



Update on the split-and-delay line at MID

W. Lu, B. Friedrich and MID team

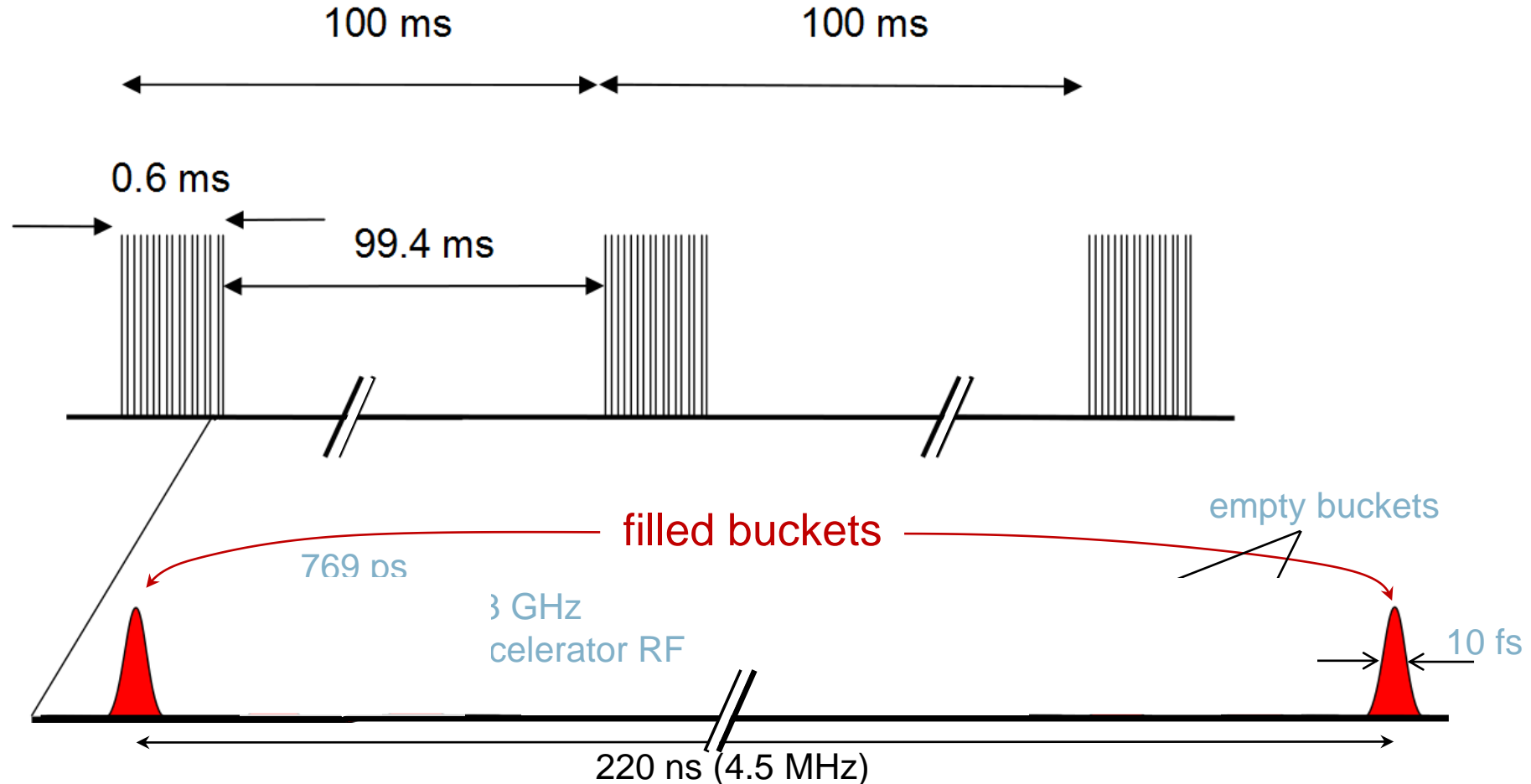
European X-Ray Free-Electron Laser Facility

24.01.2022

Outline

- Overview of the SDL project
- Conceptual and Mechanical design of the SDL
- Project milestones
- Beam commissioning of SDL
- On-going Developments
- Summary and Outlook

Standard time structure of European XFEL:



Aim of the SDL: Providing pairs of X-ray pulses with energies in the range of 5 - 10 keV and a continuously tunable delay time of -10 - 800 ps, to enable time-resolved studies on dynamic processes faster than XFEL pulse spacing provided by the machine and various experimental techniques e.g., time-resolved XPCS, Speckle Visibility Spectroscopy (SVS), ultrafast X-ray tomography, and temporally and spatially resolved X-ray holography.

Overview of the SDL project

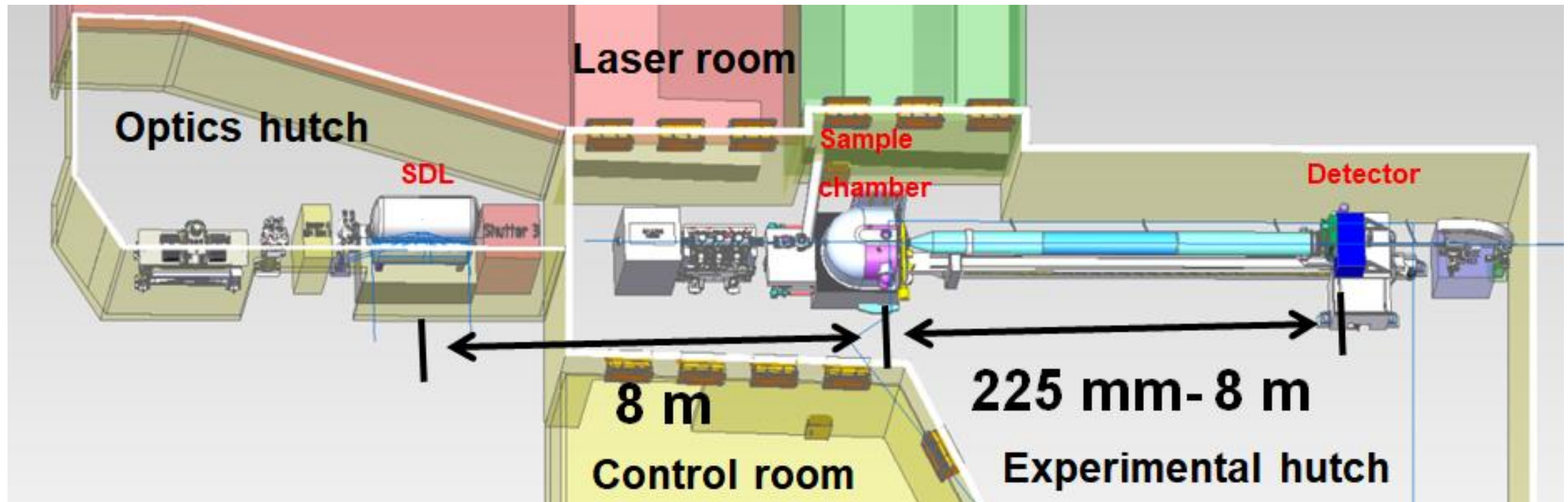
- Project start from 2013
- European XFEL and TU Berlin/MBI Berlin Collaboration
- Two periods of BMBF funding, total 6 years
- 1.4 million Euro for instrument and installation
- Permanent installation in OH of MID



