BEATS

Work Package 6

Beamline assembly and commissioning

Commissioning of the beamline components in the experimental hutch

D 6.02

June 2023

Funded by the EU's H2020 framework programme under grant agreement n°822535

PROJECT DETAILS

PROJECT ACRONYM	*PROJECT TITLE*
BEATS	BEAmline for Tomography at SESAME

GRANT AGREEMENT NO:	*THEME*
822535	

START DATE
2019

DELIVERABLE DETAILS

WORK PACKAGE: 06	*EXPECTED DATE: 30/06/2023*
WORK PACKAGE TITLE: BEAMLINE ASSEMBLY AND COMMISSIONING	*DELIVERABLE TITLE: COMMISSIONING OF THE BEAMLINE COMPONENTS IN THE EXPERIMENTAL HUTCH*
WORK PACKAGE LEADER: SESAME	*DELIVERABLE DESCRIPTION: REPORT*
DELIVERAVLE ID: D6.02	
	PERSON RESPONSIBLE FOR THE DELIVERABLE: GIANLUCA IORI

NATURE

☒ R - Report ☐ P - Prototype ☐ D - Demonstrator ☐ O - Other

DISSEMINATION LEVEL		
x	P - Public	
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	CO - Confidential, only for members of the consortium	

REPORT DETAILS

VERSION: 1	*DATE: 30/06/2023*	*NUMBER OF PAGES: 15*
DELIVERABLE REPORT AUTHOR(S): ***G. IORI ET AL.***	*FOR MORE INFO PLEASE CONTACT: GIANLUCA.IORI@SESAME.ORG.JO*	

STATUS			
☐	Template	☐	Draft
☒	Final	☒	Released to the EC

Contents

SUMMARY

Following the successful installation of

- the BEATS x-ray source and front end in the SESAME storage ring tunnel,
- the BEATS radiation protection hutch infrastructure, and
- the beamline's vacuum system,

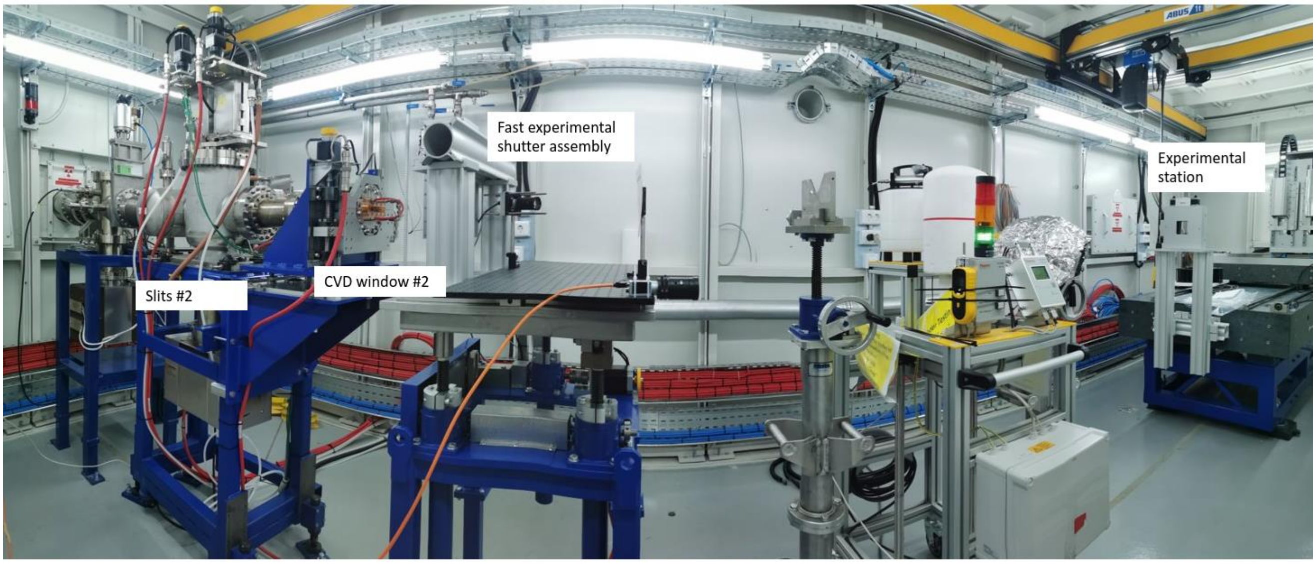
radiation tests were carried out to prove, that the BEATS infrastructure is radiation tight. Based on the positive results, a provisional authorisation to commission the beamline with x-ray was obtained from the Jordanian authorities (EMRC).

