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ALS Accelerator Physics Group

- The Advanced Light Source
  - Currently used diagnostics/feedback systems
- Orbit Stability: Short term/Long term
- User requirements – two examples
- Recent orbit feedback upgrades
- Ongoing/Future feedback development

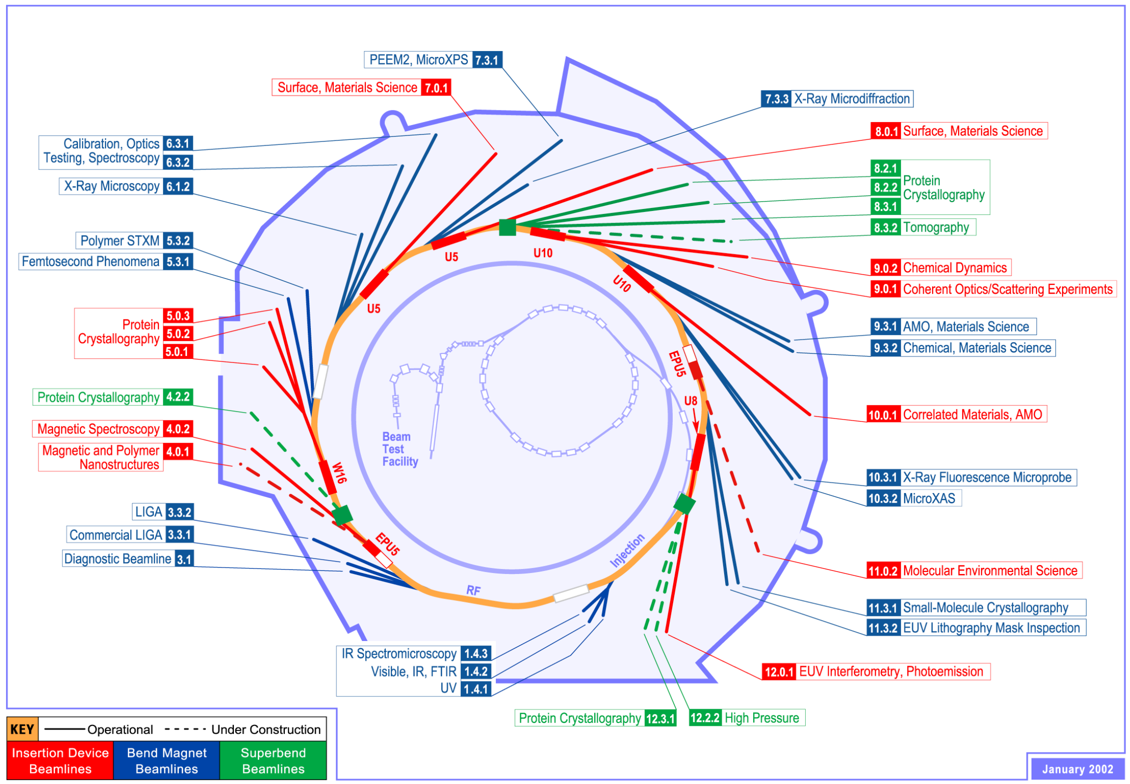
Aerial view of the Advanced Light Source

jc/ALSaerial/11-96

ALS Parameters:

BERKELEY LAB

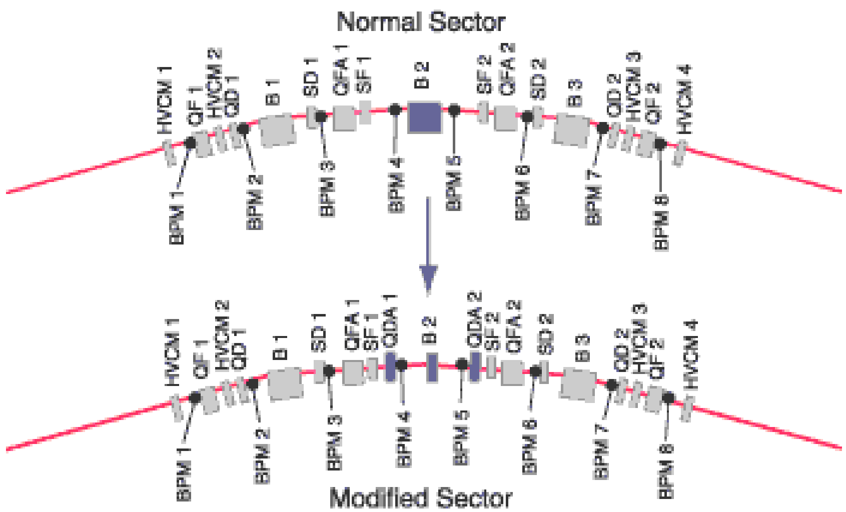
Nominal Energy	1.5-1.9 GeV
Circumference	196.8 m
RF frequency	499.642 MHz
Harmonic number	328
Beam current	400 mA multibunch 65 mA two-bunch
Nat. emittance	6.3 nm at 1.9 GeV
Emittance Coupling	Typical about 2%
Nat. energy spread	0.097%
Refill period	3 times daily multibunch, 12 times daily, two-bunch

