Frithjof Nolting :: Head of LSC :: Paul Scherrer Institut

Status PSI CB&TP

SFA-AM review meeting 17./18. March 2022

Imaging and Diffraction Platform for Advanced Manufacturing and Industrial Processing

In this project, we upgrade the characterization capabilities for advanced manufacturing in particular at the Neutron, the Synchrotron and the Muon facility at PSI, but also for additional characterization.

Investment in new technology platforms

- The focus is to improve the performance of existing beamlines by developing new or enhancing existing detectors and improving the sample environment (MS, microXAS, Poldi)
- Fully open to users (via proposal system)

Financing of key staff to operate and maintain the technology platforms

- Personal for engineering work, imaging and diffraction data analysis and for support of industrial related activities in advanced manufacturing.
- Support of users, method developments and industry projects

Co-financing of new professorships

- Joint group between PSI and EPFL

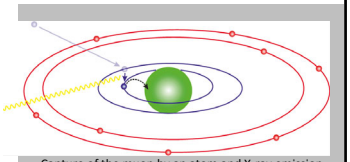
In the following some examples will be presented

Depth-dependent elemental analysis with negative muons

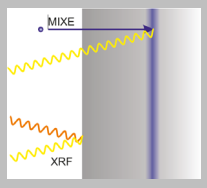
Demand for non-destructive elemental analysis

The MIXE (Muon-Induced X-ray Emission), using negative muons is a rapidly evolving technique

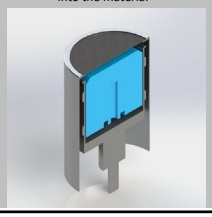
- Muons can implanted deeply into a material at a tunable depth
- The X-rays created during the cascade of the muon into its ground state have high energy and can escape from the material
- The MIXE technique is sensitive to all elements
- Possibility to determine the elemental composition of operando devices (f.ex. batteries) or costly samples
- Set-up developed at PSI
- Biswas, S. et al., Appl. Sci. 2022, 12, 2541. https://doi.org/10.3390/app12052541



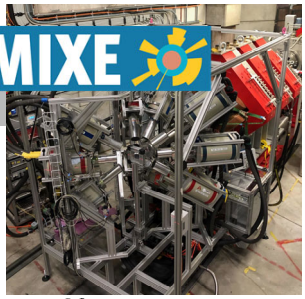
Capture of the muon by an atom and X-ray emission during ist cascade

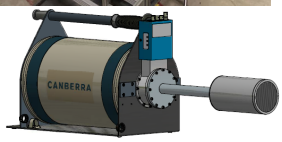


Muons can be implanted at different depth up to centimeters into the material

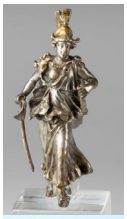


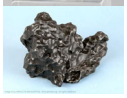
Investment Muon beamline detector

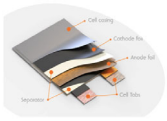




- Muon Induced X-ray Emission (MIXE)
  - Non-destructive elemental analysis
  - Sensitive to nearly all elements
  - Complementary to other techniques
  - bulk (10µm-mm) depth profiling
- PSI best institute to perform MIXE
  - Most intense continuous muon source
- Applied to e.g.
  - Precious objects like Archeological artifacts
  - Extraterrestrial objects
  - Layered structures e.g. Li-batteries
- Detection of MIXE signals by High Purity Germanium Detectors (HPGe)







Please contact us if you are interested in this technique
https://www.psi.ch/en/smus/muon-induced-x-ray-emission-mixe-project

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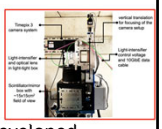
Investment in POLDI (SINQ)

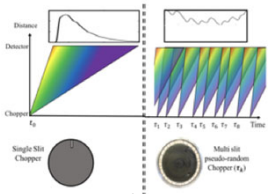
1. Investments to improve performance of Poldi beamline

- **Acquisition of TPX ToF imaging dete**

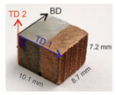


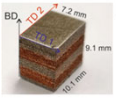
A. Losko et al. Scientific Reports 2022

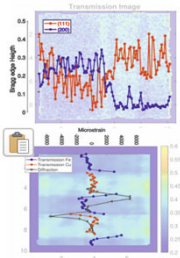
→ novel diffraction contrast strain mapping method developed and applied (e.g. in SFA-AM project MultiMat)



