

New Front Ends with the Next- Generation XBPMs for the Advanced Photon Source Upgrade*

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Abstract:

Beam stability improvement is an important part of the Advanced Photon Source (APS) Upgrade. Among the proposed new diagnostics are the grazing-incidence insertion device x-ray beam position monitor (GRID-XBPM) and intensity monitors to be installed in the front end. Due to the large space requirement of the GRID-XBPM, the first photon shutter in the front end must be removed. This causes operational logic changes in the personnel safety system (PSS) and the front end equipment protection system (FEEPS). This paper presents two types of front-end designs with the GRID-XBPM and intensity monitors: the high-heat-load front end (HHLFE), which is for single beam from multiple inline undulators; and the canted-undulator front end (CUFE), which is for two beams from canted undulators. The layout, aperture design, thermal analysis, and PSS and FEEPS operational logic will be presented in detail. These two types of front ends will serve as the base designs for the APS upgrade.

1-Introduction and Schematic of the Next-Generation XBPMs

The APS Upgrade will raise the stored beam current from 100 mA to 150 mA and improve beam stability. A new-generation XBPM system based on x-ray fluorescence (XRF) detection is designed to replace the photoemission-based XBPMs in the new front ends for the APS Upgrade. The HHLFE and CUFE are required to fit in the new XBPMs. A schematic of the next-generation XBPM system is shown in Figure 1. It consists of four components: a) GRID-XBPM uses grazing-incidence surfaces to intercept the undulator beam outside

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of the central cone, uses the XRF intensity difference of the inboard and outboard absorbers to measure the horizontal beam position, and uses pinhole cameras to measure center of mass of the XRF footprint to get the vertical beam position; b) Intensity Monitor #1 (IM1) functions as an alignment aid using XRF from the photon shutter (PS2) to center the beam in the front-end aperture; c) XBPM2 is a second XBPM based on the same principle as the GRID-XBPM using the XRF from the exit mask (EM); d) Intensity Monitor #2 (IM2) measures x-ray intensity through EM using Compton scattered x-rays from the Be window (BeW) to center the beam on the the EM.

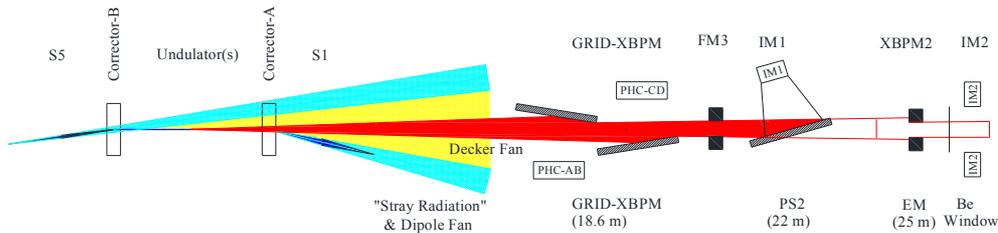


Figure 1 Next-generation XBPM system schematic.

2-Design of the New HHLFE with the Next-Generation XBPMs

The original HHLFE was designed in 2003 and installed in sector 26-ID and 30-ID [1]. The new HHLFE will be modified from the original HHLFE. The layout comparison of the new HHLFE and the original HHLFE is shown in Figure 2. In order to fit in the GRID-XBPM, the PS1 must be removed. A low-power photon shutter (LPPS) is installed in the very upstream to stop dipole radiation and protect valves in the event of front-end vacuum failure. The slow valve (SV) is moved from the mid location of the front end to the upstream end of the front end and the fast valve (FV) is moved away from the pump cross to allow the pump cross to house the IM1 aperture and photodiodes with an unobstructed view of the fluorescence from PS2. The design of the IM1 is shown in Figure 3. A pump cross upstream of the exit mask is added to house the aperture and