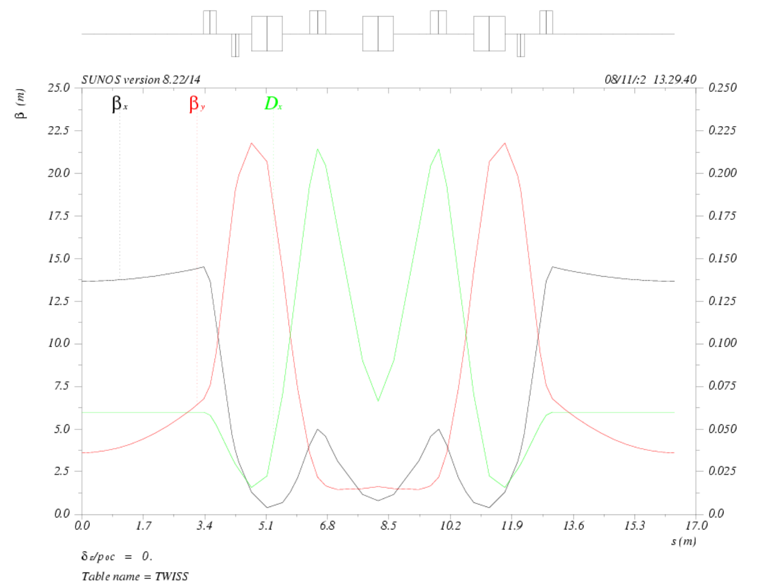


1/10 Electron Beam Size ⇒

Beam Location	Horizontal	Vertical
Straight Section	30 μm	2.3 μm
Bend Magnet #2	10.3 μm	1.3 μm

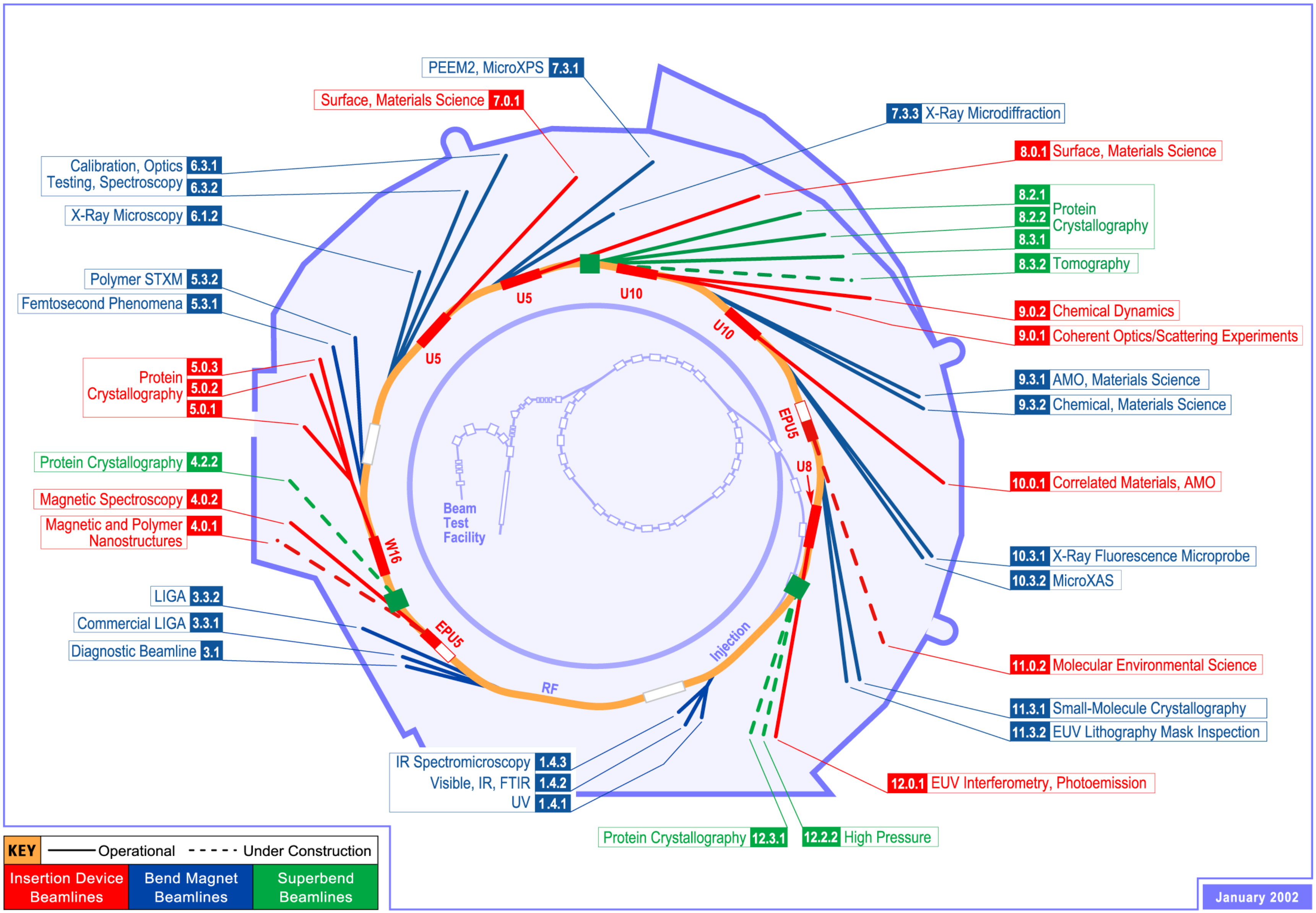
ALS Lattice





- 12 nearly identical arcs – TBA; aluminum vacuum chamber
- 96 + 40 beam position monitors (about 4 of stable type per arc)
- 8 horizontal, 6 vertical corrector magnets per arc
- 18 individual skew quadrupoles
- beam based alignment capability in all quadrupoles (either individual power supplies or shunts)
- 22 corrector magnets in each plane on especially thin vacuum chamber pieces