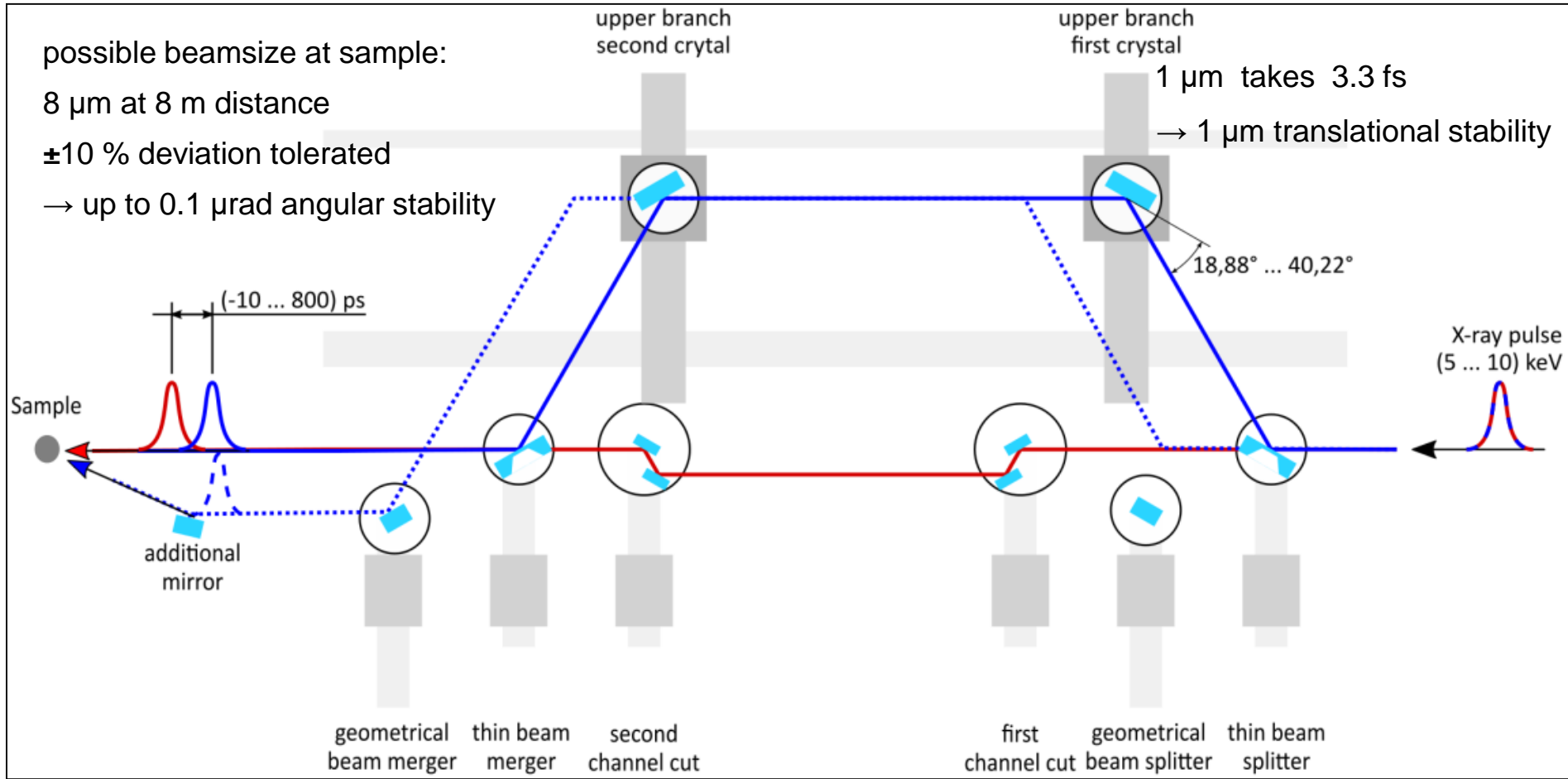
Max Born Institute



Bundesministerium
für Bildung
und Forschung

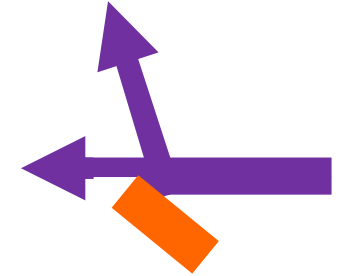


Concept of the Split and Delay Line (SDL)



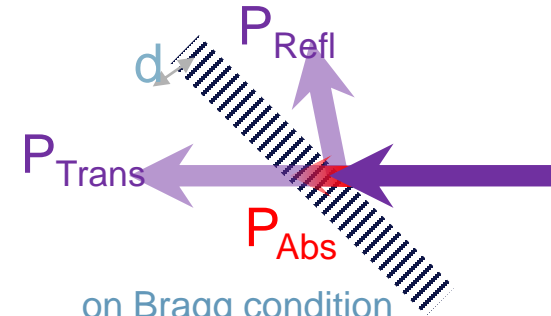
Schematic layout of the split and delay line.

Geometrical Splitting



Thick Si(220) crystal
Access to large & perfect crystals

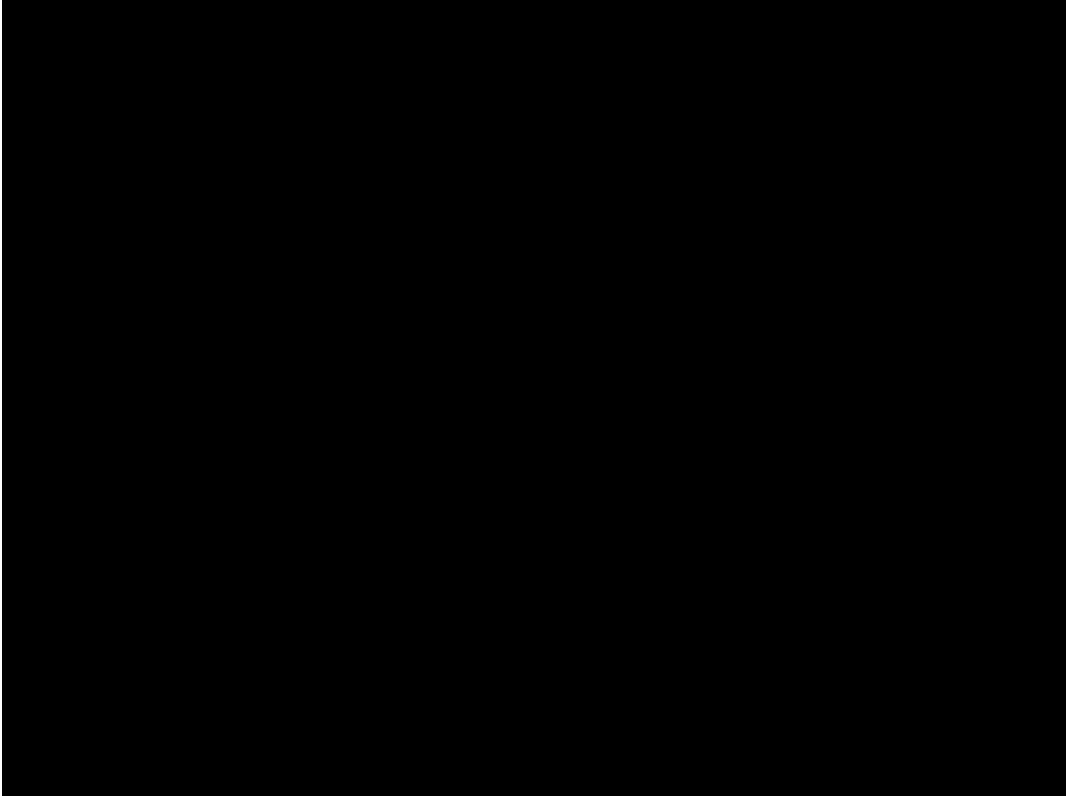
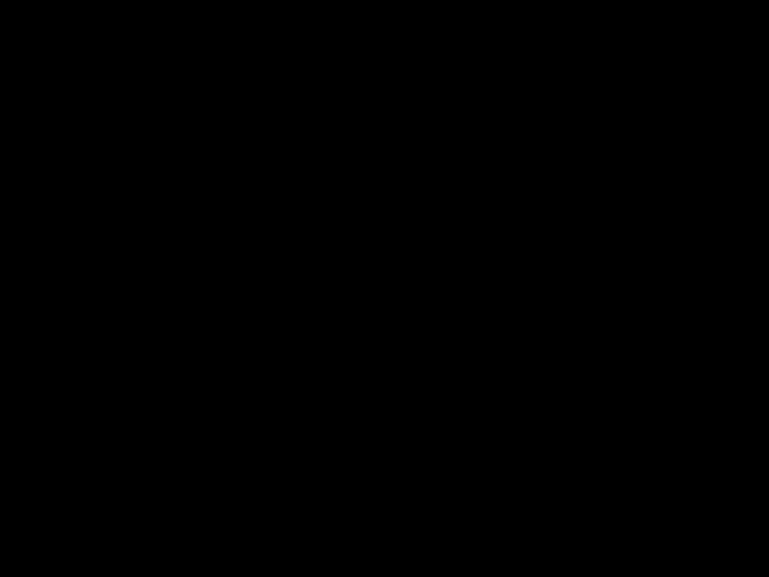
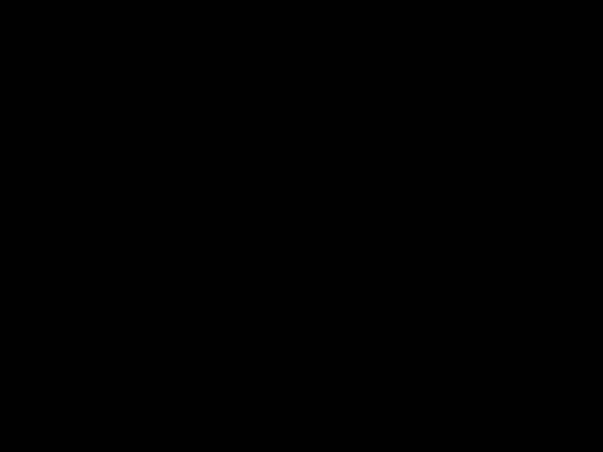
Optical Splitting



