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BDN NSLS-II PROJECT STATUS: HOW TO RECYCLE A SYNCHROTRON?*

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Figure 1: Components of NSLS X15B being moved to NSLS-II 8-BM. From left to right: focusing mirror, monochromator, vertically collimating mirror, beam-defining slits.

Abstract

With many synchrotron facilities retiring or going through upgrades, what is the future of some of the state-of-the-art equipment and the beamlines built for a specific science at these older facilities? Can the past investments continue supporting the current scientific mission?

The Beamlines Developed by NSLS-II (BDN), former NxtGen project, are reusing scientifically valuable equipment recovered from the now shuttered NSLS. For example TES(8-BM) reported 2um x 3um beam size achieved with reclaimed KB mirrors [1].

This paper describes new, reused, adapted and modified instruments, which NSLS beamlines they came from, as well as their integration into the new NSLS-II control system.

Many popular NSLS programs and custom-built equipment developed for them are welcoming old and new users in NSLS-II.

INRODUCTION

Every facility puts efforts into minimize maintenance by standardizing common infrastructure and utilities. All BDN beamlines received the following new standardized equipment: photon shutters, vacuum gauges and controllers, Beam Intensity (BI) Monitoring equipment, CCDs and surveillance cameras, network and computing infrastructure, Personnel Protection System (PPS) and Equipment Protection System (EPS). Most of the beamlines received new optic for the mirrors, while reusing vacuum chambers and motorized positioning systems. Some mirrors were reused, as well as end station equipment. Fig. 1 shows X15B instruments being moved to NSLS2.

BDN is home for instruments developed by scientific non-commercial groups. CMS(11-BM), TES(8-BM), and XFM (4-BM) use KB-mirrors, designed by the Center for Advanced Radiation Sources (CARS) at the University of Chicago [1]. In-house developed electrometer by P. Siddons was used in many beam diagnostic solutions at all BDN beamlines. This design is now sold commercially [2].

All beamlines reused ion pumps and ion pump controllers, gate valves, bellows, viewports and more, wherever it was suitable, with some beamlines building mostly from recovered components.

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CMS 11-BM

Complex Material Scattering (CMS) beamline, 11-BM completed construction in 2016, had its first light in August 2016 and started general-user operation in 2017.

Most of the CMS equipment came from NSLS X9 beamline: monochromator, KB micro-focusing mirrors, sample chamber, SAXS flight path, SAXS Pilatus 300k, WAXS Photonic Science detectors. Vertical focusing mirror support, motion and mirror tank came from X21, while the toroidal mirror substrate was replaced with a new one.

CMS procured a new experimental shutter, new sets of beam-defining slits, several beam diagnostics, new beam transport pipe, and upgraded SAXS detector to Pilatus 2M in 2017.

CMS has three GPFS servers and local storage, two user workstation areas: one area is for the data collection, and the other is for data processing, to eliminate possible resource conflicts and ensure speedy data collection by one group and data processing by another at the same time.

CMS modified monochromator from Double Crystal (DCM) to Double Multi-Layer configuration (DMM). The DCM Monochromator came from NSLS X9 beamline and was one of the first instruments of a kind built by FMB Oxford in 2007. It came with an MCS-8 motor-controller with embedded PC 104 card and servo protection unit for Bragg motion. See Fig. 2. Signal based EPICS IOC was included on Linux embedded board which was initialized at the MCS-8 power on. FMB provided EDM screens to control the instrument from the workstation. On the PMAC level motors' controls were implemented via Motion Programs; homing and over-travel protection were done in the PLCs. The Yaw and Roll for the second crystal did not have limit switches, but hard stops.