This report describes the steps undertaken to put into service the components in the experimental hutch (sample and detector stage) together with the full tomography data collection and analysis chain and shows the first experimental results obtained during the process

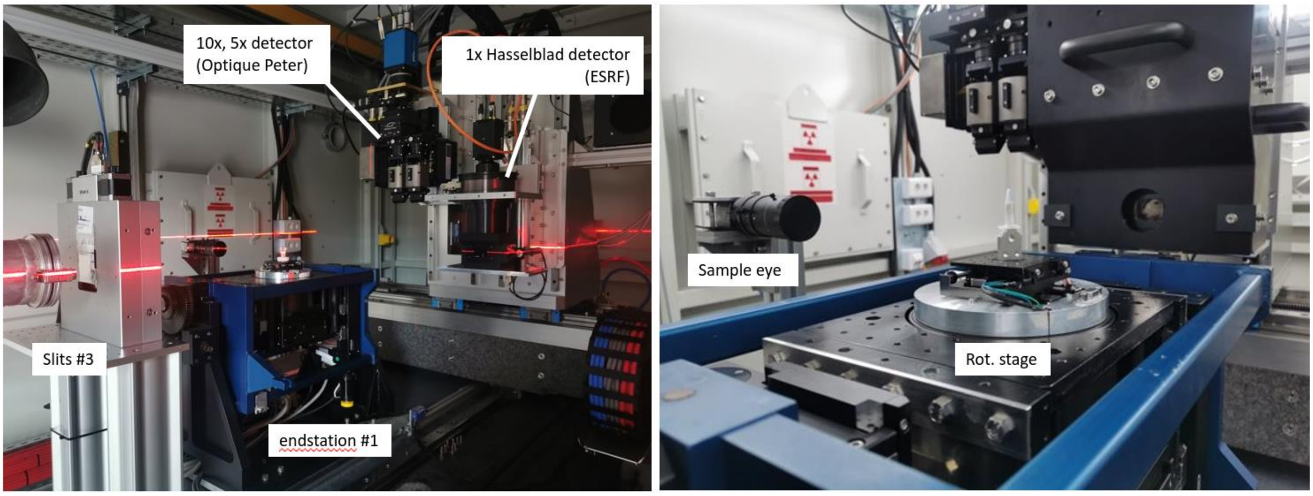
BEATS EXPERIMENTAL STATION

The BEATS experimental hutch and tomography station comprise the following equipment:

- In vacuum slits #2
- CVD window #2 with motorized vertical stroke
- Motorized assembly for a fast experiment shutter (cf. [1])
- Experimental tomography station composed of the following items
  - In air sample slits #3
  - Optical granite table and detector stage
  - 6-axis sample manipulator (BEATS endstation #1) (cf. [2])
  - Hasselblad x-ray detector (0.5x to 2x magnification) (ESRF) (cf. [3])
  - OptiquePeter Twin x-ray microscope (5x to 10x magnification)
  - Scientific CMOS cameras
  - Sample eye and IP cameras



Full view of the experiments hutch



Experimental hutch: sample and detector stage

ALIGNMENT

During the installation phase of the beamline, all of its components from ID chamber over front end and double multilayer monochromator vessel, slit and window systems downstream to the sample station and detector stage were aligned with respect to the x-ray beam.

To allow proper functioning of the tomography scanning process itself, individual components of sample and detector stage need to be aligned with respect to each other to ensure they are positioned on a common coordinate system.

This comprises in particular:

- The pitch of the tomography sample stage,
- the rotation axis of the camera sensor,
- the tomography rotation axis, and
- the detector focal plane.

