GEMS

German Engineering Materials Science Centre

Helmholtz-Zentrum Geesthacht

Centre for Materials and Coastal Research

Metal characterization at DESY photon facilities: Best practice, benefits and access

AMAP Kolloquium

May 03, 2018

Dr. Marc Thiry, Industrial Liaison Officer

GEMS/Helmholtz-Zentrum Geesthacht

Helmholtz-Zentrum Geesthacht
Centre of Materials and Coastal Research

Helmholtz-Zentrum Geesthacht
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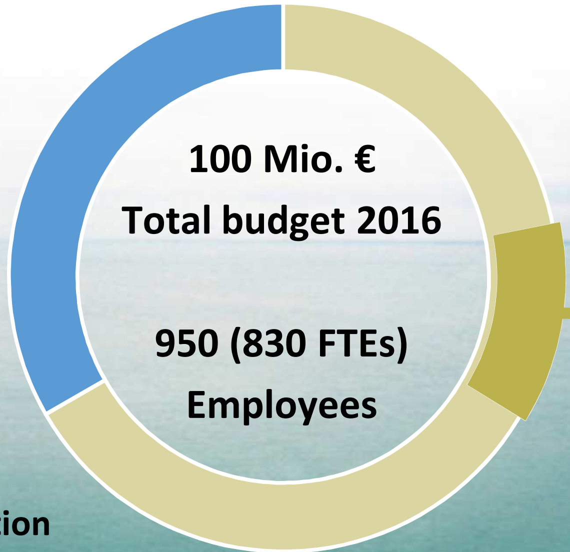
RESEARCH DIRECTIONS

- **Research on Materials and Materials Systems**
  (2/3 of budget)
- **Coastal and Climate Research**
  (1/3 of budget)



Research with neutron and synchrotron characterisation tools

Synchrotron characterisation tools at DESY

Neutron characterisation tools at MLZ

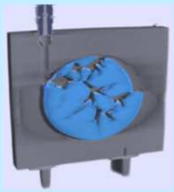
Institute for Materials Research

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Preserve resources and guarantee mobility through light-weight and multifunctional materials

Magnesium

Materials Mechanics and Joining

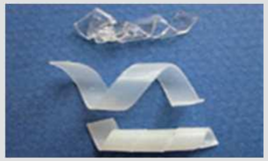


Hydrogen Storage Technology

Polymer Membranes

Enable regenerative therapies through new biomaterials

Metallic Biomaterials



Multifunctional Polymers and Regenerative Medicine

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Characterisation:
Synchrotron radiation
Neutrons

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Why are we at DESY and MLZ ?

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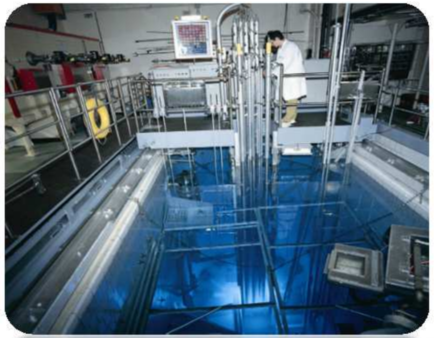
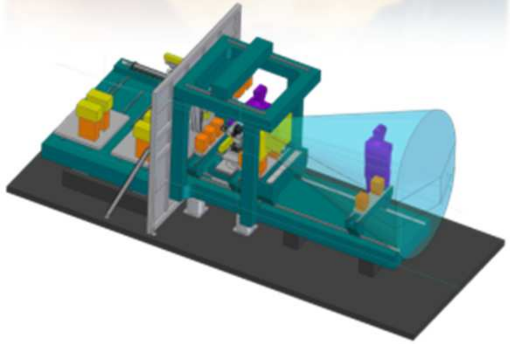


- own research reactor since 1964
- extending to synchrotron @ DESY (DORIS III/PETRA III, appr. 2000)
- extending neutron @ MLZ (FRM II, appr. 2000)
- shut-down of own research reactor 2010

DESY

MLZ
Heinz Maier-Leibnitz Zentrum



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Research with Photons and Neutrons

Helmholtz-Zentrum Geesthacht
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- competence and infrastructure for complementary research with photons and neutrons in engineering materials science
- development and operation of own (HZG) beamlines
- unique sample environments for *in situ* studies of engineering processes
- sample preparation and characterization labs
- engineering-specific user support

