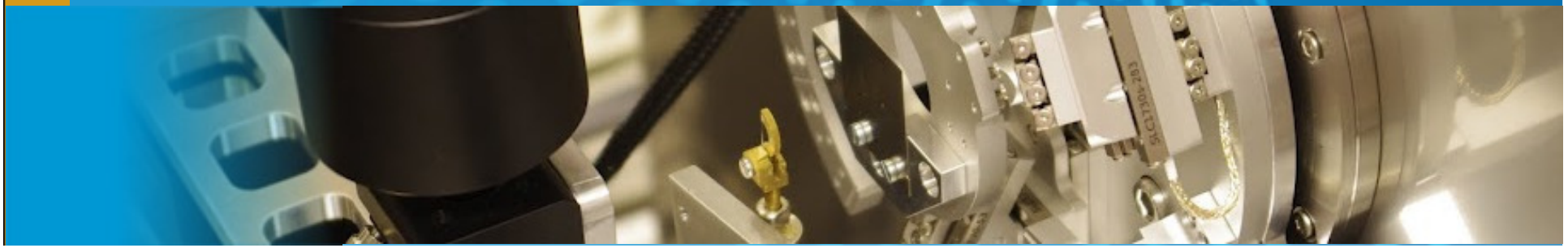
Christina Krywka

X-ray nanodiffraction meets materials science

Röntgen-Nanodiffraktion in der Materialforschung



Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

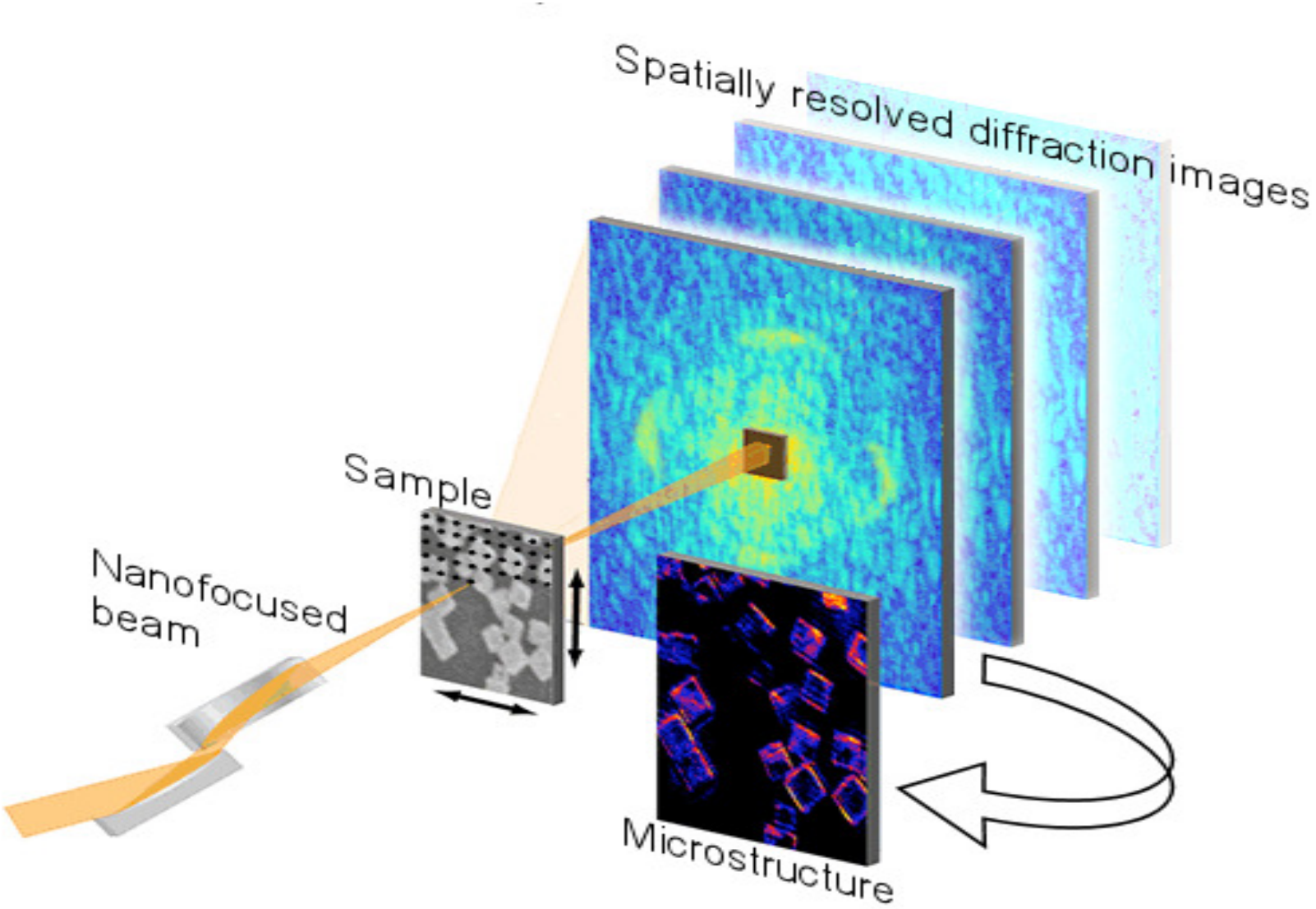
outline

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- „the why“ of nanodiffraction
- „the how“ of nanodiffraction
- nanodiffraction experiments

- German Engineering Materials Science Center

scanning nanodiffraction



scanning nanodiffraction

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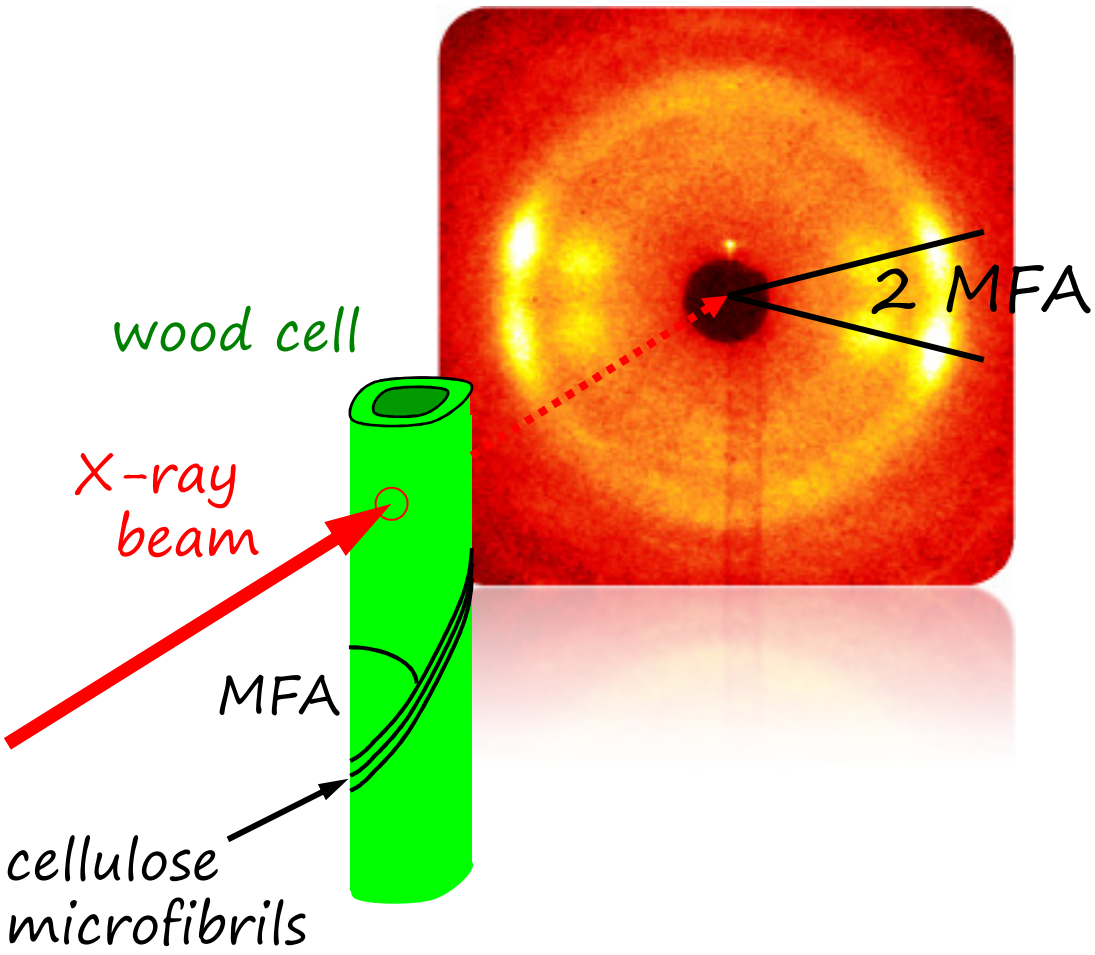
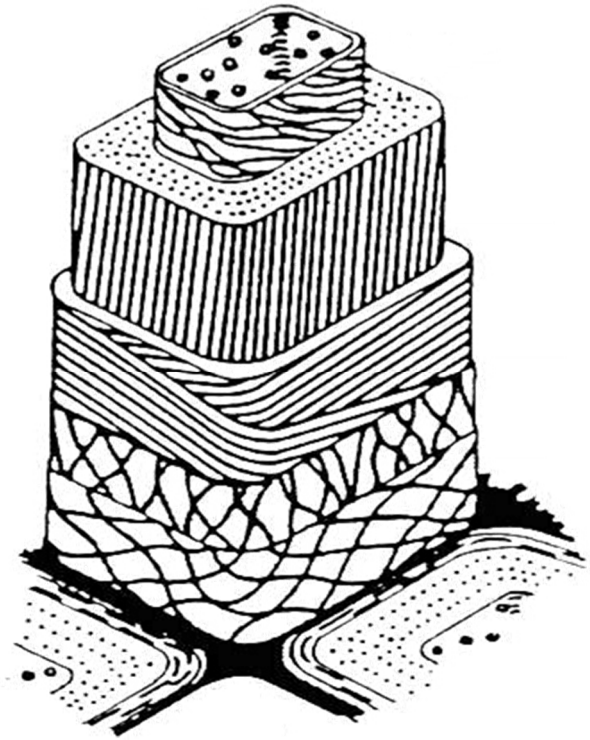
Zentrum für Material- und Küstenforschung





