FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

Einsatz eines hochgenauen Roboters zur Probenmanipulation in der Eigenspannungs- und Texturanalyse mit Neutronen

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MLZ is a cooperation between:

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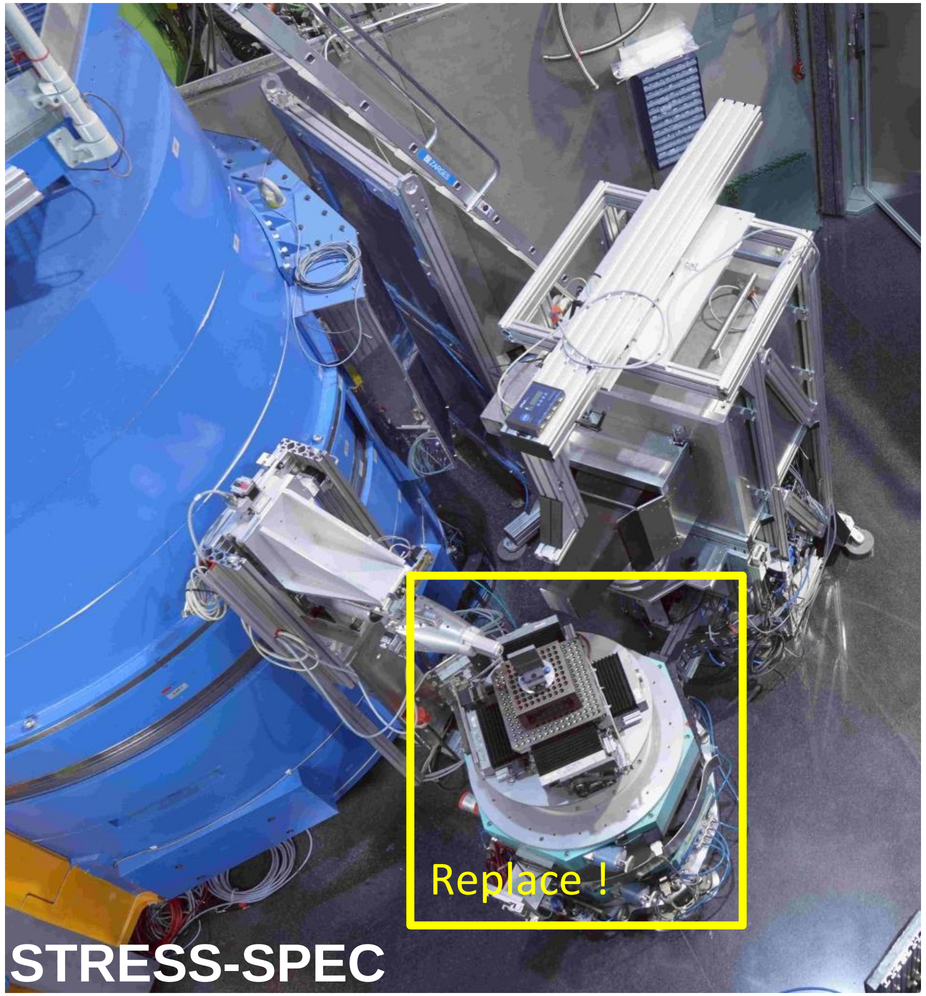
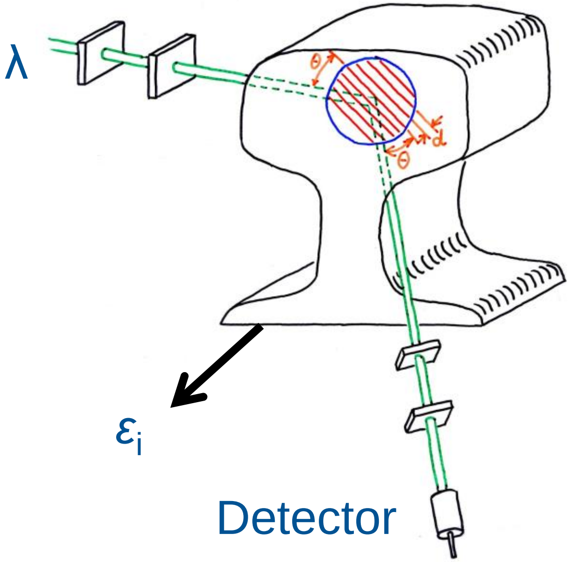


Typical Applications

- Residual Stress determination
- Texture measurements

Method = DIFFRACTION

$$2d\sin\theta = n\lambda$$



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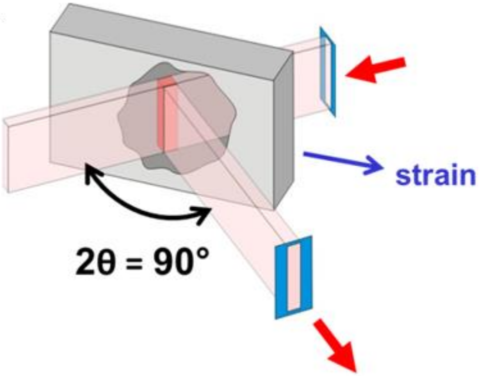
Pecularities of the measurements

- spatial resolved
- small gauge volumes (GV)

- sample needs to be measured at the same GV position in different orientations



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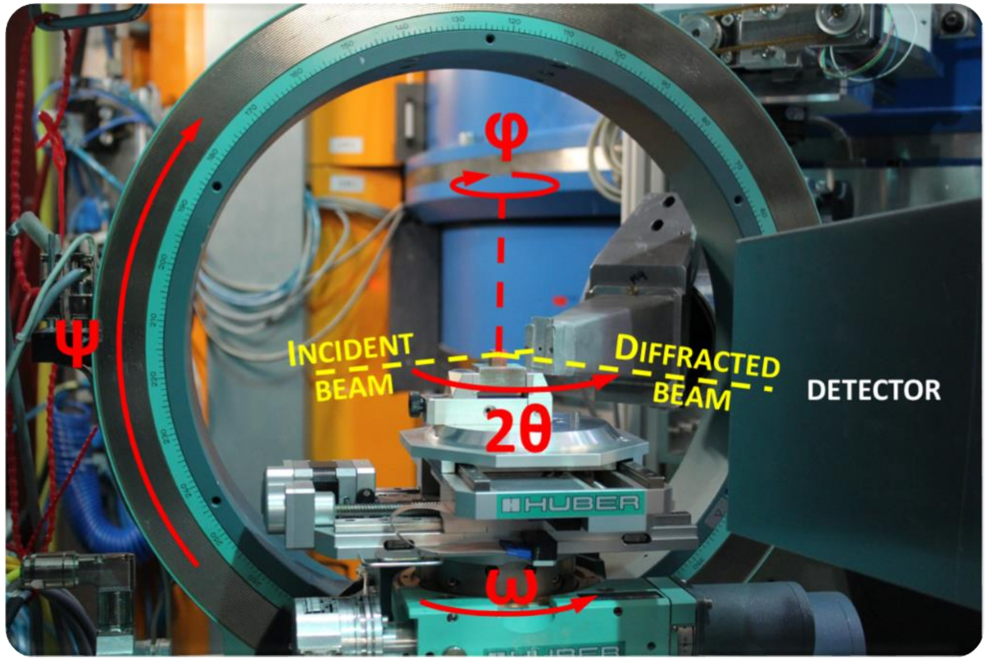
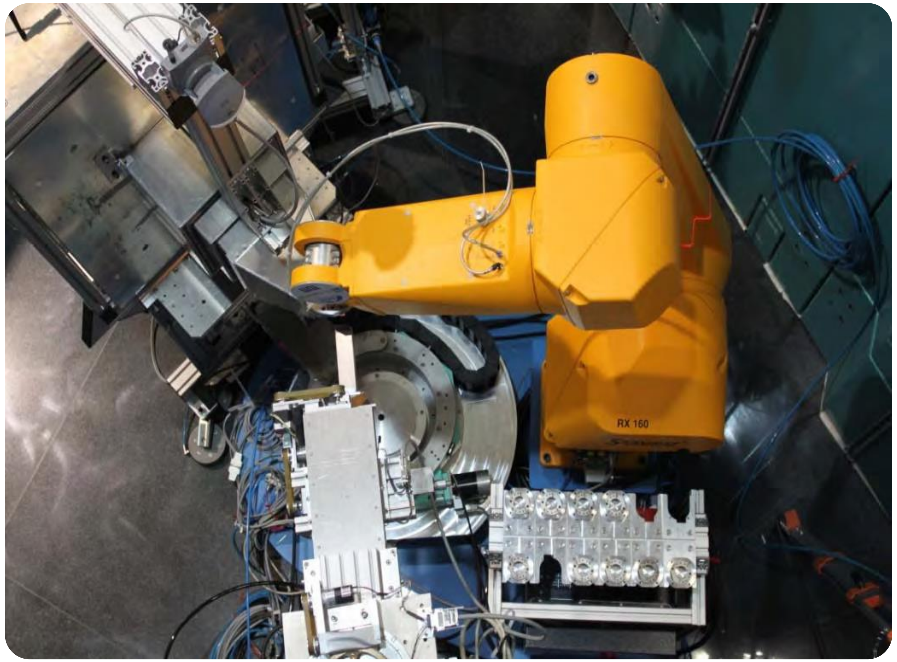
Why using a 6-axis industrial robot for sample positioning?