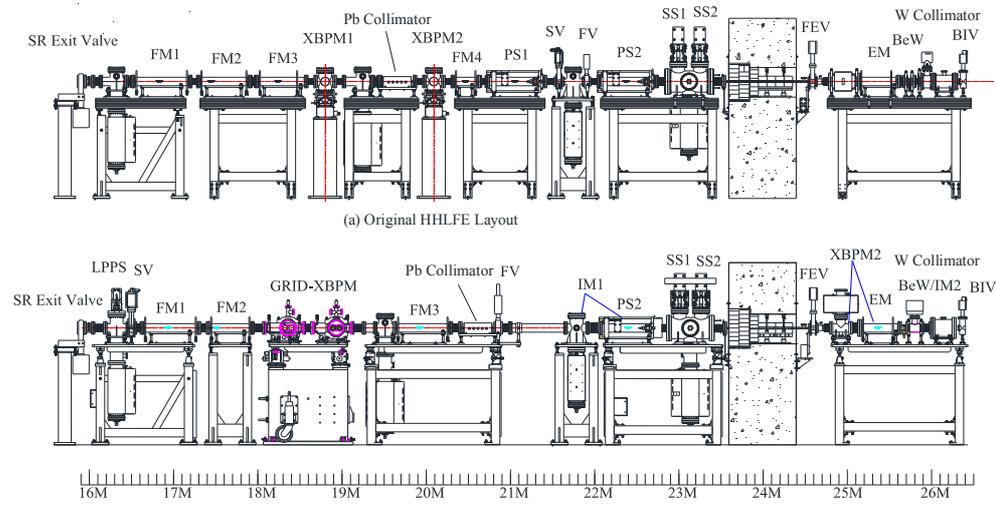


Figure 2 Layout of (a) the original HHLFE and (b) the new HHLFE with next-generation XBPMs.

photodiodes to work with the exit mask as XBPM2. The arrangement of the aperture and photodiodes for XBPM2 is very similar to the IM1. The Be window and the downstream vacuum cross are redesigned to function as IM2, as shown in Figure 4. The first two fixed masks, FM1 and FM2, provide beam missteering protection for the GRID-XBPM and allow the GRID-XBPM a full view of the x-ray beam. The controlling aperture for the front end is the FM3, which is a new design that has an exit aperture of 3.6(H)×6.0(V) mm and provides protection for all downstream components. The aperture of the GRID-XBPM is not part of the front-end radiation safety aperture system. The apertures of key HHLFE components are shown in Table 1.

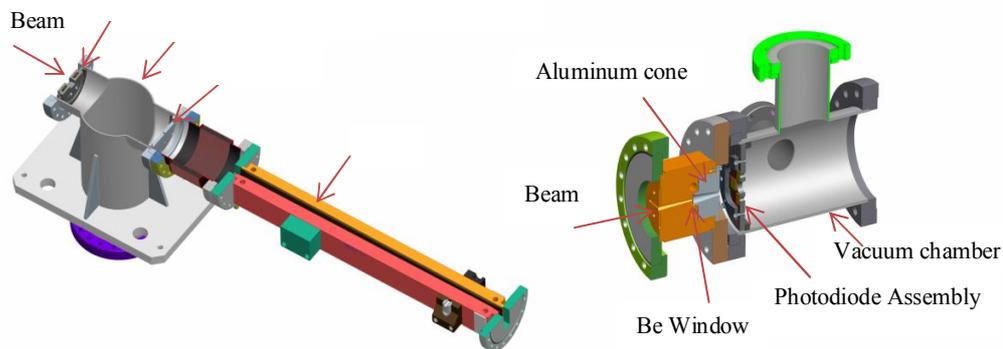


Figure 3 Cutout view of the lower half of IM1. Figure 4 Cutout view of the outboard half of IM2.

Table 1 New HHLFE key component aperture table

Component Name		Distance to the Center of the Straight Section (m)	Optical Aperture H × V (mm × mm)	Shielding Aperture H × V (mm × mm)
First Fixed Mask (FM1)	Inlet		38 × 47	
	Outlet	17.2	20 × 47	
Second Fixed Mask (FM2)	Inlet		24 × 47	
	Outlet	17.9	10.4 × 47	
GRID-XBPM	Inlet		15.5 × 47	
	Outlet	19.0	2.2 × 47	
Third Fixed Mask (FM3)	Inlet		16 × 47	
	Outlet	20.3	3.6 × 6	
Lead Collimator		20.4 (from inlet)	16.5 × 16.5	23 × 23
Photon Shutter 2 (PS2)	Inlet		10 × 47	
	Outlet	22.7	5 × 47	
Safety Shutter (SS1 & SS2)		22.95 (from inlet)	16 × 16	16 × 16
Wall Collimator		23.6 (from inlet)	27 × 17	37 × 26
Exit Mask (EM)	Inlet	25.1	12 × 47	
	Outlet	25.5	3 × 1	
Be Window (BeW)		25.6 (from center)	4.8 × 2.5 oblong	
Exit Collimator		26.0 (from inlet)	10 × 7	10 × 7

