ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH24

FRONT END DESIGNS FOR THE ADVANCED PHOTON SOURCE MULTI-BEND ACHROMATS UPGRADE *

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Abstract

The Advanced Photon Source (APS) upgrade from double-bend achromats (DBA) to multi-bend achromats (MBA) lattice is underway. This upgrade will change the storage ring energy from 7 GeV to 6 GeV and beam current from 100 mA to 200 mA. All front ends must be upgraded to fulfil the following requirements: 1) Include a clearing magnet in all front ends to deflect and dump any electrons in case the electrons escape from the storage ring during swap-out injection with the safety shutters open, 2) Incorporate the next generation x-ray beam position monitors (XBPMs) into the front ends to meet the new stringent beam stability requirements, 3) For insertion device (ID) front ends, handle the high heat load from two undulators in either inline or canted configuration. The upgraded APS ID front ends will only have two types: High Heat Load Front End (HHLFE) for single beam and Canted Undulator Front End (CUFE) for canted beams. This paper presents the final design of the HHLFE and preliminary design of the CUFE.

OVERVIEW OF APS FRONT ENDS

APS has a total of 35 sectors that can extract user beams. Currently there are 33 existing ID front ends (FE) and two vacant ID ports. The APS upgrade (APSU) will build out all 35 ID front ends with either a HHLFE for inline undulators or a CUFE for canted undulators. Out of the 33 existing ID front ends, 21 of them were built in the 1990s and are not capable of handling the heat load of the APSU ID sources and must be replaced with new FEs. The remaining 12 front ends that were built in the 2000s are capable to handle the heat load but must be retrofitted to have the next generation XBPMs and the clearing magnets. The APS existing ID front ends and their heat load limit is shown in Table 1.

Table 1: APS Existing ID Front Ends Heat Load Limit

Type of FEs	FEv1.2	FEv1.5	CUFE	HHLFE
P_{total} (watts)	6.9	8.9	10×2	21
P_{peak} (w/mrad^2)	198	245	281	590
Existing Qty.	17	4	7	5

HIGH HEAT LOAD FRONT END

The original HHLFE was designed in 2003 [1]. The original design was focused on the design of high heat load components. All photon masks and photon shutters were designed to handle the heat load limit of 21 kW total power and 590 kW/mrad^2 peak power density, equivalent of two inline 3.3-cm-period undulators at 10.5 mm gap at 180 mA. This heat load limit was sufficient for the APSU and was adopted as the design requirement for the APSU front ends. The first major redesign of the HHLFE was in 2012 to incorporate the next generation XBPMs into the front end [2]. Since then many improvements have been made to the front end. This paper presents the new HHLFE for APSU MBA to include a clearing magnet in the front end and refine the design of the XBPMs to reduce cost and ease alignment, and introduce a new design of exit mask and XBPM2 combined unit. The layout of the new HHLFE is shown in Fig. 1. The aperture of key components are shown in Table 2. The design will be initially installed in the vacant port of 28-ID for the current storage ring to test out the new designs of the XBPM system.

Table 2: HHLFE Aperture Table for APSU MBA

Components	Aperture H×V (mm)
Pre-Mask	36×26
FM1	38×26 (inlet)/ 20×16 (outlet)
FM2	24×20 (inlet)/ 9×12 (outlet)
Clearing Magnet	13×20 (optical minimum)
	18 (magnet gap)×65 (stay clear)
Lead Collimator	19.5×19.5 (optical)
	26×26 (shielding)
GRID-XBPM	15.3×50 (inlet)/ 1.6×50 (outlet)
FM3	16×47.8 (inlet)/ 3.6×6 (outlet)
Photon Shutter	10×47.8 (inlet)/ 5×47.8 (outlet)
Safety Shutter	72×20 (optical)
	72×20 (shielding)
Wall Collimator	27×17 (optical)
	37×26 (shielding)
Exit Mask	10×38 (inlet)/ 2×2 (outlet)
Exit Collimator	5×5 (optical)
	5×5 (shielding)