M. Busi et al. Sientific Reports 10, 1 2021







F. Malamud et al., manuscript in prep.

FNSNF
R'Equip

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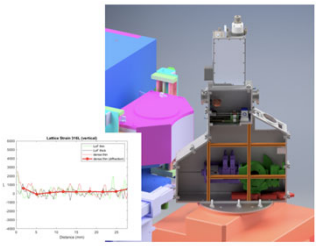
Investment in POLDI (SINQ)

1. Investments to improve performance of Poldi beamline

- **Acquisition of components operando AM machine**



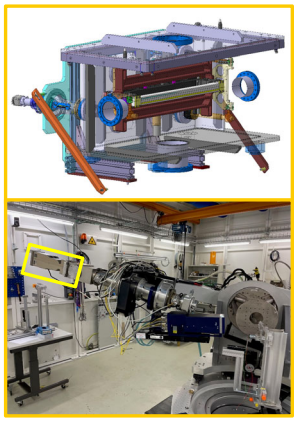
→ t.b. operational end 2022

Investment upgrade Material Science beamline (SLS)

Horizontal mirror: *to improve focusing and operability*
- Design completed
- Parts ordered
- Installation by the end of the year, including movement of DCM and vertical mirrors

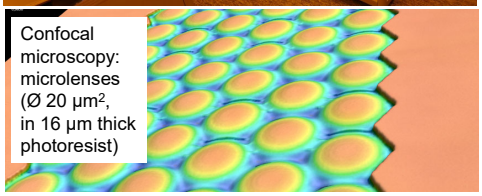
Eiger 500 K: *improved detector for 3D station*
- Installed and commissioned since Feb 22

Hexapod: *replacement, improving speed*
- Currently evaluating offers



Microscope for quality control of 3D structures

Heidelberg Instruments DWL66+



Confocal microscopy: microlenses (Ø 20 µm², in 16 µm thick photoresist)

New direct laser writer at PSI
is well suited for flexible patterning of 3D structures for research and industrial projects (ANAXAM)
- 3D diffraction gratings and microlenses
- microfluidics and mechanics

In comparison to electron beam lithography laser lithography is faster and enables patterning larger areas at industrial scales.

A confocal microscope enables
- Precise measurement of 3D contours
- Establishment of novel 3D processes for additive manufacturing
- Closes the optimization loop for the laser writer

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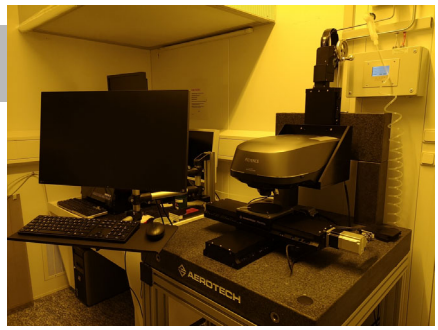
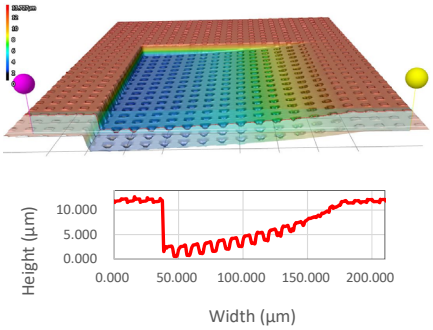
Microscope for quality control of 3D structures





Laser Scanning Confocal Microscope

Keyence VK-X 3100 with 404 nm laser with Aerotech 300x300 mm^2 stage for

- fast visualization of 3D topographies with high resolutions down to 250 nm
- large area automated scanning
- roughness measurement

Applications

- 3D quality control for new laser writer
- micro-optics from smartphones to X-ray applications (SLS)
- microfluidics for biosensors
- defect analysis in 3D manufacturing

https://www.psi.ch/en/lnq/advanced-nanomanufacturing

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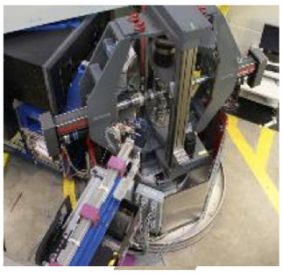
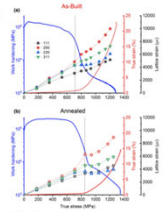
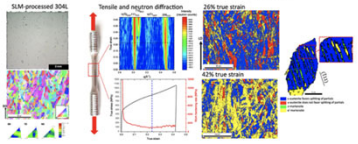
Example: Poldi

(selection)







Additive Manufacturing
Volume 34, August 2020, 101201

Research Paper
Investigation of the effect of Laser Shock Peening in Additively Manufactured samples through Bragg Edge Neutron Imaging