Unlike the alignment of the whole beamline with respect to the overall SESAME coordinate system, these alignment steps will have to be repeated more often during the normal operation of BEATS. A standard procedure has been established and is described in the beamline manual (cf. BEATS deliverable D 6.03).

SCAN MODALITIES

Detectors and cameras

To enable the implementation of the major scanning modes of the tomography station, the BEATS detector and camera components were commissioned, comprising (cf. BEATS deliverable 4.1 “Technical Design Report”)

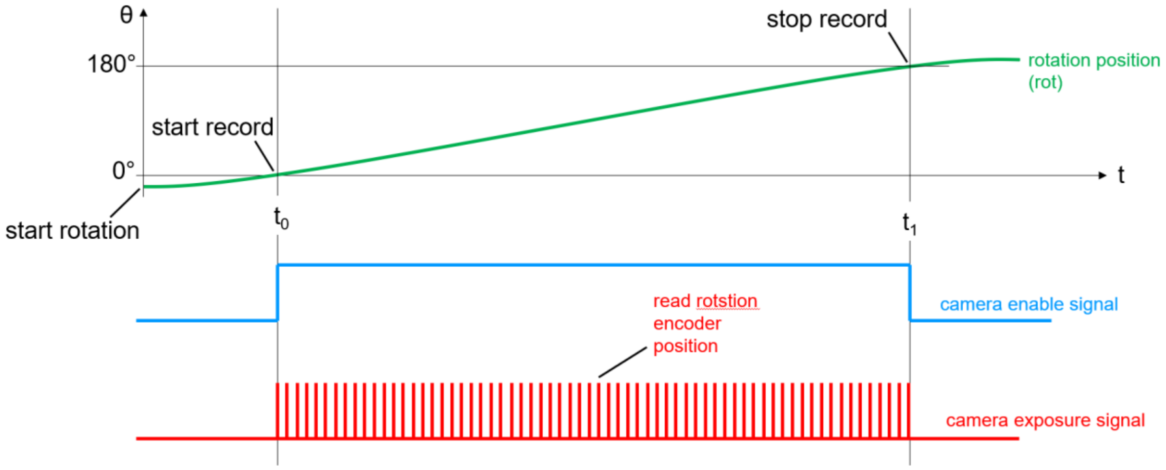
- PCO edge 5.5 CLHS camera. This camera is equipped with a water cooled, 5.5 MP sCMOS sensor with superior quantum efficiency and low noise.
- ORYX FLIR 7.1 camera. This is a high-end machine vision camera equipped with a 7.1 MP CMOS sensor.
- Hasselblad ESRF detector system with tandem optics in 1x magnification, this configuration provides 6.5 µm pixel size
- OptiquePeter Twin white beam x-ray microscope equipped with a lead-glass protected 5x magnification lens, 1.3 µm pixel size.

For the day-one operation of BEATS, two different scan modes using white (pink) beam were foreseen:

Continuous scan mode

Continuous scan

1. set rotation to constant speed; start rotation
2. wait until rotation speed is stable
3. start record of n projections; read rotation encoder readout
4. stop record; stop rotation

