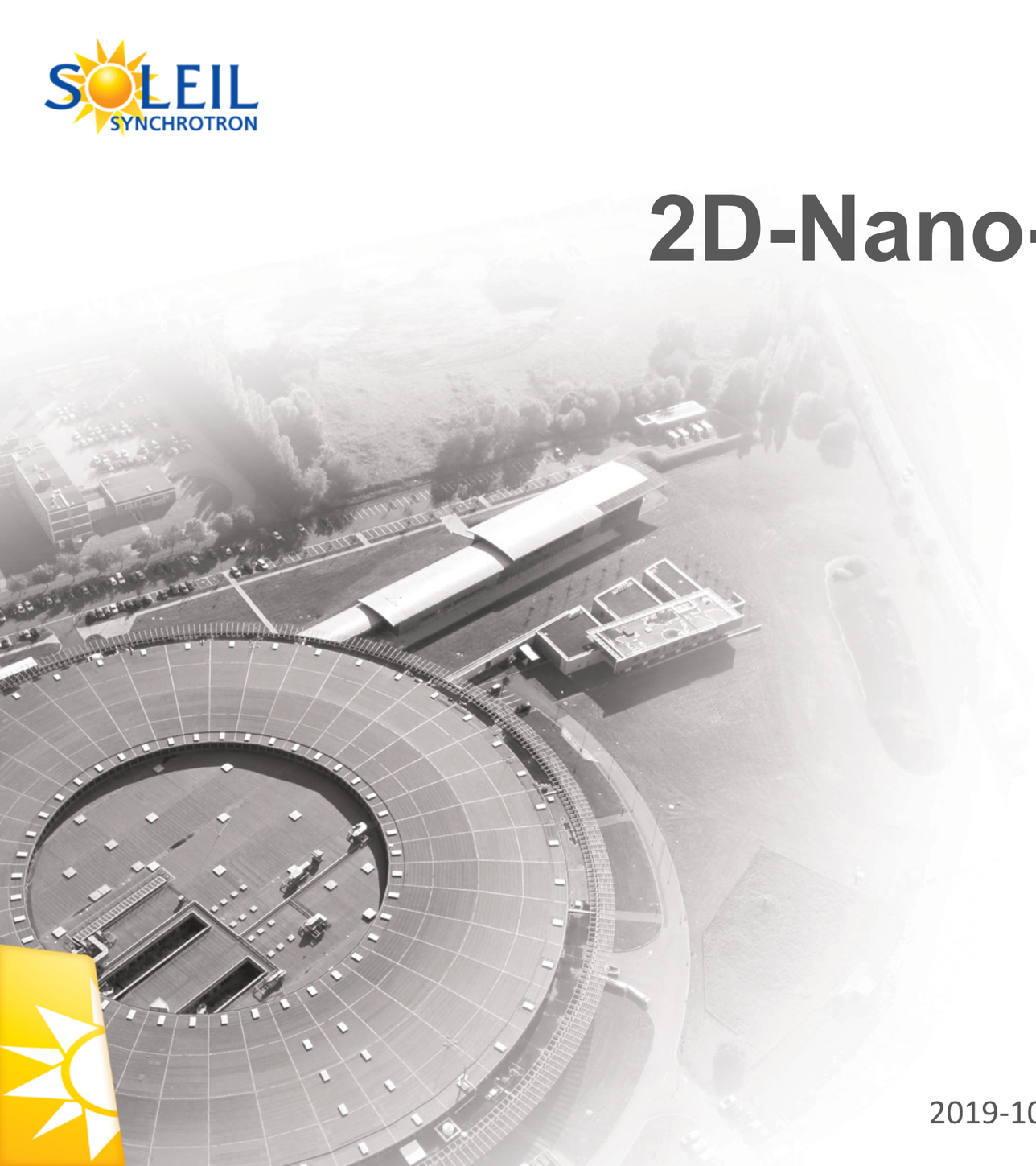
2D-Nano-Ptychography Results
at the SWING Beamline



Presentation

Christer Engblom, *Synchrotron Soleil*

ECA (Electronique de Contrôle et Acquisition) Group

– Electronics & Motion Control
(Specialized in motorized precision control systems)

On behalf of the Nanoprobe SWING team:

J. Perez (SWING beamline), A. Lestrade (Metrology), F. Alves (Mechanics), F. Langlois (Software & Ctrl), YM. Abiven (Electronics), F. Berenguer (CRISTAL Beamline), P. Montaville (PX1 beamline)

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  - Context & overview
  - Challenges & approach
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  - Experimental Hutch & Portability
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Introduction – Context & overview

Nanoprobe Project (2013-2017)

Collaboration (Synchrotron SOLEIL & MAX IV) to produce Nanoprobe endstation prototype capable of 2D- & 3D tomography on the nanometric scale.

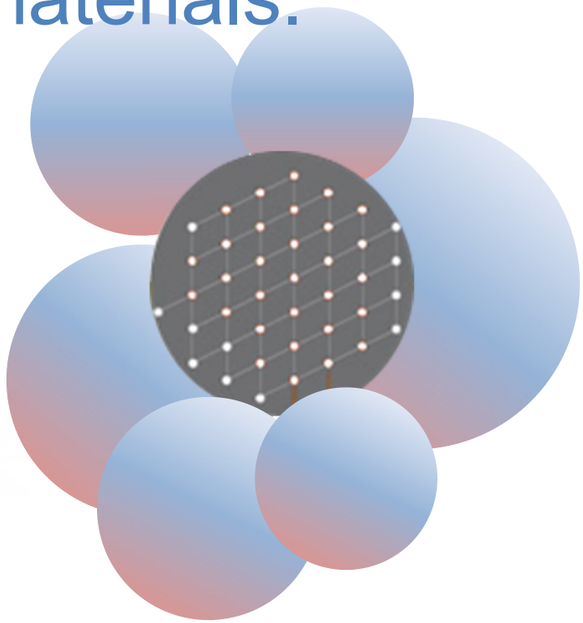
Nanoprobe-SOLEIL (2017-)

Mechatronic-oriented team dedicated to nano-positioning systems at SOLEIL.

Introduction – Context & overview

SWING Beamline, Synchrotron SOLEIL

A beamline that provides structural data at the nanometer-micrometer scale on soft condensed matter, macro-molecules, and composite materials.



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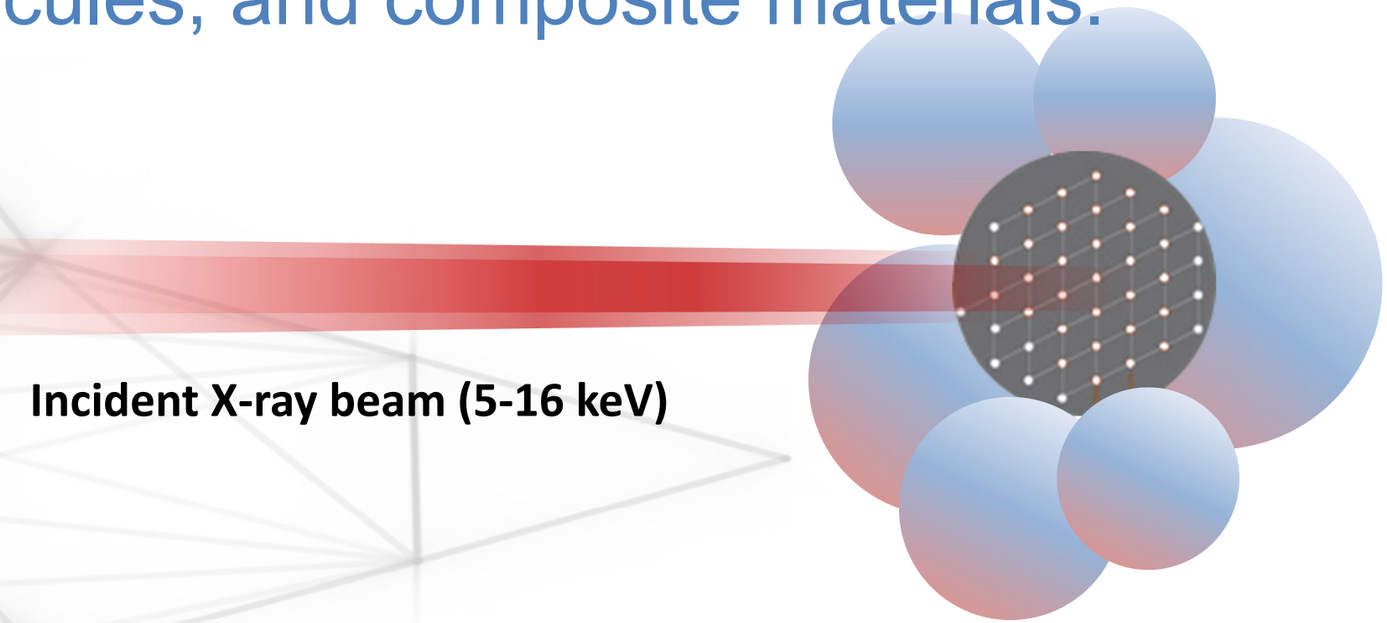

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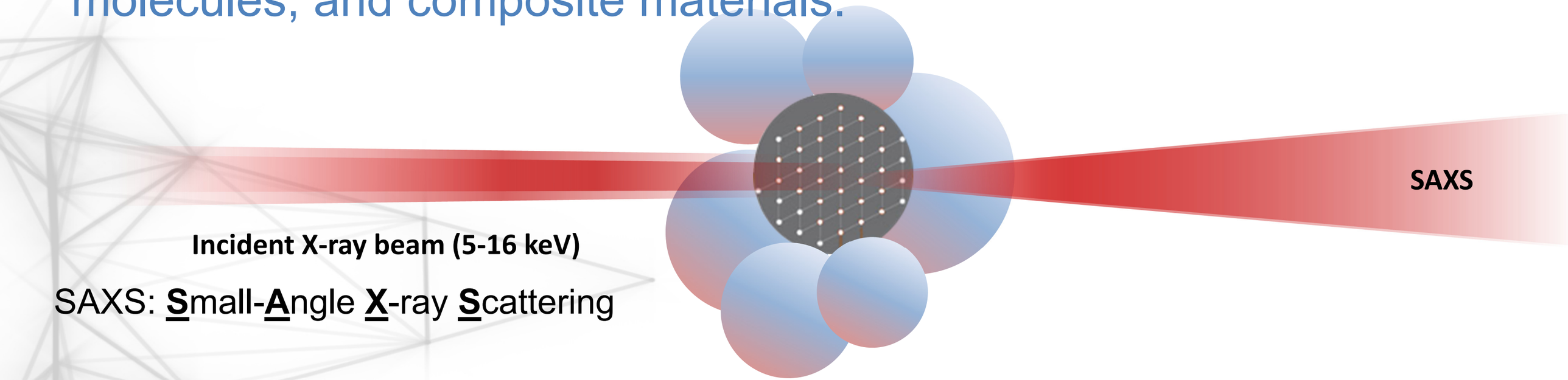

