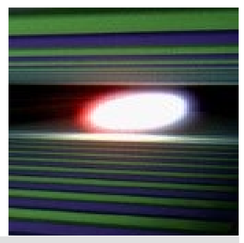
The MID Instrument at the European XFEL

G. Ansaldi[1,#], A. Madsen[1], T. Roth[1], J. Hallmann[1], M. Mattenet[2] , A. Schmidt[1],
W. Lu[1], C. Kim [1], U. Bösenberg[1], A. Bartmann [1], B. Kist [1]

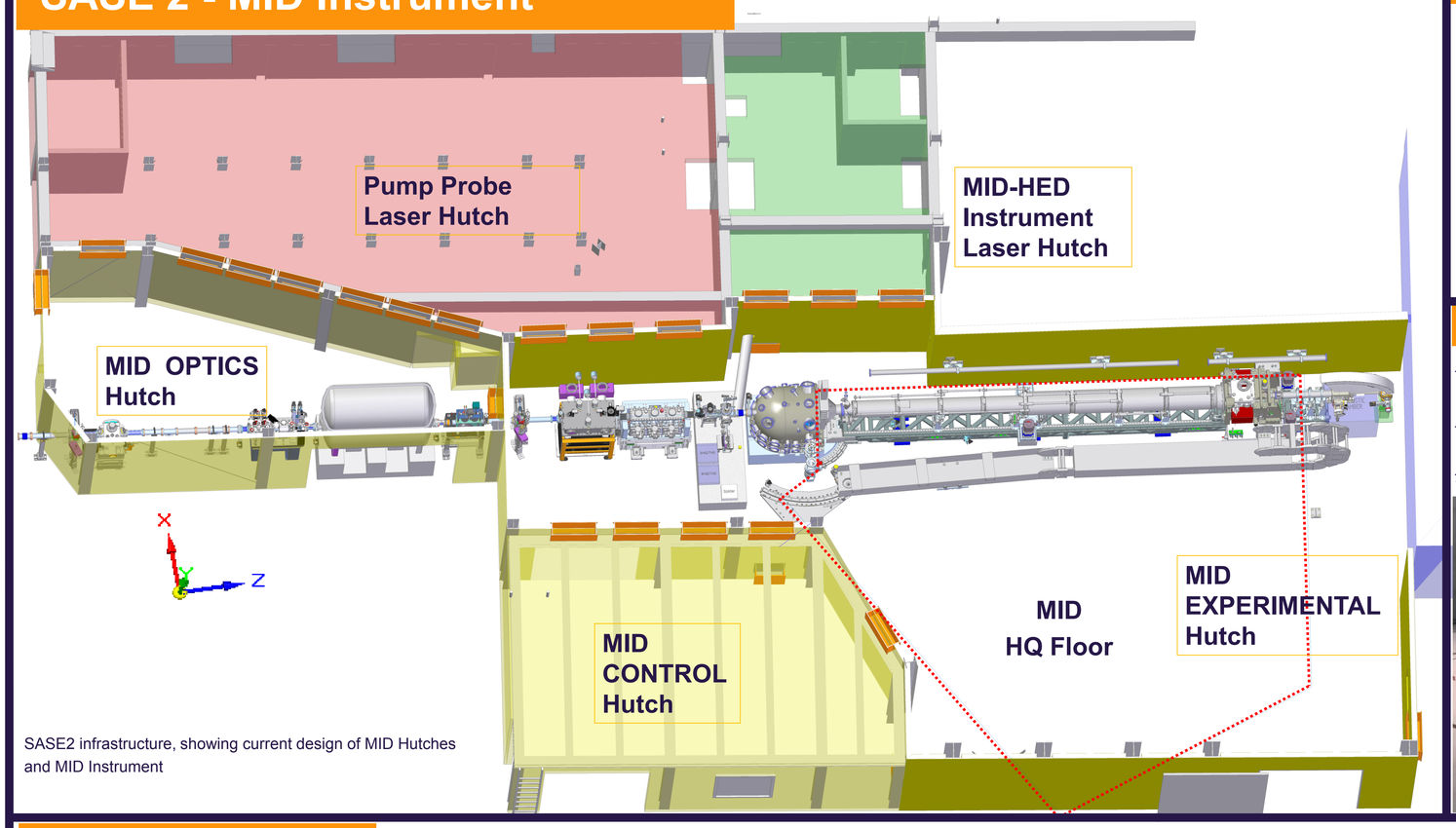
[1] European X-Ray Free-Electron Laser Facility, Hamburg, Germany
[2] ESRF European Synchrotron Radiation Facility

