Materials Imaging and Dynamics Instrument

European XFEL User Meeting,

27 Jan. 2016

MID team:

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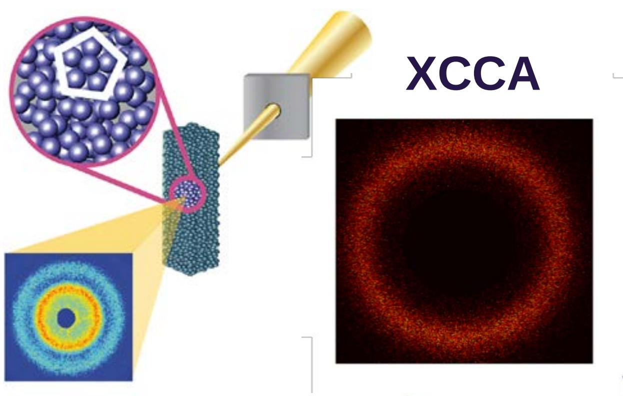
[1]also HED instrument, [2]at HZB/TU Berlin, [3]also TU Hamburg-Harburg

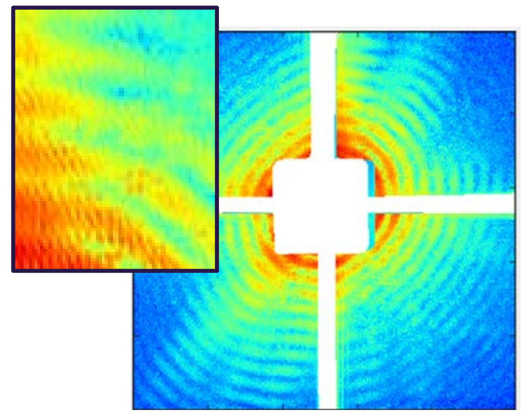
MID’s Mission

The Materials Imaging and Dynamics (MID) instrument aims at the investigation of nanosized **structure** and nanoscale **dynamics** using **coherent radiation**. Applications to a **wide range of materials** from hard to soft condensed matter and biological structures are envisaged

(1st MID workshop, Oct 2009 @ ESRF, Grenoble)

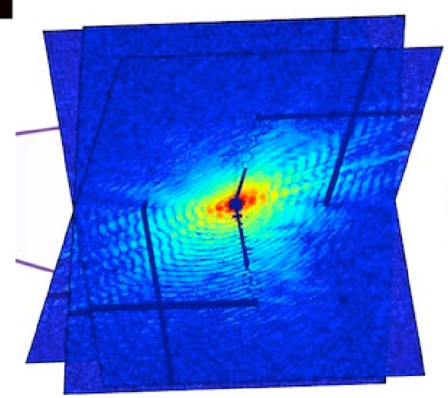


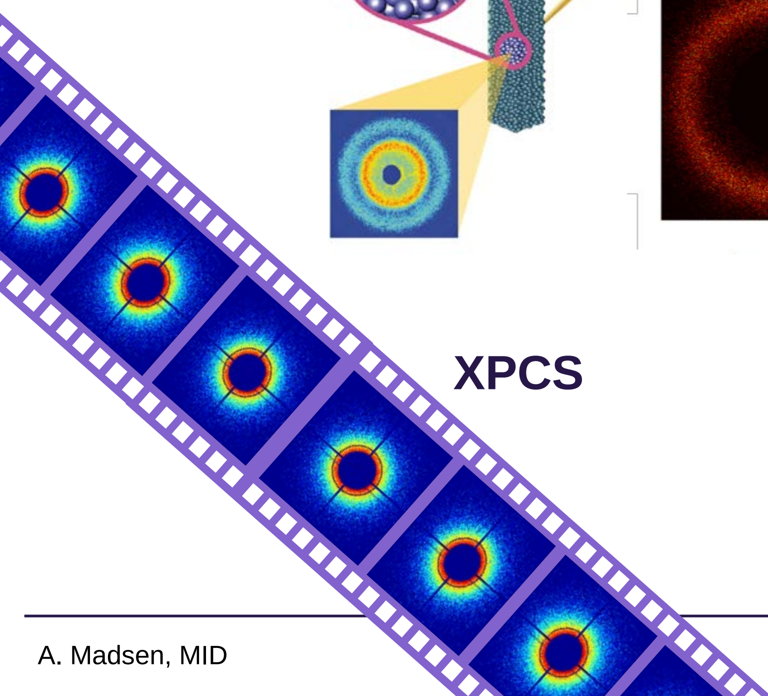
XCCA



Holography

CDI





XPCS

Hi-res techniques

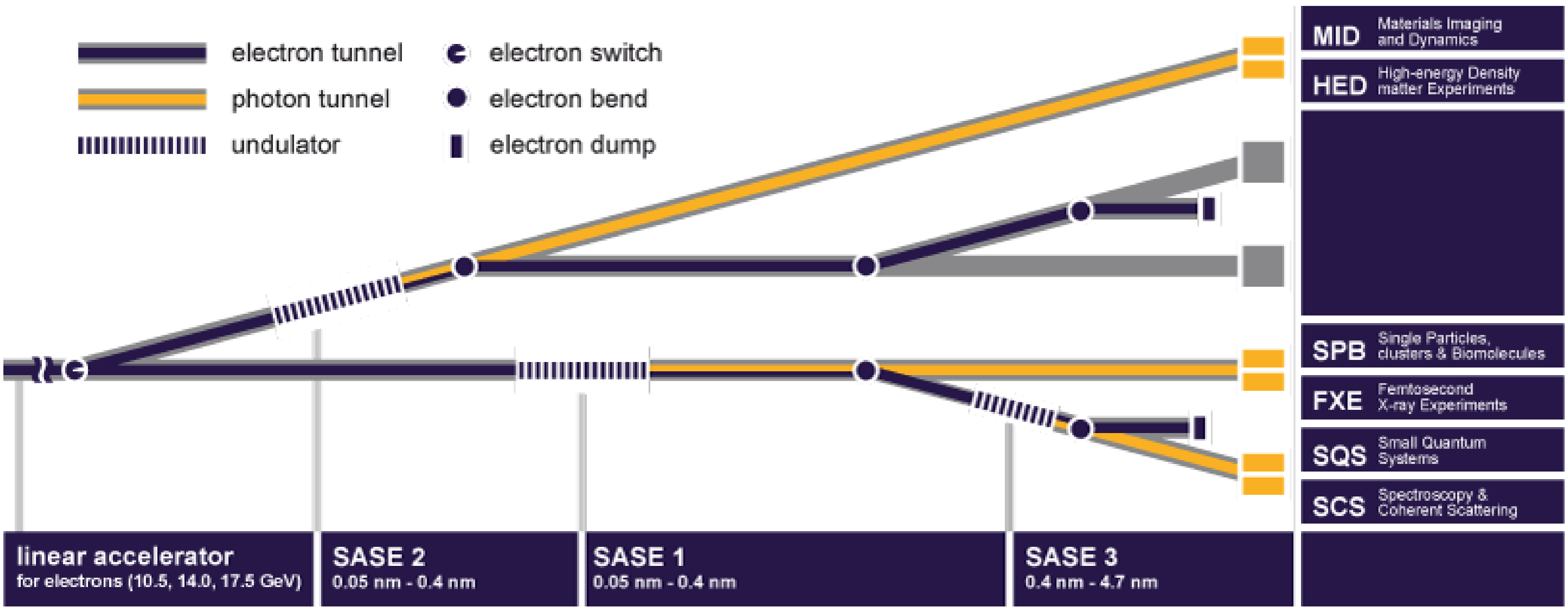
Split-delay

Pump-probe

….

Facility Outline

MID @ SASE-2



SASE-2: The Southernmost Beamline

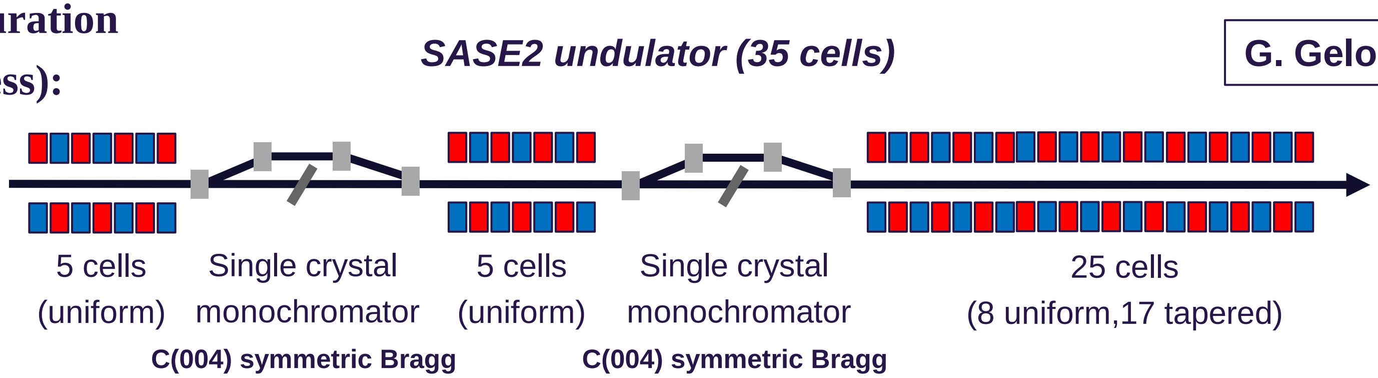
Seeding at SASE-2

- Self seeding concept (Geloni, Kocharyan, Saldin) using wake monochromators will be implemented at SASE-2

