DESIGN OF THE X-RAY BEAM SIZE MONITOR FOR THE ADVANCED PHOTON SOURCE UPGRADE

MOPAB303

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ABSTRACT

- A beam size monitor provides an intuitive display of the status of the beam profile and motion in an accelerator.
- Synchrotron radiation from a bending magnet is used as the photon source.
- In the present work, we outline the design of the X-ray electron beam size monitor for the Advanced Photon Source Upgrade.
- Components and anticipated performance characteristics of the beam size monitor are outlined.

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].
- To quantify the transverse emittances of the stored electron beam, hard X-ray (12 keV) bending magnet radiation beam size monitors (BSM) are planned for APS-U [3, 4].
- When user operations with the APS-U storage ring begin, the BSM beamline will be used to report the beam size and stability in real-time.

BEAM SIZE MONITOR REQUIREMENTS

- The BSM beamline provides four branch lines, separated horizontally in angle.
- The four instruments include:
  - X-ray beam position monitors
  - Relative beam size monitor (x)
  - Absolute beam size monitor
  - Relative beam size monitor (y)
- Electron beam source properties are outlined in Table 1.
- Resolution contribution to emittance measured using absolute beam size monitor required to be <10% (~3 μm).
- Relative beam size monitor resolution ~7 μm.

Table 1: Electron beam source properties of the APS-U BSM beamline instruments, with the APS-U operated in different modes.

Branch	BL1	BL2	BL3	BL4	–
Instr.	XBPM	Rel.(x)	Abs.	Rel.(y)	–
Prop.	–	–	–	–	Units
Angle	−0.50	−1.10	−1.70	−2.30	mrad
β_x	1.69	1.65	1.62	1.58	m
β_y	19.8	19.8	19.9	19.9	m
η_x	0.233	0.242	0.263	0.295	mm
Timing mode: $\varepsilon_x = 31.9$ pm rad, $\varepsilon_y = 31.7$ pm rad, $\Delta E/E = 0.156\,\%$					
σ_{ex}	7.4	7.4	7.3	7.2	μm
σ_{ey}	25.1	25.1	25.1	25.1	μm
Brightness mode: $\varepsilon_x = 42.0$ pm rad, $\varepsilon_y = 4.2$ pm rad, $\Delta E/E = 0.135\,\%$					
σ_{ex}	8.5	8.4	8.3	8.3	μm
σ_{ey}	9.1	9.1	9.1	9.1	μm
KPP requirements: $\varepsilon_x = 130$ pm rad, $\Delta E/E = 0.135\,\%$					
σ_{ex}	15.0	14.9	14.7	14.6	μm

BEAMLINE LAYOUT

- An elevation view of the beamline components is illustrated in Figure 1. The principal components within the storage ring and beamline enclosure are shown.

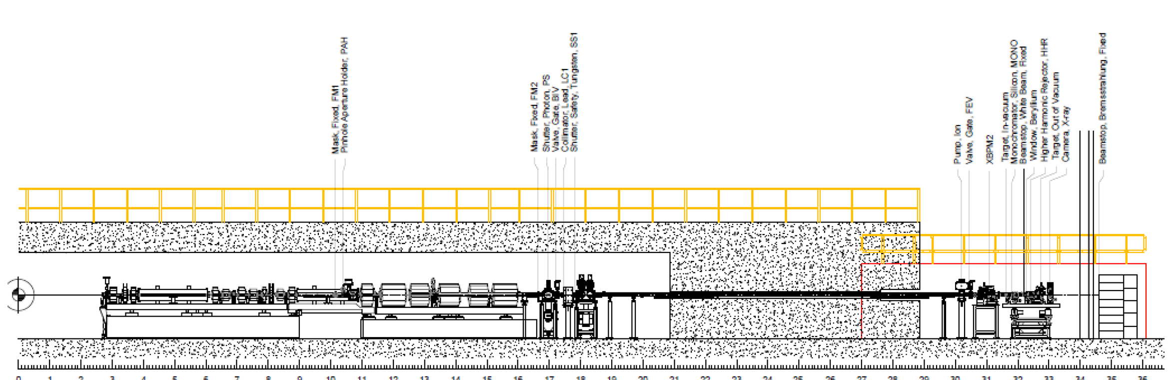

Figure 1: Elevation view of APS-U beam size monitor beamline. Principal beamline components are annotated. The longitudinal coordinate is metres from the centre of the insertion device straight. The bending magnet photon source point is at 3.83 m. The extent of the new BSM beamline enclosure is outlined in red.

- The four branch lines of the BSM beamline are separated in angle at the pinhole aperture holder. The holder and apertures are illustrated in Figure 2.

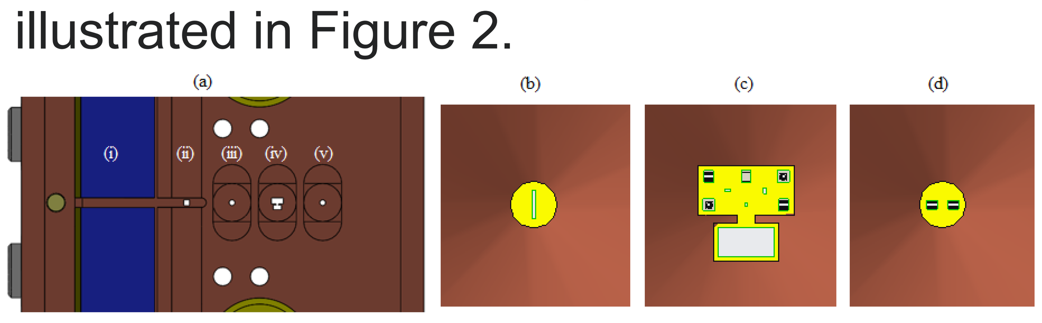

Figure 2: PAH and apertures. (a) Overview of apertures in PAH. (i) XBPM1 electrodes (in blue). (ii) BL1 (beam-defining aperture for XBPM2). (iii) BL2. (iv) BL3. (v) BL4. (b) Enlarged image of BL2 slit defining horizontal relative beam size monitor. (c) Enlarged image of BL3 apertures defining absolute beam size monitor. (d) Enlarged image of BL4 apertures defining vertical relative beam size monitor.

ABSOLUTE BEAM SIZE MONITOR

- The absolute beam size monitor is a hard X-ray (12 keV) pinhole camera.
- The principal pinhole aperture is square in profile, with an optimised size of 32 ×32 μm in a 100 μm thickness tungsten foil [5]. In addition to the principal pinhole aperture, other diffraction features are used to provide instrument resolution calibrations.
- Both the in-vacuum monochromator and higher harmonic rejector use a Si(111) channel-cut crystal with a vertical 12.7 mm offset between the entrance and exit height of the X-ray beams.
- The X-ray pinhole camera of the beamline provides a magnification of 3.8 from the electron beam source. The X-ray beam incident upon a YAG is imaged by an optical microscope (magnification ~2). The image is read out by a digital camera. An in-vacuum knife edge on a motorised translation stage is utilised as a spatial calibration target, immediately upstream of the monochromator. An in-air calibration target is also provided downstream of the higher harmonic rejector.

RELATIVE BEAM SIZE MONITORS

- Two relative beam size monitor instruments will be provided: one in each of the horizontal and vertical planes. The horizontal relative beam size monitor is illustrated in Figure 3.

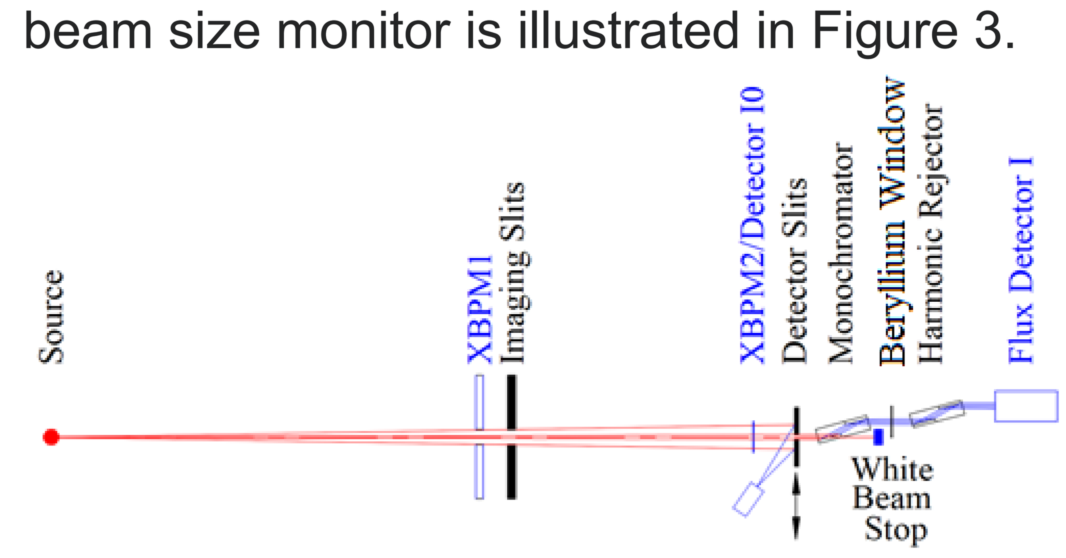

Figure 3: Schematic view of horizontal relative beam size monitor components [5].

- Operated in two modes:
  - Intensity: Relative beam size measurements at up to ~10k samples s^{-1}. Electron beam source co-aligned with the imaging slit and detector slit. Incoming intensity detected with a diode detector (*I0*). X-ray beam passing the detector slit measured using the flux detector (*I*). Oscillations in the beam size change flux passing the second slit.
  - Scanning: Slow (<0.01 Hz) absolute beam size measurements. One-dimensional profiles measured by laterally scanning the position of the detector slit. Intensity at each position is measured using the flux detector.

SUMMARY

- In the present work, we have summarised design choices for the X-ray BSM beamline instruments for APS-U.
- Absolute and relative beam size monitors will be used to characterize the beam during commissioning and user operations.
- Multiple instruments are provided in a compact arrangement, by separating them horizontally in angle.

NEXT STEPS

- Instrument and component designs of APS-U BSM beamline have significantly matured.
- We plan to complete the design this year.
- When constructed, the beam size monitor will be an important online diagnostic for APS-U.

REFERENCES

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