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

One Sector of the Advanced Photon Source Storage Ring

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 chicanes</th>
<th>BM sector without chicanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_x$</td>
<td>271.2 $\mu$m</td>
<td>91.5 $\mu$m</td>
<td>98.5 $\mu$m</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>8.8 $\mu$m</td>
<td>25.0 $\mu$m</td>
<td>25.2 $\mu$m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Divergence</th>
<th>$\sigma_x$</th>
<th>$\sigma_y$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.4 $\mu$rad</td>
<td>58.5 $\mu$rad</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>2.9 $\mu$rad</td>
<td>1.2 $\mu$rad</td>
</tr>
</tbody>
</table>

#### Beta Functions

- $\beta_x = 19.32$ m
- $\beta_y = 2.08$ m
- $\beta_x = 24.82$ m
- $\beta_y = 25.32$ m

<table>
<thead>
<tr>
<th>Other Parameters</th>
<th>$\sigma_x$</th>
<th>$\sigma_y$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00 $m^{-1}$</td>
<td>0.05 $m^{-1}$</td>
</tr>
<tr>
<td></td>
<td>0.00 $m^{-1}$</td>
<td>0.70 $m^{-1}$</td>
</tr>
<tr>
<td>$\sigma_x$</td>
<td>0.05 $m^{-1}$</td>
<td>0.01 $m^{-1}$</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>0.34 $m^{-1}$</td>
<td>0.00 $m^{-1}$</td>
</tr>
<tr>
<td>$\sigma_x$</td>
<td>0.188 $m$</td>
<td>0.059 $m$</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>0.000 $m$</td>
<td>-0.022 $m$</td>
</tr>
</tbody>
</table>

### Insertion Device Pointing Stability Specification

\[
\sigma_{y_{\text{xray}}} = \sqrt{(1 + K^2)/(2nN_u)} \cdot \gamma = \text{X-ray vertical opening angle}
\]

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

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

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

This adds in quadrature with the electron beam divergence $\sigma_{y_{\text{e}^2}} = 2.9 \text{ $\mu$rad}$

\[
\sigma_{y_{\text{total}}} = 4.4 \text{ $\mu$rad}
\]

Pointing stability = 0.05 $\sigma_{y_{\text{xray}}} = 220$ nanoradians rms
Beam Position Monitors and Magnets in One Sector

- Broad-band RF Beam Position Monitors (7) (Turn-by-Turn)
- 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)
- “Fast” Corrector Magnet (1) (~ 1000 Hz)
- “Slow” Corrector Magnets (7) (few Hz)
- Quadrupole Magnets

---

**SR Vertical BPM Status**

**SR Horizontal BPM Status**

**SR Vertical Corrector Feedback Use**

**SR Horizontal Corrector Feedback Use**
Canted Undulator Geometry
(APS sectors 21,23,24)

-1 mrad

\[ e^- \]

ID #1
+0.5 mrad

ID #2
+0.5 mrad

BPM

Dipole Magnet

Corrector Magnet

Asymmetric 4-bump

Correctors in use

BPMs in use
Symmetric 4-bump

Zoom of 4 sectors

Steering source

Interaction of local source with 4-bump

Zoom view
Correctors in use by Controllaw

BPM's in use

Use of BPM's as Null Devices to construct 3-bump

* 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
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

\[ \sigma_{P1} = 0.65 \text{ microns}, \quad \sigma_{P2} = 0.87 \text{ microns} \]

\[ \sigma_y = 183 \text{ nanoradians}, \quad \sigma_y' = 0.43 \text{ microns} \]

AC Beam Stability: Real-time feedback corrector statistics

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 MS DP RTFB

SR DCCT 102.2846
Real time calculation of rms beam motion

Horizontal RMS Motion

Vertical RMS Motion

$\beta_x = 22 \text{ m}$

$\beta_y = 6.9 \text{ m}$

E$_x = 22 \text{ m}$

E$_y = 6.9 \text{ m}$

~4 days

Time starting Fri Nov 26 03:02:57 2004

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

Power Spectral Density $\sqrt{\text{Integ}[\text{PSD}]}$, $\sqrt{\text{Reverse Integ}[\text{PSD}]}$

$\text{Pm}^2/\text{Hz}$

Horz. $\mu$m rms

Vert. $\mu$m rms

Frequency (Hz)

AC Beam Stability

Normalized to $\beta_x = 20$ meters

Normalized to $\beta_y = 5$ meters

*Spring-8 Data

Courtesy H. Tanaka

Argonne National Laboratory
Advanced Photon Source

IWBS 2004
Glenn Decker
December 6, 2004
### AC Pointing Stability

**Power Spectral Density**

- **Horz.**
  - $\mu\text{rad}^2/\text{Hz}$
  - Log scale

- **Vert.**
  - $\mu\text{rad}^2/\text{Hz}$
  - Log scale

**Sqrt[Integ[PSD]]**

- **Horz.**
  - $\mu\text{rad}$ rms
  - Linear scale
  - With Feedback
  - Without Feedback

- **Vert.**
  - $\mu\text{rad}$ rms
  - Linear scale
  - Linear scale

**Sqrt[ReverseInteg[PSD]]**

- **Horz.**
  - $\mu\text{rad}$ rms
  - Linear scale

- **Vert.**
  - $\mu\text{rad}$ rms
  - Linear scale

---

### Esoterica

#### Earth Tides

- **Frequency (Hz)**
- October 21, 2004
- October 23, 2004
- October 25, 2004

#### Earthquakes

- **Time:** Fri, Oct 8, 08:27:54 2004 UTC
- **Location:** E, 37km (10.84S 162.18E), Solomon Islands
- **Depth:** 37km
- **Magnitude:** 6.9
- **Epicenter:** HONIARA, Guadalcanal, Solomon Islands
- **Distance:** 285 km (180 miles)
- **Location:** NNE of BRISBANE, Queensland, Australia

---

*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 8 08:27:54 2004 UTC

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.