RSI* for the Sources and Front Ends

for the First Set of BM Port Beamlines (BM1)

(*Requirements, Specifications, and list of Interfaces)

Version 1

30 April 2013

VERSION CONTROL LOG

VERSION	DESCRIPTION	DATE	AUTHOR	APPROVED BY
1	First release	30 Apr 2013	J. Keister	See p. iii.

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Contents

1 DOCUMENT CONTROL

1.1 Identification

This document, *RSI for the Sources and Front Ends for the BM1 Beamlines*, is part of the Requirement Specification and Interface (RSI) documentation system, mapping to the NSLS-II project Work Breakdown Structure (WBS) and Cost Estimate Database (CED). It captures and summarizes three-pole wiggler and bending magnet requirements and specifications for the WBS element 1.03.04.07, *Beamline Front Ends*, and lists all related technical interfaces with other parts of the project. Requirements for sources and front ends for additional beamlines are also described.

1.2 Scope

This document covers the Sources and Front Ends for five BM port beamlines as well as two "generic" BM port beamlines utilizing BM and 3PW sources. The BM1 front ends support beamline optics (mirrors) subject to safety, vacuum, and access considerations.

2 ACRONYMS

3PW	Three-Pole Wiggler
BC	Bremsstrahlung Collimator
BM	Bending Magnet
BM1	First Set of BM Port Beamlines
BMPS	Bending Magnet Photon Shutter
BPM	Beam Position Monitor
BWIN	Beryllium Window
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
RSI	Requirements, Specifications, and list of Interfaces
SR	Synchrotron Radiation
SS	Safety Shutter
WBS	Work Breakdown Structure
XBPM	X-ray Beam Position Monitor (not necessarily blade type in this context)

3 SOURCES FOR THE BEAMLINES

Table 3.1: Sources for BM1 beamlines.

Beamline	BMM	SM3	XFP	QAS	"Generic" 3PW beamline	TES	"Generic" BM beamline
Source Location	366 mm upstream of 6-BM-B	366 mm upstream of 16-BM-B	366 mm upstream of 17-BM-B	366 mm upstream of 7-BM-B	any[1]	8-BM-B	any[1]
Front end allocation	6-BM	16-BM	17-BM	7-BM	any[1]	8-BM	any[1]
Floorspace Allocation	6-BM	16-BM	17-BM	7-BM	any[1]	8-BM	any[1]
Type	3PW	3PW	3PW	3PW	3PW	BM	BM
Usable photon energy range	5-25 keV	5-20 keV	5-20 keV	5-30 keV	1 - 50 keV[2]	1 – 8 keV	50 eV - 10 keV[2]
Photon Source Point Location / Centerline Definition	3PW	3PW	3PW	3PW	3PW	3.25 mrad downstream of start of BM-B[3]	3.25 mrad downstream of start of BM-B[3]
Nominal Magnetic field at source location[4]	1.13 T	1.13 T	1.13 T	1.13 T	1.13 T	0.40 T	0.40 T
Nominal source fan width[4]	~3 mrad	~3 mrad	~3 mrad	~3 mrad	~3 mrad	~3 mrad	~3 mrad
Max fan power (500 mA ring current)[4]	200 W	200 W	200 W	200 W	200 W	69 W	69 W
(Central) Source power per horizontal mrad[4]	65 W/mrad	65 W/mrad	65 W/mrad	65 W/mrad	65 W/mrad	23 W/mrad	23 W/mrad
Accepted Fan angle (mrad H)	1.75	3	3	3	3	2.5	3
Accepted Fan angle (mrad V)	0.25	0.25	0.25	0.25	0.6[2]	0.4	0.6[2]

Note 1: Although the 3PW device can be installed at B dipole of any cell, careful consideration of front end interferences should be undertaken in and near the following locations: 1) large gap dipole at cells 3, 13, and 23 – 3PW can be installed at large gap locations with 1" shift to upstream, 2) RF chambers at cells 22 and 24, 3) damping wigglers at cells 8, 18, and 28, 4) diagnostics ports at cells 22 and 30, 5) scraper at cell 1, 6) canted undulators at cells 7, 17, and others, 7) infrared beamlines using standard gap dipoles.

