# HORIZONTAL AND VERTICAL EMITTANCE MEASUREMENTS OF THE ADVANCED PHOTON SOURCE BOOSTER SYNCHROTRON BEAM AT HIGH CHARGE

## TUPP039

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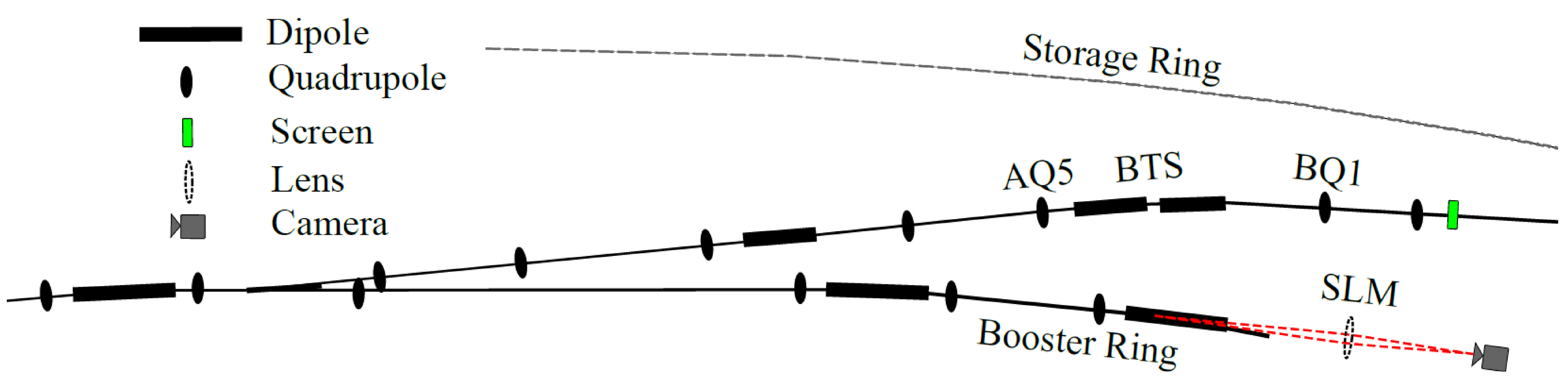
## ABSTRACT


- In order to maximise the injection efficiency from the booster synchrotron into the proposed Advanced Photon Source Upgrade storage ring, beam-based optimisation of the booster electron optical lattice is anticipated.
- In the present work, we present non-destructive beam size and emittance measurements using the booster synchrotron light monitor and destructive quadrupole scan emittance measurements in the booster to storage ring transport line.
- Destructive measurements are performed with a 0.1 mm thickness Cerium-doped Yttrium Aluminium Garnet screen.
- In order to characterise performance, both the beam energy at extraction (5, 6 and 7 GeV) and the bunch charge are varied.

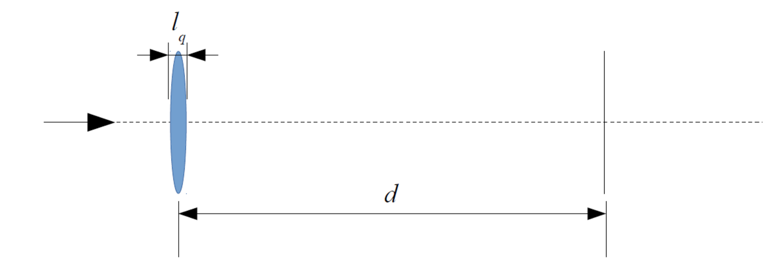




## MOTIVATION

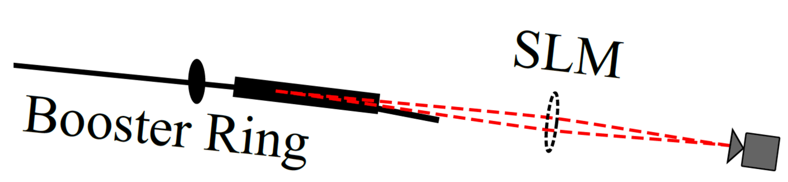
- Currently evaluating diagnostics needs in transport line for APS-U.
- In order to efficiently inject into the APS-U storage ring, it is desired to monitor and optimise in particular the horizontal emittance of the high charge electron bunch extracted from the booster synchrotron [1].
- We consider several established diagnostics to measure the horizontal and vertical emittances in the booster [2].
- In January of 2019 the old BTS flag station Chromox scintillator screen at this location was replaced with a 0.1 mm thick Cerium-doped Yttrium Aluminium Garnet scintillator [3].