scanning nanodiffraction

Helmholtz-Zentrum
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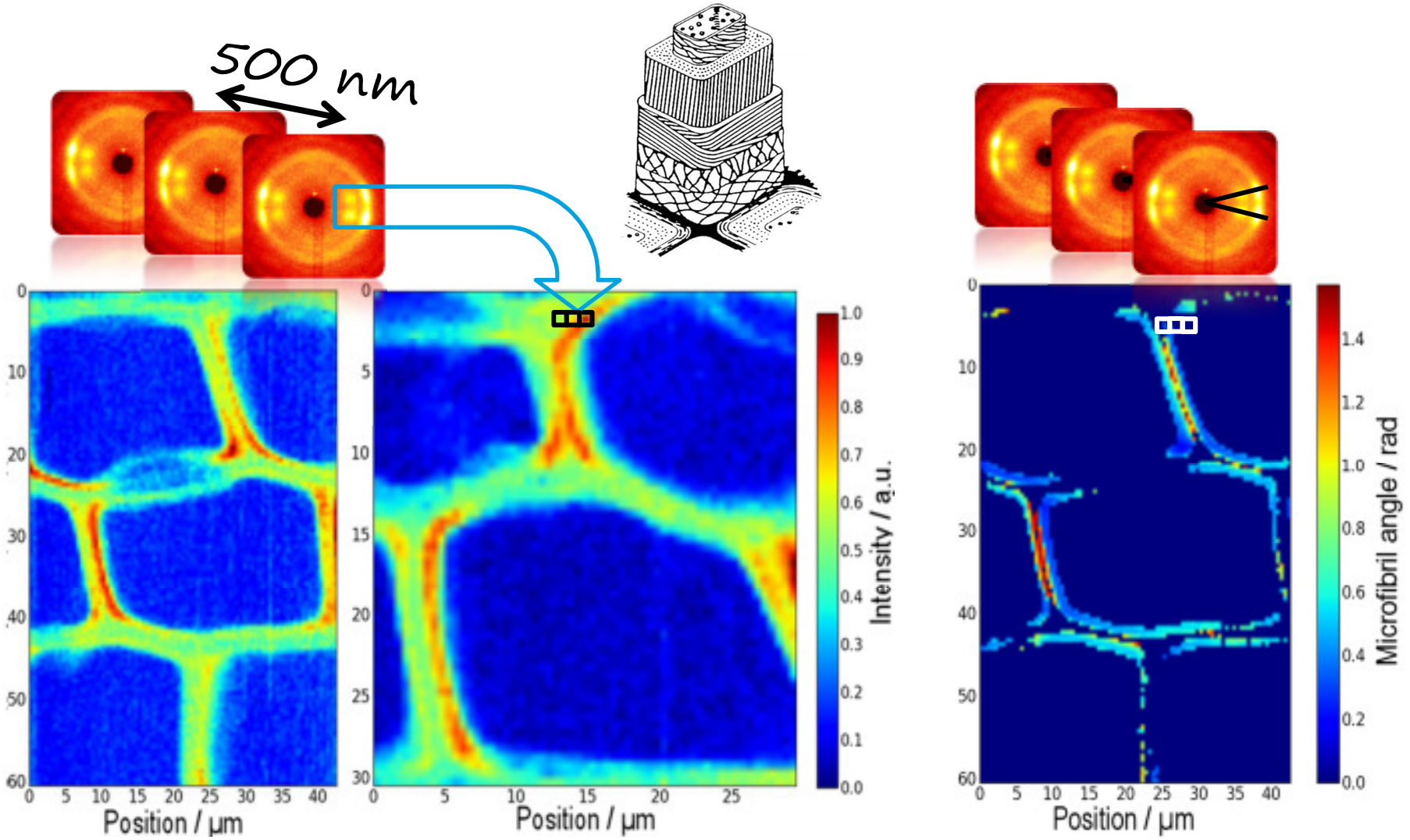
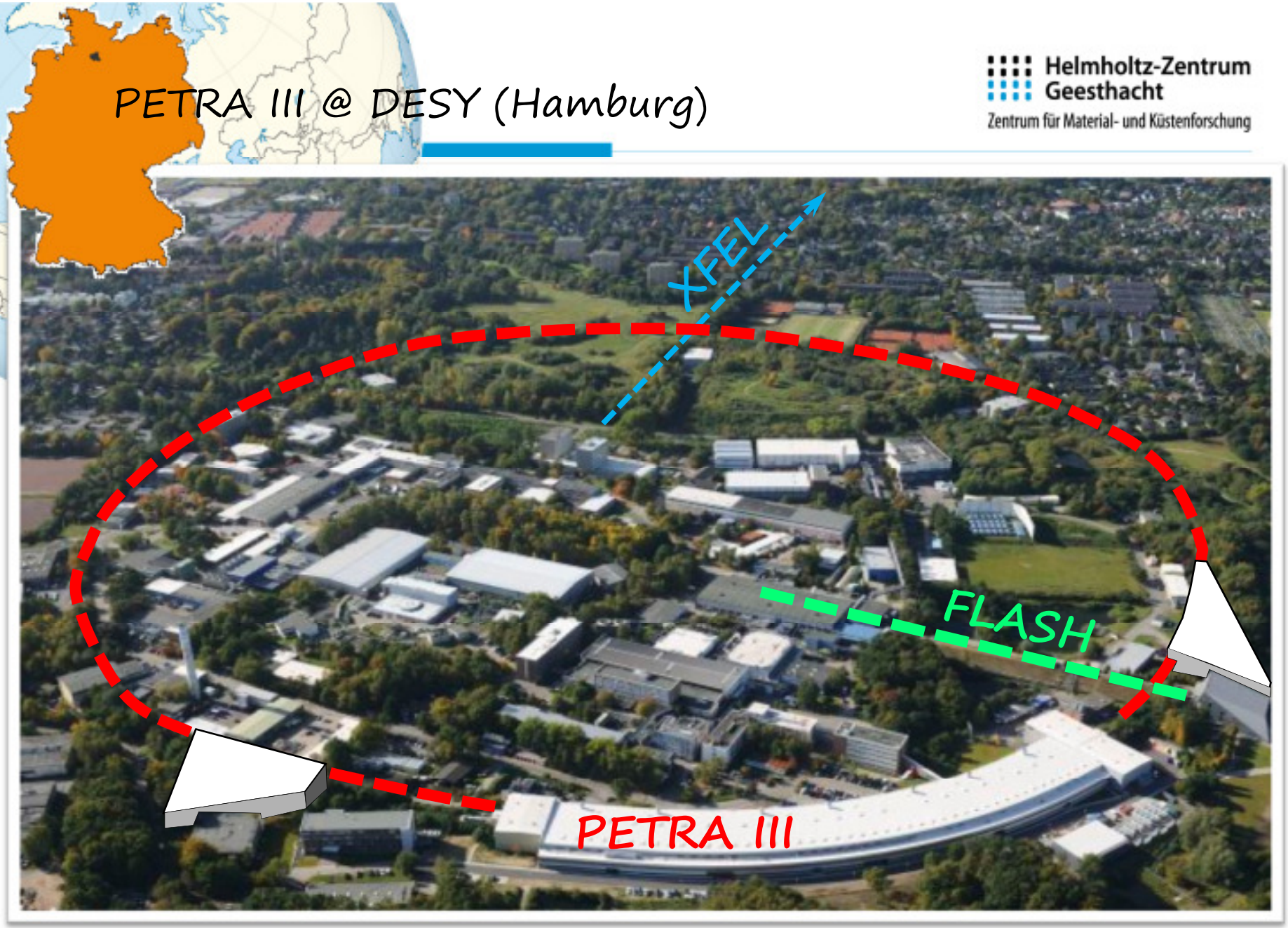


S. Storm, Master Thesis, University of Kiel (2012)

PETRA III @ DESY (Hamburg)

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Nanofocus Endstation @ P03

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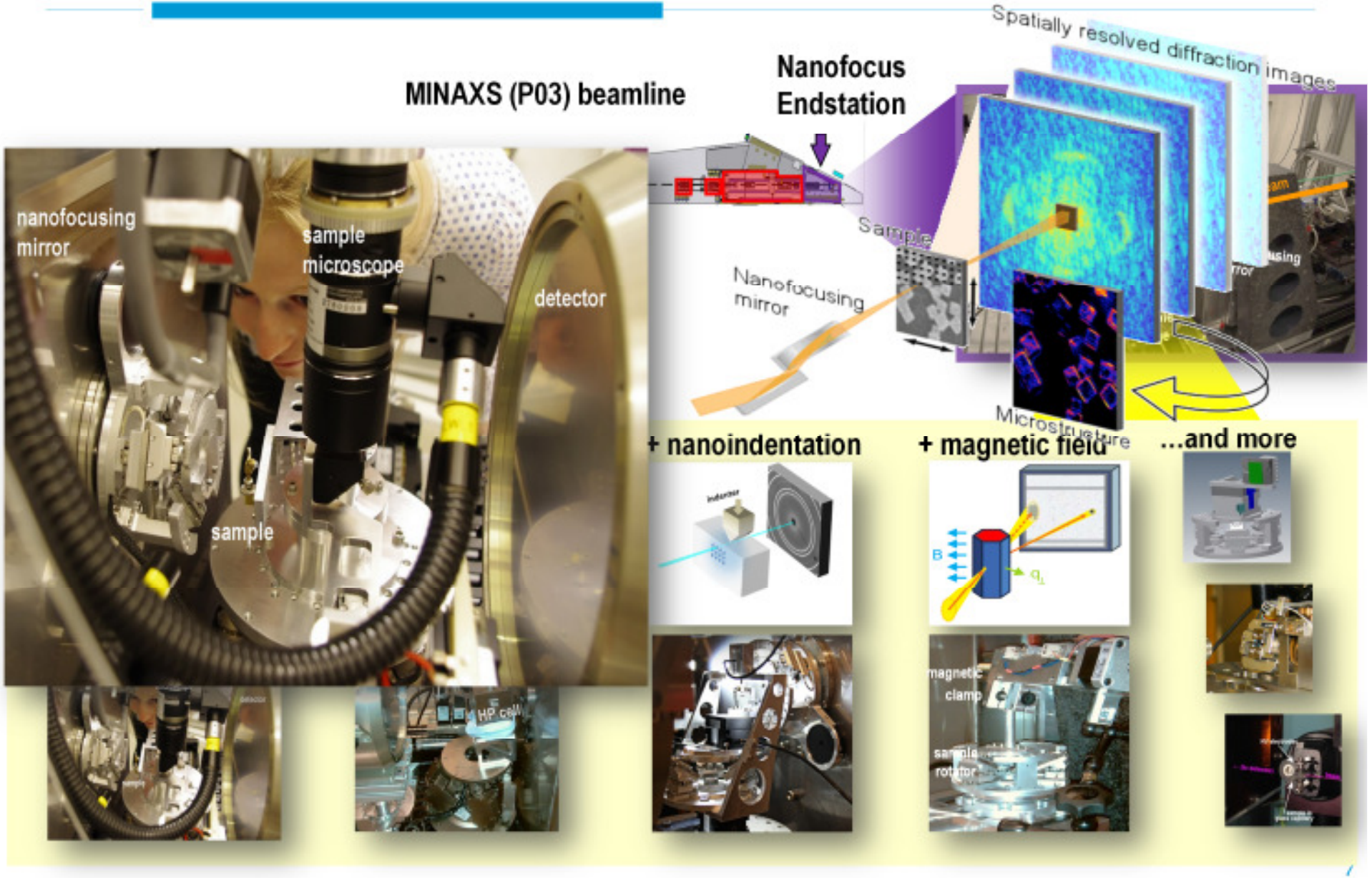

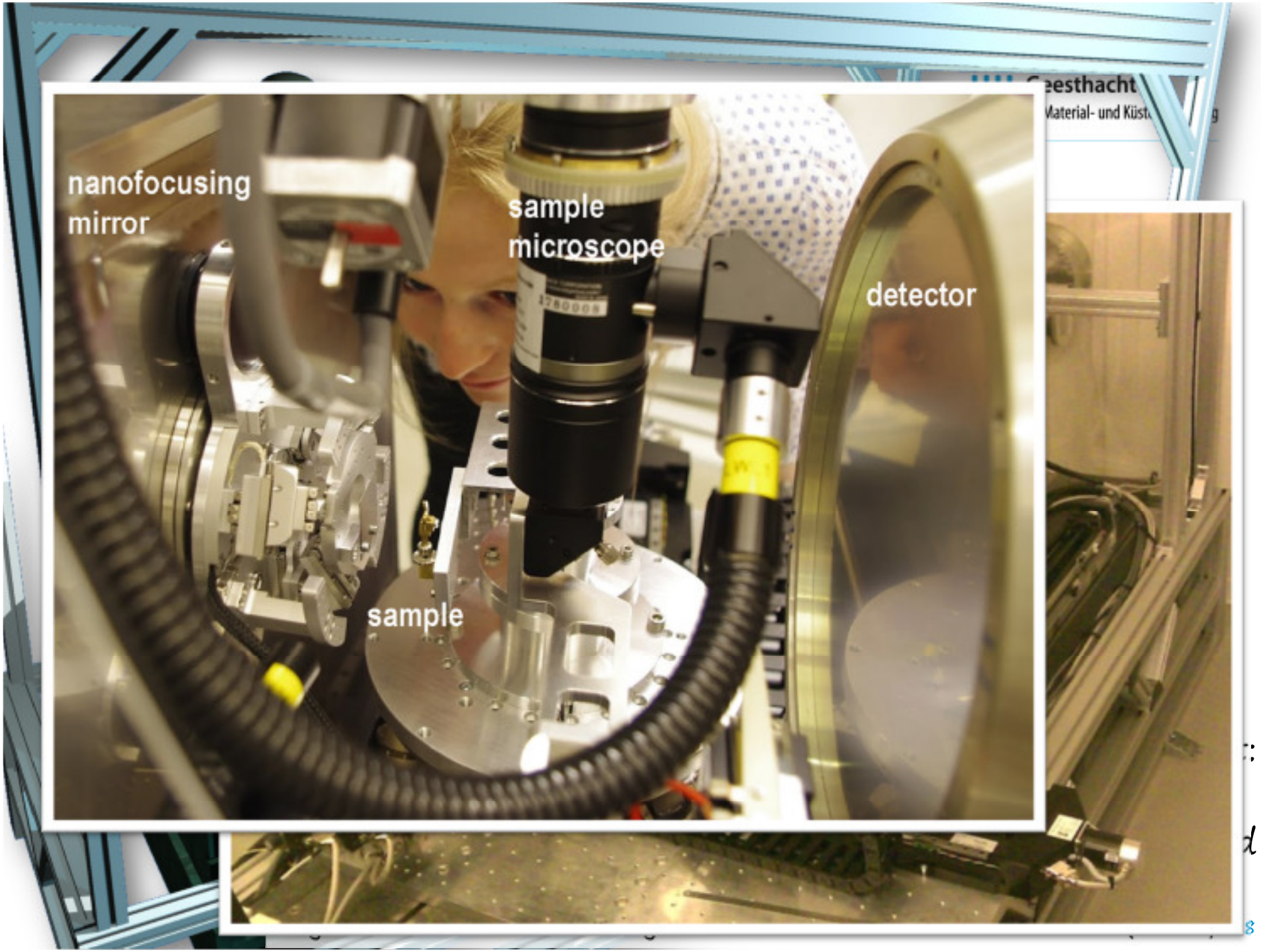
nanofocusing
mirror
sample
microscope
detector
sample