SAXS: **S**mall-**A**ngle **X**-ray **S**cattering

Introduction – Context & overview

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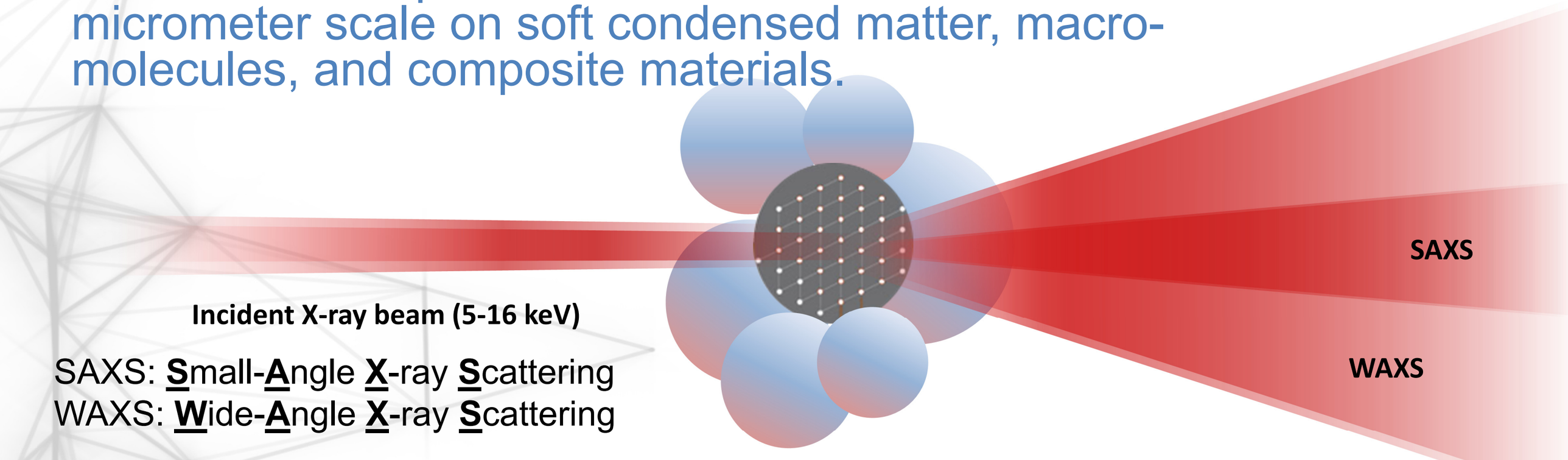

Incident X-ray beam (5-16 keV)

SAXS: **S**mall-**A**ngle **X**-ray **S**cattering
WAXS: **W**ide-**A**ngle **X**-ray **S**cattering

Introduction – Context & overview

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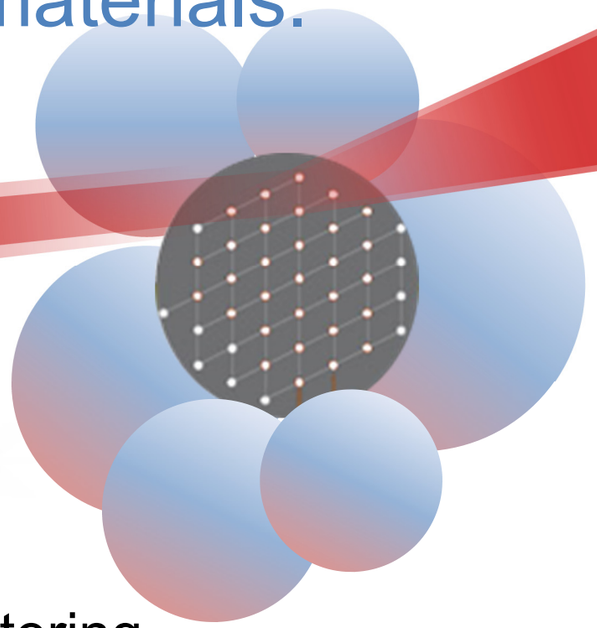


GISAXS

SAXS

WAXS

Incident X-ray beam (5-16 keV)

SAXS: **S**mall-**A**ngle **X**-ray **S**cattering
WAXS: **W**ide-**A**ngle **X**-ray **S**cattering
GISAXS: **G**razing-**I**ncidence **X**-ray **S**cattering

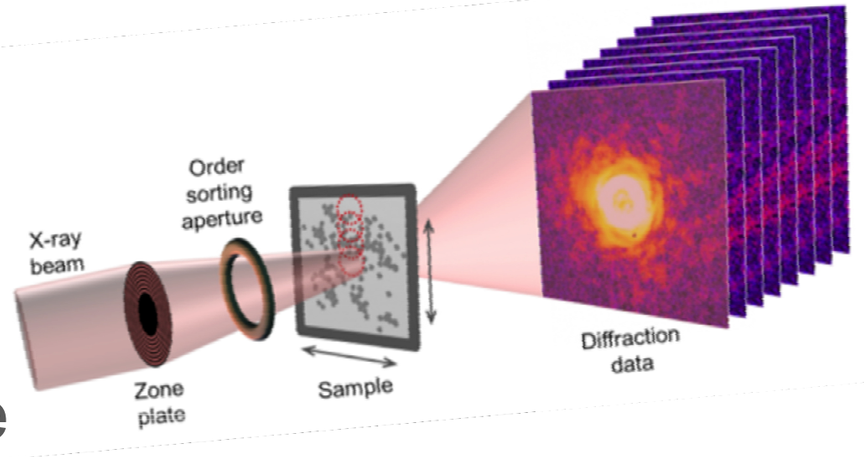
Introduction – Context & overview

SWING Beamline, Synchrotron SOLEIL

2018 – Long-term objective

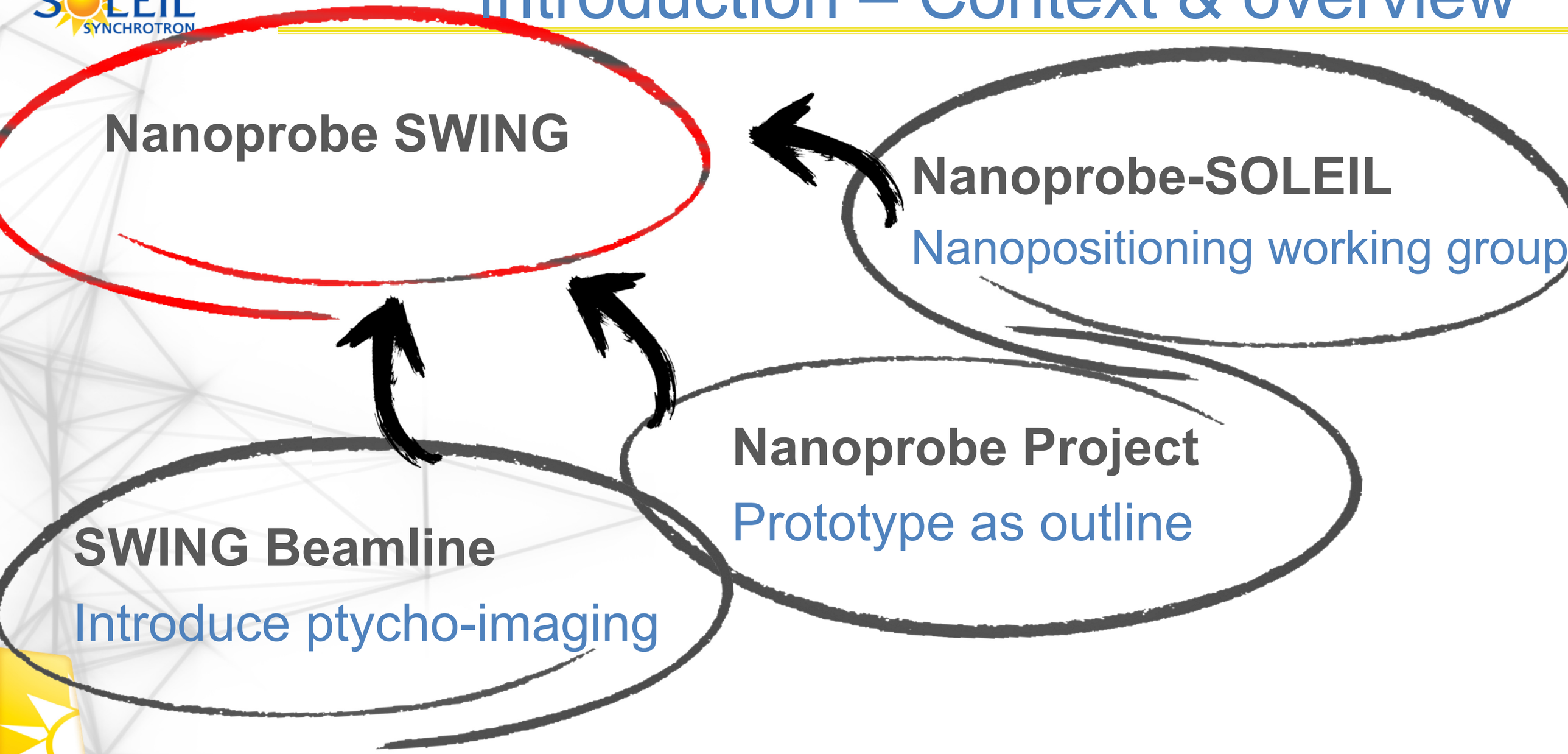
Implement *nano-tomo-ptychography* imaging on the beamline

(3D-Nano-Ptychography)



- Address a growing need amongst its users
- Prepare for upcoming synchrotron upgrade (higher coherence light source)

Introduction – Context & overview



Introduction – Context & overview

Nanoprobe SWING

Objectives:

-Install a Nanoprobe system

-Qualify feasability of 2D- ptychography on the SWING beamline with beam

-Qualify 2D scans using the Nanoprobe System

Introduction – Challenges & Approach

- Nanoprobe SWING Challenges
  - 2D-ptychography imaging resolutions of 20 nm
  - Sample sizes ranging from 10 µm up to a few 100 µm
  - Portable setup
- Approach
  - Support Structure & Environment: rigid & thermally stabilized
  - Stacked & modular designs
  - Interferometry
    - Tool to qualify and measure motion errors and be used for post-process image reconstructions
    - implemented in advanced modes of control

