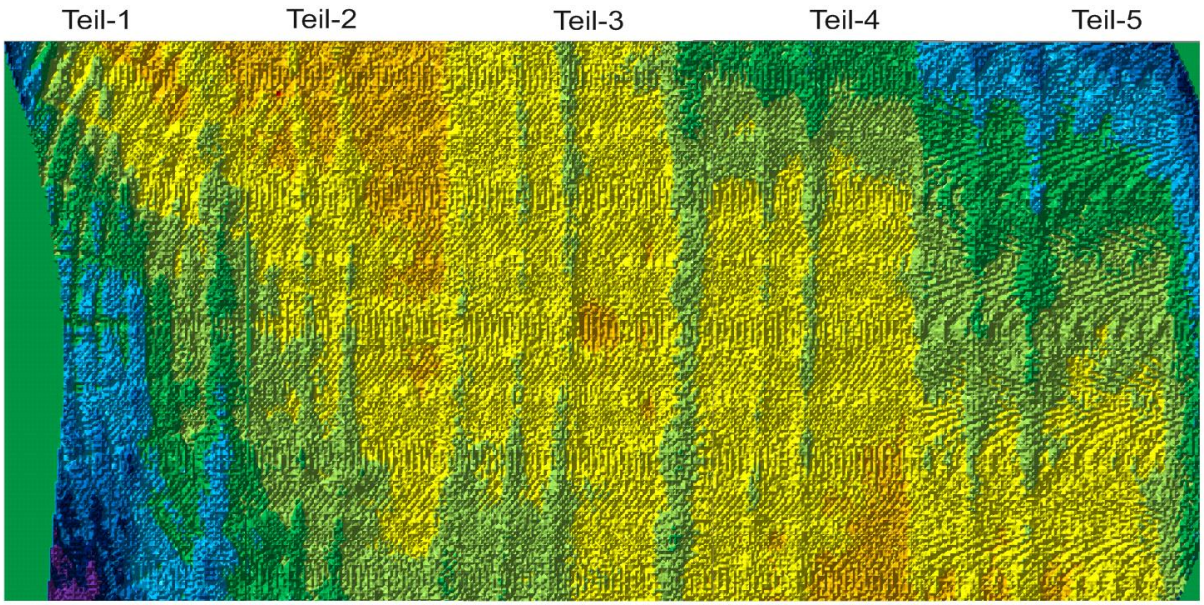
T1 T2 T3 T4 T5





Quality control of externally produced parts.
Due to restricted measuring range of 0.6 mm of sensors measured in 5 overlapping parts

Examples of Applications – Wedge Degrader



Δz [µm]

5 .. 4	0 .. -1
4 .. 3	-1 .. -2
3 .. 2	-2 .. -3
2 .. 1	-3 .. -4
1 .. 0	-4 .. -5

scanned area: 280 mm x 134 mm
slope_x = 0.09242 (design value 0.00945)
slope_y = 0.00028 (3 mrad rotated)
deviation from perfect wedge σ_z = 1.7 µm

Measured thickness data of the separate measurements assembled and fitted by Helmut Weick, FRS-group of GSI.

Perspectives

- Exploring and extending the possibilities of the current system

- Extending the potential of device possibly with additional sensor head:
  - AFM (Atomic Force Microscopy)
  - WLI (White Light Interferometer)
  - Thin Film sensor
  - Film thickness sensor
  - Confocal Microscope
  - ...