- Two seeding chicanes allow reducing the heat load on the diamond mono. High-rep rate operation. Seeding project: German-Russian “Ioffe-Röntgen Institute”

- Chicanes also helpful for high harmonic lasing (Schneidmiller & Yurkov)

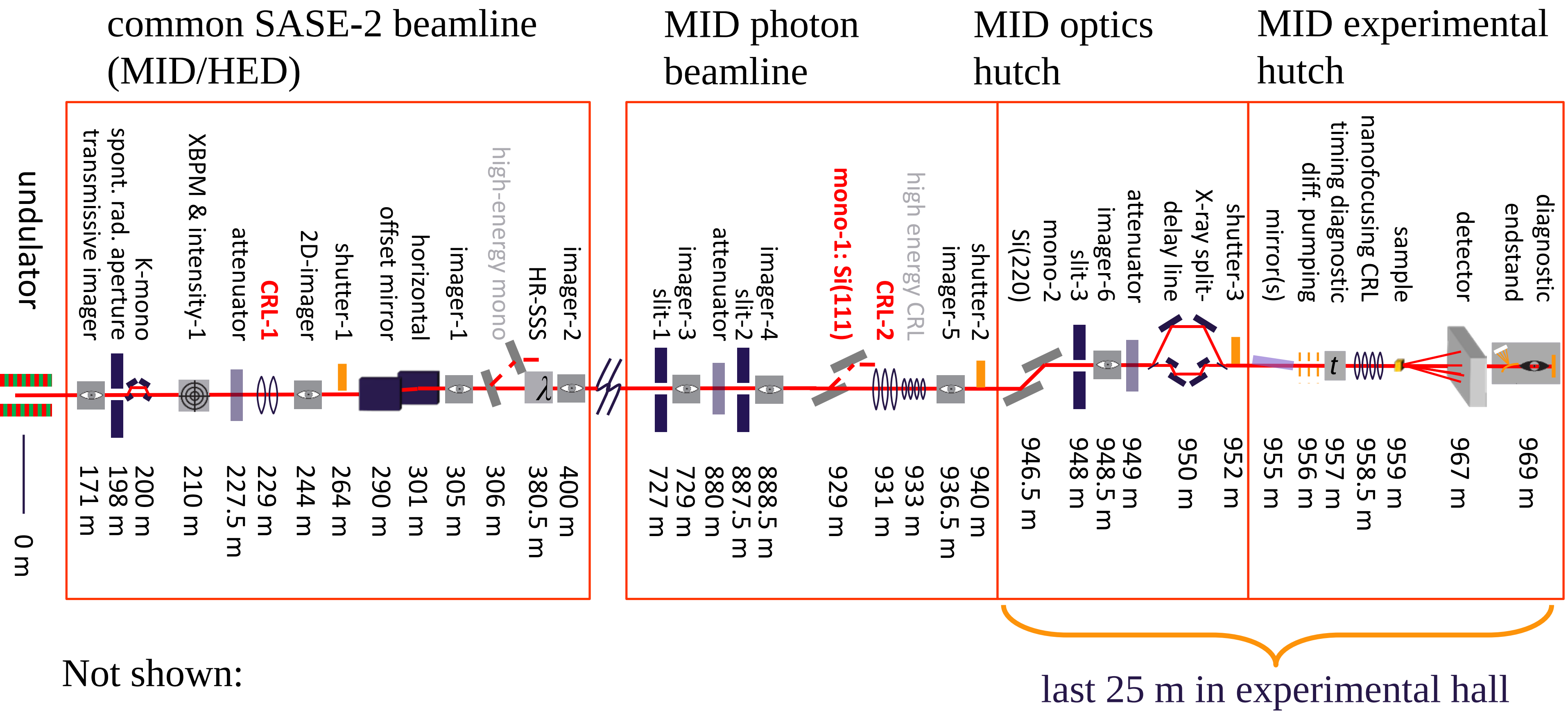
Possible configuration (work in progress):



Typical gain: $\times$100 in spectral brightness due to seeding and tapering.

I ~ 3$\times$10^{13} ph/pulse in 10^{-4} BW @ 1 nC and 9 keV $\rightarrow$ very high average flux

SASE-2 Beamline Overview



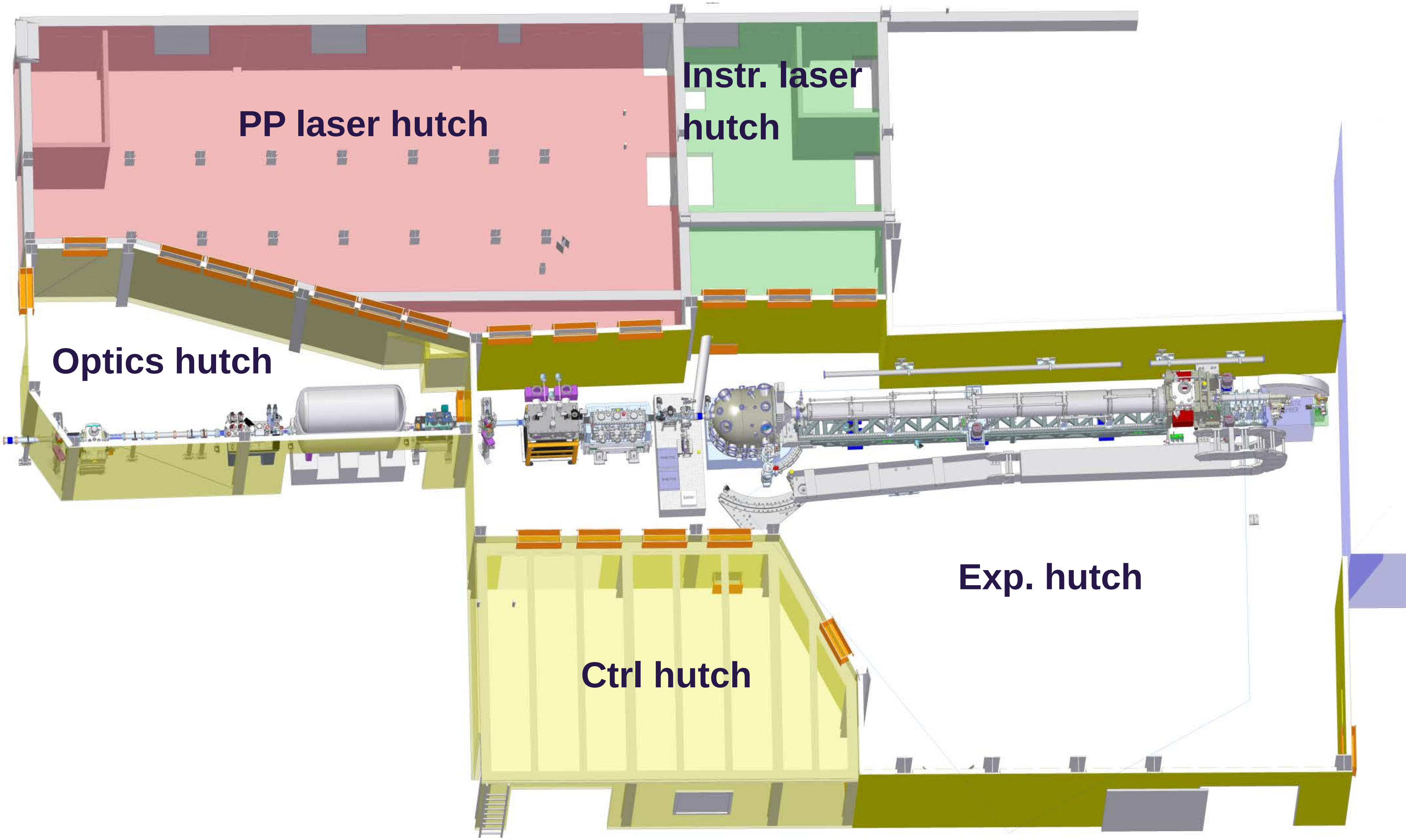
Not shown:

MCP at 303m (fine tuning of SASE)

Distribution mirror(s) at 390m and 395m (MID on central branch)