XYZ- and rotation-tables, eulerian cradle,…

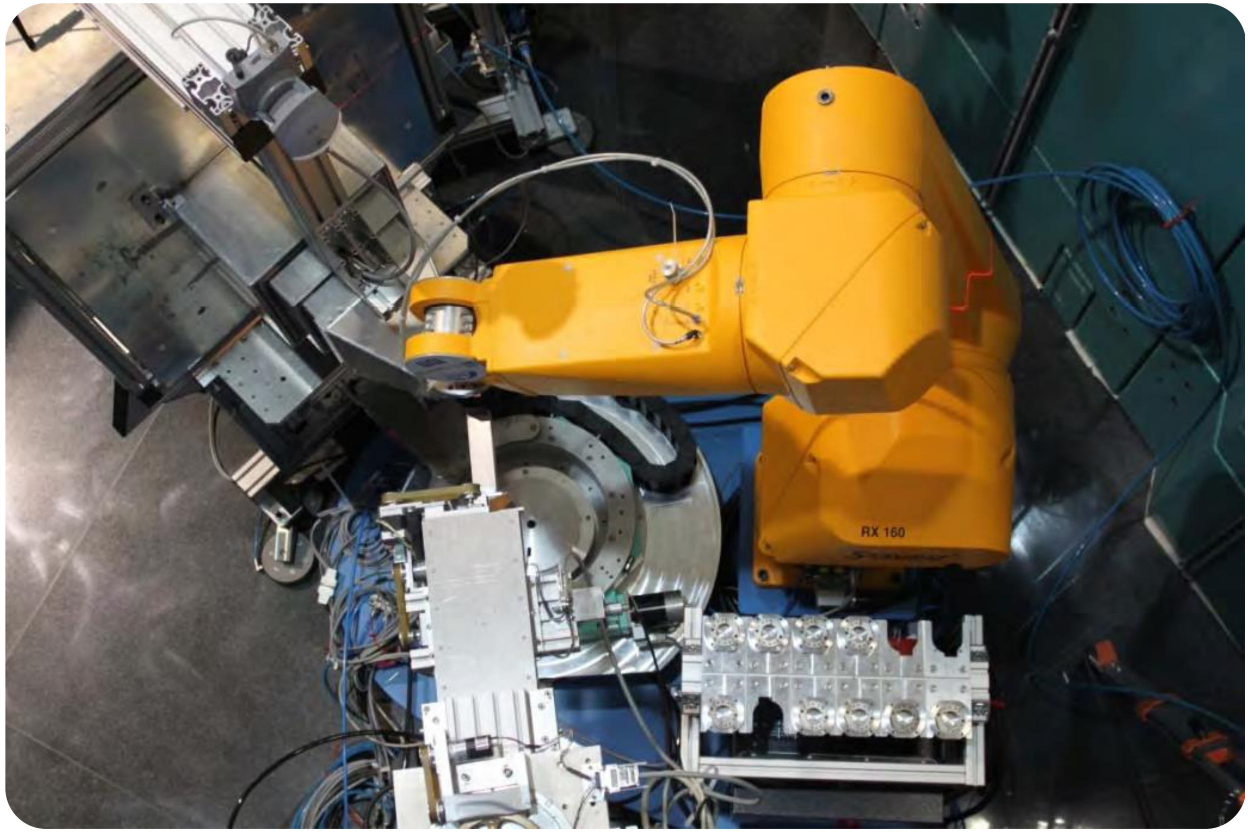
- Suitable for small sample geometries
- High precision
- Proven technology



Robot system

- High flexibility
- Automation possible (sample changer)
- Complex and larger parts
- Free choice of rotation center

Robot positioner @ STRESS-SPEC



- in operation since 2012*
- mainly used for texture measurements so far

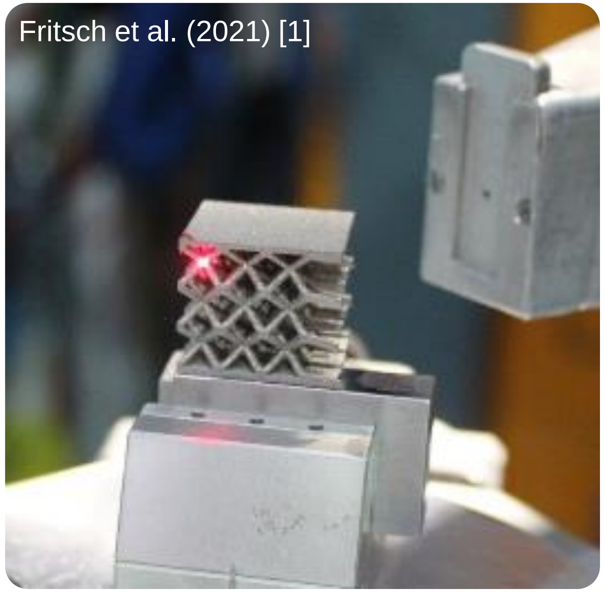
* C.Randau et al. (2015), *Nucl. Instr. Meth..* 794, p. 67-75, DOI: 10.1016/j.nima.2015.05.014

Since 2020: New project to further enhance robot capabilities

Motivation: Measurements in complex shaped samples from advanced manufacturing processes

- Make robot ready for high spatial resolution strain determination
- Increase measurement efficiency by improved alignment procedures
- *In-situ measurements at temperatures up to 1300 ℃ (e.g. recrystallization texture,…)*
- …..

