X-ray Beam Position Monitors for APS Upgrade

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October 12, 2017

Outline

- X-ray beam position monitor specifications
- XBPM for high heat load front end
- Compton XBPM R&D
- Plans for canted undulator front end XBPM
- Summary

Motivation for XBPM

The APS-U beam stability goal (10% of the x-ray beam size)

	Plane	RMS AC motion (0.01 – 1000 Hz)		RMS long term drift (7 days)	
APS-Upgrade goals	Horizontal	1.7 μm	0.25 μrad	1.0 μm	0.6 μrad
	Vertical	0.4 μm	0.17 μrad	1.0 μm	0.5 μrad

XBPM beam stability requirements (Z = 20 m)

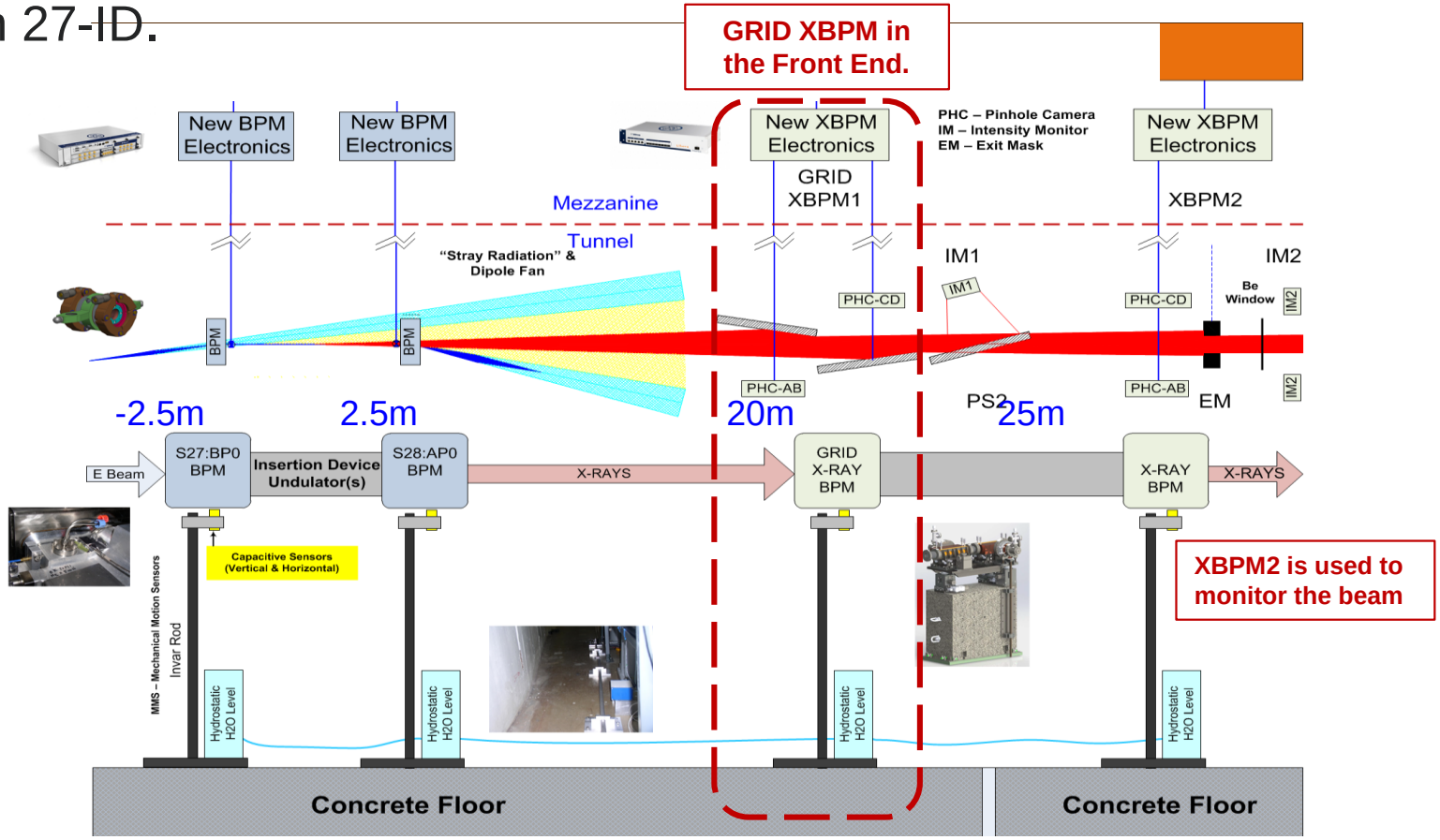
	Plane	RMS AC motion (0.01 – 1000 Hz)	RMS long term drift (7 days)
X-ray beam Position tolerance	Horizontal	5.3 μm	12.0 μm
	Vertical	3.4 μm	10.0 μm
XBPM error budget (~70%)	Horizontal	3.5 μm	7.9 μm
	Vertical	2.2 μm	6.2 μm

