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

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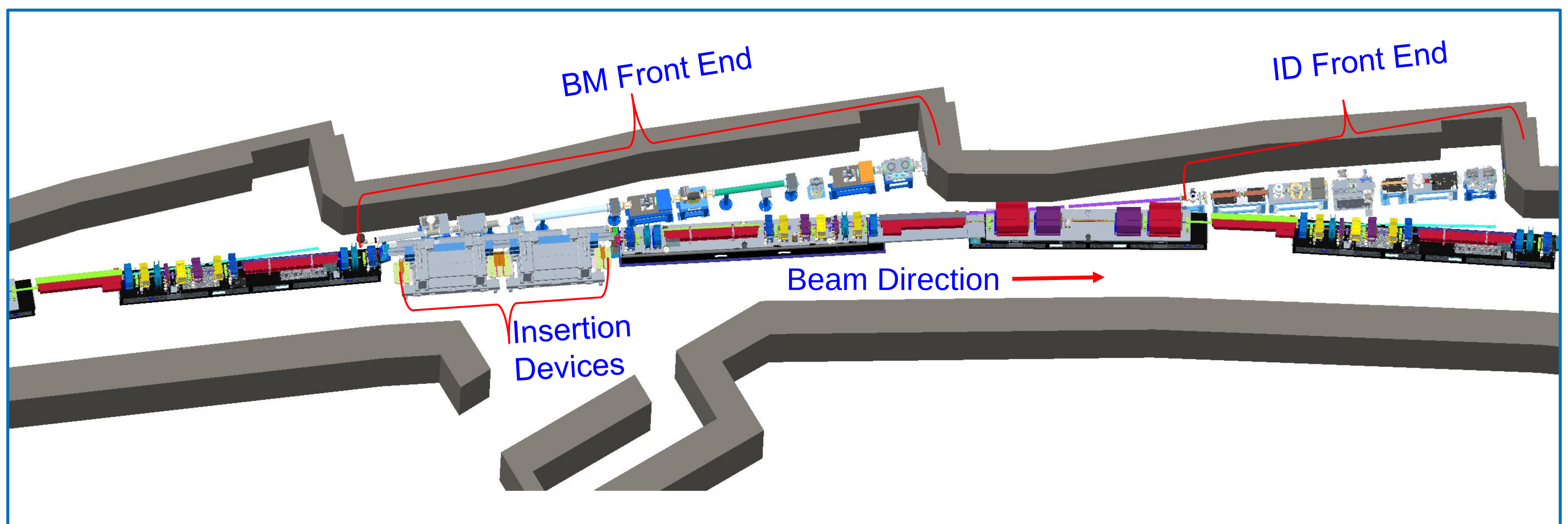
Abstract

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 beam. The final design of the HHLFE and preliminary design of the CUFE are presented.



Layout of front ends in relation to the APSU MBA accelerator components for a typical sector

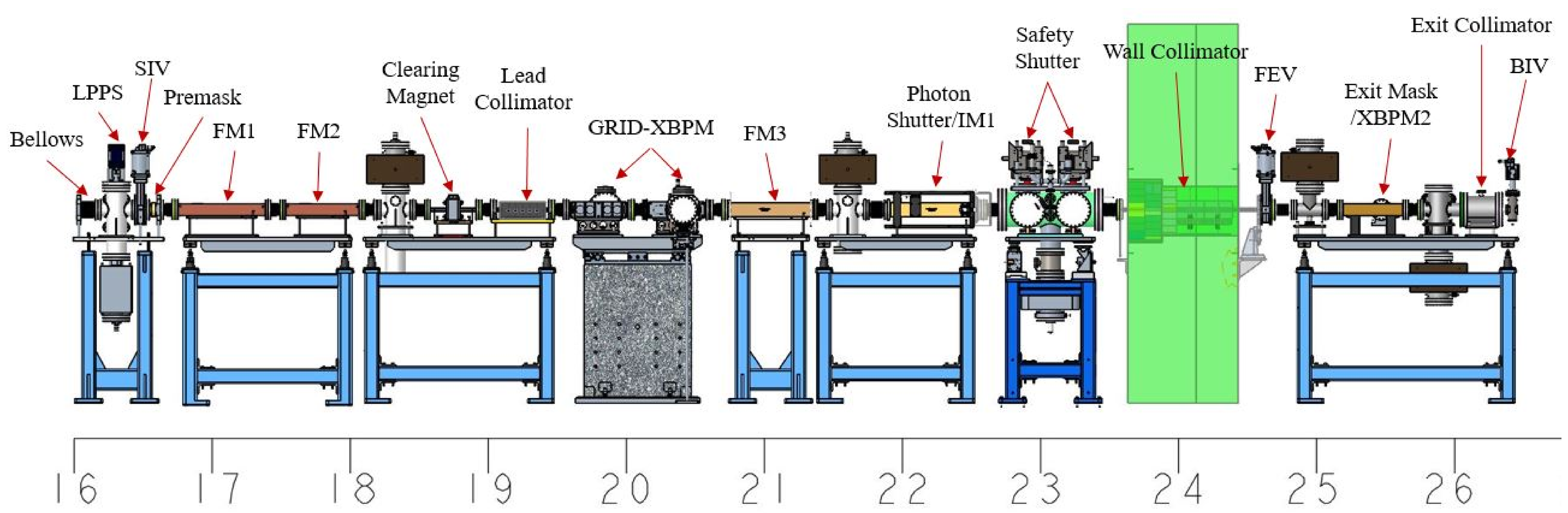
APS Existing ID Front Ends Heat Load Limit

Existing Capabilities	Original ID FE v1.2 17 units	Undulator only FE v1.5 4 units	Canted Undulator FE 7 units	High Heat Load FE 5 units
Source Parameters at 7 GeV	One 2.4-m-long U3.3 at 11-mm gap at 130 mA	One 2.4-m-long U3.3 at 11-mm gap, at 150 mA	Two canted 2.07-m-long, U3.3 at 10.5 mm gap at 200 mA	Two inline U3.3 at 10.5-mm gap, at 180 mA
Total Power (kW)	6.9	8.9	10 x 2	21
Peak Power Density (kW/mrad²)	198	245	281	590

APSU Front Ends Requirements

- All ID front ends capable of handling two undulators in either inline or canted configuration with 1.0 mrad canting angle. There will only be two types of ID front ends: High heat load front end (HHLFE) for single beam and canted undulator front end (CUFE) for canted beams
- Heat load limit for APSU HHLFE: 21 kW total power and 590 kW/mrad² peak power density
- Heat load limit for APSU CUFE: 10x2 kW total power and 281 kW/mrad² peak power density
- All ID front end must be equipped with the Next Generation X-ray Beam Position Monitor (XBPM)
- All front ends both ID and BM must have clearing magnets to deflect electrons away from the safety shutter for swap-out injection
- Reuse as many existing components as possible

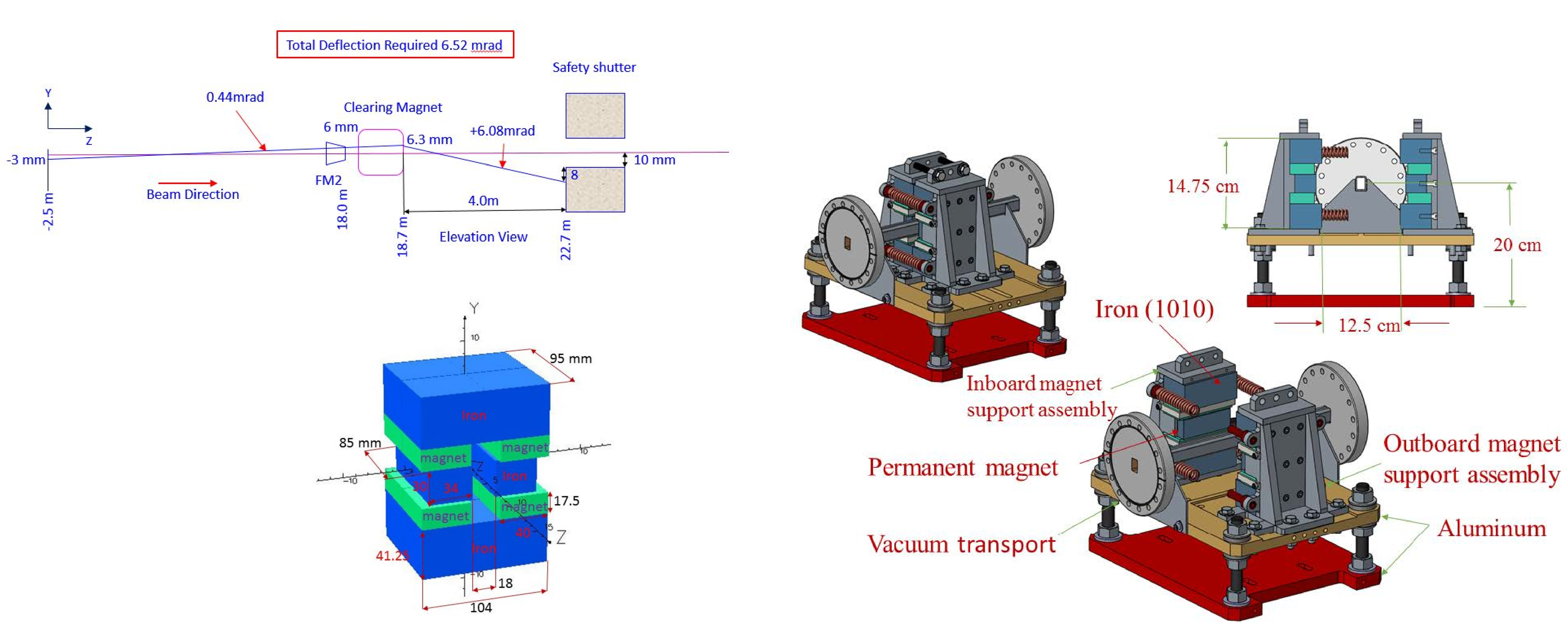
APSU High Heat Load Front End



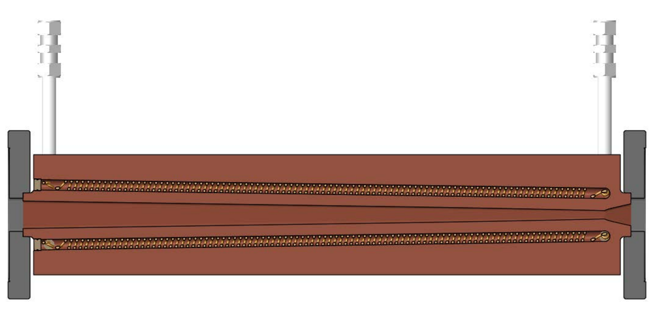
Layout of HHLFE for APS MBA upgrade

APSU HHLFE Key Components Aperture Table

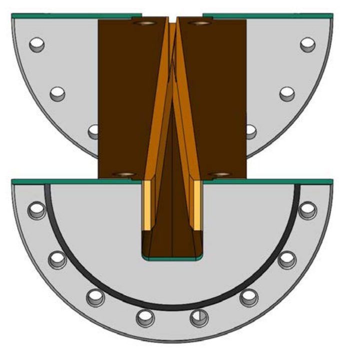
HHLFE Components	Aperture H (mm)×V (mm)	Comments
First Fixed Mask (FM1)	38×26 (inlet)/ 20×16 (outlet)	Box-cone design GlidCop Bar
Second Fixed Mask (FM2)	24×20 (inlet)/ 9×12 (outlet)	Box-cone design GlidCop Bar
Clearing Magnet	13×20 (optical)/ 18(magnet gap)×65(stay clear)	18 mm horizontal gap
Lead Collimator	19.5×19.5 (optical)/ 26×26 (shielding)	Lead surround SST tube
GRID-XBPM	15.3×50 (inlet)/ 1.6×50 (outlet)	
Third Fixed Mask (FM3)	16×47.8 (inlet)/ 3.6×6 (outlet)	GlidCop/OFHC explosion bond, two halves braze
Photon Shutter (PS)	10×47.8 (inlet)/ 5×47.8 (outlet)	
Safety Shutter (SS)	72×20 (optical)/ 72×20 (shielding)	Reuse FEv1.2
Wall Collimator	27×17 (optical)/ 37×26 (shielding)	Lead surround SST tube
Exit Mask (EM)/XBPM2	10×38 (inlet)/ 2×2 (outlet)	Integrated exit mask with XBPM2
Exit Collimator	5×5 (optical)/ 5×5 (shielding)	In-vacuum tungsten



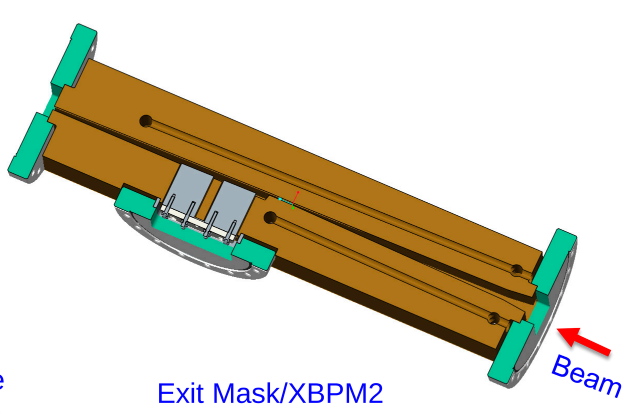
HHLFE clearing magnet schematic using horizontal magnetic gap, magnet concept, mechanical model



FM2 top view at beam orbit plane

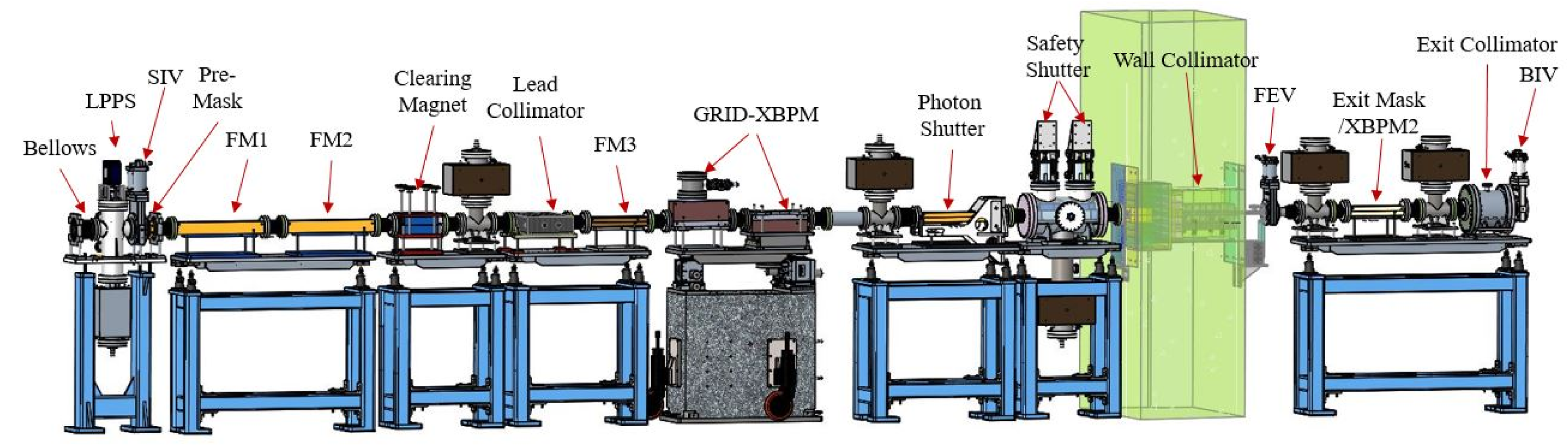


FM3 top view at beam orbit plane GlidCop/OFHC copper explosion bonded two halves braze



Exit Mask/XBPM2 GlidCop two halves braze

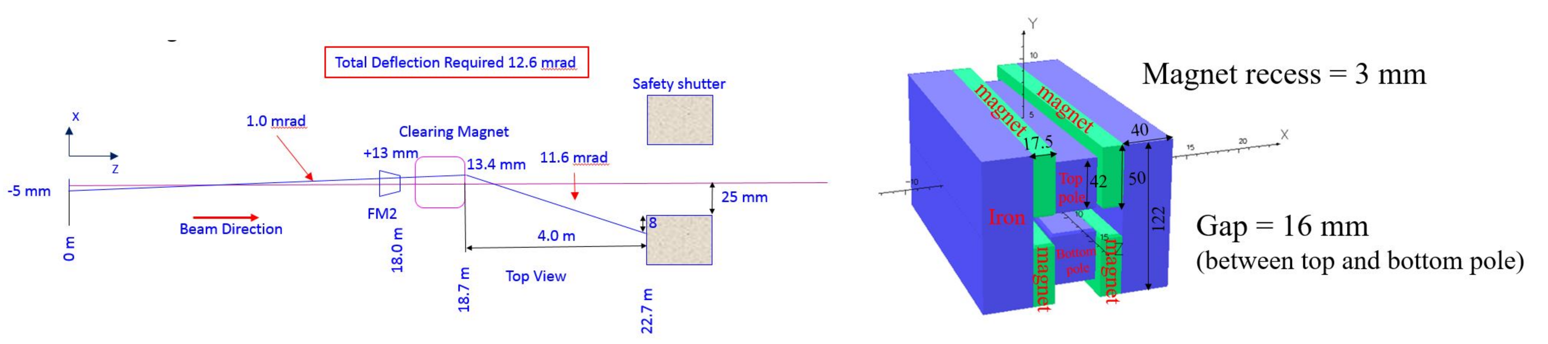
APSU Canted Undulators Front End



Layout of CUFE for APS MBA upgrade

APSU CUFE Key Components Aperture Table

CUFE Components	Aperture H (mm)×V (mm)	Comments
First Fixed Mask (FM1)	64×26 (inlet)/ 40×14 (outlet)	Existing CUFE design
Second Fixed Mask (FM2)	46×17 (inlet)/ 26×5 (outlet)	Existing CUFE design
Clearing Magnet	32×9 (optical)/ 40 (clear)×16 (v. magnet gap)	16 mm vertical gap
Lead Collimator	40×16(optical)/46×22 (shielding)	Lead surround SST tube
Third Splitter Mask (FM3)	50×10 (inlet)/ 10×4 dual (outlet)	New design
GRID-XBPM	50×10 (inlet)/50×1.0 (outlet)	New design
Photon Shutter (PS)	50×10 (inlet)/ 50×5 (outlet)	Existing CUFE design
Safety Shutter (SS)	50×16 (optical)/ 50×16 (shielding)	Existing CUFE design
Wall Collimator	47.6×16.8 (optical)/ 56×26 (shielding)	Existing CUFE design
Exit Splitter Mask (EM)	50×9 (inlet)/ 2×2 dual (outlet)	New design
Exit Collimator	7×6 (optical)/ 7×6 (shielding)	In-vacuum tungsten



CUFE clearing magnet schematic using vertical magnetic gap and CUFE magnet model

Clearing Magnet Requirement and Design Consideration

- Clearing magnet is a fail safe device to ensure that in case electrons gets into front end during swap-out injection while the safety shutters are open, the electrons will be dumped inside the front end and not passing through to the beamline.
- The location criteria for clearing magnets are: a) to allow small magnetic gap so the regular low carbon steel pole material can be used to produce sufficient field, b) to have the least deflection angle which results the shortest magnet length along the beam. Due to safety shutter has larger horizontal aperture than vertical aperture, vertical deflection is desirable.
- HHLFE has small horizontal aperture at FM2 which allow small horizontal gap for clearing magnets and deflect beam vertically resulting short magnet length. CUFE has large horizontal aperture to contain both canted beam while vertical aperture is small, so the magnet gap needs to be vertical and deflect beam horizontally which resulting longer magnet length.

Conclusion and Discussions

- All high heat load components are made out of GlidCop bar 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 installed in 27-ID in May 2018 shut down and produced good data.
- 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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