## METHODS

- Destructive quadrupole scan emittance measurements of the electron beam emittance can be performed in the booster to storage ring transport line.

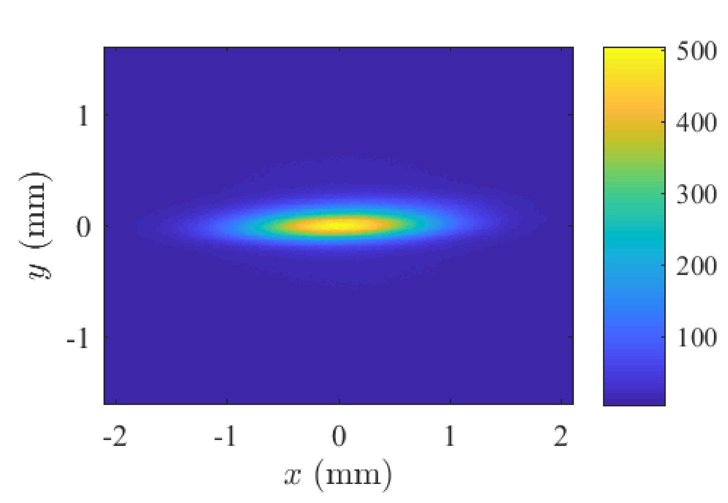



- Synchrotron light monitor imaging using one of the booster synchrotron bending magnets [4,5].




## SYNCHROTRON LIGHT MONITOR

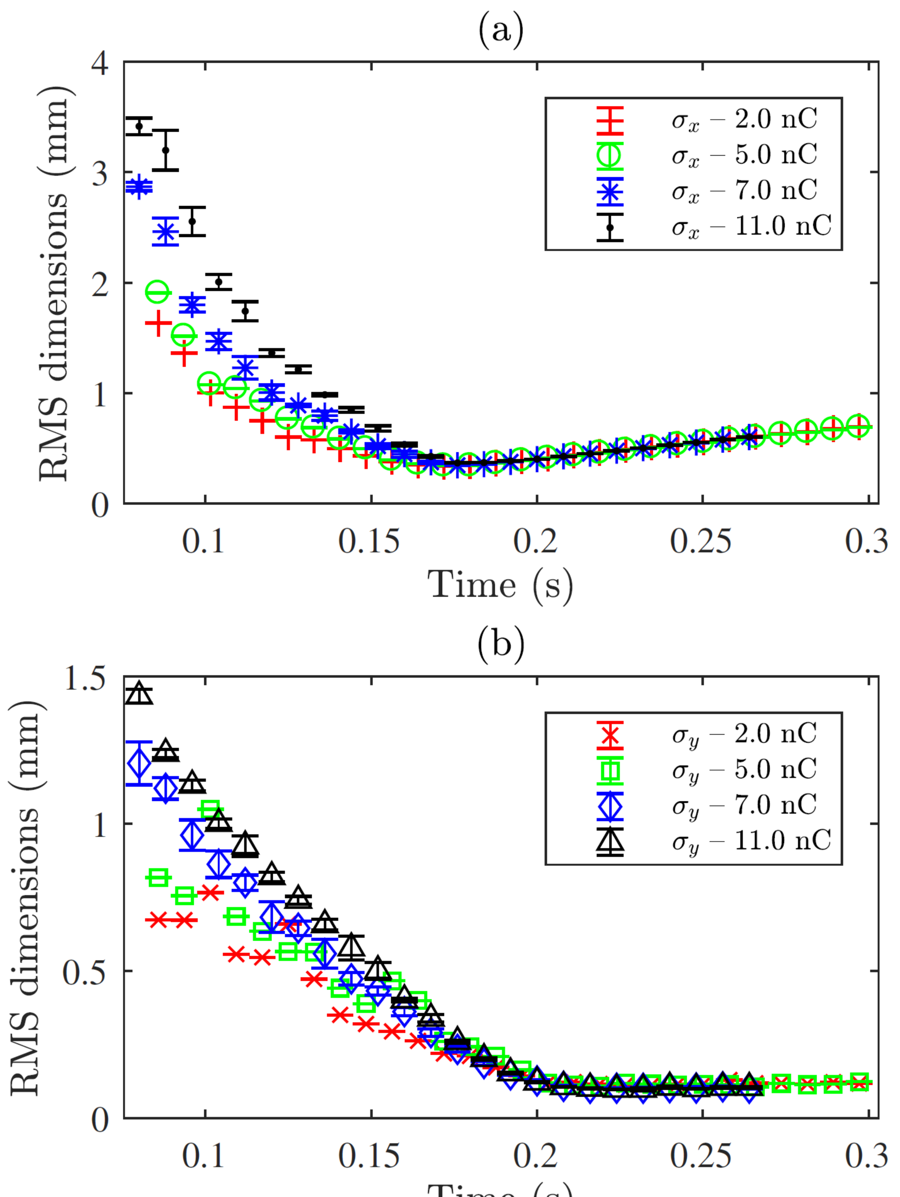
- The synchrotron light monitor is an optical beamline. The electron beam distribution is imaged using a single lens.
- An example image of the electron beam distribution imaged using the synchrotron light monitor is given below.




- Varying the camera trigger, the electron beam distribution was acquired at different times during the acceleration ramp, for different bunch charges.
- Nominal electron optical functions at source point.

| Lattice parameter | Value | Units |
|---|---|---|
| $\beta_x(s)$ | 4.18 | m |
| $\eta_x(s)$ | 0.48 | m |
| $\beta_y(s)$ | 11.83 | m |
| $\eta_y(s)$ | 0.00 | m |

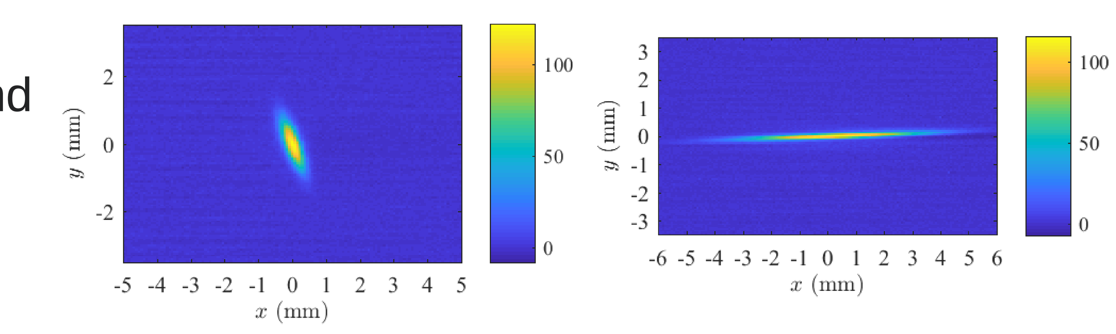
| Component | s (m) |
|---|---|
| Electron beam source | 0.000 |
| $f = +2.0$ m lens (Melles Griot LAO379) | 5.466 |
| Neutral density filters (0.0-6.0 OD) | 8.420 |
| 450 nm filter, 10 nm bandpass | 8.520 |
| CMOS Camera (Point Grey Grasshopper3) | 8.620 |

