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THE MID INSTRUMENT OF EUROPEAN XFEL: UPGRADES AND EXPERIMENTAL SETUPS

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Abstract

This article provides examples of setups and upgrades currently under development at the Materials Imaging and Dynamics (MID) instrument of the European X-Ray Free-Electron Laser (Eu. XFEL) concerning the X-ray Scattering and Imaging Setup (XSIS):

- The Multi-environmental multi-Detector Setup (MDS_2) is a set of setups designed to integrate in the MID Instrument an additional detector chamber (the Multi Detector Stage, MDS) to be used in parallel with the AGIPD detector, allowing simultaneous coverage of the wide- (WAXS) and small-angle X-ray scattering (SAXS) regions by use of several area detectors. It can also be used in Large Field-of-View (LFOV) configuration.
- The Multi-Purpose Chamber 2 (MPC-2) is an evolution of the current MPC and includes design upgrades of both the exterior of the vessel as well as some internal improvements concerning simultaneous use of optical laser excitation of the sample and Nano-focusing X-ray optics.

Both upgrades will improve the capabilities of MID and enable new types of experiments.

- We also show examples of recent developments of dedicated setups for experiments at MID, as well going in the simultaneous multi-detector-use direction.

THE MULTI-ENVIRONMENTAL MULTI-DETECTOR SETUP (MDS_2)

Environment

The MDS_2 at (Eu. XFEL) [1,2] is an important addition to the instrumentation at MID. The integration is currently in progress allowing to use and move an additional detector chamber (MDS) simultaneous the common detector AGIPD [3] in several positions of MID high-quality floor. It has been designed to be compatible with the current XSIS [1,2], but expands the capabilities of the instrument in three areas:

- AGIPD in WAXS geometry: in this case the MDS is situated on the Support Structure Girder Assembly (SSG) (see Figs. 1 and 2) with its own sliding carts and rails and movable using air pads along the beam axis for SAXS applications or direct beam imaging. The AGIPD detector on the XSIS arm can be freely positioned in the usual WAXS geometry.
- AGIPD in SAXS geometry: in this case the MDS will be mounted onto the XSIS arm using the SSG interchangeable rails, behind the AGIPD detector in SAXS position, see Fig. 3.
- LFOV: in this configuration the MDS will also be mounted onto the XSIS Arm behind the AGIPD detector, but in LFOV configuration (see Fig. 4).

For further information about the MDS, see also the paper of A. Schmidt in this conference.

Design

The MDS_2 Setup, designed and partly realized for the aforementioned three Environments consists of the following assemblies (see the **Poster** of this Paper: Nr. **WEPPP010** and Figs. 1-4):

MDS_2 SSG has been designed, simulated by FEA (see Poster WEPPP010, Fig. 1), and manufactured to withstand the expected static and dynamic loads. The motion concept has been successfully tested by moving it on its air pads.

MDS_2 Upstream Adapter Flange (UAF) has been designed, simulated by FEA (see Poster WEPPP010, Fig. 1), and manufactured to withstand foreseen vacuum load. It has been successfully tested sealing the vacuum of the MDS. It is connected to the other MPC_2 assemblies via a central DN250CF rotatable flange and features 4x DN160ISO-K viewports for visual inspection of the the detectors inside.

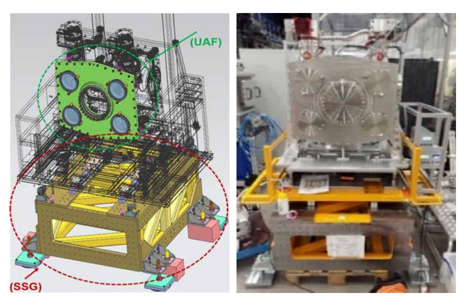

Figure 1: left) design of the Support Structure Girder Assembly moved on airpads (SSG) and Upstream Adapter Flange (UAF), in green. right): manufactured MDS_2 installation during air pads motion and vacuum tests.

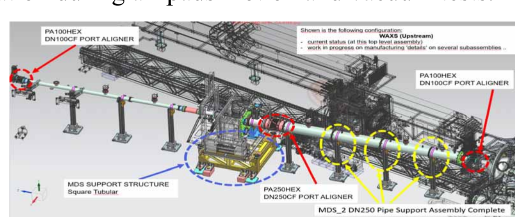

Figure 2: MDS_2 Environment in WAXS Configuration.

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MDS_2 Port Aligners (PA): new connecting elements specifically custom designed to allow for maximum possible lateral displacement and to withstand foreseen vacuum forces. They constitute the connecting elements to the Flight Tube Assemblies before and after the AGIPD detector. Therefore, they are realized in 2 versions: DN200 and DN100.

