Design, Construction and Commissioning of Two Highly Integrated Experimental stations for micro-focusing Macromolecular Crystallography (MX) Beamlines at NSLS-II

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We present the final engineering design and first commissioning results of two highly integrated experimental stations for the micro-focusing (FMX) and the highly automated (AMX) MX beamlines at the NSLS-II. These beamlines will support a broad range of biomedical structure determination methods from serial crystallography on micro-sized crystals, to structure determination of complexes in large unit cells. These experimental stations are completely designed and fabricated in-house to meet challenging requirements resulting from the small beam size of 1 μm and the extremely short working distance of only 190 mm from the beam exit window to the FMX focal spot.

The beam conditioning unit contains, within 140 mm, a beam position monitor, an attenuator, primary slits, an intensity monitor, a sub-millisecond shutter, and secondary slits. The diffraction meters consist of an interchangeable high precision air bearing based main goniometer and a secondary goniometer for crystallography plates, both with a SOC of 300 nm on horizontal axis, an on-axis microscope with a customized reflective optics, x-ray fluorescence detector and dynamic beam shaping slits. Both these robotic end stations are integrated in a compact space on a granite machine bed with high modularity for future upgrades and extensions. Novel automation concepts are being implemented to increase the throughput of the cryogenic samples.

**FMX and AMX scientific missions**
- FMX will operate as a high flux micro-beamliner beam and AMX for small molecule investigations, yet high energy, automation, high flux, and advanced automation for macromolecular crystallography will be covered on both AMX and FMX.

**User numbers**
- AMX will support programs that require high flux use of small molecules, e.g., high-resolution structure determination, and AMX will support small molecule investigations.

**Large scale tools**
- Large scale tools include a EIGER 16M Detector. The FMX/AMX end stations will be equipped with a SmarGon parallel robotics inspired goniometer (PRIGo) on secondary goniometer (PRIGo) on secondary.

**Collected on all**
- Coarse alignment and positioning, small molecule screening, automated crystallographic sample handling, detector system

**Remote**
- Remote control of sample chamber from home.

**FMX experiments**
- FMX/AMX end stations will provide the following beamline-specific capabilities:
  - Micro-focus beams
  - High energy
  - Automation
  - High flux
  - Next Generation Pixel Array Detectors
  - X-ray lenses for micro-beam applications
  - Dynamic and non-linear X/Y/Z alignment
  - X-ray tomography

**Beamline design**
- Beamline design will focus on compatibility and modularity with large scale tools, such as EIGER 16M Detector. Beamline design will be optimized for flexibility and extendability.

**Energy range**
- FMX
  - 9 – 30 keV
  - 0.4 – 2.5 Å
  - Focal spot min 1 x 0.5 μm²
  - Focal spot range 1 – 50 μm

- AMX
  - 5 – 18 keV
  - 0.7 – 2.5 Å
  - Focal spot min 4 x 3 μm²
  - Focal spot range 4 – 100 μm

**Detectors**
- FMX
  - EIGER 16M Detector
  - PILATUS 6M Detector

- AMX
  - SLS FRIGo Omega SOC < 1 μm
  - On ST150 Nelson Air Bearing.