on Bragg condition

~~Thin Si(220) crystal (a few μm)~~

Thin Diamond (111) crystal (PERDIS project)

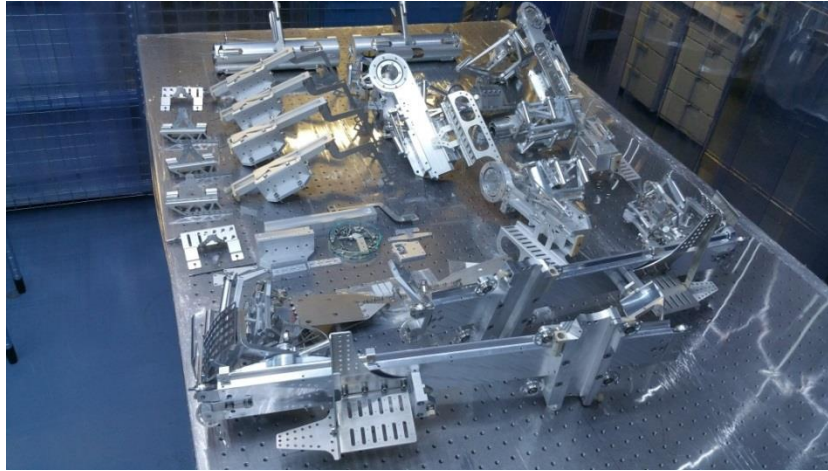


Split-Delay line at MID (installation start: Nov 2019)

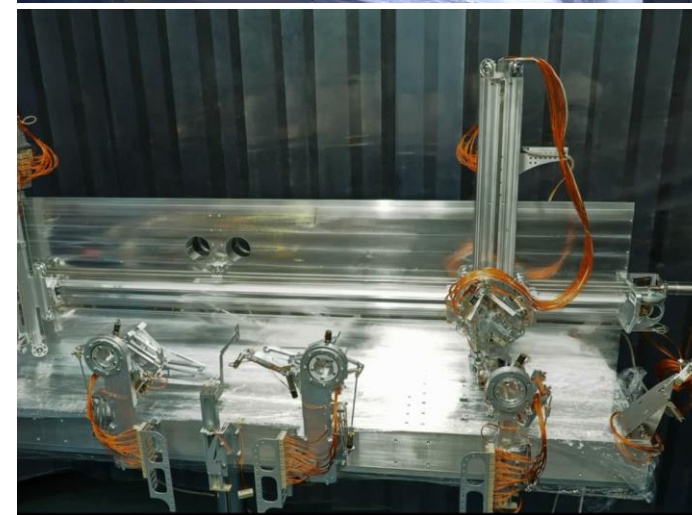
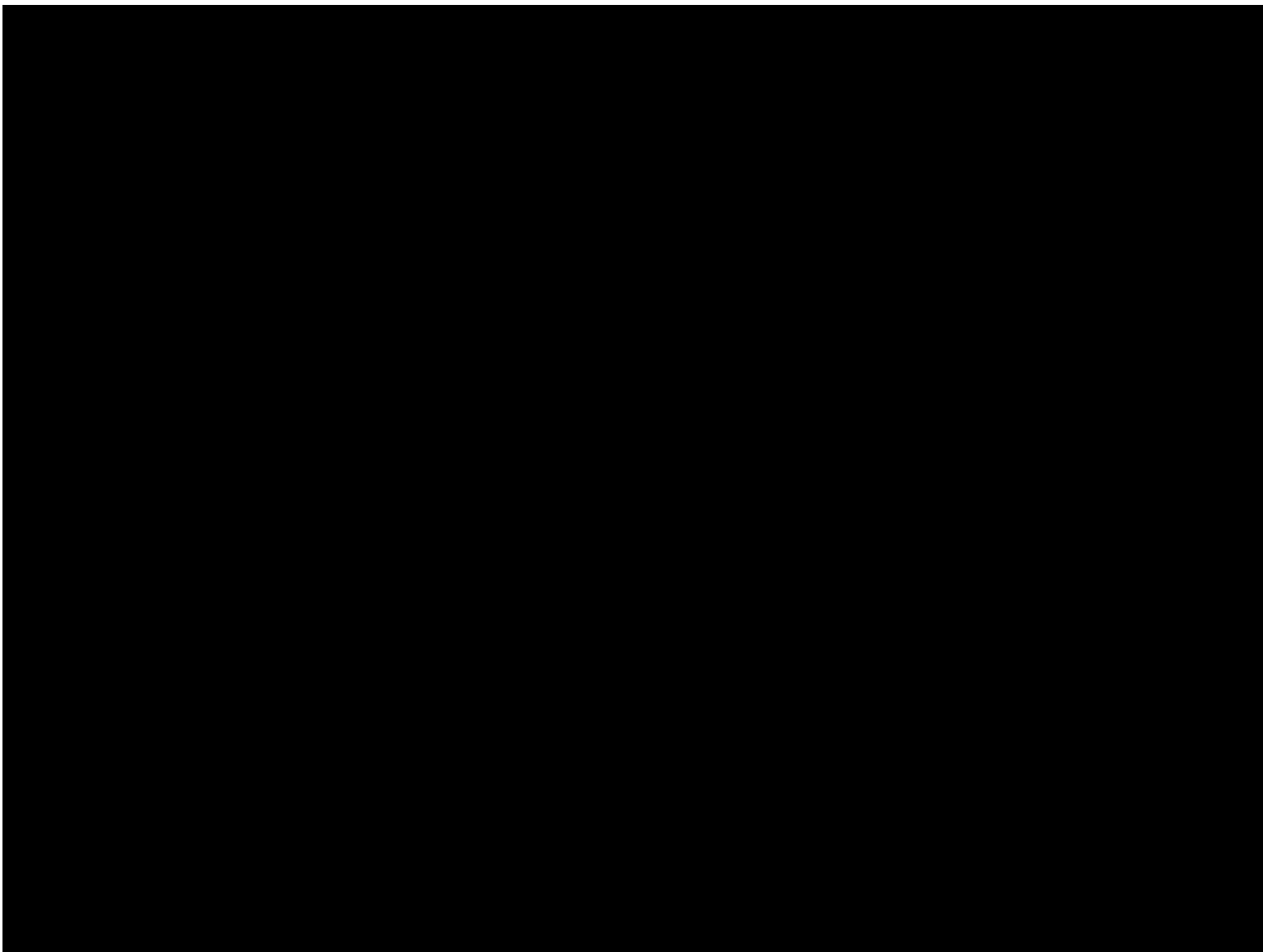
Inner mechanics