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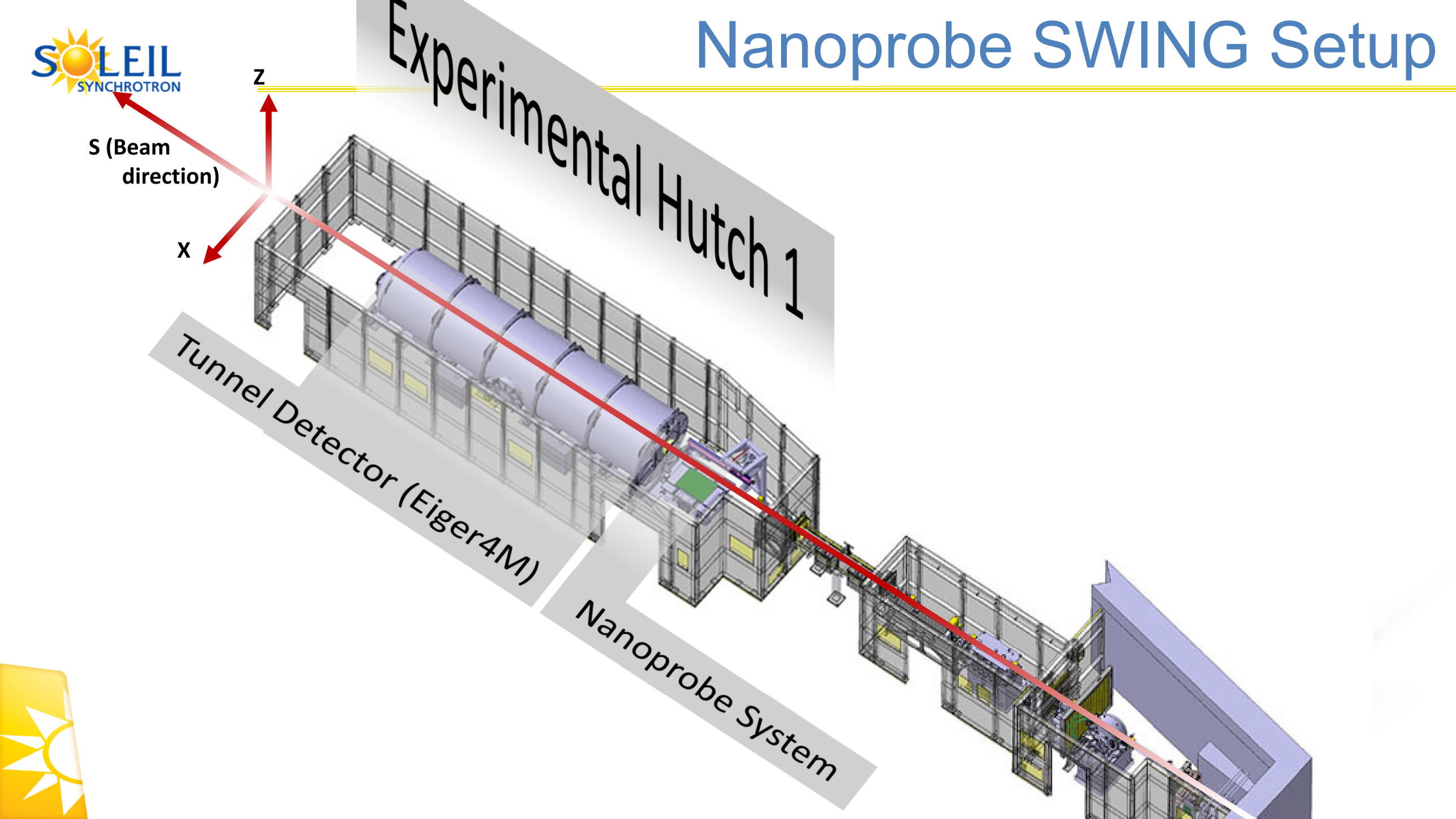
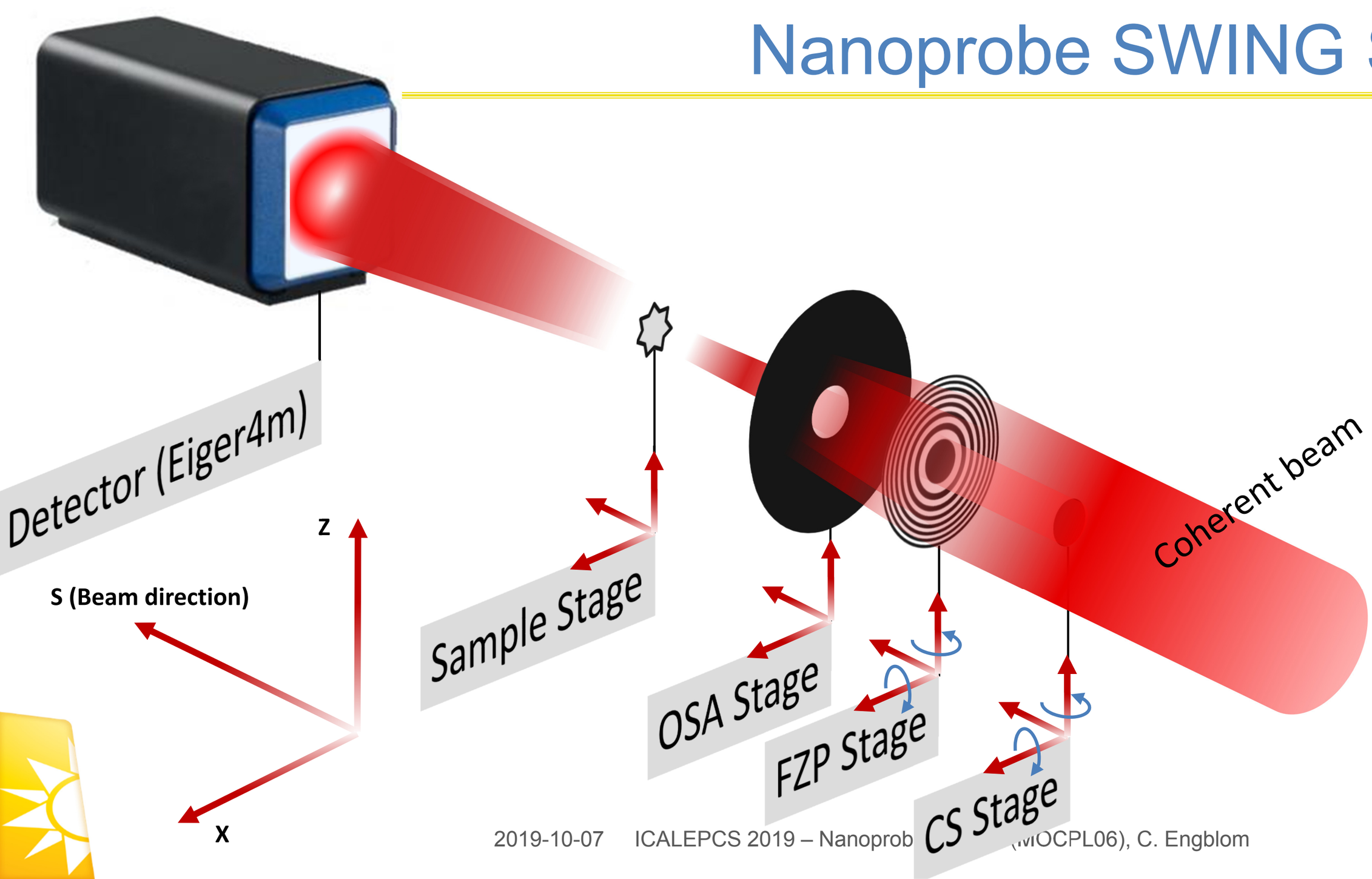
Nanoprobe SWING Setup



Nanoprobe SWING Setup

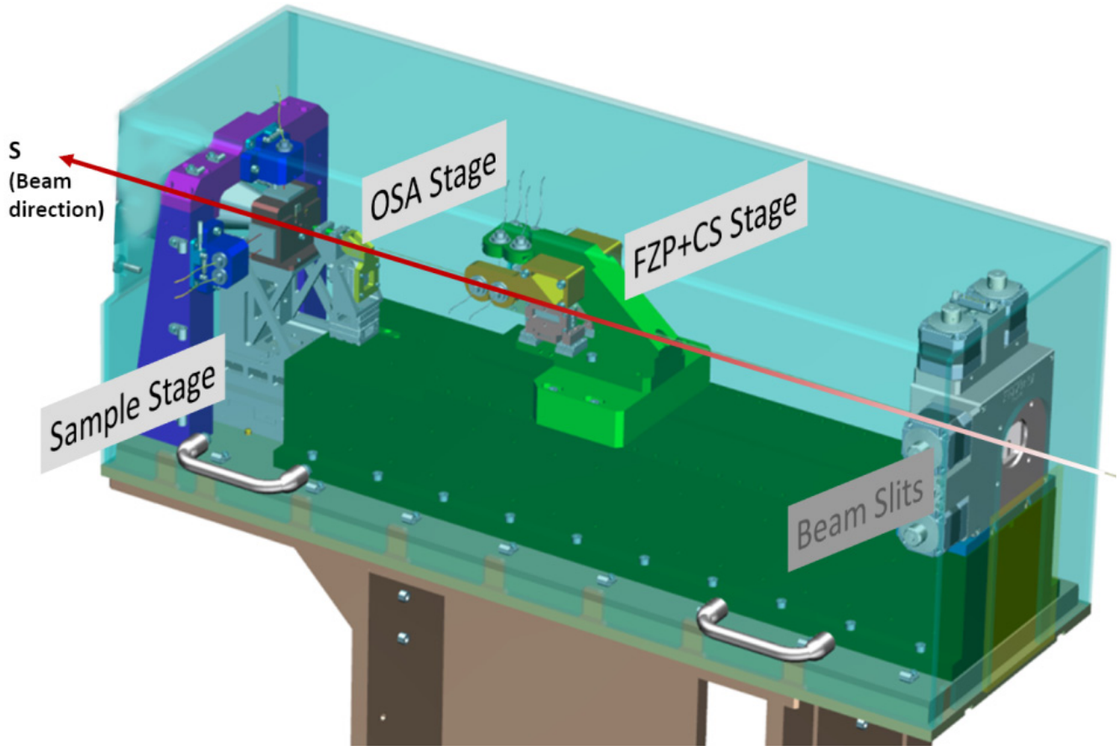


Nanoprobe SWING Setup

Support & Environment

- Hutch environment stability ensured by performing vibrational analysis prior to installation

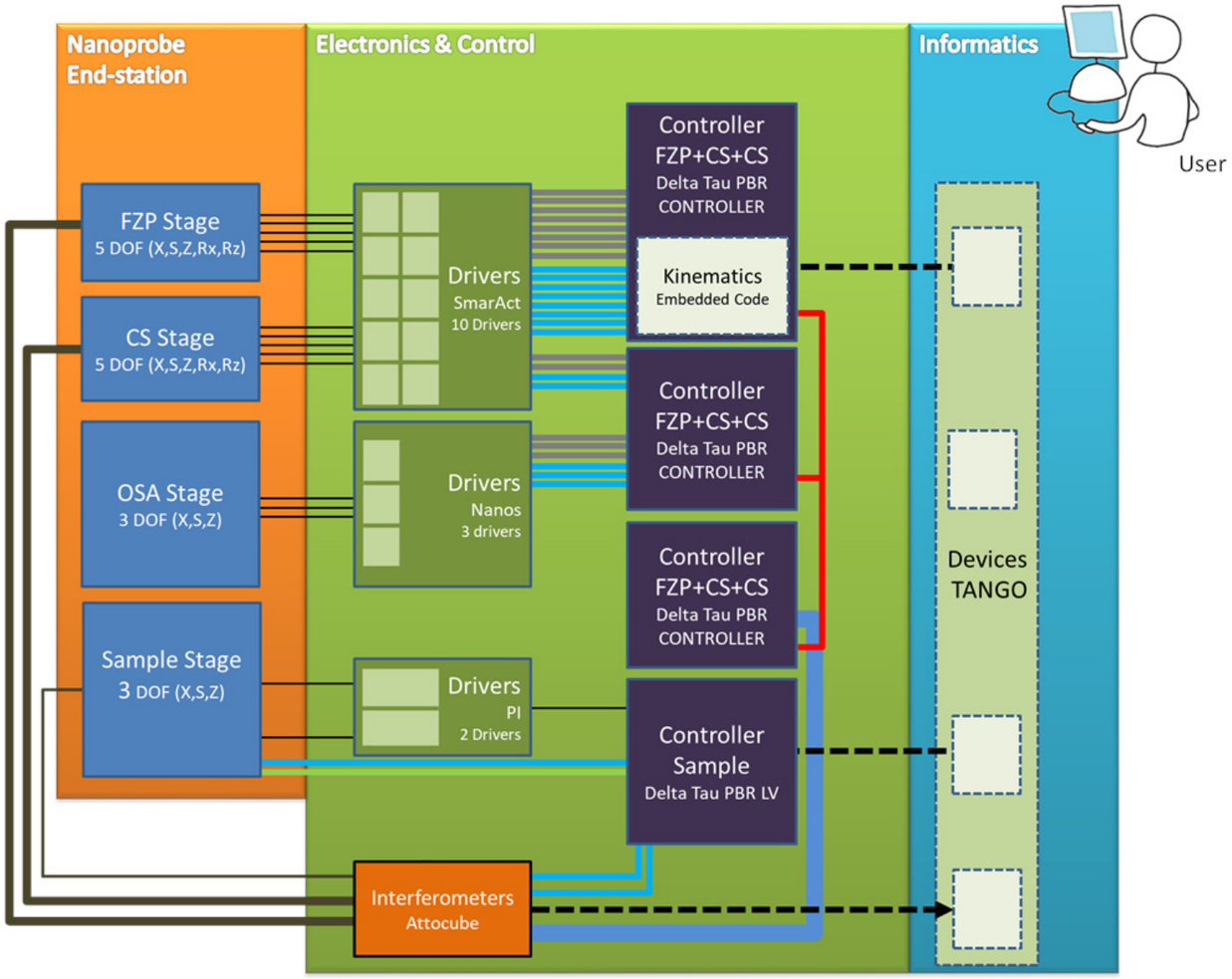
- Plexiglass enclosure added for:
  - Thermal stabilisation
  - Minimize air turbulence