Note 2: Generic front ends delivering 3PW or BM radiation provides flux limited by source output, standard aperture, front end fixed masks, mirrors and/or beryllium window(s).

Note 3: For standard BM radius 25.02 m, 3.25 mrad ≈ 81 mm arc length.

Note 4: Informational only. Existing 3PW design, with >1 T for >2 mrad, provides >3 mrad radiation fan at 10 keV photon energy.

4 FRONT END COMPONENTS FOR THE BM1 BEAMLINES

The components listed in Table 4.1 shall be included as a part of the front ends for the BM1 beamlines. All of the BM1 front ends include front end optics (mirrors). The locations are given roughly, considering only the required order of components, and using four section names (illustrated in Figures 4.1 and 4.2):

- Section A: Upstream components. Broken into 2 subsections:
  - A1: Components as far upstream as reasonably possible (including common vacuum components)
  - A2: Components as far downstream as possible without encroaching on space for beamline optics
- Section B: Beamline optics and diagnostics (beamline-dependent)
- Section C: Downstream components (located at or just inside shield wall).

Table 4.1: Front End components for BM1 beamlines.

	BMM	SM3	XFP	QAS	generic 3PW	TES	generic BM	Location reqt. / stand[1]	Comment
Source / Centerline Location	3PW	3PW	3PW	3PW	3PW	3.25 mrad into BM[1]	3.25 mrad into BM[1]	std	Standard.
Standard crotch absorber[2]	Y	Y	Y	Y	Y	Y	Y	std	Standard.
Photon shutter (BMPS)	Y	Y	Y	Y	Y	Y	Y	A1	Standard. Machine operation only
Gate Valve (GV)	Y	Y	Y	Y	Y	Y	Y	A1	Standard.
Fixed Mask (flange absorber)	Y	Y	Y	Y	Y	Y	Y		
Vertical aperture (mrad)	0.25[4]	0.25[4]	0.25[4]	0.25[4]	0.6, 0.25[3]	0.4	0.6, 0.4[3]	A1	Up to 0.6 (V) x 3.0 (H) mrad is in general available. See note 3. Here the mask is defined.
Horizontal aperture (mrad)	1.75[4]	3[4]	3[4]	3[4]	3	2.5	3		
Fast Valve (FV)	N	N	N	N	Y	Y	Y	A1	May not be required if BWIN is installed.
Bremsstrahlung Collimator BC1	Y	Y	Y	Y	Y	Y	Y	A1	
Photon shutter (alternate / additional location)	Y	Y	Y	Y	Y[3]	Y	Y[3]	A2	Alternate location: required for operation of gate valve(s) or shuttering of in-tunnel optics during machine operation (BMPS open).
Water-Cooled Beryllium Window	Y	Y	Y	Y	Y	N	N	A2	Can be used in place of or in addition to FV as needed. NSLS Design exists.
Gate Valve (GV)	Y	Y	Y	Y	Y[3]	Y	Y[3]	A2	Isolates optics from upstream components (PS required).
X-Y Slit set	Y	Y	Y	Y	Y	Y	Y	A2	Can be downstream of all (A1, A2) if no optics are included.
Bremsstrahlung Collimator BC2	Y	Y	Y	Y	Y	Y	Y	A2; just upstream of mirror	Required if a mirror is present.
Space for beamline optics (mirror / chamber, diagnostics, etc.)	Y	Y	Y	Y	Y	Y 10.4 - 12.8	Y 10.4 - 12.8[3]	10.8 - 20.0 (B)	Downstream area may be occupied by BC2b for two-mirror BM FE.
Mirror material	Silicon	Silicon	Silicon	Silicon	Silicon[3]	Silicon	Silicon[3]		For safety analysis.
Mirror attitude	Vert. up	Vert. up	Vert. up	Vert. up	Vertical up[3]	2: V dn, V up	2: V dn, V up[3]		Generic BM / TES have two mirrors; large angles used for soft x-rays.
Mirror size (LxWxT, m)	1.0 x 0.05 x 0.05[4]	1.0 x 0.1 x 0.05[4]	1.1 x 0.1 x 0.05[4]	1.4 x 0.1 x 0.05[4]	1.0 x 0.1 x 0.05[3]	(0.8,1.0) x 0.1 x 0.075[4]	(0.8,1.0) x 0.1 x 0.075[3]	B	
Mirror figure	cyl.	flat	flat	flat	flat[3]	flat, flat	flat, flat[3]		
Mirror incident angle (mrad)	3.5[4]	3.3[4]	3.5[4]	2.7[4]	3.5[3]	6-20[4]	9[3]		

