RSI* for the Insertion Devices and Front Ends for the NEXT Project Beamlines

(*Requirements, Specifications, and list of Interfaces)

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Version 5

25 November 2013

VERSION CONTROL LOG

VERSION	DESCRIPTION	DATE	AUTHOR	APPROVED BY
1	First Issue	14Sept2012	A. Broadbent	See cover
2	Revised Table 3.1 and associated notes	21Dec2012	A. Broadbent	See cover
3	Revised EPU requirements in Table 3.1.	28Jun2013	A. Broadbent	See Document Approvals page
4	Revised FXI FAPM dimensions in Table 4.1.	5Aug2013	A. Broadbent	See Document Approvals page
5	Revised EPU requirements for ESM in Table 3.1.	25Nov2013	A. Broadbent	See Document Approvals page

Document Approvals

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1 DOCUMENT CONTROL

1.1 Identification

This document, *RSI for the Insertion Devices and Front Ends for the NEXT Project 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 all requirements and specifications for the WBS element 1.04.06.03, *Front Ends*, and lists all related technical interfaces with other parts of the project.

1.2 Scope

This document covers the Insertion Devices and Front Ends for six NEXT project beamlines.

2 ACRONYMS

BC	Bremsstrahlung Collimator
BM	Bending Magnet
BMPS	Bending Magnet Photon Shutter
BPM	Beamline Position Monitor
CED	Cost Estimate Database
EPS	Environmental Protection System
EPICS	Experimental Physics and Industrial Control System
FAPM	Fixed-Aperture Mask
FE	Front End
GV	Gate Valve
ID	Insertion Device
PLC	Programmable Logic Controller
RFBPM	Radio Frequency Beam Position Monitor
RSI	Requirements, Specifications, and list of Interfaces
SR	Synchrotron Radiation
SS	Safety Shutter
TSP	Titanium Sublimation Pump
WBS	Work Breakdown Structure
XPBM	X-ray Beam Position Monitor

3 INSERTION DEVICES FOR THE NEXT PROJECT BEAMLINES

Table 3.1: Insertion devices for NEXT beamlines. Devices shown in grey cells are not in the baseline scope.