* Work supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357
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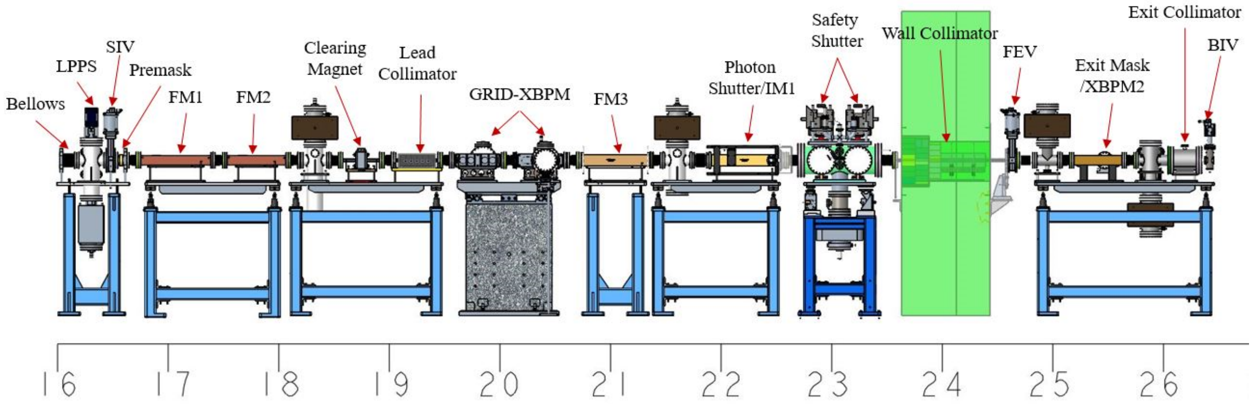

Figure 1: Layout of the HHLFE for APS MBA upgrade.

HHLFE Description

The front end starts with a bellows to be connected to the storage ring photon extraction tube, followed by a Low Power Photon Shutter (LPPS), a Storage Ring Isolation Valve (SIV), and a Premask. This table will be installed along with the storage ring vacuum system. This table is the same for HHLFE and CUFE except the aperture of the premask. The SIV provides the vacuum interface between the storage ring and the front end. As long as the LPPS and SIV is closed, the storage ring can operate without the rest of the front end being installed.

For the photon components, the first fixed mask (FM1) and second fixed mask (FM2) together provide the required aperture for the GRID-XBPM and protect the clearing magnet and lead collimator aperture from synchrotron beam. The FM1 and FM2 are box-cone design confining beam both horizontally and vertically. FM1 and FM2 are made from solid GlidCop bar. The third fixed mask (FM3) protects all components downstream of it. The FM3 is made from brazing two OFHC based halves. Each half has a GlidCop beam striking plate explosion bonded to the OFHC base material. The exit mask is a new design. It combines the exit mask and XBPM2 function into one unit. The beam intercepted by the inboard surface is detected by the detectors mounted to the outboard flange. The exit mask is made by brazing two halves of GlidCop bars. All three styles of masks are shown in Fig. 2.

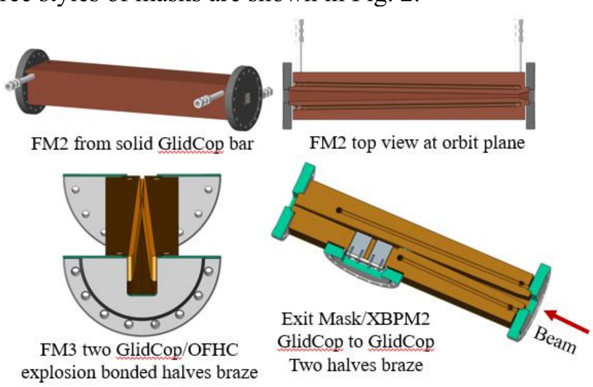

Figure 2: Three styles of masks in HHLFE.

The clearing magnet is a new component. It is a passively safe device to dump the electron beam in case the electron beam enter the front end due to the storage ring magnet steering errors. Due to HHLFE has small horizontal apertures, the clearing magnets has 18 mm horizontal magnetic gap to deflect the beam vertically towards the floor. The required deflection angle is calculated to be 6.52 mrad [3]. The magnet design and analysis has been completed and the preliminary mechanical model is shown in Fig. 3. The radiation caused by dumping the electron beam in the front end is still under evaluation.

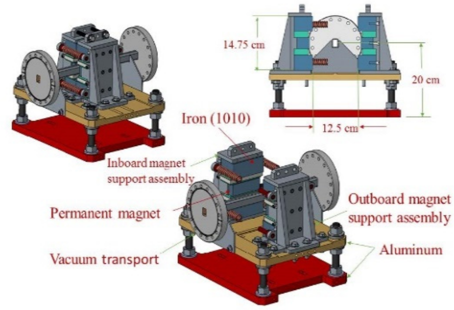

Figure 3: Preliminary mechanical model of the clearing magnet for HHLFE.

