Swedish Materials Science beamline at PETRA III: laser platform for in-operando synchrotron X-ray characterization

Prof. Johanne Mouzon



The Swedish Materials Science beamline at PETRA III

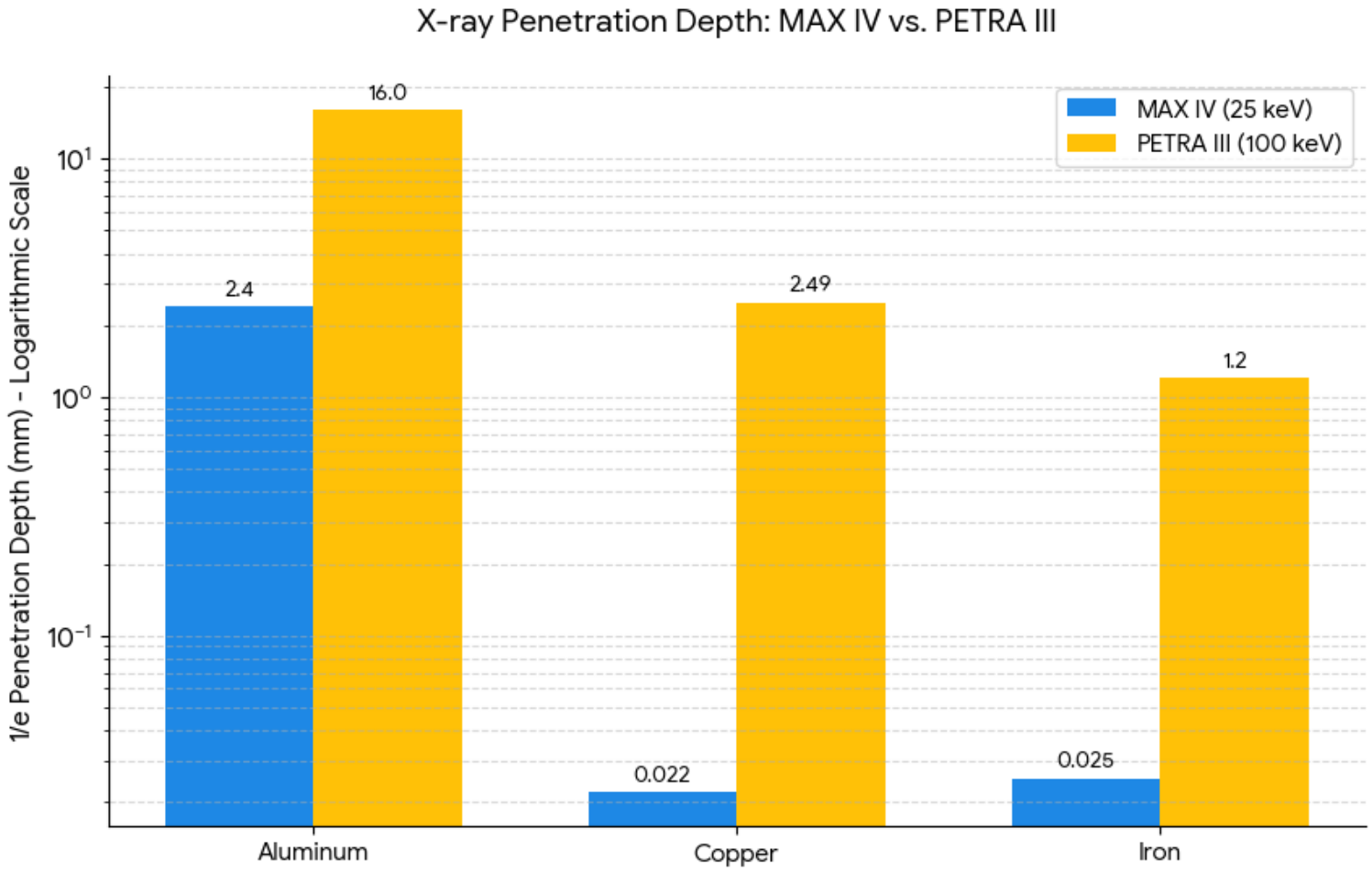
- Designed for materials research and to complement MAX IV and ESS
- Privileged access for Sweden

to high-energy hard X-rays

- 40–150 keV
- Deeper material penetration
- Important to study:

- materials with heavy elements

- larger specimens



The Swedish Materials Science beamline at PETRA III

- Historical timeline:

2010
RÅC project

Dec 2018
Friendly measurements

Swedish Research Council

DESY

KTH VETENSKAP OCH KONST

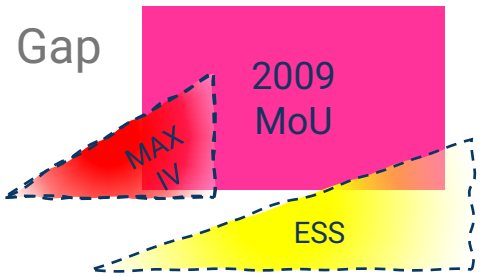
LINKÖPINGS UNIVERSITET

Academic host
Swedish beamline governance
Safeguard Swedish interests

CeXS
CENTER FOR X-RAYS IN SWEDISH MATERIALS SCIENCE

UPPSALA UNIVERSITET

Swedish Research Council



Sept 2016
SMS key ceremony



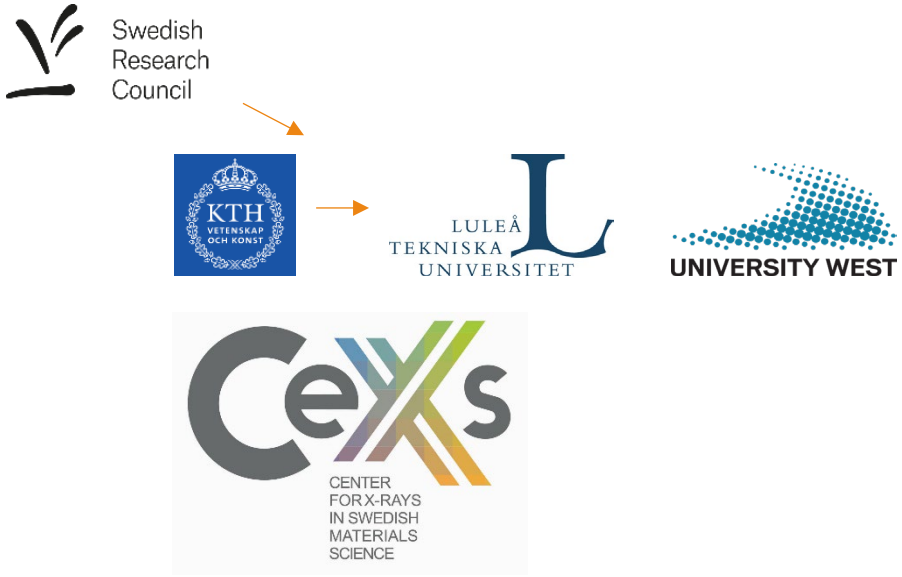
From 2019
- Privileged access
- Swedish beamline operational