Existing photoemission XBPM not good: gap dependence 100's μm, after correction 10's μm!

Need new hard x-ray BPM for APS-U

The APS-U Beam Stabilization System

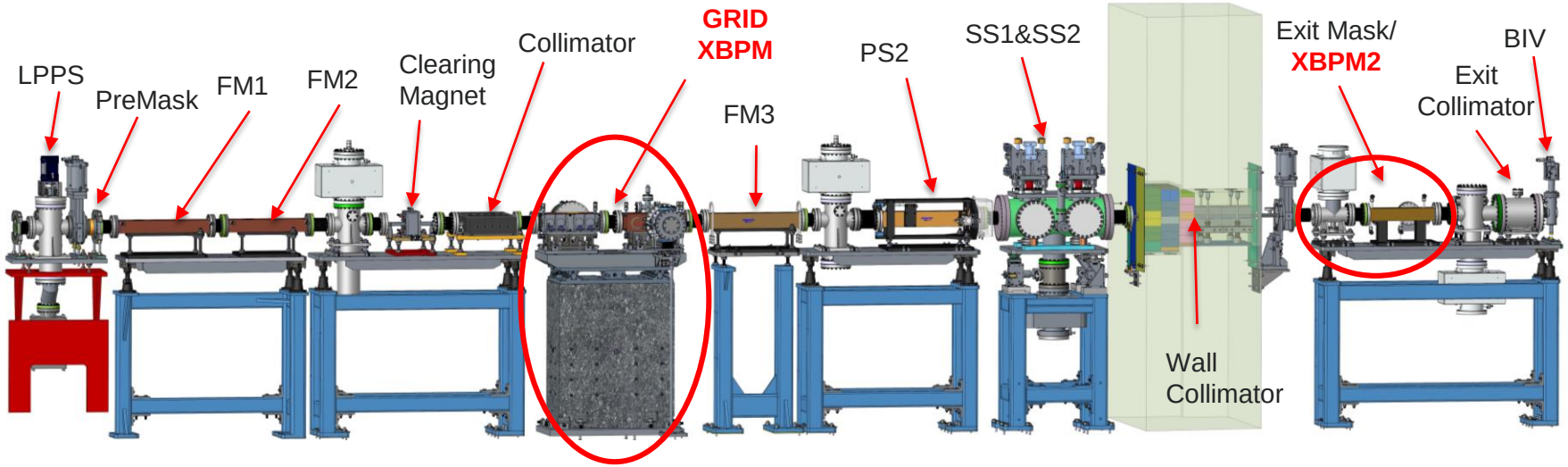
The beam stabilization system planned for the APS-U was developed and tested in 27-ID.



The long lever arm (along with using the x-rays) results in better capabilities for XBPM over RF-BPM

XBPM for HHLFE

- All High Heat Load Front Ends will have a Grazing Incidence Insertion Device (GRID) x-ray beam position monitor
- The GRID-XBPM will use the unused x-rays outside the x-ray beam's central cone to sense the "absolute position" of the beam. Its position data is used to control beam position through orbit feedback
- The exit mask located outside the shield wall is also the second XBPM. It works only when the shutter is open. Its position data is used only for monitoring the output beam.