The next generation XBPMs consists of three components: 1) GRID-XBPM which is in the storage ring feedback system, 2) Intensity Monitor 1 (IM1) which is an alignment tool for GRID-XBPM, 3) XBPM2 which is not in the storage ring feed-back system and functions as an independent check to ensure that the beam is centered at the exit mask aperture. Since the original design of GRID-XBPM, many improvement has been made to its support and the motion structures, and the detector system to reduce the cost, and increase the signal to noise ratio. For the IM1, the new design is to mount the detectors directly onto the photon shutter's upstream and downstream flanges. These detectors measure the copper fluorescence generated by the photo shutter at it closed position to aid the alignment of the GRID-XBPM. The new XBPM2 integrated the exit mask and the detectors into the same unit. [4]

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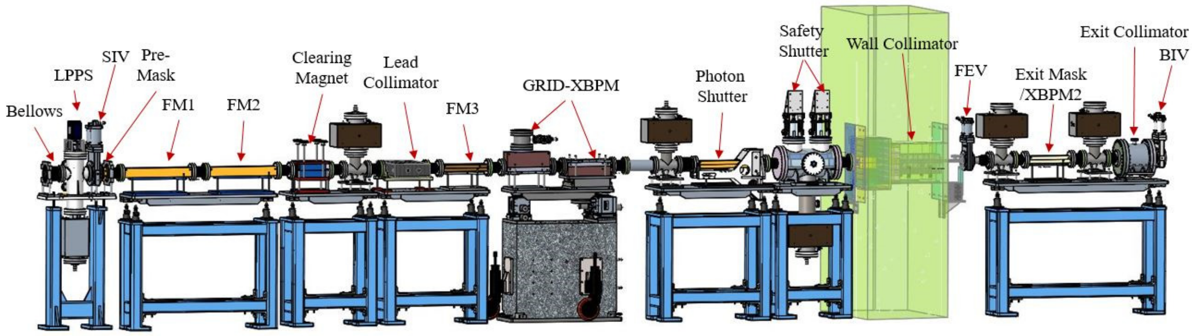

Figure 4: Layout of the CUFE for APS MBA upgrade.

CANTED UNDULATOR FRONT END

CUFE is designed for two canted beams with 1.0 mrad canting angle. Currently there are 7 CUFEs in the existing storage ring. The high heat load components in the existing CUFEs are designed to handle the heat load limit of 20 kW total power which is 10 kW per beam and 281 kW/mrad^2 peak power density, equivalent to two 2.07-m-long 3.3-cm-period undulators at 10.5 mm gap at 200 mA. [5] This heat load limit is sufficient for the APSU and is used as the design requirement for the APSU. The layout of the CUFE is shown in Fig. 4 and the aperture table is shown in Table 3. The layout is similar to that of the HHLFE. The first table is identical to that of the HHLFE except the aperture of the premask. The FM1and FM2 are existing designs to protect clearing magnet and lead collimator. Due to CUFE has large horizontal aperture to pass the two canted beams, the clearing magnet must use vertical magnetic gap to deflect beam horizontally. The principle for the GRID-XBPM in CUFE is the same as that in HHLFE. It is rotated 90º. CUFE GRID-XBPM has inclined scattering surface intercepting beam vertically with detectors mounted on the top and bottom respectively. To prevent the cross talks of the two beams, a divider must be installed in the center of the GRID-XBPM. To protect the divider from synchrotron beam strike, a splitter mask of FM3 is introduced to ensure that the beam passing through the FM3 has proper horizontal separation and will not strike the divider in the GRID-XBPM. The photon shutter and safety shutter are existing designs. A new exit mask is needed to function as XBPM2. A new exit collimator design uses in-vacuum tungsten.

Table 3: CUFE Aperture Table for APSU MBA

Components	**Aperture H×V (mm)**
Pre-Mask	62×26
FM1	64×26 (inlet)/ 40×14 (outlet)
FM2	46×17 (inlet)/ 26×5 (outlet)
Clearing Magnet	32×9 (optical minimum)
	40 (clear)×16 (v. magnet gap)
Lead Collimator	40×16 (optical)
	46×22 (shielding)
Splitter mask FM3	50×10 (inlet)/ dual 10×4 (outlet)
GRID-XBPM	50×10 (inlet)/ 50×1 (outlet)
Photon Shutter (PS)	50×10 (inlet)/ 50×5 (outlet)
Safety Shutter (SS)	50×16 (optical)
	50×16 (shielding)
Wall Collimator	47.6×16.8 (optical)
	56×26 (shielding)
Exit Mask (EM)	50×9 (inlet)/ dual 2×2 (outlet)
Exit Collimator	7×6 (optical)
	7×6 (shielding)

CONCLUSION AND DISCUSSIONS

HHLFE final design was completed for all components except the clearing magnets. All high heat load components are made out of GlidCop or GlidCop to OFHC copper explosion bond material. All three styles of masks were successfully fabricated by three vendors. The exit mask/XBPM2 combination unit was already installed in 27-ID in May 2018 shut down and are producing good data. A complete front end without clearing magnet will be installed in 28-ID in September 2018 shutdown. For CUFE, preliminary design is completed. Currently in detail design of the XBPMs. For all front ends, The Bremsstrahlung radiation caused by electron beam dumped by clearing magnet into the front end need to be evaluated by radiation physicist as soon as possible to ensure that this radiation is within the allowed limit.

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