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

Dileep K. Bhogadi, Martin R. Fuchs, Jean Jakoncic, Babak Andi, Stu Myers, James Magill, Mary Carlucci-Dayton, Lonny E. Berman, Dieter K. Schneider, Bob M. Sweet and Sean McSweeney

*National Synchrotron Light Source II, Brookhaven National Laboratory, Upton NY, 11973, USA*
***dbhogadi@bnl.gov***

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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 micron-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 diffractometers consist of an interchangeable high precision air bearing based main goniometer and a secondary goniometer for crystallization plates, both with a SOC of 100 nm on horizontal axes, 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 through-put of the cryogenic samples.

### FMX and AMX scientific missions

| | |
|---|---|
| **Specialize and Complement** | FMX will cover the micro-beam regime and AMX the mini-beam regime, yet both lines have complementary and overlapping capabilities |
| **Vast numbers** | AMX will support programs that require testing of vast numbers of specimens, e.g. studies of membrane proteins, and drug discovery explorations |
| **Micro-crystals, serial crystallography** | FMX will provide a micron sized beam and sample delivery and data processing to support efficient structure determination from micron sized crystals |
| **Large unit cells** | FMX and AMX will support structure determination of multi-component assemblies |
| **Collect on all** | High flux and short data collection times will make it possible to collect on every specimen, assisted by crystallographic decision making software |
| **Remote** | Remote data collection from home institutions |

**FMX**

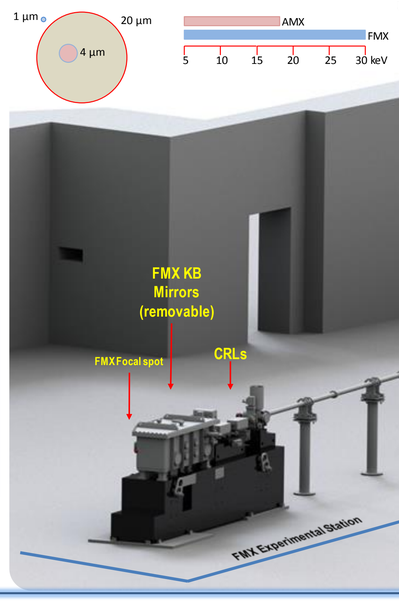
| | |
|---|---|
| Energy range | 5 – 30 keV |
| Wavelength range | 0.4 – 2.5 Å |
| Flux at focus | ~$10^{13}$ ph/s |
| Focal spot min | 1 x 0.5 µm$^2$ |
| Focal spot range | 1 – 50 µm |

Frontier Microfocusing MX

**AMX**

| | |
|---|---|
| Energy range1 | 5 – 18 keV |
| Wavelength range | 0.7 – 2.5 Å |
| Flux at focus | ~2×$10^{13}$ ph/s |
| Focal spot min | 4 × 3 µm$^2$ |
| Focal spot range | 4 – 100 µm |

Highly Automated MX

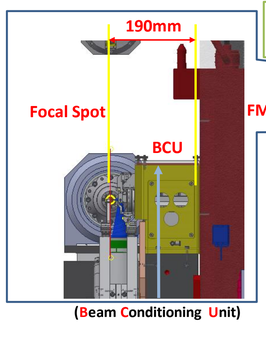



**Sector: 17-ID @ NSLS-II**
**Source: Two canted IVU-21 Undulators**

FMX & AMX's **specific & new features**
- Micro focus beams
- High energy
- Automation
- High flux
- Next Generation Pixel Array Detectors