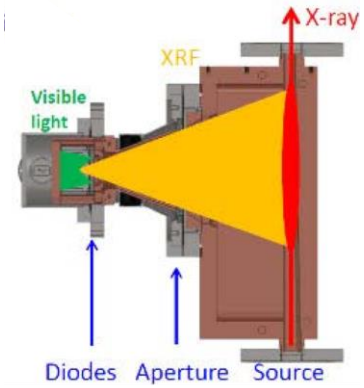


A high heat load front end layout for APS Upgrade

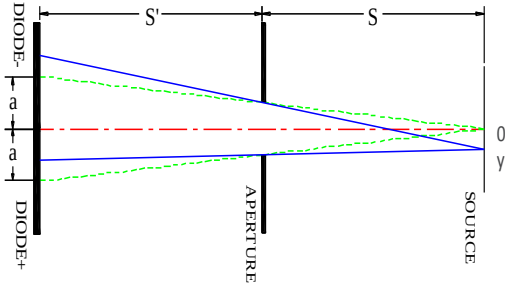
GRID XBPM for HHLFE

The Grazing Incidence Insertion Device XBPM has the following design features:

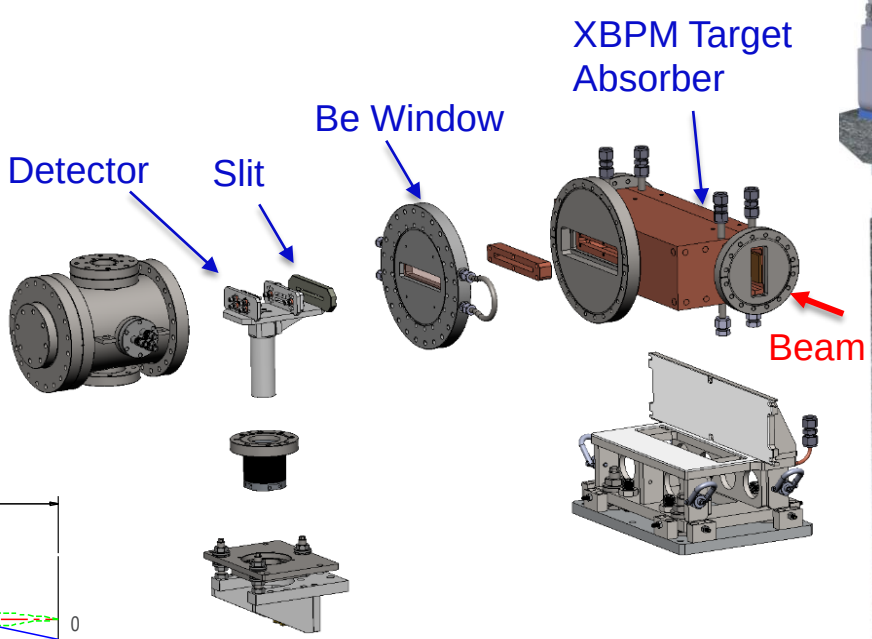
- GlidCop absorber takes most beam power at min gap (11 kW out of 18 kW)
- Uses x-ray fluorescence signals from the copper in the mask
- Independently supported imaging slits and detector
- Granite support for mechanical stability



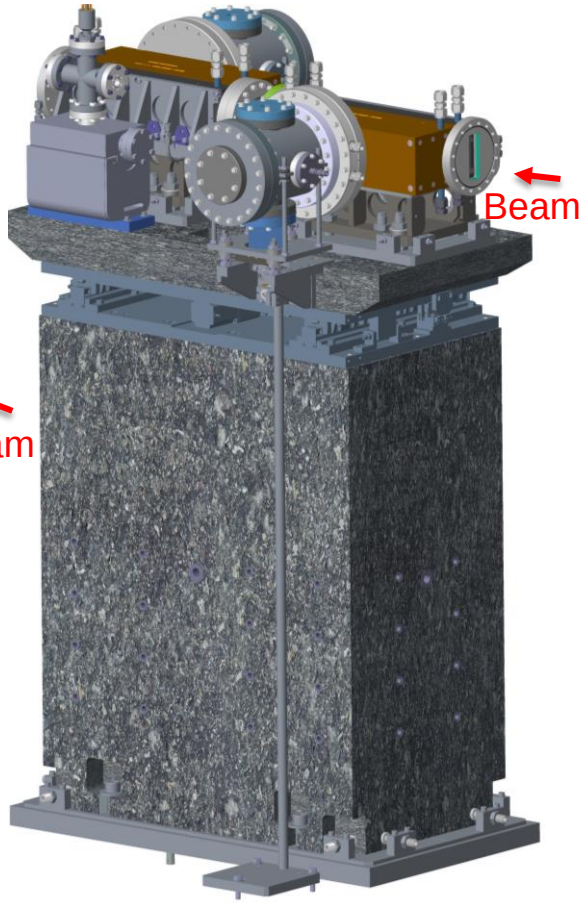
Top View



Principle of pinhole camera



Detector and optics assembly



GRID XBPM

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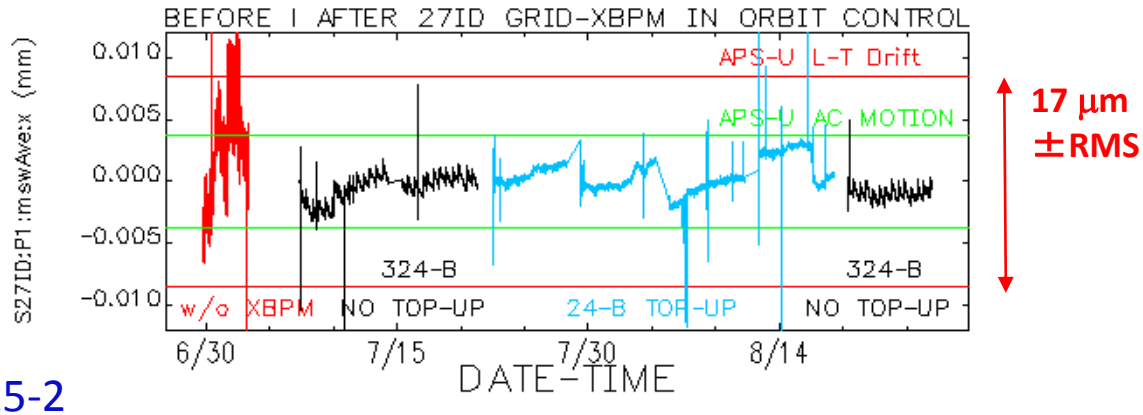
GRID XBPM: Stable Operations in Orbit Control (27-ID)

The GRID XBPM started service in the orbit control in July 2015. It significantly improved the angular stability of 27-ID undulator beam.

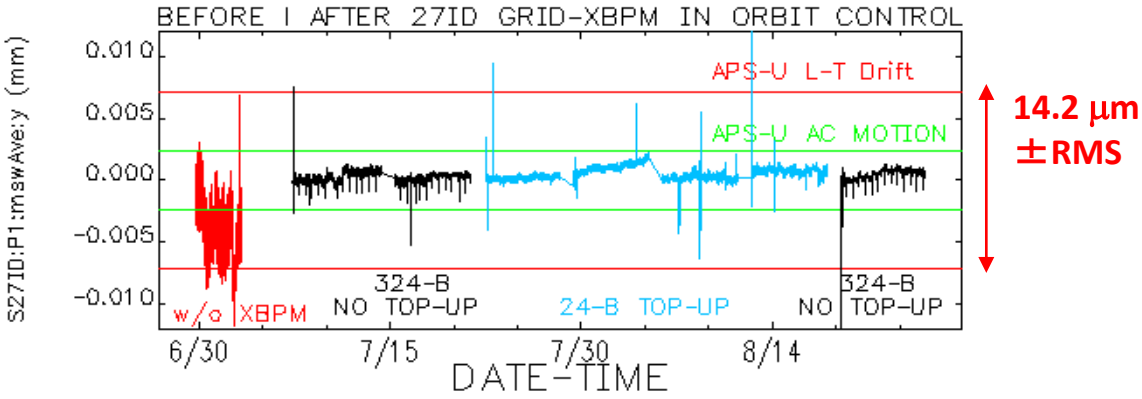
Horizontal beam positions in 60-days of User Operations



17 µm ±RMS

Data from Run 2015-2

Vertical beam positions in 60-days of User Operations



14.2 µm ±RMS

GRID-XBPM meets the APS-U beam stability requirements

All APS-U HHL front ends will have the GRID XBPM

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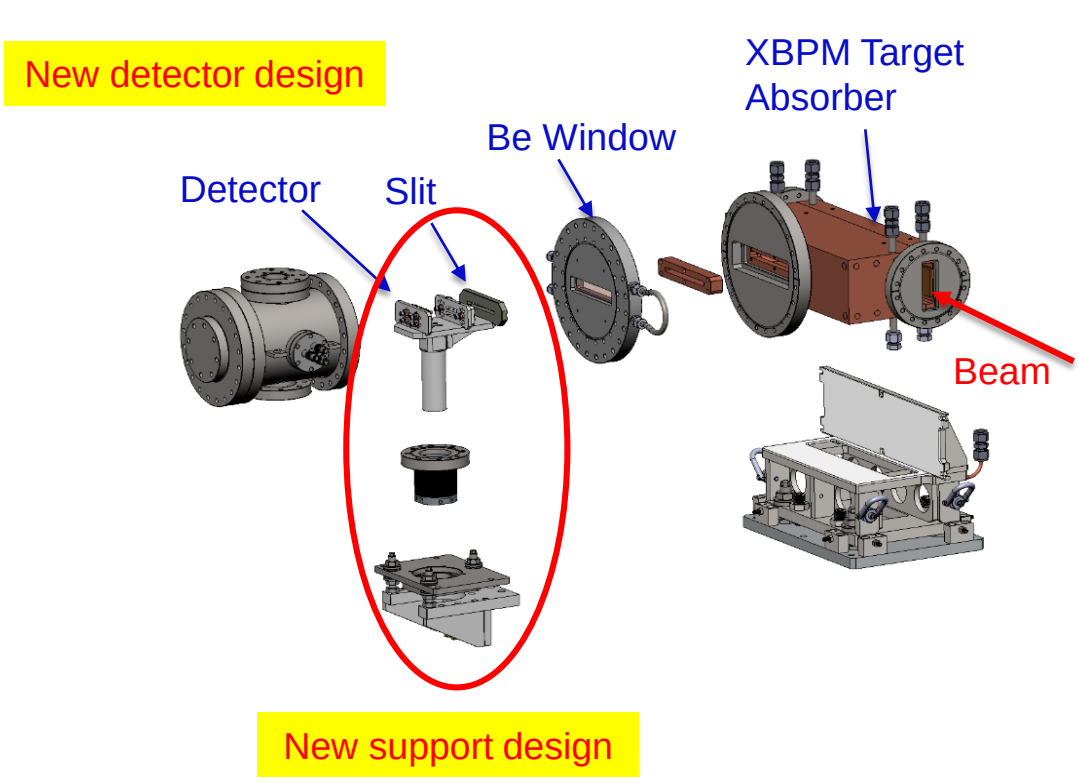
R&D for GRID XBPM

The goals of the R&D projects are to improve the GRID-XBPM:

(1) Improve stability of the XBPM supports and mover: Successfully completed.

(2) Develop high-current, radiation resistant detector: Successfully completed?
(A) Diamond is too noisy. (B) YAG + PIN (> 1 mA) meets requirements.