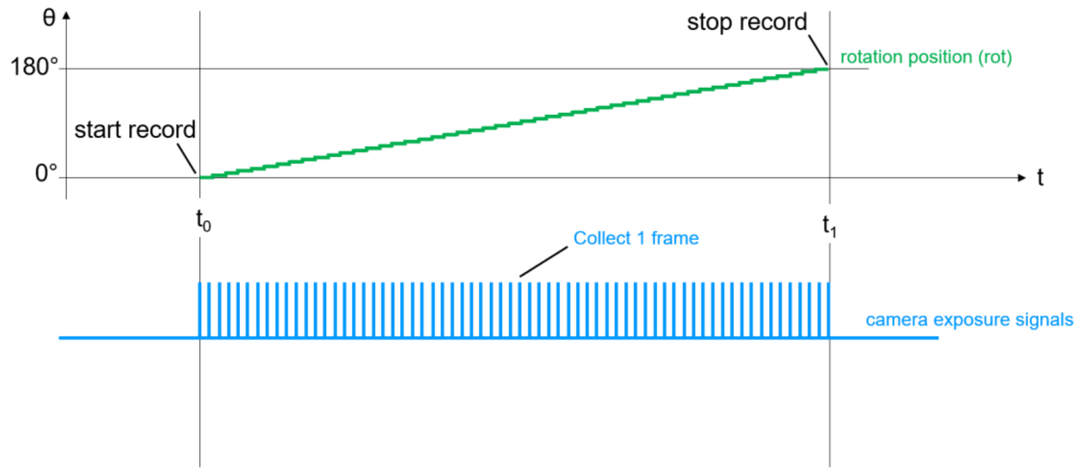


In this mode, the rotation of the sample is set to a constant angular velocity, while the camera continuously acquires projections, each image stored with the corresponding reading of the rotation encoder. This is the standard, fast scanning modality.

Step scan mode

Step scan

1. move rotation stage to step angle position
2. wait until rotation position is reached
3. collect 1 projection; read rotation encoder readout
4. repeat for all angles



In the step scan mode, the rotation axis is stopped at equidistant angular values, at which then a frame is recorded. This mode allows for extended exposure time for each frame and reduces artefacts generated by sample motion during the scan.

Both scan modalities can be combined with an extension of the scan Field Of View (FOV), also known as 360 degree scan. This scan modality doubles the available horizontal FOV, was implemented and is available as well.

Already after the reception of cameras and computing infrastructure earlier in the project, the two day-one scan modes were already set up and tested using visible, made the commissioning of these modes with x-rays straightforward and reduced the commission time.

The commissioning phase was concluded with a successful overnight stress test of the whole data acquisition chain by automatically collecting 10,000 projections which generated a HDF5 raw file of 110 GByte, including acquisition of flat field images before and after the scan.

WHITE BEAM CONFIGURATIONS

With the sample and the detector stage aligned and functioning, the data acquisition and analysis system operational, three configurations for the beamline operation during test sample tomographic scans were defined. As laid out in the BEATS technical design report (Deliverable 4.01), the day-one operation of the BEATS beamline will consist of using white/pink beam. The following beamline configurations were established and tested:

High energy beam configuration

- Wiggler gap: 11.15 mm (minimal gap, B ≈ 3 T)
- Absorbers: 2 mm Cu, 5 mm C, 2mm Al
- Mean photon energy: 60 keV

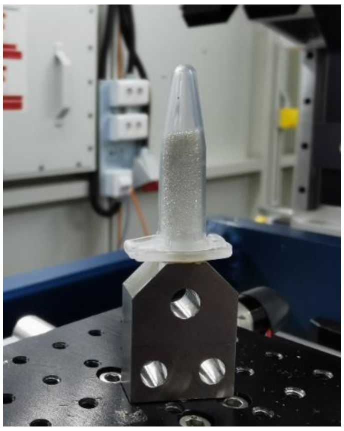
Low energy beam configuration

- Wiggler gap: 40 mm (minimal gap, B ≈ 1.5 T)
- Absorbers: 5 mm C, 2 mm Al
- Mean photon energy: 20 keV

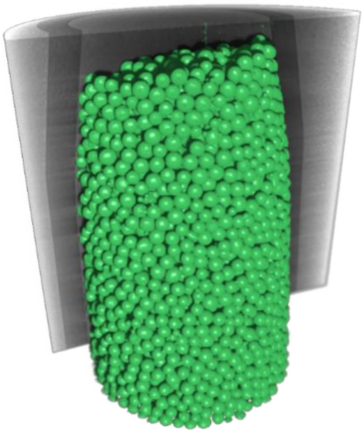
TEST SAMPLE SCANS

First sample: Glass beads (300 µm)

The very first test sample was scanned with x-ray beam in May 2023. Due to the thorough commissioning along the aforementioned steps already the very first scan led to a successful 3D reconstruction.



