# X-RAY BEAM SIZE MONITOR ENCLOSURE FOR THE ADVANCED PHOTON SOURCE UPGRADE

## TUPP05

IBIC '20 International Beam Instrumentation Conference

K. P. Wootton, W. Cheng, G. Decker, S. H. Lee, B. X. Yang, Argonne National Laboratory, Lemont, IL 60439, USA

## ABSTRACT


- Confirmation of pm rad scale emittances from the Advanced Photon Source Upgrade electron storage ring necessitates direct measurement of the electron beam size.
- In the present work, we motivate design choices for the X-ray beam size monitor shielding enclosure for the Advanced Photon Source Upgrade.
- Particular emphasis is given to outlining design choices from the perspectives of safety, overall project construction schedule and eventual beamline operations.


## MOTIVATION

- As a high average brightness source of X-ray photons, the storage ring for the Advanced Photon Source Upgrade (APS-U) is designed to operate with ambitious transverse emittances on the order of 42 pm rad [1, 2].
- In order to utilise the high brightness X-ray beams, a range of accelerator diagnostic instruments are planned to provide beam position stability and accelerator control [3].
- In particular, to quantify the horizontal and vertical emittances, beam size monitors are planned for APS-U [4].

## BEAM SIZE MONITOR REQUIREMENTS

- Hard X-ray synchrotron radiation beam size monitors are planned for APS-U to quantify the transverse emittances of the stored electron beam [4, 5]. For an operating storage ring such as the Advanced Photon Source (APS), this is an important online diagnostic of the beam in the accelerator.

Table 1: Electron Beam Sizes at Bending Magnet A:M1.1 in Timing and Brightness Operating Modes

| Parameter | Value | Units |
|---|---|---|
| Timing Mode | – | – |
| Horizontal beam size | 7.2 | μm |
| Vertical beam size | 25.1 | μm |
| Brightness Mode | – | – |
| Horizontal beam size | 7.2 | μm |
| Vertical beam size | 9.1 | μm |

- A key performance parameter for successful completion of the APS-U project is that the horizontal emittance $\varepsilon_x \leq 130$ pm rad [1]. The beam size monitor is the principal instrument for confirming the emittances. The principal functional requirement for absolute beam size measurement is that the contribution of system resolution to the measured electron beam size is not larger than 10 % when added in quadrature.
- The functional requirements of the absolute beam size monitor are summarised in Table 1 [1].

## BEAMLINE LOCATION

- Measurement of emittance based on the beam size is optimized where the contribution to the beam sizes is dominated by the emittance. For APS-U, the horizontal dispersion is zero by design in the insertion straights, and so the nominal bending magnet source for the beam size monitor is the first longitudinal gradient bending magnet in an arc cell A:M1.1 [1].
- The beam size monitor beamline will be located in Sector 38 of the APS-U storage ring. A schematic illustration of the beamline is shown in Fig. 1. This location was selected because the nominated photon source A:M1.1 bending magnet was only available in the radiofrequency cavity insertions. We will extract the bending magnet radiation through an unused insertion device photon beam extraction chamber, because user beamlines will occupy all the APS-U insertion device front ends.
- The storage ring tunnel shielding wall is not a ratchet wall geometry in this location, and is instead 1.1 m radial thickness concrete. Necessitates drilling a hole through the shield wall of approximately 8 m length.

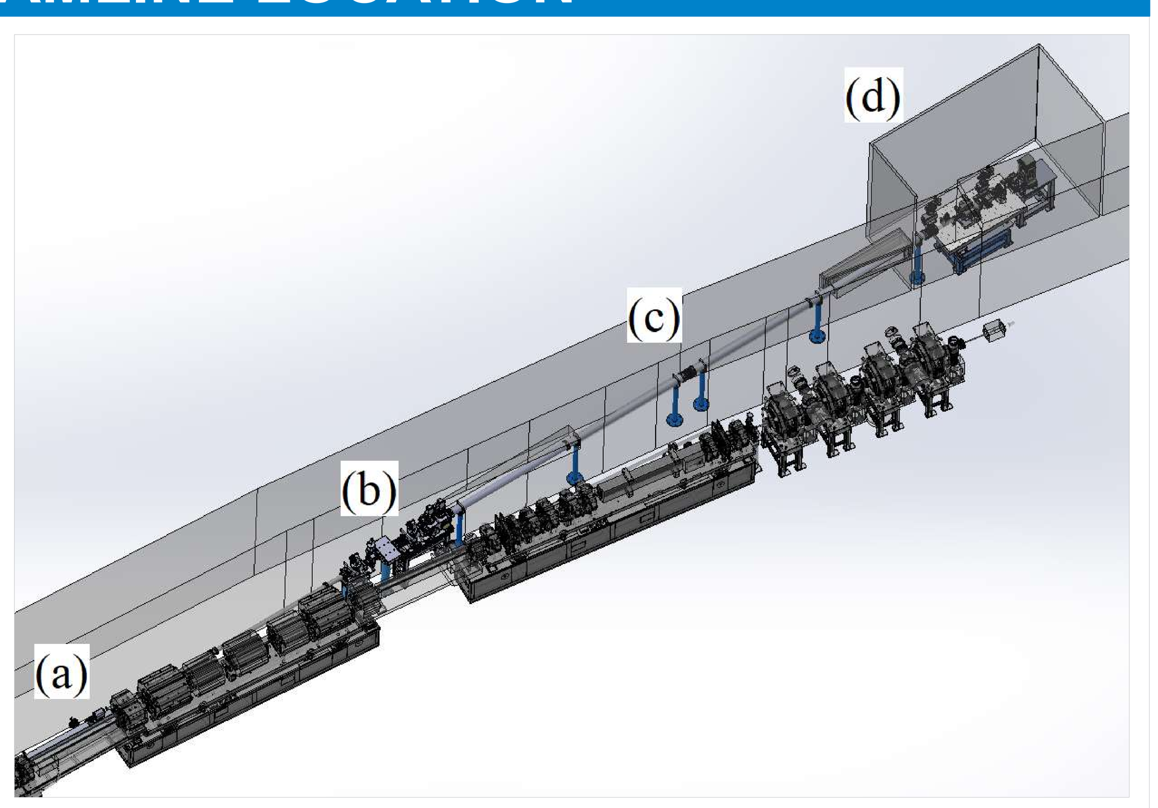

Figure 1: Schematic overview of Sector 38 beam size monitor beamline for APS-U. In this figure, the beam direction is from left to right. (a) Synchrotron radiation absorbers and pinhole mask. (b) Bending magnet beamline front end components (photon shutter, safety shutters and lead collimator). (c) Photon beam vacuum chamber through accelerator shield wall. (d) Endstation instruments and beamline enclosure.

## ENCLOSURE DESIGN CHOICES

- Image Magnification and Beamline Length
  For the X-ray pinhole camera, the distance from the A:M1.1 bending magnet source to the pinhole is 6.6 m. To achieve an optical magnification of 3, the camera is positioned 20 m downstream of the pinhole assembly.
- Safety
  Earlier designs of the beamline envisioned the use of a new concrete shielded enclosure. Nominally, this was selected to match the existing storage ring shielding. However this introduced new concerns into design and construction, specifically the need to determine the structural capacity of the footing for the existing technical floor.
  Based on Monte Carlo simulations of the beamline geometry, we have found that we can achieve the required radiological protection performance using an enclosure composed of lead panels, following the standard guidelines for hard X-ray white beam enclosures at the APS.
- Construction Schedule
  We aim to maximise opportunities for construction activities during APS operation. Choosing an enclosure construction type that is well-characterised (lead panelling) affords us the experience of previous beamline design and construction activities at APS. Construction activities for the enclosure can also begin during routine user operations. At APS-U, sector 38 is the furthest point in the accelerator tunnel from the nearest adjacent equipment access door, making it beneficial to minimise equipment to be moved in to the accelerator tunnel at this location.
- Beamline Operations
  Locating the endstation equipment within a dedicated enclosure allows for the long-term benefit of instrument access for maintenance. During user runs, access to instruments located within the accelerator enclosure is necessarily limited to maintenance and machine studies periods.

## SUMMARY

- The physics requirements of the beam size monitors for APS-U motivate the construction of a beamline in an unusual location in the storage ring.
- In the present work, we have summarised design choices for the X-ray beam size monitor shielding enclosure for the APS-U. Particular emphasis is given to outlining design choices from the perspectives of safety, overall project construction schedule and eventual beamline operations.

## NEXT STEPS

- Proposed location of beam size monitor presents unique challenges for a beamline at APS.
- We are in the process of designing the enclosure.
- When completed, beam size monitor will be an important online diagnostic for APS-U.

## REFERENCES


[1] T. E. Fornek, “Advanced Photon Source Upgrade Project Final Design Report”, Argonne National Laboratory, Lemont, IL, USA, Rep. APSU-2.01-RPT-003, May 2019.
[2] M. Borland *et al.*, NAPAC’16, pp. 877–880.
[3] N. Sereno *et al.*, IPAC'18, pp. 1204–1207.
[4] B. X. Yang *et al.*, IBIC’16, pp. 504–507.
[5] B. X. Yang and S. H. Lee, “Planned x-ray diffraction diagnostics for APS Upgrade emittance measurements”, presented at *Topical Workshop on Emittance Measurements for Light Sources and FELs*, Barcelona, Spain, Jan. 2018, unpublished.


U.S. DEPARTMENT OF ENERGY — Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.



Argonne NATIONAL LABORATORY