Beamlines at the ALS 2002



What has been done at the ALS to maximize stability

"PASSIVE"

(i.e. remove the sources)

- Temperature stability (air below 0.1, water below 0.5 degree peak-to-peak)
- Minimize water induced vibrations
- Power supply stability (no switched mode supplies, thick aluminum vacuum chamber in most magnets)
- Vibration - reduce the effects by mechanical design (ALS has big girders and moderate amplification factors) or remove the source (cryo-coolers).
- Reduce RF-phase noise (mode-0 noise for IR users)

FEED FORWARD

- Insertion device compensation (10 Hz for most IDs, 200 Hz for EPUs)
- Beta-beating, tune and coupling feed-forward presents additional challenges to orbit stability!

FEEDBACK

- Local orbit feedback (not routinely used at ALS)
- Global orbit feedback (1 Hz update rate operational, 1 kHz system in commissioning)
- BPM position detection incorporated into feedback (relative to common accelerator-experiment ground plate)
- Magnet or girder position feedback

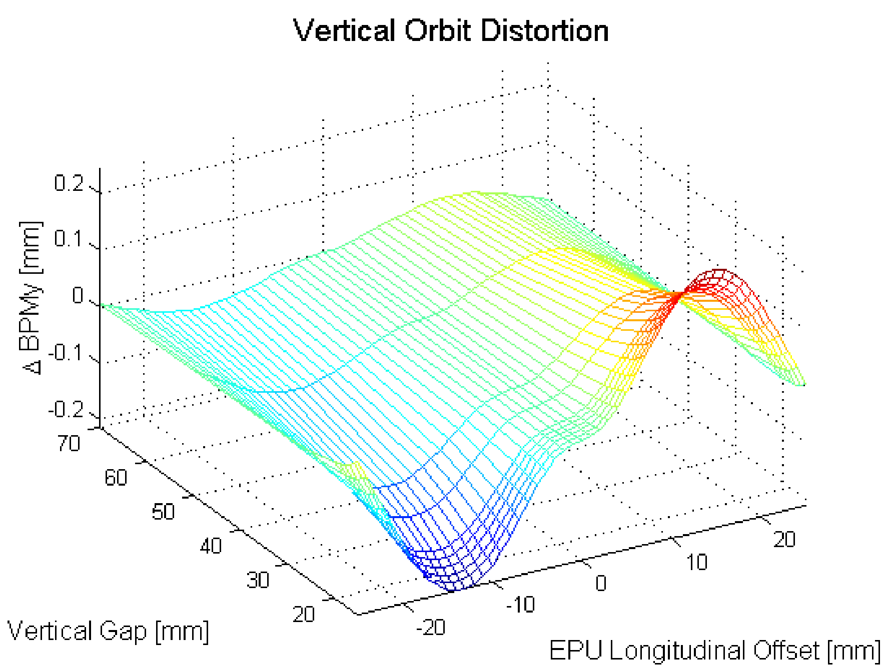
Feed-forward example: EPU COMPENSATION

Apple-II type elliptically polarizing undulators are more complex than other IDs

- ❖ The jaws can move in two directions (vertically and longitudinally)
- ❖ The motion in the longitudinal direction is fast (up to 17 mm/s at ALS)

This makes orbit compensation more difficult

Mechanically the EPU can move from left to right circular polarization mode in ~1.6 seconds

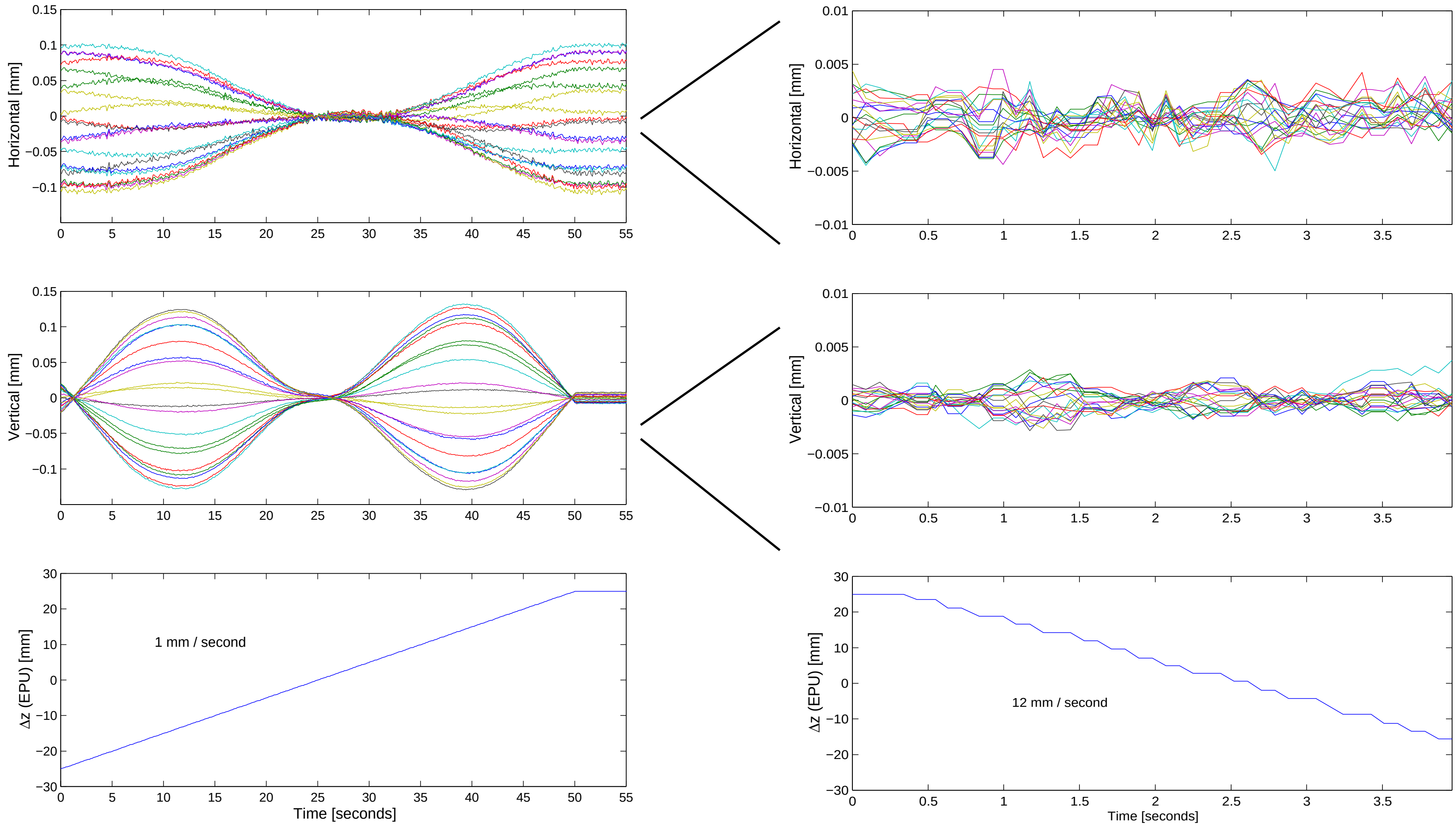


Without compensation the EPU would distort the electron beam orbit by ±200 μm vertically and ±100 μm horizontally. Using corrector magnets on either side of the EPU, 2-dimensional feed forward correction tables are used to reduce the orbit distortion to the 2-3 μm level. Update rate of feed-forward is 200 Hz.

EPU FEED FORWARD ORBIT CORRECTION

Orbit Error without Feed Forward Correction

200 Hertz Feed Forward Correction



I. Beam position monitors (BPMs)

Old in-house design (96) plus J. Hinkson/J. Bergoz multiplexed BPMs (currently 40); Bergoz BPMs used in feedback: noise level is about 0.3 – 0.5 microns at 200 Hz bandwidth and 200-400 mA; current dependence less than 5 micron for 200-400 mA

II. Photon beam position monitors (PBPMs)

Several very diverse designs; not integrated with accelerator control system; some beam-lines use them for local feedback (time-scales of feedback range from hours to ms); testing of new hopefully more unified PBPMs to start soon (on bend magnets)

III. Power supplies

All power supplies at ALS are SCR or linear; no switched mode. Noise level is typically less than 10^{-4} integrated over all frequencies (some main supplies 10^{-5}). 16-20 Bit control (all corrector magnets are 20 Bit); corrector bandwidth >200 Hz.

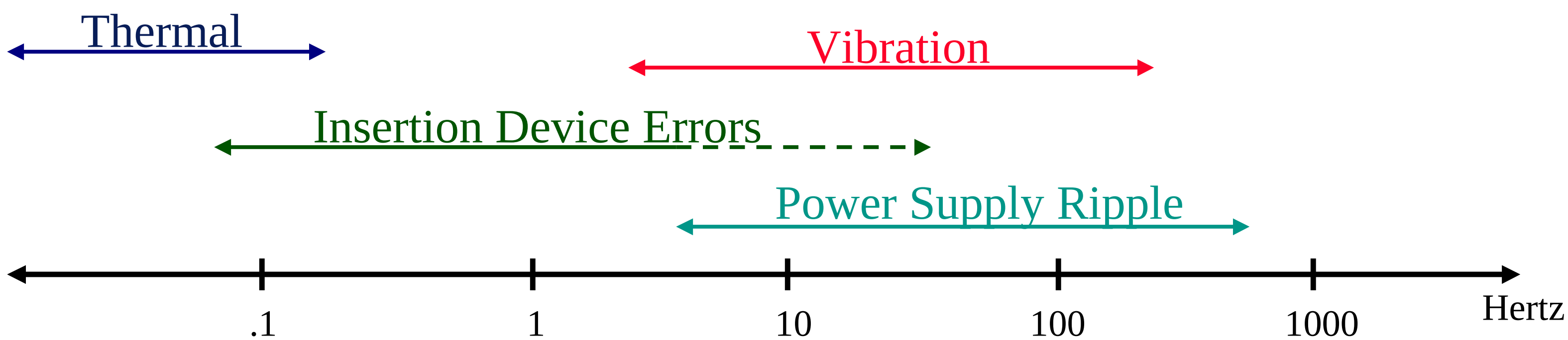
IV. Control system

High level control system has throughput of about 100 Hz and delays of less than 10 ms after upgrade. Low level (fast feedback – distributed cPCI crates) runs at 1 kHz with standard computer and network equipment, network synchronized timing; commissioning is promising so far

V. Other

Tested some simple methods to measure BPM and magnet motion; plan to incorporate measurement of BPM position relative to common accelerator-experiment ground plate into feedback

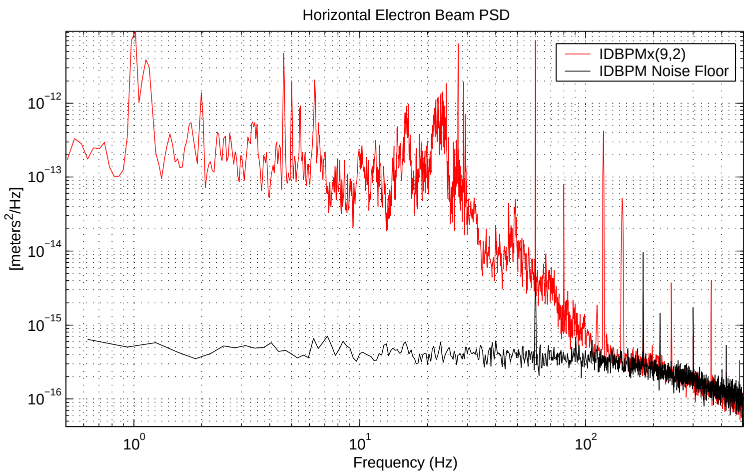
Causes for Orbit Distortions

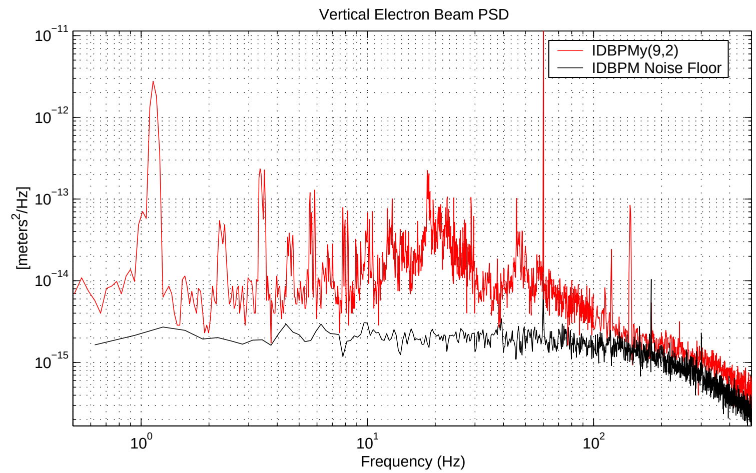


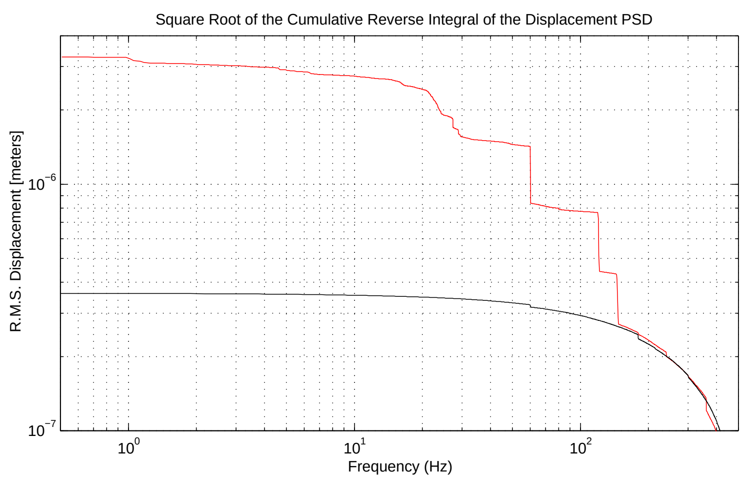
Frequency	Magnitude	Dominant Cause
Two weeks (A typical experimental run)	±200 µm Horizontal ±100 µm Vertical	1. Magnet hysteresis 2. Temperature fluctuations 3. Component heating between 1.5 GeV and 1.9 GeV
1 Day	±125 µm Horizontal ±50 µm Vertical	Temperature fluctuations
8 Hour Fill	±50 µm Horizontal ±20 µm Vertical	1. Temperature fluctuations 2. Feed forward errors
Minutes	1 to 5 µm	1. Feed forward errors 2. D/A converter digitization noise
.1 to 300 Hz	3 µm Horizontal 1 µm Vertical	1. Ground vibrations 2. Cooling water vibrations 3. Power supply ripple 4. Feed forward errors

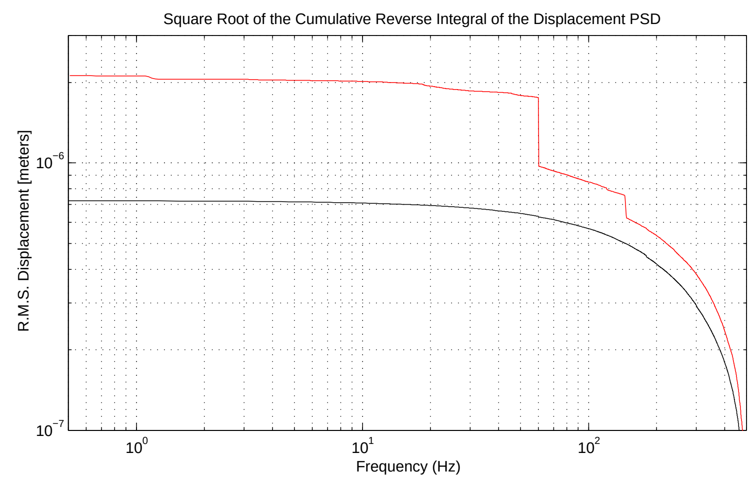
Beam Stability in straight sections w/o Orbit Correction, w/o Orbit Feedback, but w/ Insertion Device Feed-Forward