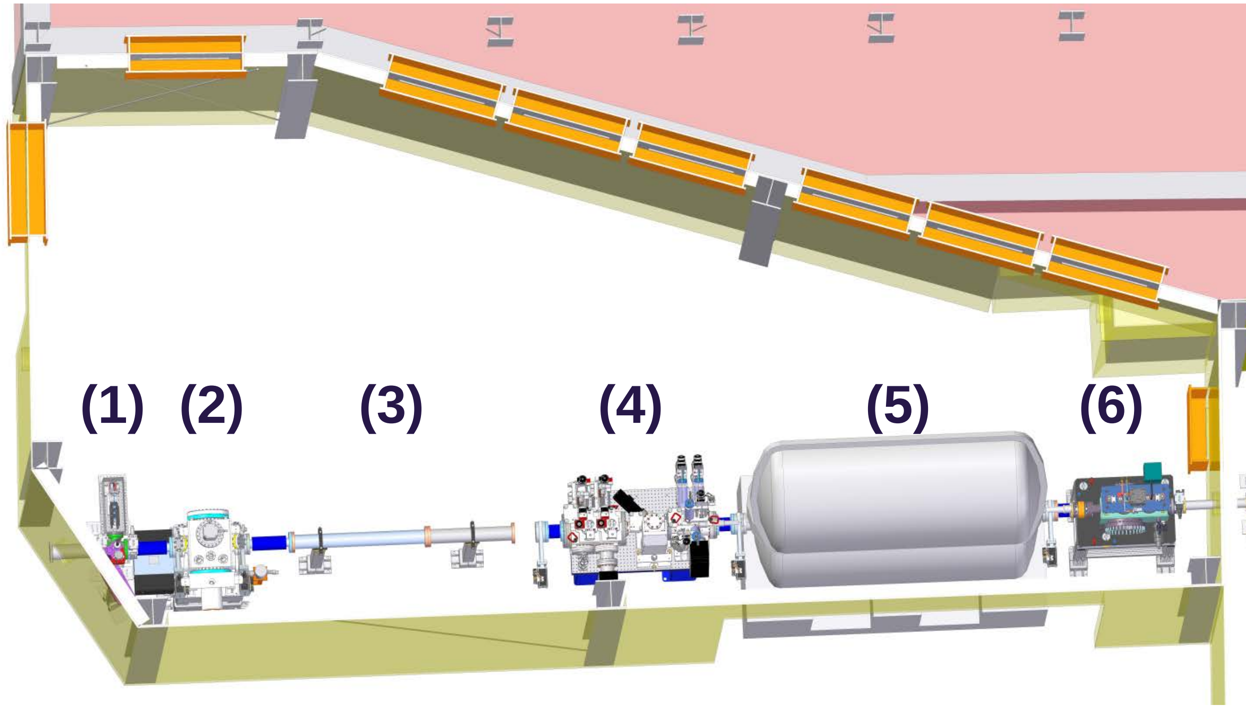
Beam loss monitors, PES

The MID Station



Optics Hutch

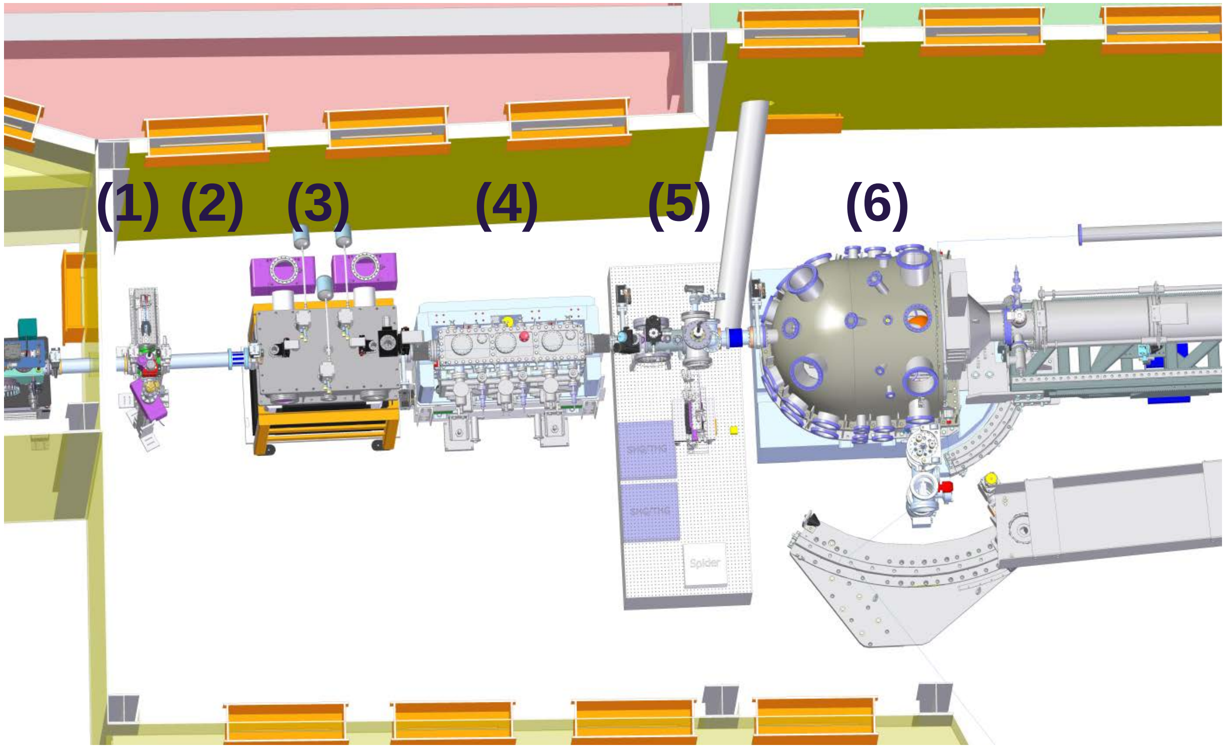
1. Alignment laser
2. Si(220) mono
3. Reserve (hi-res mono)
4. Slit – Imager – Att
5. Split-delay line
6. Beam shutter



1) Pop-in alignment laser. **2)** Double crystal Si(220) artificial channel cut mono. Range 5-25 keV, Pulse tube cryocooler . **3)** Reserve for high-resolution mono. IXS applications. **4)** High-power slit, pop-in imager & attenuator integrated on optical table. **5)** Crystal split-delay line, 0-800 ps, optical or geometrical splitting, co-linear or inclined beams. **6)** High-power beam shutter

Experimental Hutch

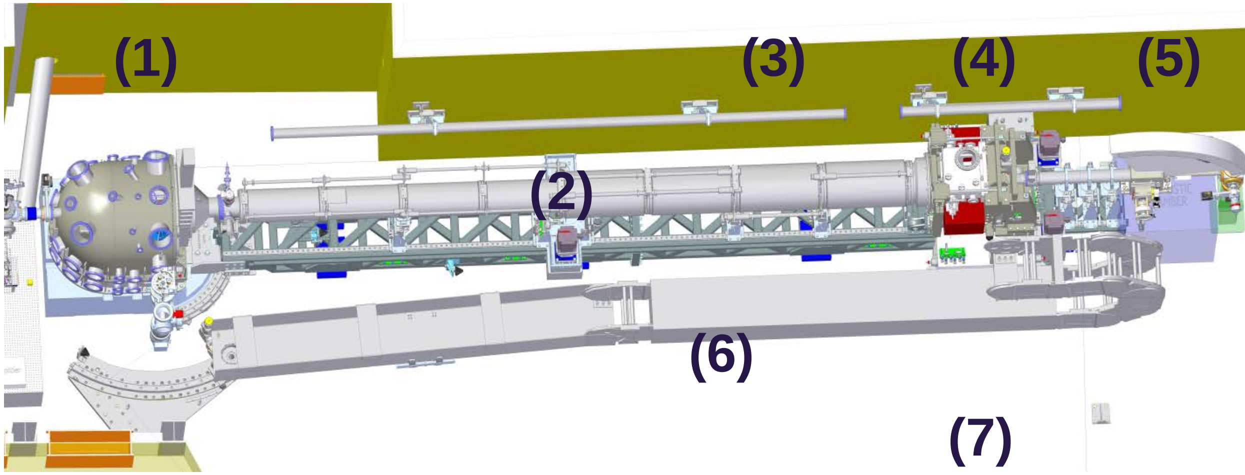
1. Alignment laser
2. Reserve (polarizer)
3. Mirror
4. Differential pump
5. Optical laser table, in-coupling & timing tool
6. Multi-purpose chamber



1) Pop-in alignment laser. **2)** Reserve for single crystal X-ray polarizer. **3)** Double mirror for upwards (with SDL) or downwards reflection (liquid surfaces). **4)** Differential pumping section with large beam aperture (4 x 40 mm^2). **5)** Optical laser transfer pipe, laser in-coupling and timing tool. **6)** Multi-purpose chamber for scattering and imaging experiments.

