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

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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.

INTRODUCTION

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 [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].

In the present work, we outline the enclosure design for the APS-U storage ring electron beam size monitor beamline.

BEAM SIZE MONITOR

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 [6, 7]. A key performance parameter for successful completion of the APS-U project is that the horizontal emittance $\varepsilon_x \leq 130\,\text{pm rad}$ [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 σ_r to the measured electron beam size σ_e is not larger than 10% when added in quadrature. For the proposed timing and brightness operating modes of APS-U, the functional requirements of the absolute beam size monitor are summarised in Table 1 [1].

Table 1: APS-U 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

BEAMLINE LOCATION

Measurement of emittance based on the beam size is optimised where the contribution to the beam sizes is dominated by the emittance. For APS-U, the horizontal dispersion η_x 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.

There are several challenges that arise in the construction of a beamline in this location. The storage ring tunnel shield-

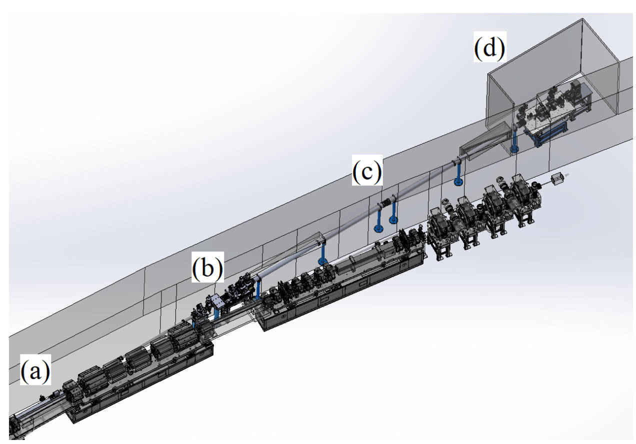

Figure 1: Schematic overview of Sector 38 beam size monitor beamline for APS-U. In this figure, the beam direction is from left to right. (a) Synchrotron radiation absorbers and pinhole mask. (b) Bending magnet beamline front end components (photon shutter, safety shutters and lead collimator). (c) Photon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

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ing wall is not a ratchet wall geometry in this location, and is instead uniformly 1.1 m radial thickness concrete. Connecting the enclosure to the storage ring necessitates drilling a hole through the shield wall of approximately 8 m length. A similar dimension hole (albeit in the backwards-going direction) was drilled through the shield wall for a previous normal incidence diffraction (NID-X) beamline at the APS [8, 9].

ENCLOSURE DESIGN CHOICES

The principal requirement of the enclosure is to provide radiation protection to personnel in the vicinity of the enclosure when the beam is permitted to enter. Several design choices impacted the design of the enclosure. Some of the principal considerations are summarised.

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

The principal function of the enclosure is to shield against prompt radiation from the accelerator. For the particular beamline geometry and beam energy of 6 GeV, this is anticipated to be synchrotron radiation photons, gas bremsstrahlung and electromagnetic showers resulting from injected beam losses [10].

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 [11, 12].

Construction Schedule

In order to minimise disruption to the synchrotron light user community, APS-U construction and accelerator commissioning are planned to occur within a period of one calendar year. In order to meet this proposed schedule for accelerator removal and installation, 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.

It is anticipated that siting the endstation instruments in an enclosure may ease both the construction and commissioning schedules for the beamline. At APS-U, sector 38 is the furthest point in the accelerator tunnel from the nearest adjacent equipment access door (‘super door’), making it beneficial to minimise the volume of equipment to be moved in to the accelerator tunnel at this location. The narrow aisle in the accelerator tunnel may also restrict the upright transport of an optical table with endstation instruments pre-assembled (or else limit the width of the table).

Beamline Operations

Locating the endstation equipment within a dedicated enclosure allows for the long-term benefit of access to the instruments 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.

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