Beamline	ESM		SIX	ISR		SMI		ISS, FXI
			One EPU in baseline		NOTin baseline		NOT in baseline	
Type	EPU (PPM)	EPU (PPM)	EPU (PPM)	IVU	IVU	IVU	IVU	DW
Length	2.8 m *8	1.4 m *8	2 x 3.5 m *8, *9	2.8 m	1.5 m	2.8 m	1.5	2 x 3.4 m
Usable photon energy range	0.015 – 1.0 keV Polarizations: LH from 0.015 to 1.0 keV, LV from 0.03 to 1.0 keV, C from 0.03 to 0.6 keV	0.165 – 2.3 keV Polarizations: LH from 0.165 to 2.3 keV, LV and C from 0.275 to 2.3 keV	0.165 – 2.3 keV Polarizations: LH from 0.165 to 2.3 keV, LV and C from 0.275 to 2.3 keV	2.4 – 23 keV	TBD	2.05 – 24 keV	TBD	5 – 40 keV (ISS), 5 – 11 keV (FXI)
Canted	N		N	Y		Y		N
Canting angle	N/A		N/A	2.0 mrad		2.0 mrad		N/A
Period	105 mm *1	57 mm	57 mm	24 mm (23 mm) *7	20 mm (TBC)	24 mm (23 mm) *7	24 mm (TBC)	100 mm
Minimum magnetic gap *2	16 mm	16 mm	16 mm	5.9 mm	5.9 mm (TBC)	5.9 mm	5.9 mm (TBC)	15 mm
Magnetic field strength $B_{(h,v)1}$ *3	1.14 T (V) 0.74 T (H)	0.83 T (V) 0.57 T (H)	0.83 T (V) 0.57 T (H)	0.94 T (0.95T)	0.61 T	0.94 T (0.95 T)	0.76 T	1.8 T
K_{eff} *4	11.2 (LH) 7.23 *5 (C) 7.23 *5 (LV)	4.41 (LH) 3.55 (C) 3.06 (LV)	4.41 (LH) 3.55 (C) 3.06 (LV)	2.11 (2.05)	1.13	2.11 (2.05)	1.7	16.5
Power total	10.1 kW (LH) 4.22 kW (C) 4.22 kW (LV)	2.67 kW (LH) 1.73 kW (C) 1.28 kW (LV)	13.6 kW (LH) 8.8 kW (C) 6.5 kW (LV)	7.6 kW (7.2 kW)	1.6 kW	7.6 kW (7.2 kW)	2.4 kW	61 kW
On-axis power density	13.1 kW/mr^2 (LH)	8.7 kW/mr^2 (LH)	46 kW/mr^2 (LH)	52 kW/mr^2 (50 kW/mr^2)	19 kW/mr^2	52 kW/mr^2 (50 kW/mr^2)	20 kW/mr^2	56 kW/mr^2
Straight section type	Short (low vert. beta)		Long (high vert. beta)					
Lowered horiz. beta desired	N/A	N/A	Y	N	N	Y	Y	N/A
Device center	D/S 0.876 m	U/S 1.426 m	Center of straight	U/S 0.57 – 0.61 m	D/S 2.68 m	D/S 0.57– 0.61 m	U/S 2.68 m	Center of straight
Fan angle *6 (mrad H)	4.15/4.52 (LH) 2.62/3.17 (C) 0.87/1.45 (LV)	1.71/2.26 (LH) 1.66/2.18 (C) 0.86/1.38 (LV)	1.86/2.31 (LH) 1.73/2.26 (C) 0.85/1.37 (LV)	0.94/1.54 (0.92/1.52)	0.60/1.23	0.94/1.54 (0.92/1.52)	0.79/1.4	6.47/6.76
Fan angle *6 (mrad V)	0.88/1.46 (LH) 2.62/3.17 (C) 2.73/3.19 (LV)	0.87/1.41 (LH) 1.66/2.17 (C) 1.25/1.84 (LV)	0.86/1.41 (LH) 1.73/2.26 (C) 1.35/1.86 (LV)	0.83/1.32 (0.82/1.31)	0.77/1.21	0.83/1.32 (0.82/1.31)	0.81/1.28	0.87/1.46

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See Notes on next page.

Gap scanning and other requirements	Gap scanning speeds: 1 eV/sec at $h\nu_1$ = 15eV (16mm gap), 10 eV/sec at $h\nu_1$ = 50 eV (30mm gap), 30 eV/sec at $h\nu_1$ = 110eV (50mm gap) Gap scanning resolution: 0.05 eV at 0.015 keV, 1 eV at 1 keV or higher Polarization switching time: 60s to go from circular left to right or from linear horizontal to linear vertical Spectral purity: flux(n=1)/flux(n=2..10) > 1.0 below 30 eV & > 0.3 below 70eV	Gap scanning speed: 45 eV/sec at hν1 = 165eV (16mm gap), > 45 eV/sec for hν1 > 165 eV (>16mm gap) Gap scanning resolution: 0.5 eV at 0.25 keV, 3 eV at 1 keV or higher Polarization switching time: 30s to go from circular left to right or from linear horizontal to linear vertical	Gap scanning speed: 45 eV/sec at hν1 = 165eV (16mm gap), > 45 eV/sec for hν1 > 165 eV (>16mm gap) Gap scanning resolution: 0.5 eV at 0.25 keV, 3 eV at 1 keV or higher Polarization switching time: 30s to go from circular left to right or from linear horizontal to linear vertical	Gap scanning speed 30 eV/sec or greater, over usable photon energy range.				

Note 1: ESM long period undulator shall be a quasi-periodic device.