Experimental Hutch

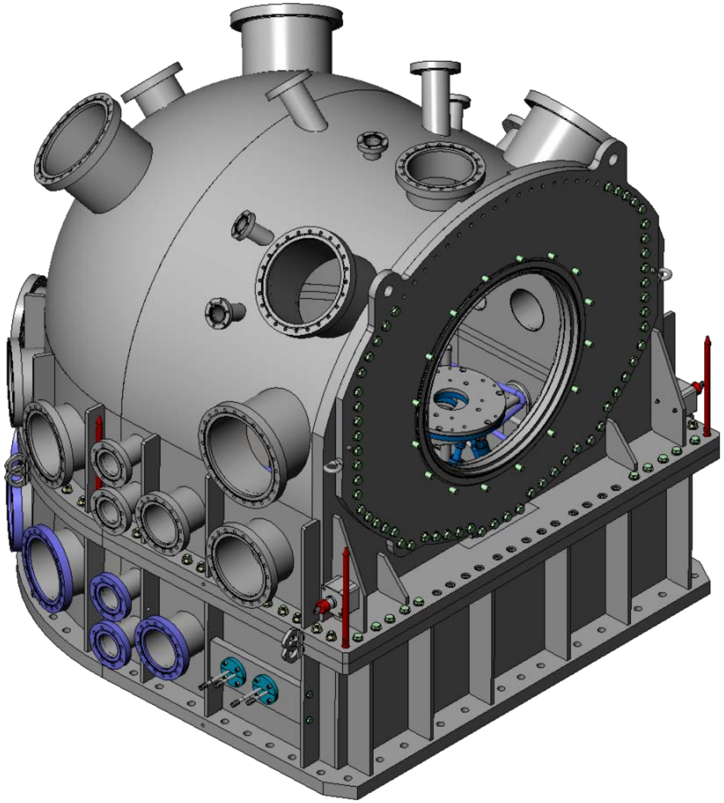
1. Multi-purpose chamber
2. Telescopic flight tube
3. Transfer pipe
4. AGIPD with stand
5. Diagnostics end-station
6. Cable tray
7. High quality floor

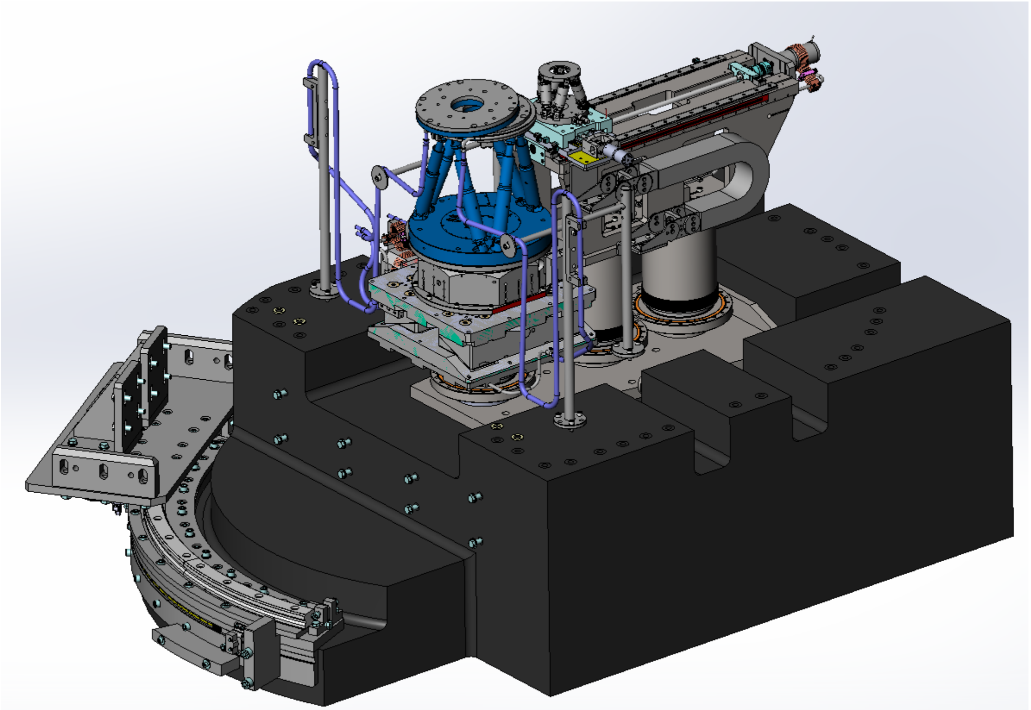


1) Multi-purpose chamber for scattering and imaging experiments. **2)** Telescopic flight tube and 2θ rail. Expand/compress and 2θ capability. **3)** Wall-mounted transfer pipe. **4)** AGIPD and support structure for detectors **5)** Diagnostics end-station with spectrometer, imager, intensity monitor, and beam stop. **6)** Cable tray for 2θ rail, AGIPD and detectors. **7)** ~70 m^2 floor of stone tiles allowing a smooth motion of the rail and detector

Multi-Purpose Chamber

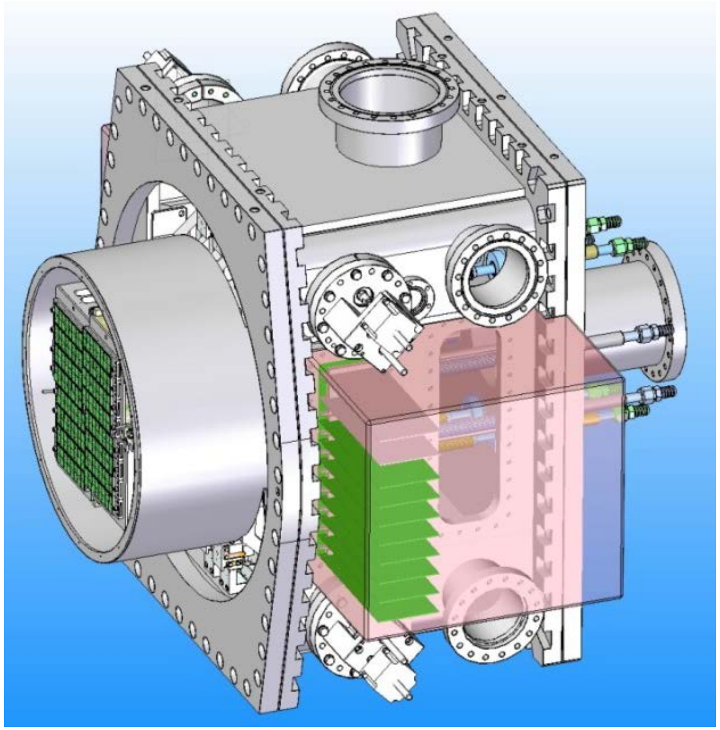
- Multi-purpose chamber: pump-probe, coherent scattering, nano-focusing,…
- Sample environments (liquid jet, aerosol injector, scanning setup, pulsed magnet,…)



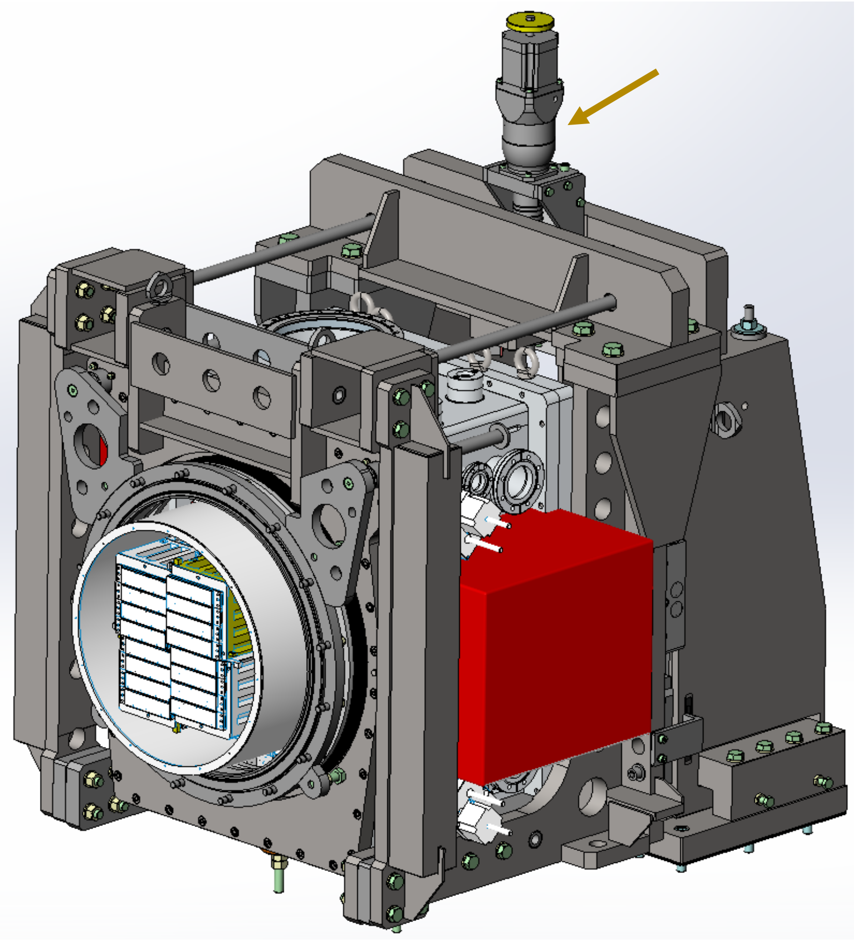


- Hexapod goniometer for solid samples
- Small-hexapod stage for nano-focusing optics
- Stages decoupled from walls of vacuum vessel