ELECTRON BEAM PSD





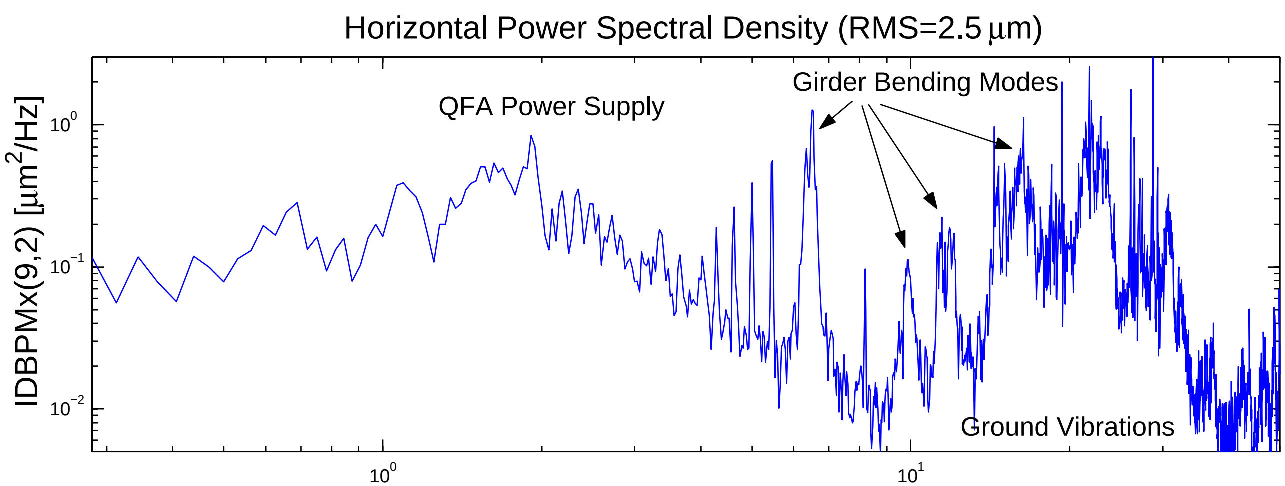


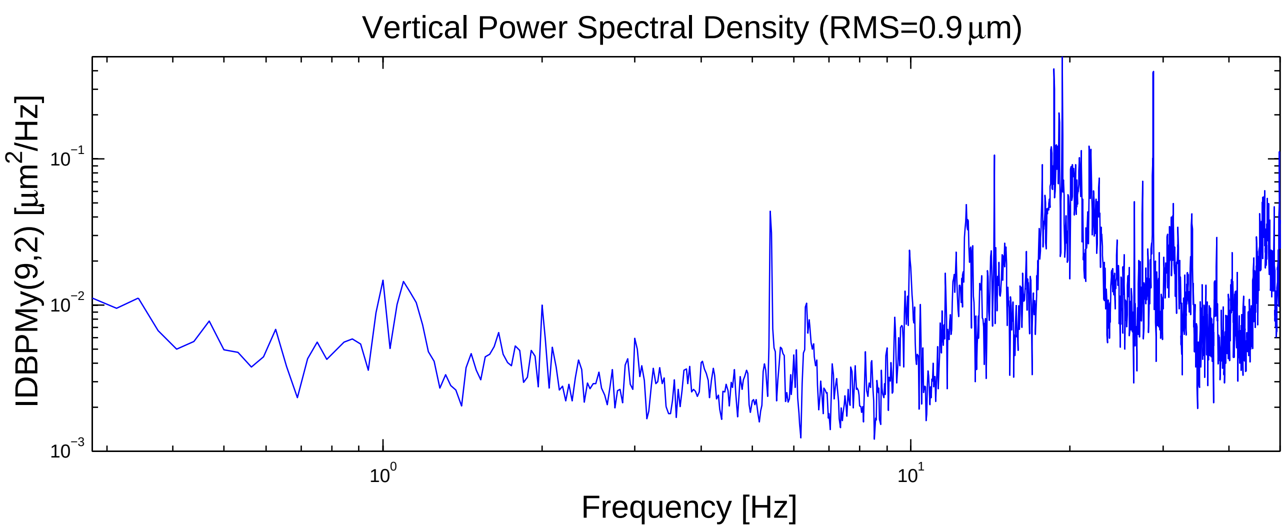


9–5–2000

9–5–2000

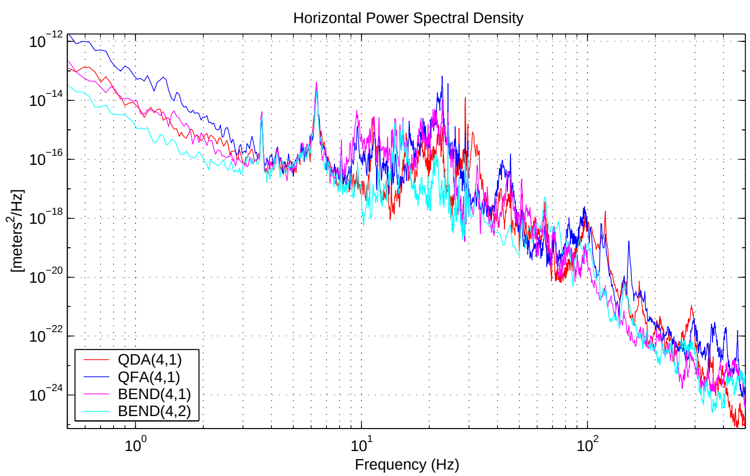
POWER SPECTRAL DENSITY