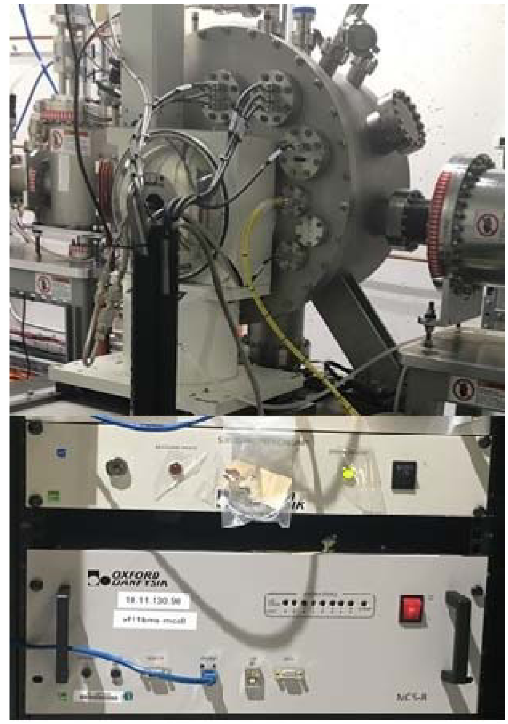

Figure 2: Monochromator controls were modified to conform to the NSLS-II standard.

The user was informed about the positive and negative boundaries via a P-variable, which was set when the following error exceeded certain value.

NSLS-II uses motor record and dedicated PLCs for homing. In order to make the controls compatible with NSLS-II standards and work with motor record we have modified the PMAC configuration and added an extra layer of PLCs, while preserving all the protection PLCs. To the user the controls look identical to everything else in the NSLS-II complex.

TES

The Tender Energy X-ray Absorption Spectroscopy (TES) beamline, 8-BM was installed in 2016, had its first light in August 2016 and is taking general users in 2017.

Most of the TES equipment came from X15B [3]. This includes collimating and focusing mirrors, pink beam slits, and double-crystal fixed-exit monochromator. The redirecting mirror was designed in collaboration with the mirror (InSync) and vacuum (Lesker) vendors, and assembled in-house. The secondary source aperture (SSA) was new; its granite support and positioning slide came from X13. TES re-claimed a good portion of the old controls system of the reused equipment. See Fig. 1. Single axes monochromator came with a Parker drive from NSLS. It is controlled by step and direction from Delta Tau Geo Brick LV at its new home.

The TES endstation sample chamber includes KB mirror system, scanning stage, and Canberra Ge and Vortex Si detectors. See Fig. 3. This endstation was built for NSLS-II but first commissioned at NSLS X15B in the last months of NSLS operation. Prototype NSLS-II controls

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were developed for operation and for on-the-fly scanning. Amplified signal from the detector goes through single channel analysers to the Struck scaler in VME crate. Thus, on day one TES had a fly-scanning system, tested and commissioned at NSLS. Fly-scanning is implemented via Position Capture and Compare feature in Turbo PMAC, selectable for either the sample stage (for imaging) or monochromator axis (for fast absorption spectroscopy). TTL trigger signal from the motor-controller is used to bin the detector and scaler data, which is buffered in the device for one row of an image or one energy scan of a series.

TES is currently integrating a new generation of solid state detector, and the Xspress-3 from Quantum Detectors to replace existing signal acquisition system. This will enable full fluorescence spectrum data collection in fly-scan mode.

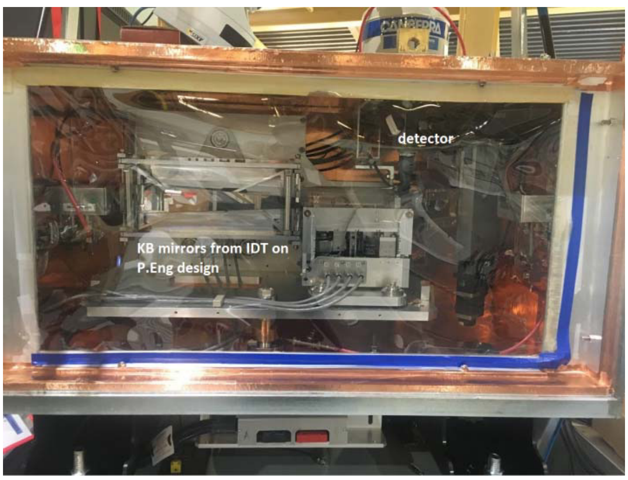

Figure: 3 TES End Station sample chamber, contains (from left to right, along beam path) I-zero ion chamber, custom KB mirror system, sample stage, visible-light camera, detectors, and transmission ion chamber.