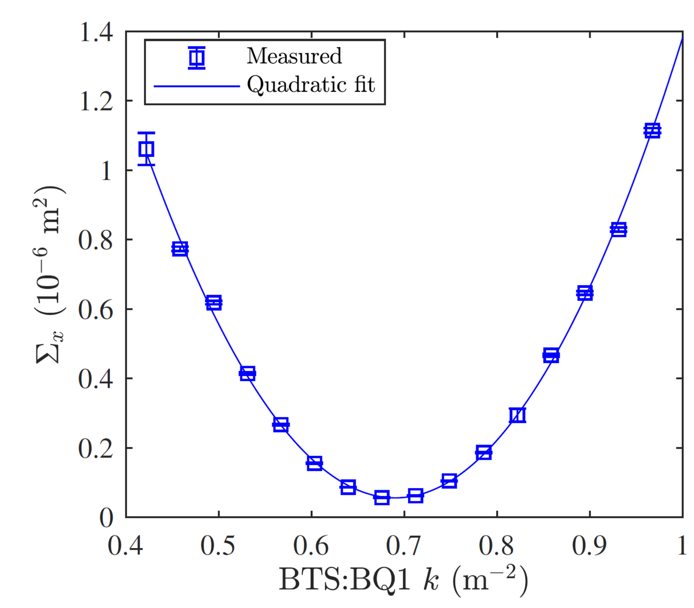



Measured booster synchrotron light monitor scan of electron beam horizontal (a) and vertical (b) size during the acceleration ramp. Multiple injected charges were measured between 2 and 11 nC. Essentially, once there is sufficient synchrotron radiation damping, the beam size damps to equilibrium independent of the injected charge within this range.

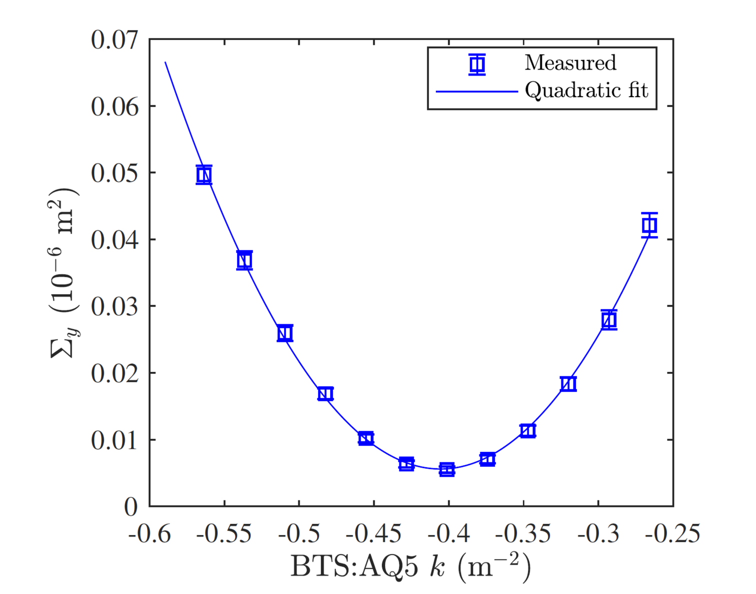
## QUADRUPOLE GRADIENT SCAN

- Effective pixel size is 115.9 µm pix$^{-1}$ in the horizontal and 90.9 µm pix$^{-1}$ in the vertical direction.
- Analysis follows Ref. [6].