„static“ nanodiffraction

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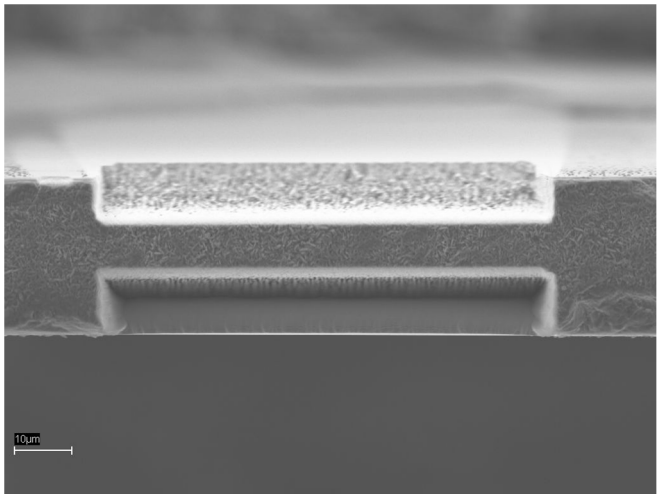
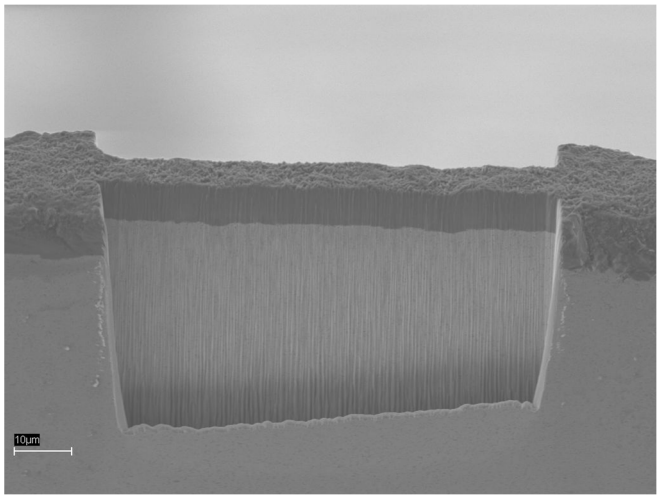
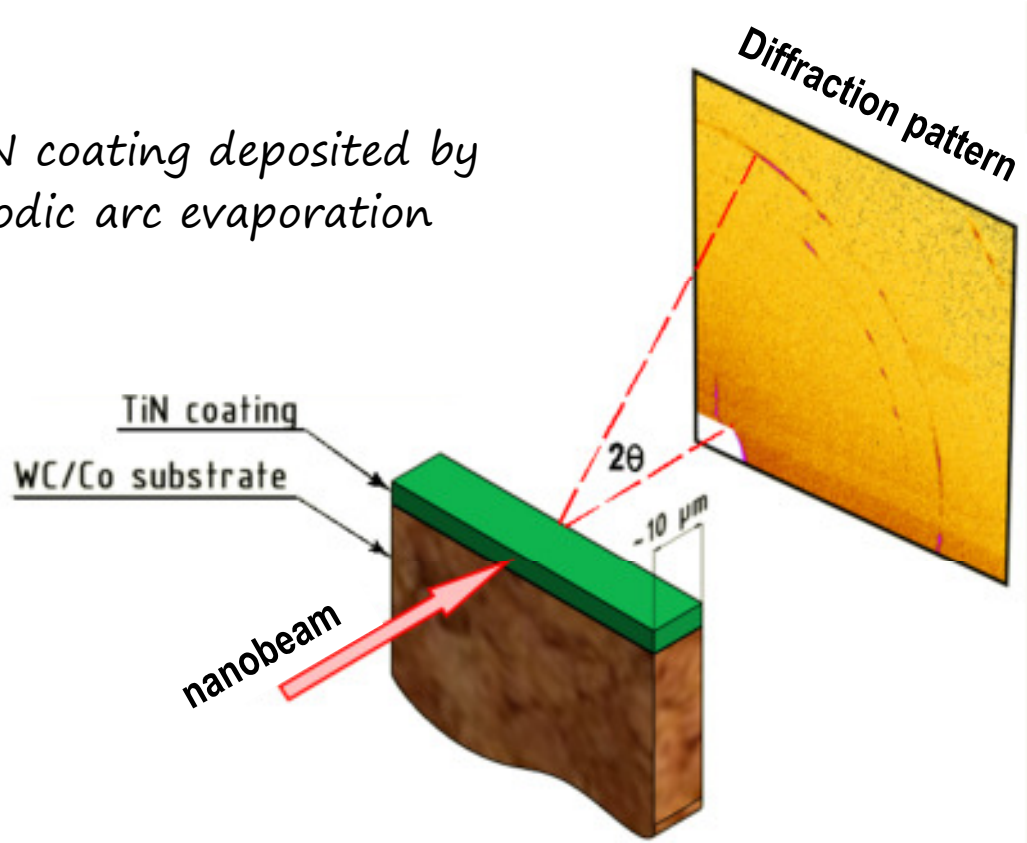
Zentrum für Material- und Küstenforschung

J. Keckes, A. Riedl, et al.
Montanuniversität Leoben, Erich Schmid Institute



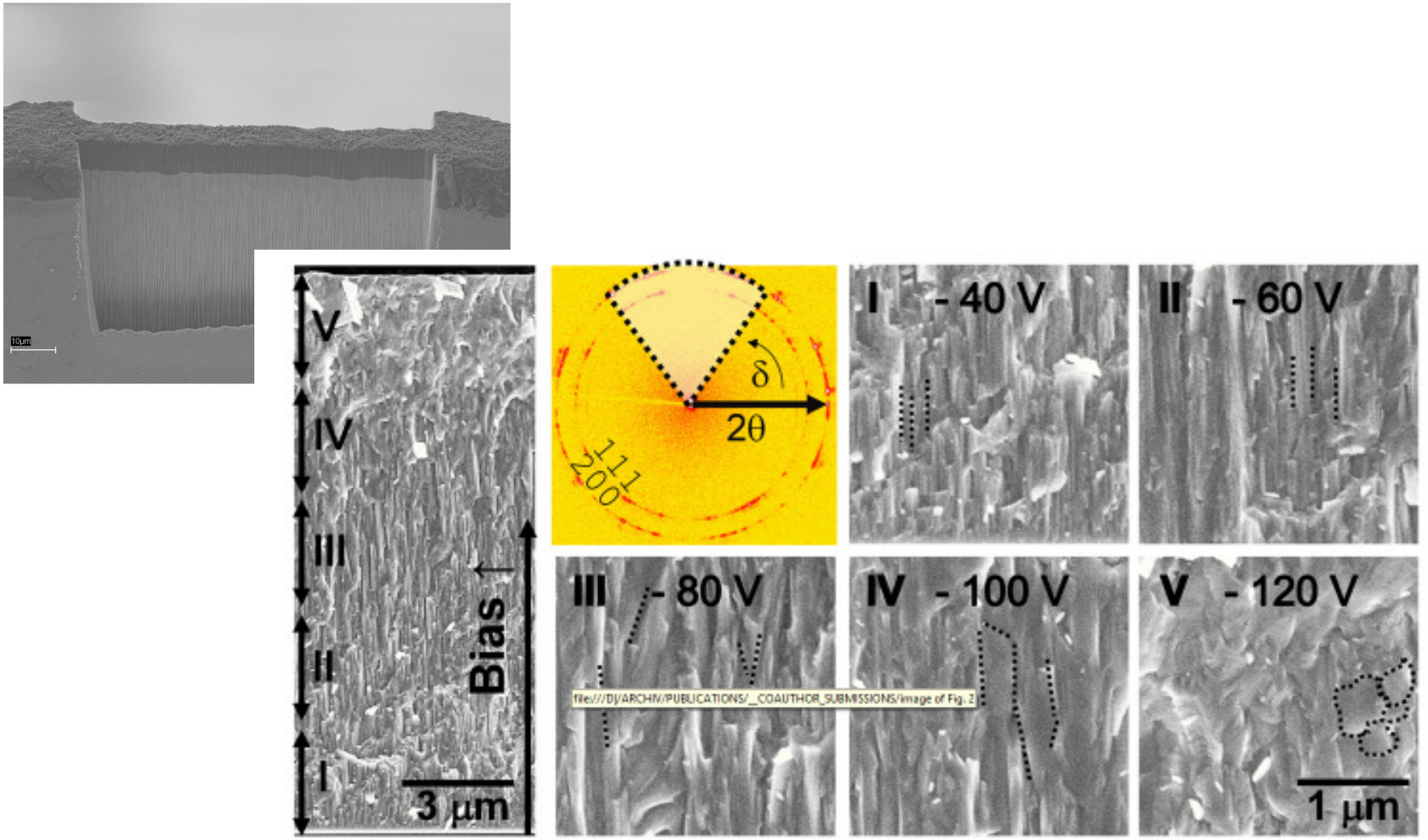


TiAlN coating deposited by cathodic arc evaporation



Krywka et al., Journal of Applied Crystallography **45**, 85 (2012)

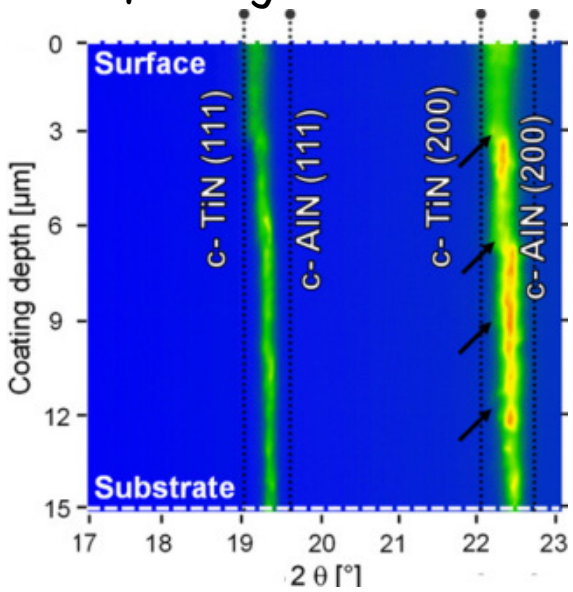
„static“ nanodiffraction

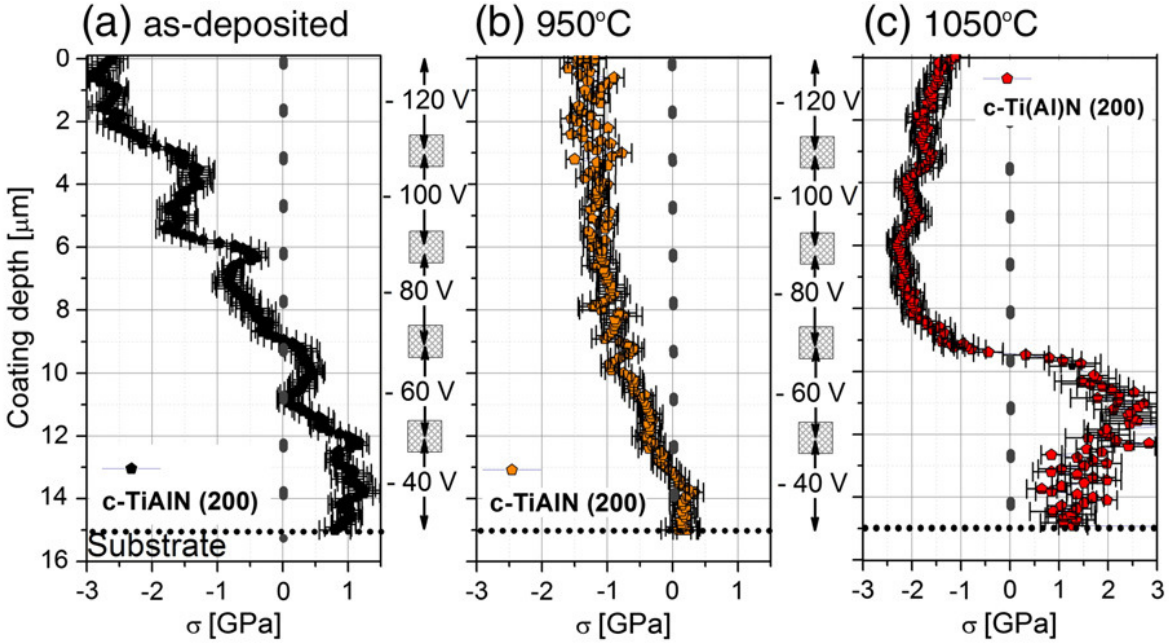


Riedl et al., Surface & Coatings Technology **257**, 108 (2014)

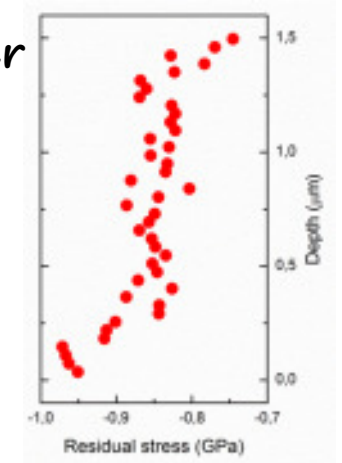
„static“ nanodiffraction

15 µm layer



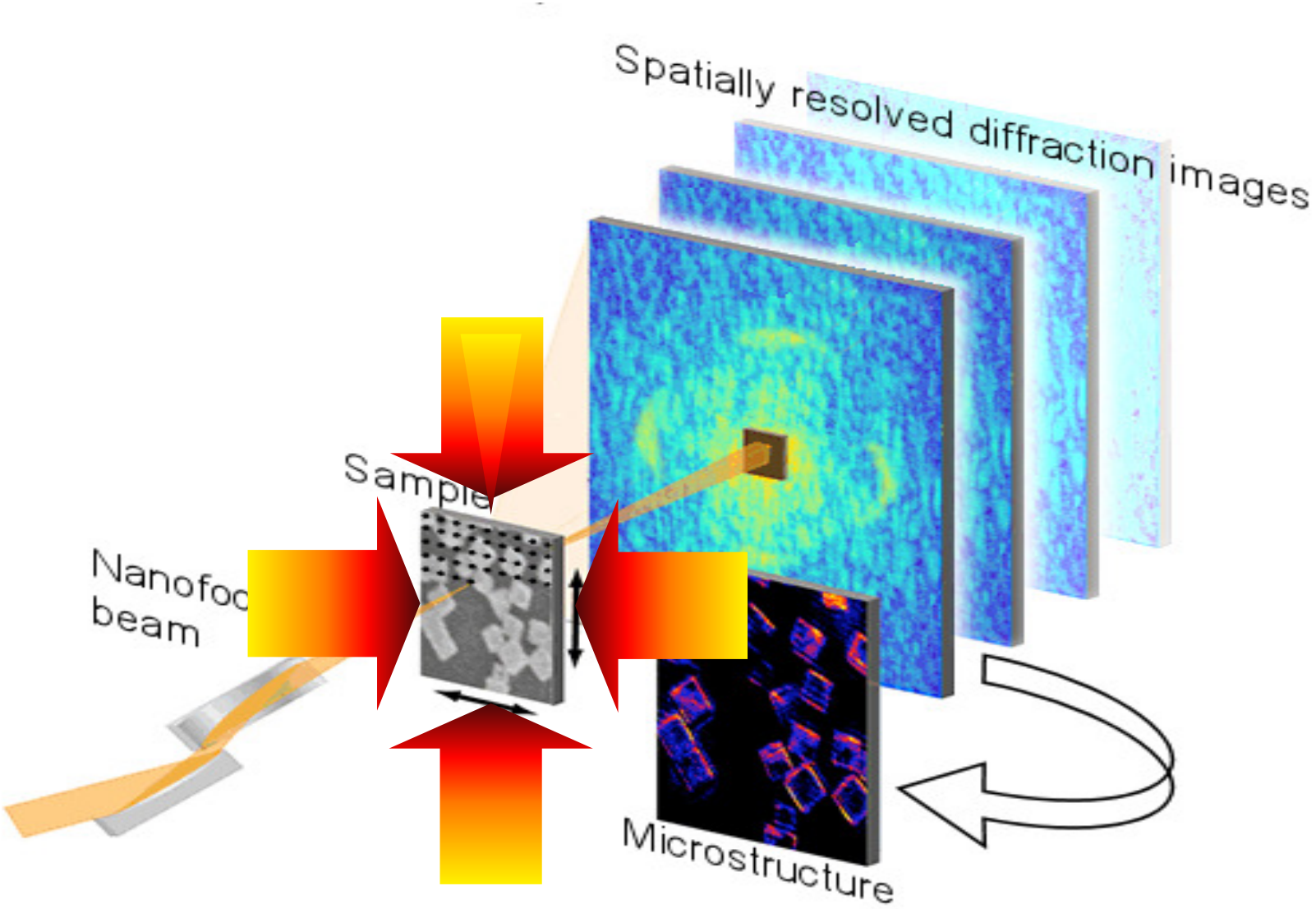


1.5µm layer



Riedl et al., Surface & Coatings Technology **257**, 108 (2014)
Hollerweger et al., Acta Materialia **83**, 108 (2014)