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Photons at DESY

PETRA III

Neutrons at MLZ

FRM II

In-situ sample environments

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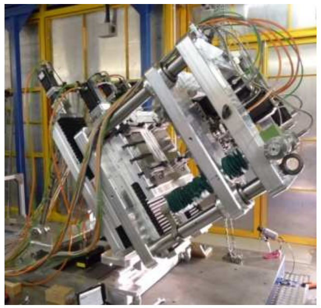
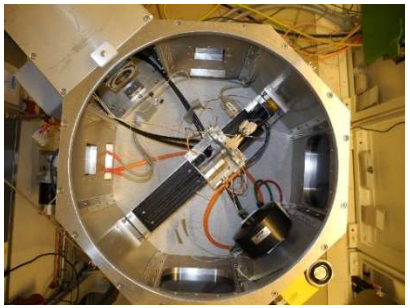
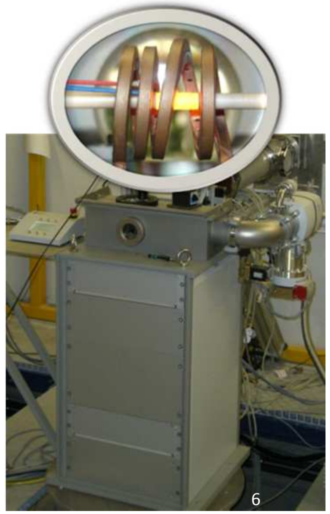
- Synchrotron radiation and neutrons offer many possibilities for *in-situ* studies of materials engineering processes
- GEMS develops novel sample environments for welding processes, heat treatment or additive manufacturing

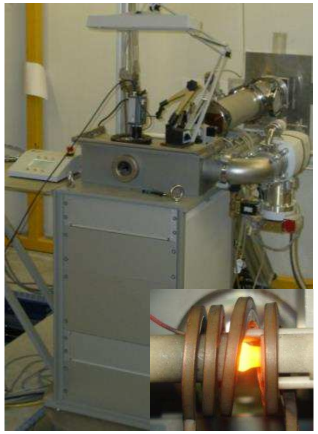


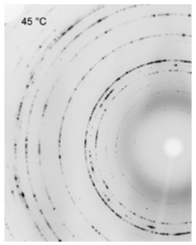


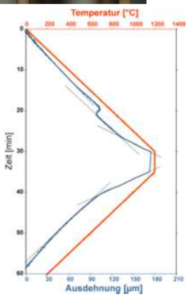



In-situ sample environments

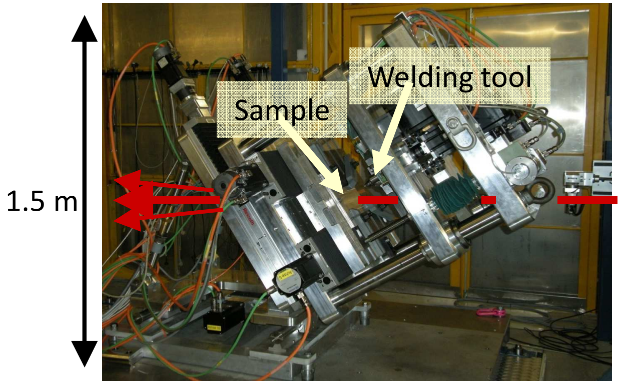
Flexi-Therm - Dilatometer:

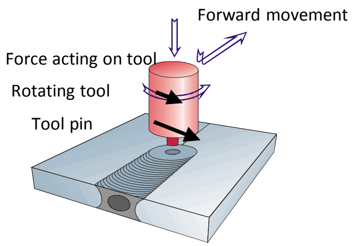






Flexi-Stir – FSW device:





- *Flexi-Las* – Laser welding chamber
- Bioreactor (for corrosion/tomography)
- Furnaces
- Stress rig

- Coming soon: Flexi - ?, SLM chamber

Sample environments for EBM and SLM

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Three-fold experimental approach:

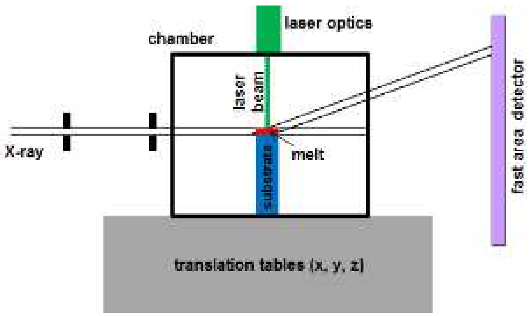
1. In-situ SLM chamber (2D)

2. In-situ LBM chamber (2D)

3. Commercial in-situ S machine (3D)

external partners **users** **external partners**

operational in spring 2018



available in spring 2019

if science case will exist

1. In-situ SLM chamber (2D)

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- **in-situ SLM experiments under near-production conditions**
- automatic powder supply
- **measurements in transmission**

2. In-situ LBM chamber (2D)

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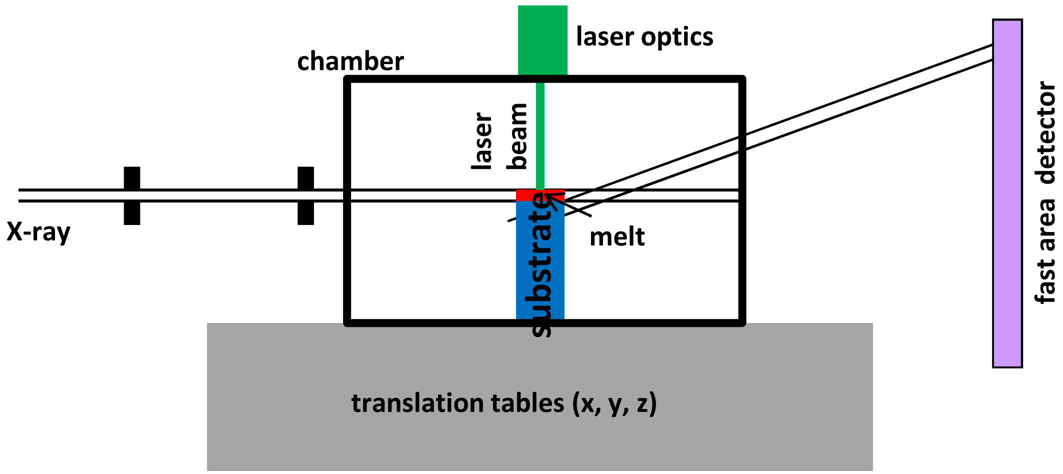
available for external users