Max Born Institute
Eisebitt group

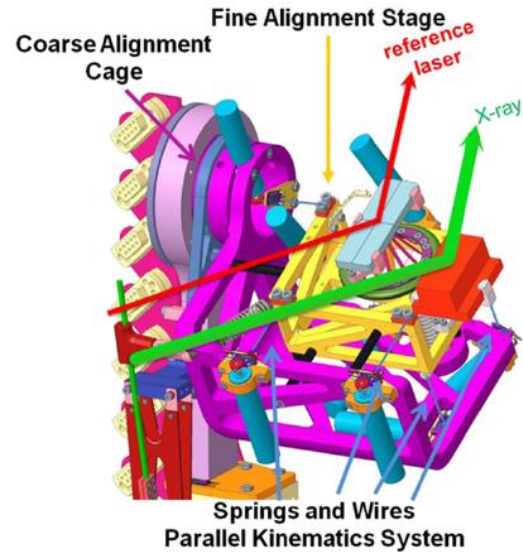


Mechanical motions

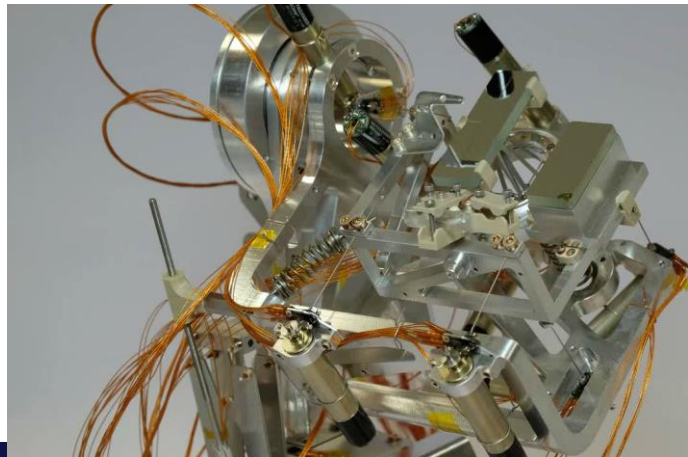


Mechanical motions

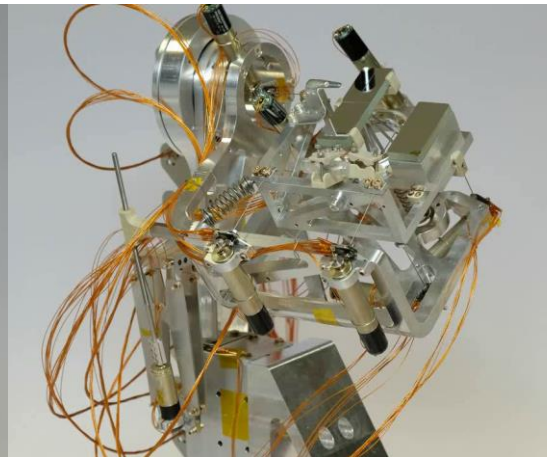
Crystal carriage with fine alignment platform (FAP)



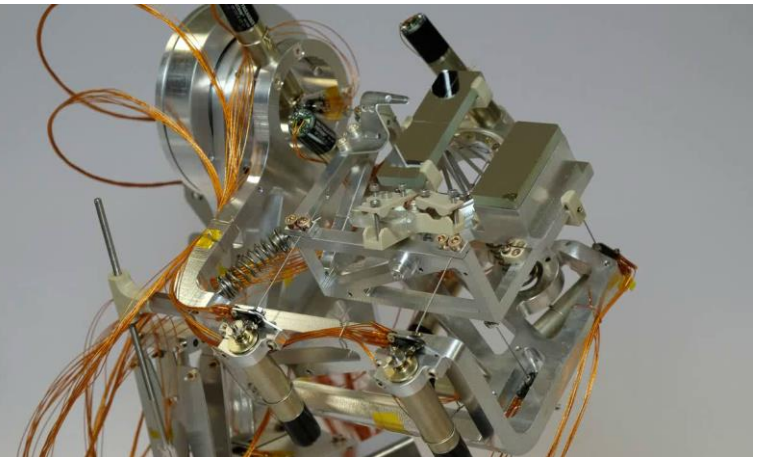
- A combination of coarse long range motion with fine alignment platform. 10-12 small stepper motors for sufficiently precise control.
- 6 DoF parallel kinematic platform for the fine alignment of optical element.
- Linear and angular resolution of about 2.5 nm and 36 nrad per full motor step, respectively.