nanodiffraction with in-situ parameters



high pressure nanodiffraction

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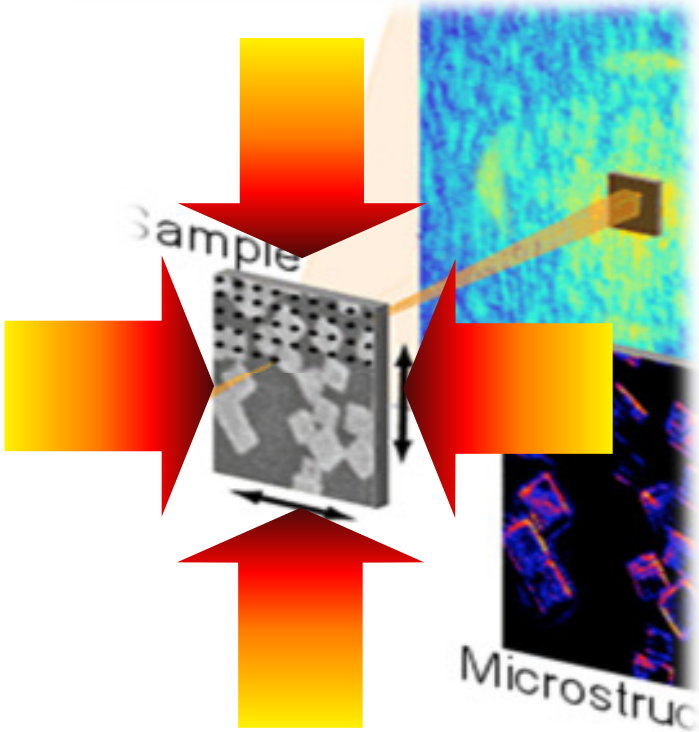
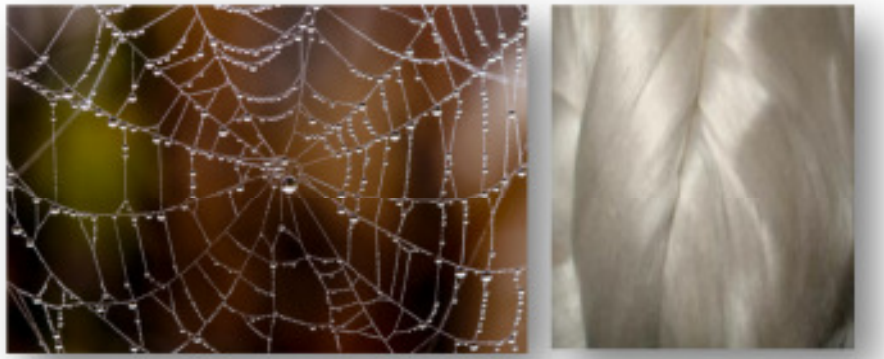
Zentrum für Material- und Küstenforschung

elastic material properties
from isotropic load

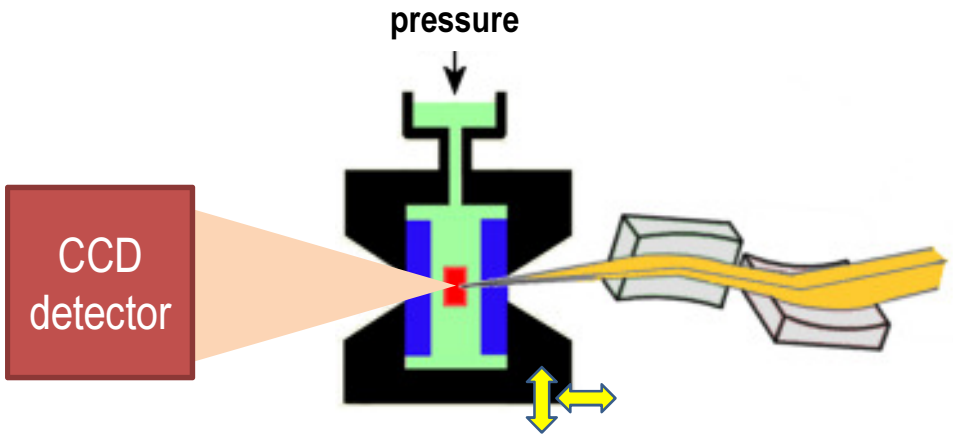
hydrogen embrittlement can
be studied „in operando“

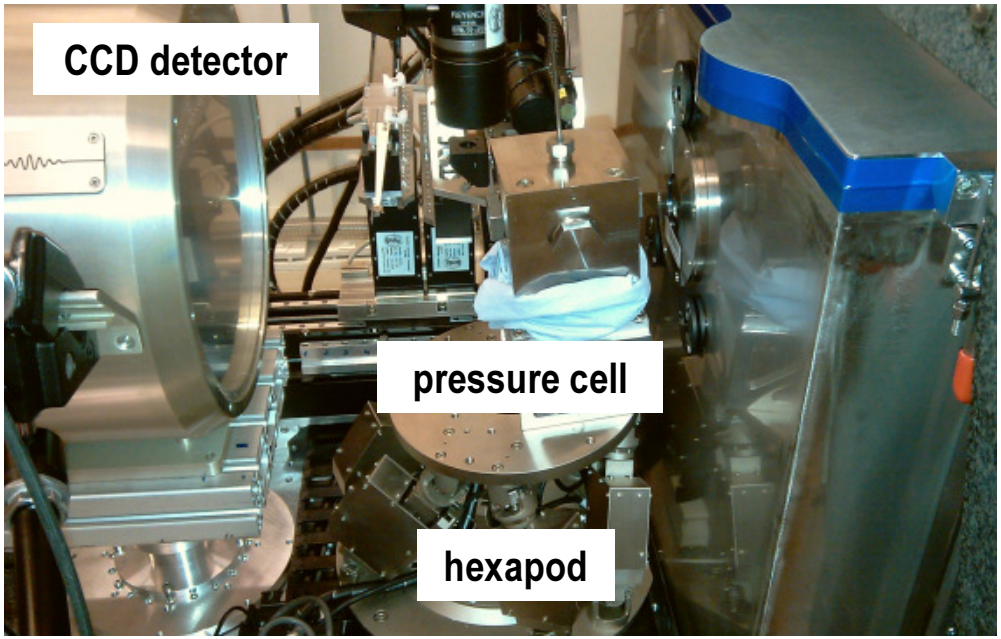


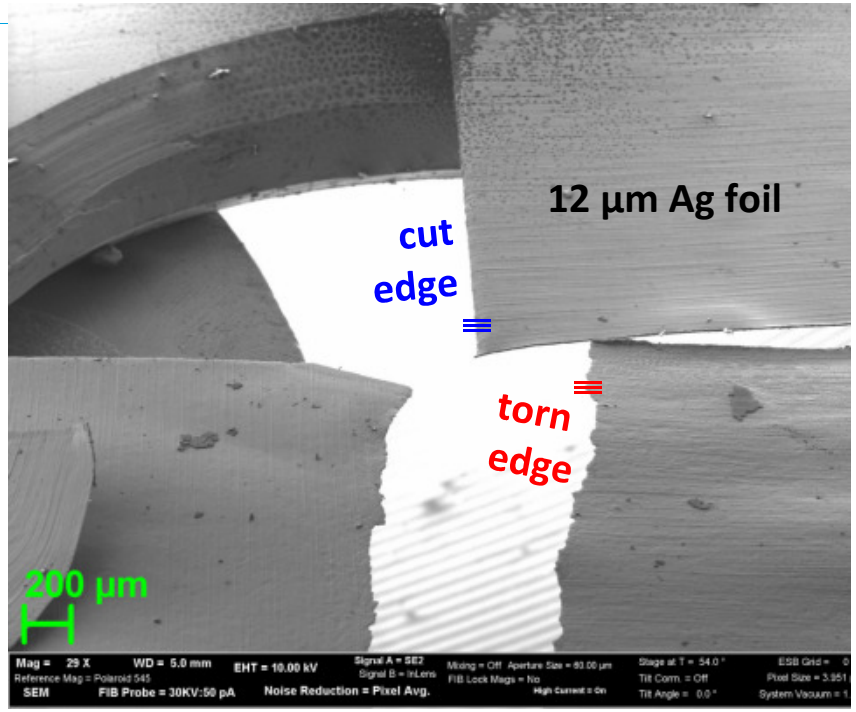


high pressure nanodiffraction

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung







Applications of HP diffraction:

Krywka et al.
Macromolecules **47**, 7187 (2014)

Ene, Krywka et al.
Polymer **53**, 5507 (2012)

Krywka et al.
Chem. Phys. Chem. **9**, 2809 (2008)

high pressure nanodiffraction

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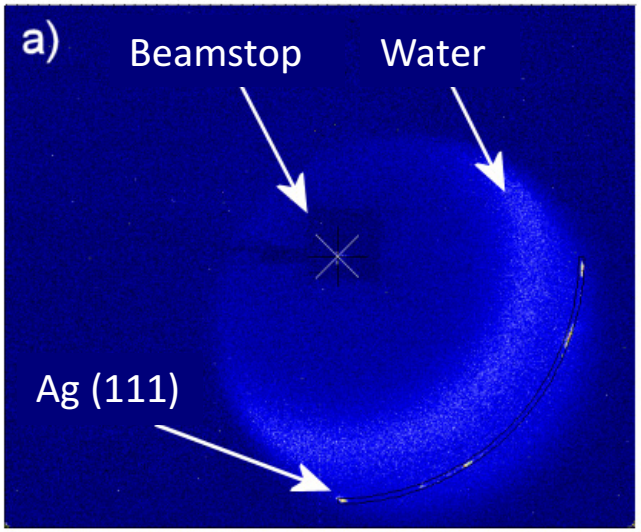
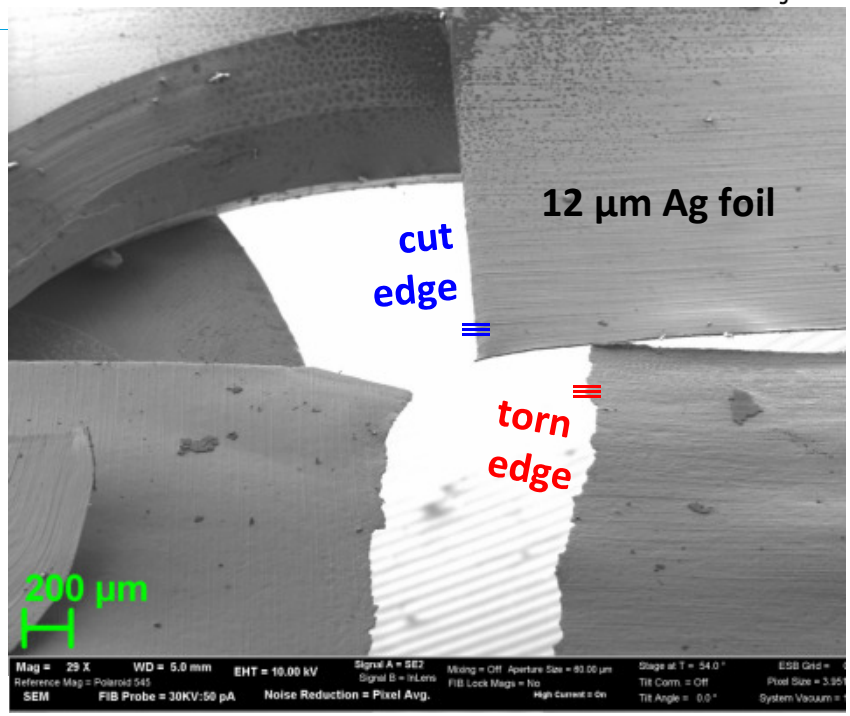
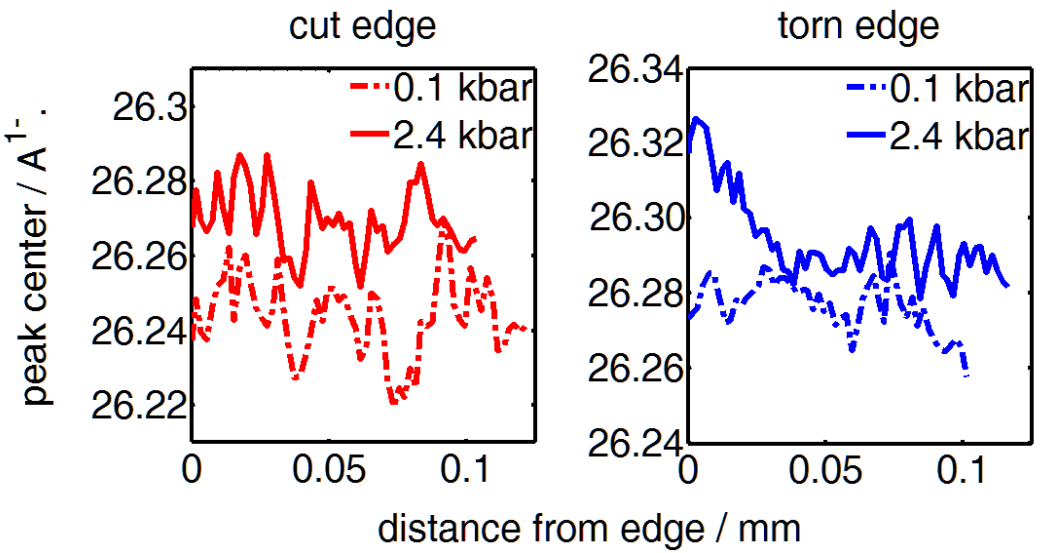
Zentrum für Material- und Küstenforschung