XFM

X-ray Fluorescence Microprobe (XFM), 4-BM was built in 2017, had its first light in September 2017, and is planning to start general user operations in 2018.

Recycled XFM equipment came from X27A, X26A, X16A, X16B and X6B: water-cooled UHV white-beam slits, motorized optical table with six degrees of freedom, water-cooled pneumatically-actuated fluorescent screen, vertical collimating mirror system, JJ X-ray AT-F7-HV slits, two Vortex ME4 SDD detectors, MAIA-384 home-built detector with electronics [4], and dozens of Newport stepper linear and rotation stages. NSLS and now NSLS-II is a proud owner of several KB mirror units custom designed and built by CARS University of Chicago [1]. XFM owns two sets of these mirror system: 100 mm and 200 mm pairs.

X16A and X16B donated two identical set of mirror mechanics. After years in operation, each one had a complementary set of problems. The collimating mirror assembly and mechanics was rebuilt from both mirrors' parts and retrofitted to side clamp cooling with external water flow. See Fig. 4. Motors were wired to interface NSLS-II control system.

In 2012, X16B upgraded its vertical collimating mirror with a new optic from InSync. This mirror is a part of XFM now.

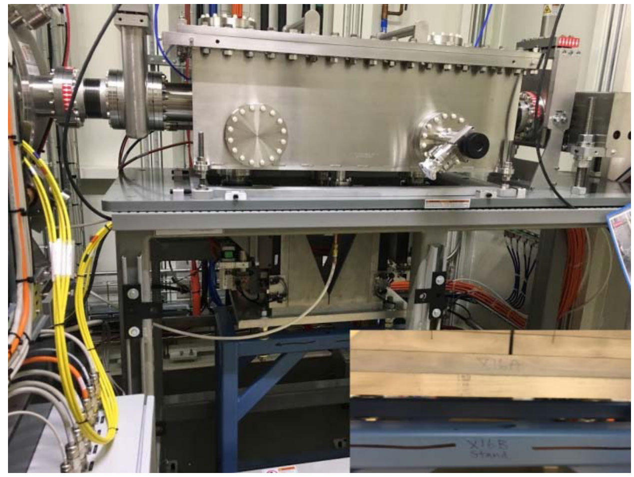

Figure 4: Vertical collimating mirror reassembled from two identical mirror systems recovered from X16A and X16B.

QAS

Quick x-ray Absorption and Scattering (QAS) on 7-BM had its first light in September 2017 and plans to take general users in 2018.

Its vertically collimating mirror and bender came from X7B, while the mirror's motorized motions came from X6B. Motions were retrofitted with absolute encoders and wiring changed to interface with the standard NSLS-II control system. The mirror was stripped and recoated with Rh and Pt stripes and cooling was added.

The monochromator, originally from X18A, was modified with a new drive. Originally, the Bragg axis was driven by DC motor and cam for fast scans and a stepper for slow ones. Instead, it was modified with direct drive servomotor NMR-FEFBA2C122AP and NSR-REML1A-10 rotary encoder with 3.6 Mct/rot, both from NIKKI DENSO. The motor is driven by VC II D-type AC servo driver (NCR-DDAOA2A-152) and controlled by Power Brick via DAC output signal. Wiring diagram is shown on Fig. 5 and upgraded monochromator on Fig.6.

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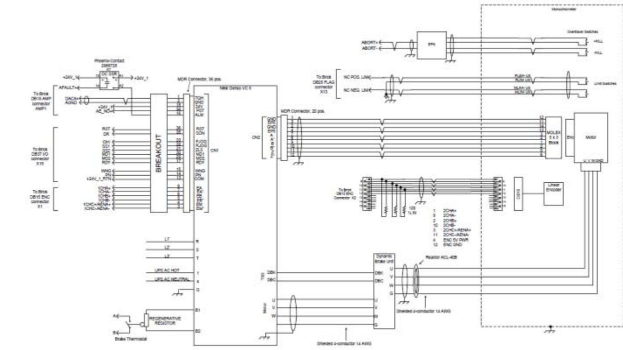

Figure 5: Wiring diagram of new direct drive motor, AC servo driver and Power Brick.