Connector part

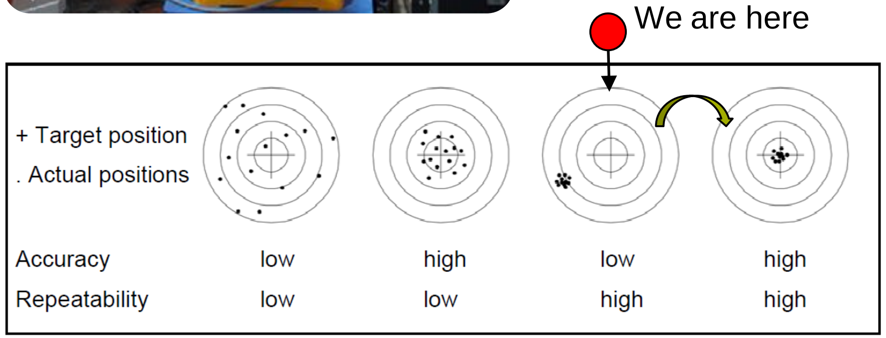


[1] Fritsch et al. (2021), *J. Appl. Cryst.* 54, p. 228-236, DOI: 10.1107/S1600576720015344

The Robot Positioning – Challenges

- Residual strain measurement is complicated because…
  - Position accuracy at the same pose (repeatability) < 50 µm
  - …but absolute position accuracy >= 500 µm

  - TO STRESS AGAIN: We have to measure the sample at the same spot at least in 6 different directions to derive a complete strain tensor – always an absolute positioning job!



Aim: Absolute position accuracy **< 50 µm**

Ramadhan et al. (2021), *Nucl. Instr. Meth..* A, 999, 165230
DOI: 10.1016/j.nima.2021.165230.

Complex Shaped Parts - Example Measuring Task

Turbine blade

- Measure the residual stress state at several points along the blade
- 2 mm sub-surface
- Following the curvature of the surface
- No CAD data is available

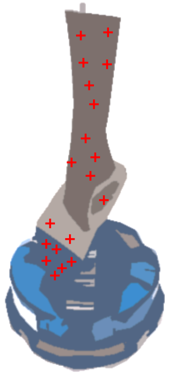
Challenges

- No flat surfaces
- Measuring points are along an „undefined“ curved line
- Principal stress directions are most likely unknown

Measurement Process Chain – From Sample to Data

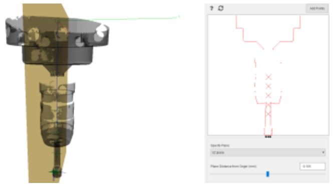
Markers applied

Sample mounted on robot holder

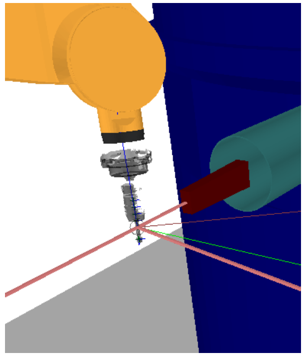


3D-Scan
Digital model
+ marker positions
Sample COSY

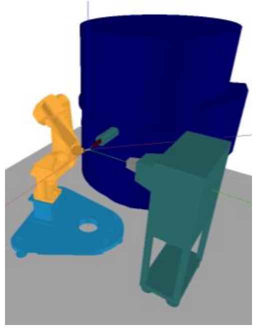
SOLIDWORKS
SScanSS 2 [1]



Define measuring points and directions

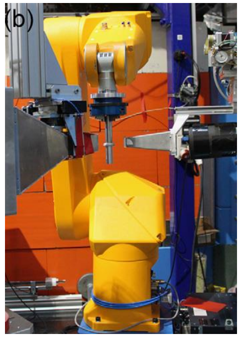


Matching robot and sample COSY

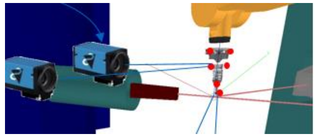


Simulate experiment

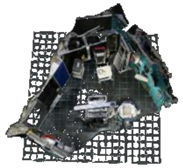
Real experiment



Optical Tracking system



Position correction



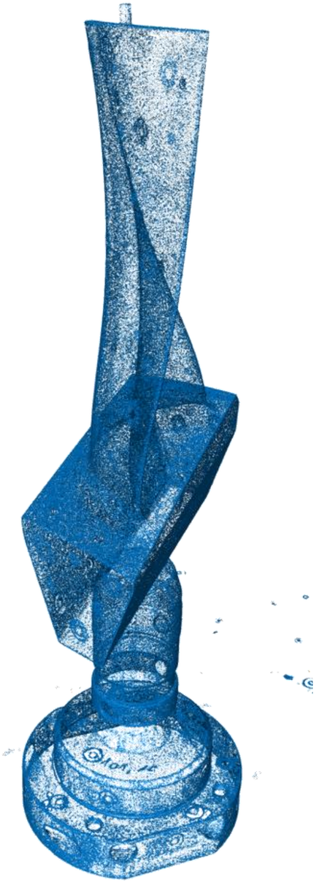
Collision detection

Future:
Data and analysis results can be projected on digital sample (online evaluation)

[1] Nneji Stephen, (2021), SScanSS 2, https://doi.org/10.5281/zenodo.5266561

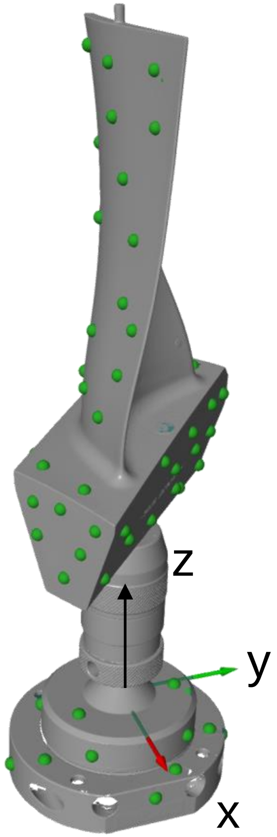
Definition of Measurement Points & Directions