4.5 MHz 1M Pixel Area Detector: AGIPD



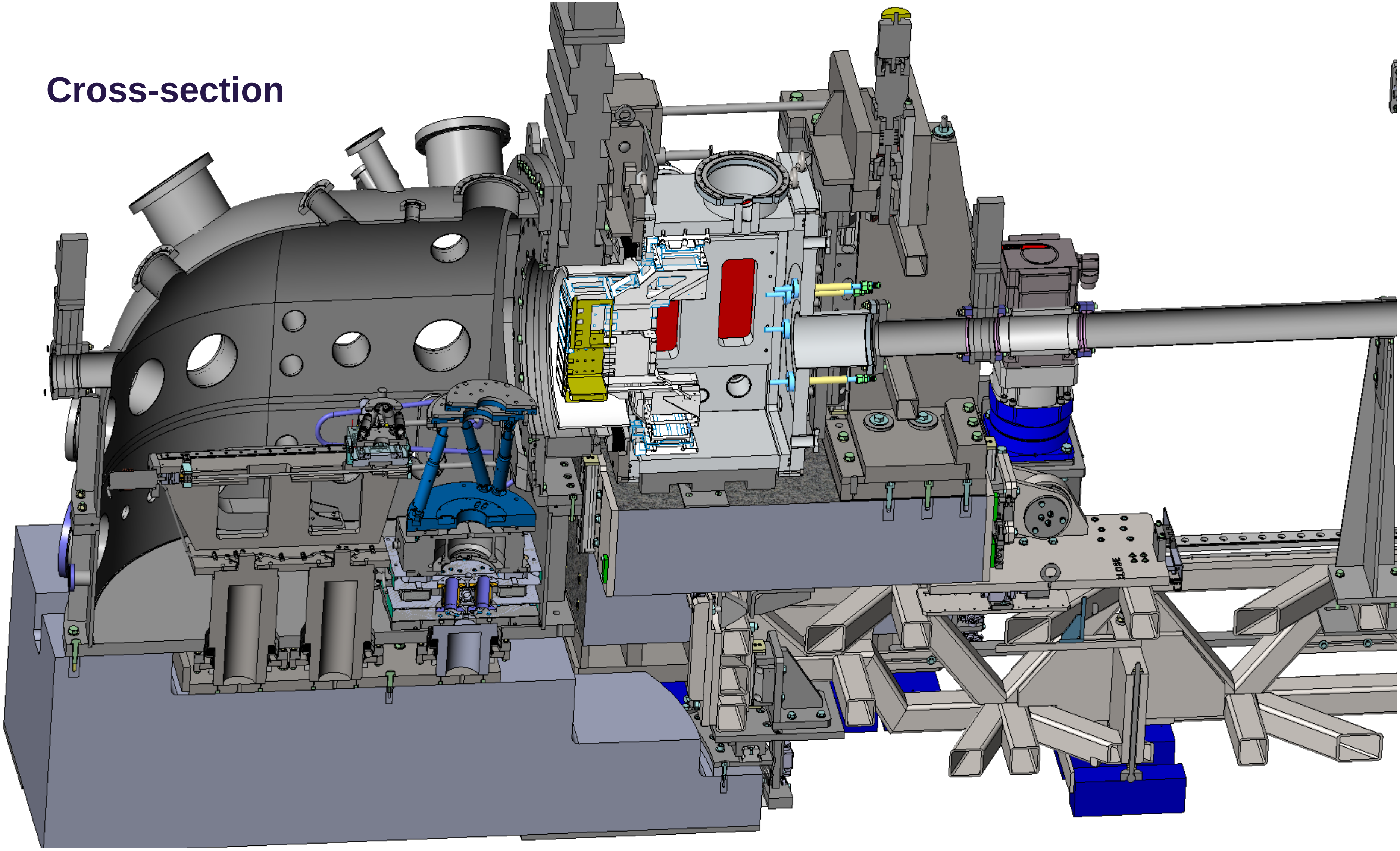
AGIPD
(Consortium lead by H. Graafsma, DESY)



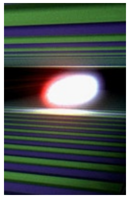
AGIPD in its cage with
the required motions

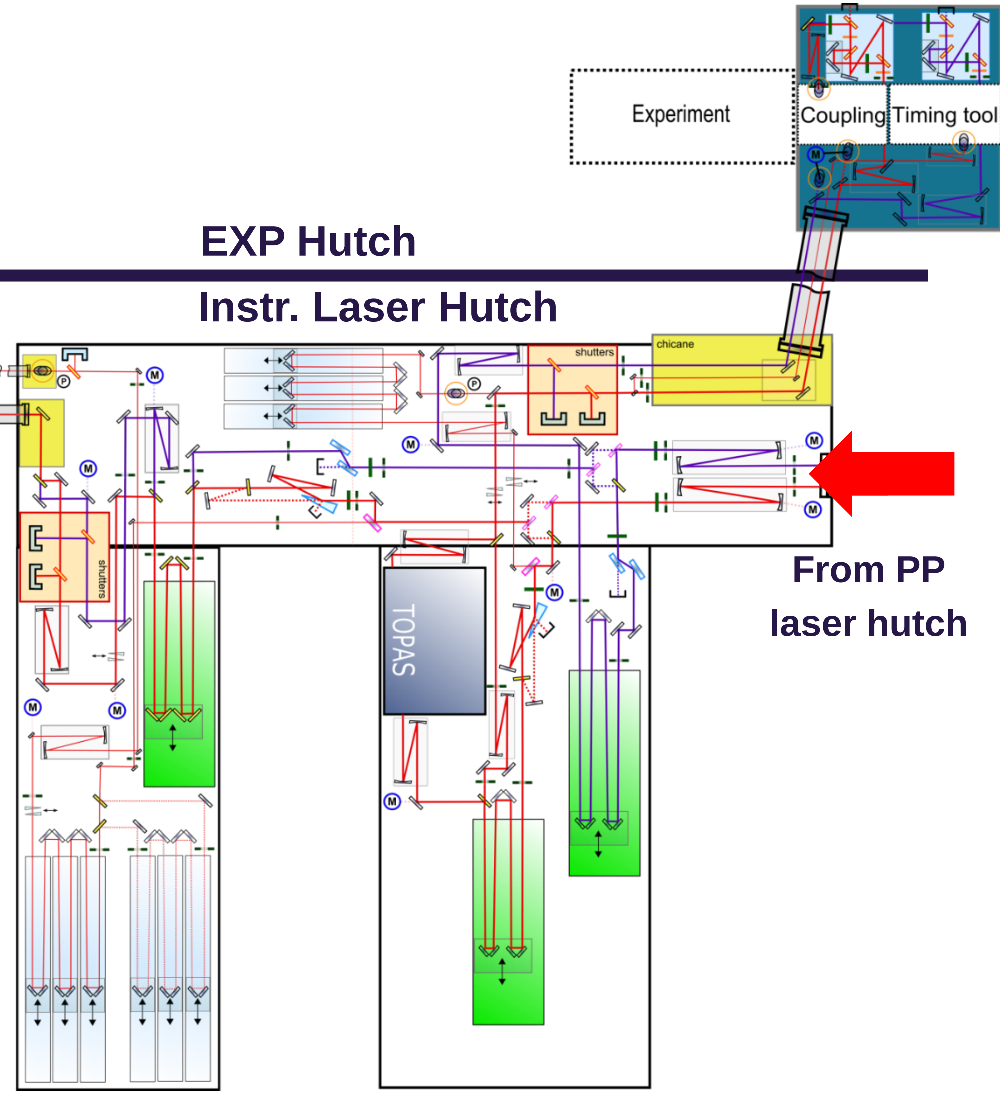
AGIPD Interfaced to Multi-Purpose Chamber

Cross-section



Instrument Laser Hutch





Optical Laser

Pump-probe mode (4.5 MHz)