high pressure nanodiffraction

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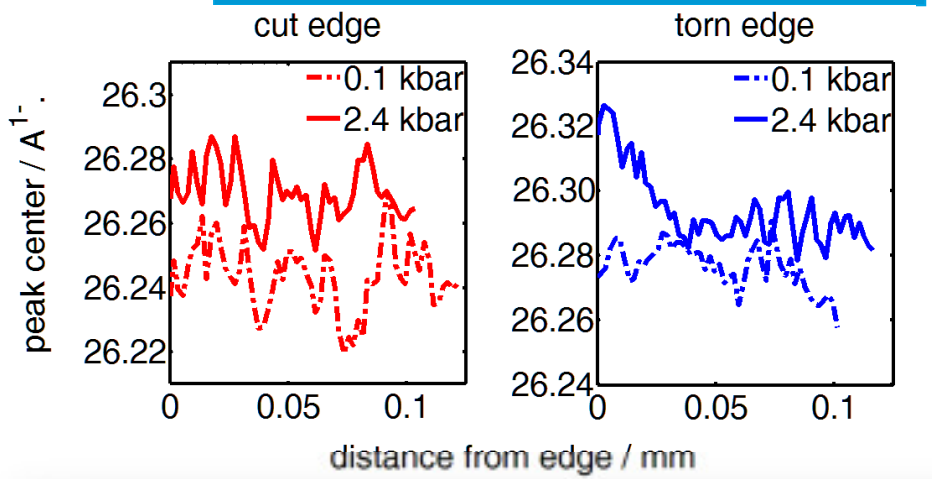
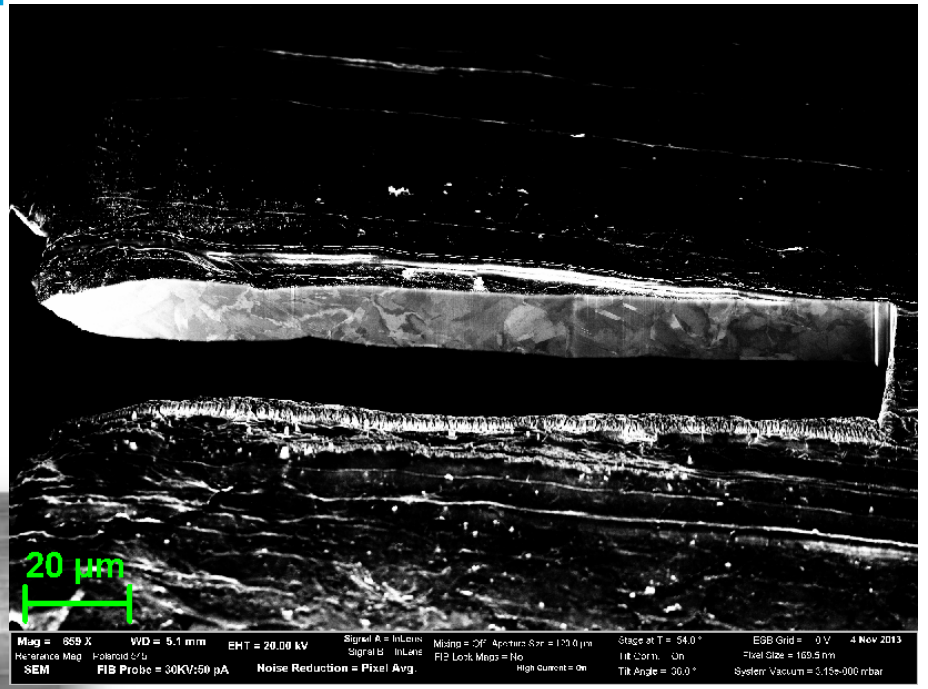
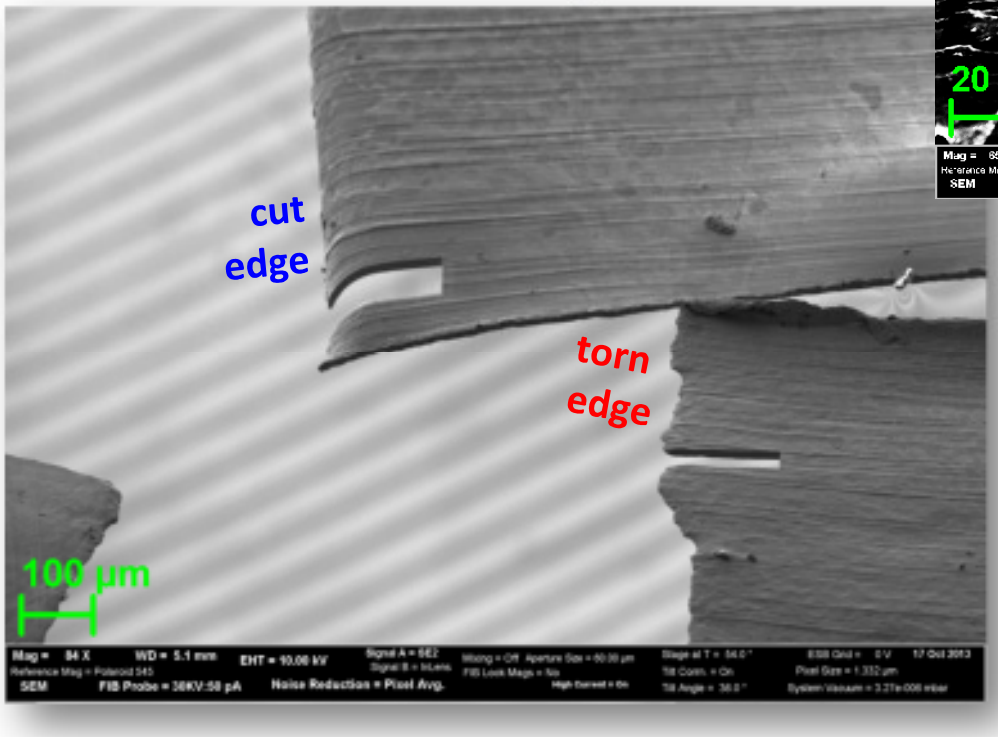
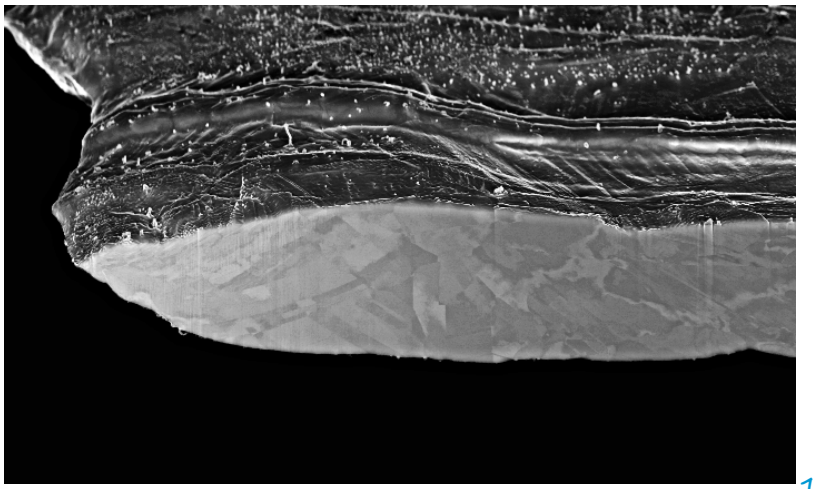
Zentrum für Material- und Küstenforschung





