TIME DOMAIN PHOTON DIAGNOSTICS FOR THE ADVANCED PHOTON SOURCE UPGRADE

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ABSTRACT

- With swap-out injection and a third-harmonic bunch lengthening cavity, time domain diagnostics will be beneficial tools for optimisation of the Advanced Photon Source Upgrade (APS-U) electron storage ring.
- In the present work, we present plans for time-domain X-ray and visible photon diagnostics for the APS-U.
- Particular emphasis is given to implementation of visible light streak cameras and X-ray bunch purity monitors as time domain photon diagnostics.

MOTIVATION

- Several user programs take advantage of the pulsed time-of-arrival of X-rays corresponding to the storage ring fill pattern.
- We plan to provide temporal photon beam diagnostics for the optimisation and diagnostics of APS-U accelerator operations.
- We outline the time distribution of photons for beamlines at APS-U. Proposed techniques for time-domain photon diagnostics are summarised. Finally, we describe the proposed changes to the existing beamline configuration to employ these diagnostics.

FILL PATTERN AND BUNCH PROFILE

- Fill patterns of the APS are controlled by the radiofrequency (rf) of the main rf cavities (352 MHz), and the storage ring circumference (1104 m). This accommodates 1296 buckets.
- At present, APS operates three fill patterns for user operations.
- Either 24, or 324 bunches equally-spaced, or a camshaft fill ('hybrid mode', $1 + 8 \times 7$), with 1 bunch, and 8 trains of 7 bunches spaced at 2.84 ns [1].
- For APS-U, a 48-bunch mode and 324-bunch mode are foreseen, with 324 bunches operating in bunch trains with ion-clearing gaps and guard bunches [2]. A camshaft fill pattern is not envisaged for future APS-U operations. Fill patterns and bunch lengths are summarised in Table 1 below.

Table 1: Temporal Structure Corresponding to Fill Patterns of APS and APS-U Storage Rings.

Description	Bunch Spacing (ns)	Bunch Length (ps)	Ref.
APS Fill Patterns:			
324 bunches	11.4	25	[6]
24 bunches	153	40	[6]
Hybrid (1, 8×7)	2.84	50, 32	[4]
APS-U Fill Patterns:			
324 bunches	11.4	88	[2]
48 bunches	77	104	[2]

BEAMLINE GEOMETRY

- An elevation view of the beamline front end is illustrated in Fig. 1, and schematically in Fig. 2.

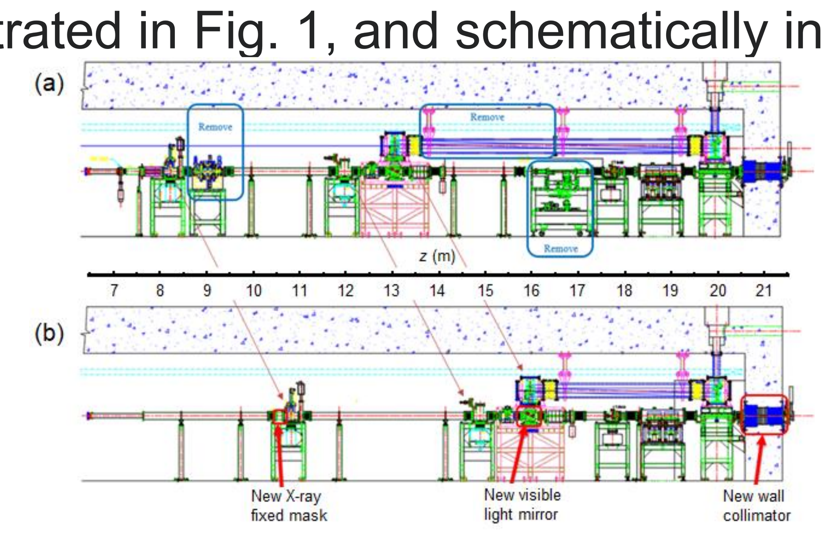

Figure 1: Profile of components in 35-BM front end [3]. The longitudinal coordinate z is with respect to the bending magnet photon source point. (a) Existing APS configuration. (b) Proposed APS-U configuration. For APS-U, a section of the visible light telescope, the pinhole aperture assembly and pinhole camera will be removed.

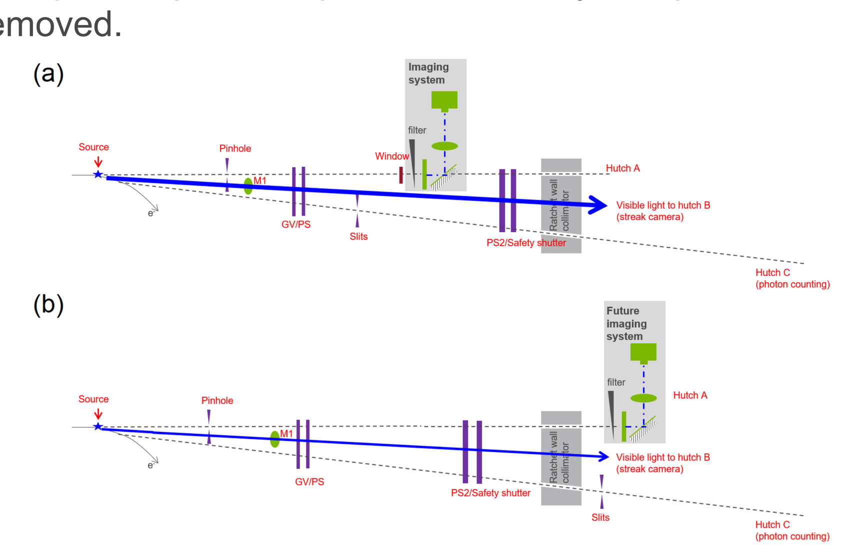

Figure 2: Schematic illustration of 35-BM beamline in plan view [4]. (a) 35-BM for APS operations. For daily operations, the outboard branch line serves a pinhole camera for imaging, M1 mirror for visible synchrotron radiation. Time-correlated single photon counting is performed in hutch C using the inboard X-ray branchline. (b) Proposed APS-U configuration. Future capability for a pinhole camera on outboard branch line. Visible light transport and X-ray photon counting for bunch purity monitoring will be preserved.

TIME DOMAIN PHOTON DIAGNOSTICS

- Bunch Length Measurement
  - Operation of APS-U higher harmonic cavity to lengthen the bunch results in a bunch distribution that potentially departs significantly from a Gaussian approximation [5].
  - This motivates experimental techniques to measure the bunch temporal profile without assumption about the bunch shape.
  - For APS-U, bunch length measurements will be performed using a visible light streak camera [6].
  - The streak camera can be synchronised with the third subharmonic of the storage ring main rf frequency (117 MHz), derived from the APS-U timing and synchronisation system [7].
- Bunch Purity Monitor
  - At APS, time-correlated single photon counting of hard X-rays is employed to measure bunch purity [8, 9].
  - This capability will be preserved in order to measure bunch purity of the APS-U storage ring.

VISIBLE LIGHT

- Calculations of the angular distribution of synchrotron radiation in the vertical plane for polarisations in both the horizontal (σ) and vertical (π) is illustrated in Fig. 3 [4].
- Parameters used in calculation are summarised in Table 2 [4].

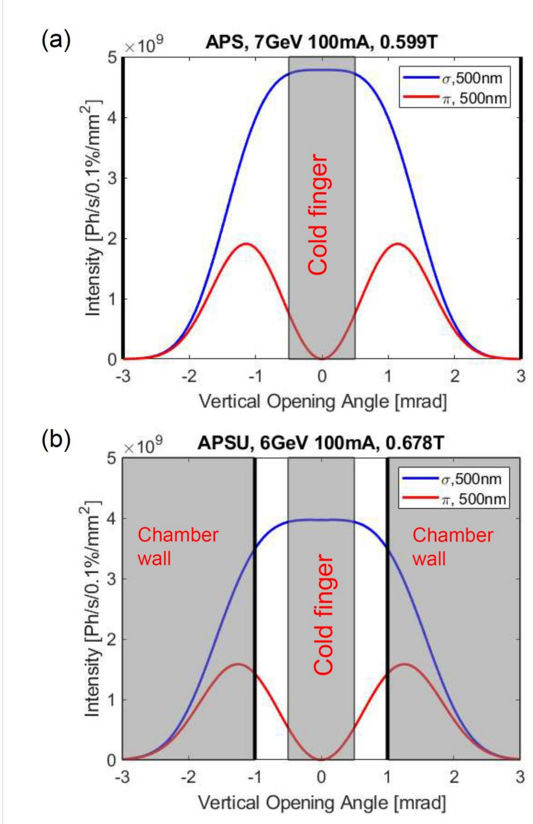

Figure 3: Calculated angular distribution of visible synchrotron radiation and angular apertures in the beamline in the vertical plane [4]. Beam parameters are summarised in Table 2. (a) Calculated flux at 500 nm for APS. (b) Calculated flux at 500 nm for APS-U. Implementation of a cold finger for the APS-U storage ring would significantly reduce the visible photon flux.

Table 2: Parameters Used in Calculation of Visible Synchrotron Radiation Flux [4].

Parameter	Units	APS	APS-U
Beam energy	GeV	7	6
Electron beam current	mA	100	100
Bending magnet field	T	0.60	0.68

SUMMARY

- Time domain diagnostics will be beneficial tools for optimisation of the APS-U electron storage ring.
- In the present work, we have presented plans for time-domain X-ray and visible photon diagnostics for the APS-U storage ring commissioning and operations.
- To the maximum extent possible, existing components are re-used.

ACKNOWLEDGEMENTS

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