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

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Outline

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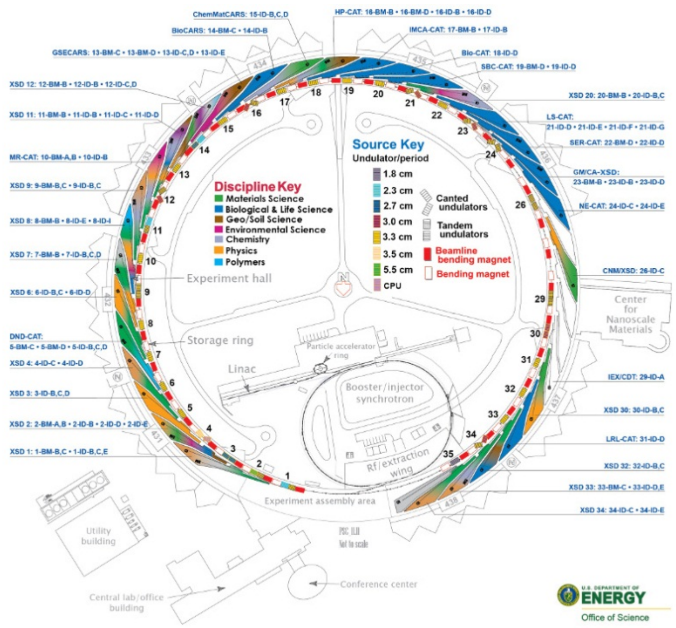
- Function of Front Ends
- APS Upgrade Requirements
- Beam Stability Requirements
- Function of the Next Generation XBPMs System
- Design of the New HHLFE with New XBPMs
- Operational Logic Change
- Design of the New CUFE with New XBPMs
- Thermal Analysis
- Summary

Introduction of APS Front Ends

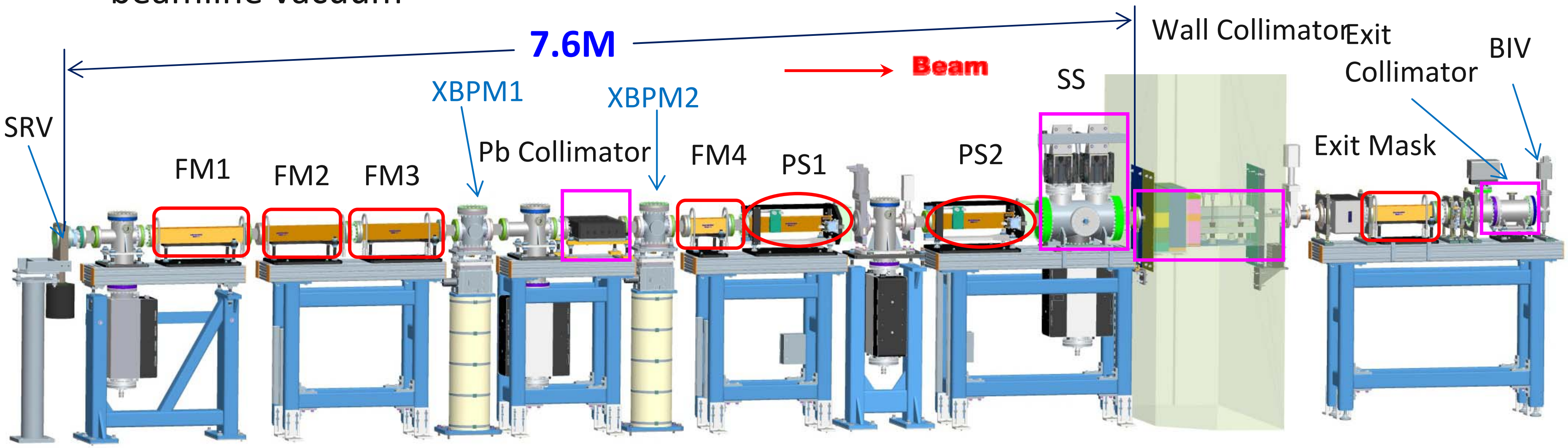
- Currently operate at **100** mA
- 35 ID beam ports with 32 operational beamlines and 3 vacant beam ports
- 4 different types of ID front ends
  - 19 original front ends FEv1.2 built in early 1990s
  - 3 undulator only front ends FEv1.5 built in late 1990s
  - 7 canted undulators front ends CUFE built in 2003, 2008 and 2010
  - 3 High heat load front ends HHLFE built in 2004 and 2009
- All front ends have photoemission types of XBPMs
- Heat Load Limit



	FE v1.2	FE v1.5	CUFE	HHLFE
Source Parameters	One U33 at 11 mm gap at 130 mA	One U33 at 11 mm gap at 150 mA	Two canted 2.1 m long U33 at 10.5 mm gap, 200 mA	Two in-line U33 at 10.5 mm gap, 180 mA
Total Power (kW)	6.9	8.9	20	21
Peak Power Density (kW/mrad^2)	198	245	281	590

Function of the Front End Subsystems

- Front End is the section from the storage ring exit valve to the Beamline Isolation Valve (BIV). The existing High Heat Load Front End (HHLFE) is shown
- Masks are used to confine the Synchrotron Radiation (SR), absorb power outside of the defined aperture.
- Lead and tungsten collimators collimate the Bremsstrahlung Radiation (BR)
- Photon shutters and safety shutters stop SR and BR inside the storage ring to allow access in the First Optics Enclosure (FOE) downstream of ratchet wall
- XBPMs provide beam position information for steering adjustments.
- Valves, pumps and gauges provide buffer zone between storage ring vacuum and beamline vacuum

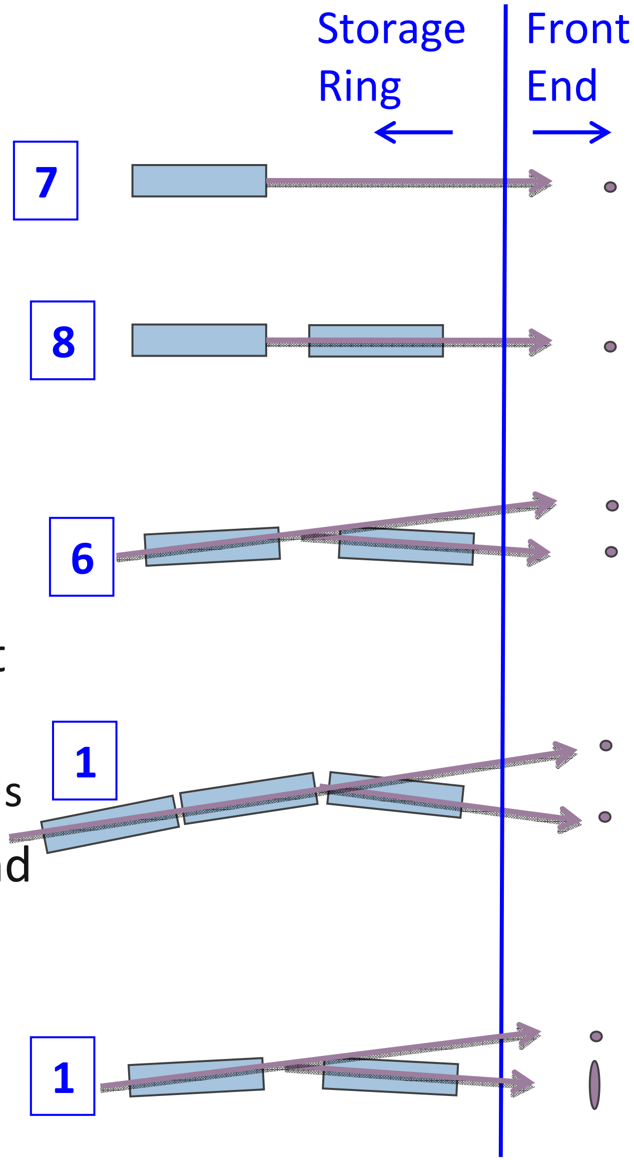


APS Upgrade Requirements

- Beam current upgrade to **150 mA** from 100 mA
- To be compatible with new IDs including
  - Permanent Magnet Hybrid Undulators (PMUs), New undulators' periods are 1.75 cm, 2.3 cm, 2.5 cm, 2.7 cm, 3.0 cm. All planned PMUs have shorter period than 3.3 cm, less power and power density than U33
  - Superconducting Undulator (SCU)
  - Electro Magnetic Variable Period Undulators (EMVPU)
  - APPLE II
- Different types of front ends are required based on different ID sources and their configurations: inline or canted
- All new front ends to be equipped with the next generation XBPM system based on Cu K-edge x-ray fluorescence (XRF)

Type of Front Ends for APS Upgrade

- Renovate Existing FE v1.2 Front End
  - For 1 undulator
- High-Heat-Load (HHL) Front End
  - For 2 inline undulators with next generation XBPMs
- Canted Undulator (CU) Front End
  - For 2 undulators in canted configuration with 1 mrad canting angle
- Long Straight Section Canted Undulator (LSSCU)Front End
  - Special case of CUFE , potential high power of two SCUs
- Short Pulse X-ray Canted Undulator (SPXCU) Front End
  - Special case of CUFE, for 2 undulators in canted configuration with large vertical aperture for SPX on one branch



New XBPM is Driving the Front End Upgrade

APS Upgrade Required XBPM resolution / stability goals at 18.6 m

	RMS Resolution (0.1 – 200 Hz)	RMS long term drift (1 week)
Horizontal	7.3 μm	13.6 μm
Vertical	2.9 μm	6.6 μm

- Existing Photoemission based XBPMs
  - Four blades, strong gap dependence
  - Software compensation (Glenn Decker, 2004): reduced the gap dependence from hundreds of μm to tens of μm residual
  - Do not meet APS-U requirements, especially for larger gaps
- Need better technology for the new XBPM

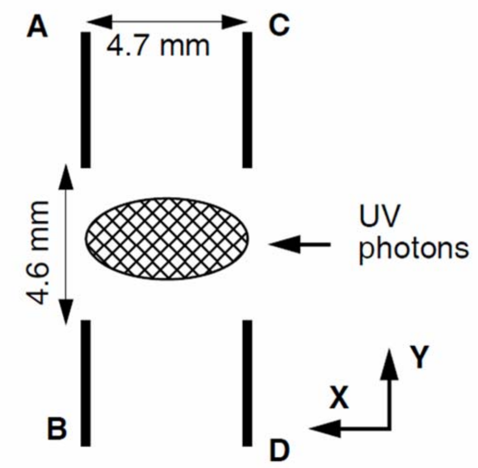
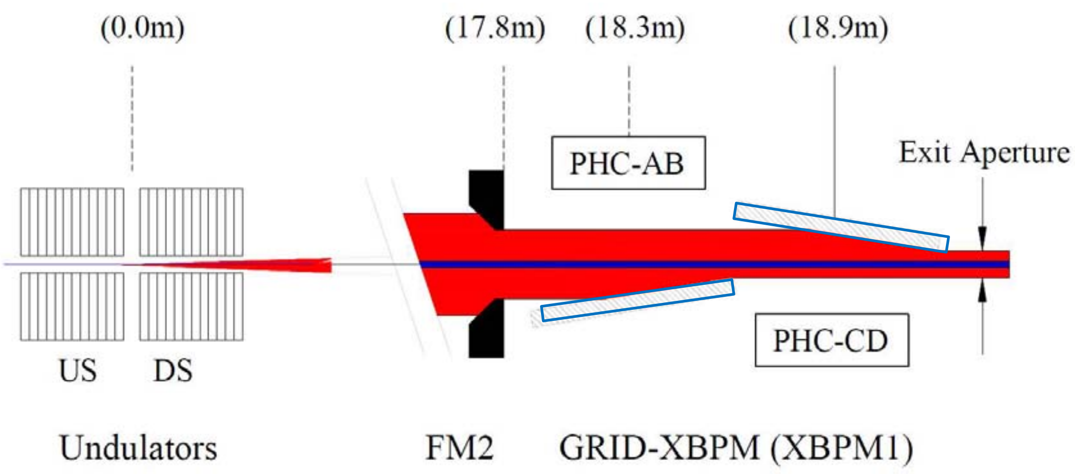
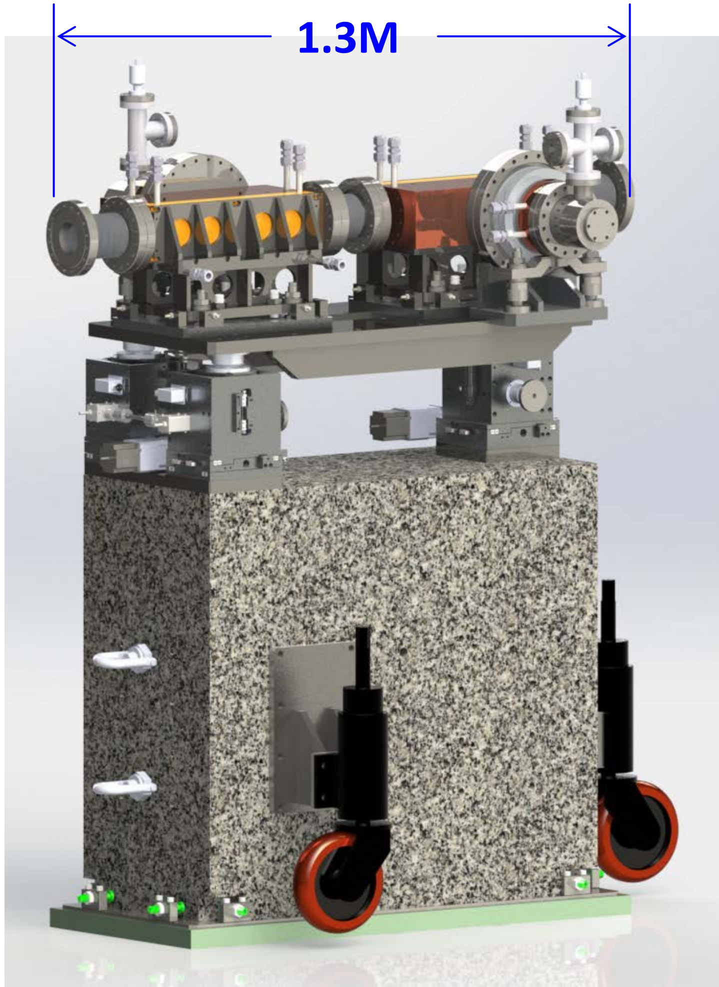


Figure 0:
P1 IDxbpm blade geometry

New HHLFE GRID-XBPM (Refer to SoonHong Lee's Talk)

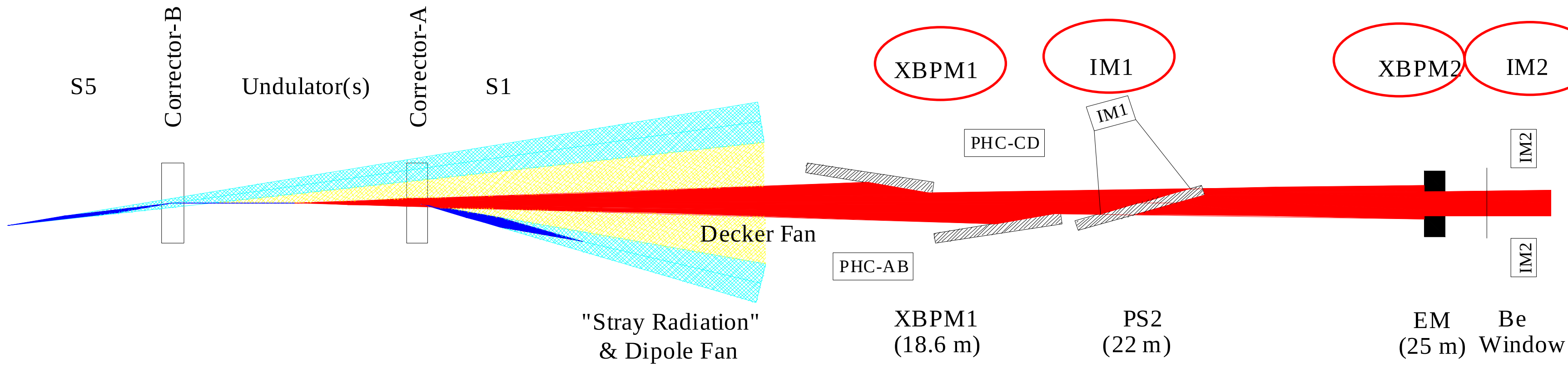
- Based on Cu K-edge x-ray fluorescence (XRF)
- Left-right absorbers measure horizontal position
- Pinhole cameras measure vertical beam position
- Undulator gap independent





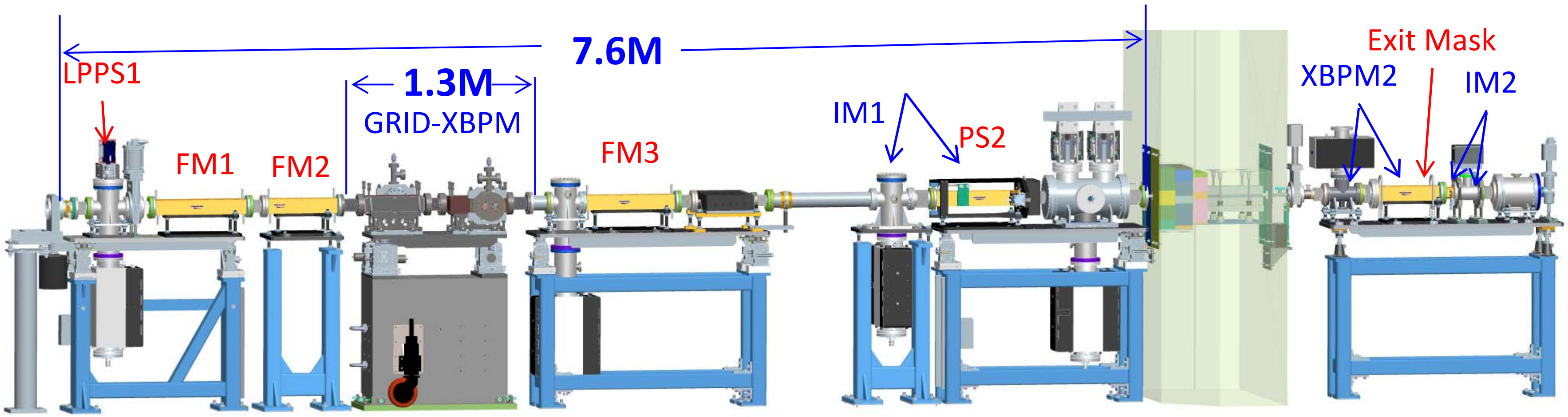
Next Generation XBPM System Schematic

- XBPM1: GRID-XBPM
- IM1 (1st Intensity Monitor): x-ray intensity monitor using XRF from the photon shutter
- XBPM2: Same operating principle as GRID-XBPM, using Exit Mask grazing-incidence surfaces intercept the undulator beam outside of the central cone.
- IM2: x-ray intensity through Exit Mask using Compton scattered x-ray from Be window. For windowless front end, a retractable diamond target will be used for scattering

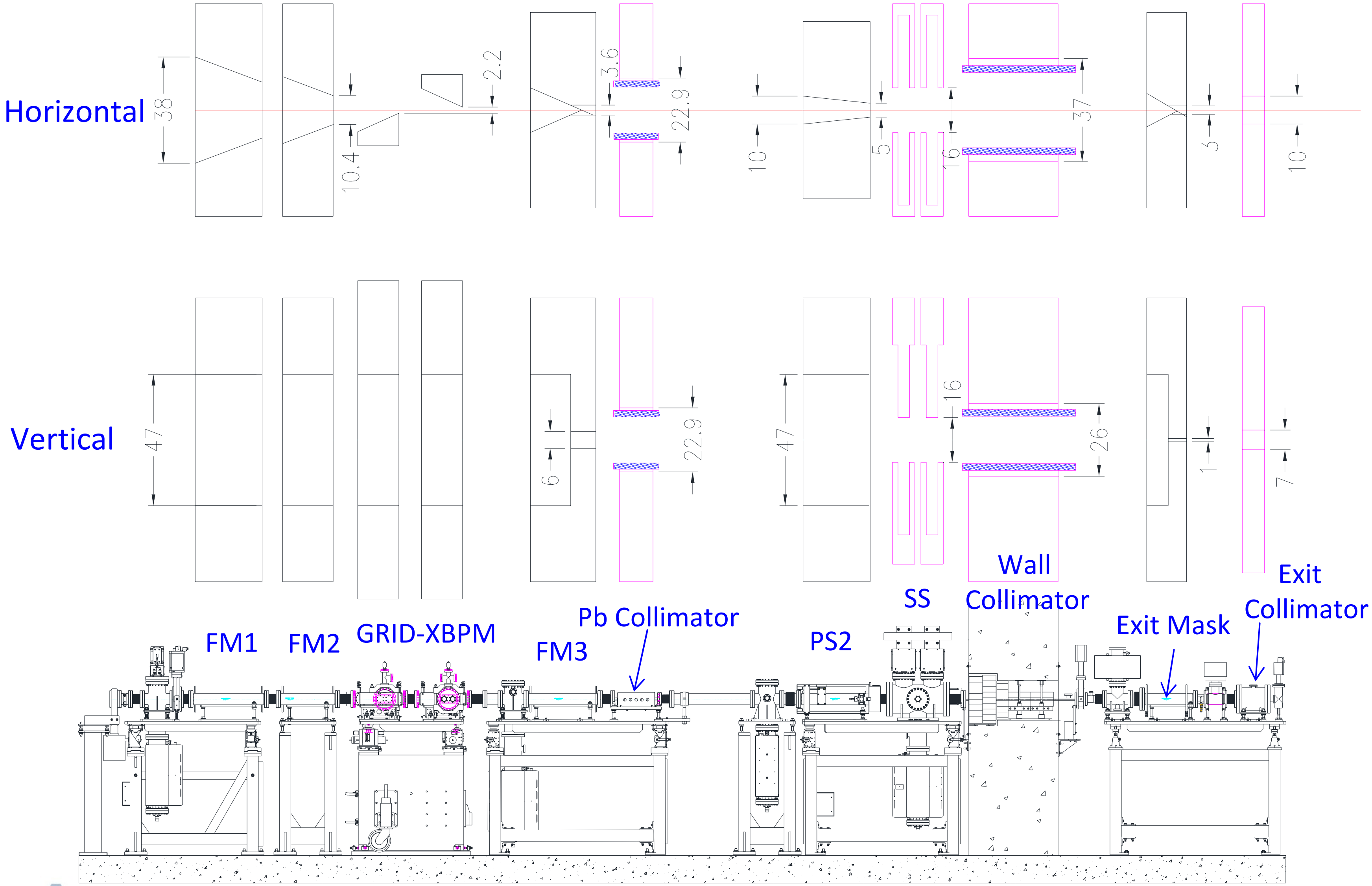


Design of New HHL Front End with Next Gen XBPMs

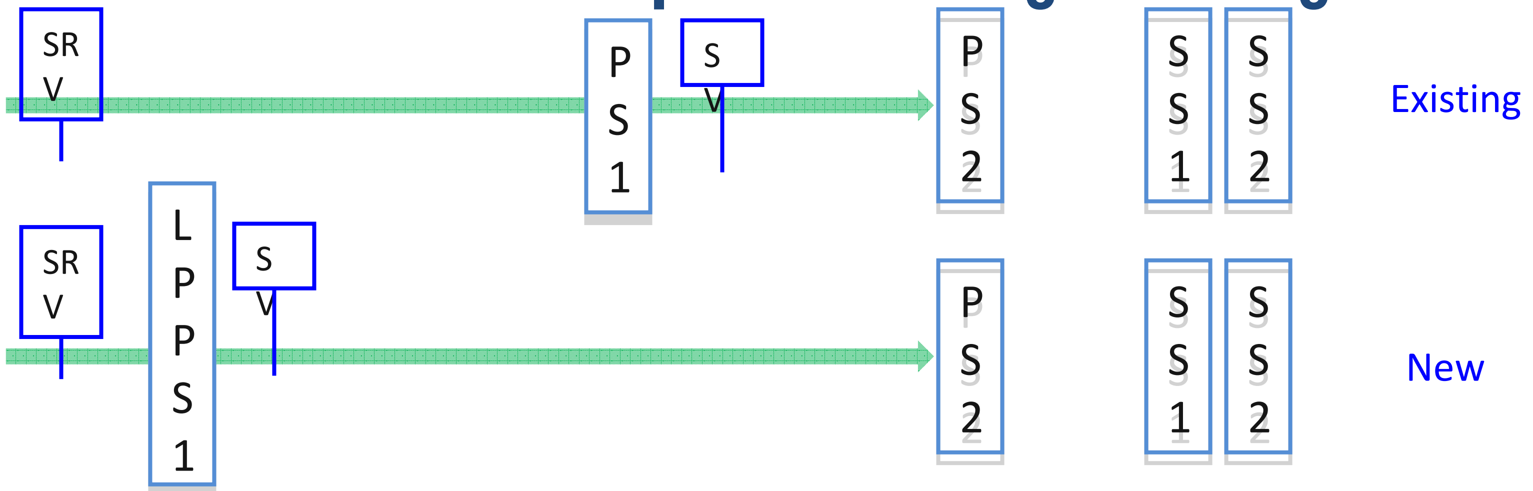
- To fit in the GRID-XBPM, PS1 must be removed. A Low Power PS1 (LPPS1) is added at the upstream to stop dipole radiation to protect valves in case of vacuum failure
- Redesign masks to fit XBPMs aperture requirement. XBPM apertures are not counted as front end radiation safety apertures
- XBPM system
  - GRID XBPM stands alone
  - Use PS2 and the vacuum cross upstream of PS2 to function as IM1
  - Use exit mask and the vacuum cross upstream of exit mask to function as XBPM2
  - Use the Be window and the vacuum cross downstream of Be window to function as IM2



HHLFE RSS Components Aperture Design



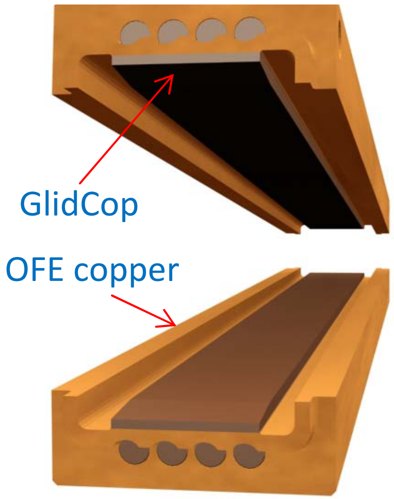
Front End Shutter Operation Logic Changes

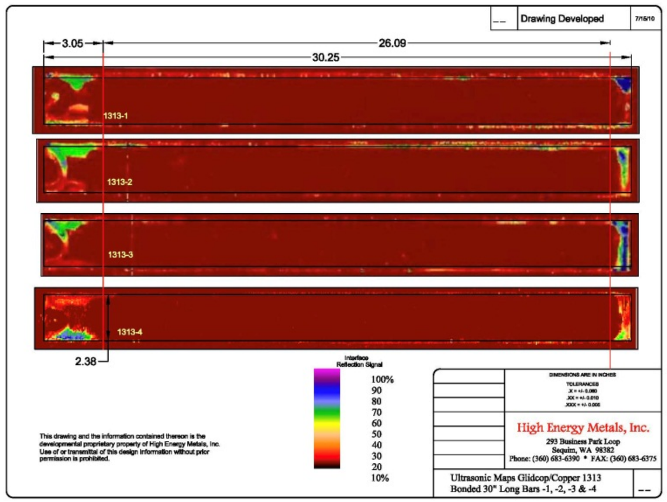


- Existing APS front end has two photon shutters and two safety shutters. The PS2, SS1 and SS2 operates as a cluster. PS1 remains open and functions as a back up to PS2
  - Pro: when PS2 fail to close, PS1 will close to protect the safety shutter. Beamline will be off line if PS2 fails, stored beam will not be dumped
  - Con: due to no thermally protected valve upstream of PS1, If vacuum failure occurs upstream of PS1, require controlled assess to replace a bellows with a beam dump, pump down, then restore the beam
- The new front end will have a LPPS1. Due to LPPS1 can not handle the undulator power, an undulator gap switch must be installed and interlocked with the LPPS1, LPPS1 can close only when the undulator gap is at the open position
  - Pro: not require controlled access for vacuum failure in front end, just dump the beam, close slow valve, close LPPS1 to protect slow valve from dipole radiation and restart the storage beam
  - Con: not a full back up for PS2, in certain cases, if PS2 fails to close, require dump the beam

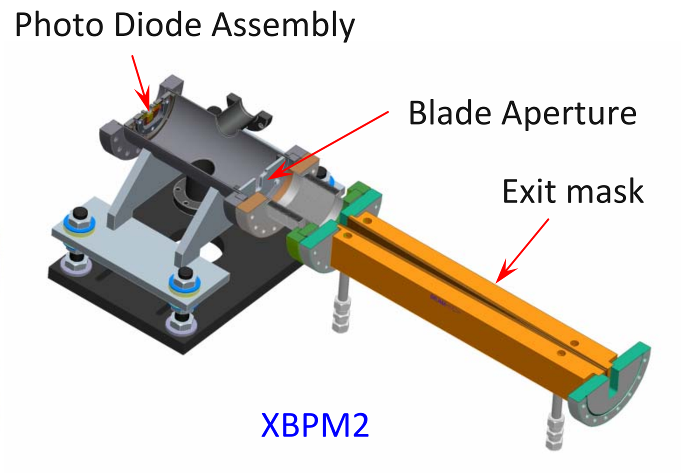
HHL Front End Masks Design and Fabrication

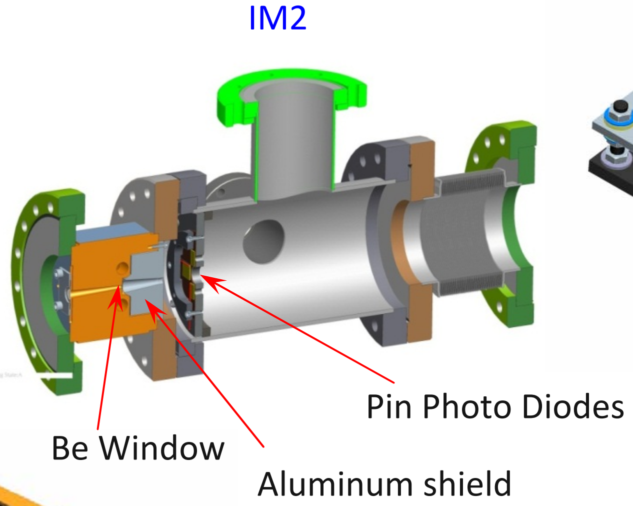
- Masks are brazed from two halves
- Each half consists of explosion bonded OFE copper base and GlidCop plate, ultrasonic scans ensure bond quality
- GlidCop plate stock has stronger material properties than GlidCop bulks, large surface OFE to OFE copper brazing is easier than GlidCop to GlidCop Brazing, Explosion bond of OFE copper to GlidCop is cheaper than large block of GlidCop
- Beam always strikes on a flat surface, no corner stress issues

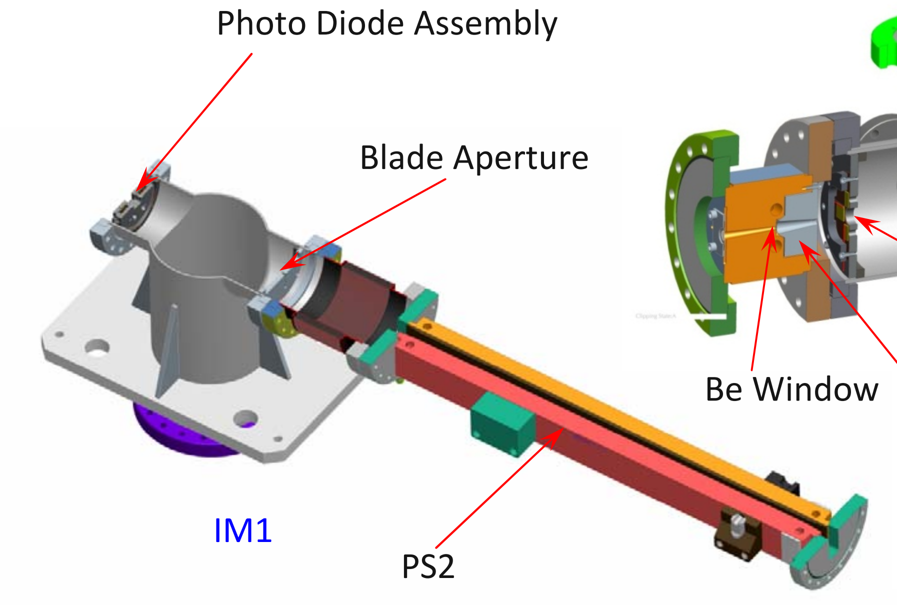


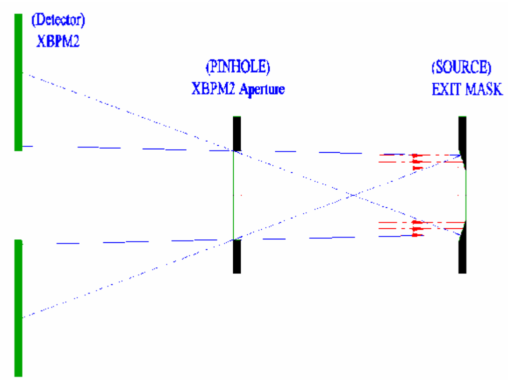


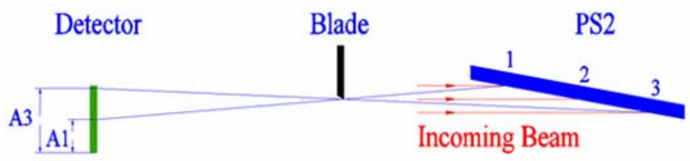
Additional Diagnostics

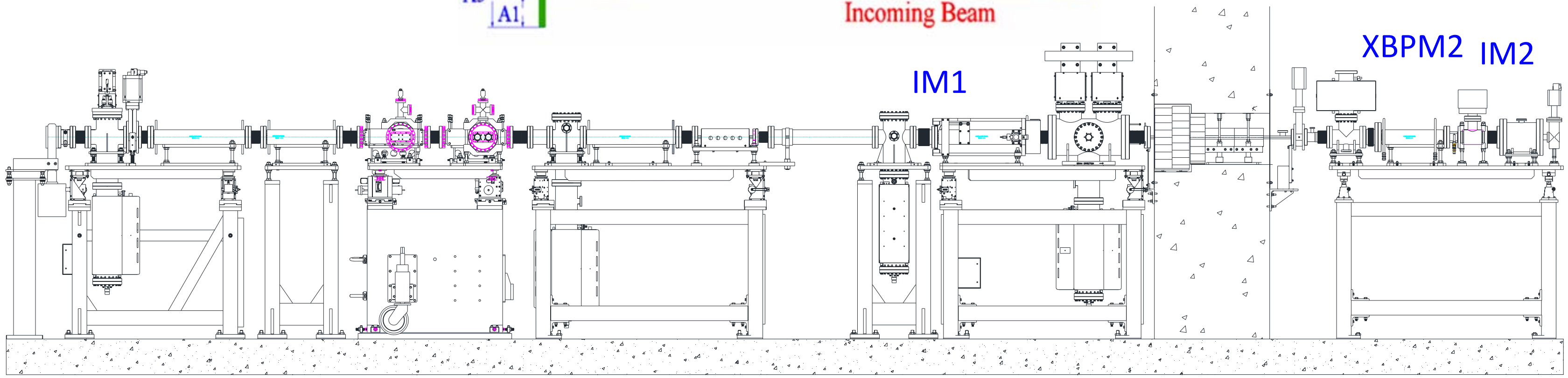






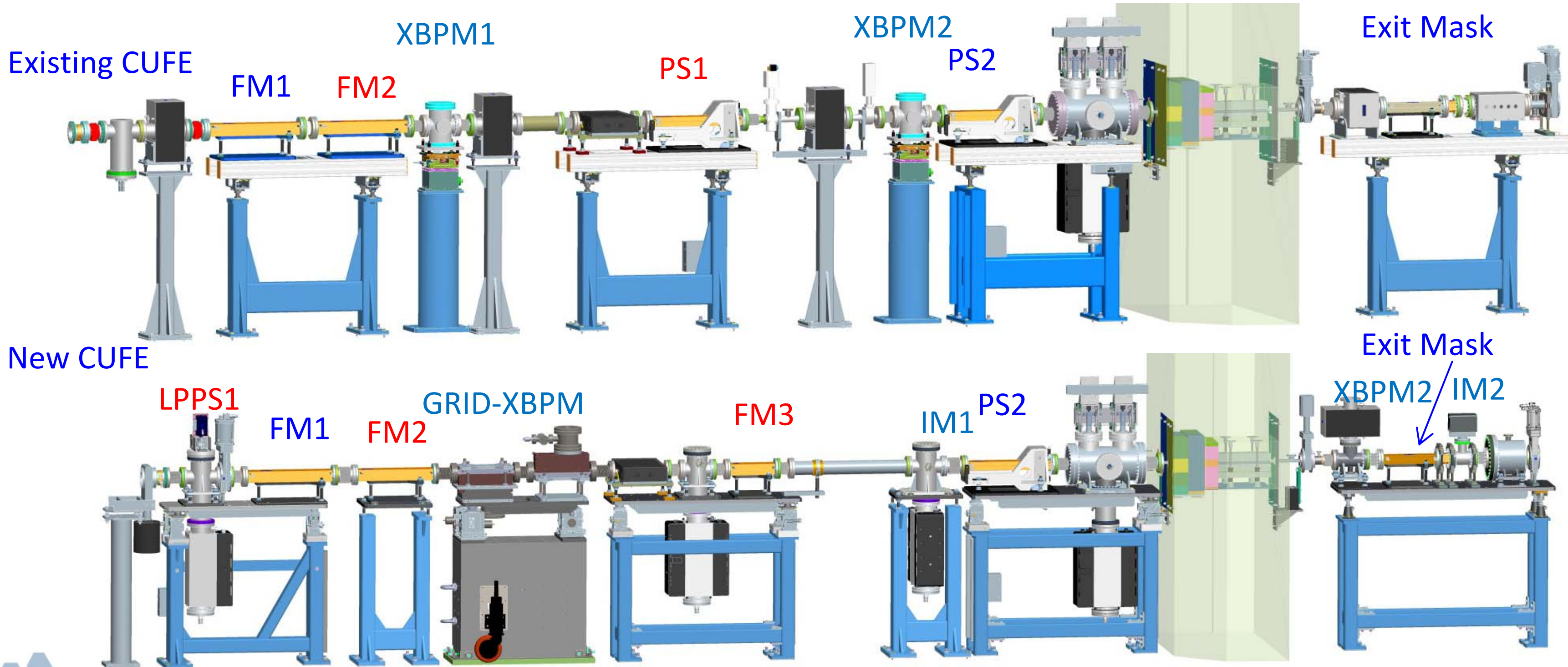




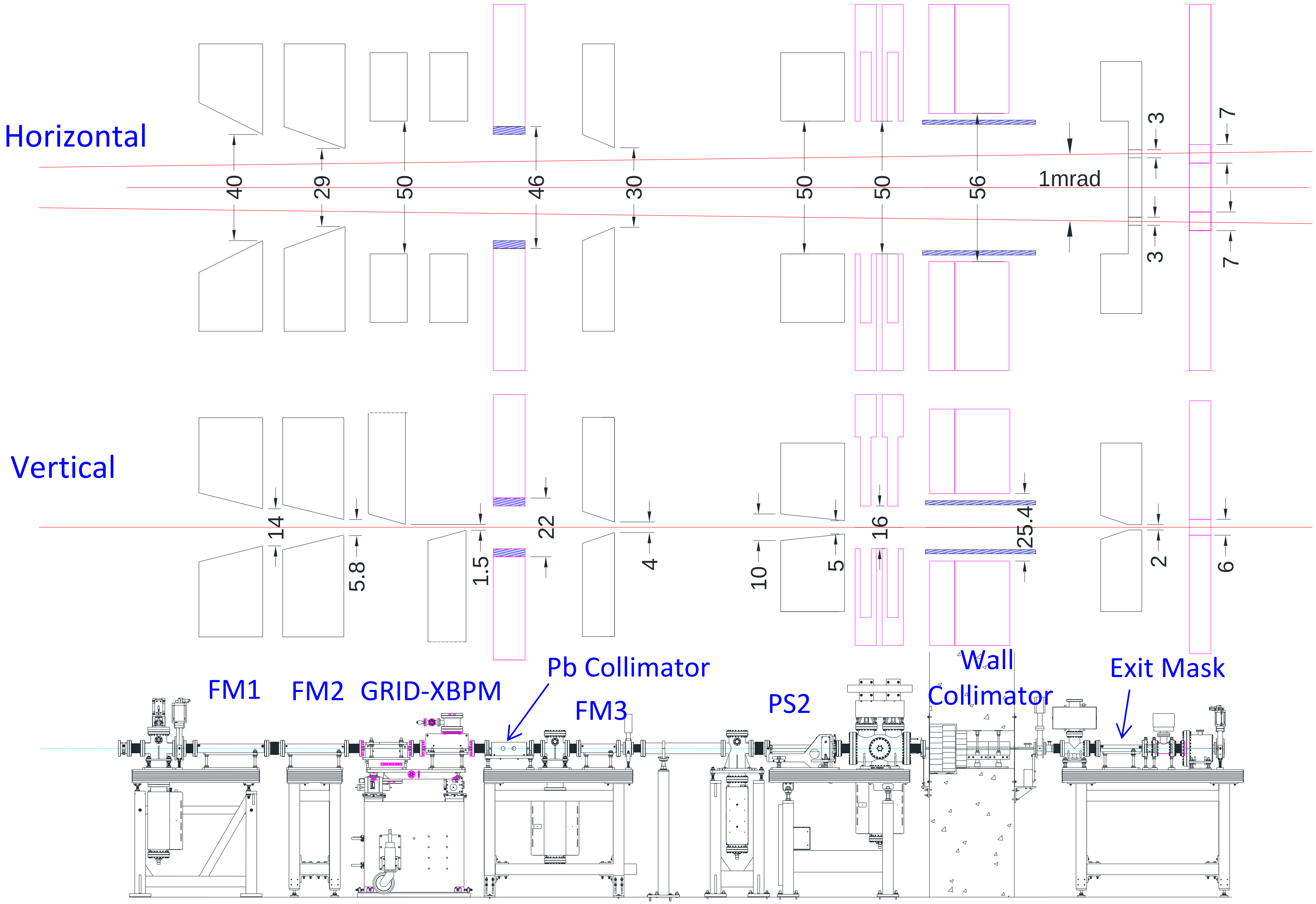


Design of New CU Front End with Next Gen XBPMs

- The original CUFE was designed in 2003. The upgrade objective is to replace the two photoemission type XBPMs with the new generation XBPMs maintain the same thermal handling capability
  - Remove PS1, add LPPS1 to protect valves, operational logic same as HHLFE
  - Redesign masks to meet the aperture requirement of next gen XBPMs
  - Design the next gen XBPM system include GRID-XBPM, IM1, IM2, XBPM2 to be fitted to the required location



CU Front End Aperture Design



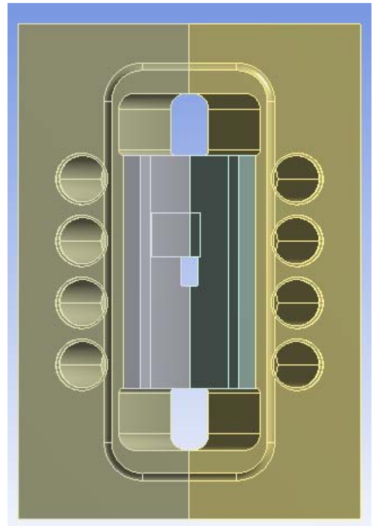
Thermal Design Criteria

- The new masks will have at least the same heat handling capability as the masks in original HHLFE or CUFE
  - HHLFE, two inline 2.4 m long U33 at 180 mA, k=2.76
  - CUFE, two 2.1 m long U33 at 200 mA, k=2.76
- Conservative failure criteria still in use for X-ray beam-intercepting components using GlidCop.
  - T_{max}<300 °C
  - σ_{vm}<400 MPa (shutters), relaxed for masks
  - T_{wall} < water boiling temperature at channel pressure (currently 153 °C @ 60 psig)
- R&D on thermal fatigue criteria is ongoing in establish new fatigue based criteria

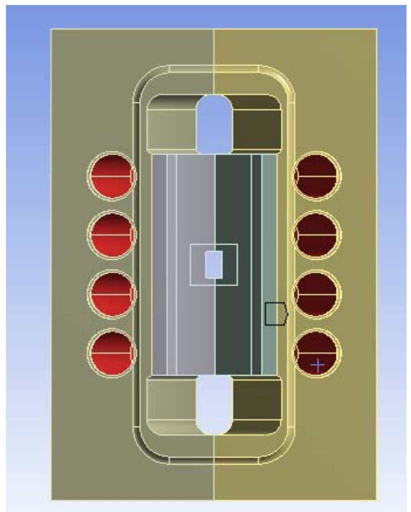
Thermal Analysis of HHLFE FM3

- FM3 design feature
  - Two vertical plane forming a “V” shape
  - Aperture machined into the “V”, changing aperture does not change the incidence angle
  - No corner stress
- 3 load cases analyzed
  - No missteering, beam hot core goes through aperture beam center [0,0]
  - Vertical missteering only, beam equally absorbed in the two vertical plane, beam center [0,7]
  - Horizontal and vertical missteering, beam absorb mainly in one vertical plane, beam center [3,8]

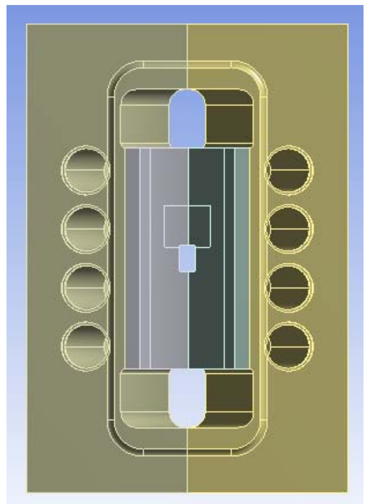
FM3 view from upstream



H&V missteering



No missteering

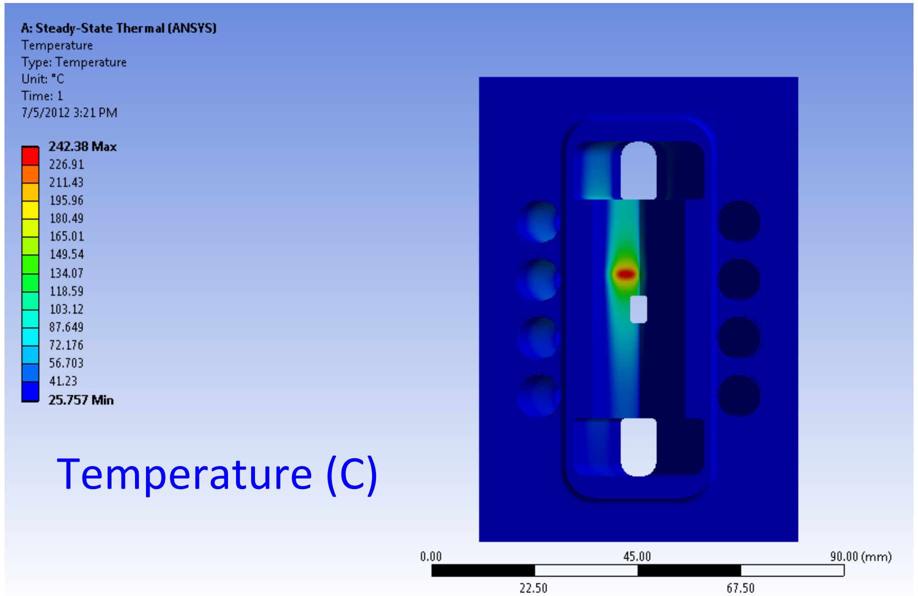


Vertical missteering

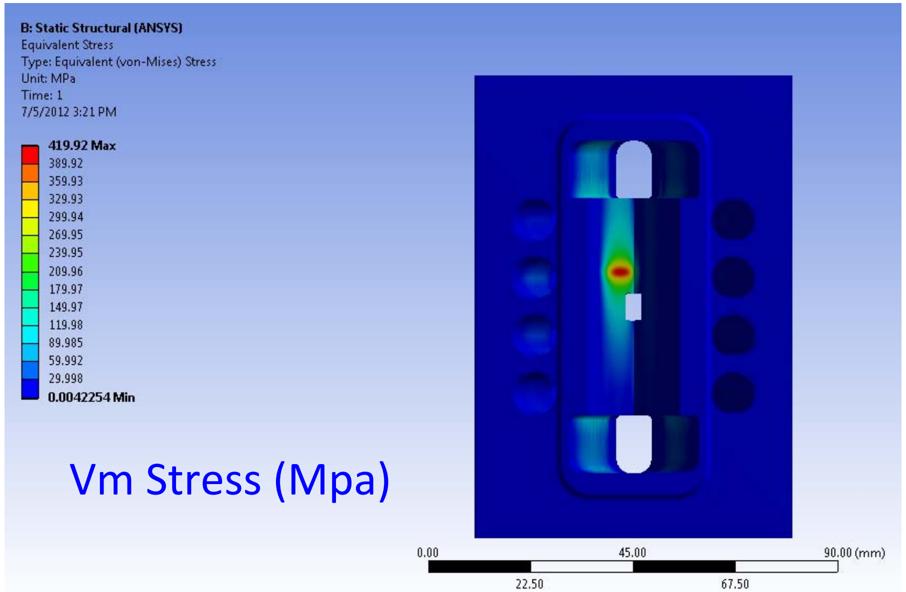
Thermal Analysis of HHLFE FM3

Two inline U33 at 10.5 mm gap (N=144, k=2.76, 180 mA, T_0=25.6°C, h=0.015 W/mm^{2}°C) distance to source 19.8 m

	beam center coordinates (mm)	T_{max} (C)	T_{wall} (C)	σ_{vm} (Mpa)	Total power absorbed (W)
Case 1	[0,0]	197.6	76.143	289.71	10360
Case 2	[0,7]	243.41	101.58	392.89	21974
Case 3	[3,8]	242.38	101.71	419.92	21975



Temperature (C)



Vm Stress (Mpa)

Summary

- The HHLFE and CUFE at APS are being redesigned to fit in the next generation XBPM systems. The HHLFE is at final design stage and the CUFE is at advanced preliminary stage
- The front end design preserved the initial HHLFE and CUFE heat load handling capability
- These two types of front ends represent the majority front ends for the upgrade and serve as the base design for other types of specially front ends
- The LSSCU front end and SPXCU front end are at the specification stage

Thank you for your attention !