[#] gabriele.ansaldi@xfel.eu www.xfel.eu



Abstract: *The Materials Imaging and Dynamics (MID) instrument of the European XFEL facility will provide unique capabilities in materials imaging and dynamics experiments, with particular focus on the application of coherent X-ray scattering and diffraction techniques. Coherent diffractive imaging (CDI) and X-ray photon correlation spectroscopy (XPCS) experiments are at the heart of the activities planned at the MID station, but also time-resolved scattering and imaging studies can be foreseen, taking advantage of the time structure and high flux of the X-ray free-electron laser (XFEL) beam. Here we present the technical realizations of the devices inside the Optics and Experimental Hutches. SAXS, WAXS and large field of view configurations are shown.*

SASE 2 - MID Instrument



SASE2 infrastructure, showing current design of MID Hutches and MID Instrument

MID Instrument characteristics

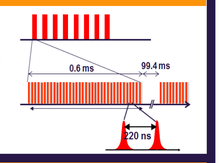
Photon energy range	5–25 keV (coherent) and > 25 keV (high-energy option)
Bunch charge	1–1000 pC
Polarization	Linear (horizontal)
Pulse duration	1–100 fs
Beam size on the sample	1–200 µm, 1 mm, and nanofocus option
Beamline optics	2 monochromators (Si(111) and Si(220)) 2 compound refractive lens (CRL) transfocator units Split and delay line High-energy Laue monochromator (optional)
Equipment	Multipurpose chamber, SAXS/WAXS geometries with long horizontal detector arm, small vertical WAXS setup, single-pulse X-ray diagnostics, different detector systems (AGIPD, FastCCD), optical pump laser source

MID HQ Floor – main characteristics

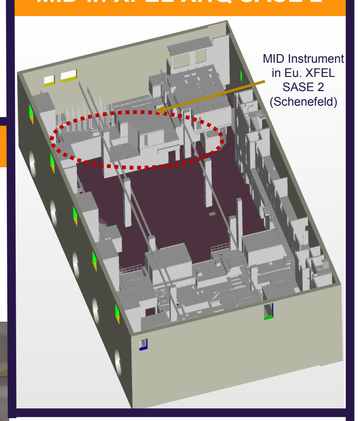
Roughness	Rz ≤ 10 µm
Planarity	≤ 70 µm / m²
	≤ 600 µm/ total HQ floor (ca 66 m²)
Hardness	Mastic: Shore 80
	Stone slabs: Shore 80 equiv.
Test run	with airpads