3-Operational Logic Change Due to Removal of PS1

All existing APS FEs have two high-power photon shutters (PS1 and PS2) and two safety shutters (SS1 and SS2). The safety shutters are operated in redundancy, meaning they open and close together. The photon shutters are not operated in redundancy; instead, PS1 is used as a backup for PS2. In normal operating conditions, PS1 remains in the open position. PS2, SS1, and SS2 operate as a shutter cluster. To close the shutter, PS2 will close followed by the closure of SS1 and SS2. To open the shutter, SS1 and SS2 will open followed by the opening of PS2. If PS2 fails to close, the PSS system will command PS1 to close, resulting in the closure of the two safety shutters. As long as PS1 is functional, the stored beam will not be dumped. However, a beamline with a failed PS2 in the FE will not be able to take beam until the next maintenance period. Since both the fast valve and the slow valve are located downstream of the PS1, PS1 also provides thermal protection for the valves in case of vacuum failure downstream of the valves. However, if the vacuum leak occurs upstream of the slow valve, then the SR exit valve must be closed to isolate the storage ring from the front end. Since the SR exit valve is not protected from dipole radiation by any cooled thermal dump, the storage ring cannot resume operation with the SR valve closed. To reopen the SR valve, a controlled access must take place to replace the bellows downstream of the SR valve with a bending magnet beam dump. The section between the SR valve and the beam dump will be pumped down. Once the vacuum reaches the ring vacuum, the SR valve will be open to resume storage ring operation. This process could take a day. The new FE improves operational convenience in vacuum protection by moving the slow valve to the very upstream end and installing the LPPS upstream of the SV. In the event of vacuum failure, the FEEPS will trigger the SV to close, and the closing logic will dump the stored beam and close the LPPS to protect the SV. A signal will be sent to the IDs to open the gap. The storage ring can resume operation after the IDs are verified to be in the open position and the ID gap is locked. No controlled access is necessary. However, since the LPPS cannot handle ID power, the logic must be changed for the LPPS to be used as a backup for PS2. If PS2 fails to close, the stored beam must be dumped, followed by the closure of the LPPS and safety shutters. Only after verifying the IDs are open and locked in the open position, the storage ring can resume operation. A beamline with a failed PS2 in the FE will not be able to take beam until the next maintenance period, which is the same as the original FE. A gap limit switch must be installed on the IDs to indicate the ID gap at open position at which the ID power is equivalent to or less than the dipole power.

4-Design of the New CUFE with New XBPMs

The layout of the new CUFE is very similar to the new HHLFE. The GRID-XBPM absorber plates are rotated by 90° so the beam vertical position will be detected by the differences in the XRF intensities from the absorbers while the horizontal position will be detected by measurements of the center-of-mass of the x-ray fluorescence footprint with pinhole-camera-like optics. The new CUFE

layout is shown in Figure 5, and the apertures of key components are listed in Table 2. The original CUFE layout can be referenced in [2].

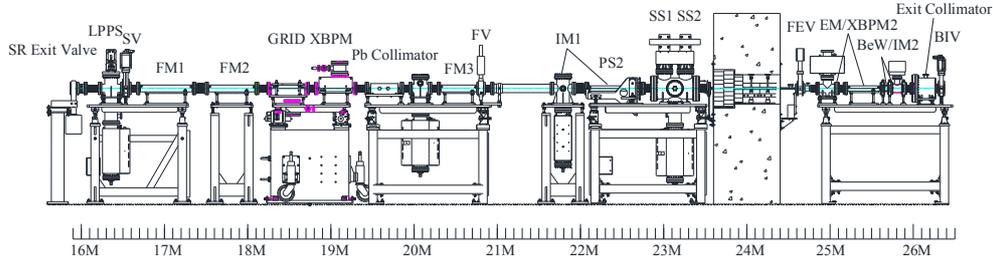


Figure 5 New CUFE layout elevation view with the next-generation XBPMs.