Note 2: Minimum magnetic gap for out-of-vacuum devices (e.g., EPUs); vertical stay-clear aperture for in-vacuum devices (e.g., IVUs)

Note 3: $B_{(h,v)1}$ is the peak magnetic field in the (horizontal, vertical) plane, assuming sinusoidal field profile (shape)

Note 4: In the general case of an ellipsoidal insertion device with non-sinusoidal periodic magnetic field:

$$K_{eff} = \frac{e\lambda_u}{2\pi mc}\left(\sum_{n=1}^{\infty}\frac{B_{hn}^2+B_{vn}^2}{n^2}\right)^{1/2} = 0.0934\,\lambda_u[mm]\left(\sum_{n=1}^{\infty}\frac{B_{hn}^2+B_{vn}^2}{n^2}\right)^{1/2}[T]$$

where e and m are charge and mass of electron, λ_u is period, B_{hn} and B_{vn} are amplitudes of n-th harmonics of the horizontal and vertical magnetic field components. In cases where detailed magnetic design of an insertion device has not yet been performed, only fundamental harmonics of the vertical and/or (where applicable) horizontal magnetic field components were used to estimate emission characteristics.

Note 5: For EPU105, the K_{eff} values for Circular (C) and Linear Vertical (LV) shown here are the maximum values permitted owing to power loading issues on the Bend Magnet and/or ID chamber walls in the vertical plane. These K_{eff} correspond to a minimum fundamental photon energy of 30 eV.

Note 6: Fan angles of the radiation quoted here are as seen at 16 m from ID center, and take into account the effect of ID length. The two values quoted for each case correspond to the points where the power density falls to values that are 1% and 0.1% of the central value. These values are accurate to within 5%. Designs of the XBPM and fixed mask entrance shall take into account these fringe power loads. For EPUs (ESM and SIX beamlines), fan sizes for linear horizontal (LH), circular (C), and linear vertical (LV) polarization modes are given.

Note 7: Either 24 mm or 23 mm period length is acceptable. 23 mm period length is preferable IF the magnetic strength at the allowed gap for this ID location can be made sufficiently high to reach 3.50 keV photon energy with the third harmonic.

Note 8: Prior to finalizing the designs of these insertion devices, the length specification may vary by up to ±15%.

Note 9: The SIX vacuum chamber should be continuous. The two SIX EPUs should work as one.

For the EPUs, the required polarization modes can be achieved with only two of the four magnet arrays movable in the longitudinal direction. The other two arrays can remain fixed in that direction.

For 2 mrad canting, the ID positions should assume a 1.0 m gap along the beam direction to allow for the canting magnets and beam position monitors, etc.

Insertion device straight sections will include RFBPMs. There will be two RFBPMs for non-canted and three RFBPMs for canted beamlines.

4 FRONT END COMPONENTS FOR THE NEXT PROJECT BEAMLINES

The components listed in Table 4.1 shall be included as a part of the front end (FE) (components shown in grey cells are not in the baseline scope). Specifications based on the scientific requirements are included in the indented rows. Figure 4.1 is a conceptual layout of a standard undulator FE, and Figure 4.2 is a conceptual layout of a canted undulator FE.

Table 4.1: Front End components for NEXT beamlines.
(Components marked with grey are NOT in the baseline scope.)