	BMM	SM3	XFP	QAS	generic 3PW	TES	generic BM	Location reqt. / stand[1]	Comment
Mirror acceptance (mrad V)	0.25[4]	0.25[4]	0.25[4]	0.25[4]	0.25[3]	0.4[4]	0.4[3]	B	~85% typical illumination.
Mirror acceptance (mrad H)	1.75[4]	3.0[4]	3.0[4]	3.0[4]	3.0[3]	2.5[4]	3.0[3]		
Mirror center position(s)	11.7[4]	11.7[4]	11.7[4]	11.9[4]	11.7[3]	11.0, 12.2[4] (22.5 mm offset)	11.0, 12.2 (22.5 mm offset) [3]		Distance from source TBD; should be as far upstream as possible within the prescribed 10.8 - 20 m range.
Fixed Mask 2 (flange absorber)	Y	Y	Y	Y	Y[3]	Y	Y[3]	just after mirror	Serves as white beam stop for mirror front ends.
Diagnostics crosses (2)	Y	Y	Y	Y	Y	Y	Y	B	6" Conflat; one just downstream of optics, one just upstream of SS
Gate Valve (GV)	Y	Y	Y	Y	Y[3]	Y	Y[3]	after mirror	Isolates optics from downstream components (PS required).
Bremsstrahlung Collimator BC2b	N	N	N	N	N	Y (~13.2)	Y (~13.2) [3]	B	As required, with 2-mirror arrangement (TBD).
Fixed Mask 3 (flange absorber)	Y	Y	Y	Y	Y	Y	Y	C	Protects SS, as needed.
Photon Shutter (standard location)	N	N	N	N	Y	N	Y	C	Can use this one and/or an upstream one if optics isolation is needed, for protection of Safety Shutters.
Bremsstrahlung Collimator BC3	Y	Y	Y	Y	Y	Y	Y	C	
Safety Shutter (SS, x2)	Y	Y	Y	Y	Y	Y	Y	C	
Ratchet Wall Collimator	Y	Y	Y	Y	Y	Y	Y	C	
Gate valve outside Ratchet Wall	Y	Y	Y	Y	Y	Y	Y	C	

Note 1: Nominal locations given are distances in meters relative to relevant source (3PW or BM) point. Where no specific distance is given, components shall be arranged in the order shown. Sections A1 and A2 include common upstream components, section B is beamline-dependent optics and diagnostics, and section C includes common downstream components. Offset between 3PW center and 3.25 mrad BM source point is ≈ 366 + 81 = 447 mm.

Note 2: Standard ~18.3 mm crotch absorber provides +/- 1.5 mrad fan for 3PW and up to 4.75 mrad inboard for BM.

Note 3: Generic front ends to be evaluated both with maximum 0.6 V x 3.0 H mrad aperture (no mirror) and with reduced vertical aperture (mirror included as indicated), with ray tracing. Components must accommodate the maximum beam size.

Note 4: Mirror parameters for individual beamlines are subject to beamline design review.