Nanoprobe SWING Setup

Control & Acquisition Architecture

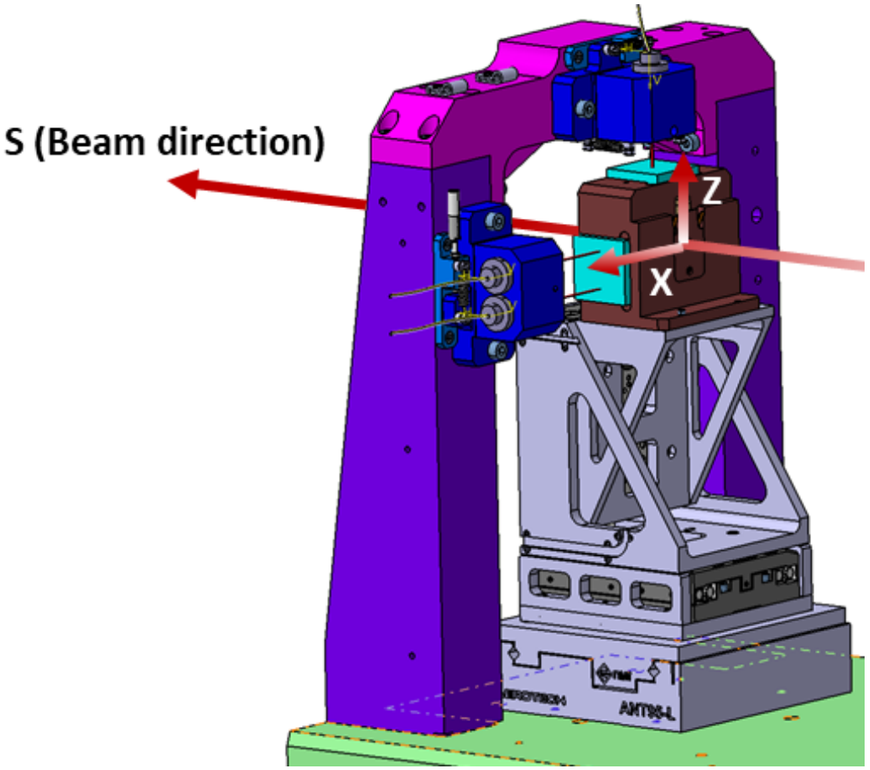
- One-rack system
- Multiple Delta Tau Controllers (master-slave config)
  - Multi-axis Control (with kinematic models)
  - Interferometry used as feedback in control loops
- TANGO devices for high-level control



Nanoprobe SWING Setup

Sample Stage

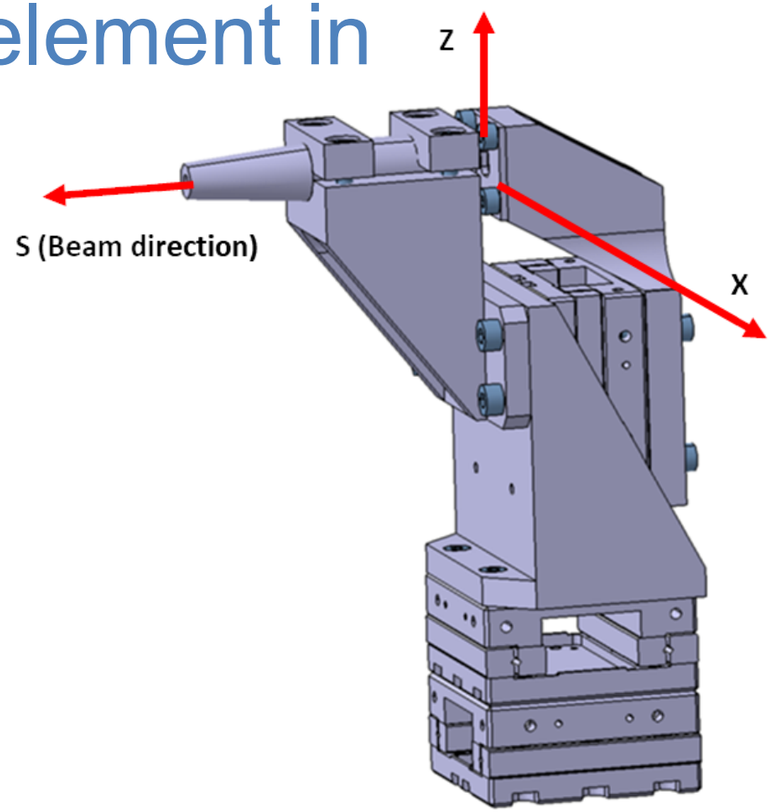
- Used for 2D sample scans in the XZ- plane
- Stacked design, actuating in 3 Degrees-Of-Freedom (DOF):
  - (X) → Linear Drive (Brushless),
  - (S,Z) → Linear Drives (Piezo multi-leg)
- Interferometer sensors: measuring motions errors in 3 DOF
  - Sample tracking for image reconstruction purposes



Nanoprobe SWING Setup

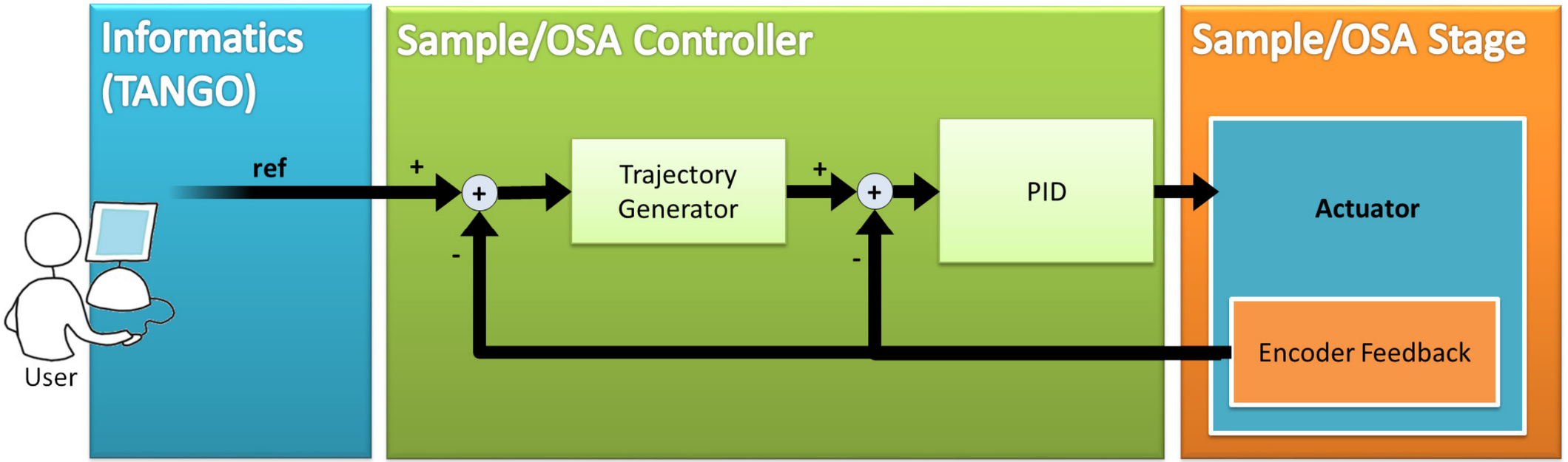
Order-Sorting-Aperture (OSA) Stage

- Used for positioning and holding optical element
- Stacked design actuating the optical element in 3 DOF (X, S, Z)



Nanoprobe SWING Setup

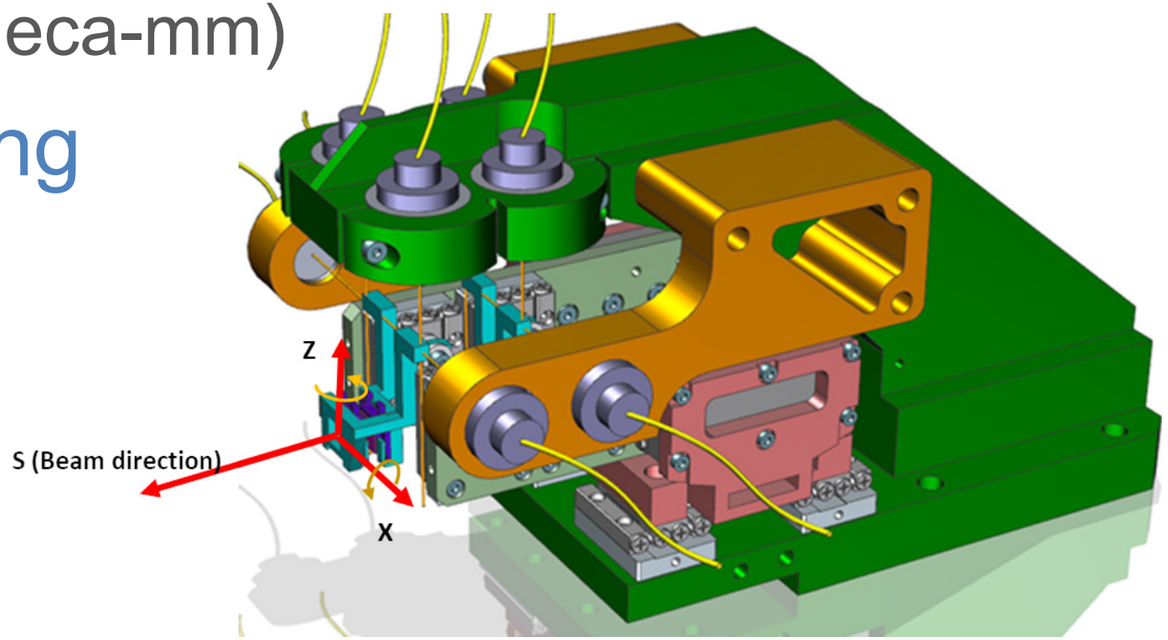
Sample/OSA Stages



Nanoprobe SWING Setup

Fresnel Zone Plate (FZP)- & Central Stop (CS) Stages

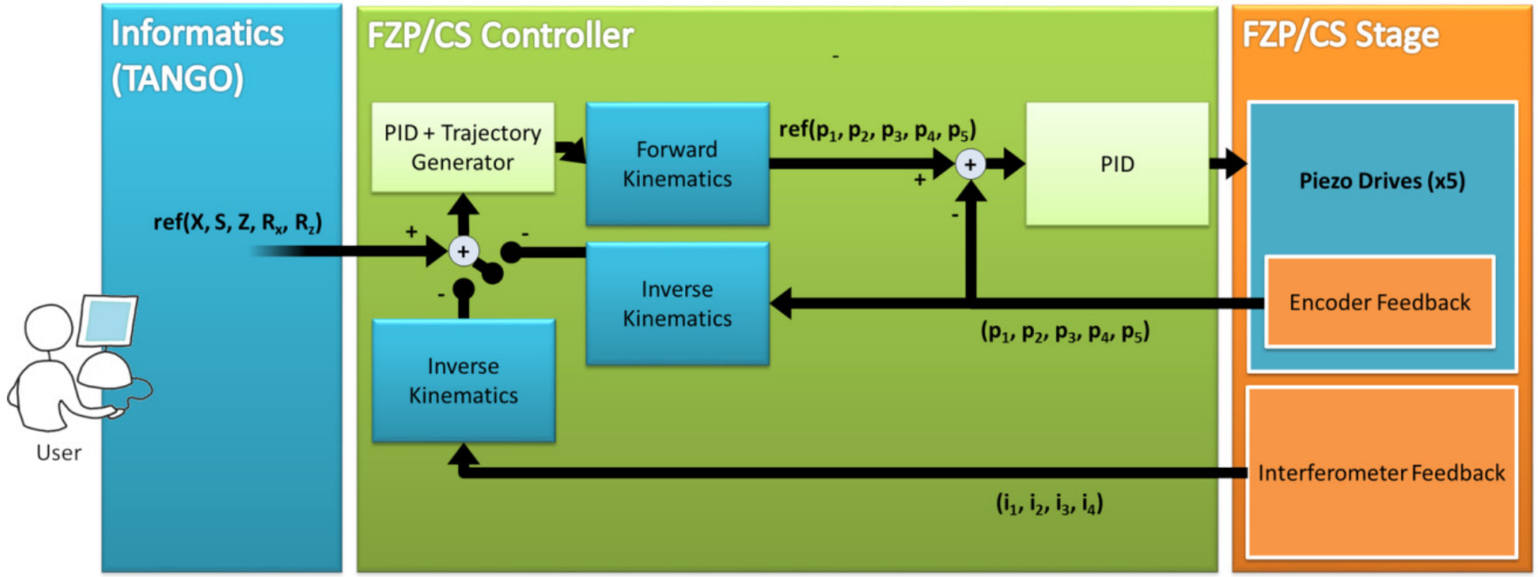
- Two identical mirror-image modules for positioning and holding optical elements
- 5 x Linear Piezo-stick-slip drives
  - High-resolution (1nm), long-range (deca-mm)
- Stacked & parallel design actuating each optical element in 5 DOF (X, S, Z, Rx, Rz)



Nanoprobe SWING Setup

FZP/CS Stages

- Multi-axial cascade-loops
  - Innermost loop: standard PID regulation with encoder feedback
  - Outer loops: Kinematic conversions with encoder/interferometer feedback



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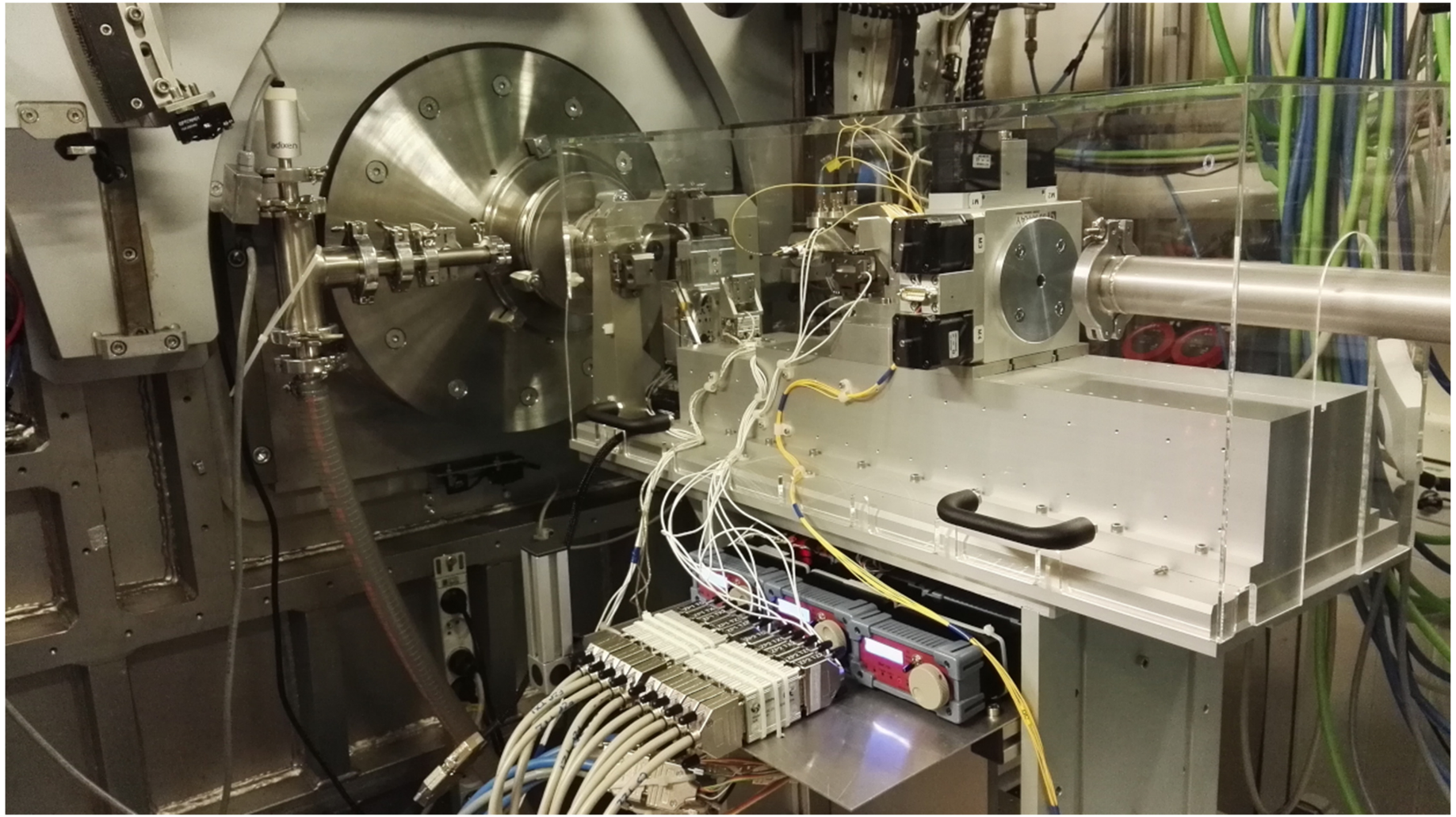
Results

Experimental Hutch

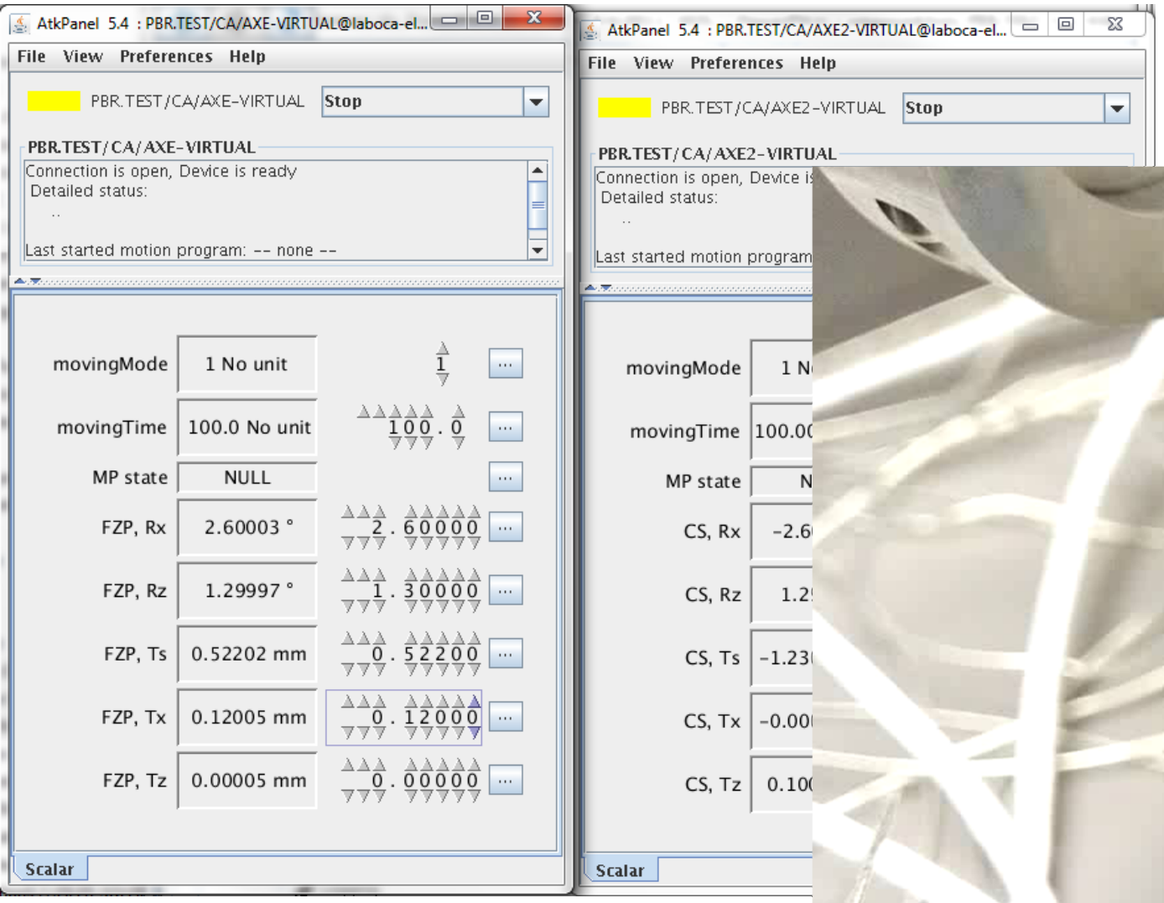


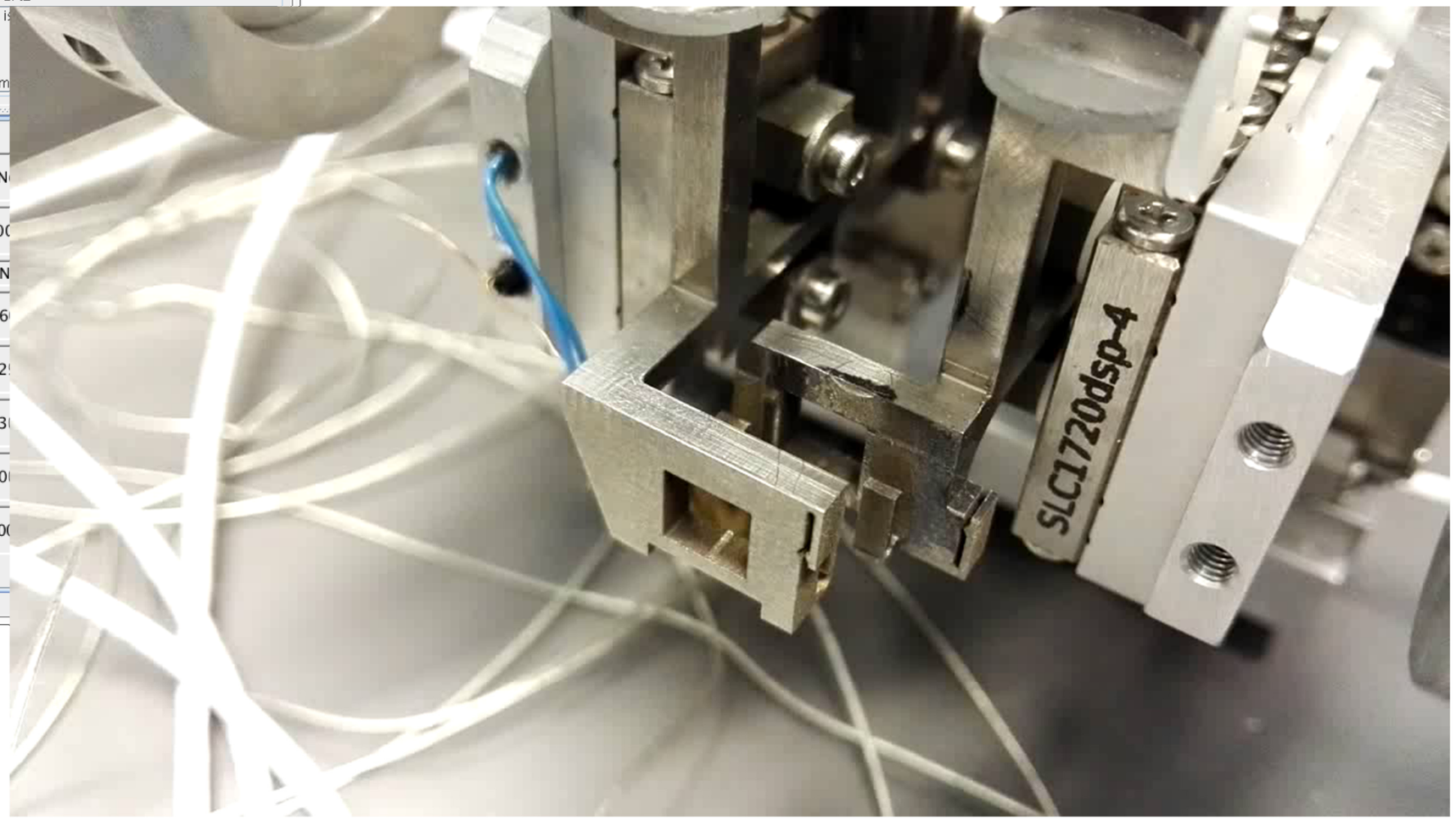
Experimental Hutch & Portability

Here with:
Filipe Alves – Mechanical Engineer
Javier Perez – Head of SWING beamline

Results

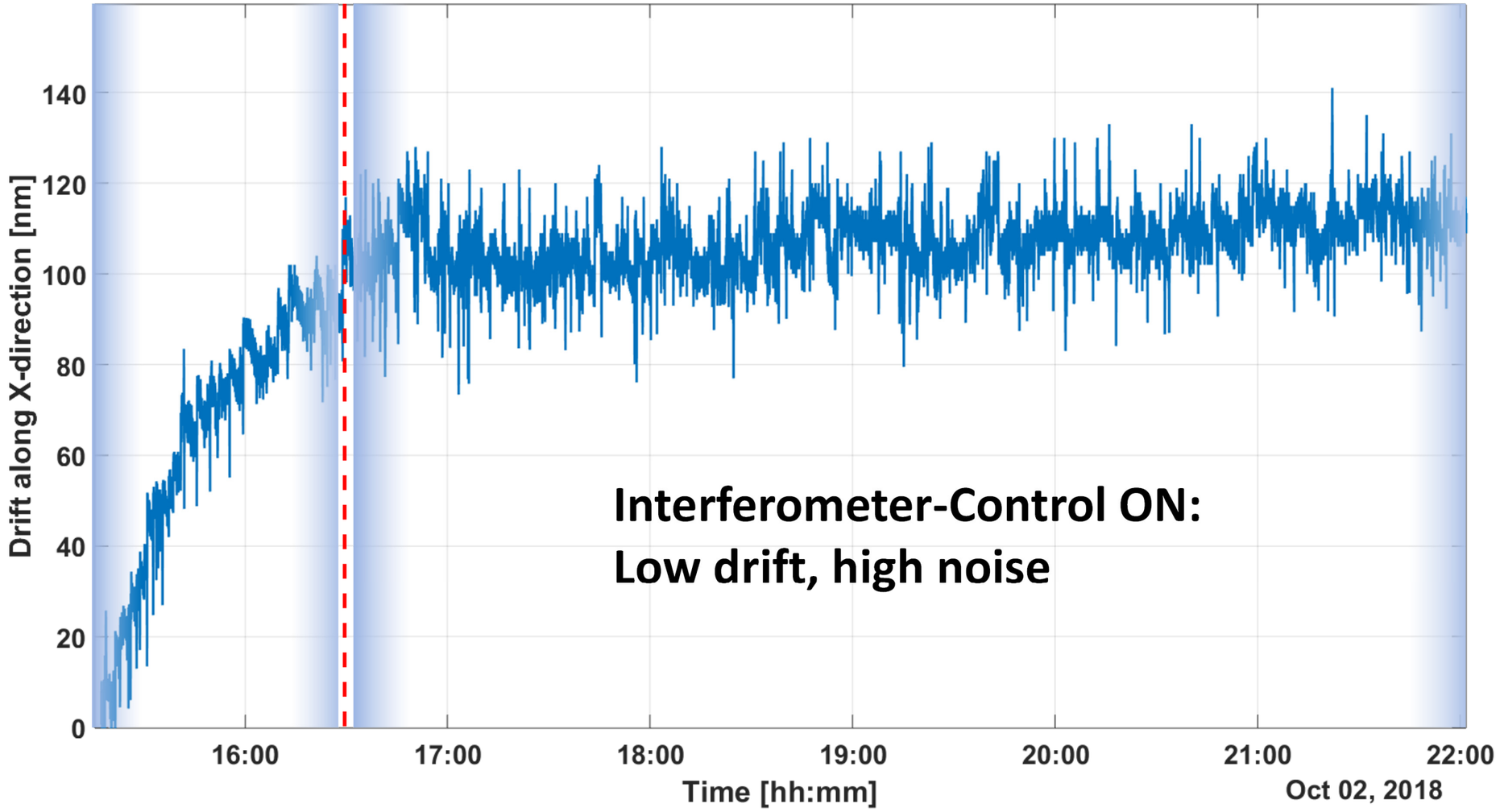
FZP/CS Control





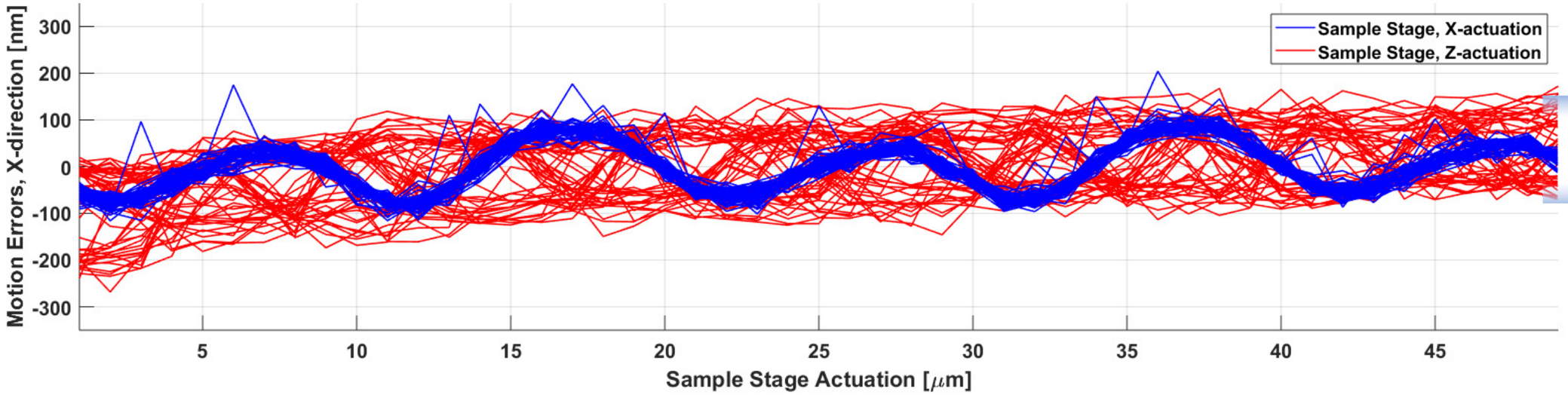
FZP/CS Control

Interferometer-Control OFF:
High drift, low noise

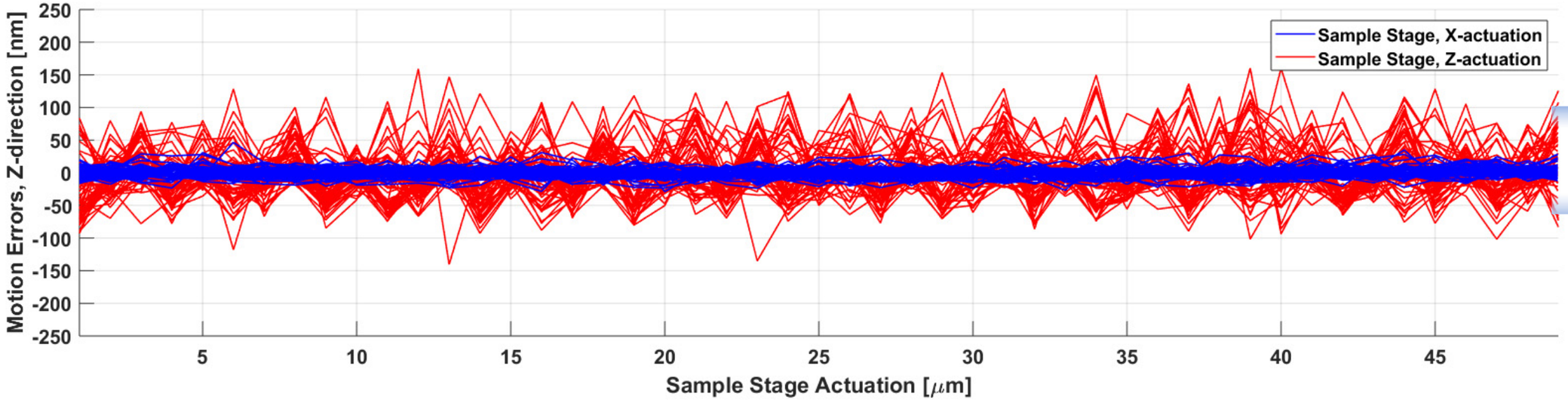


Results

Sample Stage, Motion Errors



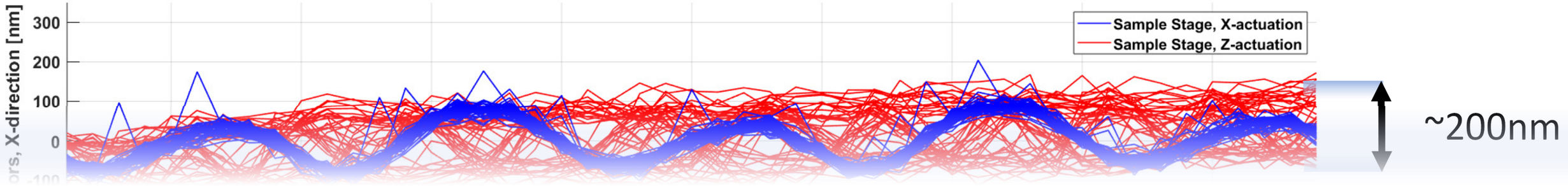
~200nm



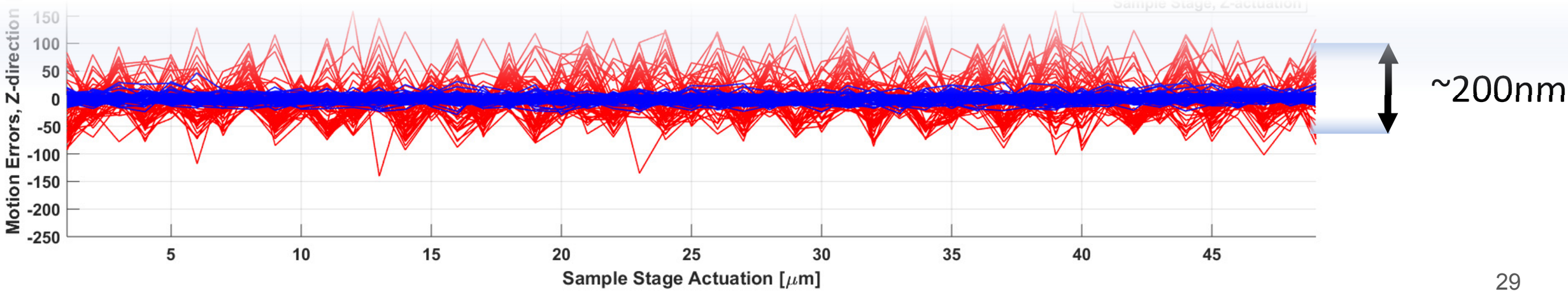
~200nm

Results

Sample Stage, Motion Errors



Interferometry is crucial to resolve the nanometer



2D-Nano-Ptychography Imaging Results

- Sample: Siemens Star (50nm inner-most spokes)

- 2D-imaging (with beam)
  - 15x15 µm scan
  - 500 nm steps
  - **Interferometer Sample tracking**
    – Image reconstructions

Results

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- Sample: Siemens Star (50nm inner-most spokes)
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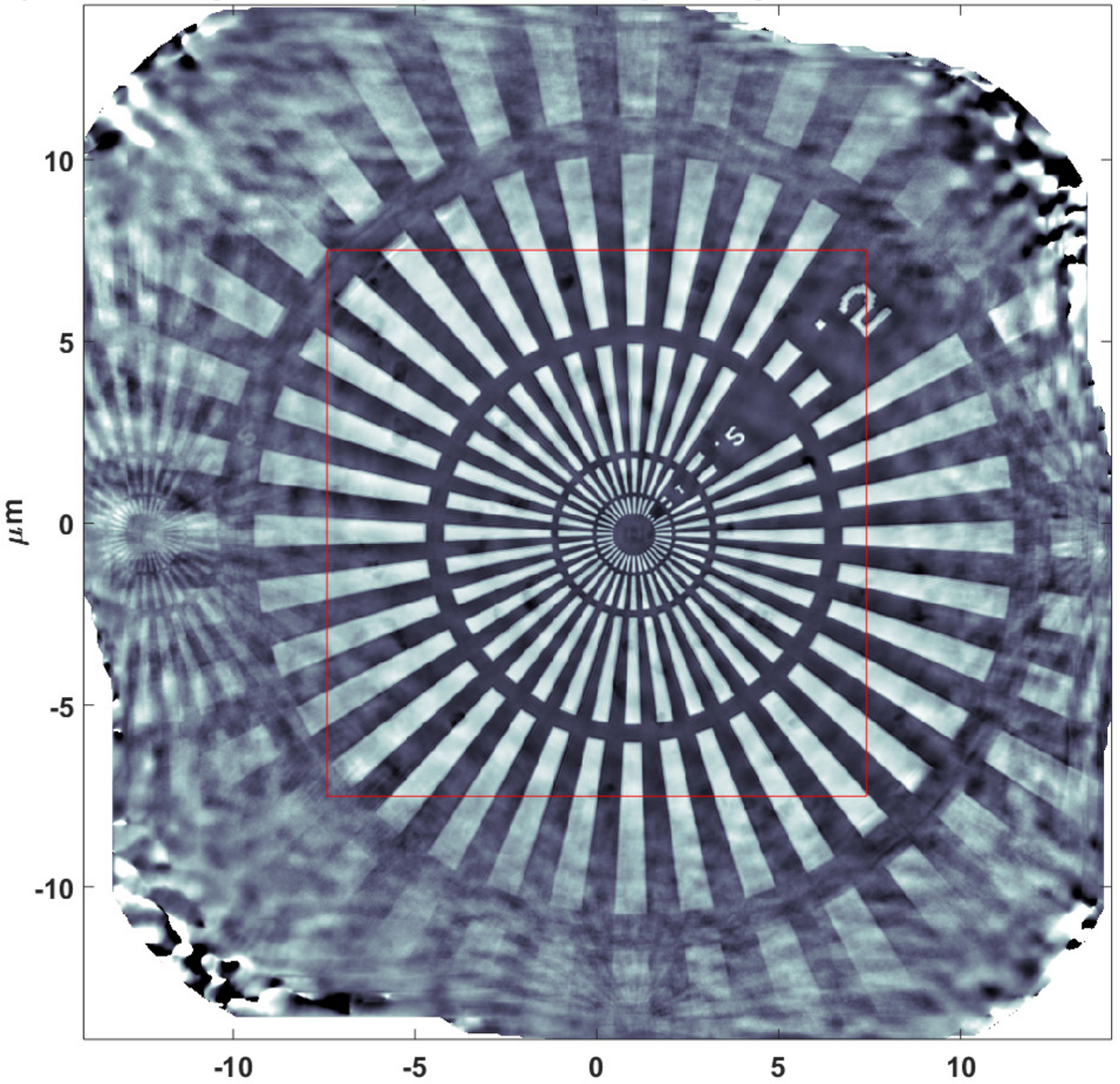
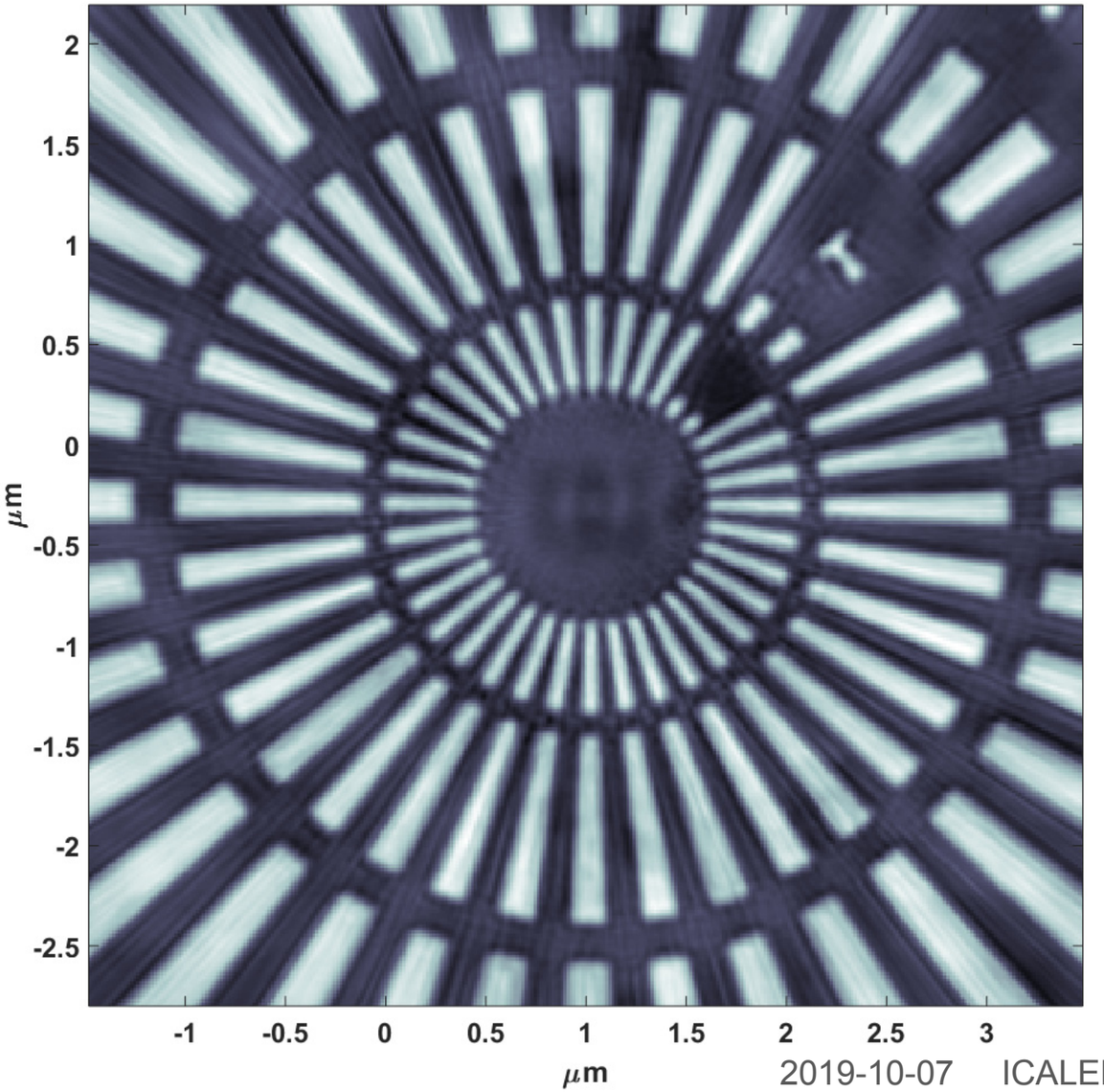


Results

2D-Nano-Ptychography Imaging Results



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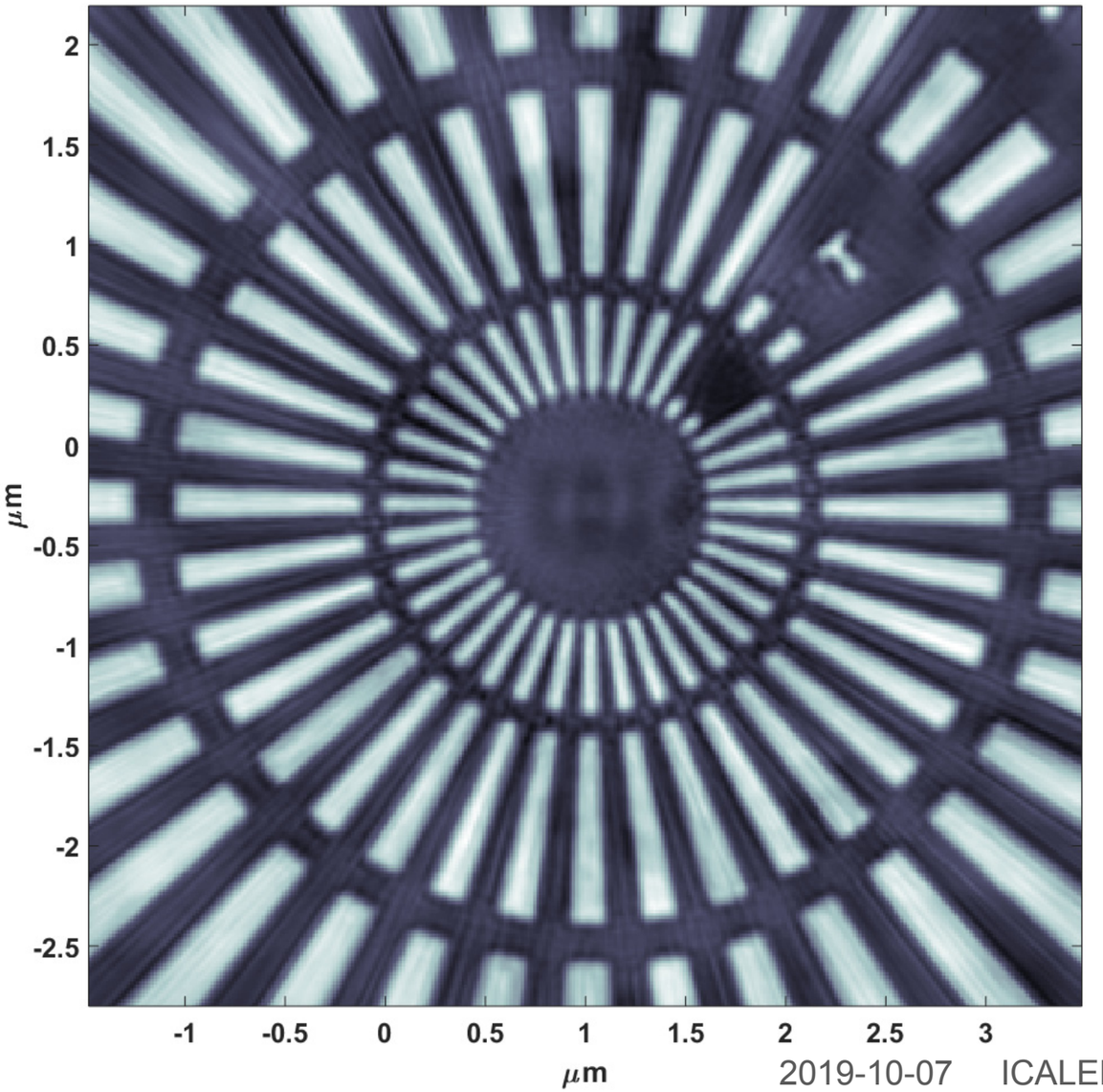
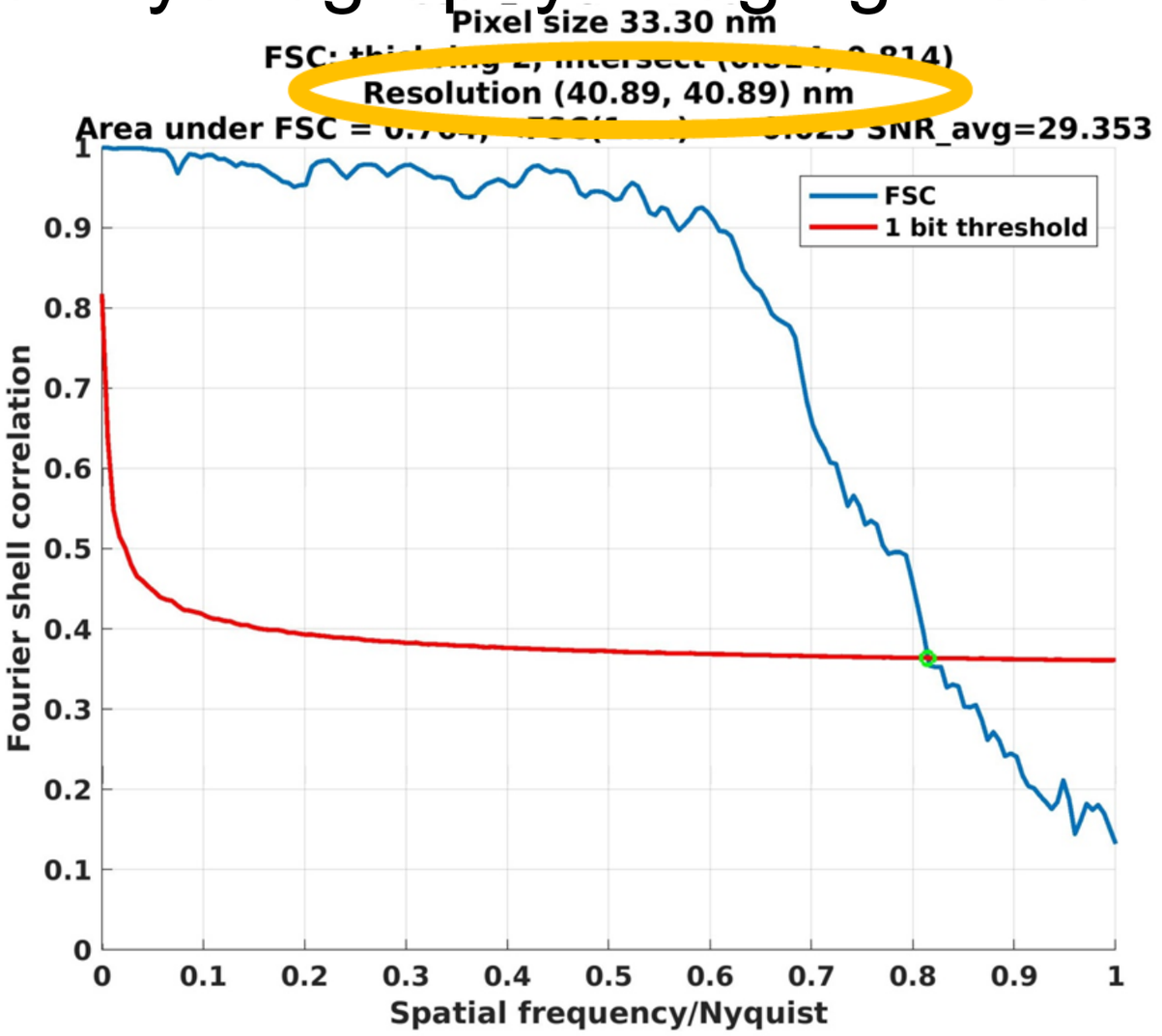
2D-Nano-Ptychography Imaging Results





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Conclusion

- System portability
  - Objective achieved, system could be installed/unistalled within hours
- 2D-nano-ptychography imaging capabilities
  - Resolution (image repeatibility) =~ 40 nm
    - **Not yet there, but a on good start!**

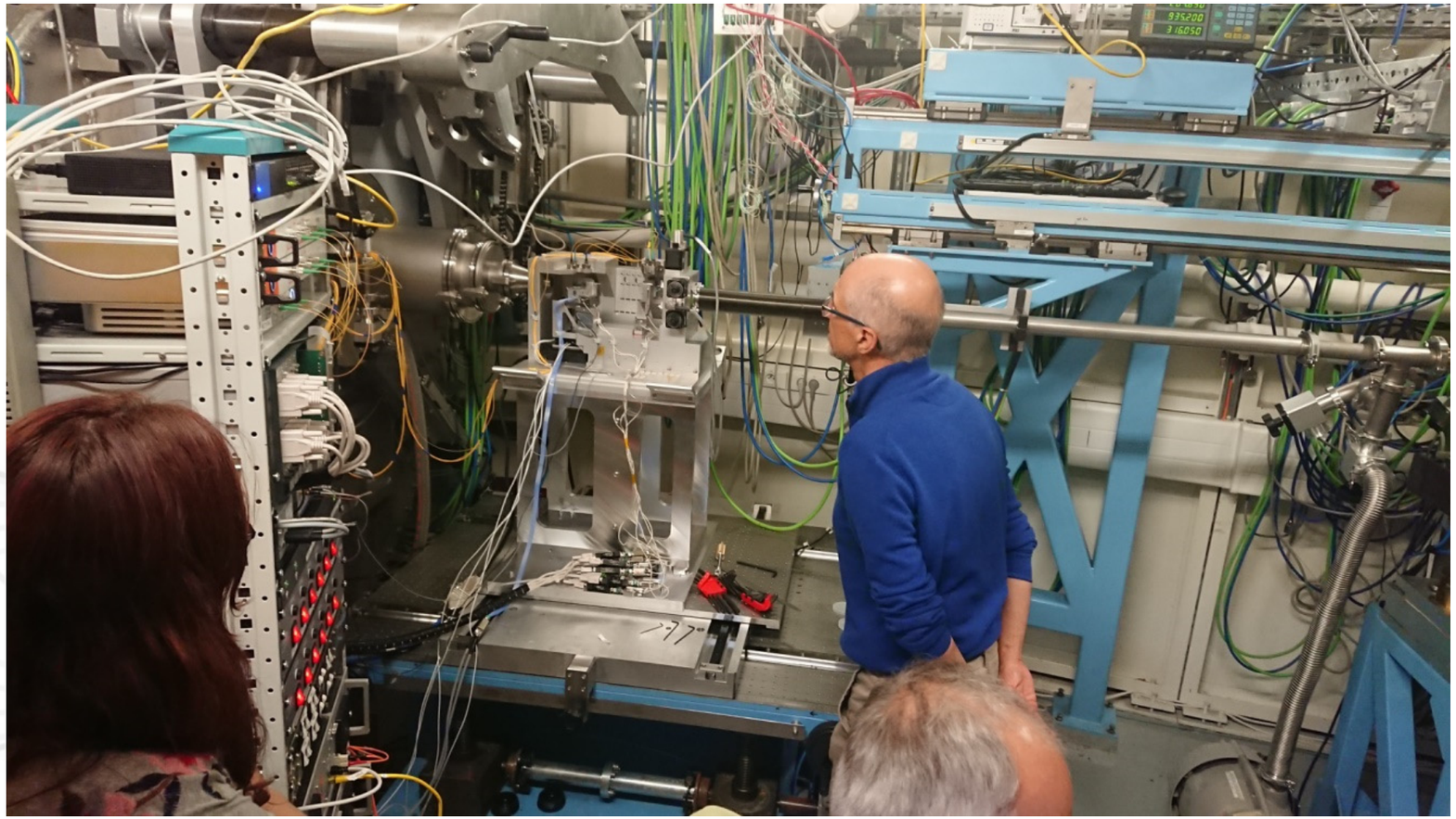
Conclusion

Prospects

- Where do we go from here?
  - Better 2D-resolution
  - To 3D from 2D

Conclusion

Prospects



3D-Nano-ptychography implementations ongoing…

Appendix

2D-Nano-Ptychography Imaging Results on the SWING Beamline at Synchrotron SOLEIL (**MOCPL06)**

Nanoprobe Results: Metrology & Control in stacked closed-loop systems (WEAPL04)

http://accelconf.web.cern.ch/AccelConf/icalepcs2017/papers/weapl04.pdf

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Nanoprobe Project – Sample Stage Control (MOCRAF 2015)

https://www.synchrotron-soleil.fr/fr/file/8047/download?token=luXoXhmR