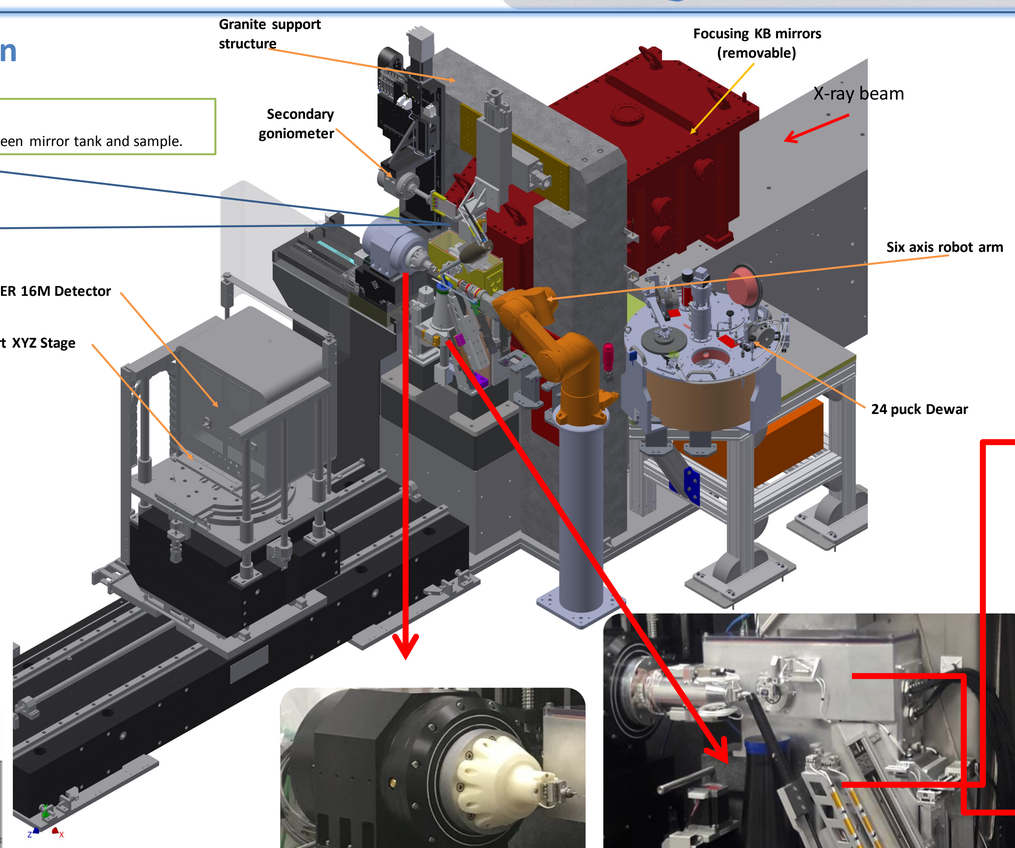
research instruments

## FMX Experimental Station

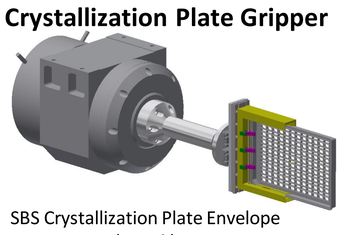



(Beam Conditioning Unit)

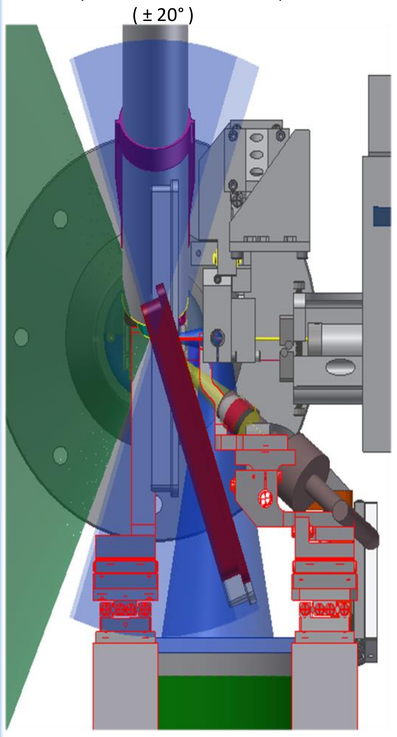
**Challenge:**
Just 190mm between mirror tank and sample.