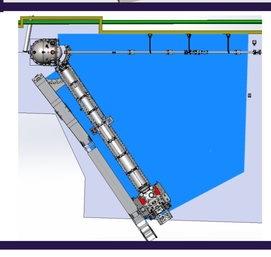
XFEL Pulse Train

- 10Hz burst pattern
- 2,7kHz full pulse train
- 4,5 MHz intra burst

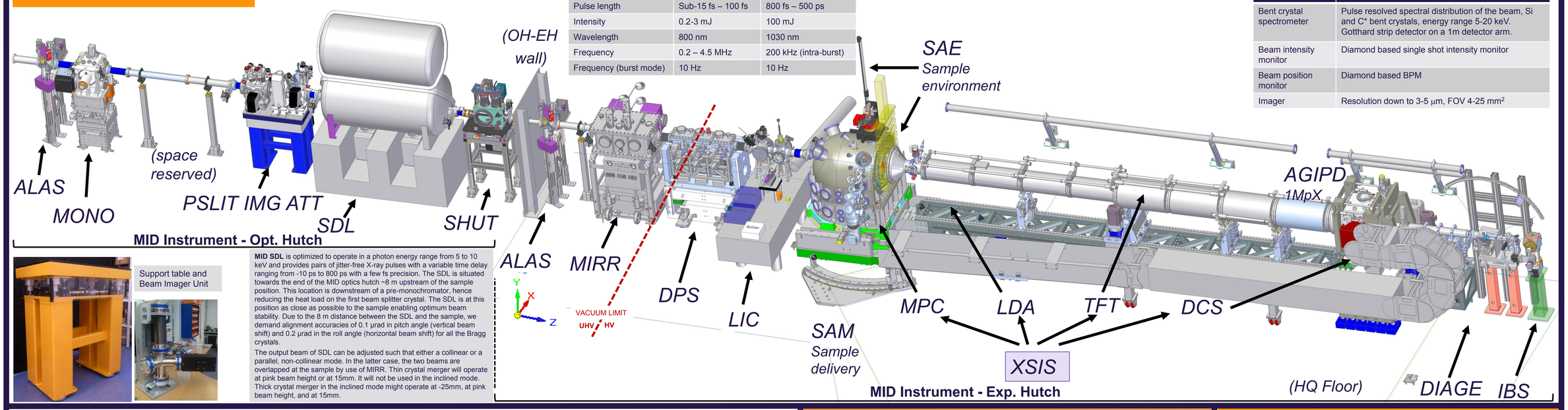


MID in XFEL XHQ SASE 2





MID Instrument



LIC Optical Laser Equipment Parameter	PP mode	MAL mode
Pulse length	Sub-15 fs – 100 fs	800 fs – 500 ps
Intensity	0.2-3 mJ	100 mJ
Wavelength	800 nm	1030 nm
Frequency	0.2 – 4.5 MHz	200 kHz (intra-burst)
Frequency (burst mode)	10 Hz	10 Hz

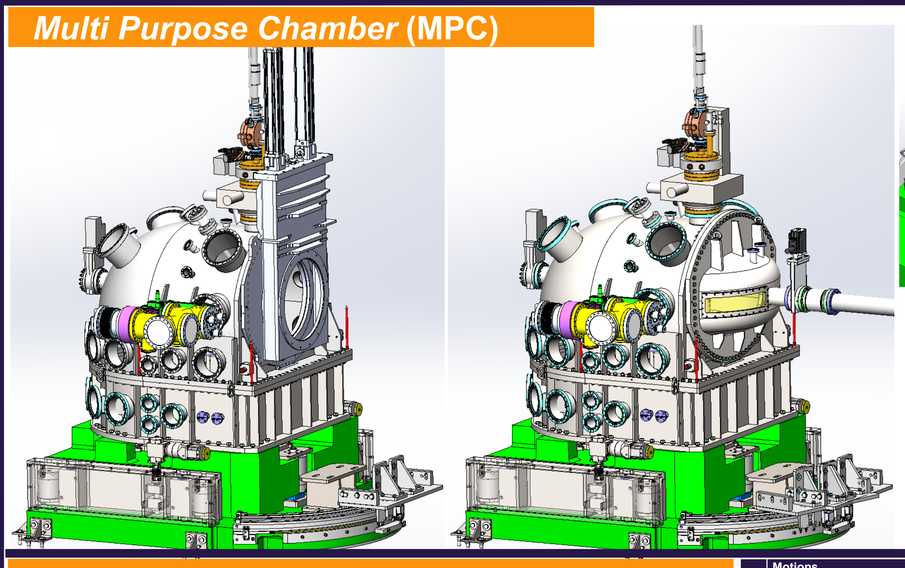
DIAGE Devices	Description
Bent crystal spectrometer	Pulse resolved spectral distribution of the beam, Si and C* bent crystals, energy range 5-20 keV. Gotthard strip detector on a 1m detector arm.
Beam intensity monitor	Diamond based single shot intensity monitor
Beam position monitor	Diamond based BPM
Imager	Resolution down to 3-5 µm, FOV 4-25 mm²

