Commissioning Plan

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Prepared by:

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Steven N. Ehrlich

QAS Lead Beamline Scientist
Signed by: Ehrlich, Steven

Approved by:

8/25/2017

Paul Zschack
Photon Science Division Director
Signed by: Zschack, Paul

By approving this plan I acknowledge the requirements set forth herein and agree with its implementation.
## Revision History

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<tr>
<td>1</td>
<td>First Issue.</td>
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## Acronyms

<table>
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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>3PW</td>
<td>Three Pole Wiggler</td>
<td>NSLS-II</td>
<td>National Synchrotron Light Source II</td>
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<td>BNL</td>
<td>Brookhaven National Laboratory</td>
<td>PASS</td>
<td>Proposal, Allocation, Safety and Scheduling</td>
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<td>BRS</td>
<td>Bremsstrahlung Stop</td>
<td>PBS</td>
<td>Pink Beam Stop</td>
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<td>CO</td>
<td>Bremsstrahlung Collimator</td>
<td>PCM</td>
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<td>CSS</td>
<td>Control System Studio</td>
<td>PFM</td>
<td>Photon Focusing Mirror</td>
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<td>DCM</td>
<td>Double Crystal Monochromator</td>
<td>PMAC</td>
<td>Programmable Multi-Axis Controller</td>
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<td>DCR</td>
<td>Diagnostic Cross</td>
<td>PPS</td>
<td>Personnel Protection System</td>
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<td>DM</td>
<td>Diagnostic Module</td>
<td>PSD</td>
<td>Photon Science Division</td>
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<td>EPICS</td>
<td>Experimental Physics Industrial Control System</td>
<td>PSH</td>
<td>Photon Shutter</td>
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<td>EPS</td>
<td>Equipment Protection System</td>
<td>QAS</td>
<td>Quick x-ray Absorption and Scattering</td>
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<td>EXAFS</td>
<td>Extended X-ray Absorption Fine Structure</td>
<td>SAF</td>
<td>Safety Approval Form</td>
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<td>FE</td>
<td>Front End</td>
<td>SGB</td>
<td>Secondary Gas Bremsstrahlung</td>
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<tr>
<td>FLUKA</td>
<td>Fluktuiierende Kaskade (Monte Carlo simulation software)</td>
<td>SLT</td>
<td>X-Y slits</td>
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<td>FOE</td>
<td>First Optics Enclosure</td>
<td>SR</td>
<td>Synchrotron Radiation</td>
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<td>GB</td>
<td>Gas Bremsstrahlung</td>
<td>TCP</td>
<td>Technical Commissioning Plan</td>
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<td>IRR</td>
<td>Instrument Readiness Review</td>
<td>WIN</td>
<td>Window</td>
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<tr>
<td>mA</td>
<td>milli-Ampere</td>
<td>XAS</td>
<td>X-ray Absorption Spectroscopy</td>
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<td>Mask</td>
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1.0 INTRODUCTION

This plan outlines the actions needed to commission the NSLS-II BDN 07-BM Beamline (QAS) from the accelerator enclosure ratchet wall to the end station. Once the readiness process is complete, and authorization to begin commissioning the beamline is received, the technical commissioning will proceed and focus on delivery of photon beam to the experimental station. There are several processes established to manage the risks associated with this task, which is outlined below.

The scope of this plan includes managing specific commissioning activities for the QAS beamline, a brief review of operational equipment requirements, and a plan for transitioning to operations. Technical commissioning of the FEs and the 3PW is managed separately from the beamline. Beamline optics in the FE are considered part of the beamline photon delivery system.