### Crystallization Plate Gripper

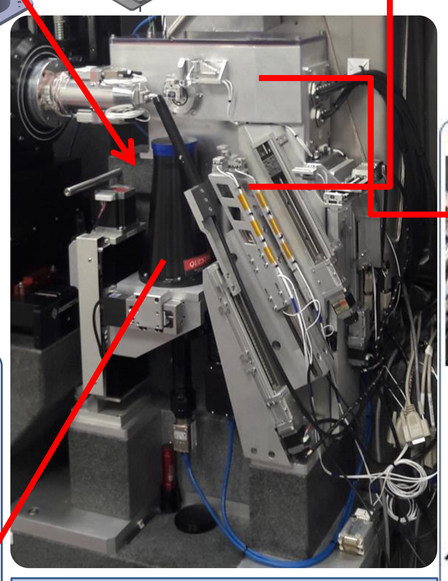


SBS Crystallization Plate Envelope
( ± 20° )



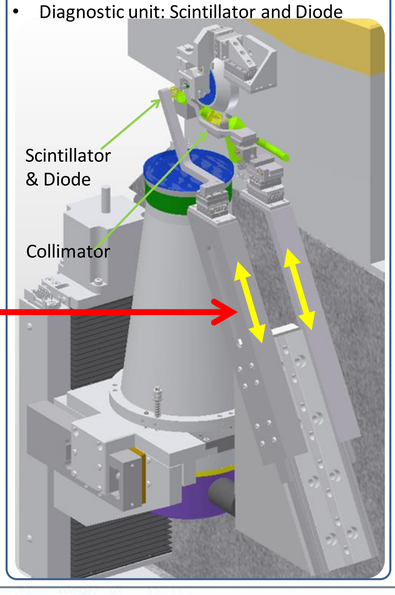


**Main Goniometer Arm**
SOC target: 100nm on Nelson Air bearing



**FMX Core Module**
**(similar construction for AMX)**

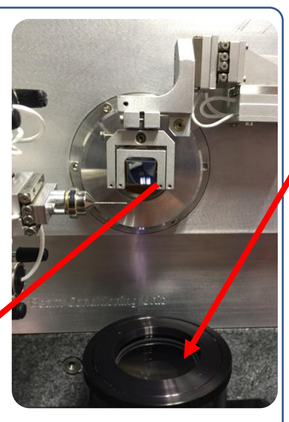
### Beam shaping
**(similar for both FMX and AMX End Stations)**
- Collimator on flexural platform to shield x-rays
- Diagnostic unit: Scintillator and Diode




**FMX Experimental Station Construction Update**

### Sample visualization

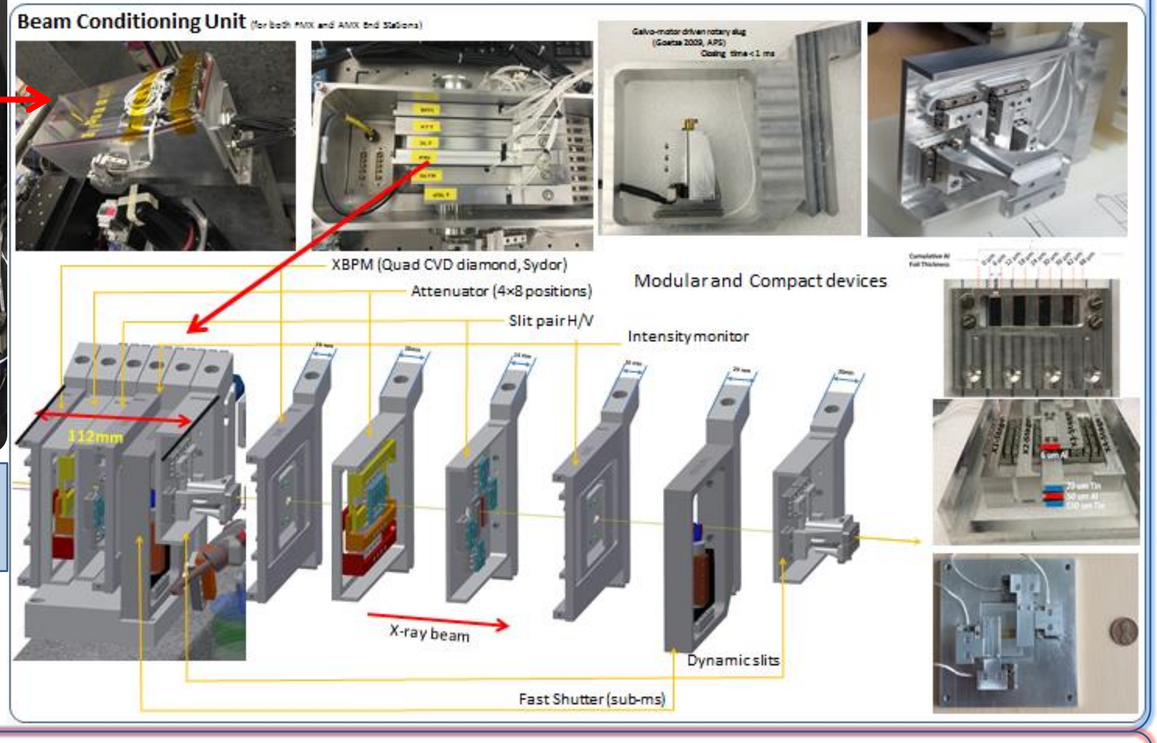
FMX/AMX end stations will provide
- Diffraction-based crystal alignment and mapping
- On-axis microscope
- UV-excited fluorescence imaging