(3) Array readout detectors and new electronics: On going

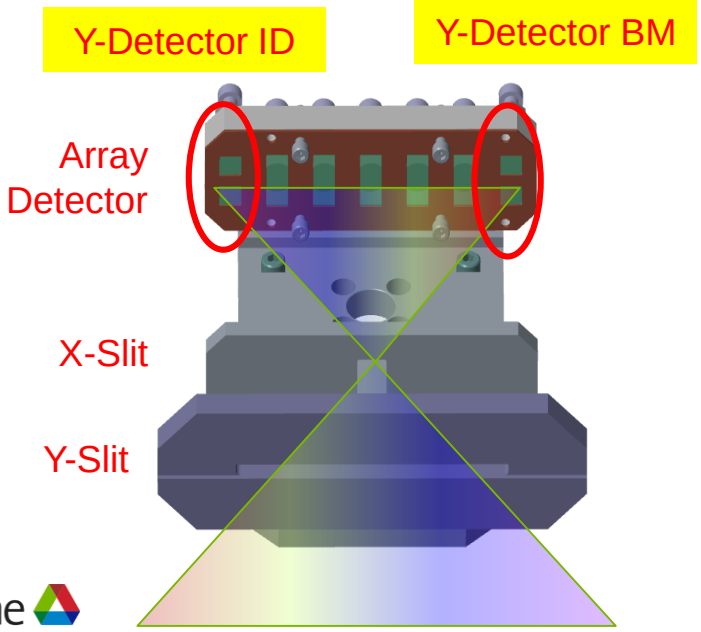


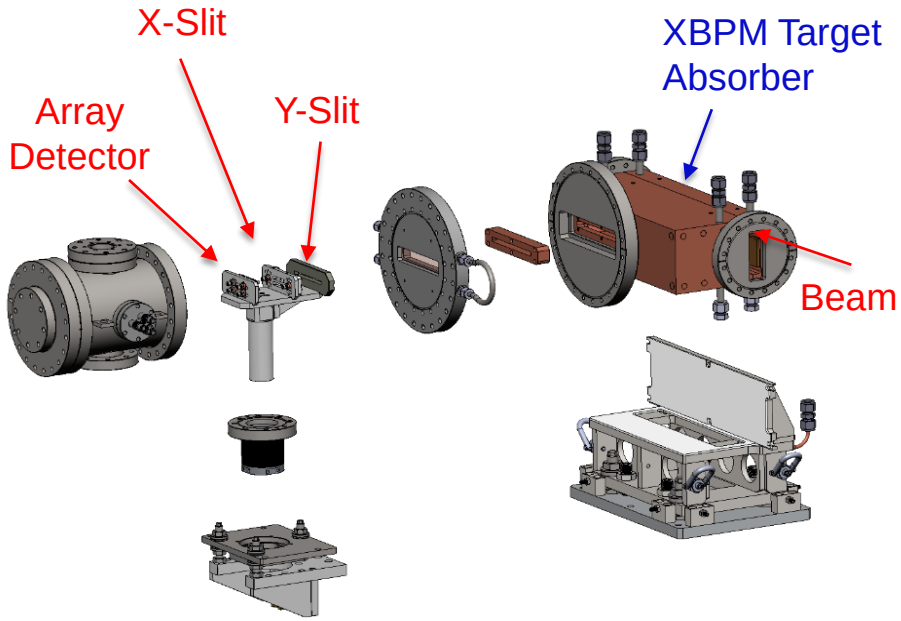
GRID XBPM

Array Detectors for GRID-XBPM

Array detector has been considered for some time, but adopted only recently:

- The APS XBPM benefits greatly from the “Decker Distortion.” Similar soft-tail magnet was considered possible in the APS-U until recently (end of 2016).
- New array detector approach for handling the strong BM background:
  - Four detectors for Y-plane on the outboard absorber: Two inner detectors for the ID beam and two outer ones for the BM background
  - 14 detectors for horizontal XRF distribution: effective subtraction of BM background
- XBPM electronics need 16-channel input and new data processing algorithm



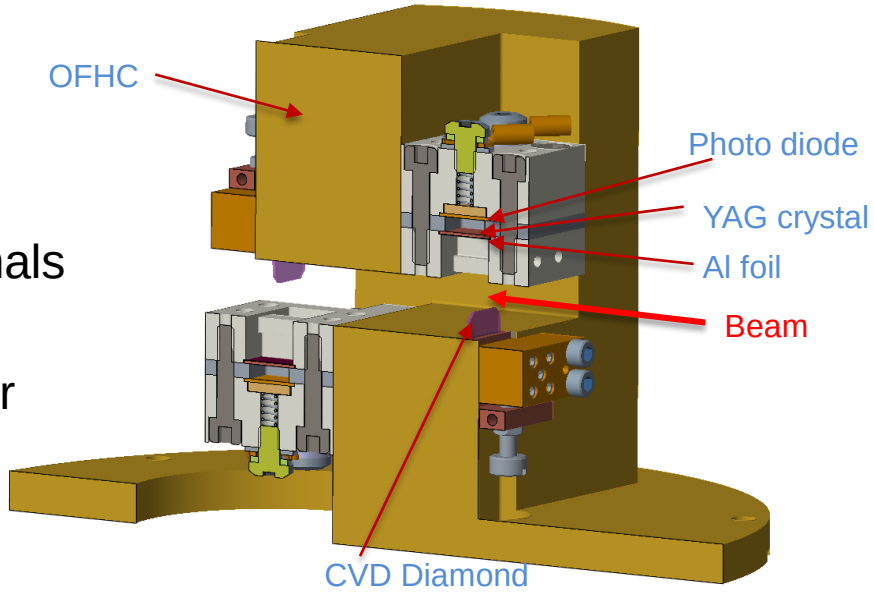


Developing Canted Beamline XBPM

- GRID XBPM was demonstrated to work for high heat loads and single beam.
- Canted beamlines have two beams separated by 1mrad with half the power in each beam. **Independent steering may be needed by the user (2015)!**
- A total of 13 canted undulator front ends will be in use with APS-U
  - Develop an alternate to GRID XBPM to reduce cost ($150K vs $30K each) using existing supports and vacuum housing
- Explored the idea of Compton scattering as a method of detecting the signal to determine the position for each beam

[Principle of Operation]

- Beam strikes a pair of CVD diamond or pyrolytic graphite blades to create scattered beam.
- Compare upper and lower detector signals to determine vertical beam position.
- Compare inboard and outboard detector signal to determine horizontal beam position



Compton XBPM R & D

- Proof of principle tests in 24-ID FOE were limited success
  - Diamond blades easily survived UA beam downstream of the exit mask. Measured temperature is lower than the calculated values.
  - Normal-incidence Compton XBPM gave good beam position data.
  - Provided detector design parameters: graphite vs diamond blades; YAG crystal type; photodiode signal level.
  - Tests were limited due to small aperture of the Exit Mask.
- Tests conducted in 26-ID front end with two inline IDs
  - Power loads in 26-ID front end is similar to APS-U canted FE loads
  - Test configuration: one graphite and one diamond scattering blade
  - XBPM test: both blades gave good beam position data for vertical blade spacing of 2.0 – 2.5 mm.
  - Photodiode current may reach 0.5 mA per diode for one undulator
  - Tests with direct beam hitting the blade: both blades survived one undulator beam (5.5 kW) but failed in two undulator beams (> 6.5 kW).

Plans for APS-U canted undulator FE XBPM

- Summary for Compton x-ray BPM R&D
  - The normal-incidence Compton XBPM is suitable for the APS front ends with one undulator (Versions 1.2 and 1.5, as well as canted front end).
  - The design is also suitable for APS-U after the Exit Mask.
  - It is not ready for APS-U canted undulator front ends due to potential damage to the diamond/graphite blades.

In the mean time, the CU GRID-XBPM concept has also evolved…, and improved:

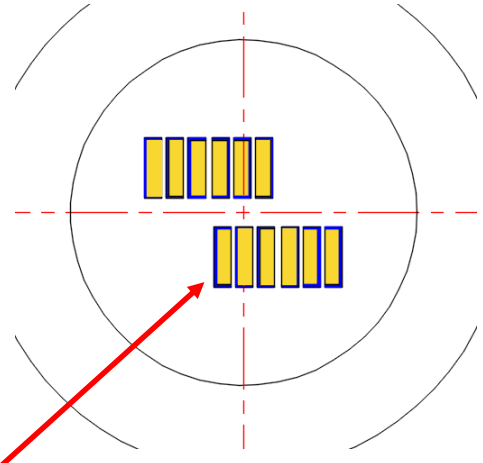
- We will use GRID-XBPM for APS-U canted undulator front ends
  - Absorbers scraping the undulator beams above and below the beamline axis (1-mm exit aperture)
  - Independent steering of two beams will be limited

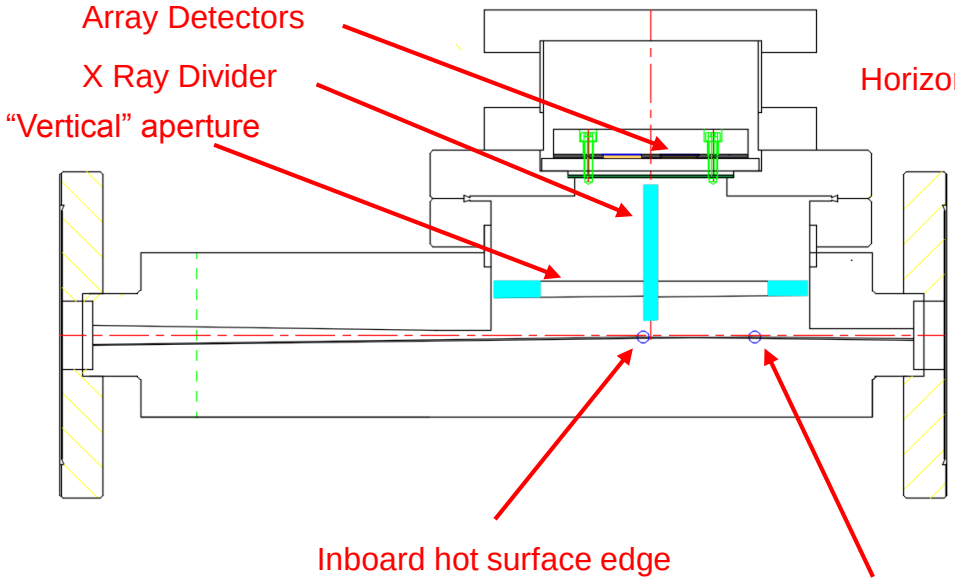
GRID XBPM for canted front ends

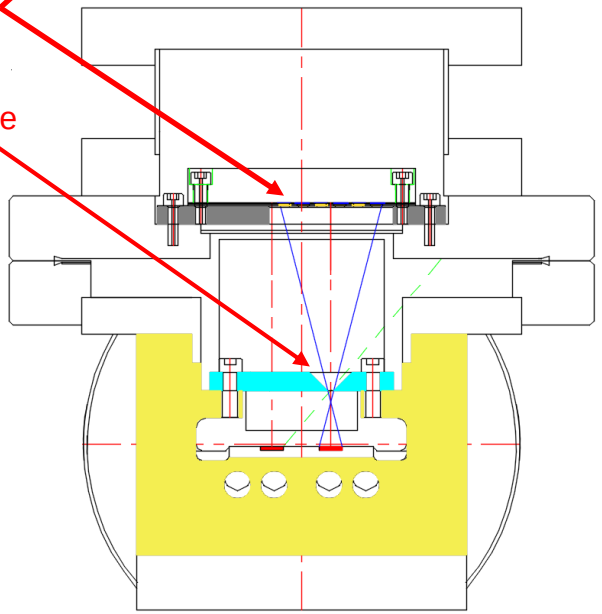
Canted undulator GRID-XBPM

[Design features]

- Two absorbers: One above and one below beam
- Sheared absorber: absorber surface for inboard undulator is displaced from that for the outboard device by 60-mm along beam axis
- Separate readout detector and optics
- Array detector to handle BM background







Summary

- The GRID-XBPM in APS operation has been very reliable for 2+ years
- The GRID-XBPM for single beam has shown to meet the APS-U beam stability requirements
- Improvement of single-beam GRID-XBPM is partially complete. A new design will be implemented in 28-ID.
- Development of GRID-XBPM for canted undulator front end with dual beams is in progress