The toroidal mirror and a chamber came from X21, while the stand and motions came from X6A. The mirror was stripped and recoated from Pt to Rh, motions rewired and easily blended with NSLS-II control system.

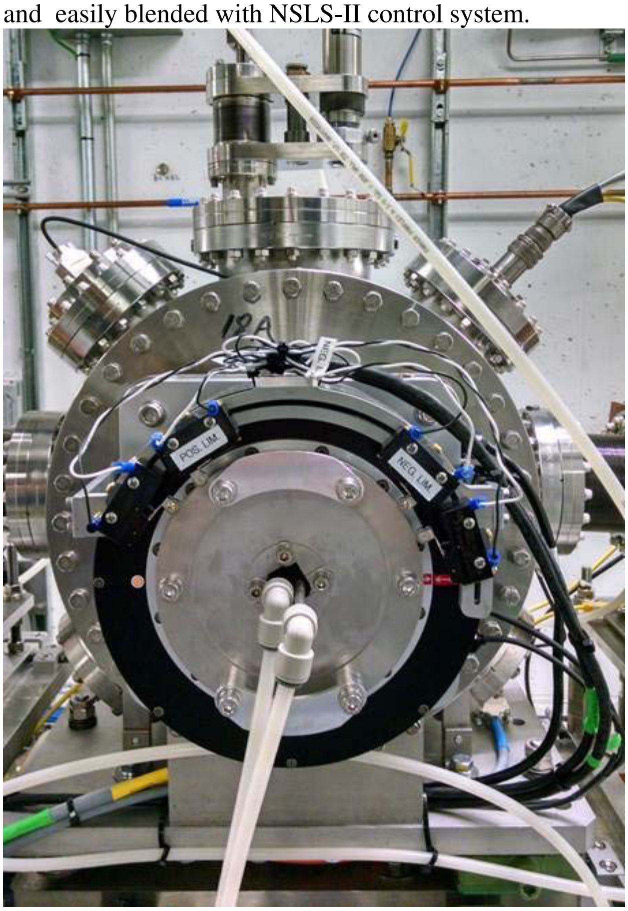

Figure 6: QAS Monochromator retrofitted with Direct Drive servomotor from NIKKI DENSO.

QAS is almost entirely built from NSLS components. Ion pump controllers' firmware was upgraded to successfully work with EPICS drivers developed for the newer models. In addition, this beamline has all ion pumps, gate valves, right angle valves, bellows and viewports collected from NSLS, a six motion end station table from X29 and a Be window from X4.

For the end-station QAS is planning to integrate a reclaimed Perkin Elmer 1621 area detector from X18A and new PCIe card, a Vortex-ME 4 element Si-drift detector from X18 and X19 with new Xspress-3 electronics from Quantum Detectors, salvaged ion chambers, Canberra PIPS from X18A with Keithley current amplifiers and home designed Pizza box [5] with 8 A-D channels.

FIS/MET

Frontier Synchrotron Infrared Spectroscopy (FIS)/Magnetospectroscopy Ellipsometry and Time-Resolved Optical Spectroscopies (MET), 22-IR is being built now to be completed in 2018.

FIS/MET equipment came from NSLS infrared programs at beamlines U2A, U4IR and U12IR. The items include the spectrometers (commercial Fourier Transform Infrared instruments from Bruker Optics), 10T magnet cryostat, a custom Müller-Matrix ellipsometer and an infrared microscope, many infrared detectors, plus a number of infrared mirrors to be used in the endstation, large vacuum gate valves, fast vacuum shutters and six Procilica cameras. Müller-Matrix ellipsometer is shown on Fig. 7. Specialized equipment included diamond anvil cells (DACs) for studying materials at extreme pressure and supporting instruments for performing Raman spectroscopy and ruby fluorescence for pressure calibration.

