Materials Imaging and Dynamics Instrument
European XFEL User Meeting,

MID team:
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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)
Facility Outline

MID @ SASE-2

- electron tunnel
- photon tunnel
- undulator
- electron switch
- electron bend
- electron dump

Linear accelerator
for electrons (10.5, 14.0, 17.5 GeV)

SASE 2
0.05 nm - 0.4 nm

SASE 1
0.05 nm - 0.4 nm

SASE 3
0.4 nm - 4.7 nm
SASE-2: The Southernmost Beamline
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.

$I \approx 3 \times 10^{13} \text{ ph/pulse}$ in $10^{-4}$ BW @ 1 nC and 9 keV $\rightarrow$ very high average flux
MCP at 303m (fine tuning of SASE)
Distribution mirror(s) at 390m and 395m (MID on central branch)
Beam loss monitors, PES

last 25 m in experimental hall
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
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 mm²). 5) Optical laser transfer pipe, laser in-coupling and timing tool. 6) Multi-purpose chamber for scattering and imaging experiments.
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 m² 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 \( \mu \)m)
- 20 \( \mu \)m possible with extra cost
**HQ Floor Installed**

- **Area:** ~70 m²
- **Planarity:** 530 μm
- **Height stddev:** 6 μm

Pillonie Enterprise (Le Versoud, France)  

March 2015
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

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

Crystal Cage Prototype

W. Lu et al., SRI-2015 Conference Proceedings (in print)
Test and implementation of laser interferometry (HERA-S) and simulations of SDL beam characteristics and

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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
$\alpha_i$ even larger with mirror coating

Separation of two beams at detector

Two scattering images on detector:
- Early beam
- Late beam

Upwards deflecting mirror

2nd pattern
1st pattern
Probe-Pump-Probe: Ratiometric Measurements of Photo-Induced Protein Dynamics

Retrieved synthetic
\( F_{\text{PUMPED}} - F_{\text{UNPUMPED}} \)

SDL inclined beam mode

\[ \varphi_1 = 0.12^\circ \quad \varphi_2 = 0.12^\circ \]
\[ \theta = 0.5^\circ \]

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
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+ numerous scientific collaborators at LCLS, DESY and elsewhere

Thank you for your attention!

Questions?

SDL Funding:  

XFEL member countries: