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Ultra Low Vertical Emittance at the Australian Light Source

Mark Boland on behalf of Rohan Dowd

Overview

- Lattice Overview
- Vertical emittance minimisation method summary

(R. Dowd, M. Boland, et al. (2011). "Achievement of ultralow emittance coupling in the Australian Synchrotron storage ring." Phys. Rev. ST Accel. Beams 14(1): 012804.)

- Beam based magnet alignment
- Latest vertical emittance results
- Summary of main issues

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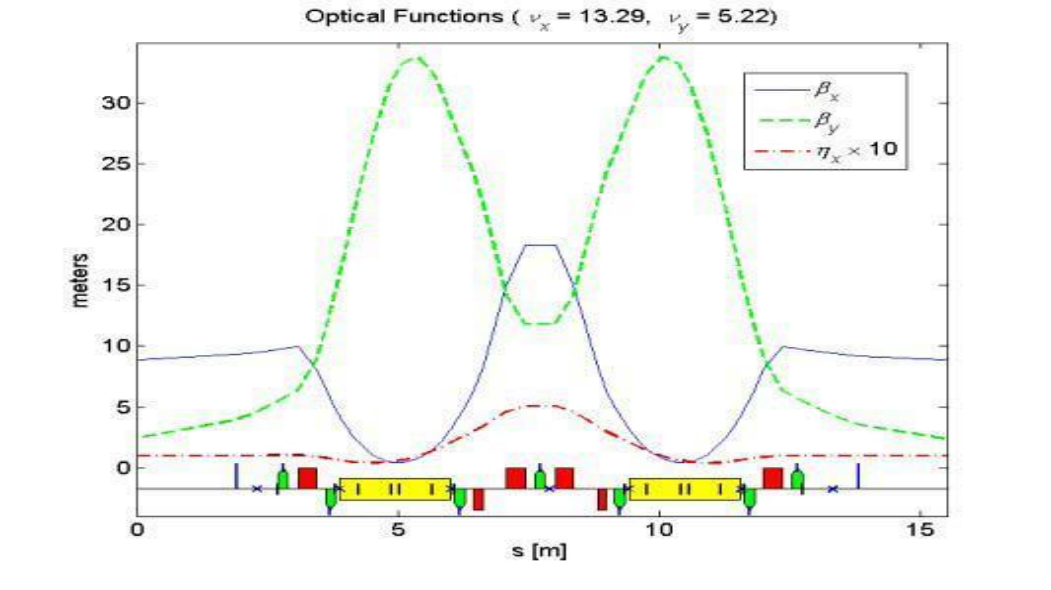
Lattice

- 3 GeV Light Source,
- Double bend achromat lattice
- Operates at 0.1 m dispersion in straights – 10 nm Hor. ε
  Can operate at 0.24 Dispersion – 7nm Hor. ε
- 28 Skew quads for coupling control, located on sextupole windings.
  28 additional unpowered windings.

•Storage Ring Parameters

Energy	3 GeV
Circumference	216 m
RF Frequency	499.654 MHz
Peak RF Voltage	3.0 MV
Current	200 mA
Betatron Tune (h/v)	13.3/5.2
Momentum Compaction	0.002
ε_x (nominal)	10.4 nm·rad



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Vertical emittance minimisation method

- Take orbit response matrix and dispersion data.
- Analyse with LOCO, fit skew quad components to every multipole in the ring. Weigh vertical dispersion highly in fit.
- Use LOCO calibrated lattice to calculate equilibrium beam envelope in AT, using Ohmi method (K.Ohmi et al. Phys.Rev.E. Vol.49. (1994)). Calculate emittance ratio from this.
- Feed calculated emittance ratio into minimisation algorithm which adjusts the skew quadrupole currents in the model to minimise the ratio (or set it to a desired value)

- Apply skew quadrupole settings onto machine and re-do LOCO analysis. Calculate emittance ratio from calibrated lattice.

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Beam Based Magnet Alignment

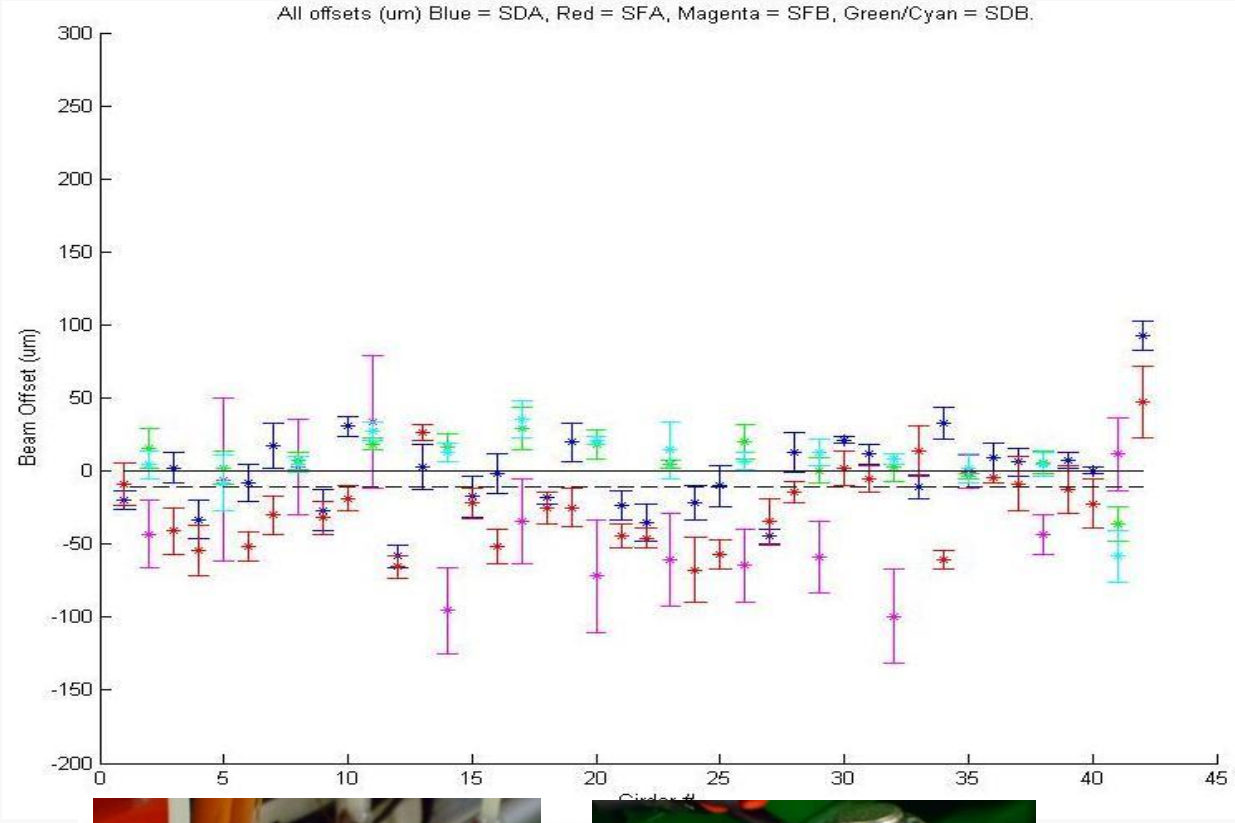
- Coupling terms rise from quadrupole rolls and sextupole vertical offsets.

- Our Alignment surveys seemed to be progressively making our coupling worse!
  - Alignment survey positioning doesn't tell you what is happening at the magnetic centre.
  - Can you get better accuracy using the beam?

- Orbit response analysis using LOCO should allow you to find the sextupole offsets. (Eg. V. Sajaev, A Xiao, IPAC10)
  - Need to take care with the LOCO fitting. Simultaneous measurements found not to work due to 'smearing' of fitted coupling.
  - Separate, family by family measurements taken.

Sextupole offsets

- Shunt each sextupole magnet family to different strengths and take a response matrix at each point
- Perform LOCO analysis and fit skew quadrupole terms to each sextupole.
- Gradient of skew field vs sextupole field gives vertical offset.
- Shim Magnets to reduce offsets



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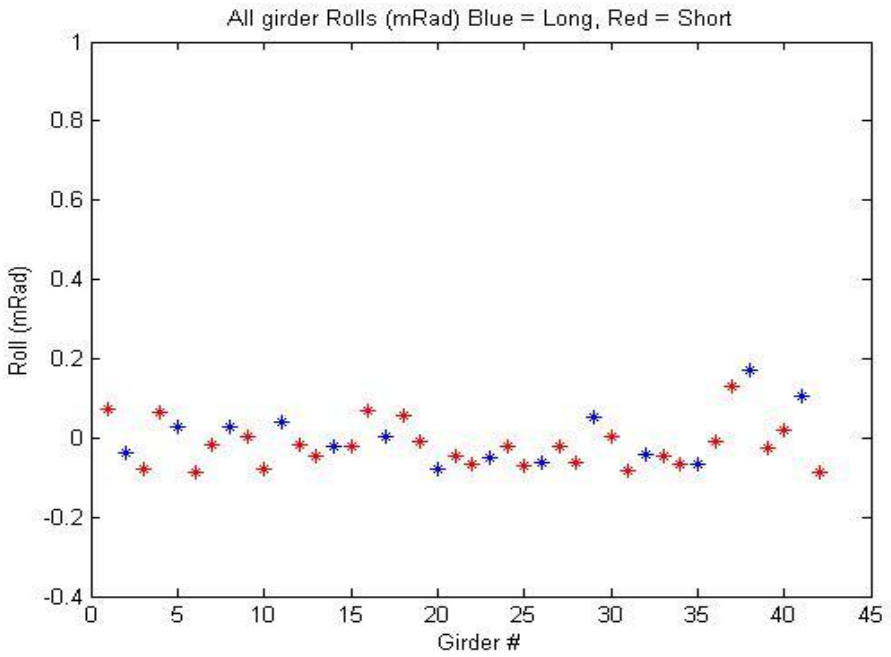
Emittance coupling – Quadrupole rolls

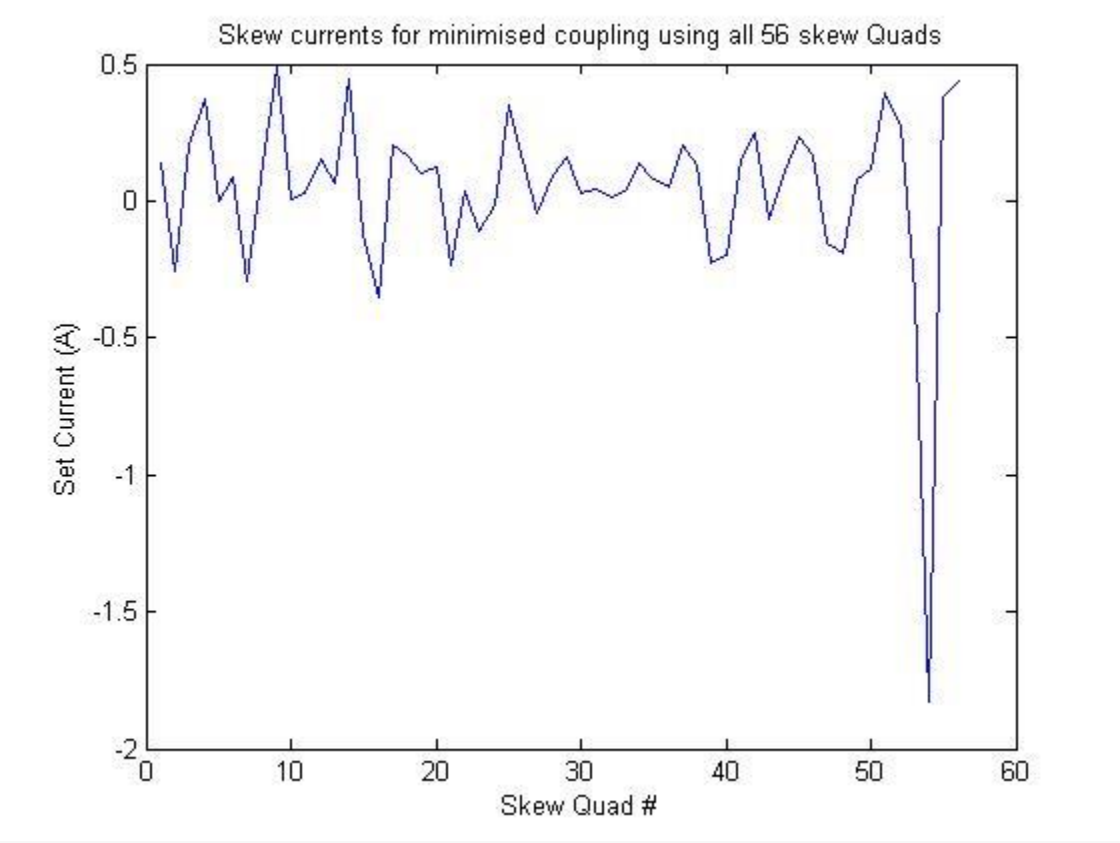
- Turn off Sextupoles and perform LOCO analysis.
- Fit skew quadrupole terms to each Quadrupole only
- Roll Girders by the amount indicated in the LOCO analysis and re-measure.
- Method was found to be accurate to ±0.05 mRad. Rolls now reduced to < 0.2 mRad. Another iteration possible



Lattice Condition	Uncorrected ε_y (pm)	Minimised ε_y (pm)
Uncorrected	36.8 ± 5.9	8.3 ± 2.3
Sextupoles Shimmed*	35.8 ± 6.2	5.4 ± 1.9
Sextupoles off	30.4 ± 4.8	6.0 ± 1.4
Sextupoles and Quads corrected	12.8 ± 2.4	0.8 ± 0.1

Skew magnet re-positioning.

