SYNCHROTRON LIGHT MONITOR FOR THE ADVANCED PHOTON SOURCE BOOSTER SYNCHROTRON

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ABSTRACT

- A new synchrotron light monitor has been tested for the booster synchrotron of the Advanced Photon Source.
- Visible light synchrotron radiation is collected by a mirror and directed to an optical imaging system and camera.
- In the present work, we describe the present synchrotron radiation diagnostic layout.
- An analysis of the synchrotron radiation power on the mirror, the optical layout with components, and features of the control system will be presented.

MOTIVATION

- Synchrotron radiation (SR) presents a significant thermal load on components in electron storage rings.
- The motivation for the present work is to enable accurate measurement of beam properties during high-charge studies of the booster synchrotron for the Advanced Photon Source Upgrade (APS-U) [1,2].
- During those studies, it appears that the mirror that reflects SR out of the vacuum (or its support) deflects under thermal load from SR [3].

BACKGROUND

- Beam profile monitors are required to support beam size measurements of the electron beam in the booster.
- Three photon ports are available for use as synchrotron light photon monitors in the booster [4-7].
- Previously, only two ports had been instrumented, and under thermal loading, the mirrors in these ports deform so much that the image of the beam is deflected off sensors used to measure the beam transverse and longitudinal dimensions [3].
- Routine measurements of electron beam such as emittance and energy spread are difficult.
- We propose to instrument all three photon monitors. The position of the beam image on the beam profile monitors needs to remain within a small enough displacement from nominal that it does not move off laterally the imaging and diagnostic devices.

SR POWER ON THE MIRROR

- For an electron beam, the vertical distribution of SR power $\frac{dP}{d\Omega}$ is [8]:

$$\frac{\mathrm{d}P}{\mathrm{d}\Omega} = 5.42 E^4 B I_b \frac{1}{(1+\gamma^2\psi^2)^{5/2}}\left[1+\frac{5\gamma^2\psi^2}{7(1+\gamma^2\psi^2)}\right],$$

- The peak power density (on-axis) $\frac{dP}{d\Omega}$ in units of W mrad^{-2} is given by [8]:

$$\frac{\mathrm{d}P}{\mathrm{d}\Omega} = 5.42\ E^4 B I_b,$$

- Integrating over the vertical angle, the power density in the horizontal direction $\frac{dP}{d\Omega}$ in units of W mrad^{-1} is given by [8]:

$$\frac{\mathrm{d}P}{\mathrm{d}\Omega} = 4.22\ E^3 B I_b$$

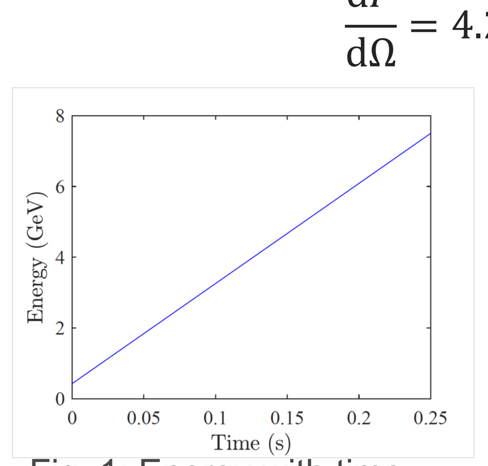

Fig. 1: Energy with time.

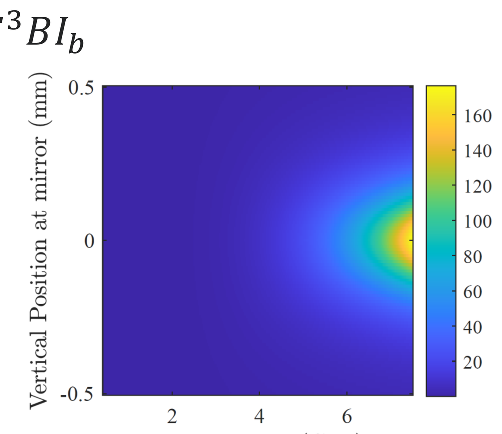

Fig. 2: SR power with energy.

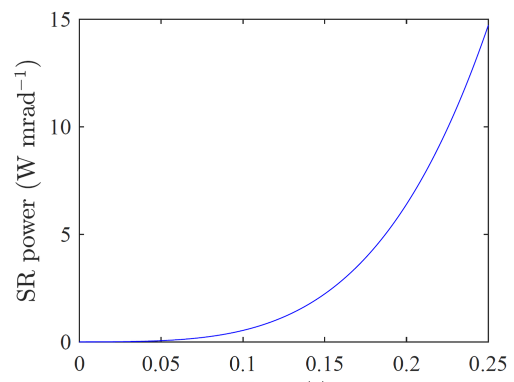

Fig. 3: SR power with time.

Integrate with duty factor 0.25, 4.1 W.

Table 1: Booster and Electron Beam Parameters

Parameter	Symbol	Value
Charge	q	17 nC
Beam current	I_b	13.9 mA
SR source to mirror	d	2.85 m
Bending radius	ρ	33.3 m
Energy at injection	E_i	425 MeV
Energy at extraction	E_e	7.1 GeV
Ramp time (E_i-E_e)	t_r	0.25 s
Booster period	T_B	1.0 s
Photon port width	w	60 mm
Photon port height	h	37 mm

NEW PROFILE MONITOR

- The beam profile monitor optical path and principal components are illustrated schematically in Fig. 4.
- Components of the beam profile monitor are located physically within the booster synchrotron enclosure, which is illustrated in Fig. 5.

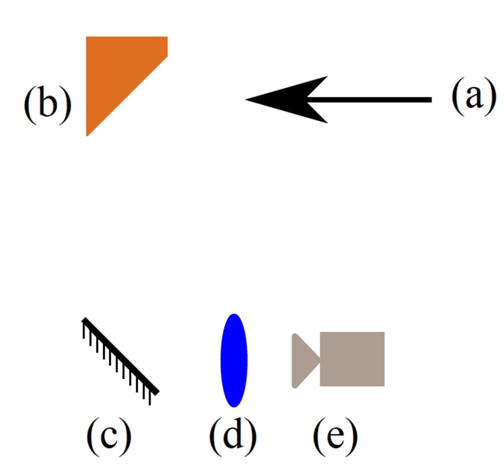

Fig. 4: Schematic of beam profile monitor in the booster ring. (a) SR from electron beam. (b) Glidcop mirror. (c) Out-of-vacuum mirror. (d) Motorised zoom-focus lens. (e) Digital camera.

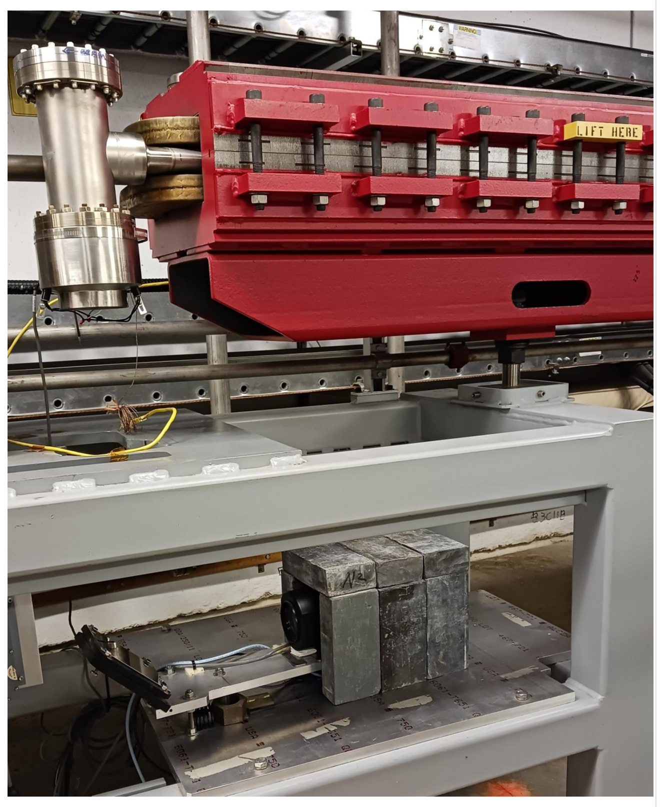

Fig. 5: Photograph of beam profile monitor in the booster ring.