- **in-situ LBM experiments**
- laser power 1 kW
- diffraction, SAXS (>50 keV)
- **measurements in transmission**
- time resolution down to 4 ms

Cooperation partners:

- Uni Erlangen-Nürnberg, Prof. Carolin Körner
- HZG Metal Physics group, Prof. Florian Pyczak

3. Commercial in-situ SLM machine (3D)

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cooperation with external partners

with cooperation partners
(full size machine >250 kEUR)

- **in-situ SLM experiments with 2D powder bed**
- full scale or small scale instrument
- science case needs to be established first
- machine needs to be tilted (few deg.) for **measurements under grazing incidence**
- diffraction (>50 keV)
- white beam diffraction, depth-resolved phase and residual stress analysis

X-ray and neutron diffraction: Examples

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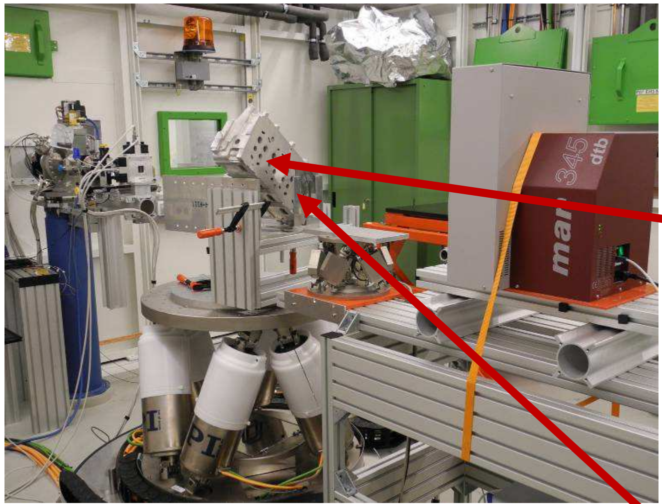
Residual stresses in light-weight materials (HEMS beamline, PETRA III/DESY)

SCIENCE LINK

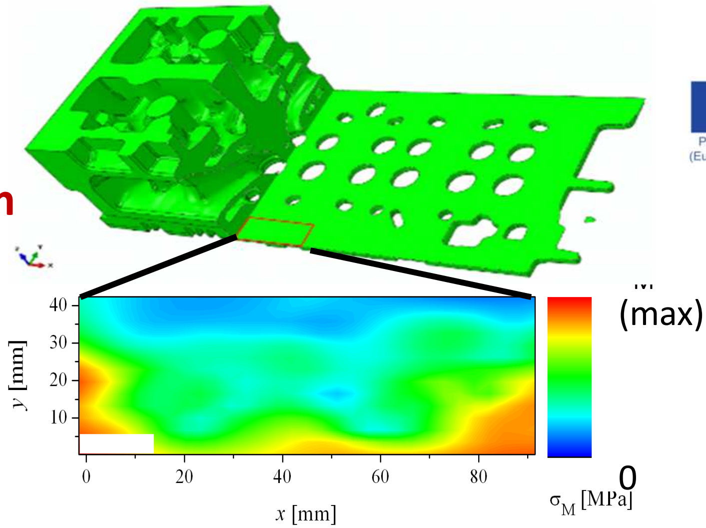
Baltic Sea Region Programme 2007-2013
Part-financed by the European Union (European Regional Development Fund)



Aluminium cylinder head

conical slits

Depth-resolved residual stress determination with conical slit cells



Results were used to validate and improve simulations by Volkswagen AG.

lightweight design, 2015 (4), ISBN/ISSN:1865-4819, S. 38 - 43

X-ray and neutron diffraction: Examples

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AMMC- Aluminium Metal Matrix Composites

successfully used as components in automotive, aerospace etc.