- Ran simulation of using all 56 skew quadrupole coils.
- One magnet seen to have large effect on total coupling
- Power supply was swapped from adjacent skew quad to power this coil. Simulated minimised emittance result dropped from 0.8 to 0.3 pm.
- 4 New skew quad power supplies are currently being installed



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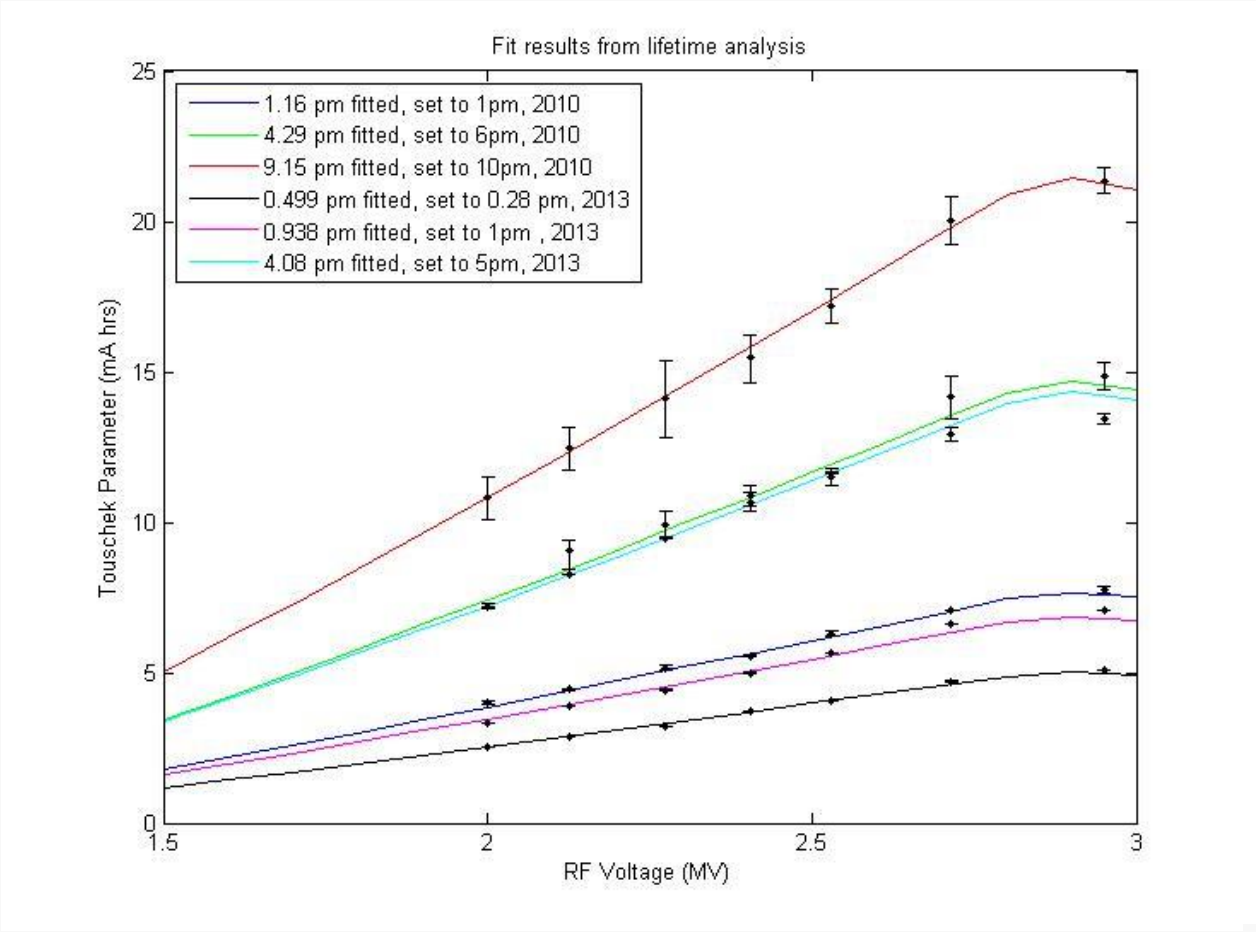
Touschek Lifetime Analysis Results



Current minimal ε_y is now ~0.5pm, quantum limit is 0.35 pm. Now in quantum dominated region and we still have some options for reducing further.

Summary

- Main issues:
  - Beam based alignment – LOCO accuracy is sensitive to BPM density and phase advance. Not suitable for simultaneous measurements, but done carefully, accuracy can be quite high.
  - Direct measurements are still very challenging, lifetime measurements track well with model estimates..

- Further developments
  - Measurements using ε_x = 7 nm lattice (~ 30% improvement)
  - Re-shim some sextupoles.
  - Incorporate new skew quads
  - Calibrate skew quads.