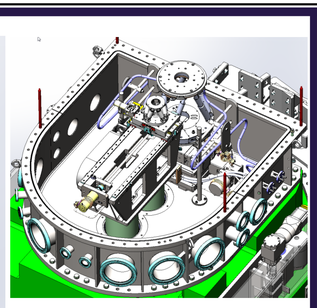
Support table and Beam Imager Unit

MID SDL is optimized to operate in a photon energy range from 5 to 10 keV and provides pairs of jitter-free X-ray pulses with a variable time delay ranging from -10 ps to 800 ps with a few fs precision. The SDL is situated towards the end of the MID optics hutch ~8 m upstream of the sample position. This location is downstream of a pre-monochromator, hence reducing the heat load on the first beam splitter crystal. The SDL is at this position as close as possible to the sample enabling optimum beam stability. Due to the 8 m distance between the SDL and the sample, we demand alignment accuracies of 0.1 µrad in pitch angle (vertical beam shift) and 0.2 µrad in the roll angle (horizontal beam shift) for all the Bragg crystals.

The output beam of SDL can be adjusted such that either a collinear or a parallel, non-collinear mode. In the latter case, the two beams are overlapped at the sample by use of MIRR. Thin crystal merger will operate at pink beam height or at 15mm. It will not be used in the inclined mode. Thick crystal merger in the inclined mode might operate at -25mm, at pink beam height, and at 15mm.

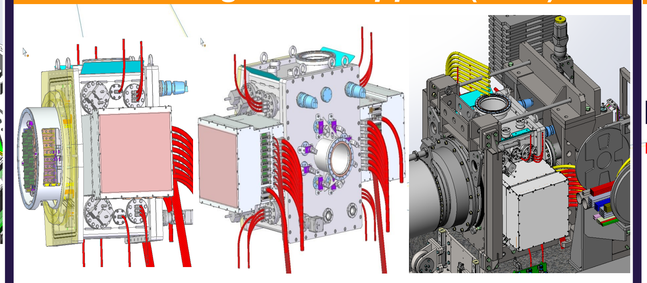
Multi Purpose Chamber (MPC)





Interior of MPC showing sample stage and nanofocusing setup

Detector Cage and Support (DCS)



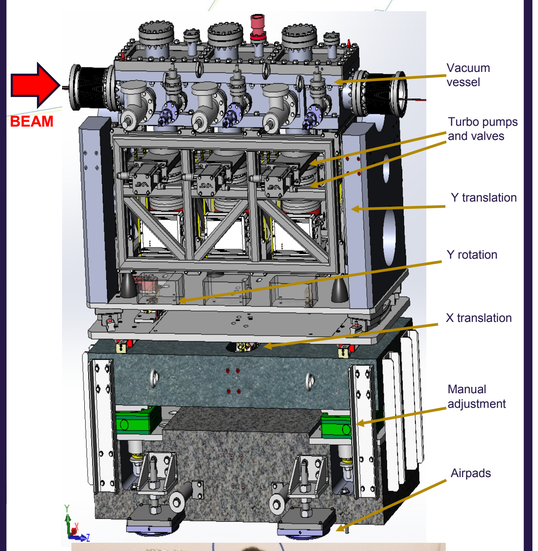
Adaptive Gain Integrating Pixel (AGIPD) detector

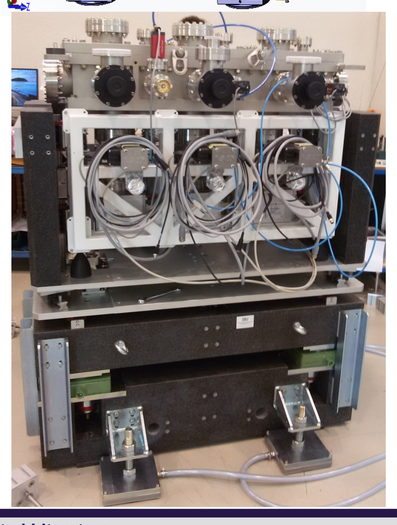
The detector cage and support (DCS) of the XSIS