- ✓ high stiffness & strength
- ✓ good resistance to creep
- ✓ low thermal expansion coefficient
- ✓ better dimension stability

Particle reinforced AMMCs rotating blade sleeves used in helicopter

- X poor formability
- X poor weldability

FSW- Friction Stir Welding technique

✓ powerful joining method

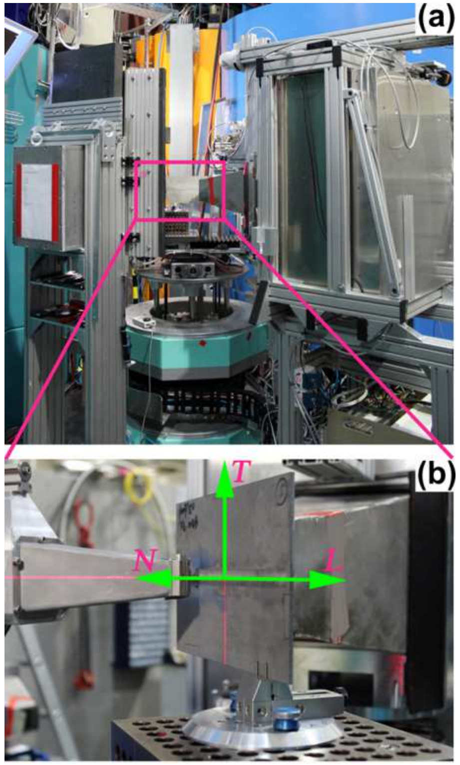
X heating + deformation produce strong RS- Residual Stresses

RS determination in welds is complicated

- includes the macro & micro-scopic RS due to elastic mismatch, thermal misfit and plastic misfit);
- is tough to be measured due to the missing of unstrained reference lattice parameters.

Determine RS in AMMCs by neutron diffraction

X-ray and neutron diffraction: Examples



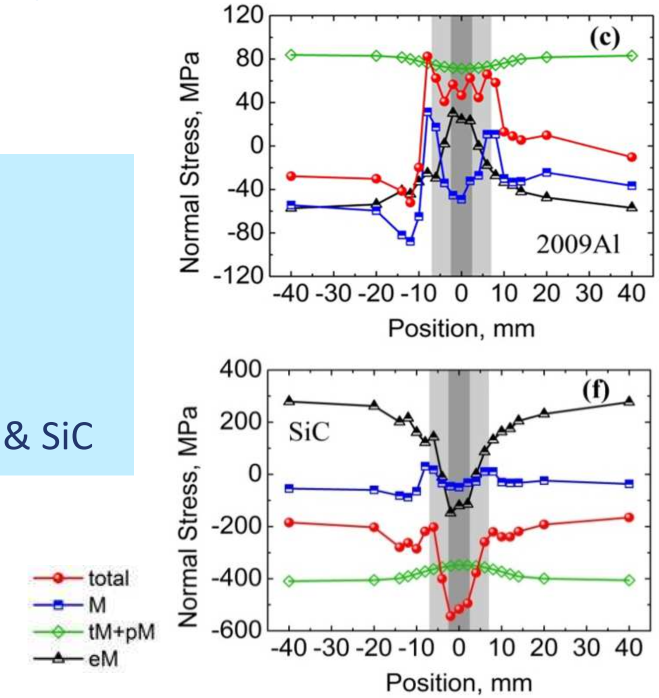
Neutron diffraction: **With neutron diffraction all macro & micro strain components can be determined for each phase!**

Profiles of the macroscopic (M),

elastic mismatch (eM),

thermal plus plastic misfit (tM+pM)

and total residual stresses in both Al & SiC



Dilatometer: *In situ* studies of phase and microstructure transformations

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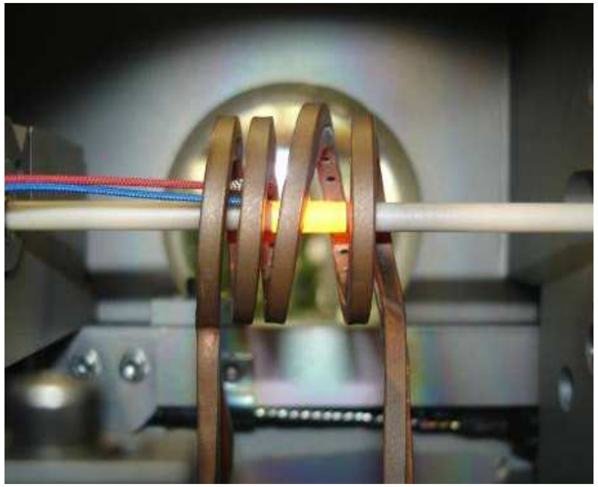
commercial dilatometer, modified for *in situ* experiments



Dilatometer: *In situ* studies of phase and microstructure transformations

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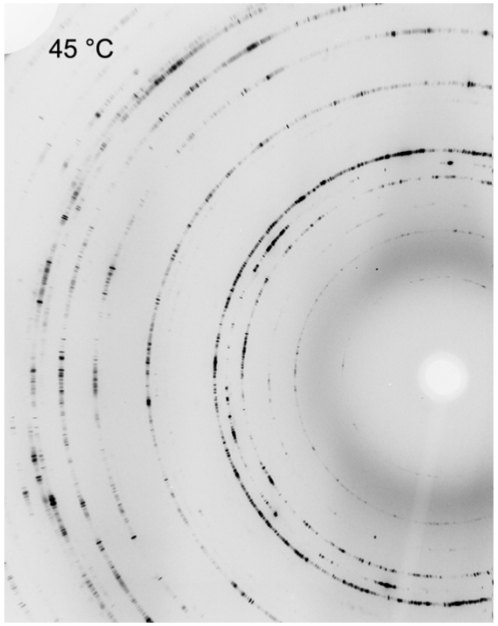
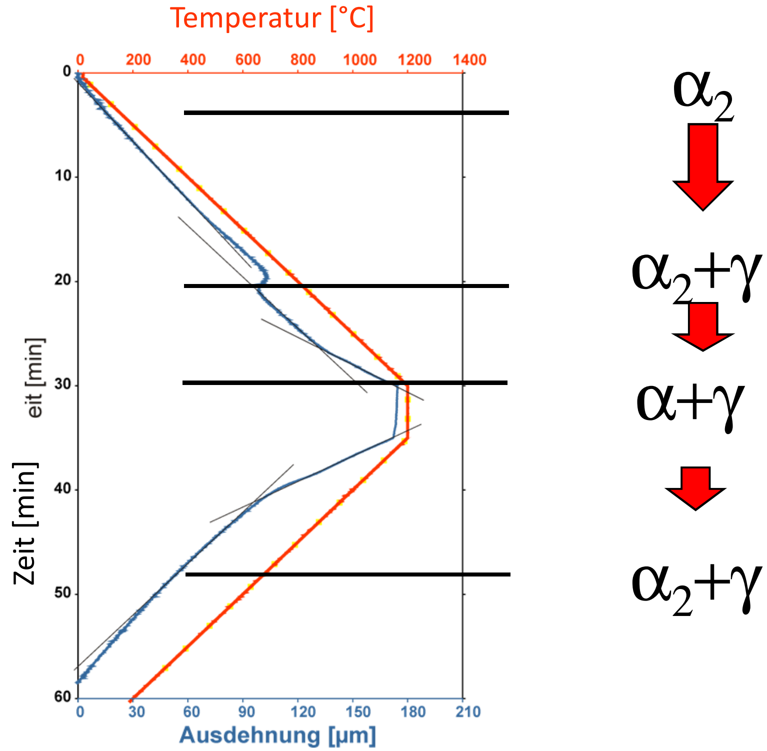


Titan-Aluminium-Gussmaterial,
Synchrotron-Experiment



A. Stark, M. Oehring, F. Pyczak, A. Schreyer, Adv. Eng. Mater. 13 (2011) 700–704

Kleinwinkelstreuung

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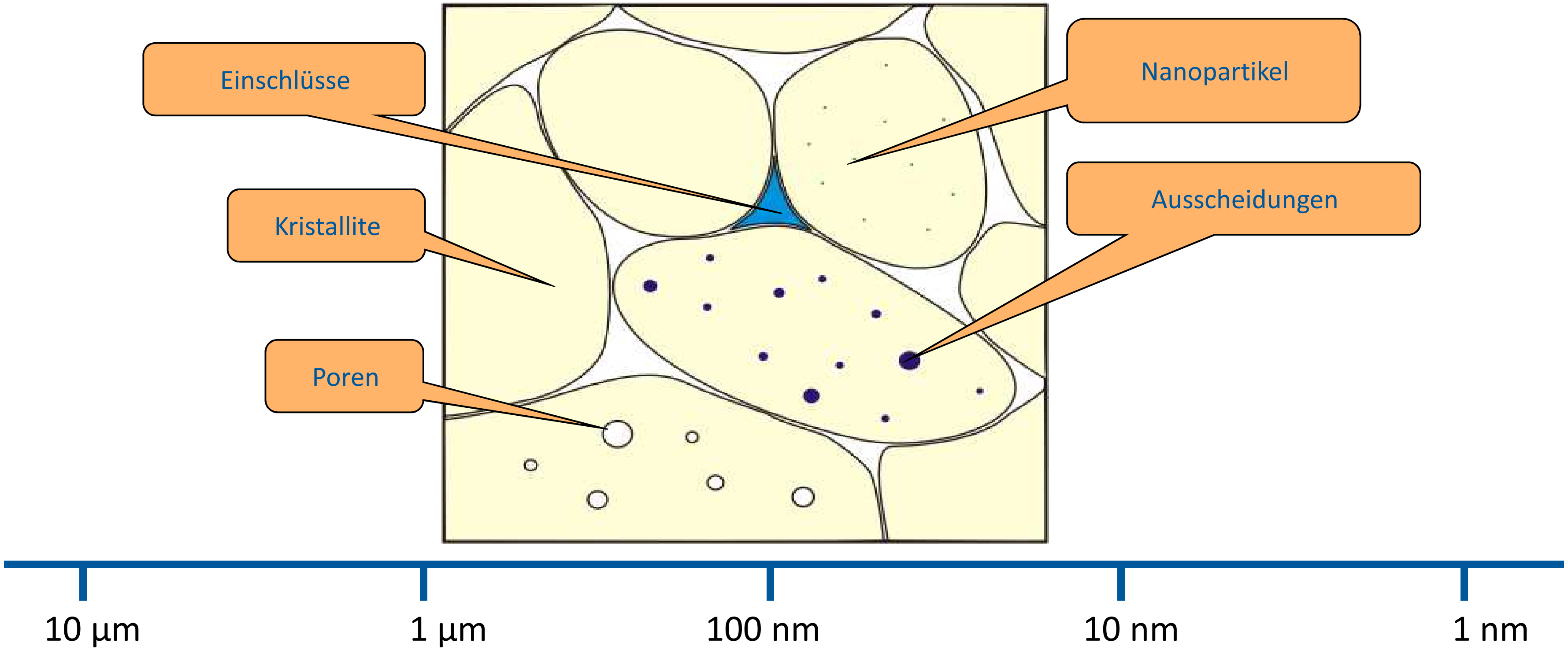
Untersuchung mikrostruktureller Eigenschaften von ungeordneten Systemen