	ESM	FXI	ISR	ISS	SIX	SMI
Photon shutter (BMPS)	Y	Y	Y	Y	Y	Y
Slow Gate Valve (GV)	Y	Y	Y	Y	Y	Y
Beam Position Monitor 1 (XBPM1)	Y *10	Y *10	Y *10	Y *10	Y *10	Y *10
Beam Position Monitor 2 (XBPM2)	N	N	Y *10	N	N	Y *10
Fixed Aperture Mask (FAPM)	Y	Y	Y	Y	Y	Y
Type	Single	Single	Dual	Single	Single	Dual
Vertical aperture (mrad)	0.7	0.26	0.3	0.15	0.3	0.3
Horizontal aperture (mrad)	Round	0.46 *11	0.5	1.1	0.3	0.5
Bremsstrahlung Collimator BC1	Y	Y	Y	Y	Y	Y
Number of X-Y Slit sets ('2' means both BLs of a canted pair have separate X-Y slits)	1 *12	1 *12	2 *12	1 *12	1 *12	2 *12
Photon Shutter	Y	Y *13	Y	Y	Y	Y
Fast Gate Valve (FV)	Y	Y	Y	Y	Y	Y
Bremsstrahlung Collimator BC2	Y	Y	Y	Y	Y	Y
Safety Shutter (x2)	Y	Y	Y	Y	Y	Y
Ratchet Wall Collimator	Y	Y	Y	Y	Y	Y
Gate valve outside Ratchet Wall.	Y	Y	Y	Y	Y	Y

Note 10: Front End design will allocate space for XBPMs.

Note 11: Horizontally, the FXI FAPM aperture opening extends from 0.33 mrad (inboard) to 0.13 mrad (outboard).

Note 12: The X/Y slit blades need to be able to move across the entire aperture.

Note 13: This Photon Shutter can be fixed (not movable) until a beamline is constructed.

TYPICAL NON-CANTED FRONT END CONFIGURATION

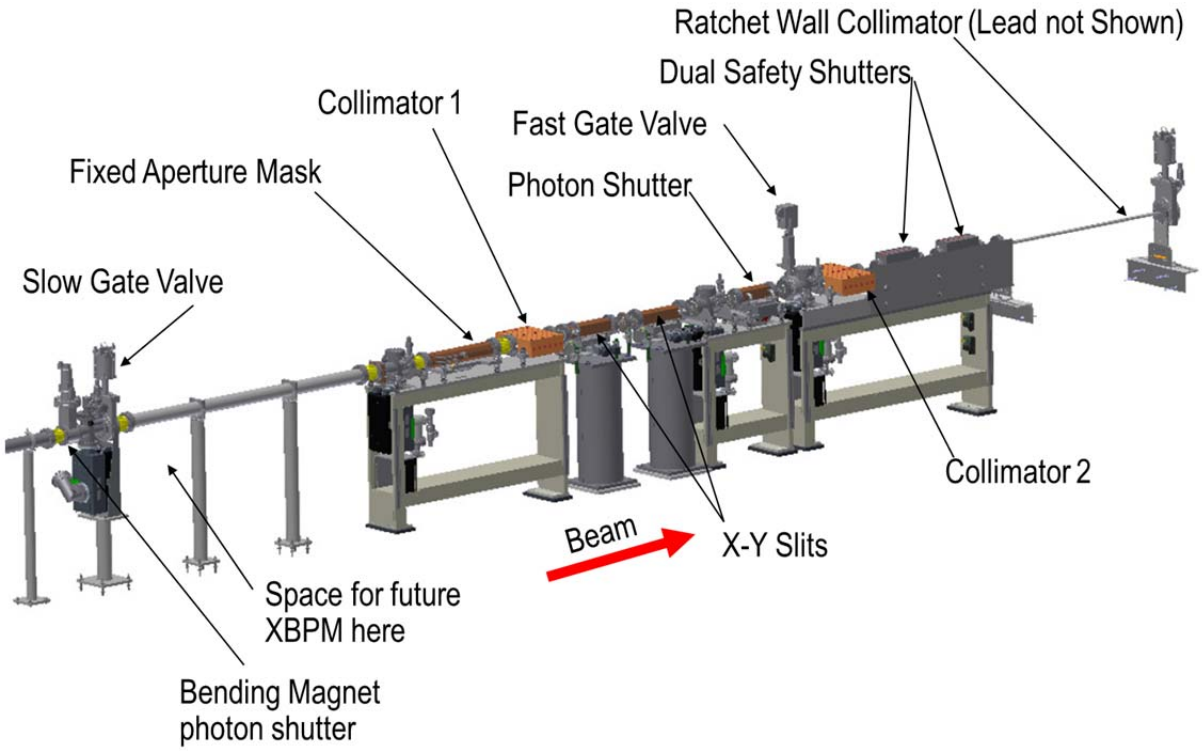

Figure 4.1 Conceptual layout of front end for standard undulators.