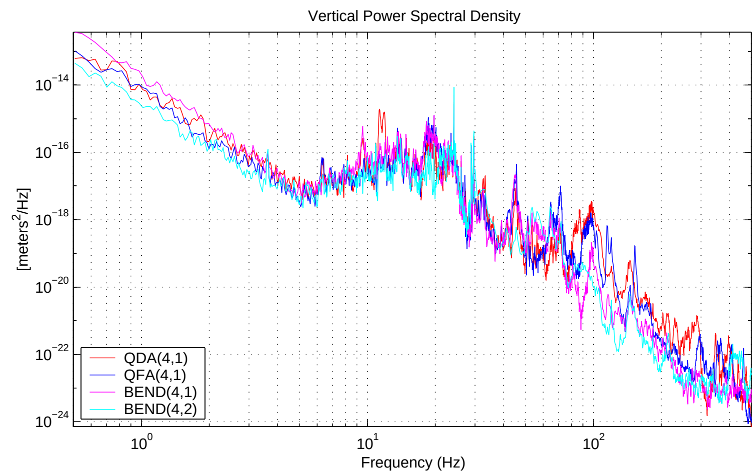


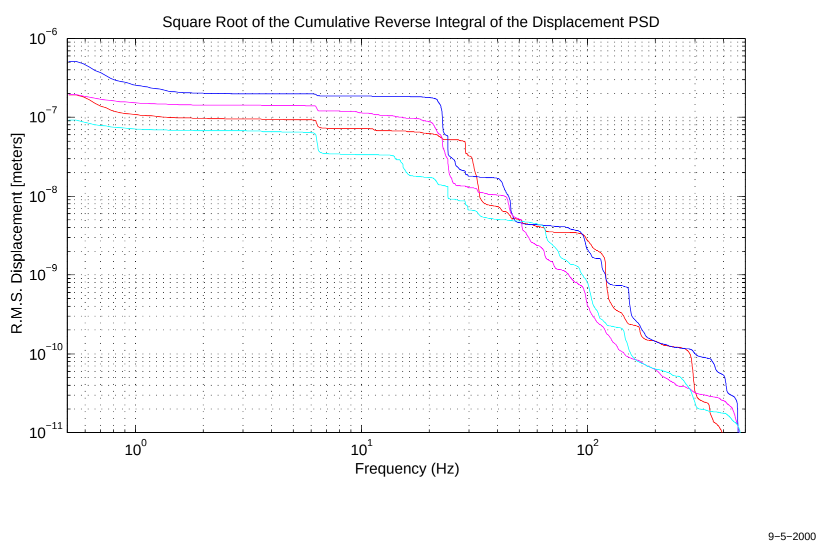


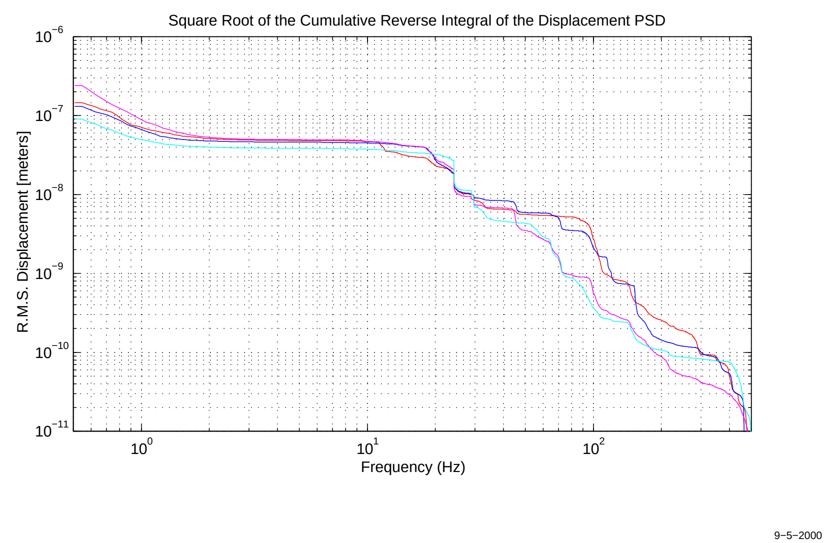
Data taken on 12−12−1999, during a 1.9 GeV user run at 278 mAmps