Late 2020
Inventory entry

2022
Uppsala's affiliation
Extensions

The PETRA III Swedish Materials Science beamline

- Platform enabling streamlined in-operando synchrotron X-ray characterization of laser- and electron-beam processes



2023-2026
VR- Research Infrastructure Grant

Center for X-rays in Swedish Materials Science (CeXS)

- CeXS focuses on the use of high energy X-rays in materials R&D
- academic host of the Swedish Material Science beamline at PETRA III
- https://www.cexs.kth.se/
- Operational team



Peter Hedström, Director



Denise McCluskey, Manager

CeXS

CENTER FOR X-RAYS IN SWEDISH MATERIALS SCIENCE

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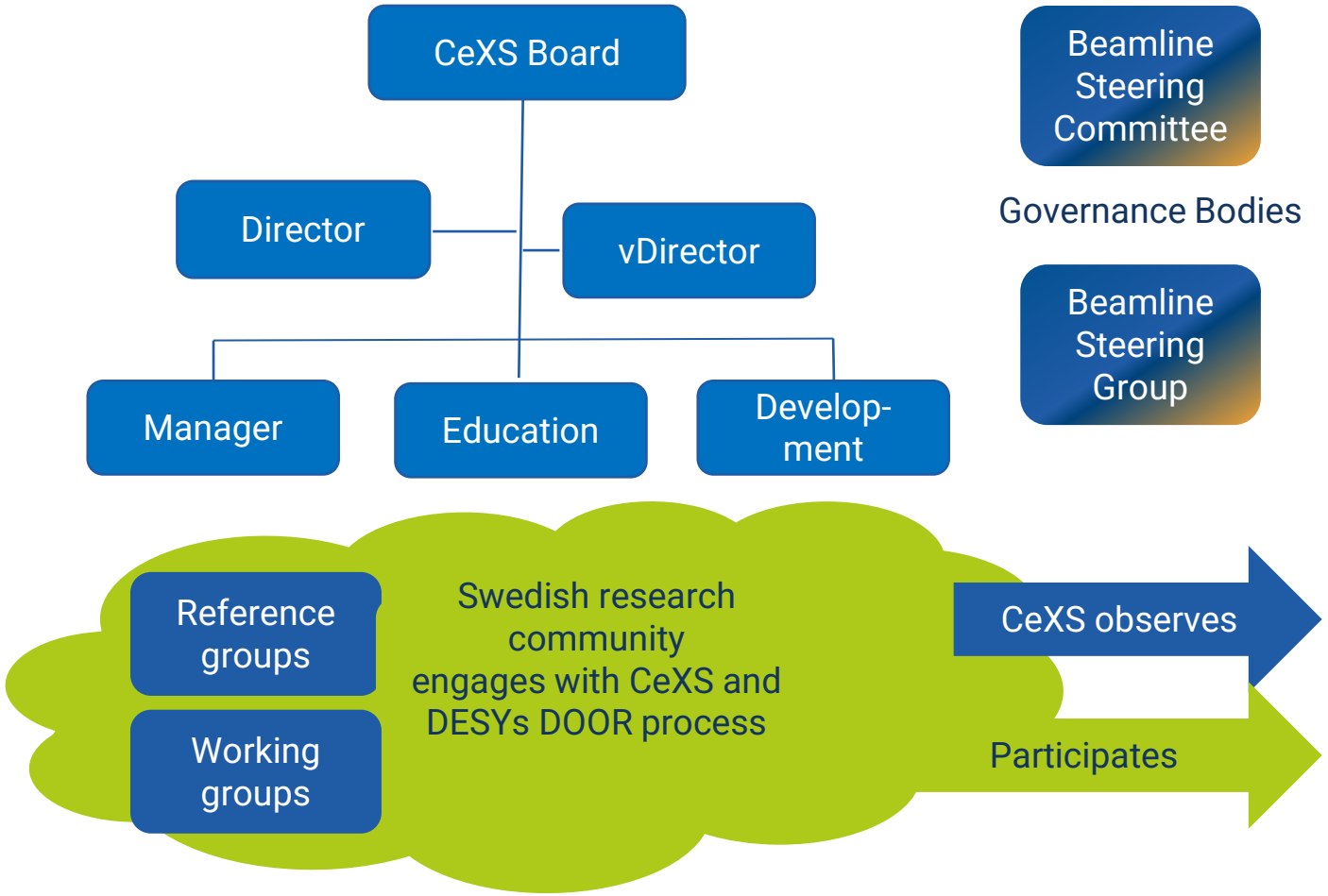
PETRA III Swedish Node

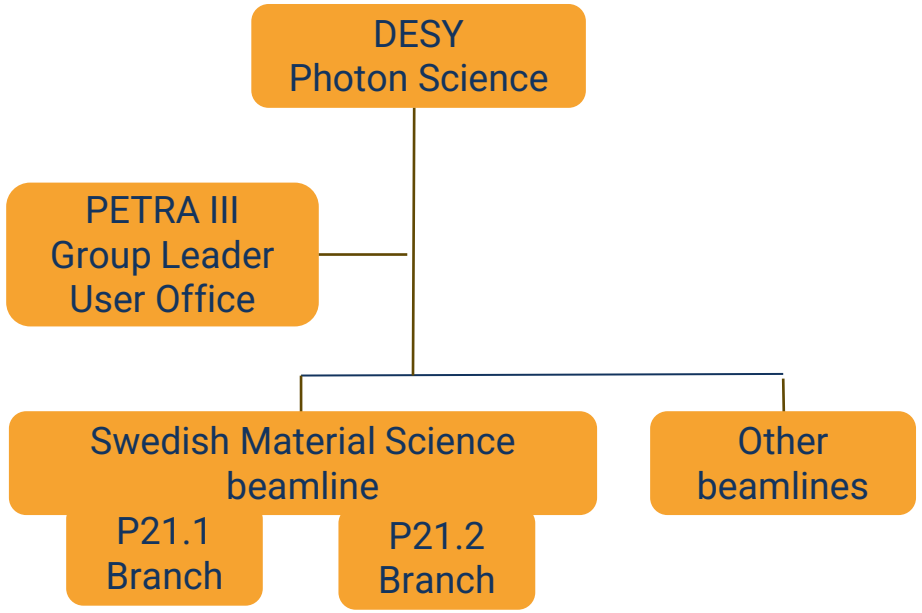
- Organizations and governance



Beamline Steering Committee

Governance Bodies

Beamline Steering Group



DOOR application process's review panels

Proposal Review Panel P21

Proposal Review Panel Px

Center for X-rays in Swedish Materials Science (CeXS)

Education with advanced courses:

- Synchrotron and neutrons for engineering materials in spring 2024 with theory at KTH and practical sessions at P21.2 on 3-5 June
- Advanced beamline data analysis in autumn 2024, Uppsala University. Oversubscribed. 47 people completed the course
- For more info:

https://www.cexs.kth.se/news-and-events/courses-and-hands-on-training-1.1003402

Center for X-rays in Swedish Materials Science (CeXS)

Streamlining in-situ SAXS/WAXS heat treatment experiments:

- Aim to support researchers to approach in-situ SAXS/WAXS measurements on precipitation kinetics and microstructural evolution during heat treatment more easily
- From planning to result:

1. Preparing beamtime proposals
2. Beamtime preparations
3. Beamtime measurements
4. Comprehensive data analysis

SMS beamlines at PETRA III in Hamburg

2 beamlines:

- P21.1 (Side Station):

  - Co-funded by DESY and Sweden; uses a side branch configuration

  - scattering and high-energy diffraction for physics and chemistry

  - running at fixed energies (such as around 52, 85, and 100 keV)

- P21.2 (Inline Station):

  - Fully funded by Sweden; uses the main inline path with an extended layout spanning multiple hutches.

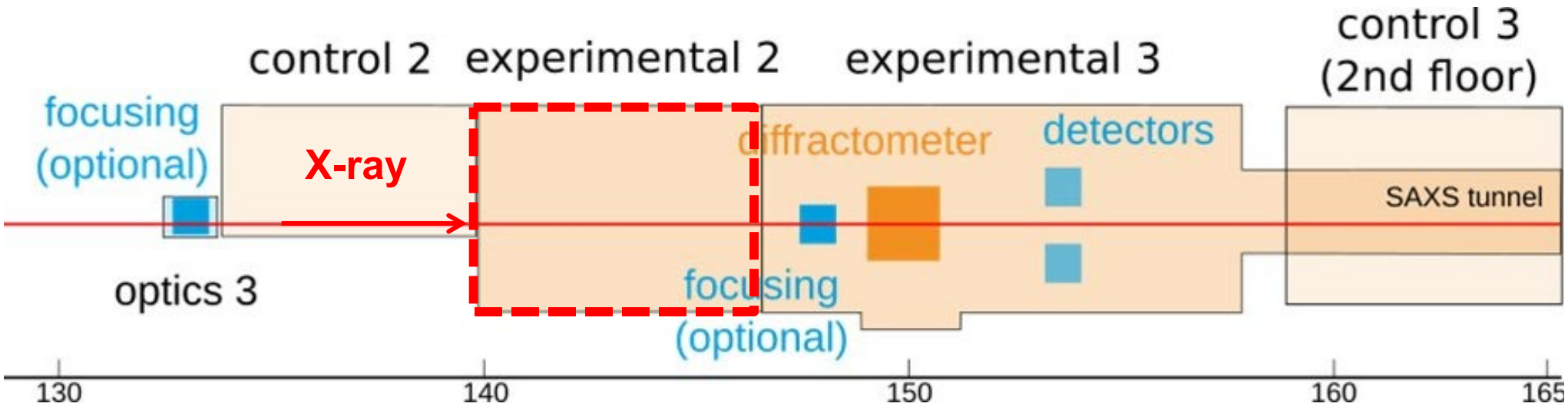
  - Focuses on engineering materials science, combining wide-angle X-ray scattering (WAXS), small-angle X-ray scattering (SAXS), and imaging techniques.

  - Operates flexibly across a broader continuous high-energy range (~40–150 keV)

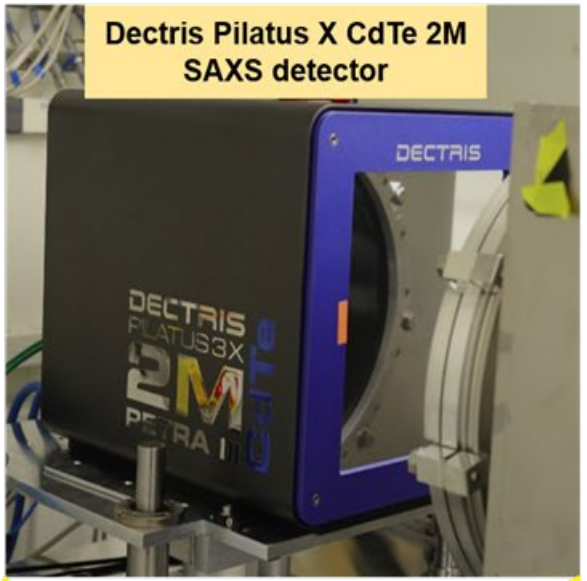
P21.2 Beamline at SMS

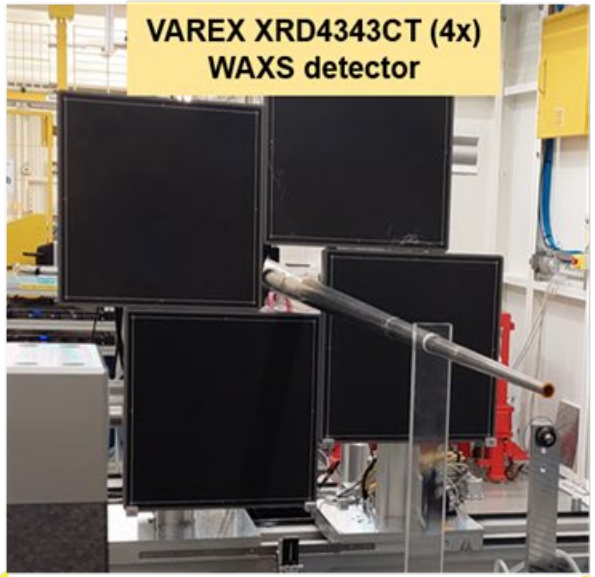
2 experimental hutches:

- EH3: where all equipment is currently located and placed on rails
- EH2: Roll-in station currently under construction, enable users to setup offline before the start of the experiment



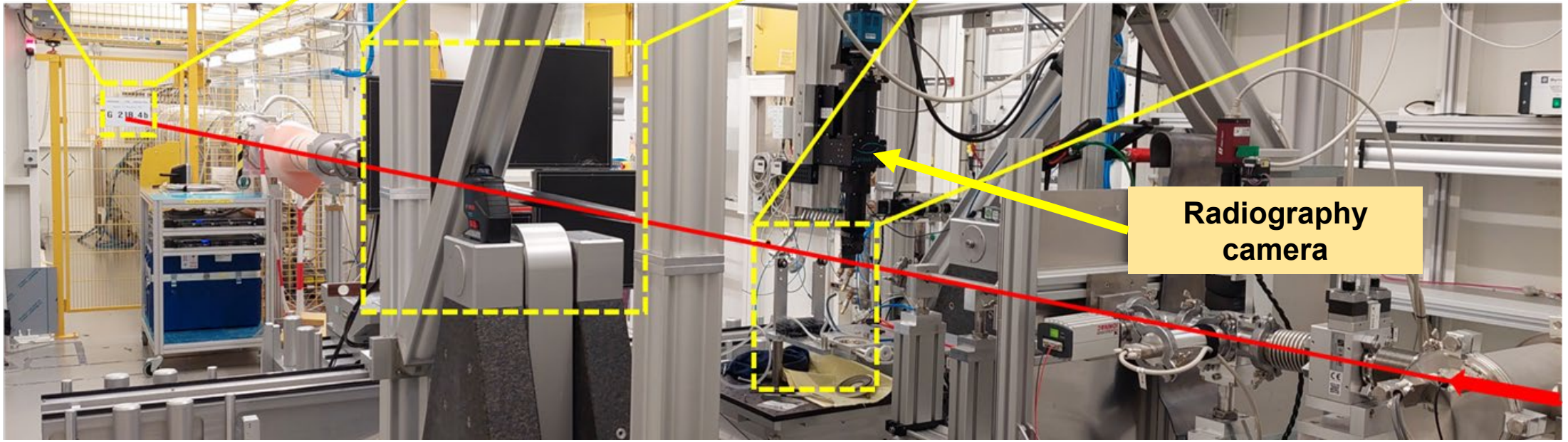
EH3:





SAMPLE

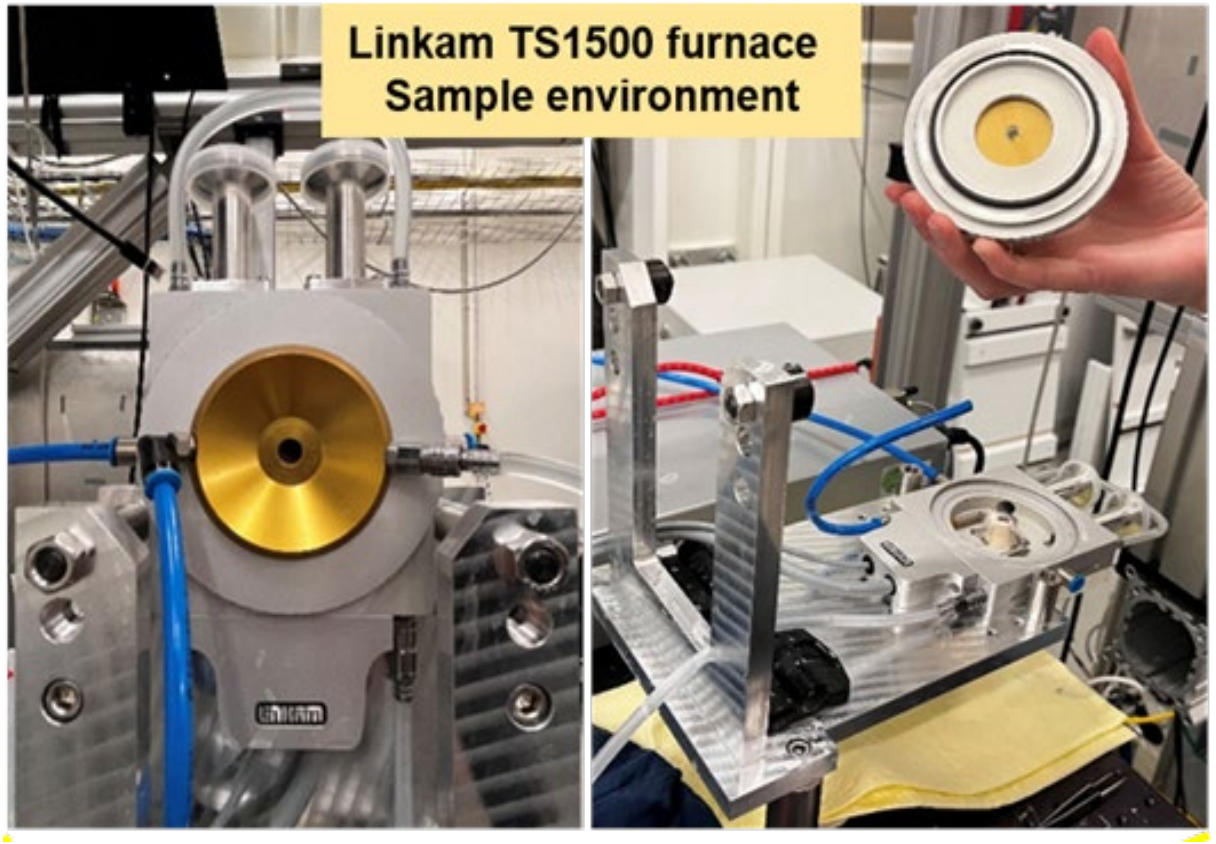
ENVIRONMENT



Sample environment

Linkam TS1500 high-temperature heating stage:

- Ambient to 1500°C
- 1°C/min to 200°C/min
- Ø 7mm x 3mm deep (ceramic crucible)
- Inert atmosphere
- Vacuum levels down to 10^{-3} mbar



Sample environment

MiniMelt:

- Electron beam as a heat source
- For:

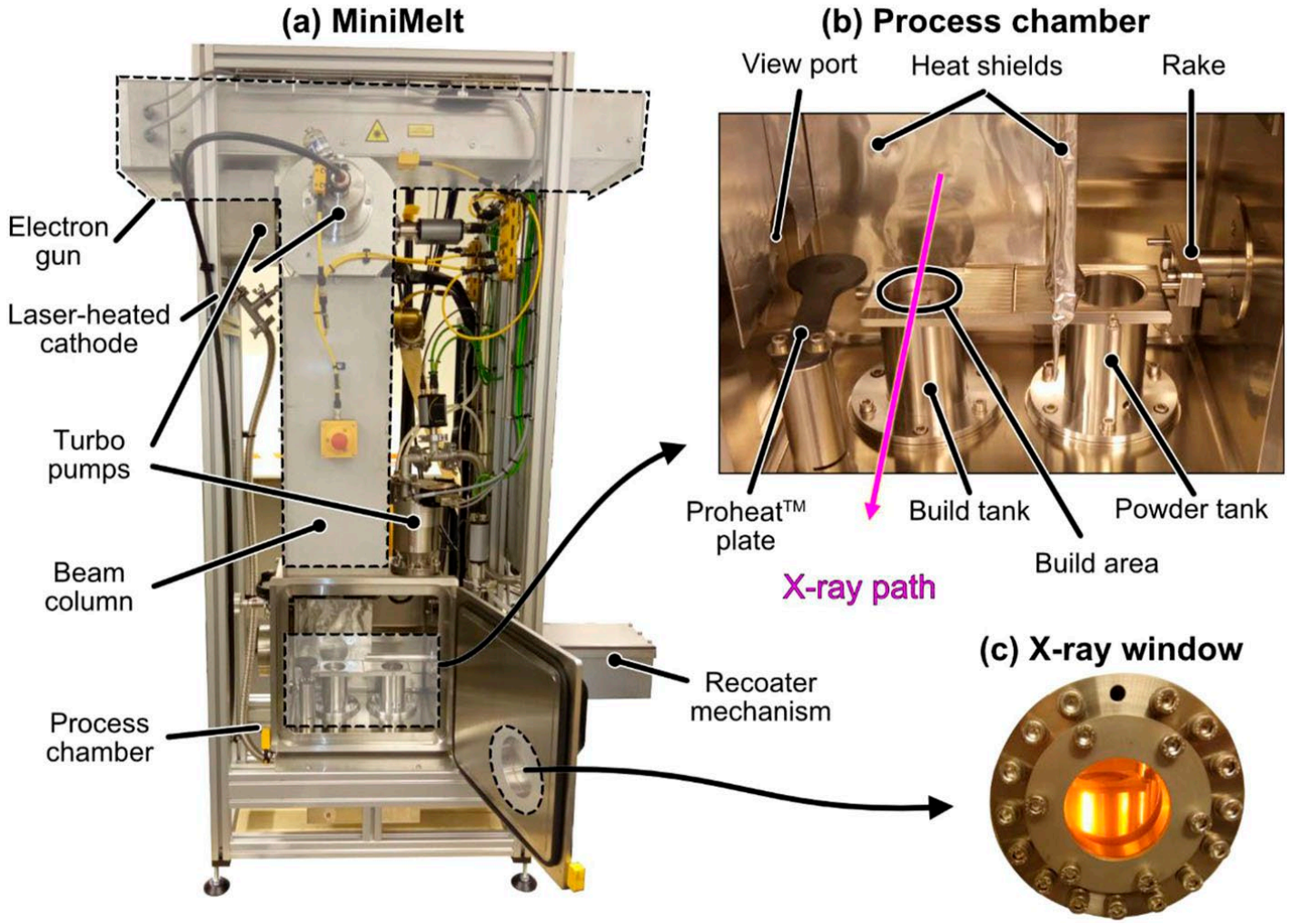
- Powder Bed Fusion (PBF-EB)

- Electron beam welding

- Commissioned at:

- P21.2 for WAXS + SAXS

- P61A for high-speed imaging (+WAXS)



Sample environment

Hybrid fiber-coupled diode laser:

- Diode laser 4 kW, 600 µm fibre
- Converter fibre laser 2 kW, 100 µm fibre
- Laser commissioned in 2025.
- Cladding/DED optics (*no powder feeder yet*)
- Other optics need to be brought on-site (*e.g. welding*)
- Linear axis.











Sample environment

Hybrid fiber-coupled diode laser:

- Laser as a heat source
- For:

- Heat-treatment (hardening, sintering, etc.)

- Welding

- Cutting

- Additive manufacturing (Directed laser deposition, DED)

- For more info and support, contact:

johanne.mouzon@ltu.se





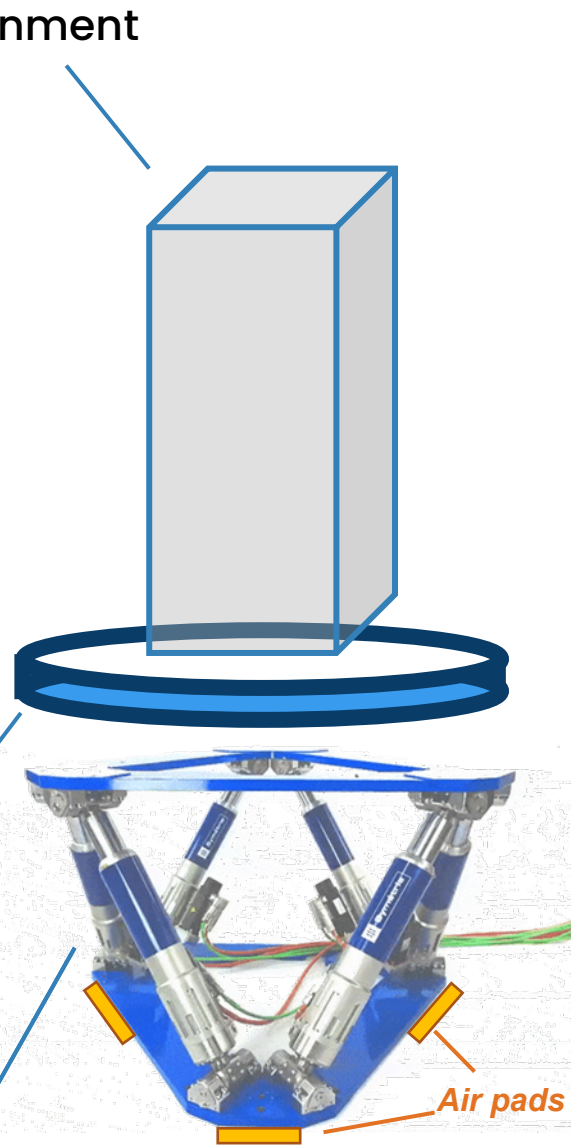




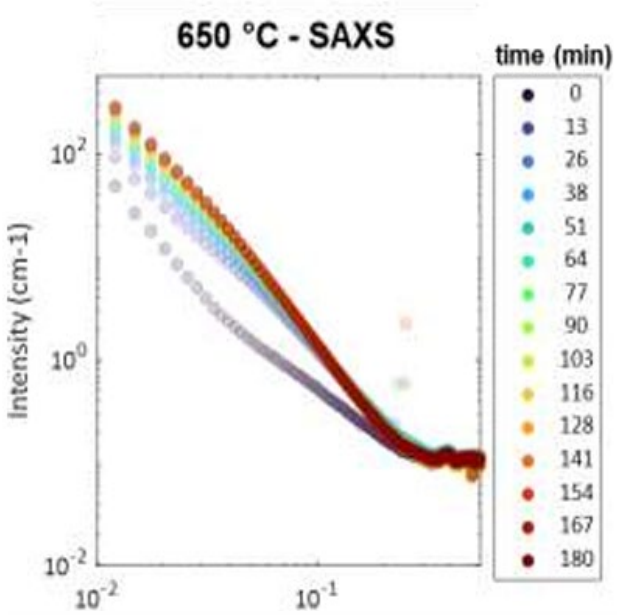


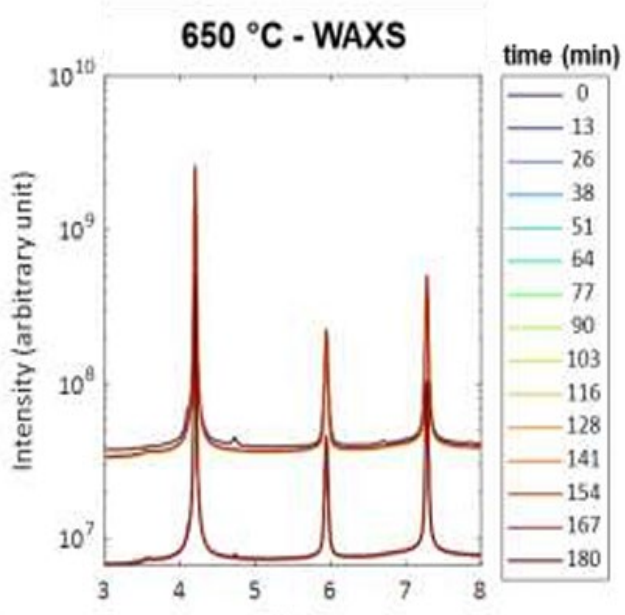
EH2:

- Sample environment up to 1 ton with heavy-load hexapod
- Fast WAXS measurement
- Wide q-range WAXS
- High resolution, fast acquisition (up to 200 fps) radiography
- 12.5 MSEK budget to equip EH2

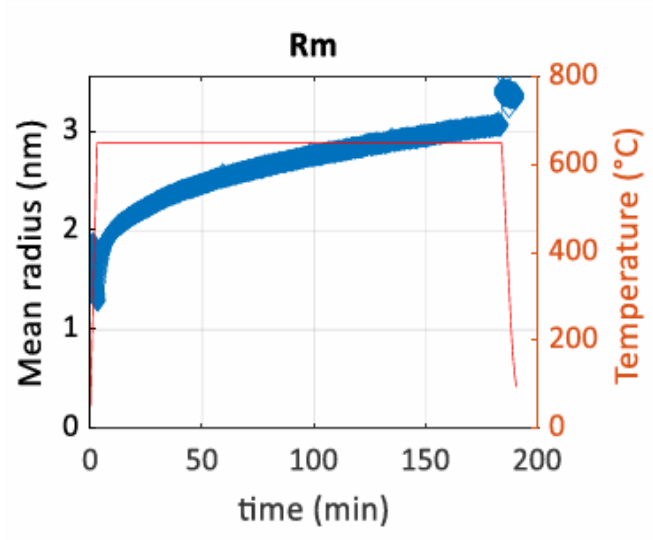


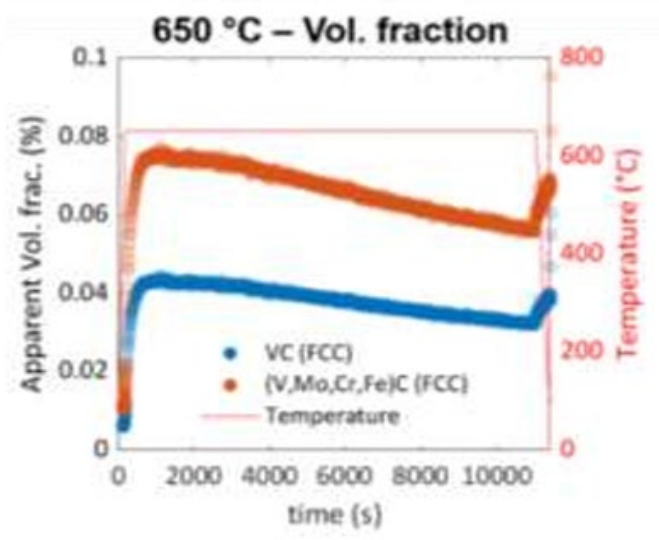
Example 1: *in-situ* evolution of precipates in high-alloyed steel



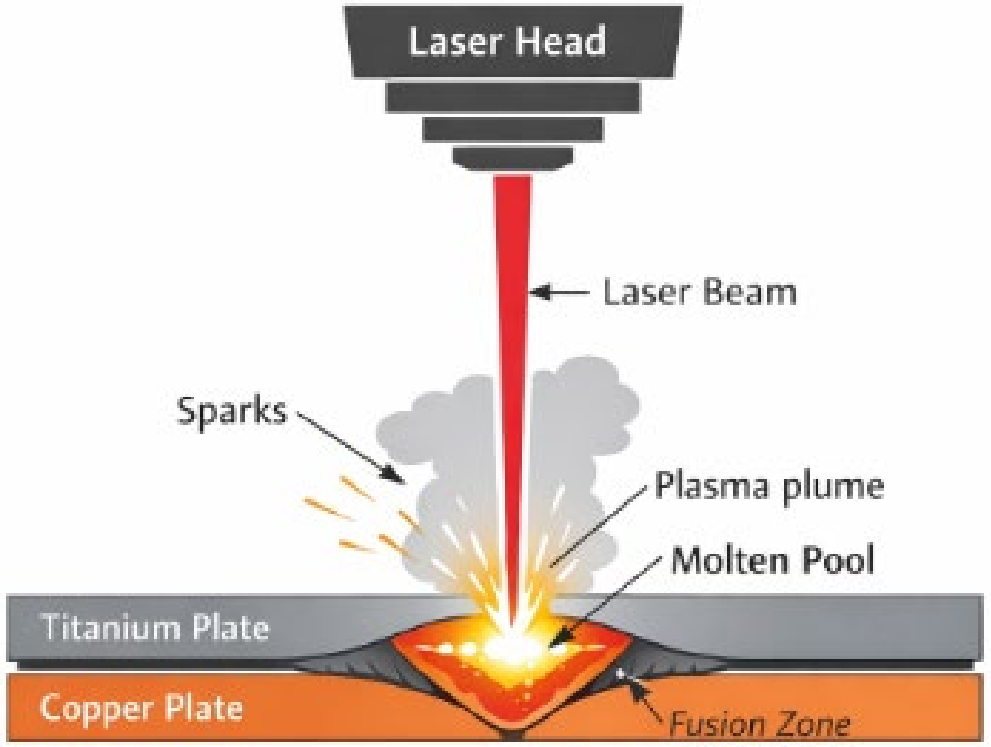


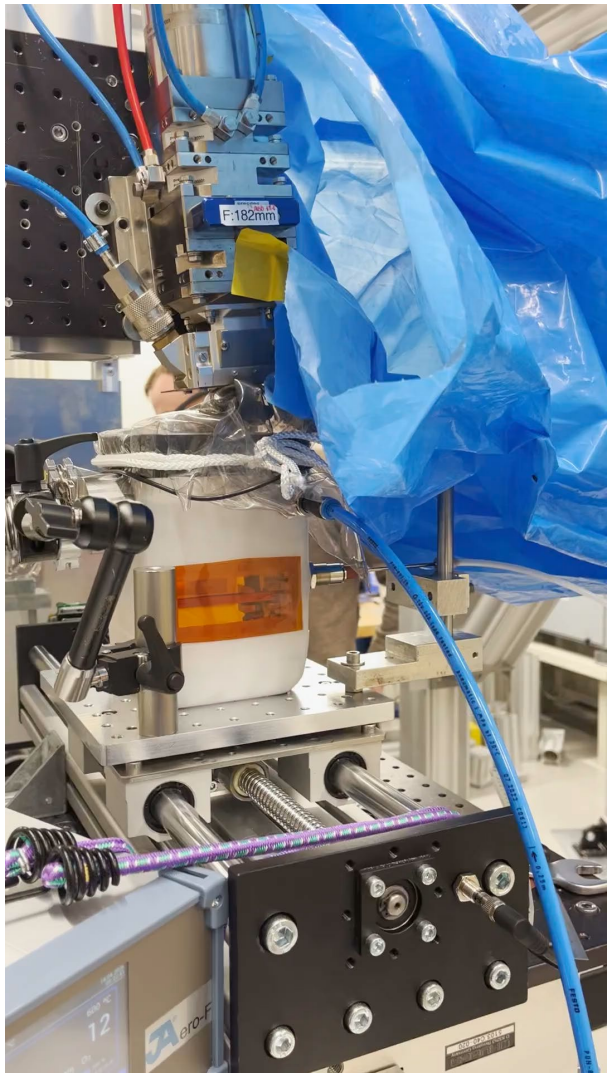
+ phase identification





Example 2: *in-situ* radiography during welding of Ti onto Cu



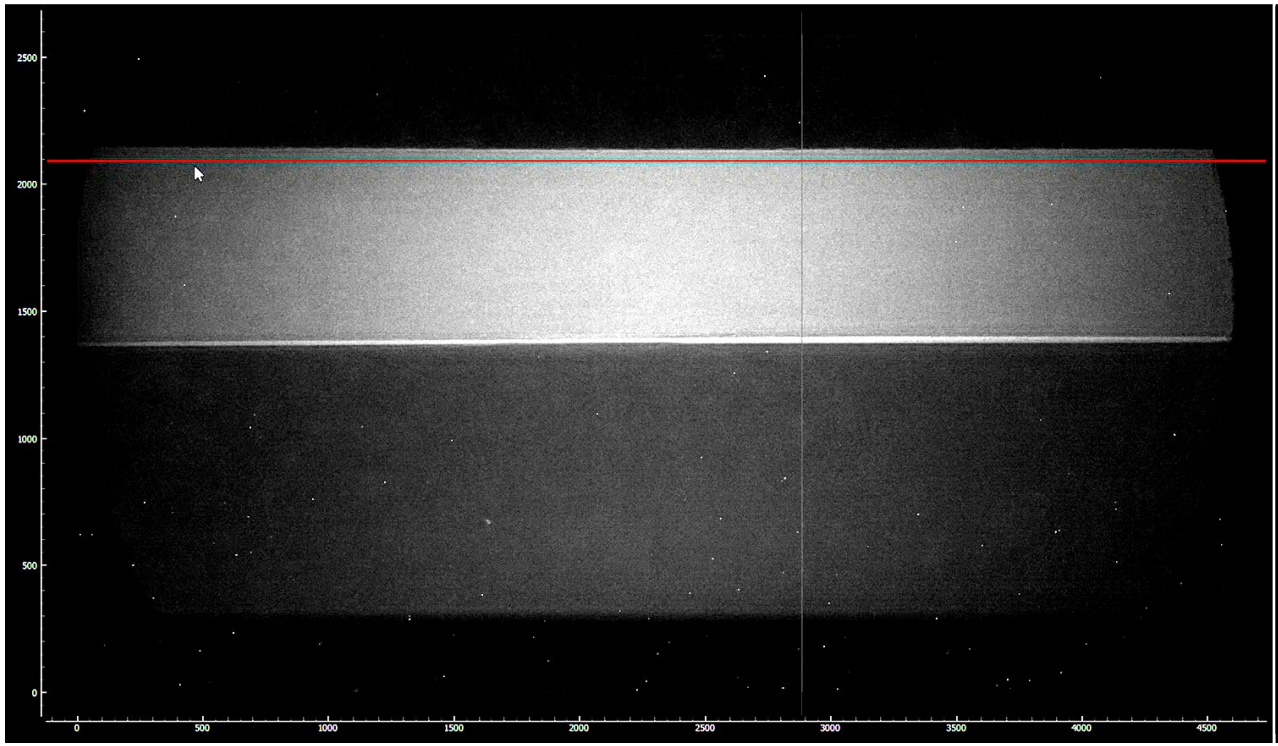


Radiography through 3 mm thick copper

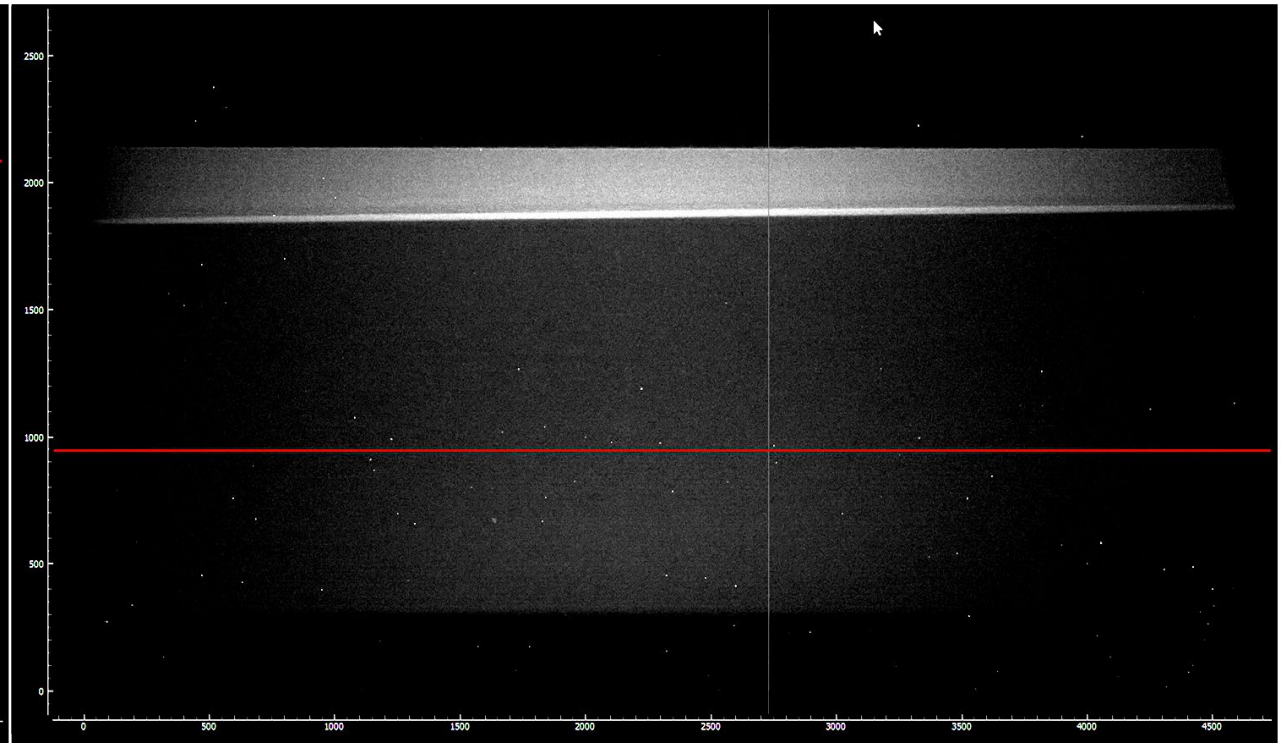
+ strain measurement with WAXS

Example 2: *in-situ* radiography during welding of Ti onto Cu

Under argon



In air



How to apply for beamtime?

- Contact CeXS and discuss your idea
- Discuss your idea and the details of the needed set-up with the staff at P21.2:

https://photon-science.desy.de/facilities/petra_iii/beamlines/p212_diffraction__imaging/contact__staff/index_eng.html

- You need to be convincing and show that you understand what you want to do:

  Why do you need synchrotron radiation?

  Is it really feasible? Novelty?

- Write proposal (2 A4 pages) and apply through the DOOR portal:

https://door.desy.de/door/index.php

Deadlines

- Typically occurs twice a year on March 1 and September 1
- September 1, 2026: beamtime period for spring 2027.
- Note 1: PETRA III has a scheduled maintenance shutdown between September 2026 and April 2027
- Note 2: Upgrading to PETRA IV will start in 2027 until 2032, but it will be still possible to perform experiments until 2030.

Service providers

- If researchers do not have practical mastery of the techniques and do not wish to perform the measurements themselves, alternative workflows are also available.
- For routine X-ray diffraction, Pair Distribution Function (PDF) analysis, and small-angle X-ray scattering (SAXS), samples can be sent to external providers, such as Momentum Transfer GmbH in Germany: https://momentumtransfer.com
- In these cases, results can be obtained within approximately two weeks.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