High speed detector intended for use at the European XFEL. It allows single pulse imaging at 4.5 MHz frame rate with a dynamic range allowing single photon detection and detection of more than 10.000 12.4 keV photons in the same image and is capable of storing 352 frames. It's a 1 Megapixel camera with moveable quadrants to give a central hole of variable size for passage of the direct FEL beam. It consists of 16 modules (four per quadrant), each of which is made up of a single 500 mm-thick sensor bump-bonded to 2x8 ASICS of 64x64 pixels each – so one module has 128 x512 pixels. Pixel dimension: 200µm x 200µm.

(Ref. H. Graafsma et al., DESY-FS Group)
http://photon-science.desy.de/research/technical_groups/detectors/projects/agipd/index_eng.html
http://journals.iucr.org/s/issues/2016/01/00/xl5020/xl5020.pdf

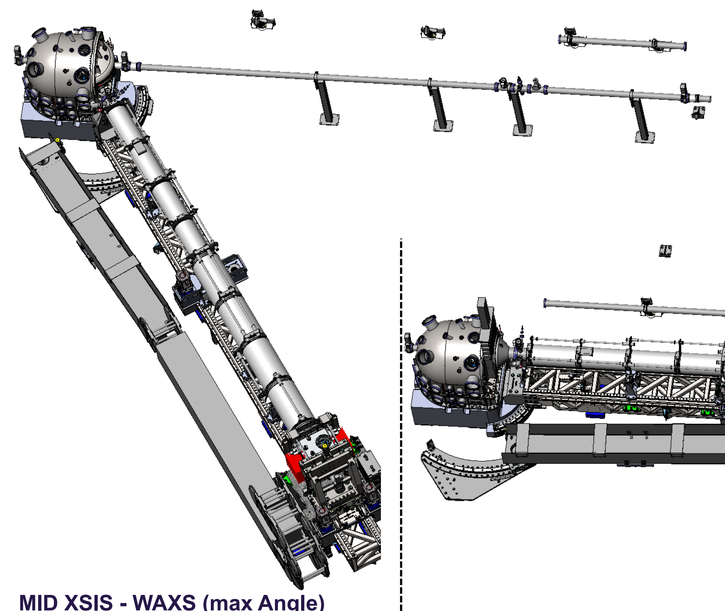
Differential Pumping System (DPS)



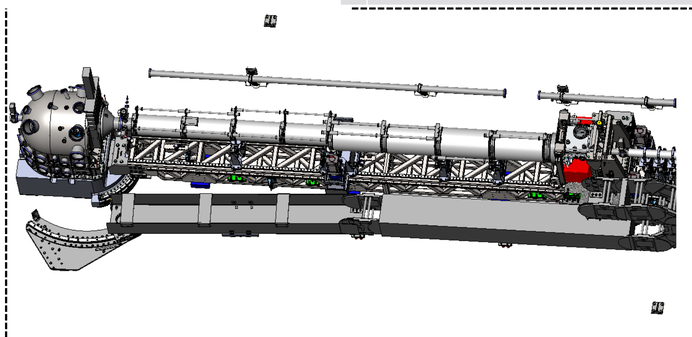


X-ray MID X-Ray Scattering and Imaging Setup (XSIS)