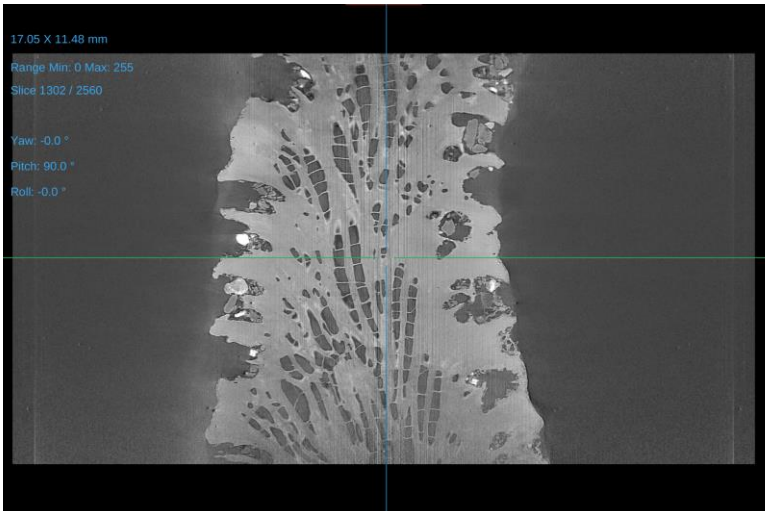
Test sample glass beads: The glass spheres in their sample holder mounted on the BEATS tomography sample stage



3D reconstruction of the glass beads test sample, voxel size $(4.5\ \mu m)^3$, 1000 projections, 12 s scan duration, ORYX FLIR camera, “1x” Hasselblad lens

Test sample: Red sea coral

- Sample: Coral (Aqaba beach)
- Hasselblad detector 1x; ORYX FLIR camera
- 4.5 micron voxel size
- Scan settings:
  - Filtered white beam (mean energy ~50 keV)
  - 35 ms exposure time
  - Scan time: ~1 min