MDS_2 Movable Chamber (MC) in principle a new small vacuum chamber carrying the new MDS_2 Beam Stop Assembly (BS), that can be vertically inserted into/removed from the beam via the MDS_2 Manipulator (see Fig. 4).

MDS_2 Zero Length Adapter (ZLA) design allows the transition from PA DN250 to DN100 components upstream of the AGIPD, while at the same time featuring 2x DN40ISO-K viewports for direct visual inspection of the interaction point and components inside the MDS (see Fig. 4).

The MDS_2 is completed with several different sets of connecting elements to accommodate the various setups, for instance DN100 and DN250 flight tube assemblies with matching pipe support structures.

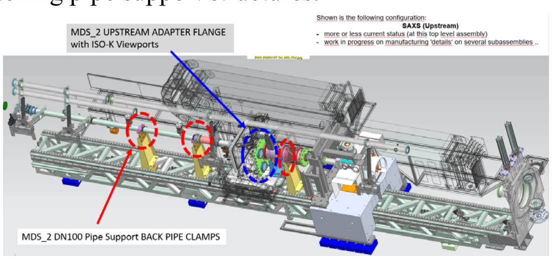

Figure 3: MDS_2 Environment in SAXS Configuration.

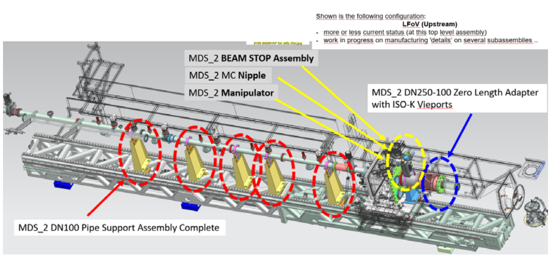

Figure 4: MDS_2 Environment in LFOV Configuration.

THE MULTI PURPOSE CHAMBER 2 (MPC-2)

The MPC-2 project represents another upgrade of MID's instrumentation which is currently being developed. It is an evolution of the current multi-purpose chamber which has been used at MID since the first experiments in 2019. The aim is to enable new types of scientific experiments to expand the current capabilities of MID. Another aim is to make operation of experiments easier with better access to the sample environment and possibilities to install ancillary equipment (see Figs. 5-7).

Design

A recurrent request, beyond the capabilities of the current MPC setup, is to use an optical pump laser beam in

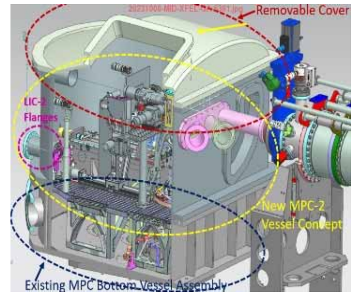

Figure 5: MPC-2 design (VESSEL SEGMENTED) and interior assembly with BA and LIC-2 (section).

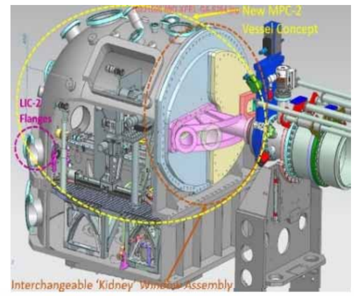

Figure 6: MPC-2 design (VESSEL SUCCESSOR) and interior assembly with BA and LIC-2 (section).

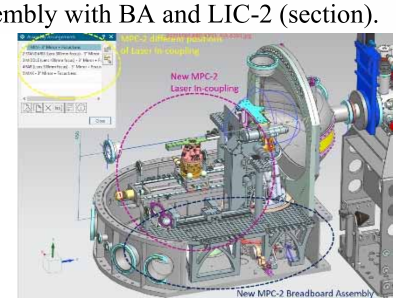

Figure 7: MPC_2 Interior Assembly Upgrade: design in progress with examples of different LIC-2 positions on the BA.

vacuum in combination with the existing nano-focusing (NaFo) setup using beryllium lenses. The new MPC-2 will accommodate this possibility by adding additional windows and flanges, hence allowing the optical laser beam to enter the chamber parallel to the X-ray beam (Figs. 5-7) and with sideboards mounted inside the vessel to accommodate optical components for the laser beam path (see also Fig.7).

Two scenarios of the MPC-2 Vessel are currently under development. Both must fulfil the following requirements:

- Compatibility with the current MPC bottom part onto which MPC-2 will be mounted;
- Compatibility with the current infrastructure and ancillary sample environment setups, including developments in progress (e.g. the Interior Assembly Upgrade (MPC-2_IAU) and laser in-coupling (LIC2)) and other additional future upgrades (e.g. the Interferometer Project).
- Easy access to the sample and internal setups via larger side ports.