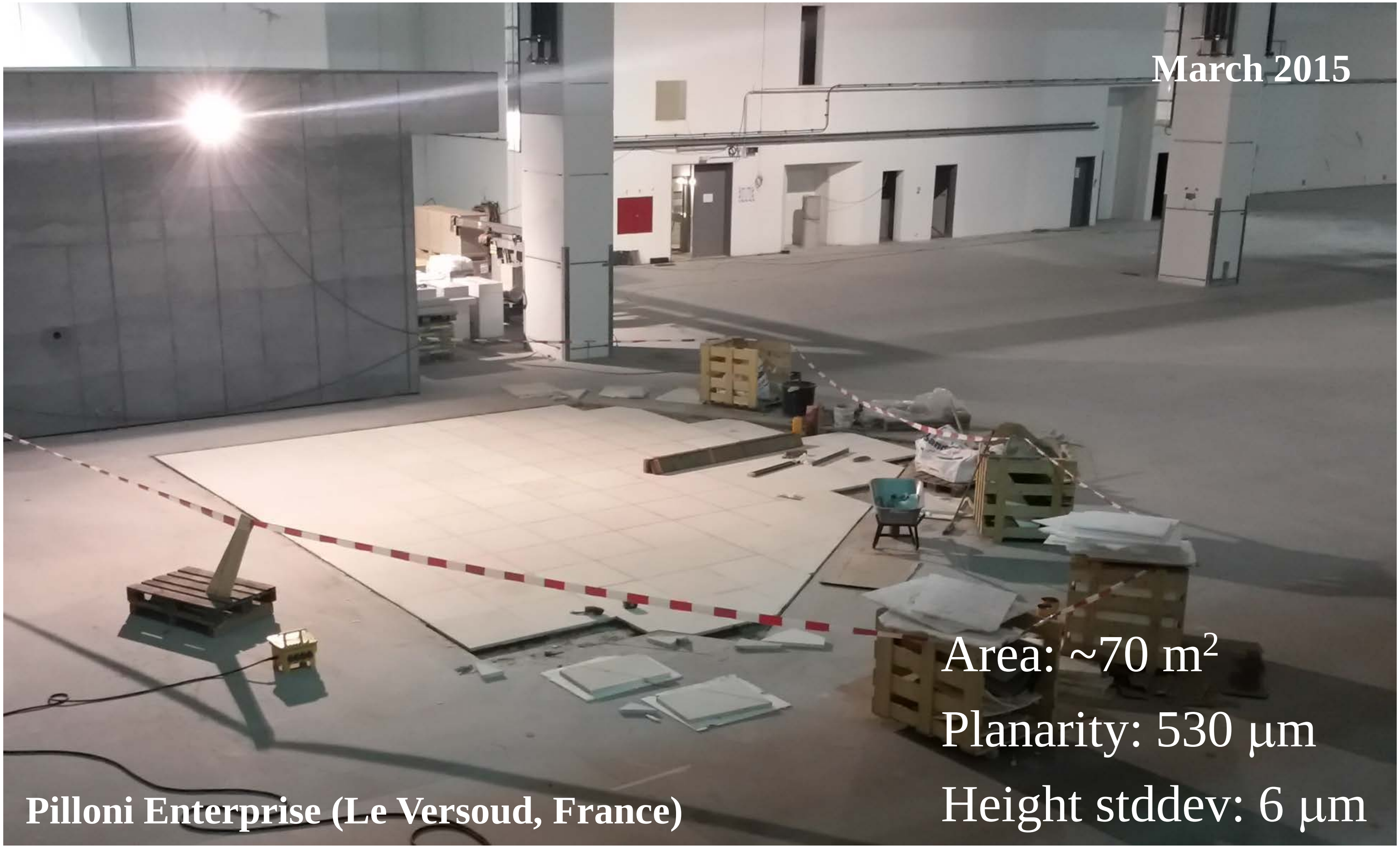
- 800 nm wavelength (0.2 mJ pulse)
- Down to 15 fs pulses

Molecular alignment mode (200 kHz)

- 800 nm wavelength (up to 3 mJ/pulse)
- 1080 nm wavelength (up to 0.1 J/pulse)
- <20 fs – 0.5 ns pulses

- Frequency conversion (SHG & THG) and TOPAS system (267 nm-15 μm)
- 20 μm possible with extra cost

HQ Floor Installed



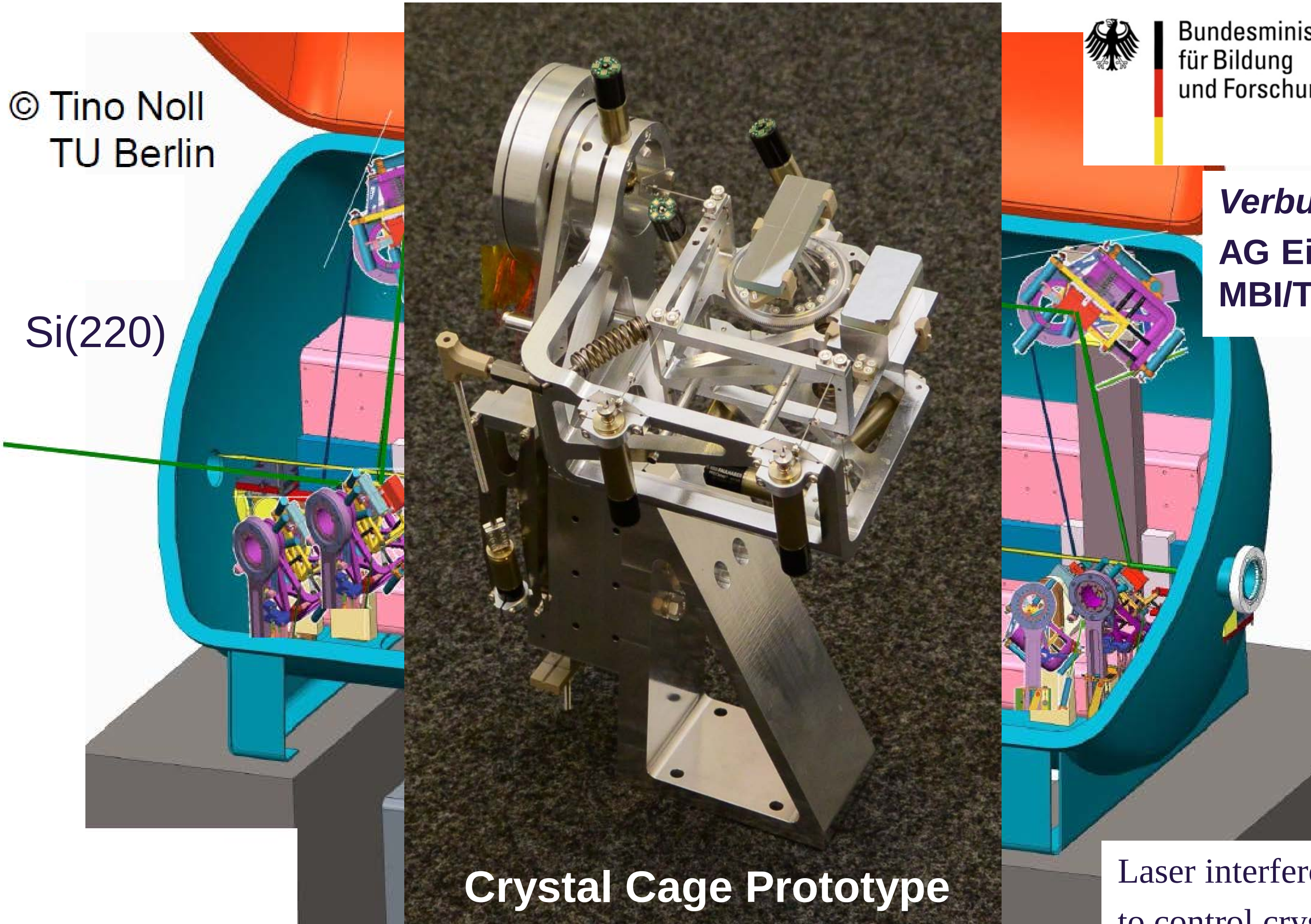
Progress in MID Planning and Construction

- Contracts awarded for all major instrument parts
- Overall Exp hall schedule (PSPO):
  - Hutch Construction at SASE-2 starts March 30, 2016
  - Contract lead hutches awarded
  - Contract optical laser hutches awarded
  - CfT steel construction published
  - CfT infrastructure out soon (readiness review last week)
  - Planning of cabling in progress
- Instrument installation start: January 14, 2017
- 1st lasing SASE-2: April 2017

BMBF Verbundforschung Project: Hard X-Ray Split-Delay Line

Bundesministerium für Bildung und Forschung

FSP-302



Crystal Cage Prototype

Verbundforschung
AG Eisebitt, MBI/TUB

Laser interferometer required to control crystal positions (collaboration M. Holler, PSI)

W. Lu *et al*., SRI-2015 Conference Proceedings (in print)

BMBF Verbundforschung Project: Hard X-Ray Split-Delay Line

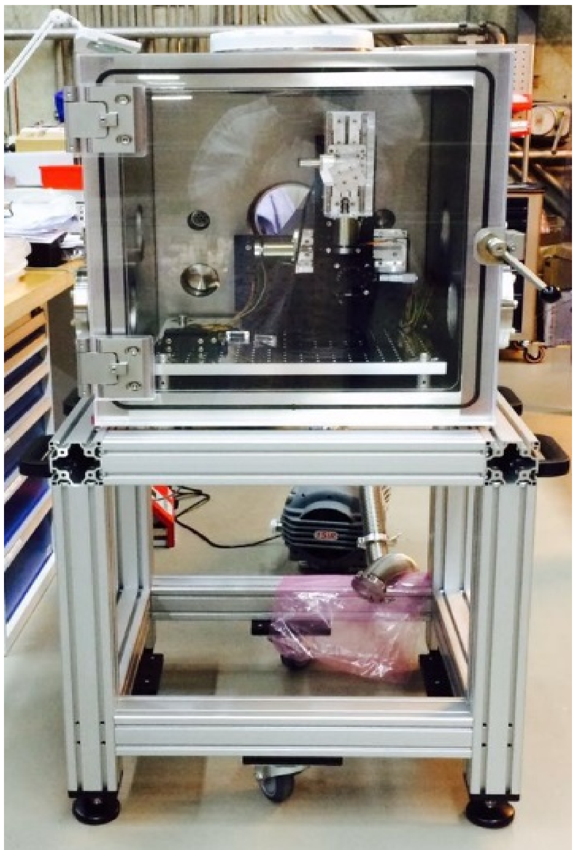
Bundesministerium für Bildung und Forschung