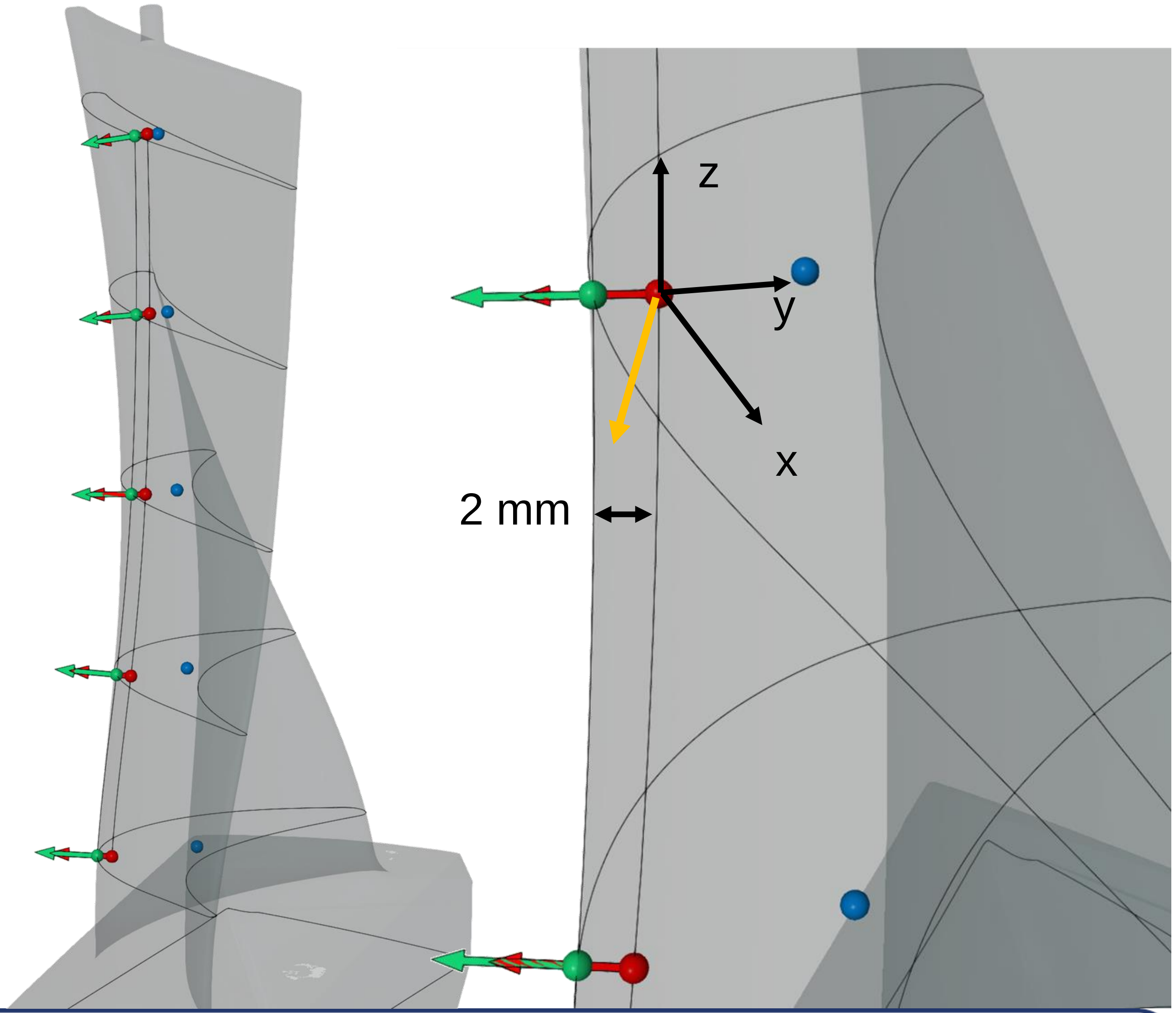
Sample



Scan to point cloud

Meshing and markers





Simulation & Control Environment for Measurement Kinematics

- …includes the robotsystem, the actual sample, the walls,…
- Provides
  - Interface to the robot controller hardware
  - Path-planning
  - Collision avoidance
  - Alignment to measurement vectors
- OpenSource!

Stäubli RX160 robot

ROS industrial

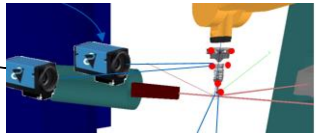
NICOS
Networked Instrument COntrol System

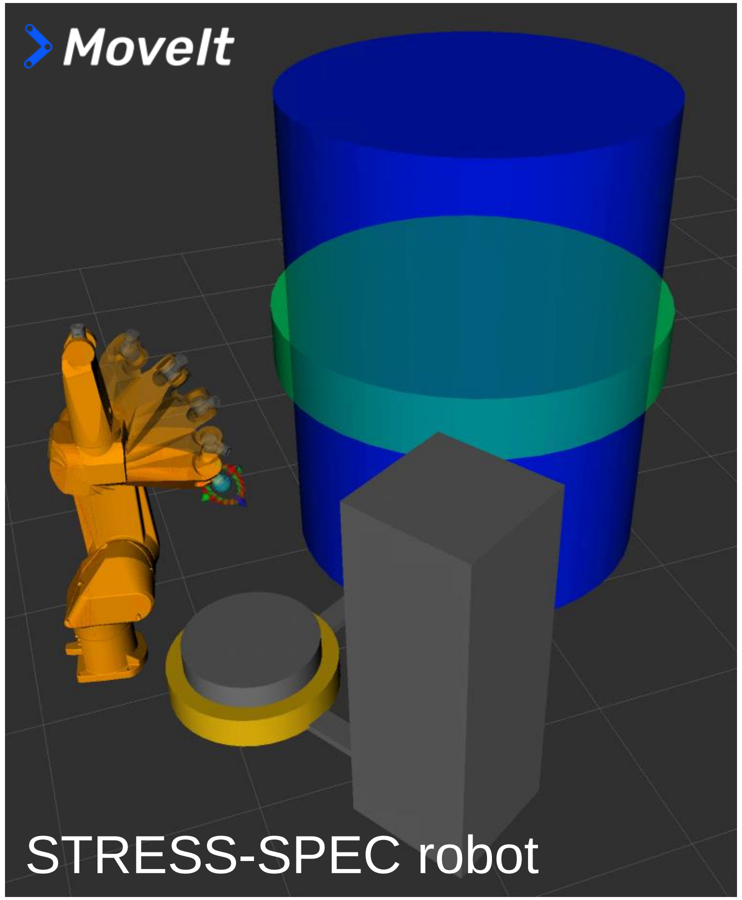
ROS

MoveIt

OpenCV

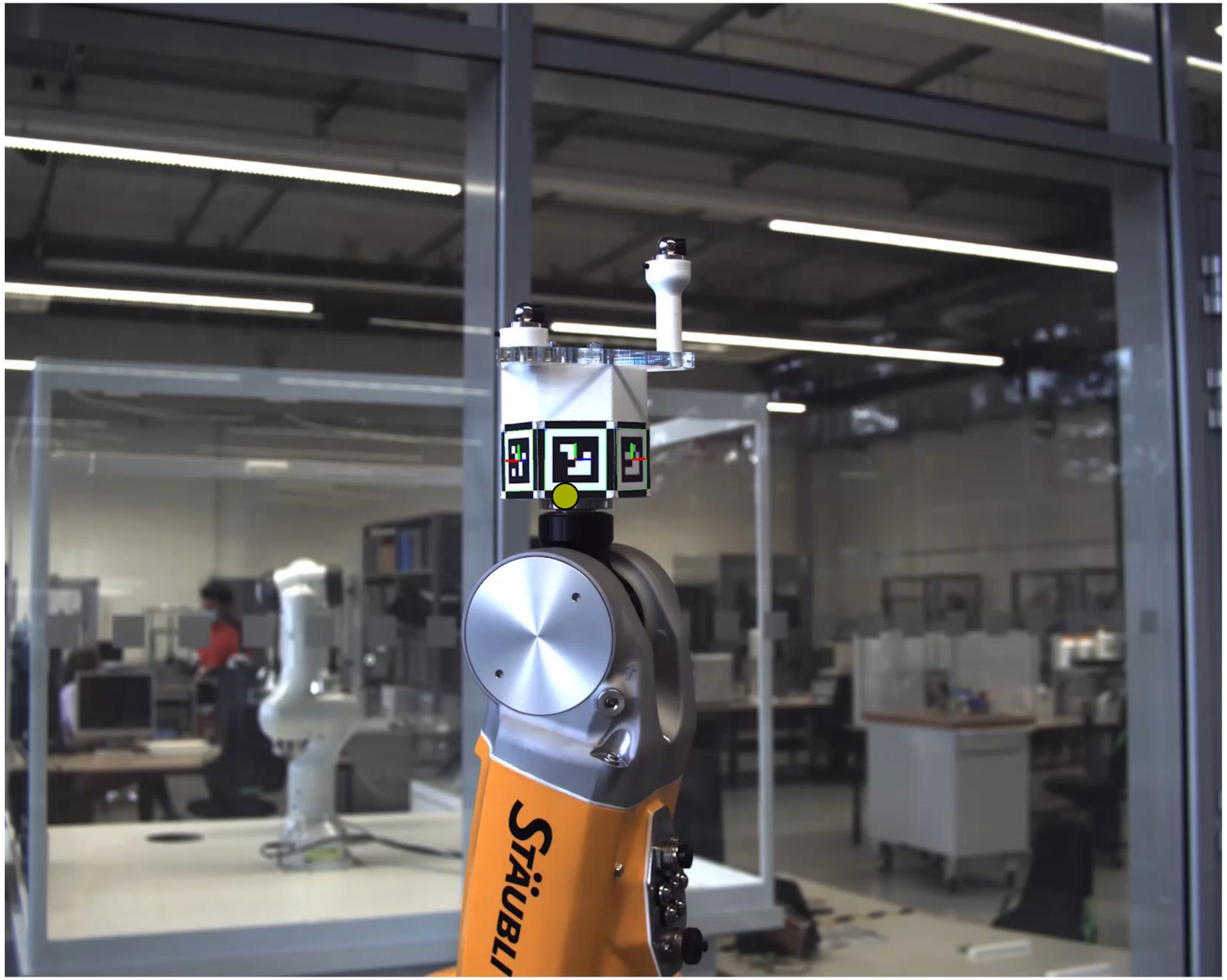
Tracking system (optical)