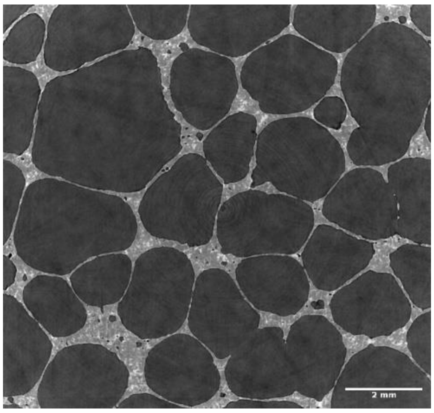


Read sea coral, slice of the 3D reconstruction

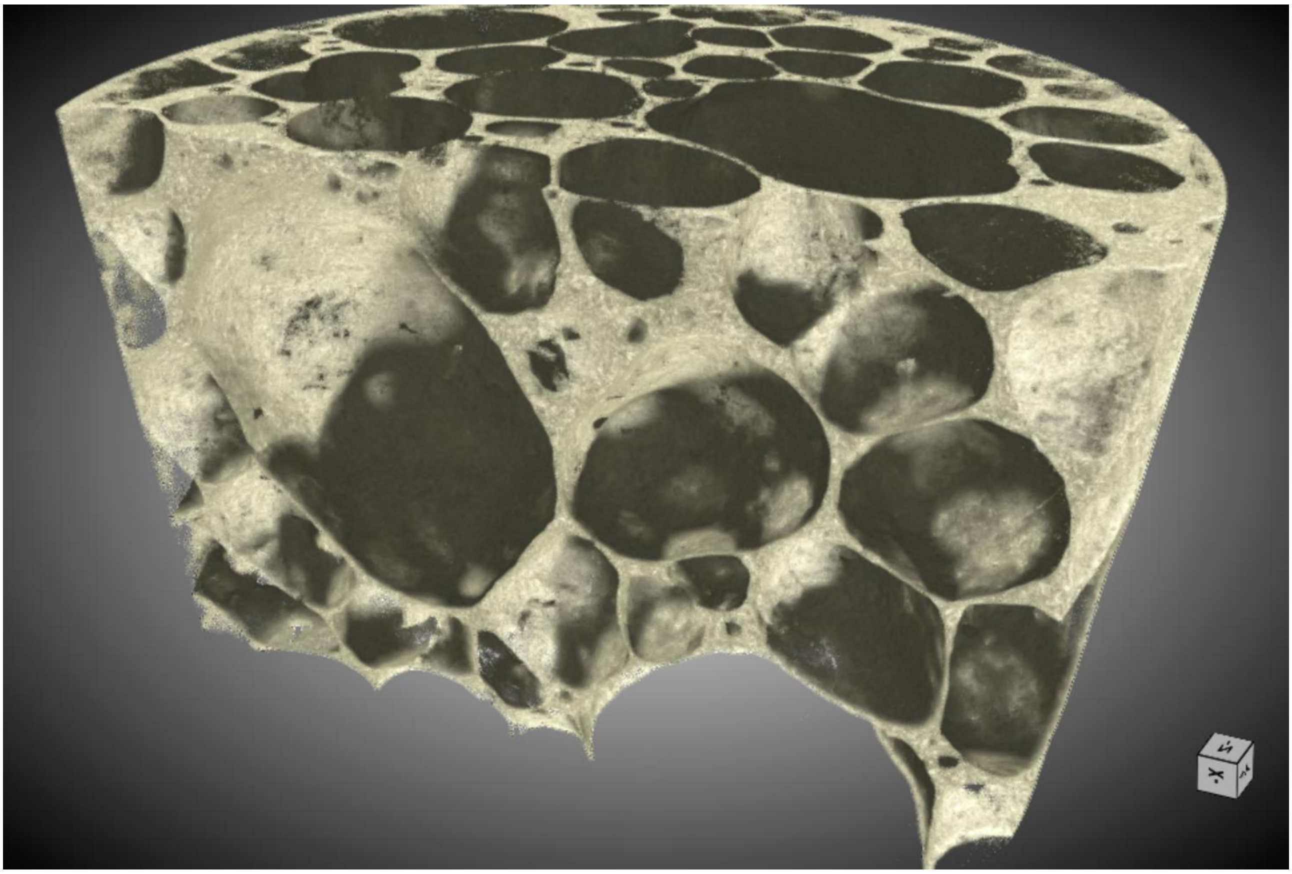
Red sea coral, 3D reconstruction

Test sample: Aluminium foam

- Sample: Al foam from industrial application (courtesy A. Rack ID19 ESRF)
- Hasselblad detector 1x; PCO edge 5.5 camera
- 6.5 micron voxel size
- Local tomography (sample larger than FOV)
- Scan settings:
  - Filtered white beam (mean energy ~30 keV)
  - Scan time: <1 min