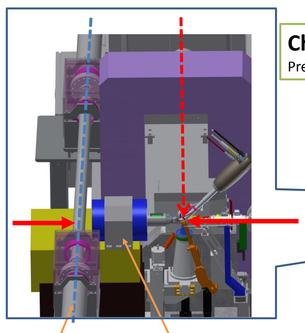
Flexural deflection mirror stage

(Custom Questar QM 100 telescope)
Gofron, K. J. & Duke, N. E. C. "Using X-ray excited UV fluorescence for biological crystal location"
*Nucl. Instr. and Meth. A*, (2011) **649** 216-218

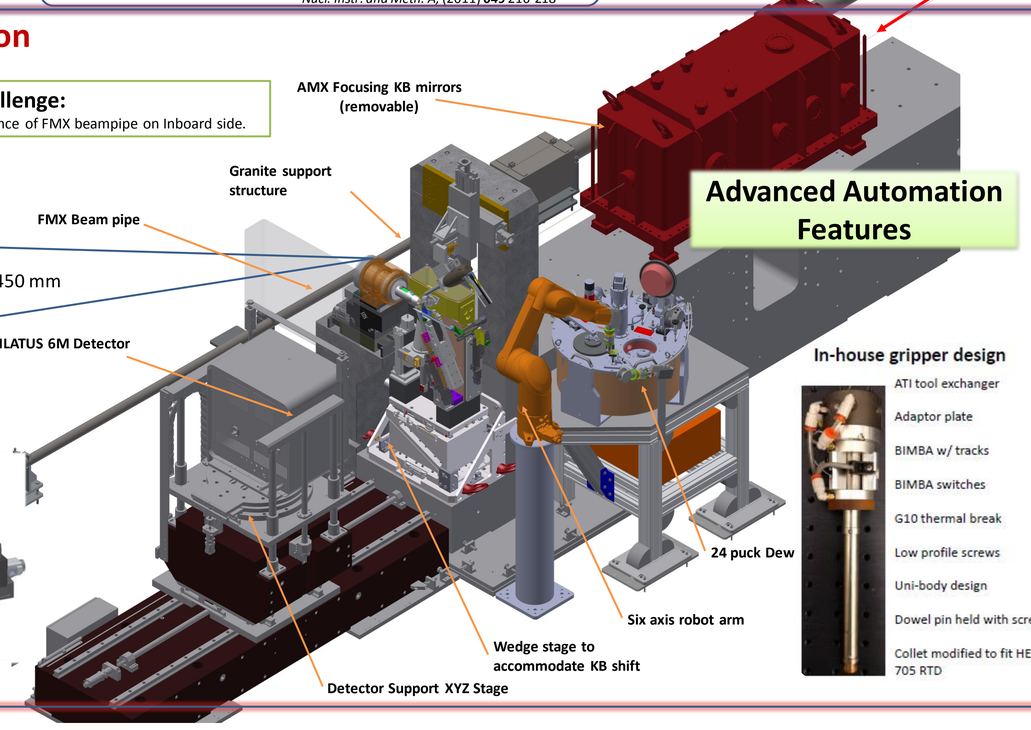
### Beam Conditioning Unit (for both FMX and AMX End Stations)