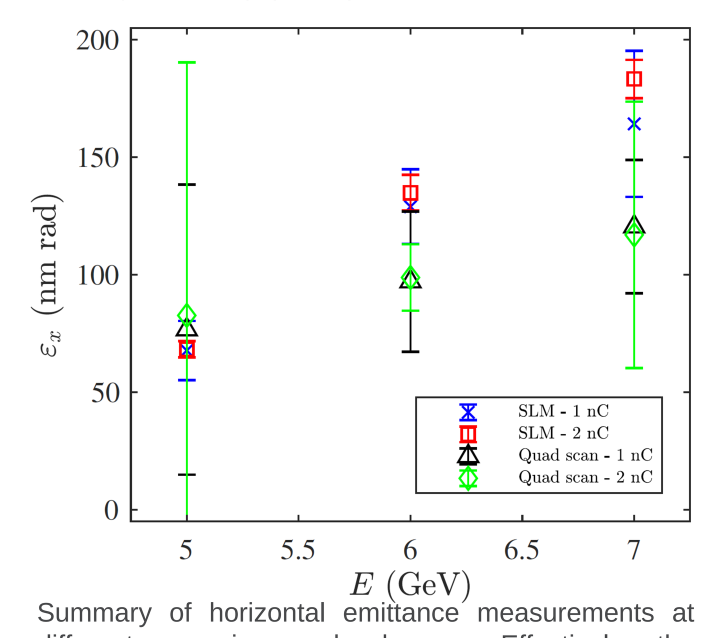


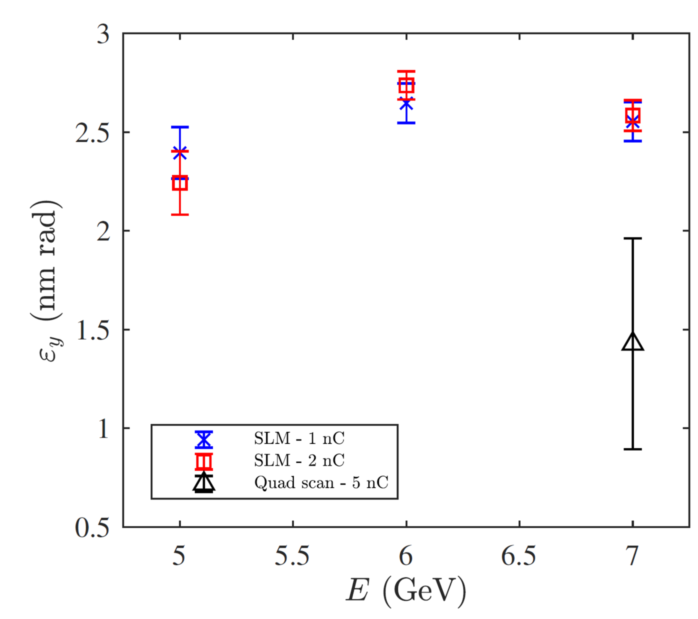

Measured electron beam horizontal moment with variation of vertically focussing quadrupole BQ1 excitation current.




Measured electron beam vertical moment with variation of vertically focussing quadrupole AQ5 excitation current.




Summary of horizontal emittance measurements at different energies and charges. Effectively, the measured emittance is increasing with the excitation from synchrotron radiation as the energy increases.




Summary of vertical emittance measurements at different energies and charges. Effectively, the measured emittance is not changing with energy.

## CONCLUSIONS

- Operation of the booster synchrotron at bunch charges exceeding 10 nC will be important for several proposed electron beam filling patterns of the APS-U.
- For efficient beam transport and acceptance into the APS-U storage ring, low transverse emittance is desired.
- Measured beam size and emittance in the booster using a light monitor and quadrupole scans.
- We have not observed a significant increase in transverse emittance with injected bunch charge.

## NEXT STEPS

- We have measured the transverse emittance of high charge beams in the booster synchrotron using optical synchrotron radiation.
- We have not yet measured the emittance of beams extracted at the same high charge in the BTS transport line.
- In order to measure the emittance in the BTS transport line using quadrupole scans at higher charge, new radiological surveys will be performed.

## REFERENCES

[1] K. Harkay, *et al.*, *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 3423-3426.
[2] B. Yang, *AIP Conf. Proc.*, 648, pp. 59--78, (2002).
[3] A. H. Lumpkin, *et al.*, NAPAC'19, Lansing, MI, USA, Sep. 2019, paper TUPLE11.
[4] A. Lumpkin, *et al.*, in *Proc. PAC'95*, Dallas, TX, USA, May 1995, pp. 2473-2475.
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[6] F. Löhl, "Measurements of the transverse emittance at the VUV-FEL", Diploma thesis, University of Hamburg, Hamburg, Germany, July 2005.

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