Al foam, slice of the 3D reconstruction

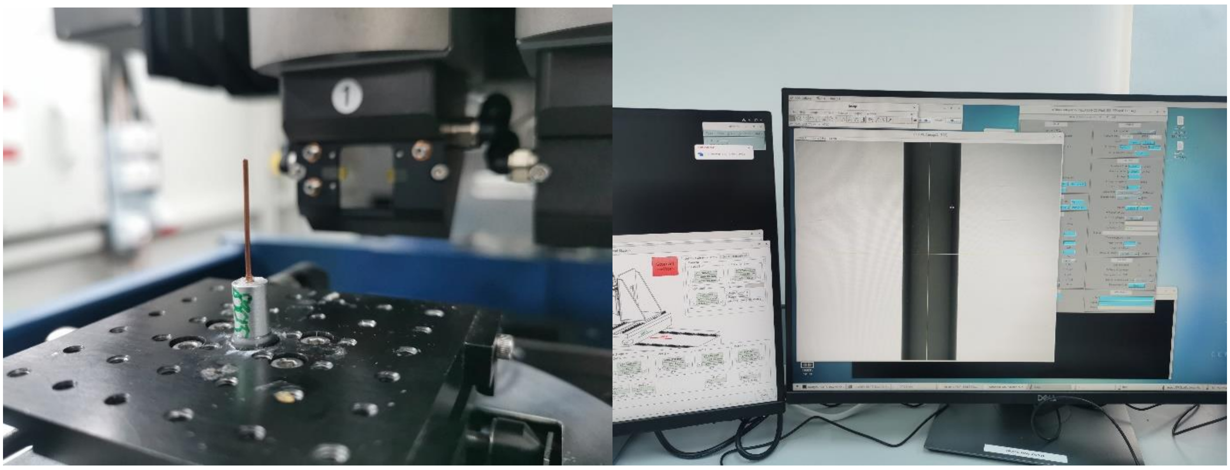


Al foam, 3D reconstruction, voxel size (6.5 µm)^3

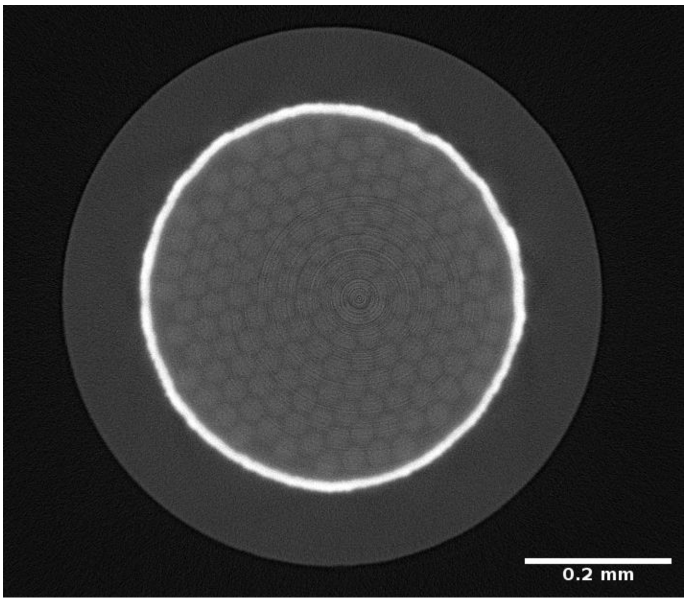
Sample: Nb3SN superconducting wire

Finally, a sample that had already been investigated on ESRF's tomography beamline ID19 (cf. [4]), was scanned at BEATS: A Nb3Sn superconducting wire of 0.82 mm diameter. This scan and the subsequent 3D reconstruction proved, that the BEATS beamline reached the foreseen performance levels with respect to flux and contrast even for dense, i.e. highly absorbing samples.

- Sample: Nb3Sn superconducting wire; diameter: 0.82 mm (courtesy A. Rack ID19 ESRF)
- OptiquePeter Twin microscope detector 5x; PCO edge 5.5 camera
- 1.3 micron voxel size
- Scan settings:
  - Filtered white beam (mean energy ~60 keV)
  - Continuous scan time: 40 min
  - Stress test step scan time: ~ 6 h



Alignment of the Nb_3Sn superconducting wire sample



Nb_3Sn superconducting wire, slice of the 3D reconstruction

REFERENCES

[1]

C. Muñoz Pequeño, J. M. Clement, P. Thevenau, and P. Van Vaerenbergh, "Development of a Linear Fast Shutter for BM05 at ESRF and BEATS at SESAME," in *Proceedings of the 11th Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation*, Chicago, USA, Jul. 2021. doi: 10.18429/JACoW-MEDSI2020-WEOB03.

[2]

M. Stampanoni *et al.*, "TOMCAT: A beamline for TOmographic Microscopy and Coherent rAdiology experimenTs," *AIP Conference Proceedings*, vol. 879, no. 1, pp. 848–851, Jan. 2007, doi: 10.1063/1.2436193.

[3]

A. Mittone, I. Manakov, L. Broche, C. Jarnias, P. Coan, and A. Bravin, "Characterization of a sCMOS-based high-resolution imaging system," *Journal of Synchrotron Radiation*, vol. 24, no. 6, pp. 1226–1236, 2017, doi: 10.1107/S160057751701222X.

[4]

C. Barth *et al.*, "Quantitative correlation between the void morphology of niobium-tin wires and their irreversible critical current degradation upon mechanical loading," *Sci Rep*, vol. 8, no. 1, Art. no. 1, Apr. 2018, doi: 10.1038/s41598-018-24966-z.