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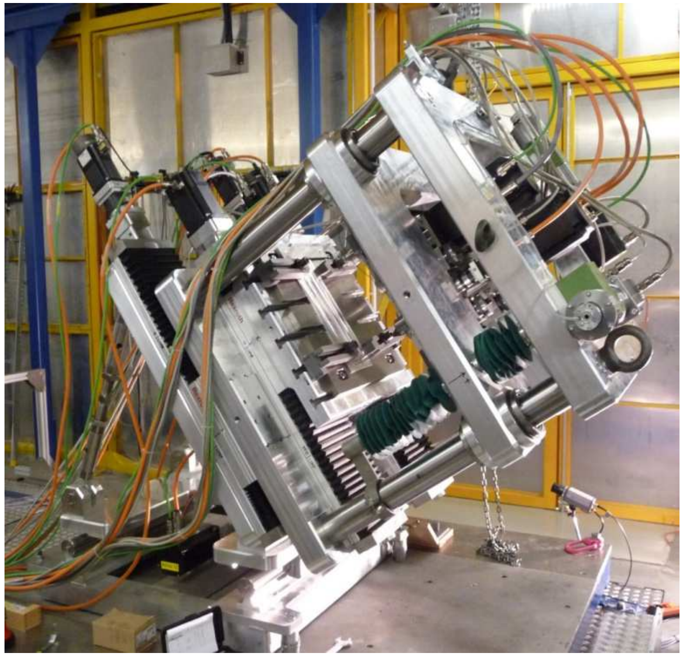
FlexiStir-Einheit

- Spezielles Design für den Einsatz am Synchrotron
- SAXS & WAXS
- In-situ Untersuchung:
  - Spannungsentwicklung
  - Rekristallisation
  - Phasenumwandlungen
  - Ausscheidungsbildung
  - Schweißtechnik



Kartierung der WEZ

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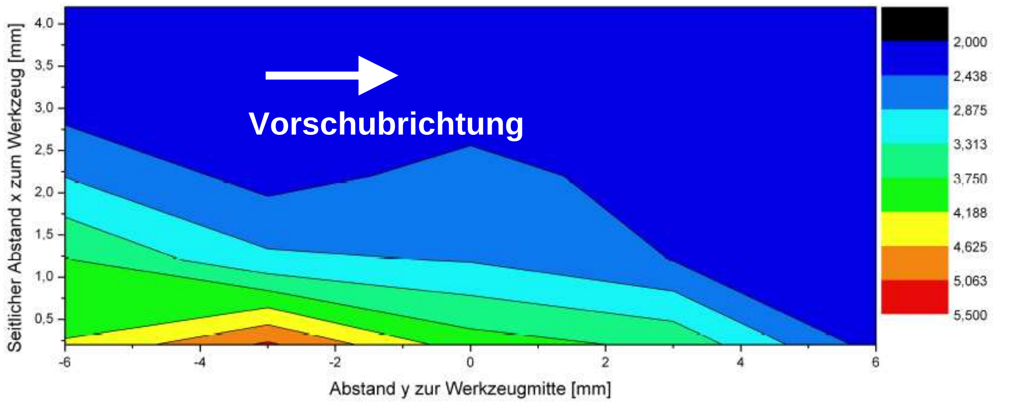
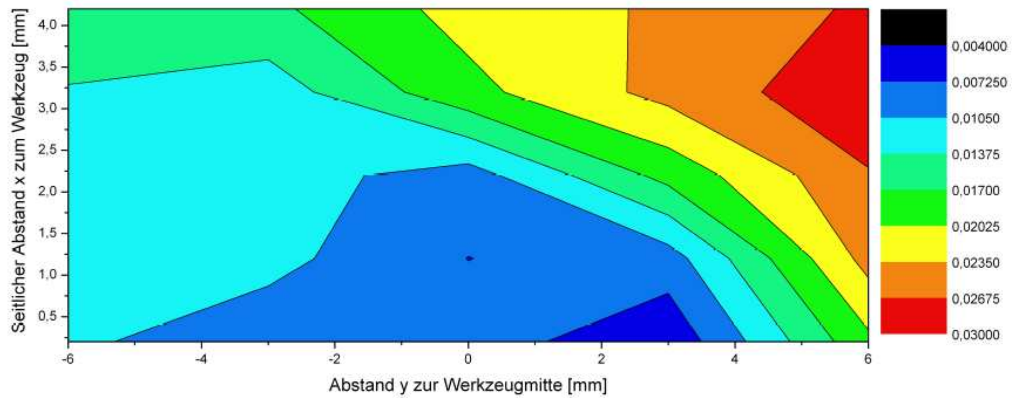
Mittlerer Radius der Ausscheidungen