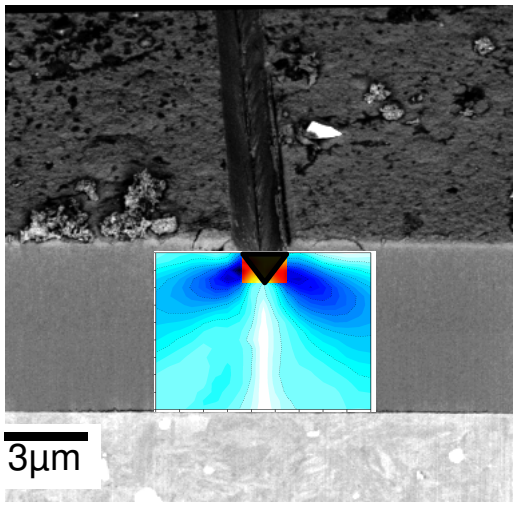


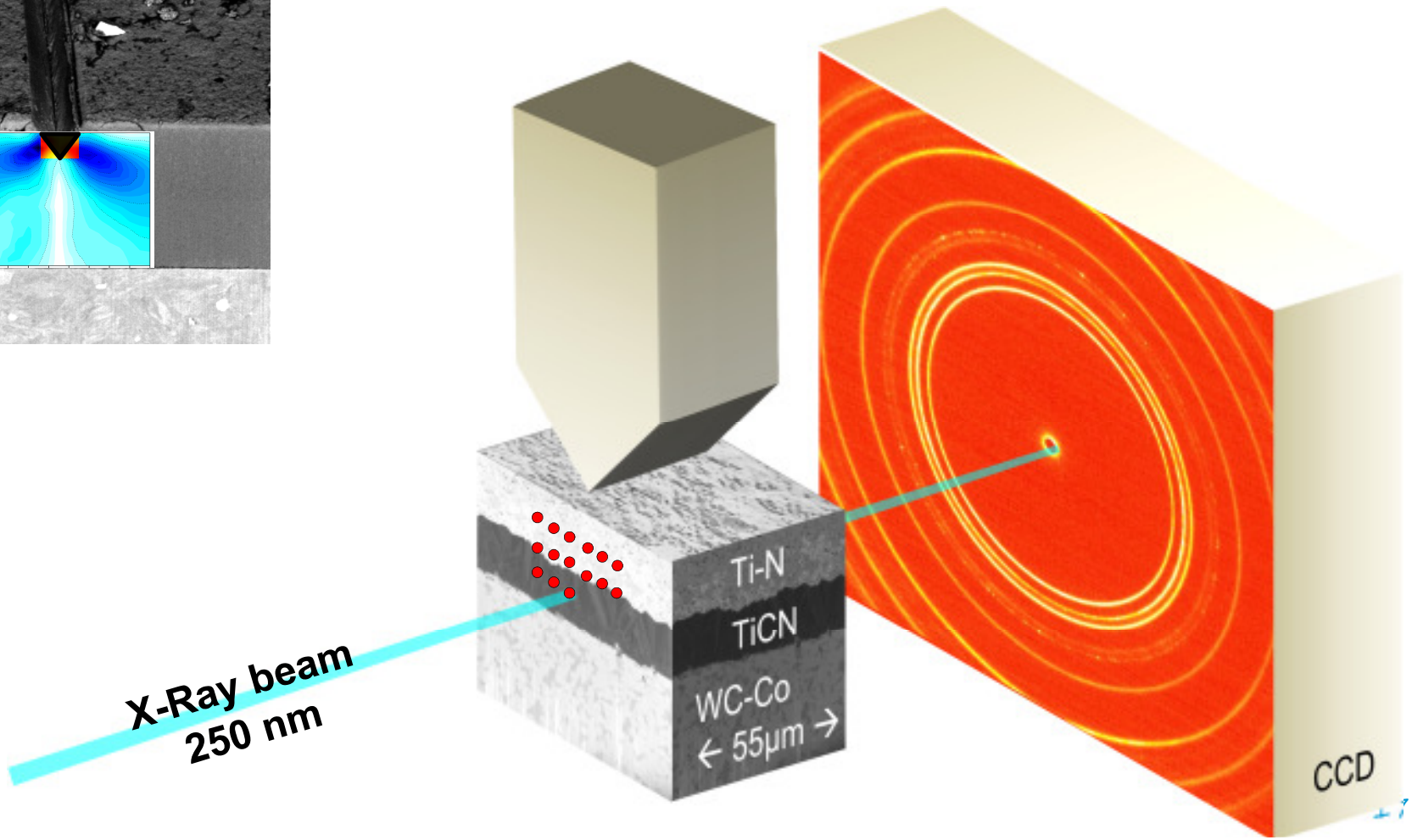


nanoindentation

A. Zeilinger, J. Keckes et al.
Montanuniversität Leoben, Austria

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung





nanoindentation

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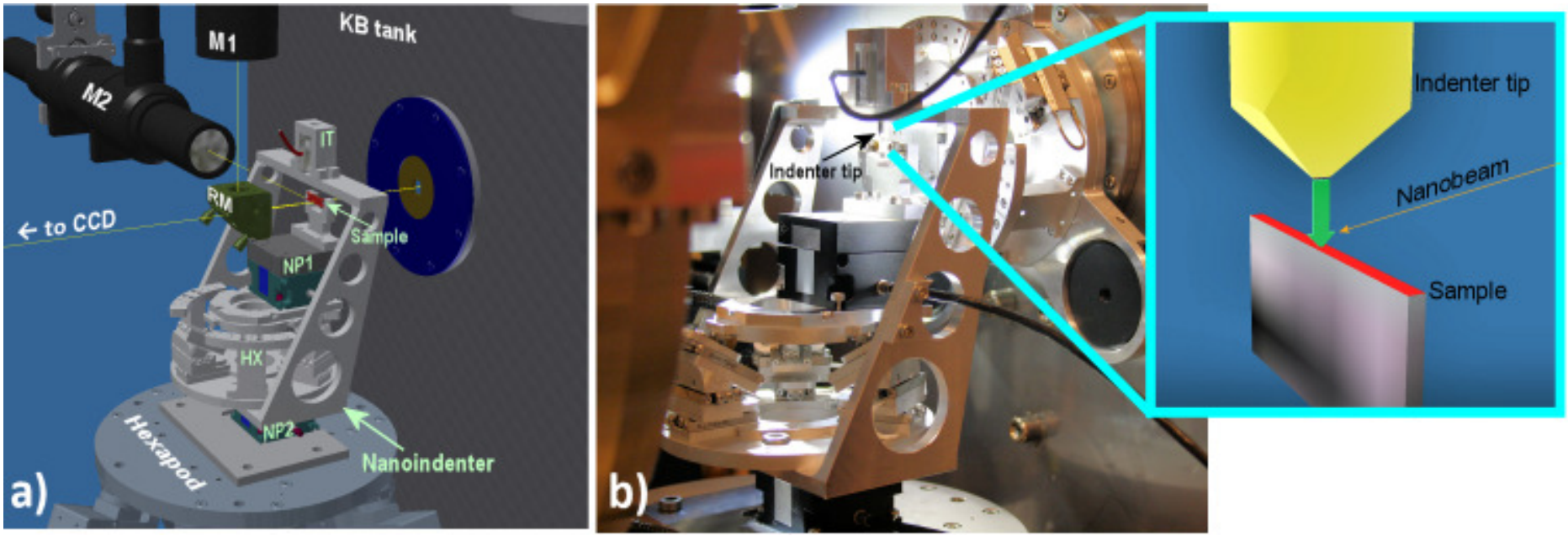
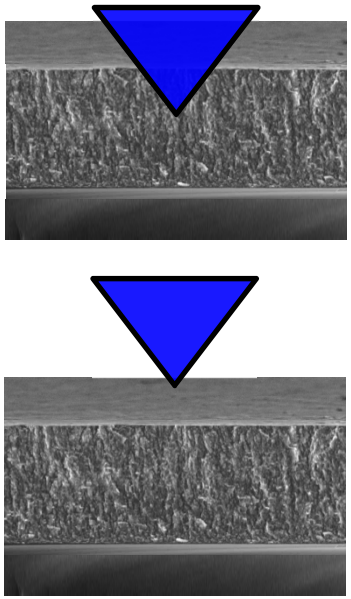
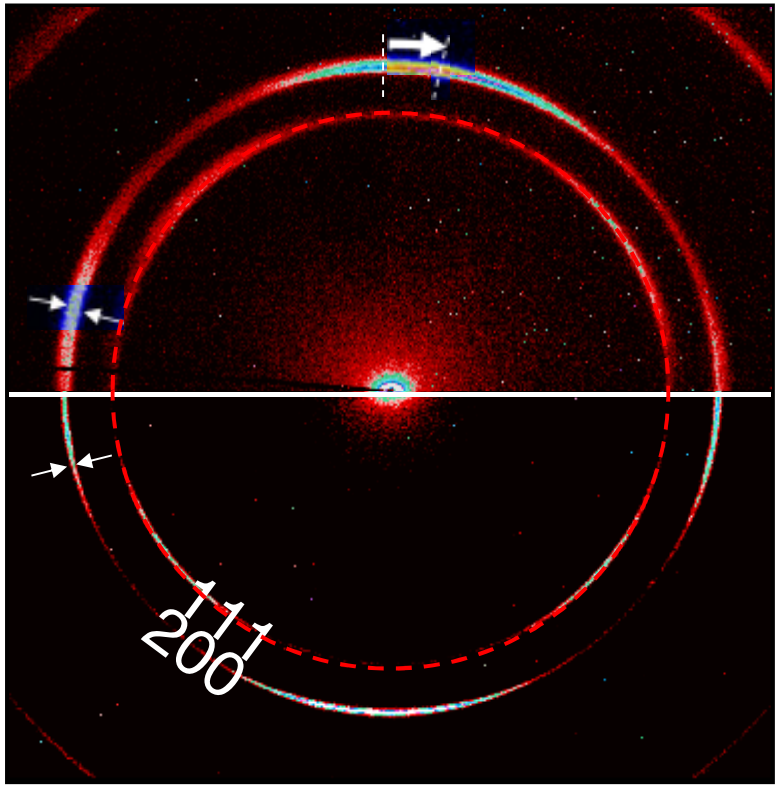


nanoindentation





i) Broadening of the diffraction rings: Strain 2nd 3rd order

ii) Shift of the intensity maxima: Crystal rotation

iii) Changes in ring shape: Macroscopic strain / Elastic response

nanoindentation

Helmholtz-Zentrum Geesthacht
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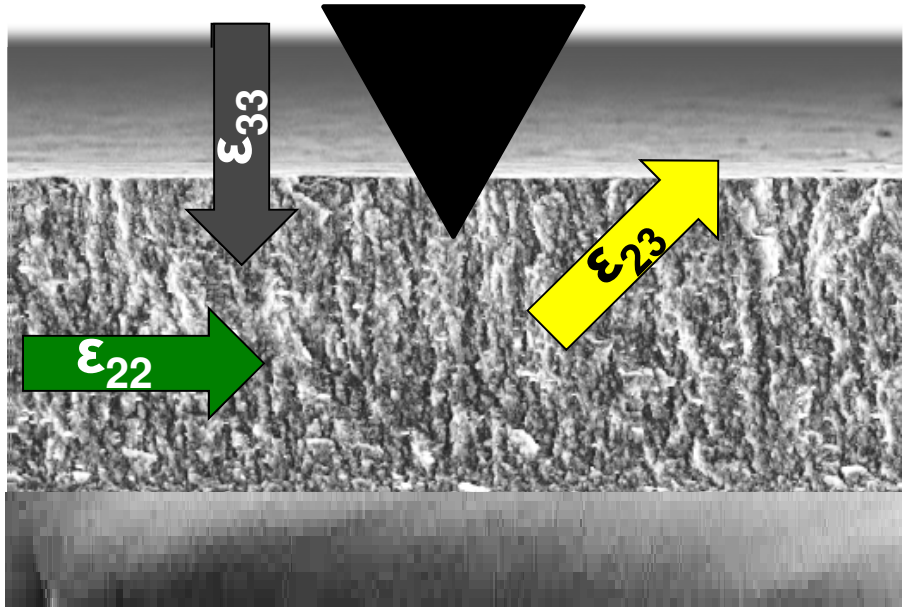
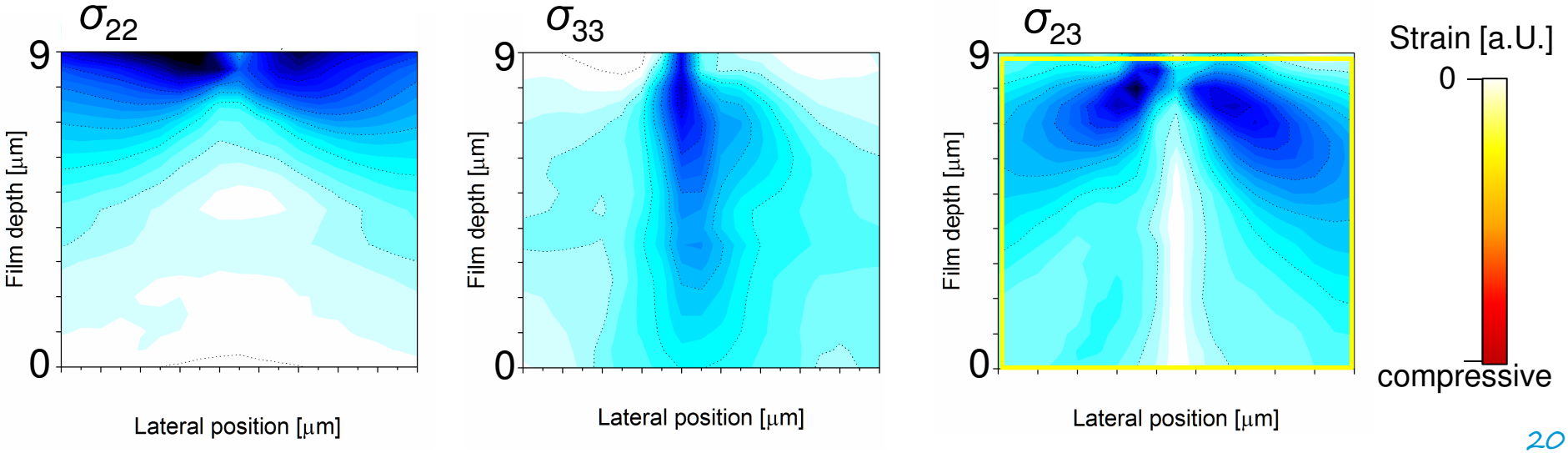
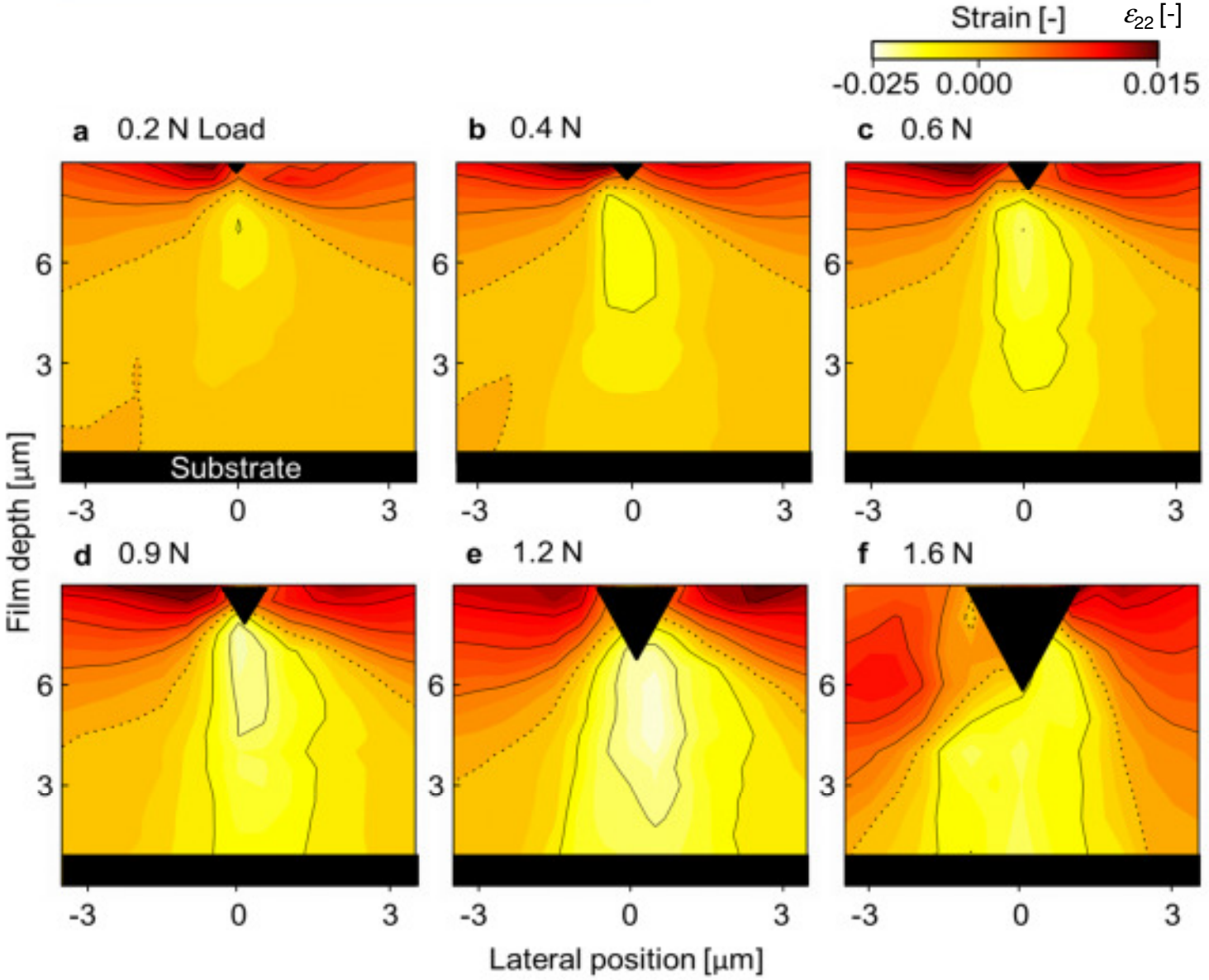