BEAMLINE LATTICE

- Small average SR beam power on the mirror (4.1 W), endeavoured to improve imaging stability using a rigid mirror assembly composed of a bulk material.
- Glidcop was selected as the mirror substrate material.
- Mirror was fabricated and polished in-house. The mirror substrate was cut and then polished using Loose Abrasive Polishing (lapping) to achieve the desired mirror surface finish. The mirror surface was specified as 60-40 scratch-dig, and a flatness error of 1λ. The mirror geometry is illustrated in Fig. 6.

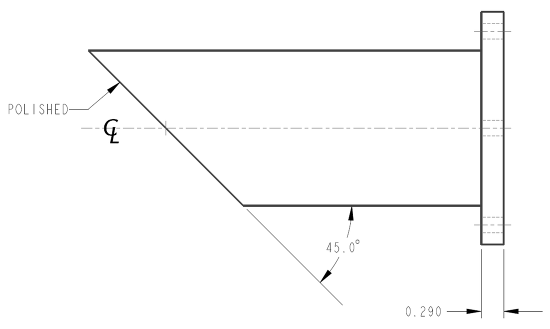

Fig. 6: Mirror geometry.

For polishing, lapping was performed in several stages. Glidcop Mirror and polishing fixture assembly were mounted in a precision vice on an Okamoto surface grinder (Fig. 7). The finished polished mirror is illustrated in Fig. 8.

Fig. 7: Photograph of the mirror and polishing fixture during machine lapping.

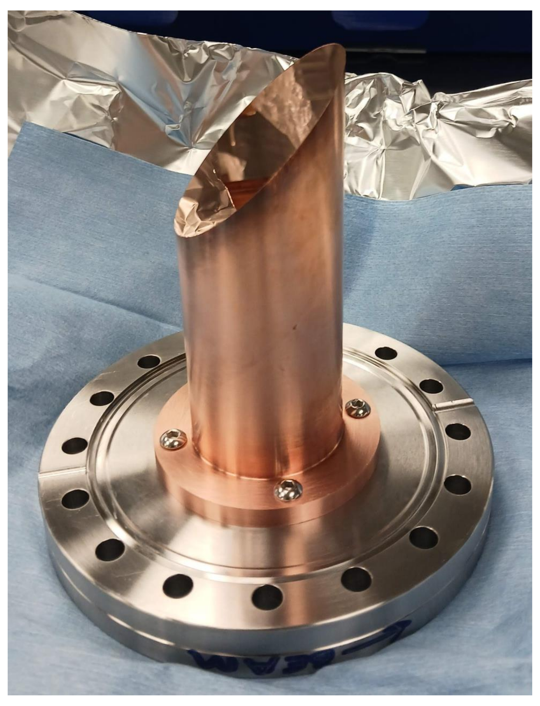

Fig. 8: Finished mirror after final polishing.

IMAGE STABILITY

- We have tested the mirror performance in machine studies.
- Most demanding test was 5 nC beam charge at 2 Hz repetition rate. Average 2.4 W SR power on the mirror (compared to the design of 4.1 W).
- Observed beam using two monitors: existing (B:SLM1) and new (B:SLM3).
- The motion of the beam image on both monitors is illustrated in Fig. 9.

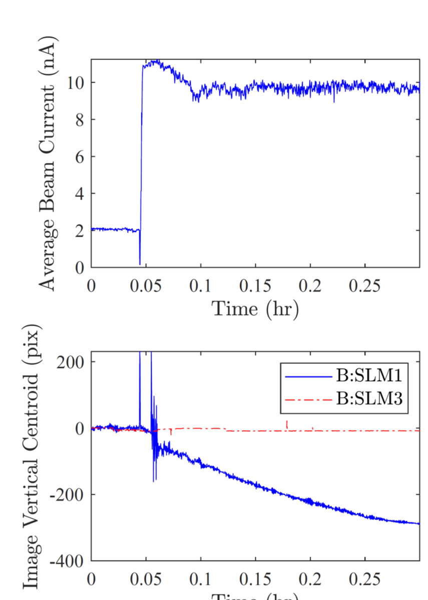

Fig. 9: Image centroid with time.

SUMMARY

- Specified, designed and fabricated a mirror to observe and image visible synchrotron light from the booster synchrotron at the APS.
- Calculated the SR power on mirror under anticipated beam conditions for APS-U operations (4.1 W).
- Mirror was fabricated and installed.
- Tested mirror under representative loading. Mirror achieves the primary objective of stable SR transport without measurable distortion.

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