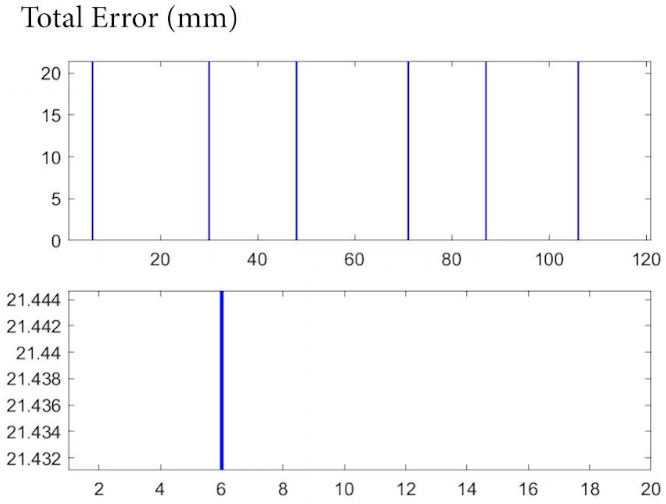


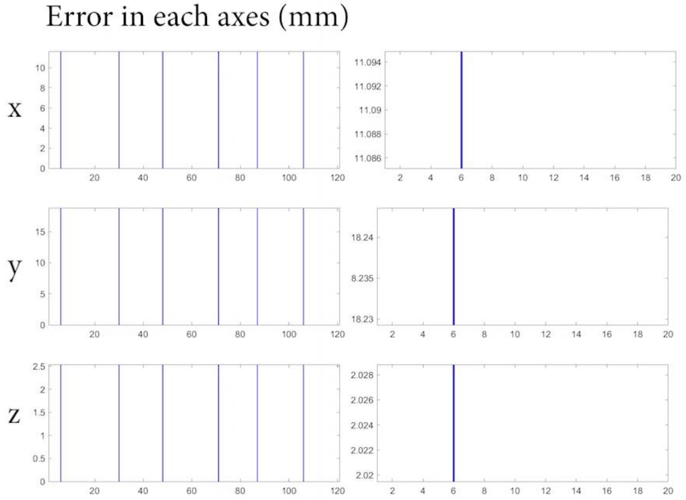


This is what the users sees!

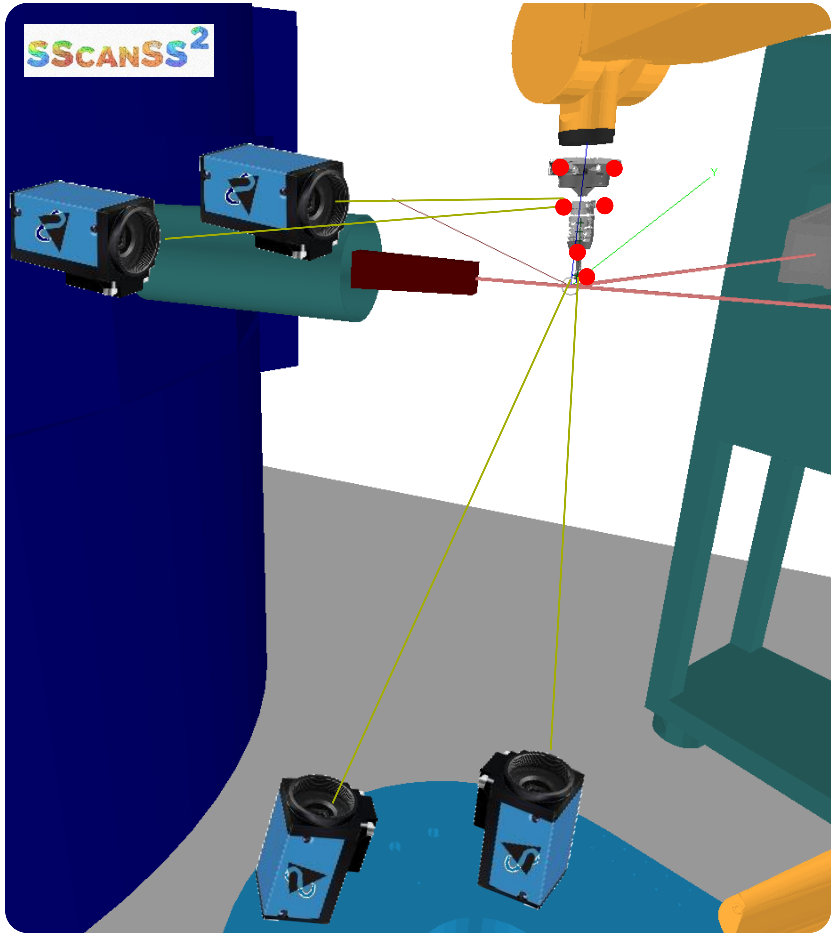
Results - Feasability Studies of Sample Tracking



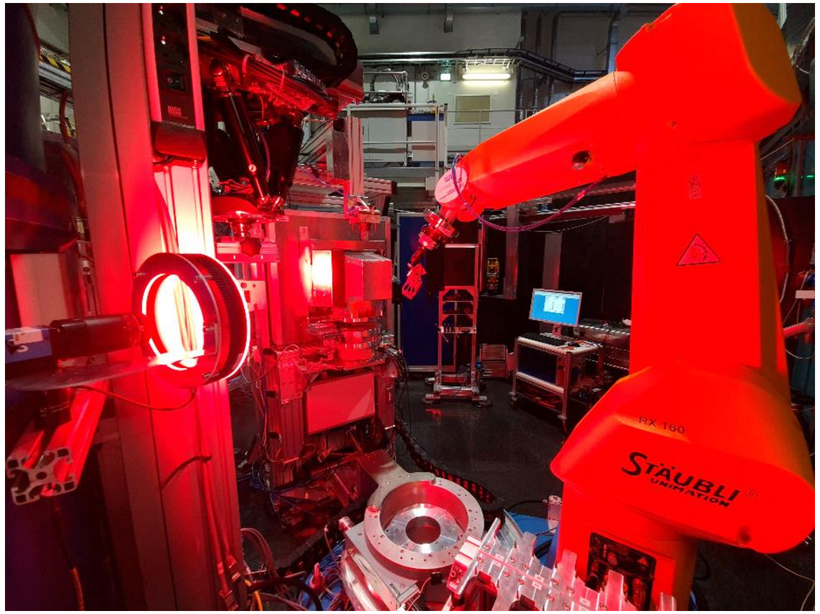




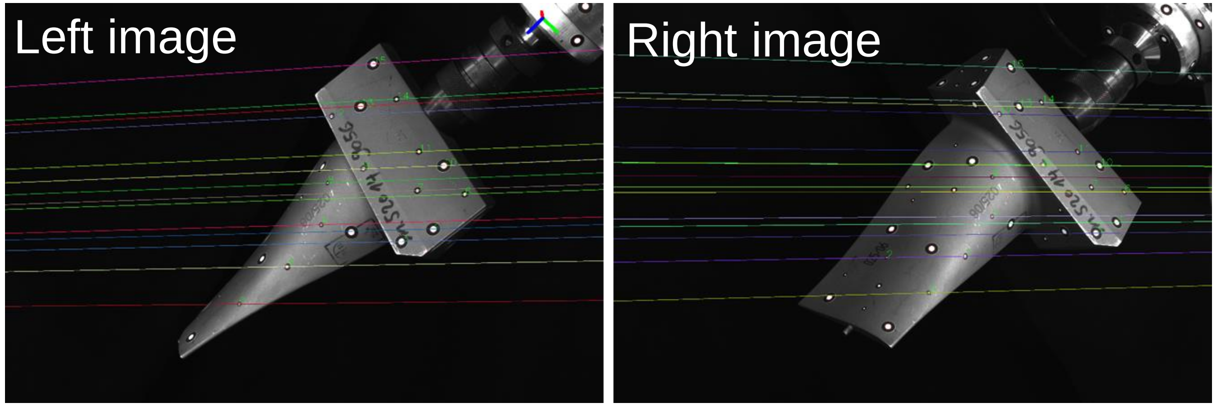
Optical Tracking System at our diffractometer - triangulation

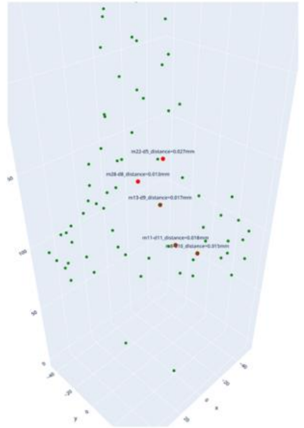


Robot position correction - planned

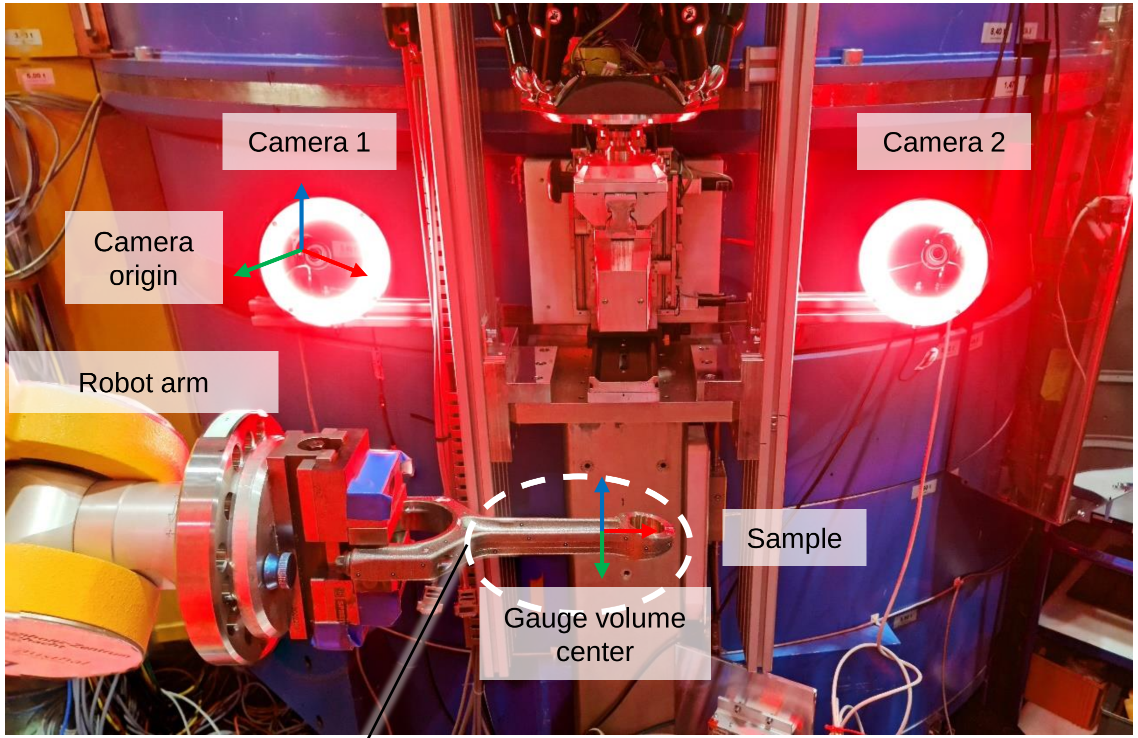


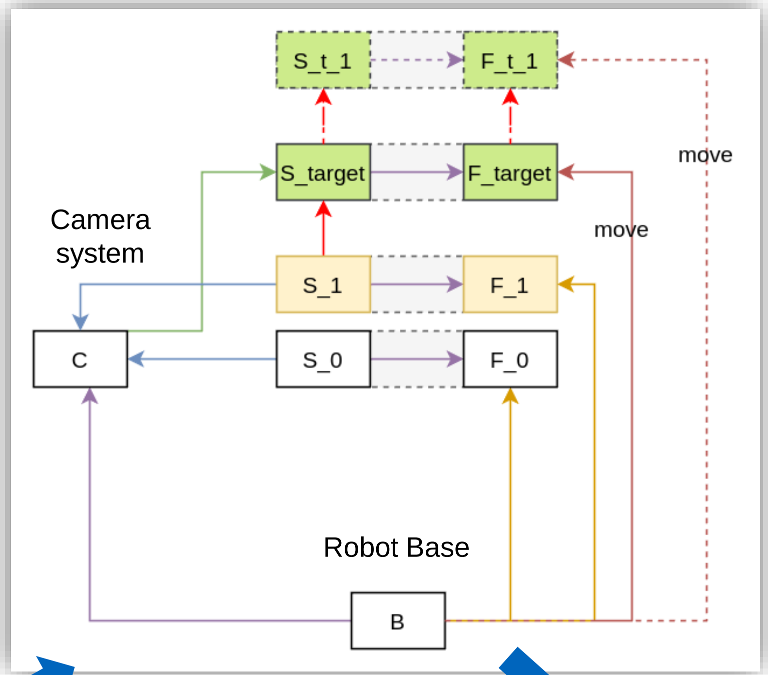
… in commissioning



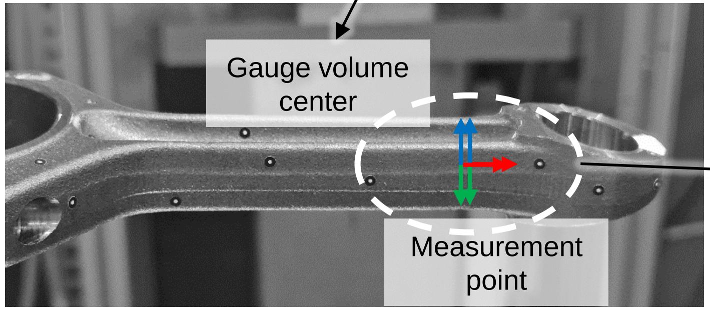


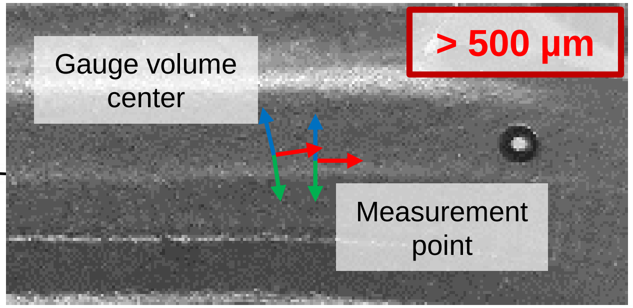
Optical Tracking System at our diffractometer - compensation