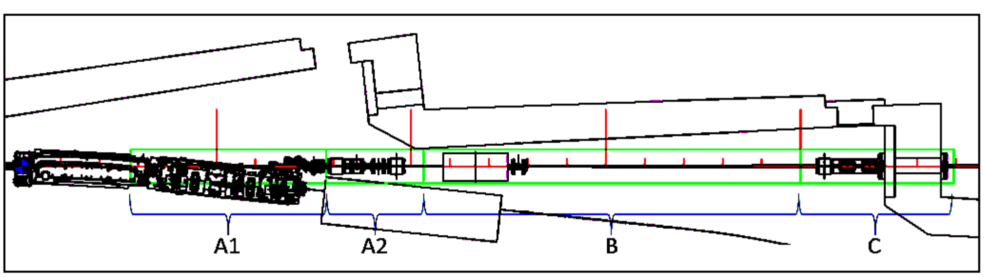

Figure 4.1 Conceptual layout for a generic (even cell) 3PW front end, illustrating division of the front end into four sections as described above, as well as adjacent ratchet wall and downstream ID. Section C will be ~ 1.3 m longer for odd cell BM/3PW front ends. Tick marks indicate distance in meters from the 3PW source.

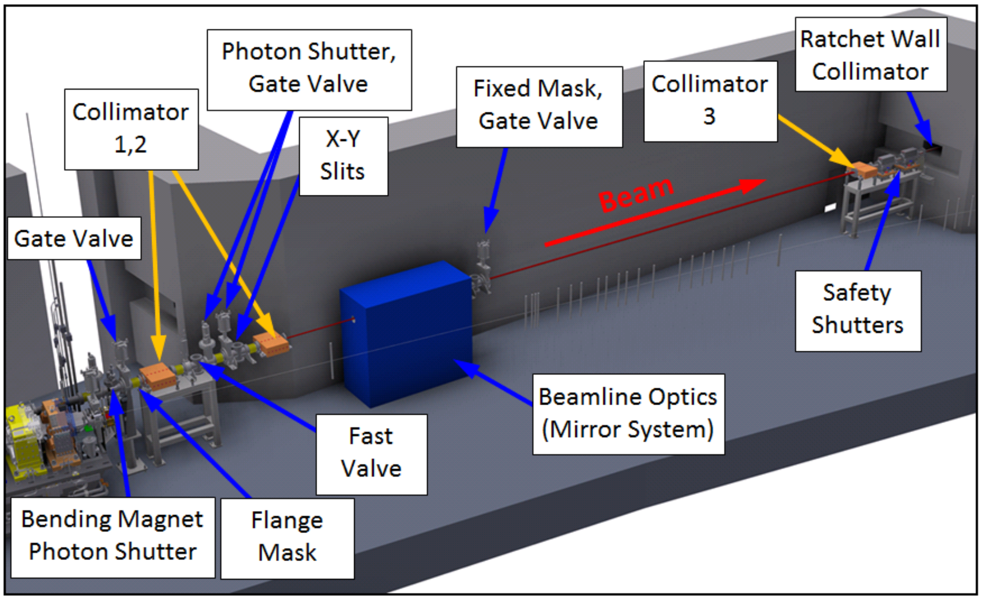

Figure 4.2 Conceptual layout for a generic (even cell) 3PW front end with specific components identified.

4.1 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.

4.2 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. The GV is controlled and monitored by the FE vacuum PLC using a voting scheme with inputs from vacuum sensors at both sides of the valves and the position of the BMPS.

4.3 Fixed Masks / Flange Absorbers (MSK)

The first fixed mask shall provide radiation fans to the beamline as defined in the table above. No tolerance shall be added to the mask for mis-positioning; however, a manufacturing tolerance of ±0.2 mm for the aperture (at the downstream end of the mask) shall be included in the downstream fan definition. Normal incidence onto water-cooled glidcop conflat flange offers an attractive space-saving option for BM/3PW front ends. The existing design illustrated below can be modified for the required fans.