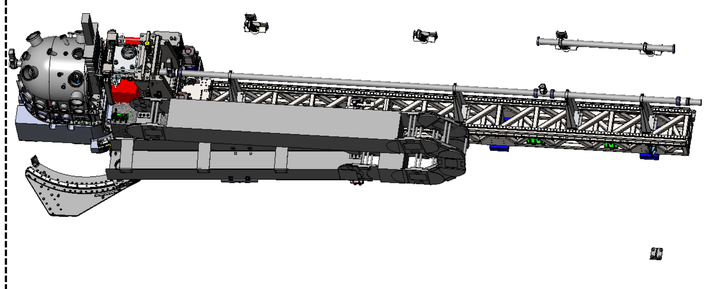
	Motions	Axis	Stroke	Resolution	Repeatability
1	MPC	Y	+21 / -5 mm	25 µm	**50 µm**
2	local optics (inside MPC)	Z	430 mm	1 µm	**5 µm**
3	local optics (inside MPC)	X	40 mm	1 µm	**5 µm**
4	local optics hexapod (inside MPC)	X, Z	±15 mm	1 µm	**2 µm**
		Y	±5 mm	1 µm	**2 µm**
		RX , RY , RZ	±10°	0.01 mrad	**0.02 mrad**
5	sample (inside MPC)	Y	± 15 mm	1 µm	**5 µm**
6	sample (inside MPC)	θ	±100°	5 µrad	**10 µrad**
7	sample hexapod (inside MPC)	X, Z	±50 mm	1 µm	**2 µm**
		Y	±25 mm	1 µm	**2 µm**
		RX , RY , RZ	±15°	0.01 mrad	**0.02 mrad**
8	Detector cage on DCS Detector cage on DCS	Y	+21 / -10 mm	25 µm	**50 µm**
9		X	±10 mm (manual)	NA	**NA**
10	DCS (in the position where AGIPD is connected without TFT to the MPC) DCS, for SAXS and WAXS (in the position where the TFT is between the MPC and AGIPD)	Z	~125 mm travel ~5 m travel (from ~3 m to ~8 m)	100 µm	**200 µm**
11	upstream TFT length when moving DCS	Z	~5 m travel (from ~3 m to ~8 m)	100 µm	**200 µm**
12	downstream TFT length when moving DCS	Z	free moving	NA	**NA**
13	upstream TFT	Y	+21 / -10 mm	Not critical	**Not critical**
14	downstream TFT	Y	+21 / -10 mm	Not critical	**Not critical**
15	**LDA with TFTs and DCS connected to it (WAXS configuration)**	**2θ**	**~42° (from ~14° to ~56°)**	**0.02 mrad**	**0.1 mrad**



MID XSIS - WAXS (max Angle) Configuration



MID XSIS - SAXS Elongated Configuration



MID XSIS - SAXS Large Filed of View Configuration

Related Literature:

1. **Technical Design Report of the XFEL**
http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e79991/e68669/european-xfel-tdr_eng.pdf
2. **Technical Design Report of the MID instrument**
https://docs.xfel.eu/alfresco/d/a/workspace/SpacesStore/ecb39ac1-16ae-43e0-8e30-f74e81deb471/TR-2013-005_TDR_MID.pdf
3. **MID X-Ray Scattering and Imaging Setup (XSIS) Specification**
https://docs.xfel.eu/alfresco/d/a/workspace/SpacesStore/54e0dd33-aa7b-45fd-8bfb-6a80f0a4f9e5/cft_XSIS.pdf
4. **MID Differential pumping (DPS) Specification**
https://docs.xfel.eu/alfresco/d/a/workspace/SpacesStore/3bfb16f9-915b-4740-9d7a-59ad1672599f/141030-MID-Differential-Pumping-Specification-CFT-REV2_7FINAL.pdf
5. **The adaptive gain integrating pixel detector AGIPD a detector for the European XFEL** B. Henrich, H. Graafsma et al., Nucl. Instrum. Meth. in Phys. Research A, vol. 633, p.S11–S14, 2011, https://docs.xfel.eu/alfresco/faces/jsp/login.jsp?_alfRedirect=%2Falfresco%2Fd%2Fa%2Fworkspace%2FSpacesStore%2Fa5cc0ba3-0331-4da3-a5d7-c626a7b0294b%2Fhenrich_adaptive_2015.pdf

www.xfel.eu

Gabriele Ansaldi, Instrument Engineer for Materials and Imaging Dynamics (MID) Instrument
Gabriele.ansaldi@xfel.eu : www.xfel.eu

MEDSI 2016
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION