RSI* for the Frontends

for BM Port Beamlines

(*Requirements, Specifications, and list of Interfaces)

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Version 3

2014 November 20
VERSION CONTROL LOG

<table>
<thead>
<tr>
<th>VERSION</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>AUTHOR</th>
<th>APPROVED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First release</td>
<td>2013 April 30</td>
<td>J. Keister</td>
<td>See p. iii.</td>
</tr>
<tr>
<td>2</td>
<td>Full revision</td>
<td>2014 March 25</td>
<td>J Adams</td>
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</tr>
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<td>3</td>
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<td>2014 November 07</td>
<td>J Bohon, J Adams</td>
<td>See p. iii.</td>
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</table>

List of Acronyms

3PW Three-Pole Wiggler
BC Bremsstrahlung Collimator
BM Bending Magnet
BMPS Bending Magnet Photon Shutter
BPM Beam Position Monitor
CED Cost Estimate Database
EPS Equipment Protection System
EPICS Experimental Physics and Industrial Control System
MSK Fixed Mask
FE Front End
FV Fast Valve
GV Gate Valve
ID Insertion Device
PLC Programmable Logic Controller
PSD Photon Sciences Directorate
PSH Photon Shutter
RSI Requirements, Specifications, and list of Interfaces
SR Synchrotron Radiation
SS Safety Shutter
WIN Window (typically beryllium)
WBS Work Breakdown Structure
XBPM X-ray Beam Position Monitor (not necessarily blade type, in this context)
Document Approvals

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1 DOCUMENT CONTROL

1.1 Identification

This document, RSI for the Frontends for BM Port Beamlines, is part of the Requirement Specification and Interface (RSI) documentation system, mapping to the NxtGen project Work Breakdown Structure (WBS) and Cost Estimate Database (CED). It captures and summarizes three-pole wiggler and x-ray bending magnet Frontends, and lists all related technical interfaces with other parts of the systems.

1.2 Scope

This document describes the frontends for five BM port x-ray beamlines utilizing BM and 3PW sources. These frontends support beamline optics (mirrors) and diagnostics, subject to safety, vacuum, and access considerations.

2 SOURCES FOR THE BEAMLINES

The source data for the beamlines are listed in the following table.

Table 2.1: Sources for BM port beamlines.

<table>
<thead>
<tr>
<th>Source Location</th>
<th>CMS</th>
<th>QAS</th>
<th>TES</th>
<th>XFM</th>
<th>XFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Location</td>
<td>366 mm upstream of 11-BM-B</td>
<td>366 mm upstream of 7-BM-B</td>
<td>8-BM-B</td>
<td>366 mm upstream of 4-BM-B</td>
<td>366 mm upstream of 17-BM-B</td>
</tr>
<tr>
<td>Front end allocation</td>
<td>11-BM</td>
<td>7-BM</td>
<td>8-BM</td>
<td>4-BM</td>
<td>17-BM</td>
</tr>
<tr>
<td>Floor space allocation</td>
<td>11-BM</td>
<td>7-BM</td>
<td>8-BM</td>
<td>4-BM</td>
<td>17-BM</td>
</tr>
<tr>
<td>Source Type</td>
<td>3PW</td>
<td>3PW</td>
<td>BM</td>
<td>3PW</td>
<td>3PW</td>
</tr>
<tr>
<td>Usable photon energy range</td>
<td>10-17 keV</td>
<td>4.5-31 keV</td>
<td>1 – 8 keV</td>
<td>2.3-23 keV</td>
<td>5-20 keV</td>
</tr>
<tr>
<td>Photon source point location / centerline definition</td>
<td>3PW</td>
<td>3PW</td>
<td>3.25 mrad downstream of start of BM-B ^1</td>
<td>3PW</td>
<td>3PW</td>
</tr>
<tr>
<td>Nominal magnetic field at source location ^2</td>
<td>1.2 T</td>
<td>1.2 T</td>
<td>0.40 T</td>
<td>1.2 T</td>
<td>1.2 T</td>
</tr>
<tr>
<td>Nominal source fan width ^2</td>
<td>~3 mrad</td>
<td>~3 mrad</td>
<td>~3 mrad</td>
<td>~3 mrad</td>
<td>~3 mrad</td>
</tr>
<tr>
<td>Max fan power (500 mA ring current) ^2</td>
<td>250 W</td>
<td>250 W</td>
<td>69 W</td>
<td>250 W</td>
<td>250 W</td>
</tr>
<tr>
<td>Max power density within aperture ^2</td>
<td>365 W/mrad^2</td>
<td>365 W/mrad^2</td>
<td>115 W/mrad^2</td>
<td>365 W/mrad^2</td>
<td>365 W/mrad^2</td>
</tr>
</tbody>
</table>

Note 1: For standard BM radius 25.02 m, 3.25 mrad ≈ 81 mm arc length. Offset between 3PW center and 3.25 mrad BM source point is ≈ 366 + 81 = 447 mm. 3PW location is 25 mm further upstream on cells 3, 13, and 23.

Note 2: Informational only. Existing 3PW design, with >1 T for >2 mrad, provides >3 mrad radiation fan at 10 keV photon energy (includes side pole radiation). 3mrad maximum fan for 3PW or BM source is defined by fixed absorbers and/or masks. The standard 18.3 mm crotch aperture is assumed for all beamlines (total >6 mrad / 340 W).
3 FRONT END COMPONENTS FOR THE BEAMLINES

The components listed in Table 3.1 shall be included as a part of the front ends for the beamlines. Many of the front ends include front end optics (mirrors).

Table 3.1: Front End components for BM port beamlines.

<table>
<thead>
<tr>
<th>Location</th>
<th>Comment</th>
<th>CMS</th>
<th>QAS</th>
<th>TES</th>
<th>XFM</th>
<th>XFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical acceptance (mrad)</td>
<td>The frontend shall define the SR beam at the most upstream location possible</td>
<td>0.15</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Horizontal acceptance (mrad)</td>
<td></td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>Crotch absorber</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Photon shutter</td>
<td>Standard, Machine operation only</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Gate Valve (GV)</td>
<td>Standard</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Fixed Mask</td>
<td>Standard</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Vertical aperture (mrad)</td>
<td></td>
<td>0.15</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Horizontal aperture (mrad)</td>
<td></td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>Bremsstrahlung</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Collimator BC1</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Water-Cooled Beryllium Window</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Fast Valve (FV)</td>
<td></td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>X-Y Slit set</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Mirror system</td>
<td></td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Mirror material</td>
<td></td>
<td>N/A</td>
<td>Silicon</td>
<td>Silicon</td>
<td>N/A</td>
<td>Silicon</td>
</tr>
<tr>
<td>Mirror attitude</td>
<td>TES have two mirrors; large angles are used for soft x-rays.</td>
<td>N/A</td>
<td>Vert. up</td>
<td>2: V Dn, V Up</td>
<td>N/A</td>
<td>Vert. up</td>
</tr>
<tr>
<td>Mirror size (LxW, m)</td>
<td></td>
<td>N/A</td>
<td>1.4 x 0.1</td>
<td>(0.8,1.2) x 0.1, 0.07</td>
<td>N/A</td>
<td>1.1 x 0.1</td>
</tr>
<tr>
<td>Mirror figure</td>
<td></td>
<td>N/A</td>
<td>Cylinder</td>
<td>Cylinder, flat</td>
<td>N/A</td>
<td>Toroid</td>
</tr>
<tr>
<td>Mirror incident angle (mrad)</td>
<td></td>
<td>N/A</td>
<td>2.7</td>
<td>6-20</td>
<td>N/A</td>
<td>4.2</td>
</tr>
<tr>
<td>Mirror acceptance (mrad V)</td>
<td></td>
<td>N/A</td>
<td>0.3</td>
<td>0.4</td>
<td>N/A</td>
<td>0.4</td>
</tr>
<tr>
<td>Mirror acceptance (mrad H)</td>
<td></td>
<td>N/A</td>
<td>3.0</td>
<td>2.5</td>
<td>N/A</td>
<td>3.0</td>
</tr>
<tr>
<td>Mirror center position(s)</td>
<td></td>
<td>N/A</td>
<td>11.7</td>
<td>11.0, 12.3 (25.0 mm offset)</td>
<td>N/A</td>
<td>14</td>
</tr>
<tr>
<td>Fixed Mask 2</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
### 3.1 Photon Shutter (BMPS)

The BMPS is designed to protect the GV from BM/3PW radiation. It is under accelerator control and not for routine beamline use.

### 3.2 Gate Valve(s) (GV)

The Gate valve is included to isolate the machine and FE, but will not withstand white beam from 3PW or BM radiation. All GV’s are integrated into the machine EPS using a voting scheme with inputs from vacuum sensors at both sides of the valves and the position of the BMPS.

### 3.3 Fixed Masks (MSK)

The fixed masks shall be water cooled and interlocked to the machine EPS. Each mask shall be sized to intersect the white or pink beam and deliver the required synchrotron radiation to the beamline FOE.

### 3.4 Bremsstrahlung Collimators (BC1, 2, & Ratchet Wall Collimator)

The bremsstrahlung collimators shall restrict the bremsstrahlung radiation (both primary and secondary) exiting the shield wall. Bremsstrahlung collimators shall be out-of-vacuum lead design. The Bremsstrahlung collimators shall collimate with the smallest custom size aperture possible as defined by the SR ray tracing.

### 3.5 X-Y Slits

The X-Y slits shall be of water-cooled, normal incidence design, allowing full independent adjustment of all four blades. The specifications are as follows:

<table>
<thead>
<tr>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2 mm tungsten blades (stopping 99.997% of photons with energy of up to 50 keV)</td>
</tr>
<tr>
<td>UHV / water-cooled assembly</td>
</tr>
<tr>
<td>Total heat load of up to 250 W (power density up to 4 W/mm² at 9.5 m source distance)</td>
</tr>
</tbody>
</table>
3.6 **Photon Shutter(s) (PSH)**

The photon shutter is required to stop full white/pink beam; for BM/3PW beamlines this shall be water cooled at a normal incidence (similar to BMPS). This shutter is closed to stop synchrotron beam whenever Safety Shutters are closed and shall be integrated into the machine PPS. The photon shutter shall have a duty cycle lifetime exceeding 50,000 cycles for monochromatic photon beamlines (ie. CMS, QAS, TES & XFM) for pink photon beamlines (ie XFP) the shutter shall have a duty cycle lifetime exceeding 1,000,000 cycles.

3.7 **Fast Valve (FV)**

The fast valve where specified is to shut within 15 milliseconds once triggered by FV sensors located in the FE and beamline whenever there is a sudden increase of pressure of a few decades. The valve shall be interlocked to the storage ring. Sensors shall be included in the front end after the safety shutter, and in the beamline FOE (12 m or more from the FV). No FV is necessary when a beryllium window is installed in the FE.

3.8 **Beryllium Window**

A water-cooled Beryllium window shall where specified provide vacuum isolation of storage ring vacuum from beamline vacuum, where the beamline photon energy range permits. The window shall be polished to RA < 100 nm RMS. Utilizing 250 µm window thickness over a 35 x 10 mm aperture. The design of the Be window will have large safety factor, i.e. capable of sustaining > 2.4 bar pressure differential in either direction.

3.9 **Beamline Optics and Diagnostics**

Each frontend shall where specified a have grazing incidence mirror or mirrors, where there is a single mirror it shall be of vertical bounce up configuration with either a tangential cylinder or toroidal shape. For tender x-ray front ends (1000 -5000eV) a pair of mirrors in the vertical bounce down, vertical bounce up configuration shall be installed, with a tangential cylinder on the first mirror.

3.10 **Safety Shutter**

The safety shutter is redundant a pair of shutters. These shall be air actuated with independent, redundant, and diverse position sensing. The shutters shall block bremsstrahlung radiation passing through the Ratchet Wall Collimator in order to allow personnel access to the beamline FOE. The Safety Shutter does not withstand synchrotron radiation and must be protected by an upstream photon shutter. The safety shutter shall have a duty cycle lifetime exceeding 50,000 cycles for monochromatic photon beamlines (ie. CMS,
QAS, TES & XFM) for pink photon beamlines (ie XFP) the safety shutter shall have a duty cycle lifetime exceeding 1,000,000 cycles.

3.11 Frontend Gate Valve
This gate valve shall be pneumatically actuated and shall be integrated into the machine EPS. The frontend gate valve is the final component of the frontend and is the primary interface for the beamline photon delivery system.

3.12 Motion Controls
The FE components, including slit, mirror system and diagnostics, will typically require 10-16 stepper motion control axes, including the following:
1. X-Y slits: 4 axes
2. Beamline optics (mirror system): up to 6 axes (2 units possible)
3. Pneumatic actuator (diagnostic)

Two standard NSLS II Delta Tau GeoBrick LV motion controllers shall be positioned in the machine 19” instrumentation racks adjacent to the beamline port on the storage ring tunnel; these motion control systems shall be integrated into the beamline control system and shall not be included in the storage ring systems.

3.13 Vacuum Requirements
The front end vacuum shall be less than 1 x 10^-9 Torr. If the front end includes a Beryllium window then the vacuum downstream of the window shall be less than 1 x 10^-8 Torr.

3.14 Equipment Protection System and Personal Protection System
All the front end system except the motion systems shall be interlocked to the machine EPS and PPS systems. All departures from the nominal operation settings shall inhibit the operation of the storage ring. The status of the beamline frontend EPS and PPS shall be made available in the beamline EPICS control system.

3.15 Utilities
The FE must support water cooling, pneumatic actuators, ethernet for diagnostics and motion control of the slits and mirror systems. All the required utilities shall be available either in the storage ring tunnel on in the frontend control rack.

3.16 Ratchet Wall Penetration
The ratchet wall penetration shall be modified where specified to enable beam deflected from frontend mirror(s) to exit the shield wall with appropriate radiation shielding.

3.17 Access
The FE must be accessible for installation and commissioning of mirror system up to size 1725 mm length x 710 mm width x 1525 mm height and chamber weight 850 kg (to support mirror up to 1.5 m length), regardless of installation status of insertion devices and FE components for neighboring beamlines.

A stay-clear area will be defined for installation of components for the BM-port front ends. The anticipated installation path for front end components is via upstream ID front end (requiring temporary removal of upstream ID beamline SS if installed), with installation of section downstream components performed last.
Figure 3.4. Conceptual design of an even-cell 3PW front end in the proximity of an odd-cell ID, illustrating access limitations imposed by neighboring ID front ends and beamlines.