Table 2 CUFE key components aperture table

Component Name		Distance to Center of Straight Section (m)	Optical Aperture H × V (mm × mm)	Shielding Aperture H × V (mm × mm)
First Fixed Mask	Inlet		64 × 26	
	Outlet	17.3	40 × 14	
Second Fixed Mask	Inlet		46 × 17	
	Outlet	18.1	29.0 × 5.8	
GRID-XBPM	Inlet	18.3	47 × 13	
	outlet	19.3	47 × 1.5	
Lead Collimator		19.5 (from inlet)	40 × 16	46 × 22
Third Fixed Mask	Inlet		40 × 12	
	Outlet	20.8	31 × 4	
Second Photon Shutter	Inlet	22.2	50 × 10	
	Outlet	22.8	50 × 5	
Safety Shutter		22.95 (from inlet)	50 × 16	50 × 16
Wall Collimator		23.6 (from inlet)	47.6 × 16.8	56 × 25.4
Exit Splitter Mask	Inlet	25.1	50 × 9	
	Outlet	25.5	Dual 3 × 2 oblong	
Be Window		25.6 (from center)	Dual 4.5 × 3.0 oblong	
Exit Collimator		25.75 (from inlet)	Dual 7.0 × 6.0	Dual 7.0 × 6.0

5-Thermal Analysis

The heat-load-handling capability of the new HHLFE and CUFE with a GRID-XBPM is the same as the original HHLFE and CUFE, respectively. All new components have at least the same thermal handling capability as their original counterparts. Thermal analyses are carried out to validate the design with the heat load parameters from the original HHLFE and CUFE. FM3 is the only component that requires thermal analysis for both the HHLFE and the CUFE. Beam positions of vertical, horizontal, and corner missteering are considered. For HHLFE, the power load of two inline Undulator A's at 10.5-mm gap

($k=2.76$) at 180 mA is used. The temperature plot of the beam vertical missteering is shown in Figure 6. For the CUFE, the heat load of two 2.1-m - long Undulator A's at 1-mrad canting angle at 10.5-mm gap ($k=2.76$) at 200 mA is used. The temperature plot of the beam vertical missteering is shown in Figure 7. Peak temperature below 300°C, cooling wall temperature below 153°C and von Mises stress below 450 MPa are the failure criteria used for the analysis.

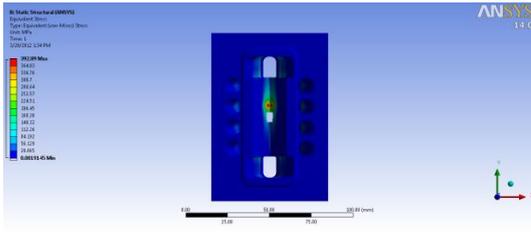


Figure 6 Temperature plot of HHLFE FM3 with vertical beam missteering.

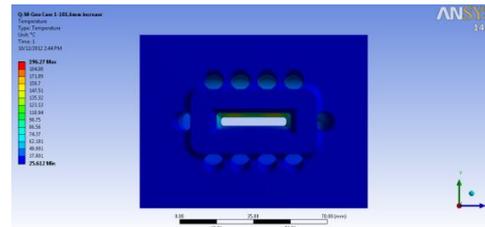


Figure 7 Temperature plot of CUFE FM3 with vertical beam missteering.

6-Conclusion and Future Work

The design of the HHLFE with next-generation XBPMs is at the final design stage and the design of the new CUFE is at the advanced preliminary design stage. The heat-load-handling capability of each front end is the same as or better than its original counterparts. Many components are standardized. These two designs will serve as base designs for the APS upgrade. In the foreseeable future, there are two new front ends to be designed for the APS Upgrade. One is CUFE for high power from superconducting undulators in long straight section, and the other is CUFE with large vertical aperture for short pulse x-rays. There will be challenges in both high heat load management and in aperture scheme designs.

References

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