Orbit Feedback Using X-ray Beam Position Monitoring at the Advanced Photon Source

Glenn Decker
• APS beam stability specification
• System overview
• Accomplishments to date
• Improvement plans
One Sector of the Advanced Photon Source Storage Ring

27.6 meters

(APS has forty sectors - 1104 meters total circumference)
APS Beam Stability Specification

1) Original engineering specification 5% of CDR beam size values
   • 4.5 microns rms vertical (@ ID source points)
   • 17 microns horizontal

2) With present low-emittance lattice, (1% coupling) this amounts to
   • 590 nm / 120 nanoradians rms vertical
   • 12.6 microns / 900 nanoradians rms horizontal
100 nanoradians rms means the bullet goes through the hole 68 times out of 100 without touching the sides.

10 mm - Diameter Bullet

Target is 11 mm - hole

10 Kilometers
APS Orbit Correction System Components

- 360 broadband (monopulse) RF BPMs
- 48 narrowband RF BPMs (mounted on ID vacuum chambers)
- 48 insertion device X-ray BPMs
- 38 bending magnet X-ray BPMs
- 317 combined-function horizontal / vertical corrector magnets
APS Orbit Correction System Components (cont’d)

- 21 VME crates, each with 2 DSP boards [Pentek 4283 (TI C30 DSP), 4284 (TI C40 DSP)] for real-time feedback. [4285 (multi-C40 board) used in “master” crate.]
- One additional 4284 DSP board used in feedback crates for X-ray- and narrowband RF- BPM data acquisition and filtering.
- Singular Value Decomposition (SVD) algorithm used in DC and AC systems.
- Workstation-based (DC) algorithm has 0.1 Hz closed loop BW
- Real-time (AC) algorithm operates at 1.5 kHz allowing closed loop bandwidth from 0.1 to 60 Hz
  - Access to 38 “fast” correctors
  - Access to all RF and X-BPM data (not all used in algorithm)
Orbit Control Configuration

Legend:

C: Corrector Magnet
- RF Beam Position Monitor
P1, P2: X-ray Beam Position Monitors
Q: Quadrupole
BM: Bending Magnet
ID: Insertion Device

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<th>BPMs</th>
<th>Correctors</th>
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<td>Global</td>
<td>11 RF (all)</td>
<td>2</td>
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<tr>
<td>Local - 1</td>
<td>P1 or P2</td>
<td>4</td>
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<td>Local - 2</td>
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Bending Magnet and BPM Layout

RFBPMs

BM

0.5 0 2.8 (meters)

 XBPMs

#1 #2

11 18 (meters)

Insertion Device and BPM Layout

RFBPMs

ID

2.5 0 2.5 (meters)

XBPMs

#1 #2

16.3 20 (meters)
APS X-ray BPM Photoemission Blade Sensor Geometry

Upstream X-BPM (P1)  Downstream X-BPM (P2)

4.65 mm

4.50 mm
Noise Sources Impacting APS Orbit Stability

- Magnet power supply noise / ripple
  - Dominant source of beam motion
  - DSP-based regulator prototyped
- RF system high voltage power supply
  - Induces 360 Hz phase (energy) ripple + harmonics
- Thermal effects (Tunnel air / water temperature)
- Earth tides
- Mechanical vibration
  - Affects primarily horizontal beam motion
- Insertion device gap changes <-----
Variation of ID X-ray BPM Readbacks with Horizontal Position, Gap
Data Pool Crate
Master Crate
Storage Ring

Double-Sector Feedback IOC

Corrector Power Supplies
Feedback 'Slave' Station

from previous station
Reflective Memory Network
to next station

Controls Network

Turn-by-turn rf BPMs
Narrow-bandwidth rf BPMs
X-ray BPMs
X-bpm preamps

Patch panels to merge Xbpm, NbBpm signals to two ribbon cables

ADC’s

EPICS IOC

DSP

Reflective Memory
Spectrum of Beam Motion Averaged over ID Source Points
Specification = 5% of Beam Size

APS Horizontal and Vertical Beam Position Stability History (0.016 Hz - 30 Hz)

Horiz. RMS Motion (microns)

- Specification = 5% of Beam Size (10% coupling design value)
- Noisy Power Supply Repaired
- Slow Drift Correction Refined
- Change to Low Emittance Mode

Vert. RMS Motion (microns)

- Specification = 5% of Beam Size
- Power Supply Quality Control Improved
- Operation Period

Slow Drift Correction Refined

5% of Beam Size with 1% coupling
Stored Beam Current

I (mA)

Vertical RMS Motion @ID Source Points
(0.1 - 30 Hz)

(Yrms) peak
(microns)


24 Hours

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Plots showing < 200 nanoradian rms vertical beam stability over a 5 day period
Colors indicate data for individual days

BM X-ray bpm distances from source point: P1 - 11 meters
P2 - 18 meters

Data collected 8/8 - 8/13/01

P1 Position (microns)
P2 Position (microns)

P1 Position (microns)
P2 Position (microns)

σ_{P1} = 0.65 microns
σ_{P2} = 0.87 microns
σ_y' = 183 nanoradians
σ_y = 0.43 microns

Average Position (microns)
Recently Completed Upgrades

- Replaced X-ray bpm data acquisition (86 channels, BM and ID)
  - Allowed factor of ten reduction in long term vertical drift
- Fabricated mobile X-ray bpm translation stage controllers
  - Allows for convenient and precise calibration of x-bpms
Upgrade Strategy

- Systems now in operation:
  - Real time feedback using monopulse RF bpms (0.1 - 30 hz closed loop bandwidth with 1.5 kHz data rate).
  - Software for reconfiguration of DC orbit control using arbitrary bpms, steering correctors, number of singular values, and bpm weights.
  - Software providing local steering on demand.
  - Vertical DC global orbit control using bending magnet x-bpms.
- Things we know how to do and will do in FY02:
  - Increase update rate of “DC” correction algorithm from 0.4 Hz to 50 Hz or more
    - Involves addition of “data pool” IOC hooked into reflective memory network
  - Implement feedforward to reduce ID gap change - induced orbit transients
  - Integrate insertion device x-bpms into global and local orbit control algorithms
    - Comprehensive understanding of systematic effects after two years’ intensive study are well in hand
• Long range upgrade plans:

- Incorporation of x-bpms and narrow-band bpms into fast feedback algorithm (This places a fundamental limit on vertical beam size / brightness)
- Blade geometry optimization of ID x-bpms
- Design of x-bpm’s for dual-undulator sources
Conclusions

- APS orbit correction system is mature, integrating RF and X-ray beam position monitors.
- System uses > 60 DSP’s tied together with real-time reflective memory network.
- Bending magnet X-bpm’s are in operation for DC orbit control.
- Data pool IOC will allow integration of insertion device X-bpm’s into DC orbit control (‘fast’ feedforward necessary)
- Integration of X-bpm’s into 1.5 kHz global feedback will allow sub-micron orbit stability from “DC” to 30 Hz.