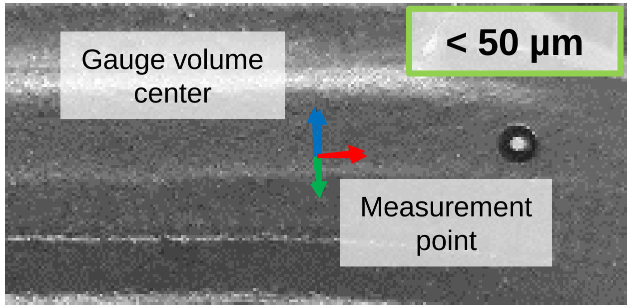




…2-3 interations

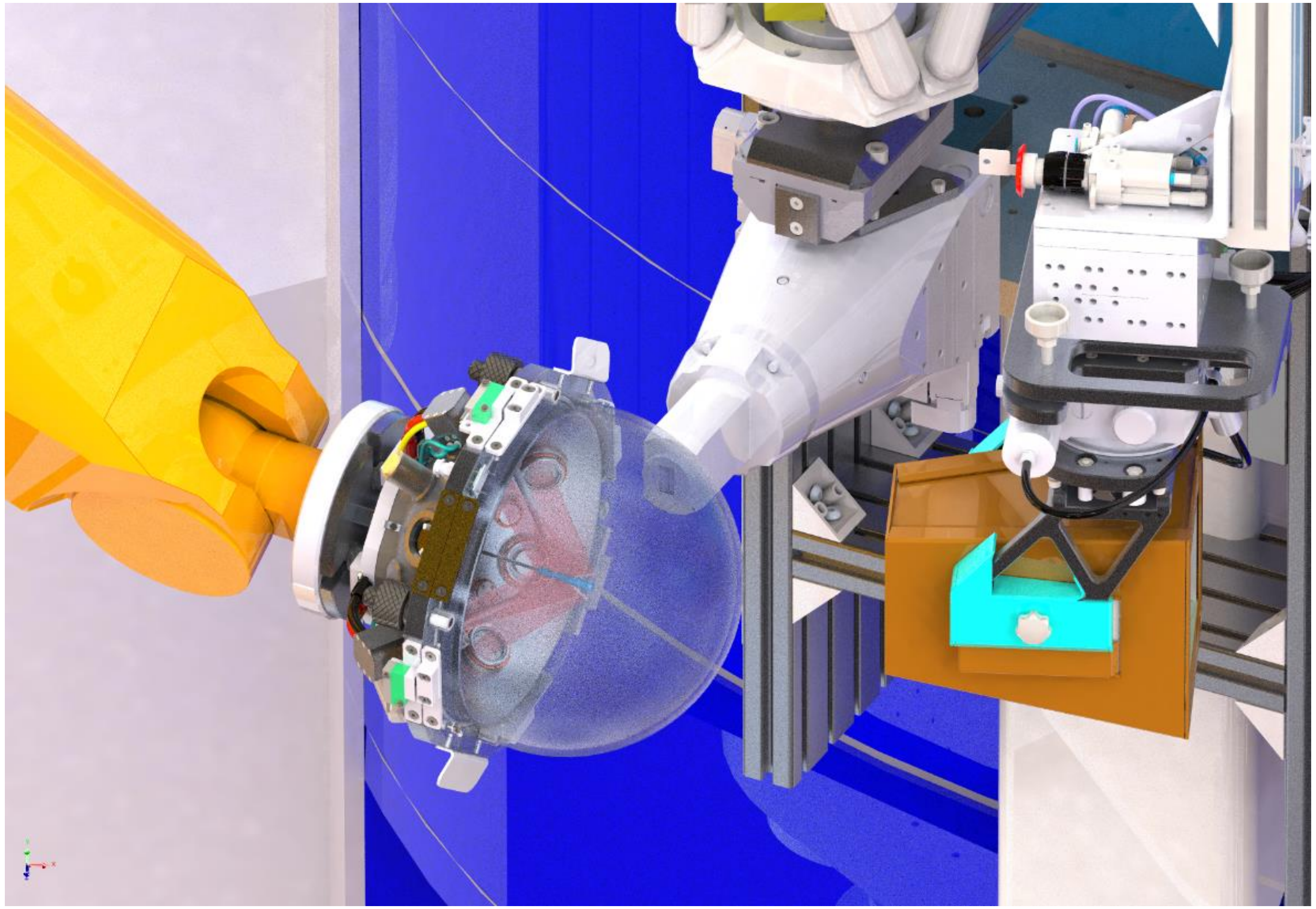




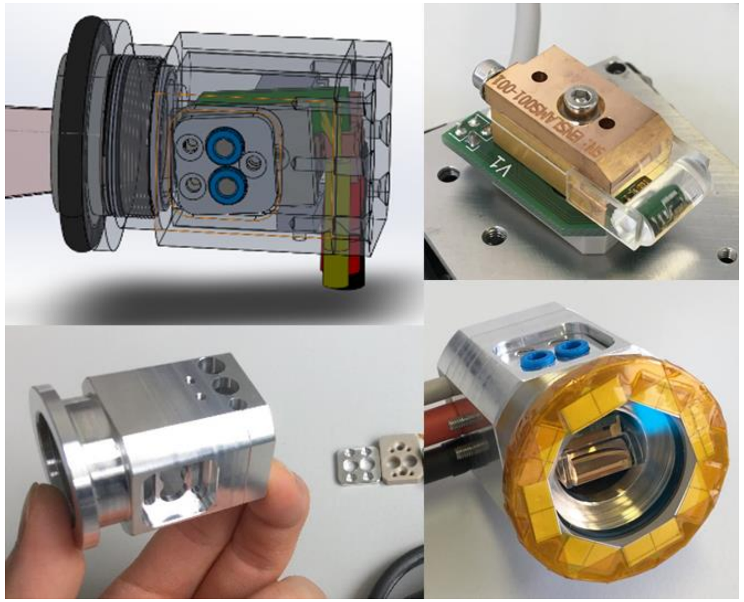


Sample Environment – Laser Furnace

- Temperatures up to 1300 ° C
  in vacuum or inert gas atmosphere
- Heating with IR-Lasers
- Mounted at the robot
- Cupola design for texture measurement

