Orbit Stabilization at the Advanced Photon Source

Glenn Decker
IWBS 2004
December 6, 2004

Argonne National Laboratory

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago
27.6 meters

(The APS has forty sectors - 1104 meters total circumference)
## Nominal APS Storage Ring Parameters

### Standard Lattice

- **Emittance:** 2.5 nm-rad
- **Effective emittance at ID:** 3.1 nm-rad
- **Coupling:** 1%

<table>
<thead>
<tr>
<th>Source Size</th>
<th>ID</th>
<th>BM sector with chicane</th>
<th>BM sector without chicane</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_x$</td>
<td>271.2 μm</td>
<td>91.5 μm</td>
<td>88.5 μm</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>8.6 μm</td>
<td>25.0 μm</td>
<td>25.2 μm</td>
</tr>
</tbody>
</table>

### Divergence

- **$\sigma_x'$:** 11.4 μrad
- **$\sigma_y'$:** 2.9 μrad

<table>
<thead>
<tr>
<th>Beta Functions</th>
<th>$\beta_x$</th>
<th>$\beta_y$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19.32 m</td>
<td>2.09 m</td>
<td>1.96 m</td>
</tr>
<tr>
<td>$\beta_x$</td>
<td>2.00 m</td>
<td>24.92 m</td>
<td>25.32 m</td>
</tr>
</tbody>
</table>

### Other Parameters

<table>
<thead>
<tr>
<th></th>
<th>$\alpha_x$</th>
<th>$\alpha_y$</th>
<th>$\gamma_x$</th>
<th>$\gamma_y$</th>
<th>$\eta_x$</th>
<th>$\eta_x'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_x$</td>
<td>0.00</td>
<td>0.95</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_y$</td>
<td>0.00</td>
<td>0.70</td>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma_x$</td>
<td>0.05 m$^{-1}$</td>
<td>0.91 m$^{-1}$</td>
<td>0.91 m$^{-1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma_y$</td>
<td>0.34 m$^{-1}$</td>
<td>0.06 m$^{-1}$</td>
<td>0.05 m$^{-1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta_x$</td>
<td>0.166 m</td>
<td>0.058 m</td>
<td>0.057 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta_x'$</td>
<td>0.000</td>
<td>-0.032</td>
<td>-0.033</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Insertion Device Pointing Stability Specification

$$\sigma_{y'_{\text{xray}}} = \sqrt{(1 + K^2)/(2nN_u)}$$

Here, \(\gamma\) is the X-ray vertical opening angle.

\[
\gamma = \frac{E}{(mc^2)} = 13700 \text{ @ 7 GeV}
\]

Where:

- \(N_u\) = Number of undulator periods
  = 72 for APS und. A
- \(n\) = undulator harmonic number

\[\therefore \sigma_{y'_{\text{xray}}} = 3.3 \mu\text{rad rms (}n=7, K=1\)\]

This adds in quadrature with the electron beam divergence \(\sigma_{y'_{\text{e-}}} = 2.9 \mu\text{rad}\)

\[\sigma_{y'_{\text{total}}} = 4.4 \mu\text{rad}\]

Pointing stability = 0.05 \(\cdot\) \(\sigma_{y'_{\text{total}}} = 220\) nanoradians rms
Beam Position Monitors and Magnets in One Sector

- • : Broad-band RF Beam Position Monitors (7) (Turn-by-Turn)
- x : Narrow-band RF Beam Position Monitors (4) (~ 300 Hz)
- □ : BM X-ray Beam Position Monitors (2 - Vertical Only) (~165 Hz)
- ○ : ID X-ray Beam Position Monitors (2) (~165 Hz)
- FC : “Fast” Corrector Magnet (1) (~ 1000 Hz)
- C : “Slow” Corrector Magnets (7) (few Hz)
- Q : Quadrupole Magnets
Canted Undulator Geometry
(APS sectors 21,23,24)
Asymmetric 4-bump

Correctors in use

BPMs in use
Symmetric 4-bump

Zoom of 4 sectors
Interaction of local source with 4-bump

Steering source

Zoom view
Use of BPM’s as Null Devices to construct 3-bump

Correctors in use by controllaw

Controllaw Response

* 136 Amps = ~ 1 mrad
“Simo-bump” used for cross-calibration of ID photon bpm’s

No ID’s here

Sector 4 ID source point

Asymmetric setpoint changes

Setpoints unchanged

Zoom view

Argonne National Laboratory
Advanced Photon Source

IWBS 2004
Glenn Decker
December 6, 2004
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

σ_p1 = 0.65 microns
σ_p2 = 0.87 microns
σ_y' = 183 nanoradians
σ_y = 0.43 microns

Argonne National Laboratory
Advanced Photon Source
AC Beam Stability: Real-time feedback corrector statistics

RTFB Corrector/Drive Summary

Orbit Feedback Horizontal Corrector Error StdDev

Orbit Feedback Vertical Corrector Error StdDev

Orbit Feedback Horizontal Drive StdDev

Orbit Feedback Vertical Drive StdDev

Orbit Feedback Status

WS X Y

DP X Y

RTFB Horz On Vert On

SR DCCT 102.2846 mA DC

HB 05-03-04
Real time calculation of rms beam motion
Horizontal RMS Motion

β_x = 22 m

~4 days

Time starting Fri Nov 26 03:02:57 2004

Vertical RMS Motion

β_y = 6.9 m

0.01 - 767 Hz

0.01 - 100 Hz

0.01 - 30 Hz

Time starting Fri Nov 26 03:02:57 2004
APS Real-time feedback system allows simultaneous acquisition of 40 waveforms
AC Beam Stability

Power Spectral Density

Horz.  µm²/Hz

Vert.  µm²/Hz

µm rms

Frequency (Hz)

Sq rt[Integ[PSD]]

Sqrt[ReverseInteg[PSD]]

Normalized to βₓ = 20 meters

Normalized to βᵧ = 5 meters

APS  SPring-8*

(No Feedback)

Spring-8 Data

Courtesy H. Tanaka

IWBS 2004

Glenn Decker

December 6, 2004

Argonne National Laboratory

Advanced Photon Source
AC Pointing Stability

Power Spectral Density

Horz. µrad²/Hz

Vert. µrad²/Hz

with Feedback

without Feedback

Power Spectral Density

Sqrt[Integ[PSD]]

µrad rms

µrad rms

Frequency (Hz)

Frequency (Hz)

Frequency (Hz)

Frequency (Hz)

With Feedback

without Feedback

µrad rms

µrad rms

µrad rms

µrad rms

Frequency (Hz)
Earth Tides

2004 Phases of the Moon
Universal Time

NEW MOON       FIRST QUARTER       FULL MOON
  d   h   m    d   h   m    d   h   m
OCT. 14  2  48   OCT. 20  21  59   OCT. 28  3  07

Earthquakes

04/10/08 08:27 M 6.9 SOLOMON ISLANDS Z= 37km 10.84S 162.18E

This information is provided by the USGS
National Earthquake Information Center.

A magnitude 6.9 earthquake IN THE SOLOMON ISLANDS has occurred at:
10.84S 162.18E Depth 37km Fri Oct 08 08:27:54 2004 UTC

Time: Universal Time (UTC) Fri Oct 08 08:27:54 2004
Time Near Epicenter Fri Oct 8 19:27:54 2004
Central Daylight Time (CDT) Fri Oct 8 03:27:54 2004

Location with respect to nearby cities:
285 km (180 miles) ESE of HONIARA, Guadalcanal, Solomon Islands
2070 km (1290 miles) NNE of BRISBANE, Queensland, Australia

Summary

- The APS is a mature facility with a lot of sophisticated orbit control capability.
- Use of BM and ID photon beam position monitors has improved long term pointing stability and repeatability in the past few years.
- The real-time feedback system continues to run well, in operation since 1997.
- Future plans include upgrades to broadband rf bpm data acquisition and real-time feedback system.
- A “hard x-ray” beam position monitor is being designed to be placed in the beamline first optic enclosure 25 meters from the insertion device source point. Objective is to achieve 100 nrad-scale long-term pointing stability, making local steering requests unnecessary.