2.0 SHIELDING

Ray tracing and computer modeling (FLUKA) indicate that 07-BM is shielded for the maximum planned stored electron beam current of 500 mA. The primary Gas Bremsstrahlung ray traces have been completed in accordance with Synchrotron and Bremsstrahlung Ray Trace Procedure (PS-CXFD-PRC-008) and Insertion Device Front End Ray Tracing Procedure (PS-C-ASD-PRC-147) and analyzed for top-off safety (NSL SII-TOS-RPT-014). All Synchrotron white beam is contained within the FE, stopped by fixed mask 3, and all primary GB is stopped in the FOE by collimator 1. The scattering of Bremsstrahlung has been modeled using FLUKA, which showed that the no secondary shields are required up to 500 mA beam current. The summary of these simulations including the simulation of the monochromatic beam containment in beam transport and end station enclosures are provided in 7-BM QAS Beamline Radiation Shielding Analysis (Tech Note #260).

3.0 BEAMLINE COMMISSIONING SEQUENCE

The commissioning of the QAS beamline and its transition to operations begins with the IRR. This will be followed by the first phase of the Technical Commissioning Plan (TCP) in which the electron beam current is gradually increased while monitoring equipment safety. The TCP is conducted in parallel with Radiation Survey Commissioning, which monitors radiation safety as the electron beam current is increased. When the beamline equipment has been demonstrated to be capable of safely operating during standard x-ray operations, there is a final comprehensive radiation survey. The TCP then moves on to a new phase. This begins with a full functional test of all key components with beam in order to confirm their correct response; then all the key
optical components such as the mirrors and monochromator are commissioned in detail in order to determine optimal operating parameters. In the final phase of the TCP, the end station is commissioned. Scientific commissioning will then follow with the participation of expert users, to verify that the beamline meets the design performance goals, and to build up end station and beamline parameters, and configurations that optimize beamline performance for routine user operations. It is expected that different capabilities of the beamline will be used at different stages of technical and scientific commissioning during the overall commissioning phase.

3.1 Radiation Survey Commissioning

A comprehensive Beamline QAS (07-BM) Radiation Survey Procedure (NSLSII-7BM-PRC-001) was developed in accordance with NSLS-II Beamlines Radiation Safety Commissioning Plan (PS-C-XFD-PRC-004), which guides the steps needed to control radiological hazards. It includes specific hold points to manage identified radiation risks and maintain commissioning within an approved envelope. The Radiation Survey Procedure requires participation and coordination between Beamline, Operations, Radiological Control, and ESH Staff. It identifies specific radiation scatter points along the beamline and provides instruction for mechanical manipulation of the optics to allow for a comprehensive radiological survey along the beamline. Execution of the Radiation Survey Procedure, along with the evaluation of the data collected, will be used as a basis by the PSD Director and ESH Manager to approve commissioning activities at an electron beam current of up to 3 times the electron beam current measured during the survey. Approval of commissioning of the beamline at a higher electron beam current requires re-execution of the Radiation Survey Procedure. The maximum current allowed during commissioning is indicated on the Caution Tag that is applied by Operations Staff to the beamline enable key. Enabling the beamline at a higher current requires re-execution of the full Radiation Survey Procedure and re-approval by the PSD Director and ESH Manager.

3.2 Technical Commissioning

The TCP, described in Section 7 below, documents in some detail the sequence of activities planned to safely commission the beamline. The TCP starts with the lowest ring current and it gradually increases ring current until it reaches the value for standard operations. At the completion of TCP, all major beamline components will be ready to use and parameters that optimize their performance will be documented.

3.3 Science Commissioning

The QAS beamline has an end station that will enable x-ray absorption spectroscopy and x-ray diffraction experiments in the 4.7-31 keV energy range and under various in-situ or operando sample conditions. A scientific commissioning plan will be developed while the technical commissioning takes place. The goal of scientific commissioning will be to define the beamline
parameters and configurations needed for the anticipated scientific program and to develop the process for bringing the complete beamline into routine operations for users.

4.0 COMMISSIONING ACTIVITY APPROVAL

Work planning needed for safe and efficient commissioning, requires a commissioning SAF and is performed in accordance with *Experiment Safety Review* (PS-C-ESH-PRC-039). This process drives definition of scope, identification of hazards and controls, and review and approval requirements for all commissioning activities. A commissioning SAF describing the commissioning tasks to be undertaken by the commissioning team will be submitted. This form will include the equipment and materials that will be used, the personnel authorized to participate in the commissioning, and any controls that will be placed on the beamline (such as a current limit). This form will be submitted to the ESH Manager and PSD Director for approval. This commissioning activity approval process authorizes the commissioning team for a specific task or tasks (such as performing a radiation survey) thereby enforcing a step-by-step and HOLD point approach to commissioning. Most commissioning tasks are expected to take approximately one week to complete, though some may be longer. All commissioning activities will be reviewed on a weekly basis to determine if a new commissioning SAF is needed. This allows for flexibility in the commissioning process, but at the same time ensures that during commissioning the work is periodically reviewed and that the necessary controls are placed on the commissioning activities.

An approved commissioning SAF is required for the beamline to be enabled. Beamline enable is managed in accordance with *Enabling Beamlines for Operations* (PS-C-XFD-PRC-003). This procedure defines the process for enabling the beamline safety shutter and for giving control of that shutter to the Beamline Staff. The process requires participation and coordination between Beamline, Operations, and ESH Staff. A checklist is employed to assure systems are ready (PPS and safety system configuration control) and that staff is prepared to begin.

5.0 BEAMLINE EQUIPMENT ADDITIONS

Experimental modules and automation equipment will be added to the end station as commissioning moves from technical to scientific, and the focus is shifted to optimizing the photon beam and preparing end station instrumentation for the expected scientific program. All equipment will be added in accordance with the *NSLS-II Process Description: Review Process for Facility Additions and Modifications* (PS-C-CMD-PLN-001), which provides a process for determining the type and extent of reviews warranted.
The tailored review plan for the end station equipment is currently under preparation and will be developed in accordance with the *NSLS-II Process Description: Review Process for Facility Additions and Modifications* (PS-C-CMD-PLN-001).

### 6.0 **End of Commissioning; Transition to Operations**

Commissioning ends when the beamline has shown, through the execution of procedures and surveys that it meets the NSLS-II shielding policy, that radiation leakage or scatter is controlled to as low as reasonably achievable, that the photon beam is ready for data collection, and that the necessary authorizations for beginning operations have been obtained. Prior to the beamlines commencing User Operations, the process outlined in *Beamline User Readiness* (PS-C-XFD-PRC-030) will be completed.

The safety of ongoing beamline operations will be managed with the *Experiment Safety Review* (PS-CESH-PRC-039) process, which will control materials, equipment, and tasks at the end station areas through the use of the BNL electronic ESR system. A Cognizant Space Manager is assigned to the area and has responsibility to assure that the system is current and accurate. This system provides a valuable envelope for the resources and allows operations at each location.

Individual experiments will be managed with the electronic SAF section of PASS; a system for Proposal, Allocation, Safety, and Scheduling for User science. The SAF will allow collection of information specific to each experiment and will be reviewed by NSLS-II Staff to determine what hazards are outside the safety envelope established. The SAF will provide the mechanism for definition of scope, analysis of hazards, establishment of controls, and collection of feedback for each experiment. Users must identify the materials and equipment they wish to bring along with a task analysis describing how those items will be used. An iterative review between the User, Beamline, and ESH Staff results in a final approval with definition of requirements.

The SAF process combined with the BNL ESR safety envelope provides the basis needed to assure ongoing control of beamline operation and changes. No additional readiness reviews are expected for the 07-BM beamline at this time.
7.0 QAS BEAMLINE TECHNICAL COMMISSIONING PLAN

7.1 QAS Beamline Subsystem Definitions

1. FE Mirror System
   - Mirror (PCM) chamber with ion pump

2. Beamline Vacuum System
   - Cross with ion pump 1 (IP1)
   - X-Y slits (SLT1) with ion pump 2 (IP2)
   - Monochromator (DCM) with ion pump 3 (IP3)
   - Mirror (PFM) with ion pump 4 (IP4)
   - Diagnostic cross (DCR1) with ion pump 5 (IP5)
   - Beam transport pipe between hutch A and B with ion pump 6 (IP6)
   - Be window (WIN1) inside hutch B (7-BM-B) terminates beamline vacuum

3. Photon Delivery System
   - Vertically collimating/harmonic rejection, water-cooled mirror (PCM) in FE
   - X-Y slits assembly (SLT1), water-cooled, with 4-jaws and drain current monitoring
   - Double-crystal water-cooled monochromator (DCM)
   - Toroidal focusing mirror (PFM)
   - Photon shutter (PSH)
   - Be window beamline termination (WIN1) in hutch B

4. Diagnostics
   - Water cooled fluorescent screens in fixed mask 2 in FE
   - Diagnostic cross with pneumatically inserted water-cooled fluorescent screen in FE
   - Drain current monitoring on X-Y slit assembly (SLT1)
   - Diagnostic (inserted water-cooled fluorescent screen) in monochromator chamber
   - Diagnostic cross (DCR1) with pneumatically inserted uncooled fluorescent screen
   - Fluorescent screen in end station
   - Ion chamber in end station

5. End Station Instrumentation
   - Experimental table including detectors and sample positioning system in hutch B
   - Hutch utilities including integration to XAS and XRD stations

6. Beamline Controls System

7. Equipment Protection System (EPS)
7.2 QAS Beamline Commissioning without Beam

The following activities are performed without requiring beam. Many of these are completed during installation and are captured in the Traveler process for each component, but are confirmed in this plan.

7.2.1 Vacuum Systems

1. Verify that all ion pumps and vacuum gauges are functional.
2. Pump down each vacuum section. Perform vacuum leak checking and remediate any deficiencies.
3. Verify the motion of the various beam diagnostics.
4. Verify water flow in the cooling systems for PCM, MSK1, SLT1, MSK2, DCM/diagnostic and PBS1 using flow meters integrated into the EPS.
5. Verify the functionality of the EPS system in response to vacuum failures by simulating trip signals from the vacuum gauge controllers.

7.2.2 EPS and PPS

1. Verify the function of the EPS in response to temperature faults on water-cooled components.
2. Test the photon shutter and verify that the PPS is operational.

7.2.3 PCM (in FE)

1. Verify motions of all motor axes.
2. Verify functionality of thermocouples.
3. Place mirror in nominal position based on survey results obtained during installation, unless required to be moved for radiation surveys.

7.2.4 SLT1

1. Verify motions of all motor axes.
2. Verify functionality of thermocouples and drain current signals.

7.2.5 DCM

1. Verify motions of all motor axes, Bragg and second crystal tilt.
2. Verify function of thermocouple.
3. Place Bragg motion in nominal position based on survey results during installation.
7.2.6 **PFM**

1. Verify motions of all motor axes.
2. Place mirror in its nominal position based on the survey results obtained during installation, unless required to be removed from beam for initial radiation surveys.

7.2.7 **Beamline Diagnostics**

1. Verify all motions.
2. Verify all signal connections, read-outs, and cameras to the extent possible without beam.
3. Verify that all diagnostic cameras are aligned and in focus based on visible references.
4. Verify that EPICS PVs exist for all diagnostic signals.

7.2.8 **End Station Systems**

1. Incident beam path:
   - Verify motion of incident beam path vertical translation, and verify that the range of motion is adequate for both focused and unfocused configurations.
   - Verify all motor motion axes of X-Y slits.
2. Experimental Table:
   - Verify all motor motion axes.
   - Place table in its nominal position.
3. Sample stage:
   - Verify all motor motion axes.
4. Detectors:
   - Verify all connections.
   - Verify signal chain functions properly for commissioning activities.

7.2.9 **Control System**

1. Verify existence of engineering control screens for all beamline axes.
2. Verify alignment, focus, and video capture of all cameras and verify existence of engineering screens for camera control.
7.3 QAS Technical Commissioning with Beam

7.3.1 Pre-start Commissioning Activities
The 07-BM FE has been installed and will be commissioned in collaboration with the Accelerator Division in September 2017. Since beamline optics are integrated into the 7-BM Front End, FE commissioning will be conducted in combination with Beamline commissioning.

Prior to the beamline commissioning activities, the following prerequisites shall be satisfied:

- IRR completed and pre-start findings closed
- PPS and EPS are functional
- Accelerator operating at a current determined by the Accelerator Division
- FE slits controllable by the beamline control system, slit current reading is functional
- Cameras connected and working to align beam with respect to diagnostic screens
- Beamline control environment in place with basic capabilities (including motor control and scanning, vacuum monitoring) and basic graphics and user interface
- For a given commissioning-with-beam activity, relevant commissioning-without-beam activities are completed.

7.3.2 First Light Commissioning and Radiation Surveys
Accelerator studies time is required to conduct Gas Bremsstrahlung (GB) and Synchrotron white, pink and monochromatic beam radiation (SR) surveys as described in the radiation survey procedure (NSLSII-7BM-PRC-001). These radiation surveys are initially carried out at low electron beam currents; a succession of successful radiation surveys will allow increasing the electron current with the goal to rapidly obtain authorization to operate the beamline during regular accelerator operations for the purpose of beamline optics commissioning, beam characterization, and end station commissioning.

It should be noted that due to the mirror in the 07-BM FE, all Synchrotron white beam is stopped inside the FE. In addition, all primary GB is stopped by collimator 1/Bremsstrahlung stop (CO1/BRS) immediately downstream of the ratchet wall. Thus, upon the opening of the FE photon and safety shutters, only pink beam enters the FOE and strikes the monochromator as the first optical component. During the GB/SR radiation survey, the monochromator and the mirrors are set to their nominal configurations based on the survey results obtained during installation; FE, FOE, and end station slits shall be open; and diagnostic fluorescence screens and cameras will be used to visualize and verify the presence of beam.
7.3.3 Commissioning of the Photon Delivery System

Prerequisites:

Preliminary commissioning phase of the FE:

- Primary FE slits scans and alignment with electrometer drain current signals
- Vacuum conditioning

Goals of Beamline Optics Commissioning:

The goal is to achieve complete control and understanding of beamline optics operation, energy selection, beamline alignment procedure, and beamline optimization for different experimental configurations.

Start with all shutters closed, both x-y slits closed and collimating and focusing mirror out of beam path.

7.3.3.1 Basic Alignment

- Basic testing and alignment of FE slits
  - PCM retracted from beam.
  - Open BMPS and confirm that beam is hitting FE X-Y slits using drain current measurements.
  - Use the drain current measurements from the slit blades to check the beam center position for each of the 4 slit blade axes.
  - Open FE X-Y slits slowly and check beam dimensions and position using fluorescent screen on fixed mask 2, just downstream of collimating mirror PCM.
  - Adjust the slit openings to set the nominal beam acceptance to 2.0 mrad H x 0.3 mrad V.

- Basic alignment of collimating mirror PCM
  - Insert fluorescent screen in FE diagnostic cross.
  - Set horizontal position of PCM so beam center, as surveyed, aligns with Rh stripe.
  - Raise upstream end of PCM so that beam hits disaster mask in order to test thermocouples on mask.
  - Monitoring thermocouples on PCM substrate, set nominal angle of PCM and raise into beam so light reflects off of the PCM. Set nominal position based on survey results and check beam trajectory using fluorescent screens in fixed mask 2 and the FE diagnostic cross. Verify that beam follows correct trajectory.
o Adjust motions to optimize reflected beam.

o Adjust FE vertical slits so beam footprint fits within length of PCM.

o Set horizontal position of PCM to reflect off Pt stripe and readjust motions, if necessary, to optimize reflected beam. Check and record alignment parameters.

- Testing and alignment of FOE slits
  
  o Retract fluorescent screen in FE diagnostic cross.
  
  o Open FE shutters.
  
  o Confirm that beam has penetrated ratchet wall and is hitting FOE X-Y slits using drain current measurements.
  
  o Check thermocouples and drain current on individual slit jaws.
  
  o Check center of FOE X-Y slits using beam and drain current signals.
  
  o Using FE and FOE vertical slit positions, adjust bend of PCM so beam is roughly collimated in the vertical.