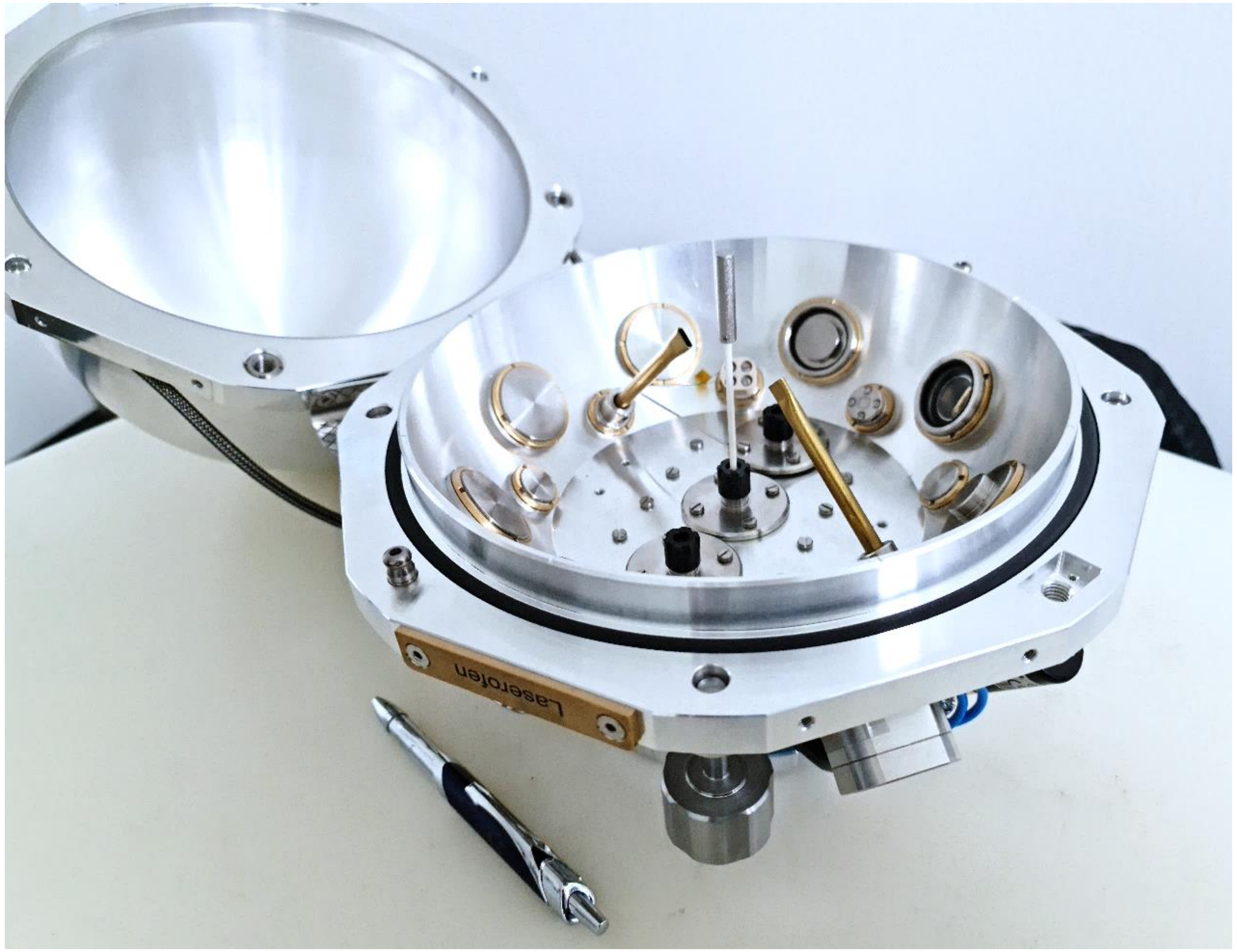


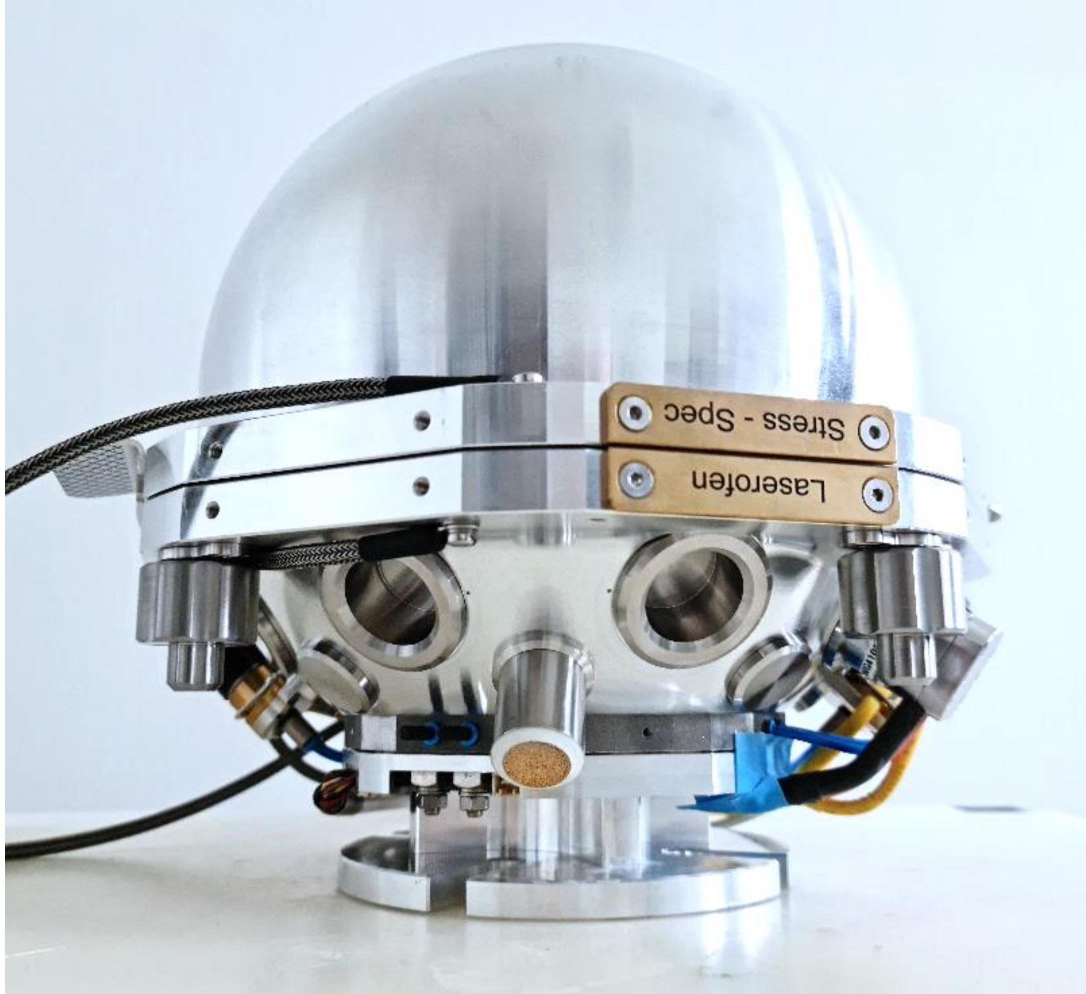
Laser furnace concept



Laser diode with housing

Sample Environment – Laser Furnace

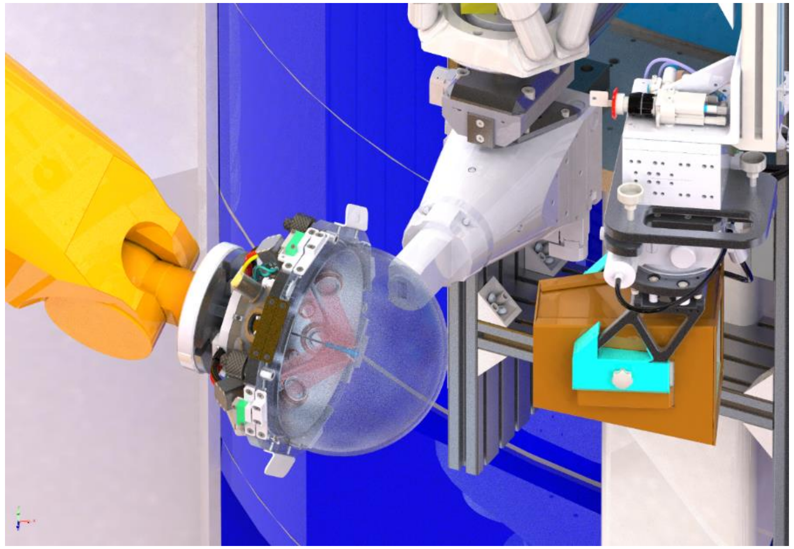




Conclusion and Outlook

- Current state of the project
  - Proof-of-concept is made: **Accuracy better than 50 µm!**
  - Experiments can be planned and simulated in advance with less effort
  - Communication between NICOS > ROS/MoveIt > Robot controller > Robot hardware established
  - Collision detection avoids damage on the instrument
  - Dedictaed sample environment and neutron optics for the robot sytsem are availabe

- Future tasks – what‘s next?
  - User friendly workflow and assisted measurement
  - Automated choice of best measurement direction (intensity based)
  - Automatated neutron optics alignment
  - Markerless pose estimation



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