FIS/MET plans to procure six IR mirrors for photon delivery, four of which to be positioned inside the ratchet wall, and have at least 6 GigE cameras for beam diagnostic.

The unique beamline specialization will use a number of custom instruments with a diverse control support, developed and built by IR user groups across the globe. One of them, Müller-Matrix ellipsometer, made by the group of Prof. Andrei Sirenko from New Jersey Institute of Technology delivers a unique functionality to extract electric and magnetic property of a sample, while scanning across energies and polarization [6]. Polarization State Generator (PSG) and Polarization State Analyser (PSA) chambers enclose many motorized optical components.

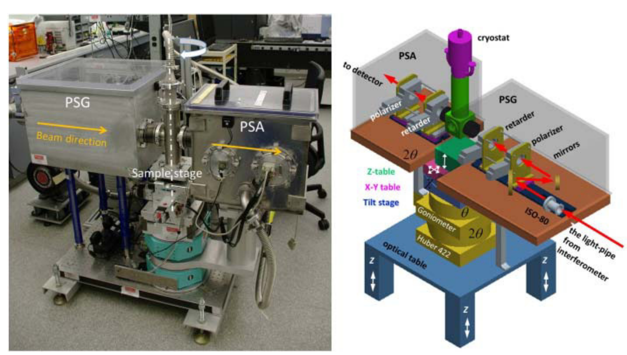

Figure 7: Müller-Matrix ellipsometer‡ with Polarization. State Generator (PSG) and Polarization State Analyser (PSA) [6].

‡ The development of the Ellipsometer was supported by NSF under Grant No. DMR-0821224.

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Controls for this instrument are done via LabVIEW. It includes many custom algorithms developed and tested at different stages of the instrument's life. The challenge for such custom instruments is to seamlessly blend them with standard NSLS-II control system, incorporating all partners' contribution to the beamline capabilities.

PDF

Total Scattering Beamline Pair Distribution Function (PDF) is being built now to be completed in 2018. Most PDF components are brand new, state of art instruments with high automation, yet some of the expensive sample environment equipment came from NSLS: Oxford Cryostream 80-500 K, Cryo Industries of America (CIA) liquid He cryostat 5-500 K, superconductive magnet 0 – 5 T. The super conductive magnet was purchased in 2013 for the joint research with Condense Matter Physics and Material Science Department (CMPMSD) †. When deployed, the experiment will allow changing temperature and magnetic field at the same time. See Fig.8.

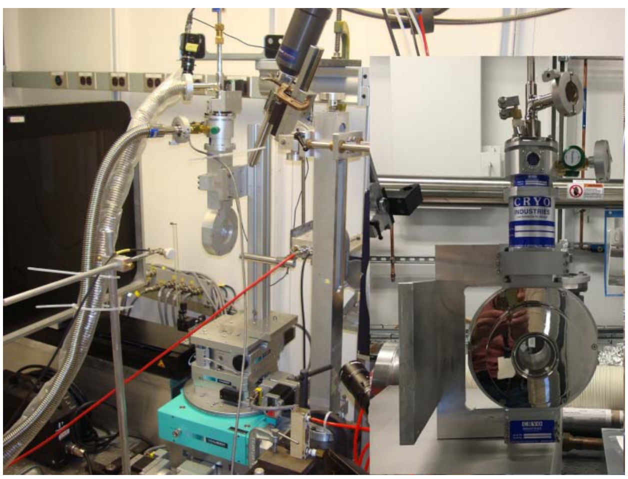

Figure 8: 5K cryostat on the left, and superconducting 5T magnet on the right, both from Cryo Industries of America (CIA), to be combined in a unique sample environment.

Optical table with four motorized motions, Huber motion stack x, y, yaw will be enhanced with new z motion from the same vendor.

CONCLUSION

Reused, rebuilt, or refurbished scientific equipment sometimes decades old can be successfully retrofitted with modern controls solutions and customized to fit the control system standards.

This then brings the component up to current specifications and gives the design a long life and the world class performance.

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