Volumenbruchteil der Ausscheidungen



X-ray tomography: 3-dimensional analysis of engineering materials

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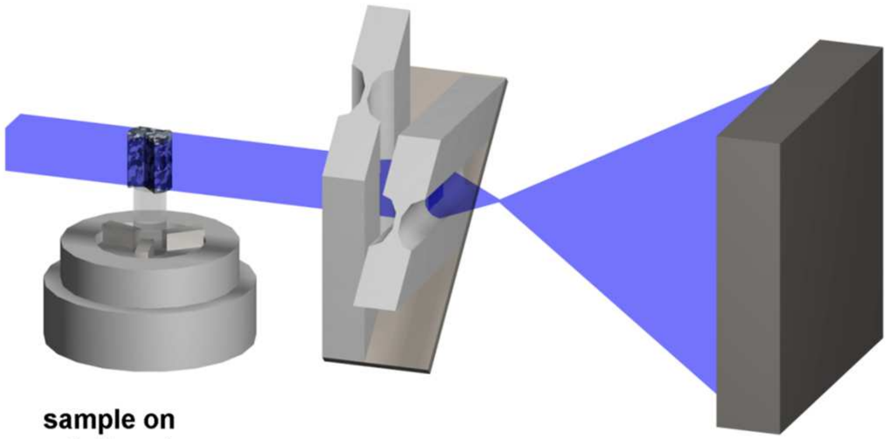
- Rotation of the sample in the X-ray beam
- 3-dimensional image is created by computer software



X-ray tomography: Inside a laser weld

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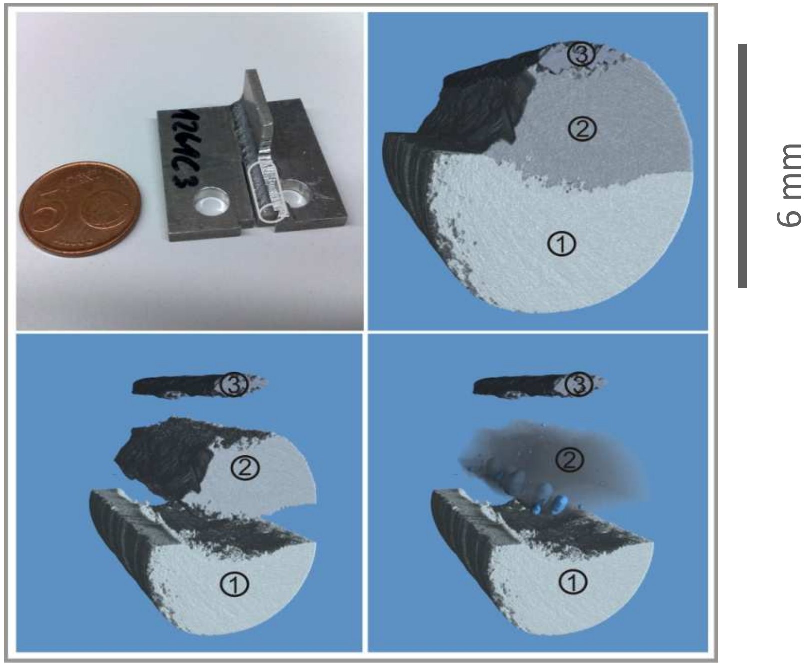

- Pores in Al laser weld
- High density resolution:

  (different metals and alloys can be determined)

J. Herzen et al., *Proc. of SPIE* **7078,** 70781V (2008)

X-ray tomography: Mg-Implant corrosion *in vivo*

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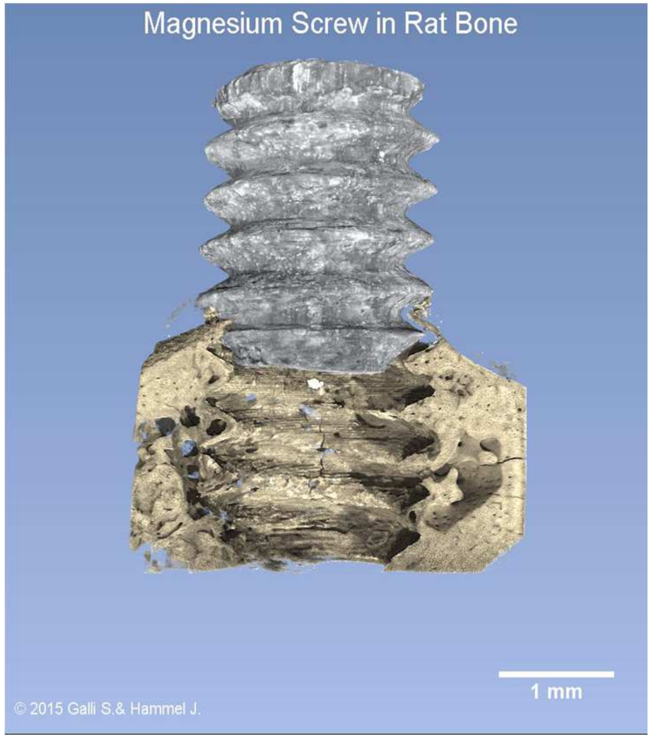