ε_{ij} = strain tensor

σ_{ij} = stress tensor

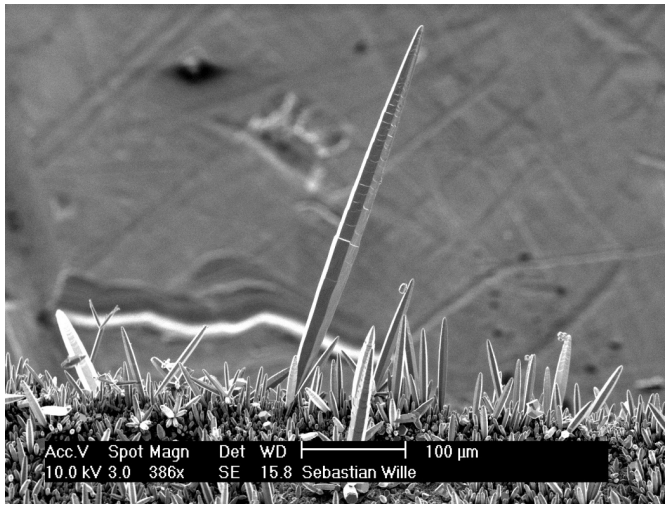


nanoindentation

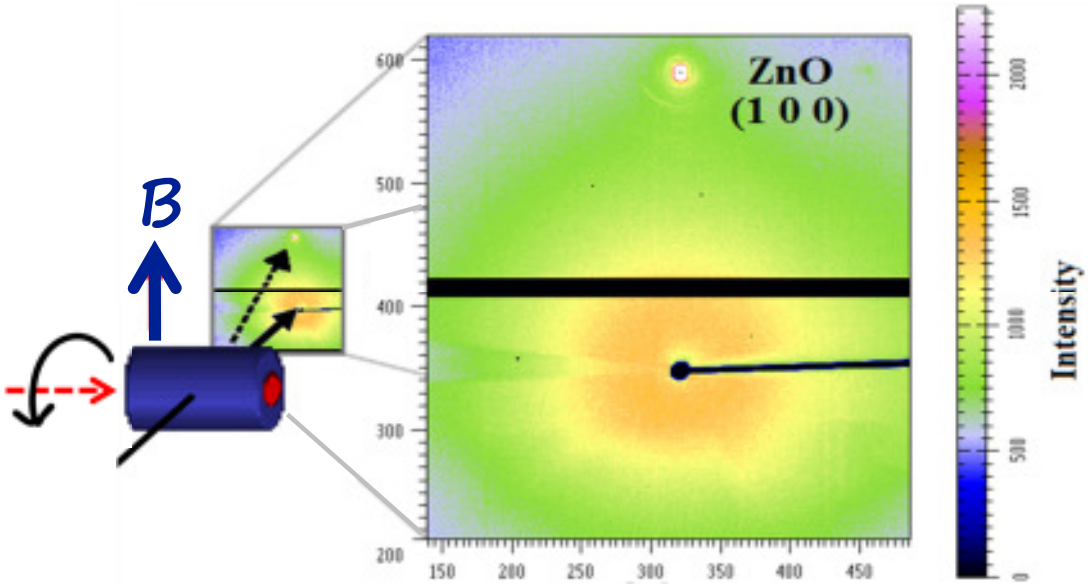


nanodiffraction in external fields

S. Hrkac, B. Murphy
Christian-Albrechts-Universität Kiel

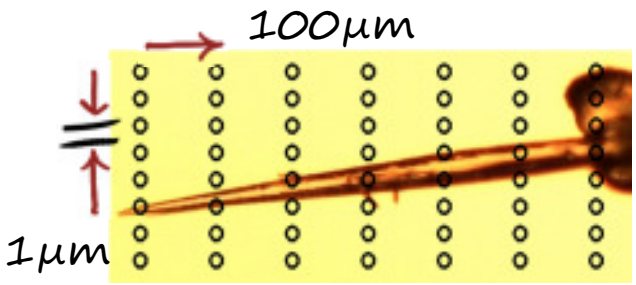


ZnO needles
(piezoelectric)
coated with METGLAS ®
(magnetostrictive)

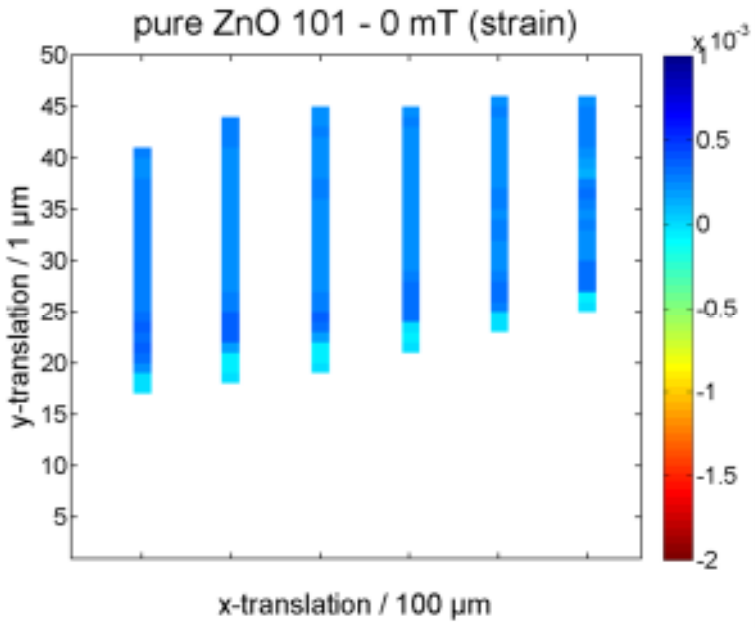


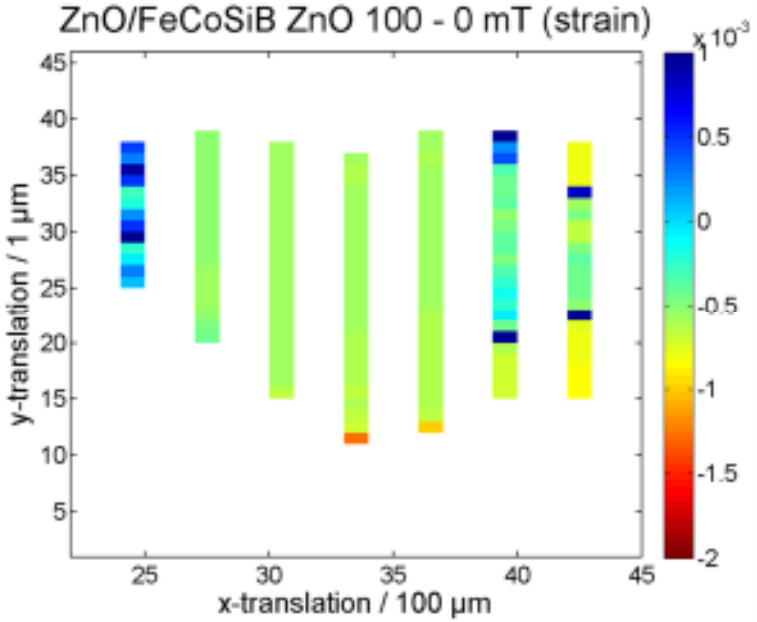
Hrkac et al., Appl. Phys. Lett. **103**, 123111 (2013)

nanodiffraction in external fields



measured strain



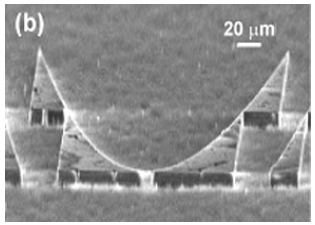


Hrkac et al. Appl. Phys. Lett. **103**, 123111 (2013)

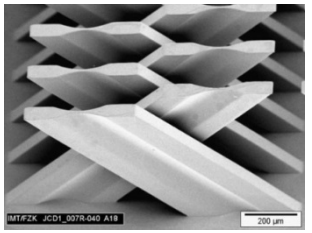
future plans

Small(er) beams:

kinoform lenses and
adiabtic lenses



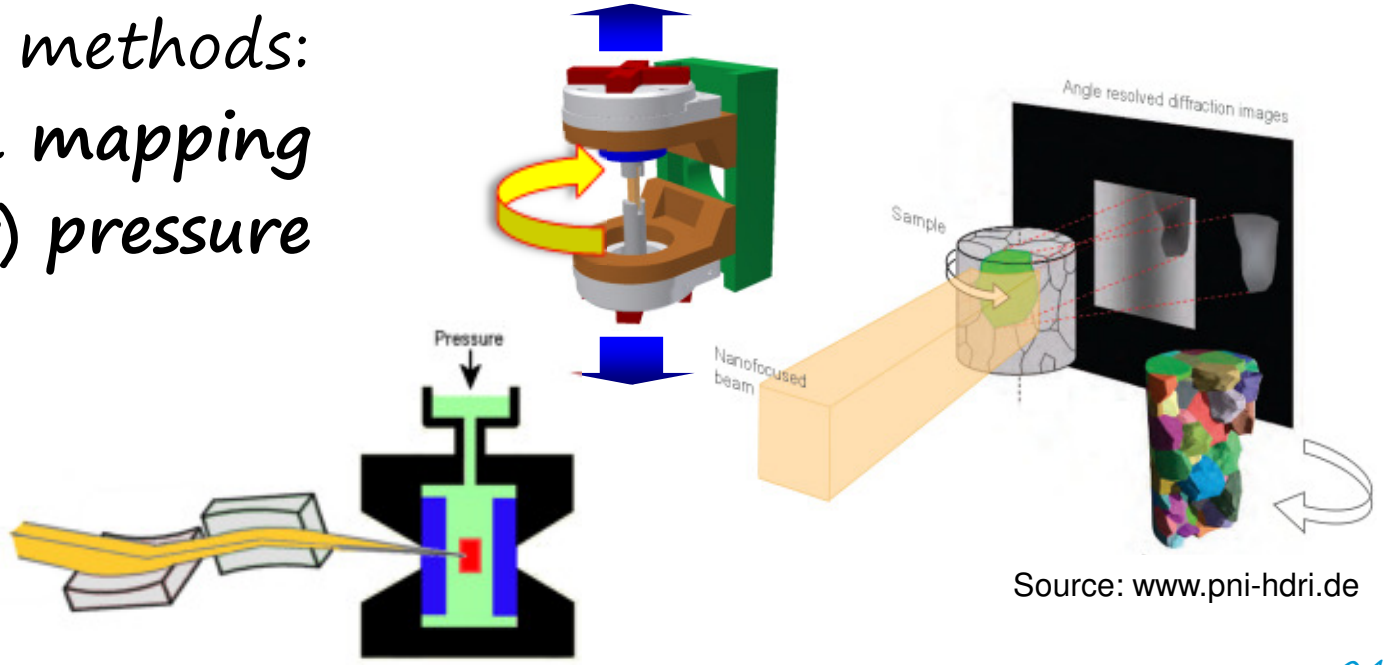
BNL, USA



KIT, Karlsruhe

New methods:

grain mapping
high(er) pressure



Source: www.pni-hdri.de

summary

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

nanodiffraction ♥ materials science

P03 Nanofocus ♥ in situ methods

we can resolve
strain fields, texture, crystal structure ...
with sub-µm resolution

interested ? please contact me


GEMS
German Engineering Materials Science Centre
HEMS (with DESY), IBL, BioSAXS (with EMBL) & P03 NFE (with CAU & DESY) at PETRA III
HARWI III