The two different MPC designs explored are:

MPC-2 VESSEL UPGRADE SEGMENTED is a possible design scenario featuring a completely removable top

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cover, wide apertures, interchangeable flight-tubes at distinct scattering angles and new laser in-coupling flanges (see Fig. 5).

MPC-2 VESSEL UPGRADE SUCCESSOR is another possible design scenario featuring a kidney-shaped window compatible with current WAXS window, wide apertures and interchangeable flight-tubes at distinct scattering angles and new laser in-coupling flanges (see Fig. 6).

The MPC-2 Project also comprises the Interior Assembly Upgrade (MPC-2_IAU), featuring (see Fig. 7):

- A new Laser In-Coupling (LIC-2) device, positioned downstream of the NaFo Setup and movable along the beam direction. It is designed to make the X-rays and optical laser beam to hit the sample co-linearly;
- Upgraded Breadboard Assembly (BA), a suitable support structure designed to ensure a secure mounting of the future LIC-2, as well as mounting and aligning lenses, mirrors and cameras. It will be fixed to the existing threads at the bottom part of the current MPC.

EXPERIMENTAL SETUP FOR WIDE-ANGLE SCATTERING XPCS ON LIQUID JETS

In these experiments speckle patterns need to be detected with high precision in space and time and in WAXS geometry.

Design

The setup consists of (see Figs. 8 and 9):

- XSIS installed in SAXS Configuration
- Multi-purpose chamber (MPC) in vacuum

  - DN200ISO-K Flight Tube Setup (FTS) at 25 deg from the beam, installed on XSIS Arm (2 scenarios: @1.2m and @1.8m from the interaction point)

  - 2x or 4x EPIX detector [4] Setup installed on FTS
- Liquid Injector setup (LIS)
- Cold Trap installed on MPC

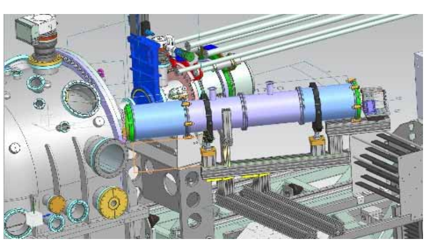

Figure 8: Design of WA-XPCS setup - Scenario: @1.8m from the interaction point and 2x Epix Detectors.

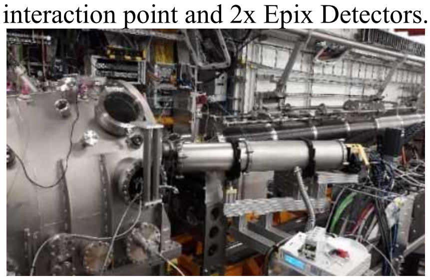

Figure 9: Implementation of Design.

EXPERIMENTAL SETUP FOR SMALL-AND WIDE-ANGLE SCATTERING XPCS ON SOLID SAMPLES

In these experiments speckle patterns need to be detected with high precision in space and time in SAXS and WAXS geometry.

Design

The setup for this kind of experiment consists of (see Figs. 10 and 11):

- XSIS Instrument installed in SAXS Configuration;
- DN40KF Flight Tube Assembly connecting the MID Laser In-coupling (LIC) to MID XSIS
- R+K Assembly Setup installed on bottom of MPC;
- DN200ISO-K FTS;
- a sample chamber (cryostat) integrated into MID FTS;
- Jungfrau [5] detector Setup installed on FTS.

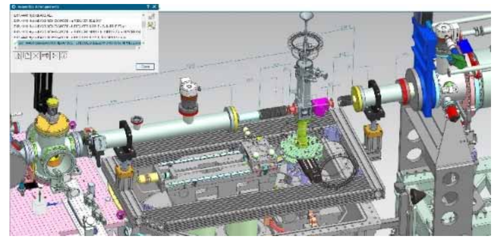

Figure 10: Design of Exp. Setup - Scenario: reducer bellow.

Figure 11: Implementation of Design.

CONCLUSION

Several upgrades are currently underway at the MID instrument of EuXFEL. The MDS_2 manufacturing and assembly is in progress but not yet in operation. MPC-2 is in the design phase, allowing for improved operation of MID and simultaneous use of nano focused X-ray beams and optical laser excitation of the sample. The flexibility of the MID instrument is illustrated by examples of experimental setups and the MDS_2 and MPC-2 projects aim at standardizing some of these configurations.

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