Fine angular motion

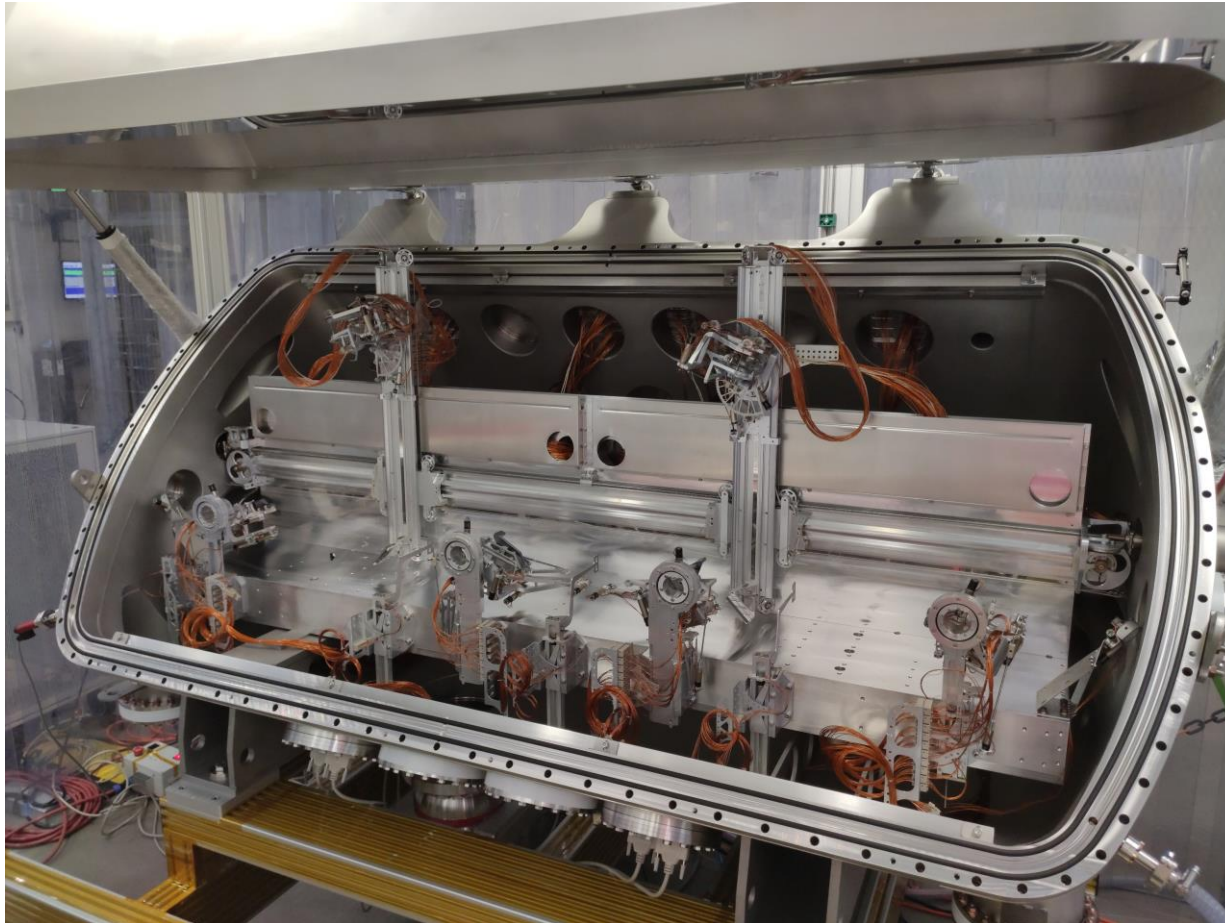


Coarse angular motion



Fine linear motion

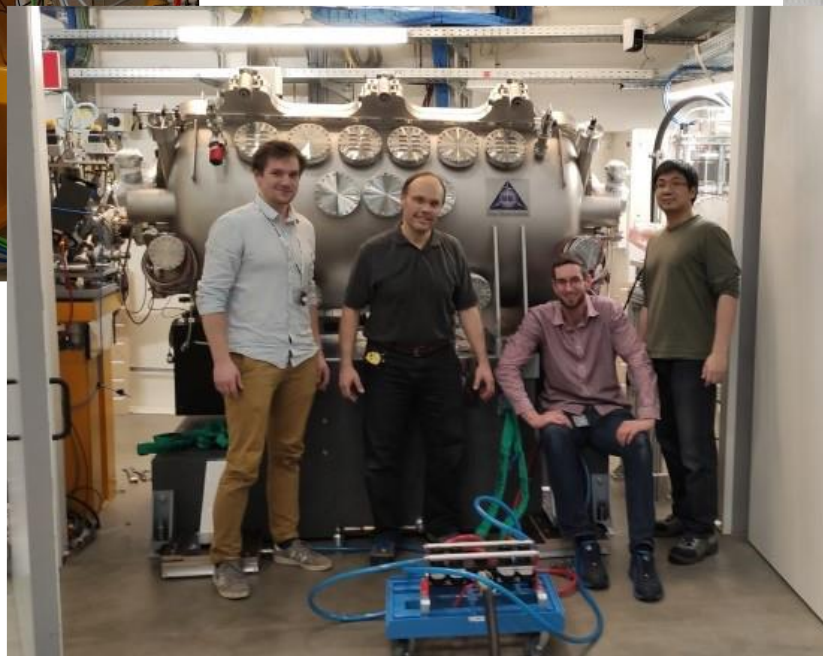
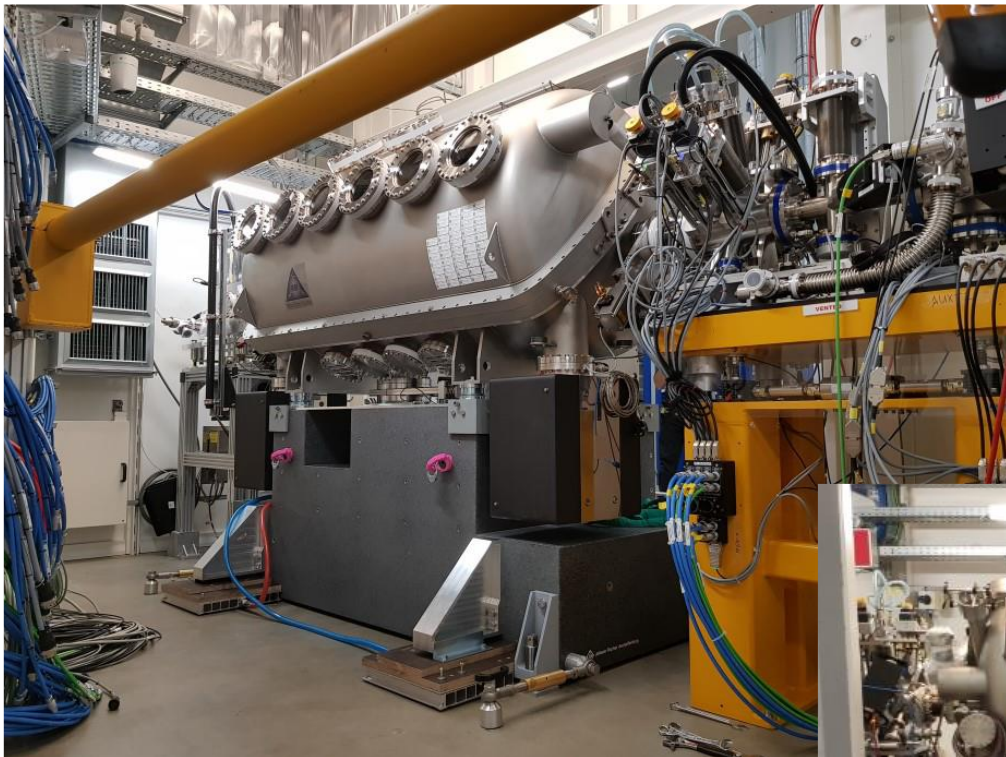
Final Assembly



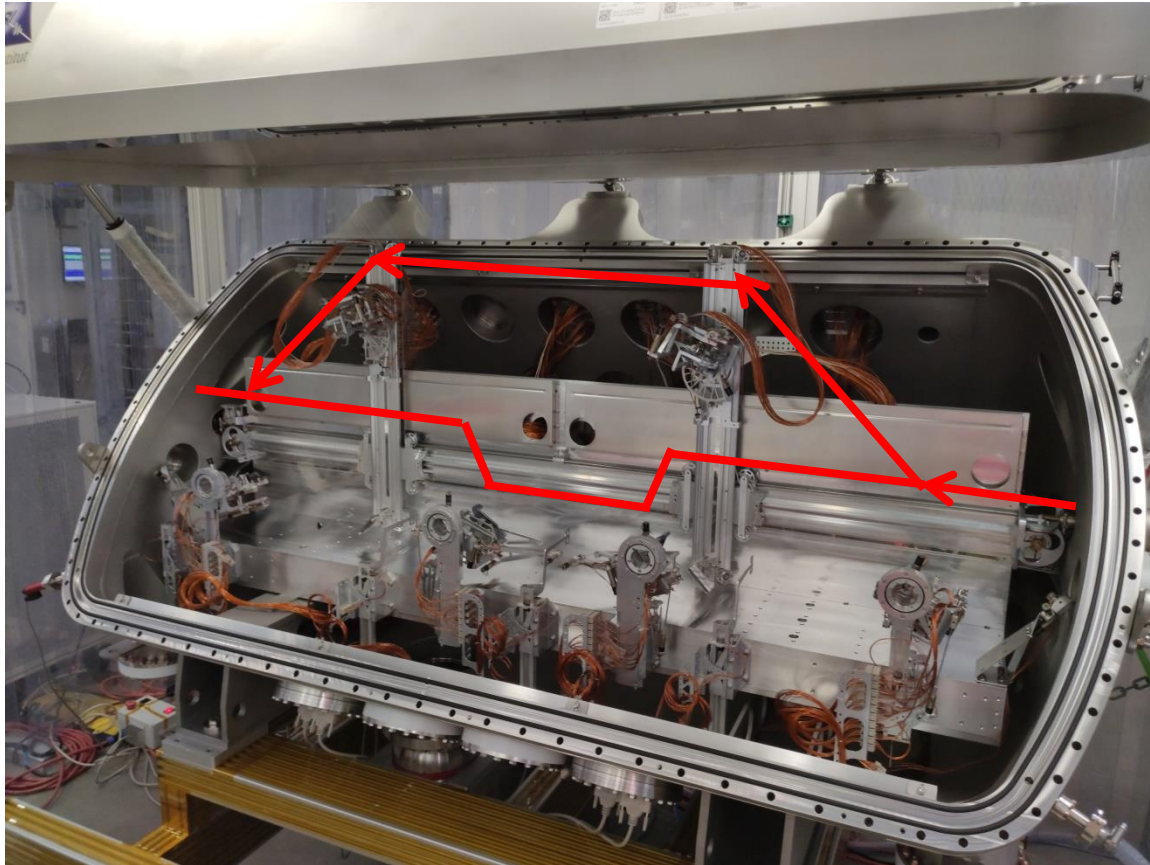
- A cylindrical UHV chamber with the dimensions of about 2 m x Ø1 m on massive granite base.
- 2m long One-piece optical bench as stiff supporting structure for the optomechanics.
- Separate positioning stages for each X-ray optical element.
- Fast long-range travel of up to 1000 mm with μm resolution for delay crystals
- Components:
 - 6-8 pieces X-ray crystals
 - 117 In-vacuum motors, 10 air-side motors
 - 8 X-ray beam diagnostic imagers/diodes
 - 38 PT100s, 34 in-vacuum heater units
 - 12 in-vacuum cameras, 5+ air-side cameras