Scripta Materialia
Volume 176, February 2020, Pages 53-57

High ductility and transformation-induced-plasticity in metastable stainless steel processed by selective laser melting with low power

In Situ Synchrotron and Neutron Characterization of Additively Manufactured Alloys | Open Access | Published: 18 November 2020

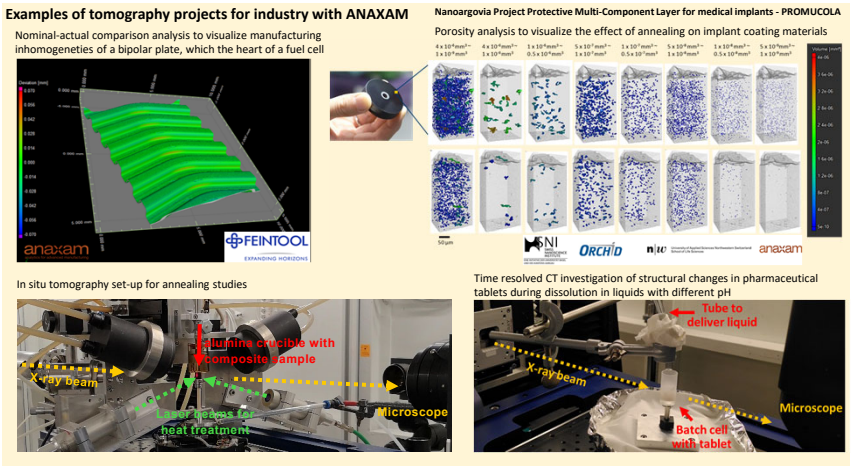
The Effect of γ'' and δ Phase Precipitation on the Mechanical Properties of Inconel 718 Manufactured by Selective Laser Melting: An In Situ Neutron Diffraction and Acoustic Emission Study

Jan Čapek, Efthymios Polatidis, Michal Knapek, Christophe Lyphout, Nicola Casati, Robert Pederson & Markus Strobl

JOM 73, 223-232 (2021) | Cite this article

J. Capek
https://www.psi.ch/en/lns/people/jan-capek

Example: TOMCAT Industrial Liaison Scientist



Margie Olbinado
https://www.psi.ch/en/x-ray-tomography-group/people/margie-olbinado

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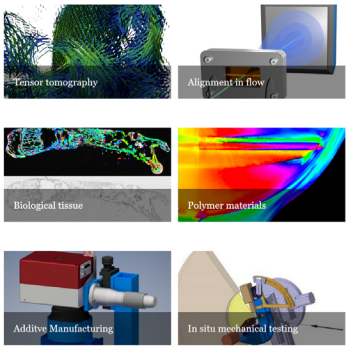
PSI – EPFL group

SCHOOL OF ENGINEERING
MATERIALS

Structure and Mechanics of Advanced Materials
Head: Marianne Liebi
Joint group between PSI, Photon Science Division,
and EPFL, Institute of Materials
Successor of Helena van Swygenhoven

Performs research on structural and mechanical properties of diverse soft matter systems, including samples of biological origin, as well as of metals and alloys.

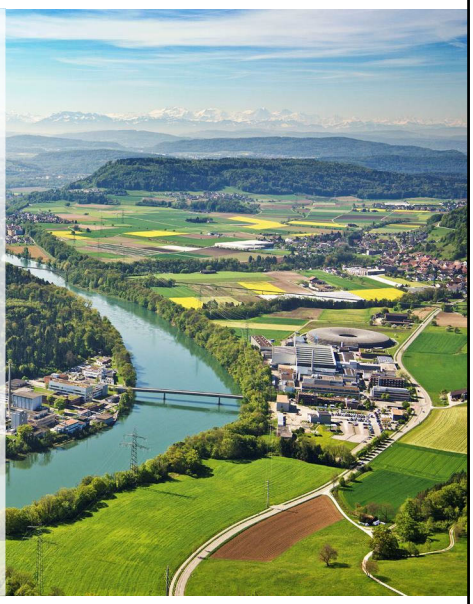


Steven van Petegem

https://www.psi.ch/en/smam
https://www.epfl.ch/labs/cam-x/

PAUL SCHERRER INSTITUT

Wir schaffen Wissen – heute für morgen

PSI an ideal place for advanced micro- and nano-structure analytics for Advanced Manufacturing

Funding of SFA-AM enables to improve capabilities and make them to the scientific community and to industry available