Use of multiple fixed masks provide equipment protection for potentially mis-steered beam as follows. Mask 1 limits the radiation fan at an upstream position to allow use of smaller-aperture components downstream of it, while also defining size of subsequent bremsstrahlung collimators. Mask 2, located just downstream of a beamline mirror system, serves as a white beam stop in the event of the mirror being withdrawn from beam. Mask 3, located just upstream of BC3, serves to protect BC3 and the Safety Shutters (when open) from synchrotron radiation. As a pair of apertures separated by several meters, mask 2 and mask 3 effectively ensure the correct beam trajectory from the beamline mirror system, and absorb any mis-steered beam.

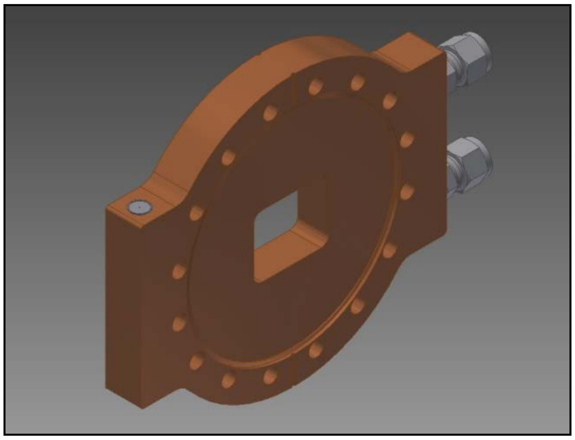

Figure 4.3 Example Fixed Mask / Flange Absorber.

4.4 Bremsstrahlung Collimators (BC1, 2, 3 & Ratchet Wall Collimator)

The bremsstrahlung collimators restrict the bremsstrahlung radiation (both primary and secondary) exiting the shield wall. Bremsstrahlung collimators should be made using out-of-vacuum lead design. BC1 should be as far upstream as possible; BC2 should be upstream of, but close to, any beamline mirror; for beamlines with a two-mirror system, an additional collimator BC2b will be needed just downstream of the mirrors and subsequent fixed mask; BC3 should be as far downstream as possible, just upstream of the Safety Shutters.

4.5 X-Y Slits

The X-Y slits shall be of water-cooled, normal incidence design, allowing full adjustment of all four "blades" via either two X-Y stages or four independent slides. The specifications are as follows:

Material	Water-cooled glidcop with tungsten edges, to stop 99.997% of photons with energy of up to 50 keV.
Maximum opening	Sufficient to allow full radiation fan to continue to the beamline without clipping. Suggested size no less than 50 mm H x 10 mm V for BM/TPW fans of 3.125 x 0.625 mrad at source distance of up to 16 m (in front end section B)
Motorized	Yes, to allow selection of any part of the FAPM fan.
Position stability	Δx, Δy = 10 µm or better over any 8-hour period
Aperture stability	Δx, Δy = 5 µm or better over any 8-hour period
Minimum Aperture Size	0 mm (fully closed)
Speed	No requirement
Position resolution	x and y = 5µm or better

Requirements for electrical readout, greater stability, resolution, or opening can be provided on an as-needed basis (requiring upgraded design).

4.6 Photon Shutter(s)

The photon shutter is required to stop full white beam, for BM/3PW beamlines this is expected to be water cooled at a normal incidence (same component as the BMPS). This shutter is closed to a) stop beam from striking downstream components, e.g., slits and mirrors, b) protect downstream gate valves, and c) stop synchrotron beam whenever Safety Shutters are closed.

4.7 Fast Valve (FV)

The fast valve 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 stored beam will have dumped as well, and the cause investigated and mitigated). Location of this valve is to be as far upstream as possible.

4.8 Beryllium Window (BWIN)

A water cooled Be window will provide additional (or alternative) vacuum isolation where fast valve operation is not sufficient, or wherever vacuum quality needs improvement. The NSLS design may be a viable option (to be evaluated).

4.9 Beamline Optics and Diagnostics

Beamline optics, including mirror and other diagnostics will be supported. Generic beamlines described herein include mirrors, in order to define ray tracings and identify shielding requirements common to many anticipated beamlines. 3PW beamlines will generally use one mirror deflecting beam upward; BM beamlines will generally employ two mirrors in order to reach the steeper incidence angles required for low energies, while still utilizing the standard exit port. Each major component should be isolated with gate valves (and at least one photon shutter upstream for its protection). Designs for chambers, stands, and utility support for these elements are supported by the complete FE design; detailed design elements of the optics systems are the responsibility of the beamline groups. Diagnostics systems can include sensors mounted to optics chambers or vacuum crosses on stands in the available front end area.

4.10 Safety Shutter

The safety shutter is actually a pair of shutters, required for redundancy, air actuated with independent, redundant, and diverse position sensing. This must be closed to block bremsstrahlung radiation and scatter from 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 survive a minimum of 30,000 cycles.

4.11 Gate valve downstream of Ratchet Wall

This gate valve, pneumatically actuated and with position sensing switches, will be monitored and controlled by the FE vacuum PLC using vacuum sensors in the FE and beamlines.

Note 1 This valve cannot be removed after commissioning.

Note 2 This gate valve must be protected from any exposure to (white) beam (using an upstream photon shutter).

4.12 Motion Controls

The FE components, including mirror system and diagnostics, will typically require 20-30 stepper motion control axes, including the following:

1. X-Y slits: 4 axes each (2 units possible)
2. Beamline optics (mirror system): up to 8 axes each (2 units possible)
3. Beamline-specific diagnostics system, TBD (4-6 axes total)

The individual beamlines are expected to define these as needed for optics and diagnostics, although rack space will be provided by NSLS-II. Racks above the tunnel may be used for front ends, as well as 3PW device. Additional controls elements (diagnostics readbacks) may also occupy such rack space. Beamlines must individually state requirements for rack space and locations, numbers, and types of cables terminating at front end components including beamline-specific (optics and diagnostics) elements, while adhering to NSLS-II cable and connector standards. Cable lengths of up to 30 m may be required.

4.13 Vacuum controls

The FE vacuum control is part of storage ring vacuum control through EPICS and the FE vacuum PLC. EPICS provides the menu-driven online control and logging of all vacuum devices, while the PLC provides control logics for various vacuum devices. The BMPS and all GVs with dual sensors are also connected to the sector EPS PLC for status and beam interlock.

4.14 Utilities

The FE must support water cooling, electricity and compressed air for front end components, including in-tunnel beamline optics and diagnostics. Mains power nominally will be provided at rack locations on the mezzanine level except where otherwise indicated as a special requirement for instruments in-tunnel. All mirrors will be water cooled. Water cooling of optics (mirrors) should be accomplished with mirror as first element in the loop, for maximum temperature stability, utilizing available front end cooling circuits.

4.15 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 BM1 front end components is via upstream ID front end (requiring temporary removal of upstream ID beamline SS if installed), with installation of section A2 components performed last.

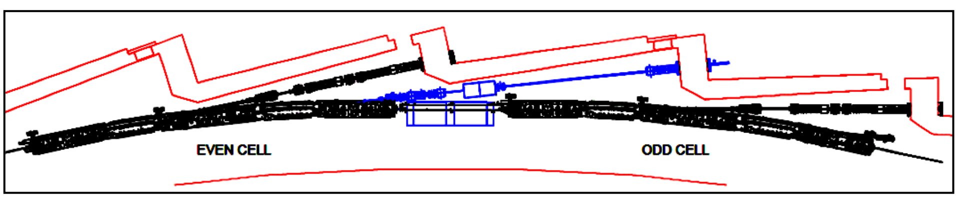

Figure 4.4 Conceptual design of an even-cell 3PW front end in the proximity of an odd-cell ID, illustrating access limitations imposed by neighboring ID front ends and beamlines.