Split-Delay line at MID

Installed January 2020
Commissioning following

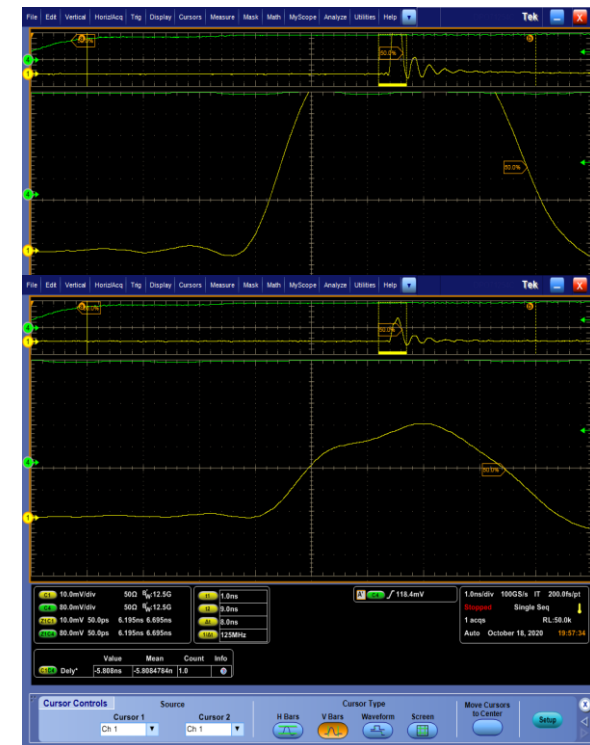
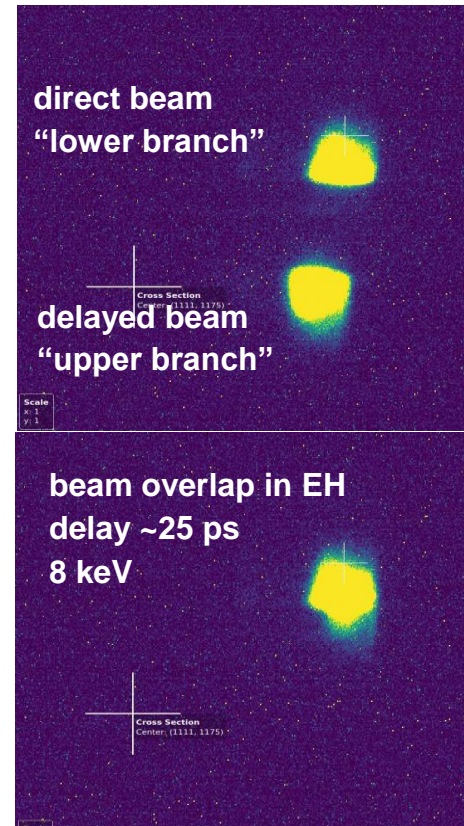


Beam commissioning (Aug. and Oct. 2020)



- Test all coarse motions and some fine motions in UHV
- Alignment of 8keV & 9keV beam through both branches to the end station. The pictures is taken at the DES.
- Achieve spacial overlap of both beams. It about 25ps between two branches.

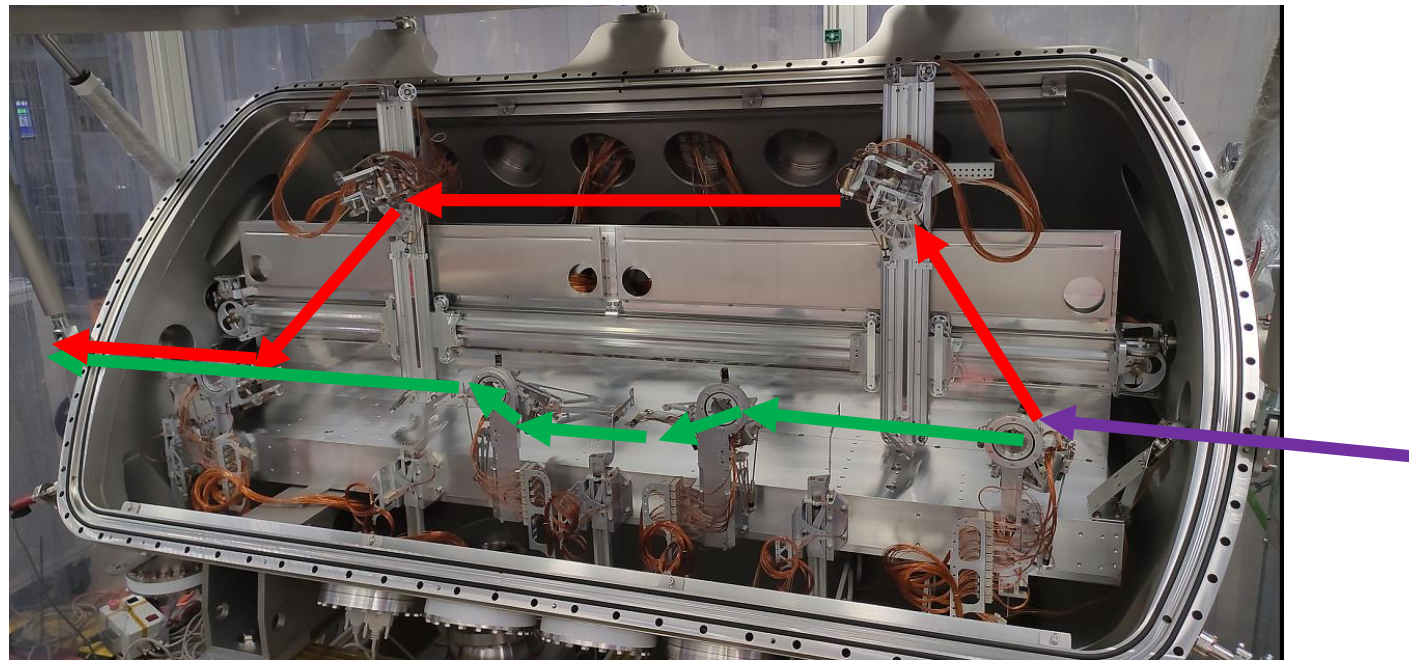
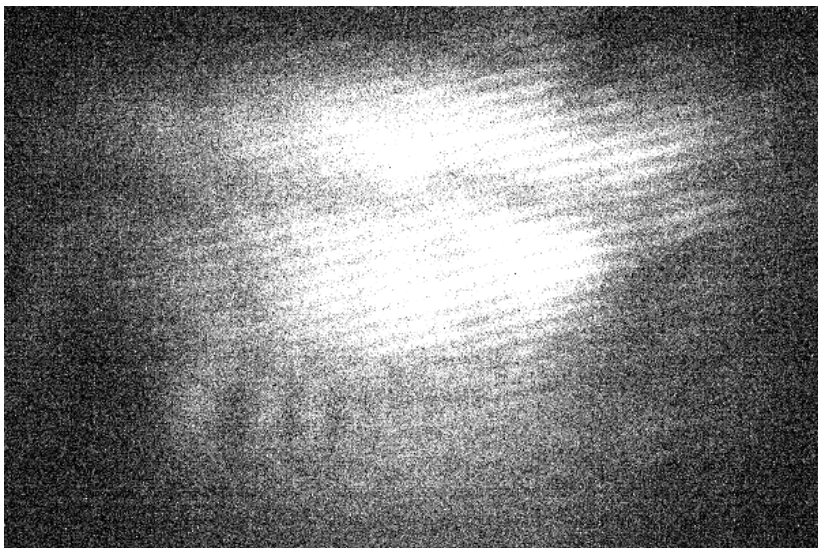
Lower branch beam



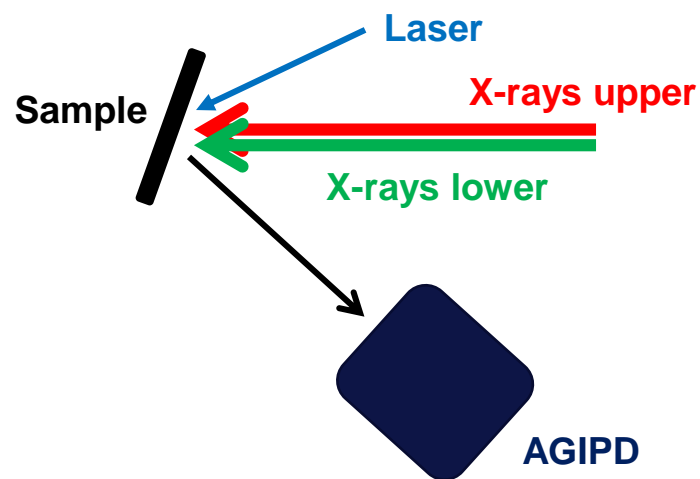
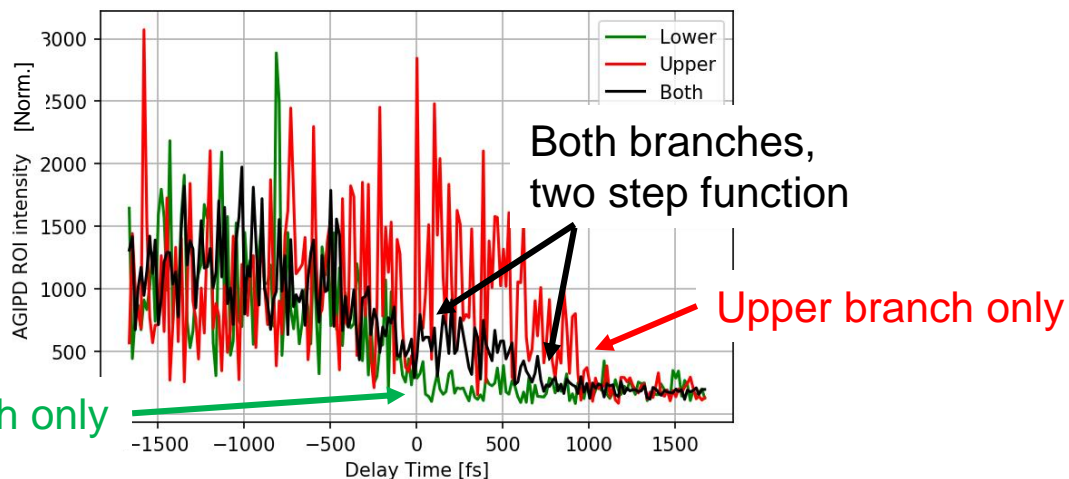
Upper branch beam

Commissioning of the Split and Delay Line (SDL) 2021

X-ray split pulses with zero time lag (within the coherence time ~20 fs) and interference visible!



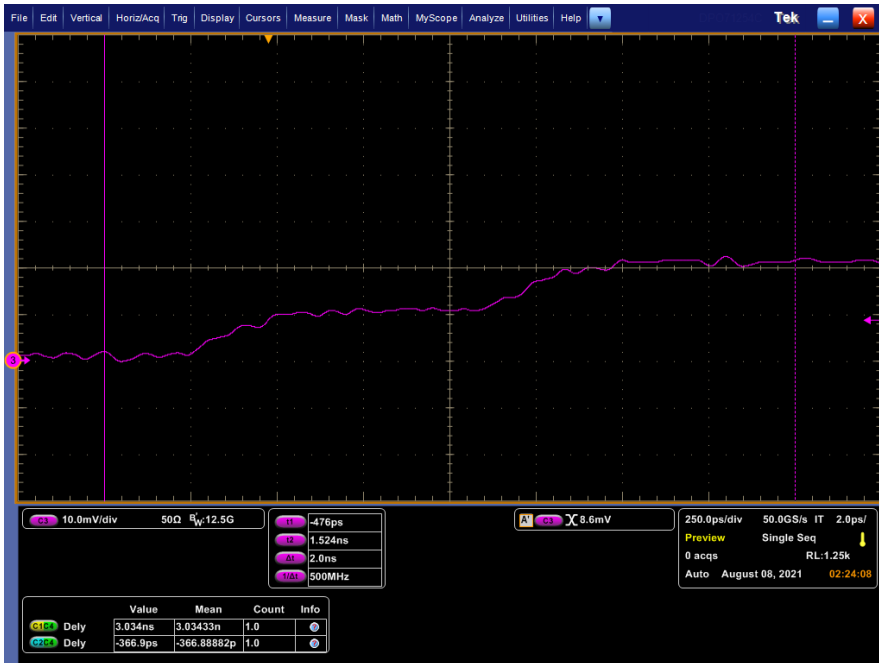
Laser pump – two x-ray probe experiments on SrRuO₃



Commissioning of the Split and Delay Line (SDL) 2021

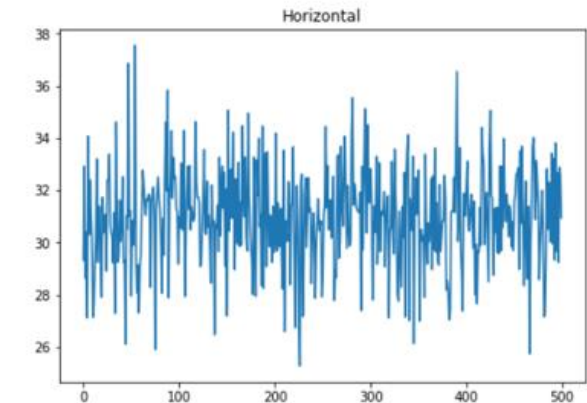
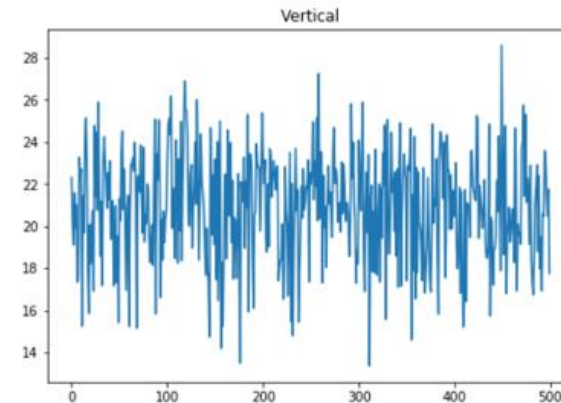
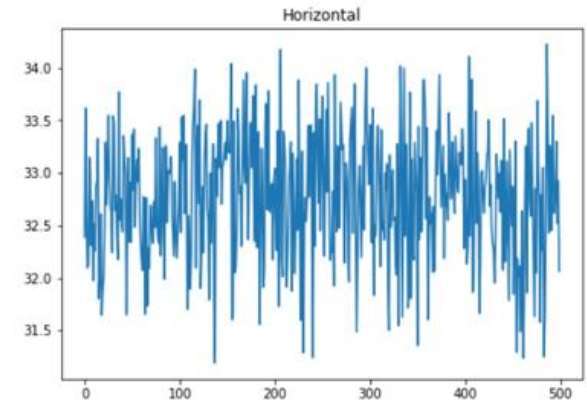
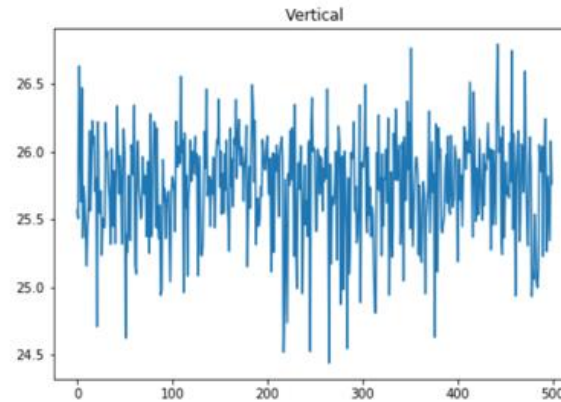
Large delay of two pulses (≈ 830 ps)