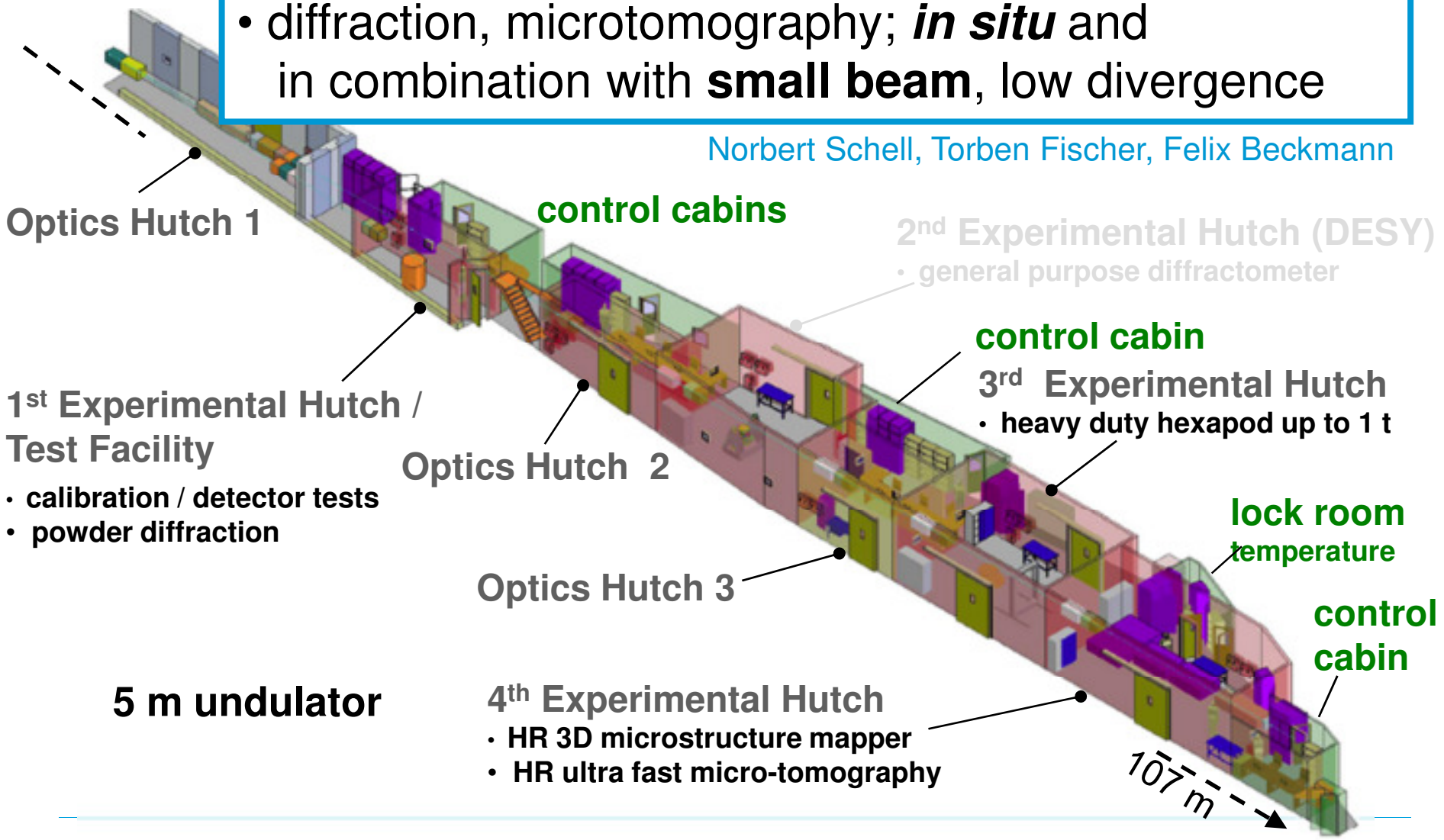
High Energy Materials Science Beamline (HEMS)

GEMS
German Engineering Materials Science Centre

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- high energy, P07 at PETRA III, 1/3 DESY (EH 2)
- diffraction, microtomography; ***in situ*** and in combination with **small beam**, low divergence

Norbert Schell, Torben Fischer, Felix Beckmann



GEMS
German Engineering Materials Science Centre

Imaging Beamline (IBL)

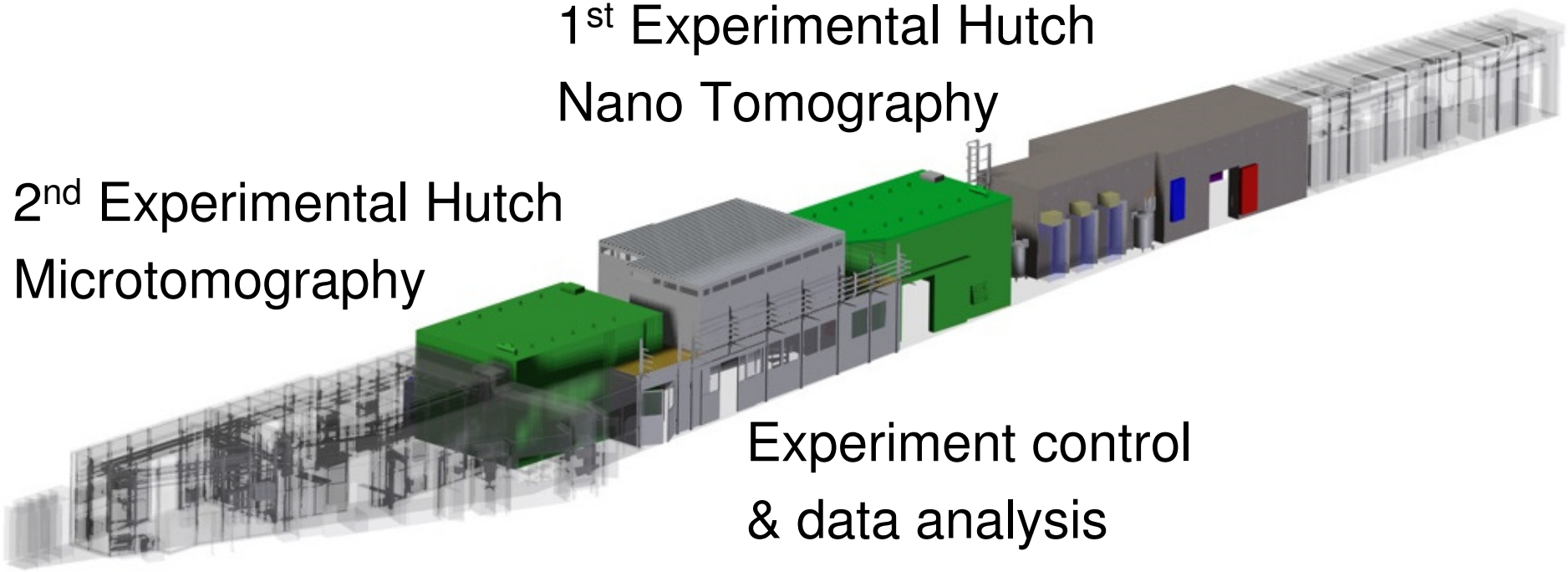
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- medium energy, P05 at PETRA III
- micro- and nanotomography
  with mm- and µm-size samples

Fabian Wilde, Julia Herzen, Malte Ogurreck, Imke Greving, Felix Beckmann

1st Experimental Hutch
Nano Tomography

2nd Experimental Hutch
Microtomography



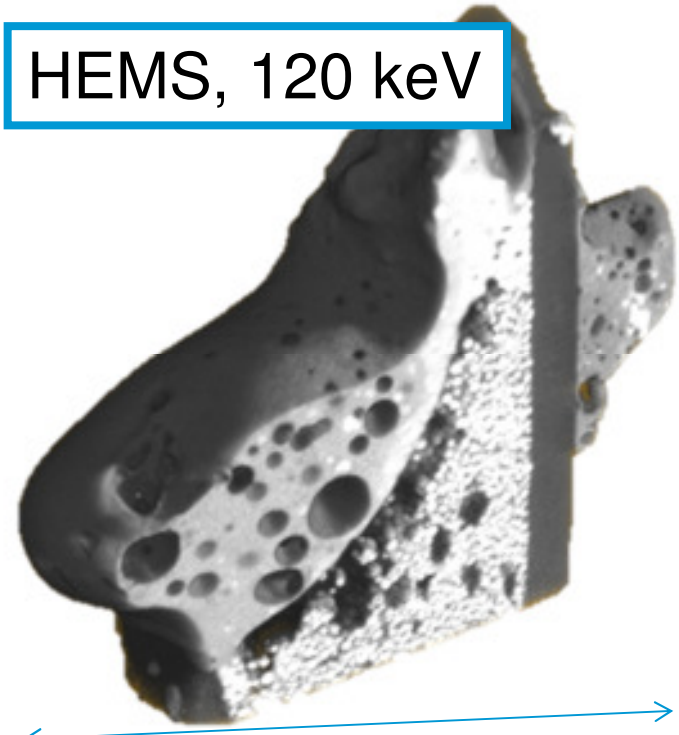
Experiment control
& data analysis

GEMS
German Engineering Materials Science Centre

3D imaging of complex materials

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

HEMS, 120 keV



1.5 mm

IBL, 7 keV

3 mm

understanding thermal spraying process for WC/Co coatings

J. Nellesen (TU Dortmund), F. Beckmann

microstructure of wood on different length scales

S. Lautner, J. Fromm (Uni Hamburg)
J. Herzen, F. Beckmann, F. Wilde

GEMS
German Engineering Materials Science Centre

BioSAXS

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- medium energy, P12 at PETRA III, 85 % EMBL
- small-angle (solution) scattering, microfluidics

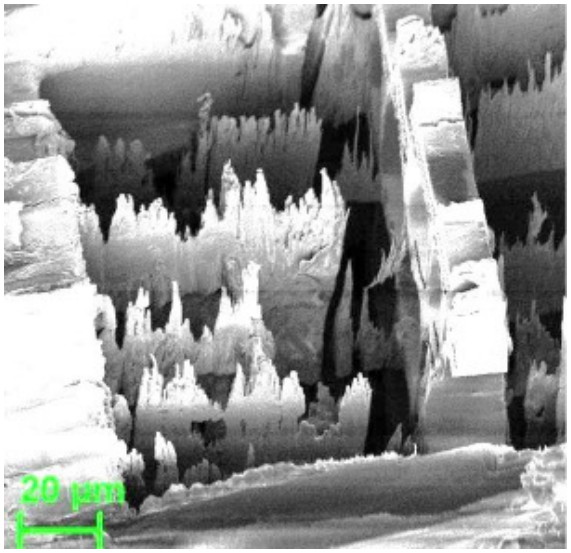
Vasyl Haramus, Regine Willumeit

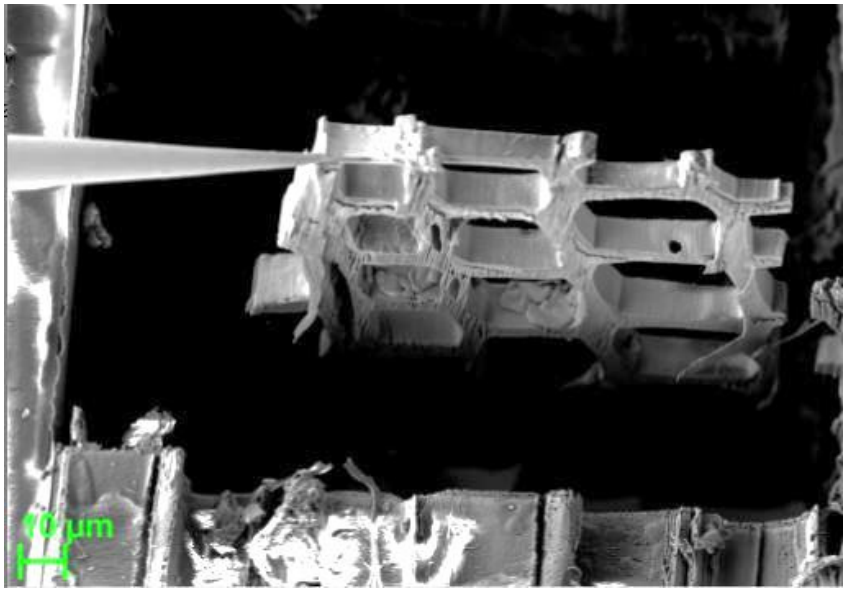
strong request for small-angle scattering in biochemistry and in materials science (SFB 986)

FIB / SEM dual beam instrument

instrument in Geesthacht

Daniel Laipple





preparation
of thin wood sections

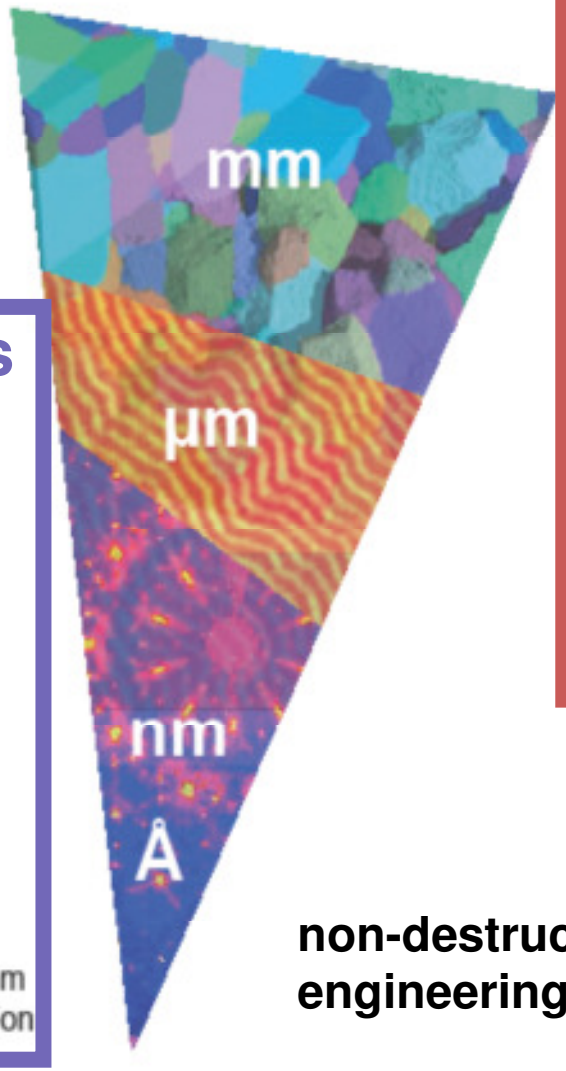
S. Storm, *Master's thesis*, Kiel (2012)

GEMS
German Engineering Materials Science Centre

Forschungsplatform GEMS

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Experiments with
synchrotron radiation
and **neutrons**



Imaging methods

Real Space

- Micro and nano tomography
- Absorption contrast
- Phase contrast
- Diffraction contrast

Resolution:
< µm (700 nm)
Nano tomography:
~ 60 nm, smaller until 2016

Scattering Methods

Reciprocal Space

- Small-angle scattering
- Diffraction
- High spatial resolution with small beams on the nm length scale

Resolution:
- Beam sizes down to 20 nm (scanning)
- Diffraction 10^{-4} Å
- Small-angle scattering: particles and pore sizes ~ nm – 2000 nm

→ *in situ* experiments with ms time resolution

non-destructive characterisation
engineering-specific in-situ devices

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