TYPICAL CANTED FRONT END CONFIGURATION

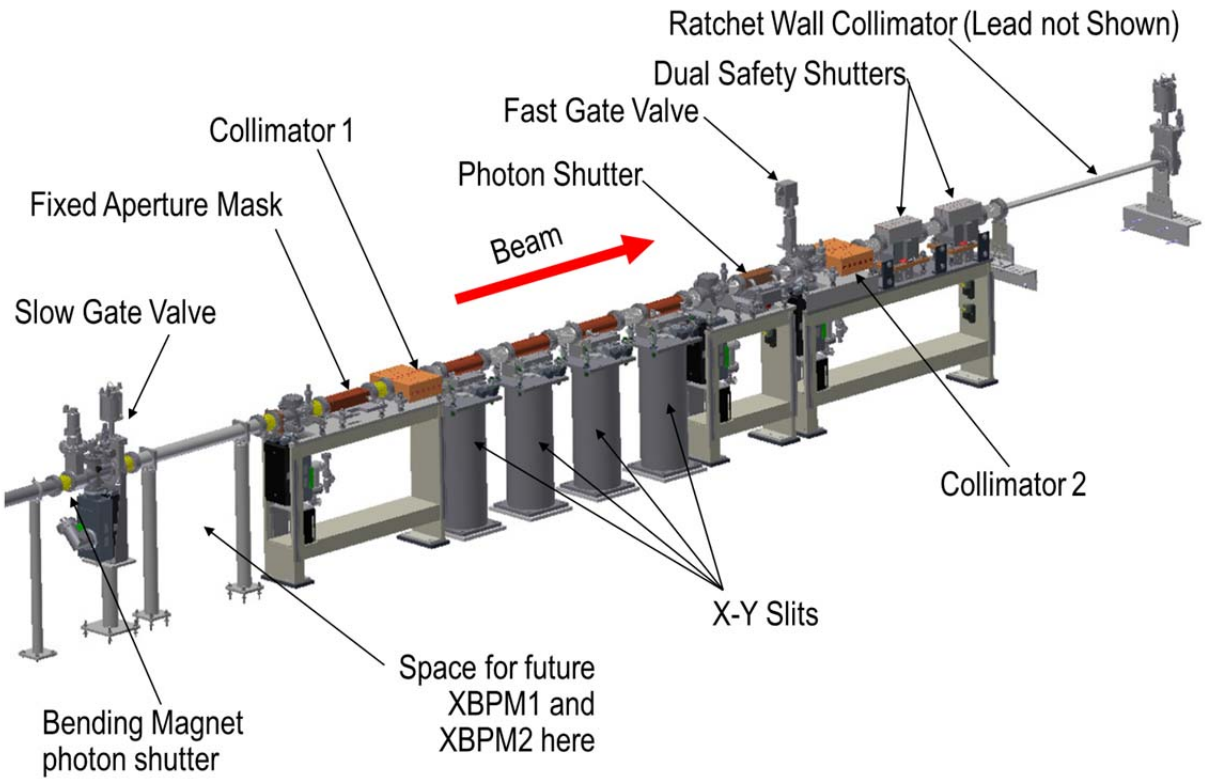

Figure 4.2. Conceptual layout of front end for canted undulators.

4.1 Photon Shutter (BMPS)

The BMPS is designed to protect the GV from BM radiation before the upstream straight is fitted with an insertion device and a complete front end.

4.2 Slow Gate Valve (GV)

The Slow Gate valve is included to isolate the machine and FE, but will not withstand white beam from IDs 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 Beam Position Monitor 1 (XBPM1)

The XBPMs shall be designed to work with the insertion devices specified.