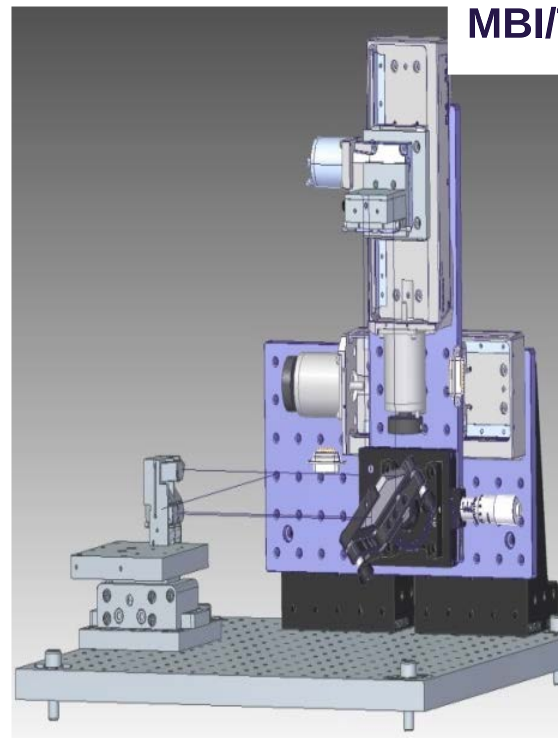
FSP-302

Test and implementation of laser interferometry (HERA-S) and simulations of SDL beam characteristics and

Verbundforschung

AG Eisebitt, MBI/TUB





W. Lu *et al*., SRI-2015 Conference Proceedings (in print)

BMBF Verbundforschung Project: Hard X-Ray Split-Delay Line

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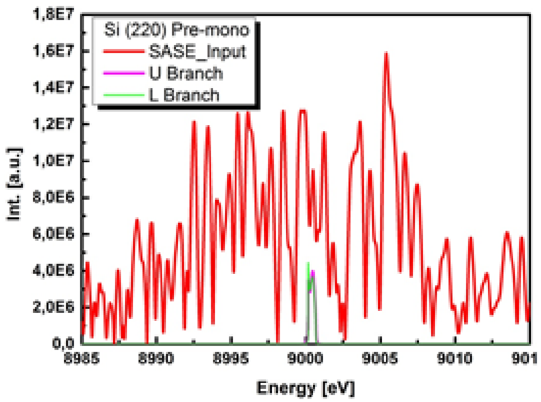
FEL FSP-302

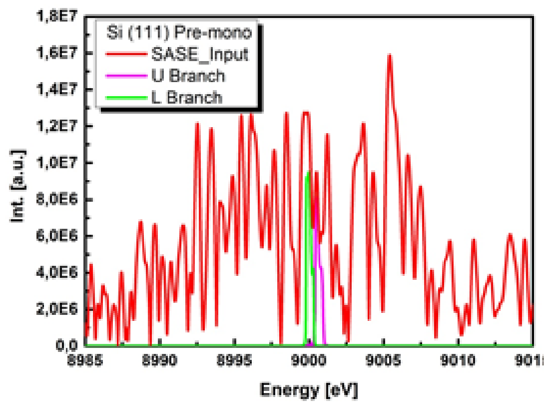
Test and implementation of laser interferometry (HERA-S) and **simulations of SDL beam characteristics**

Verbundforschung

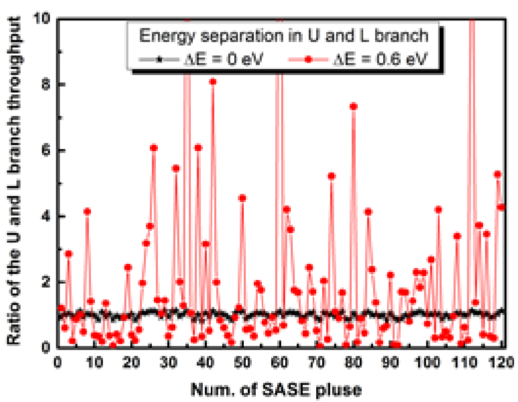
AG Eisebitt, MBI/TUB



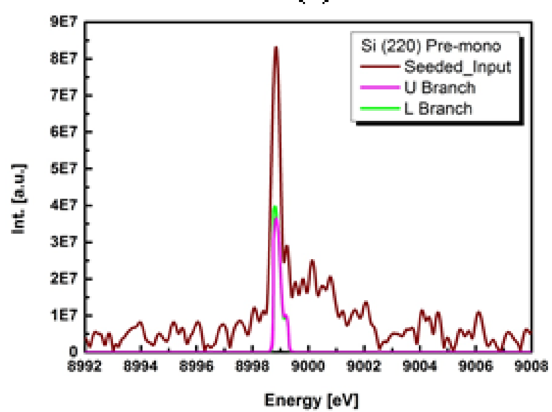
(a)



(b)



(c)



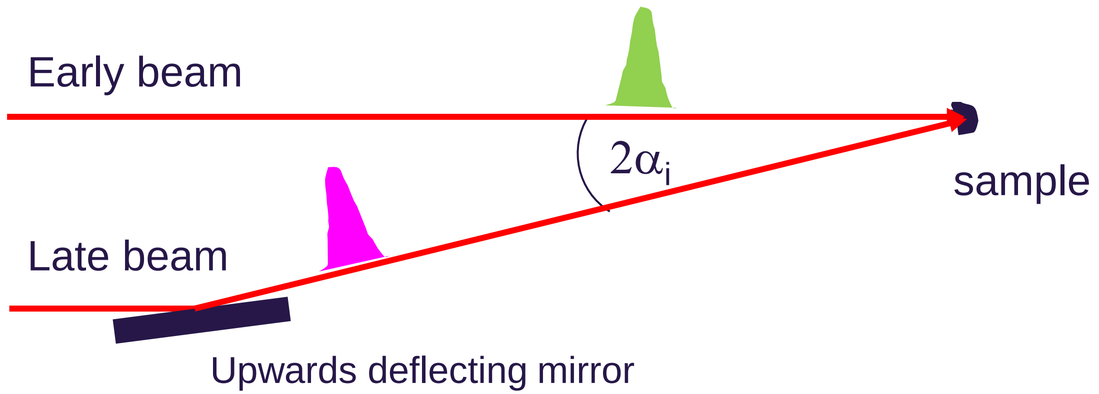
(d)

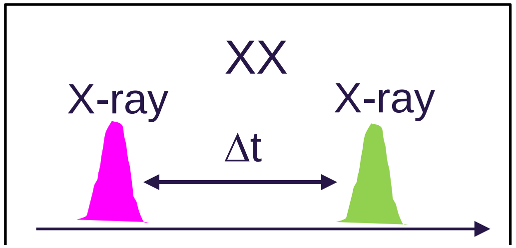
Seeding improves intensity throughput by x10 with increased stability

Agapov, Lu, and Geloni

W. Lu *et al.*, SRI-2015 Conference Proceedings (in print)

Inclined Beams From Split-Delay Line



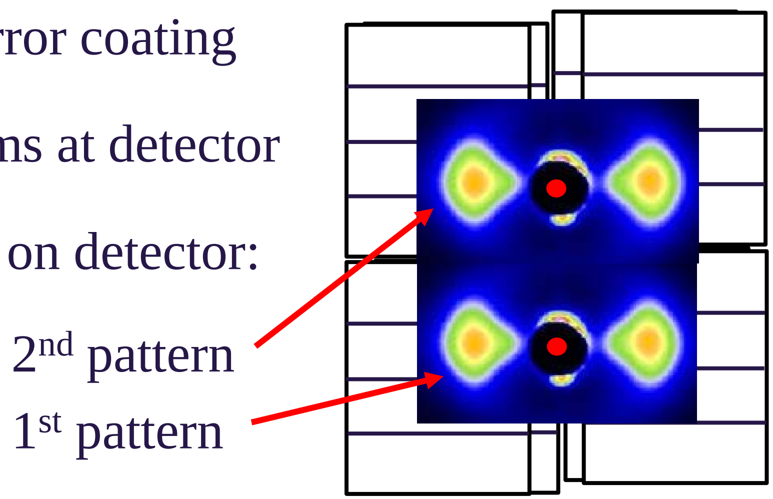


4 m mirror-sample distance, $2\alpha_i = 0.4$ deg

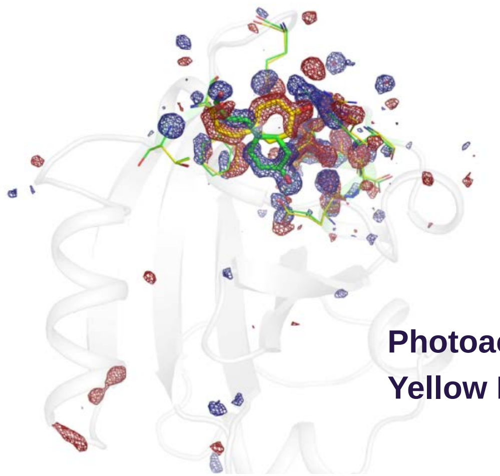
α_i even larger with mirror coating

Separation of two beams at detector

Two scattering images on detector:

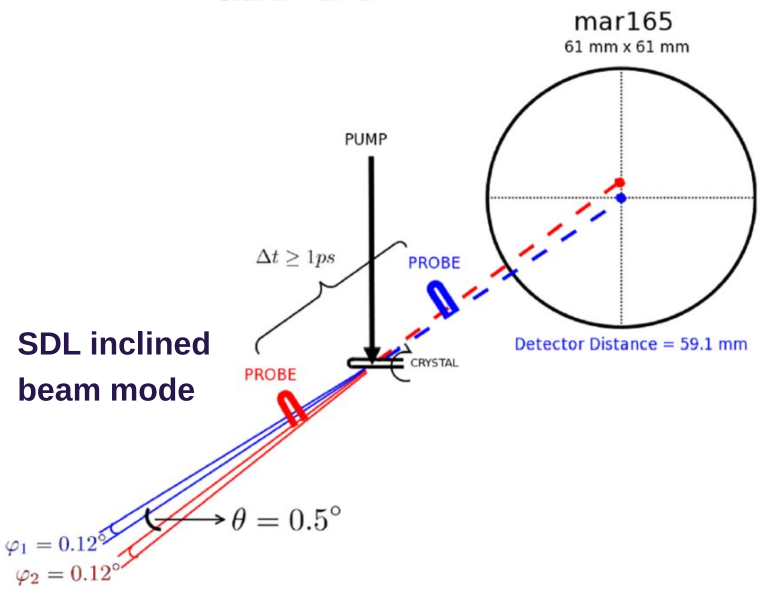


Probe-Pump-Probe: Ratiometric Measurements of Photo-Induced Protein Dynamics

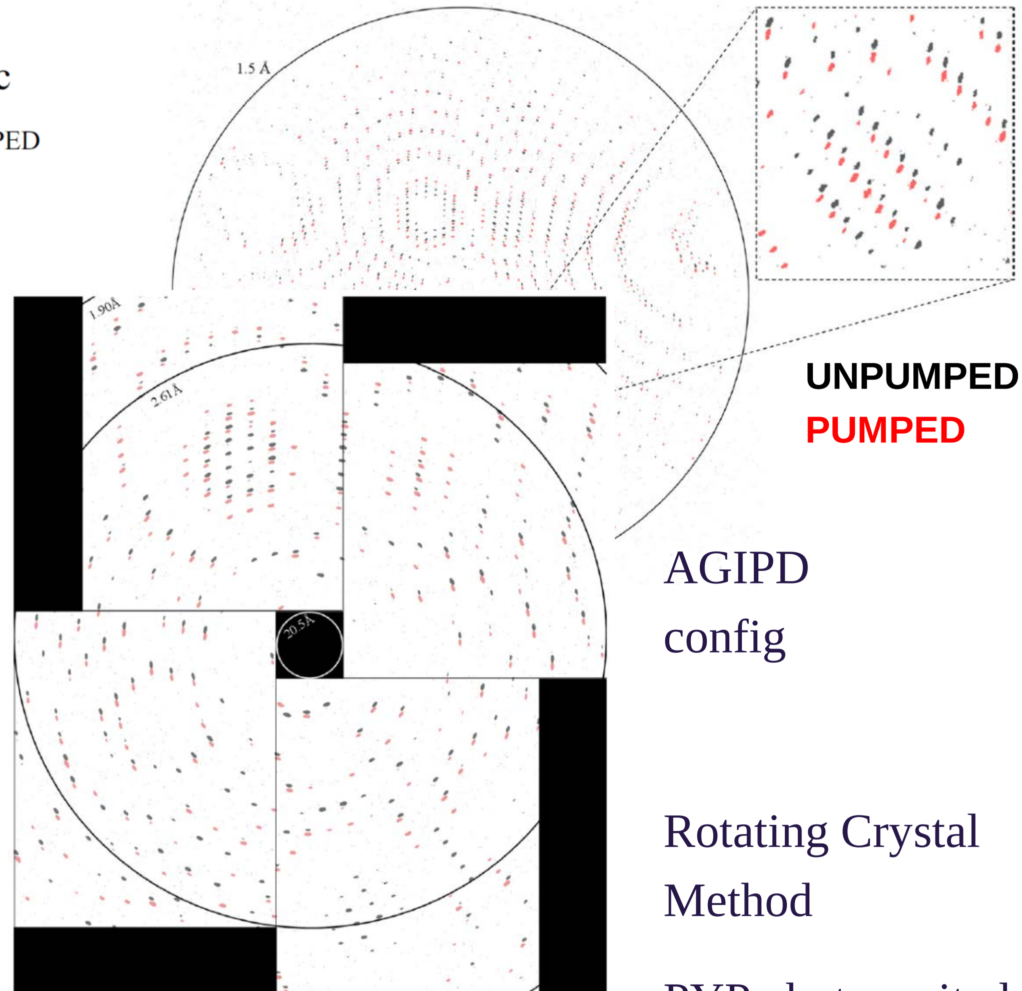


Retrieved synthetic
$F_{PUMPED} - F_{UNPUMPED}$

Photoactive Yellow Protein



SDL inclined beam mode



AGIPD config

Rotating Crystal Method

PYP photoexcited intermediate

Van Thor and Madsen, Structural Dynamics. **2**, 014102 (2015)

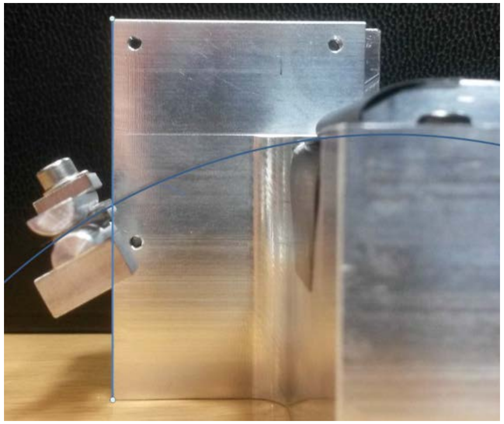
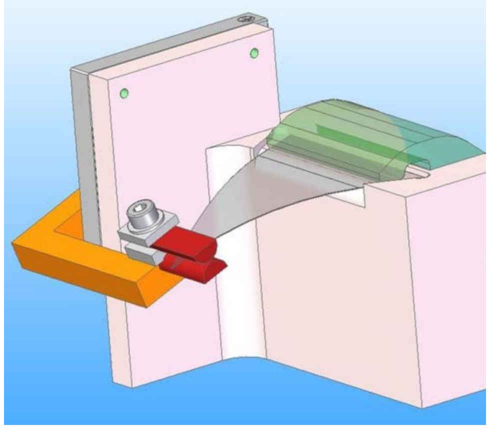
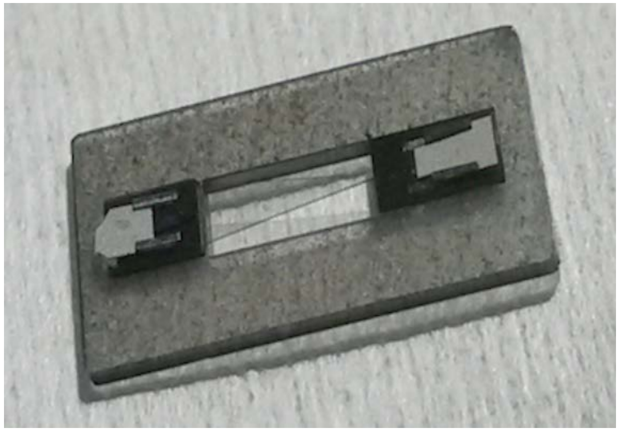
Diagnostics End-Station (DES)

DES function:

- Intensity, shape, position, spectrum of direct beam
- Measurement of SAXS ptychography (for ptychographic reconstruction of beam profile at the sample position)
- Stop the direct beam

Single-shot spectrometer

- Si bender constructed (BA thesis, B. Kist)
- Development of diamond single-shot spectrum analyzer with TISNCM (V. Blank, S. Terentiev) and XFEL Optics Group (Samoylova, Sinn)
- Diamond spectrum analyzer tests at LCLS in Feb 2016

MID Specifications & important dates

- 5-25 keV, synchronized optical laser
- pink SASE, Si(111), Si(220), or self-seeded beam
- 4.5 MHz, 220 ns spacing (native), 0-800 ps, few fs precision (SDL)
- high throughput optics, variable spot size, nano-focus
- straight, or up/down deflected beam (SDL/liquid surface)
- up to >10^{13} photons/pulse (SASE-2 seeding and tapering)
- window-less (diff pump) or sample in air (diamond window)
- detectors (AGIPD), attenuators, slits, single-shot diagnostic,..

- 1st lasing at SASE-2: April 2017…
- thereafter beamline & instrument commissioning
- 1st MID experiments (reduced specs): August 2017
- full performance and user operation: 2018

Acknowledgements

All XFEL groups involved, particularly Optics, Optical laser, Detector, Sample Env. Vacuum and Diagnostics Groups. PSPO, TS, CIE, and IT, Software and Electronics

M. Mattenet & ESRF instrument engineering,

G. Geloni and I. Agapov (XFEL), S. Eisebitt and T. Noll (MBI/TUB/HZB),
M. Holler (PSI), S. Terentiev & V. Blank (TISNCM), AGIPD consortium,
+ numerous scientific collaborators at LCLS, DESY and elsewhere

Thank you for your attention!

Questions?

SDL Funding: Bundesministerium für Bildung und Forschung; FEL FSP-302

XFEL member countries: +