Pointing stability at sample position (Center of mass)



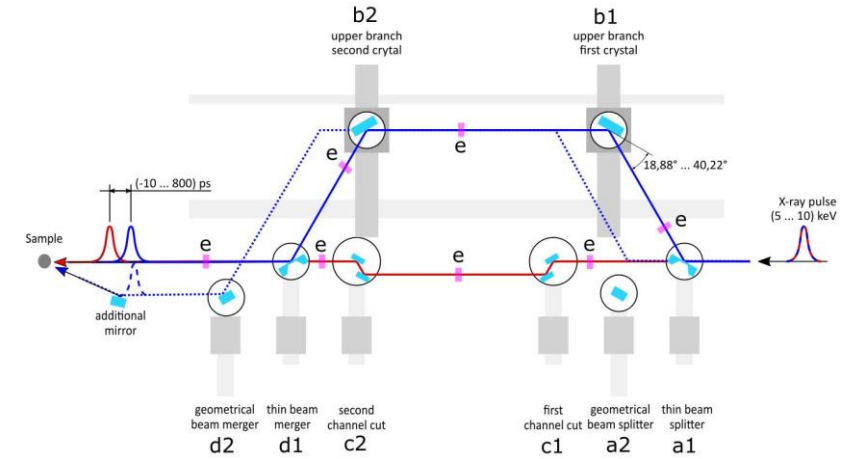
Channel Cut branch

Delay branch

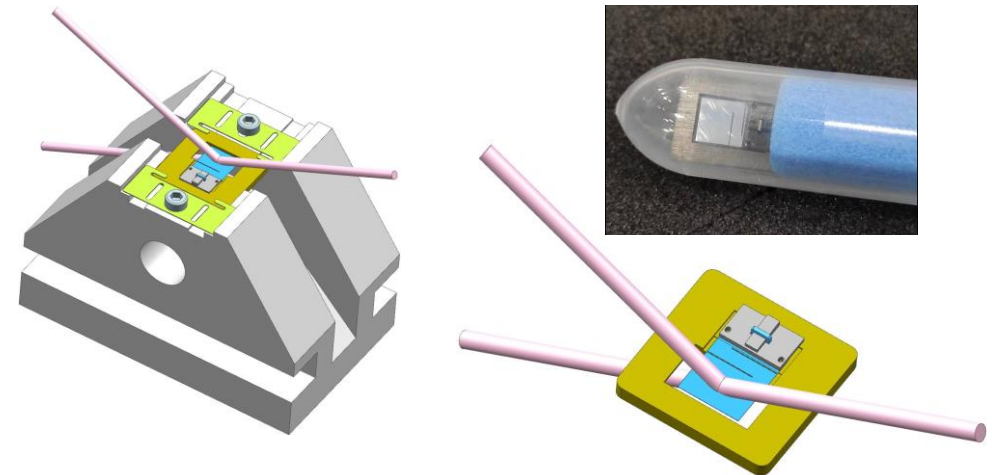
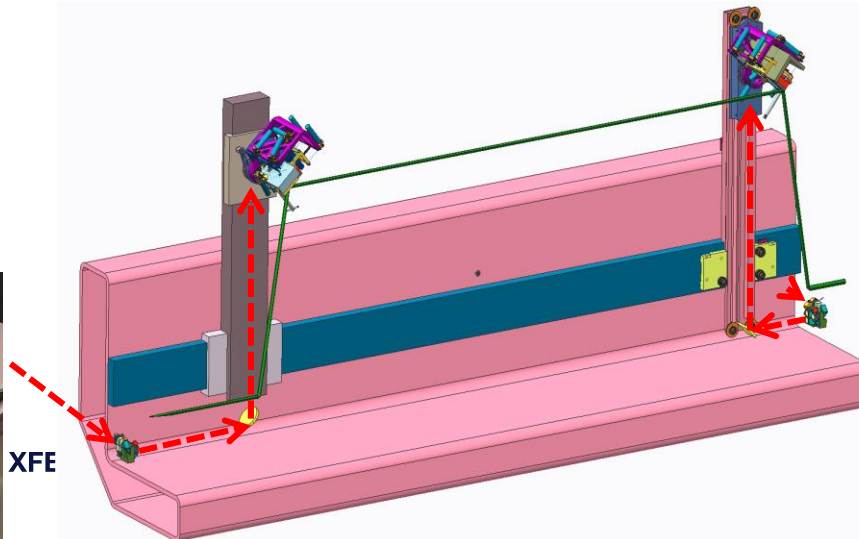
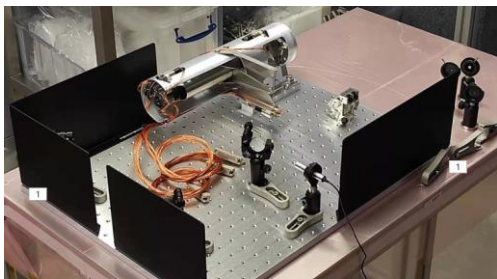
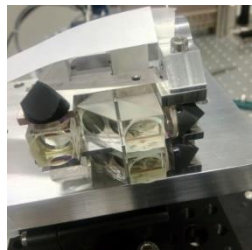


On-going Developments

- Online X-ray diagnostics (Diamond detectors)
- Thin Diamond crystal beam splitters
- Laser interferometer for the position feedback of delay branches
- Commissioning of focusing scheme when using SDL
- ...



UHV compact 3-axis laser interferometer



- Produce by TISNCM institute, Russian
- Thin diamond (111) type IIa crystals
- Size of defect-free area 3x3 mm
- MHz operation ?

Summary

- **SDL project is accomplished**
- **SDL commissioning**
 - Test all functionality of the complicate mechanics
 - Alignment of beams from both branches through the device
 - Operation at photon energy of 8 and 9 keV
 - Achieve spacial and temporal overlap of both beams
- **SDL operation and outlook**
 - Self-seeding mode will provide better throughput for the device
 - Single/Two-color mode for X-ray pump-probe and XPCS experiments
 - Enable delay scan experiments with SDL with position feedback
 - ...

Acknowledgement

- MBI : T. Noll, S. Eisebitt
- MID group
- XRO : M. Vannoni, L. Samoylova, I. F. Martín
- SPF: S. Serkez, G. Geloni
- XPD : J. Grünert, W. Freund, J. Liu
- CAS : R. Schaffer, C. Youngman, R. Fabbri
- EEE : M. Stupar, N. Coppola, B. Fernandes

Thank you!