- Optimization of Monochromator
  
  o Begin with Bragg angle for energy near 10 keV.
  
  o Open FOE x-y slits slowly to bring light to the monochromator using the fluorescence screen in the monochromator chamber and DCR1.
  
  o Monitor the thermocouple on the monochromator.
  
  o Check that beam is hitting first monochromator crystal in correct position.
  
  o The pitch of the second crystal will be adjusted as needed to maximize flux as seen on the monochromator diagnostic screen.
  
  o Remove monochromator diagnostic screen and observe beam on DCR1.

- Transport of beam into hutch B
  
  o Retract DCR1 fluorescent screen.
  
  o Open X-Y slits in hutch B and open FOE photon shutter.
  
  o Observe beam on fluorescent screen in hutch B.
  
  o Verify this for several monochromator angles.
  
  o Check operation of hutch B X-Y slits.
  
  o Measure beam with ion chamber.
• Alignment and characterization of toroidal mirror PFM
  o Insert DCR1 fluorescent screen.
  o Observe unfocused beam on DCR1 fluorescent screen
  o Raise upstream end of PFM to block half of beam in order to confirm surveyed height.
  o Raise downstream end of PFM to align mirror with center of beam. Observe on DCR1 fluorescent screen.
  o Set pitch to nominal 2.135 mrad by lowering upstream end and raising downstream end appropriate amounts, observing reflected beam on DCR1 fluorescent screen.
  o Adjust mirror yaw to center mirror horizontally.
  o Retract DCR1 fluorescent screen, open hutch B slits and observe focused beam on fluorescent screen in hutch B at sample position.
  o Using fluorescent screen at sample position optimize focus of beam using mirror motions.
  o Bend mirror and observe focus using fluorescent screen in hutch B.

7.3.3.2 Specific Optimization and Characterization

• Optimize Collimating Mirror
  o Borrow crystal spectrometer from Joe Dvorak to measure energy resolution of unfocused beam in hutch B.
  o Adjust the bend of the collimating mirror to maximize energy resolution.
  o Repeat at different monochromator energies.

• Characterize monochromator
  o Move to different Bragg angles between 3.6 and 25 degrees and monitor vacuum and thermocouple readings, beam position and intensity.
  o Run monochromator in continuous mode and measure stability and quality of data.
  o Using ion chambers and foils perform energy calibrations using absorption edges in the 4.7 – 30 keV range.
  o Monitor the effect of vibration on beam stability. Correlate with cooling water if necessary.
  o Test and optimize different scanning speeds at different energies.
- Implement digital pizza box in monochromator encoder chain.

- **Optimize Focusing Mirror**
  - Optimize vertical height and pitch of focusing mirror using vertical stages and observe beam shape at each downstream diagnostic screen.
  - Optimize horizontal alignment of focusing mirror and observe beam shape at each downstream diagnostic screen.
  - Scan slit at sample position through focused beam horizontally and vertically; minimize hot spot and maximize flux of focused beam using mirror motions.
  - Repeat measurements at different Bragg angles between 3.6 and 25 degrees.

### 7.3.3.3 End station commissioning with beam

This section covers aspects of the end station and data acquisition system that require commissioning with beam.

- **Detectors**
  - Confirm connections and functionality of detectors.
  - Install and optimize gridded ion chambers.
  - Implement ionization chambers with analog pizza boxes.
  - Implement SDDs with Xpress3 detector electronics and optimize.
  - Optimize and characterize area detector on its mount with LaB₆ reference powder at different energies, different detector heights and different detector-sample distances with both focused and unfocused beam.
  - Test hardware synchronization of energy scanning with detector acquisition.
  - Using well-characterized reference standards, evaluate detection sensitivity vs. background.
Appendix A: QAS FE and FOE Components

QAS 07-BM FE Components

QAS 07-BM FOE Components