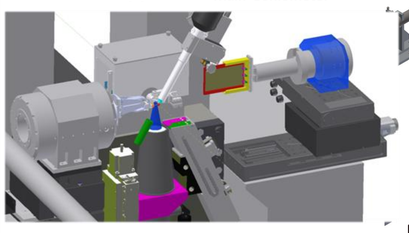

## AMX Experimental Station




**Challenge:**
Presence of FMX beampipe on Inboard side.




**Advanced Automation Features**



AMX secondary goniometer (optional)

### In-house gripper design



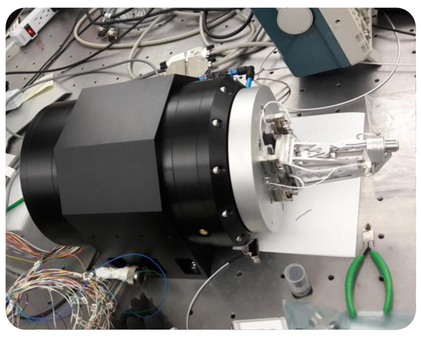
ATI tool exchanger
Adaptor plate
BIMBA w/ tracks
BIMBA switches
G10 thermal break
Low profile screws
Uni-body design
Dowel pin held with screws
Collet modified to fit HEL-705 RTD

### Multi-axis goniometry : SmarGon by SmarAct

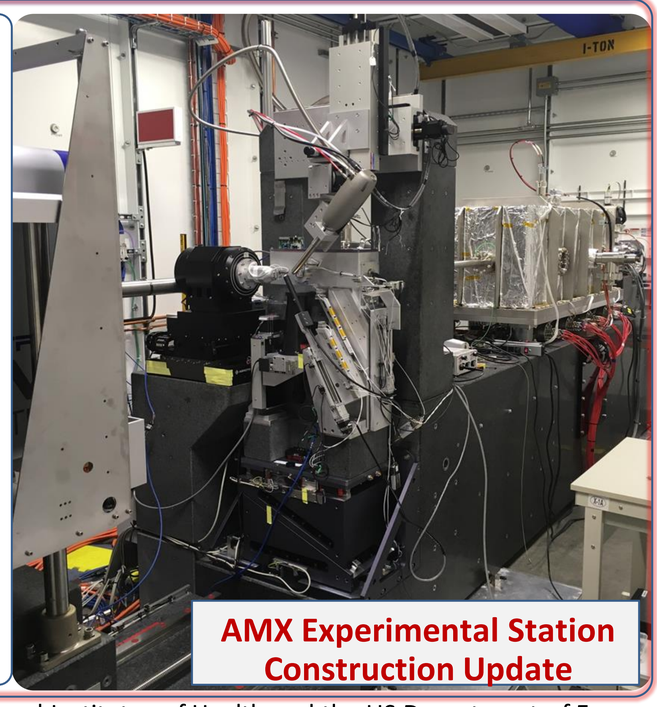
Formerly known as PRIGo:
Parallel Robotics Inspired Goniometer

Plans for implementation:
- AMX: SmarGon on main axis
- FMX: SmarGon on secondary goniometer

➢ SLS technology licensed to SmarAct



- SLS PRIGo: Omega SOC < 1 µm
- ➢ On SP150 Nelson Air Bearing.



**AMX Experimental Station Construction Update**

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