Experiment at IBL/P05

In collaboration with:

Silvia Galli – Malmö University
Regine Willumeit-Römer - HZG

EU funded initiatives for industrial use

SINE 2020
Industry Consultancy

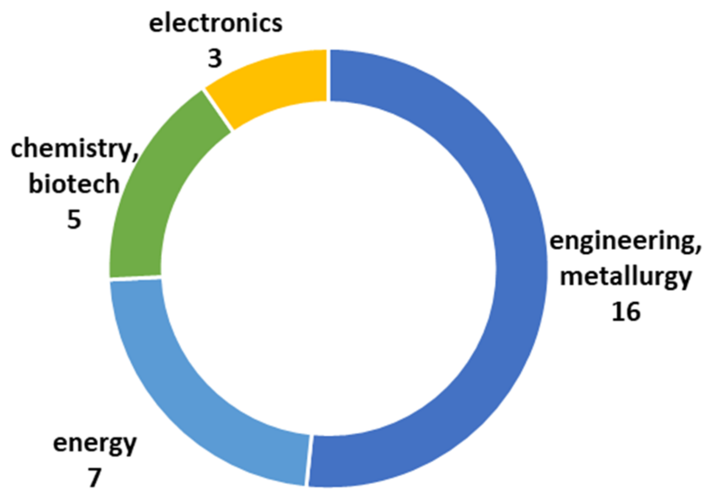
http://www.sine2020.eu/industry.html

Science & Innovation with Neutrons in Europe in 2020

- **EU Horizon 2020**
- Free of charge test measurements/feasibility studies at neutron sources
- E-learning, Training

33 requests:

5 Denmark
8 France
4 Germany
2 Italy
2 Luxembourg
3 Netherlands
1 Poland
1 Slovakia
1 Spain
4 Sweden



EU funded initiatives for industrial use

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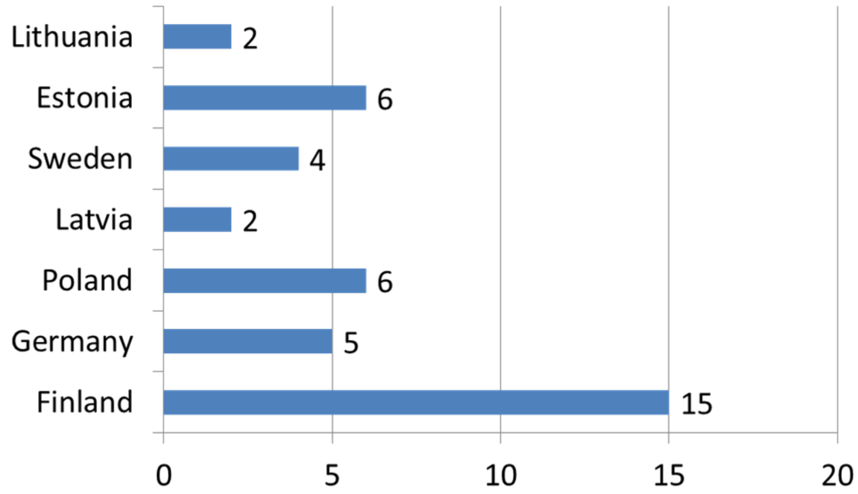
Transnational Research Access in the Macro region

BALTIC TRAM

Results:

- Creation of a network of 12 IReCs in the seven partner countries
- 48 applications for analytic feasibility studies by companies

Applications submitted (1st and 2nd call)



https://www.baltic-tram.eu/

Baltic Sea Region
Programme 2007-2013
Part-financed by the European Union
(European Regional Development Fund)

EU funded initiatives for industrial use

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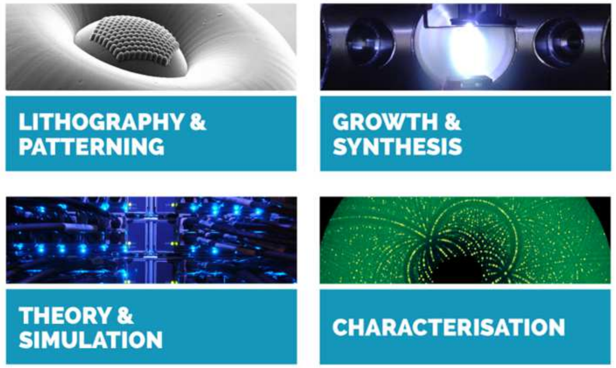
nffa.eu
nanoscience foundries & fine analysis

www.nffa.eu



Transnational Access activities

Multidisciplinary research at the nanoscale performed at nano-laboratories and ALSFs
Integration of theory & numerical analysis with advanced characterization

Convenient Access to Lightsources Open to Innovation, Science and to the World

- Tailor-made support and access programmes for SMEs

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Thank you for your attention!

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