Material	Water-cooled mountings and Tungsten blades
Power protection	A pre-mask may be included if design considerations dictate
Motorized	Yes to allow centering of the device around the beam.

The XBPMs shall be mounted on X/Y stages with the following specifications:

Position stability	Δx, Δy = 1 μm or better over any 8-hour period
Speed	No requirement
Position resolution	x and y = 0.1 μm (expected value from calculations); <<1micron (guaranteed)

The X/Y stage for the XBPM and the X/Y slits are expected to be the same design, including the stand, where possible.

4.4 Beam Position Monitor 2 (XBPM2)

This device and X/Y stages shall be included only for canted beamlines. In canted ID straights, the centers of XBPM1 and XBPM2 will be aligned with each of the canted beams. XBPM2 will be identical to XBPM1; however, the blades shall be relocated to avoid masking effects.

4.5 Fixed Aperture Mask (FAPM)

The fixed aperture mask shall provide radiation fans to the FOE 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. It is permissible for the mask aperture to have corner radii equivalent to half the aperture height, as shown below.

4.6 Bremsstrahlung Collimator (BC1)

The bremsstrahlung collimator restricts the bremsstrahlung radiation fan exiting the shield wall. This should be as tight to the beam as is reasonable without undue mechanical tolerances or alignment difficulty.

4.7 X-Y Slits

The X-Y slits shall be of the SPring8 dual "L" type design, connected with bellows to allow full adjustment of all four "blades" via two X-Y stages. The specifications are as follows:

Material	Water-cooled Glidcop with Tungsten blocks
Power protection	A pre-mask may be included if design considerations dictate
Maximum opening angle	Sufficient to allow full FAPM fan to continue to the FOE without clipping.
Motorized	Yes to allow selection of any part of the FAPM fan. The same X/Y stage shall be used for the XBPMs.
Position stability	Δx, Δy = 1 μm or better over any 8-hour period
Aperture stability	Δx, Δy = 1.5 μm or better over any 8-hour period
Minimum Aperture Size	0 mm
Speed	No requirement
Position resolution	x and y = 0.1 μm (expected value from calculations); <<1 μm (guaranteed).
Corner radius of slit aperture	< 0.2 mm
Life Expectancy	30,000 cycles

The aperture stability specification is governed by differential movement between the two X/Y slit units; the specification will be met but some form of additional coupling between stands may be required to constrain any differential movement.

The X/Y slits are to be under beamline control except when disabled by the machine control room.

4.8 Photon Shutter

The photon shutter is required to stop full white beam, for IDs this is expected to be water cooled Glidcop at a grazing incidence angle.

4.9 Fast Gate Valve (FV)

The fast gate 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 has to be dumped prior to FV closing, and the cause then investigated and mitigated.

4.10 Bremsstrahlung Collimator (BC2)

Bremsstrahlung collimators 1 and 2 and the ratchet wall collimator should be made as tight as possible using out-of-vacuum lead designs, or in-vacuum tungsten, if needed.

4.11 Safety Shutter

The safety shutter is actually a pair of shutters, required for redundancy, air actuated with independent, redundant, and diverse position sensing. The safety shutter does not need to separate beams in canted configuration and shall survive a minimum of 30,000 cycles.

4.12 Ratchet Wall Collimator

See comment above for BC2.

4.13 Gate valve downstream of Ratchet Wall.

This slow 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.

4.14 Motion Controls

The FE components requiring motion control include the XBPMs (two units, X/Y axes for each) and the slits (four axes).

4.15 Vacuum controls

The FE vacuum control is part of storage ring vacuum control through EPICS and the SR vacuum PLC. EPICS (Experimental Physics and Industrial Control System) 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 two GVs at the FE are to be connected directly to the sector EPS (Environmental Protection System) PLC for status and beam interlock.