MAGNET VIBRATION PSD









Achieved orbit stability at ALS

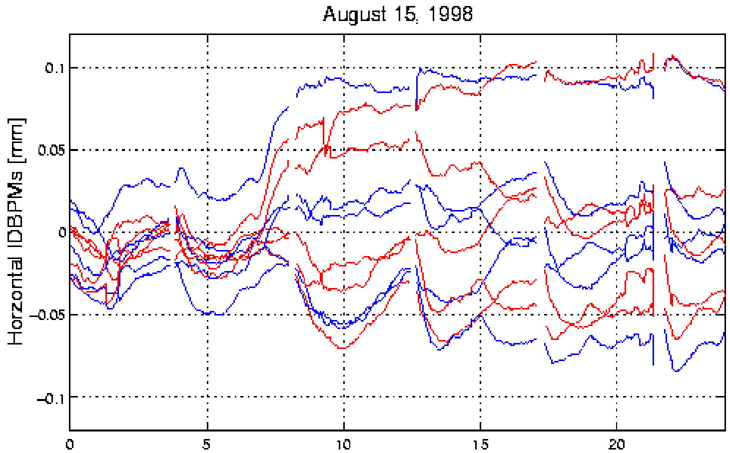
Frequency	Magnitude	Dominant Cause
1 hour – 2 weeks	±3 μm Horizontal ±5 μm Vertical	1. BPM chamber motion 2. BPM electronics drift and systematic errors 3. Limited number of BPMs/correctors
Minutes	< 1 μm	1. BPM noise and beam vibration (aliasing) 2. Corrector resolution (digitization)
.2 to 300 Hz	3 μm Horizontal 1 μm Vertical	1. Ground vibrations 2. Cooling water vibrations 3. Power supply ripple 4. Feed forward errors

Beam Stability in straight sections w/ Orbit Feedback and w/ Insertion Device Feed-Forward

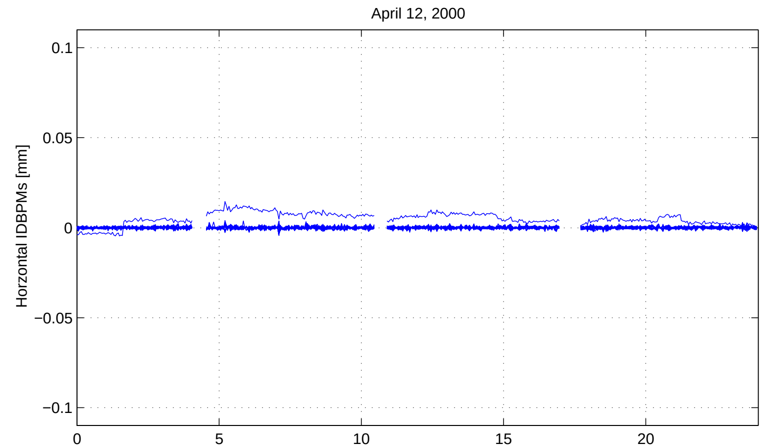
- Improve long term stability with measurement of physical BPM location (relative to ground plate)
- Improve fast jitter with active fast feedback (global)

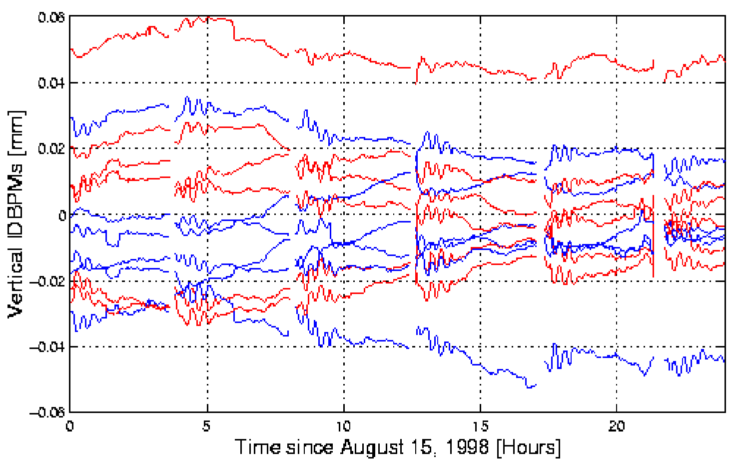
DAILY ORBIT VARIATIONS WITH AND WITHOUT SLOW ORBIT FEEDBACK

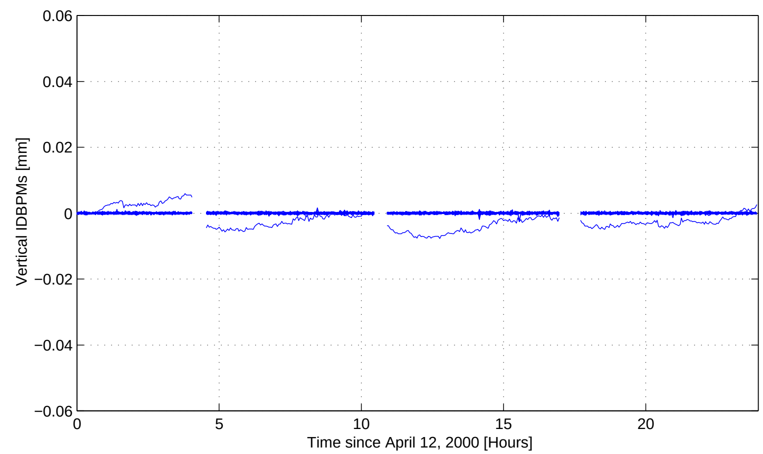
w/ ID Compensation
August 15, 1998: w/o Orbit Correction
w/o Slow Orbit Feedback



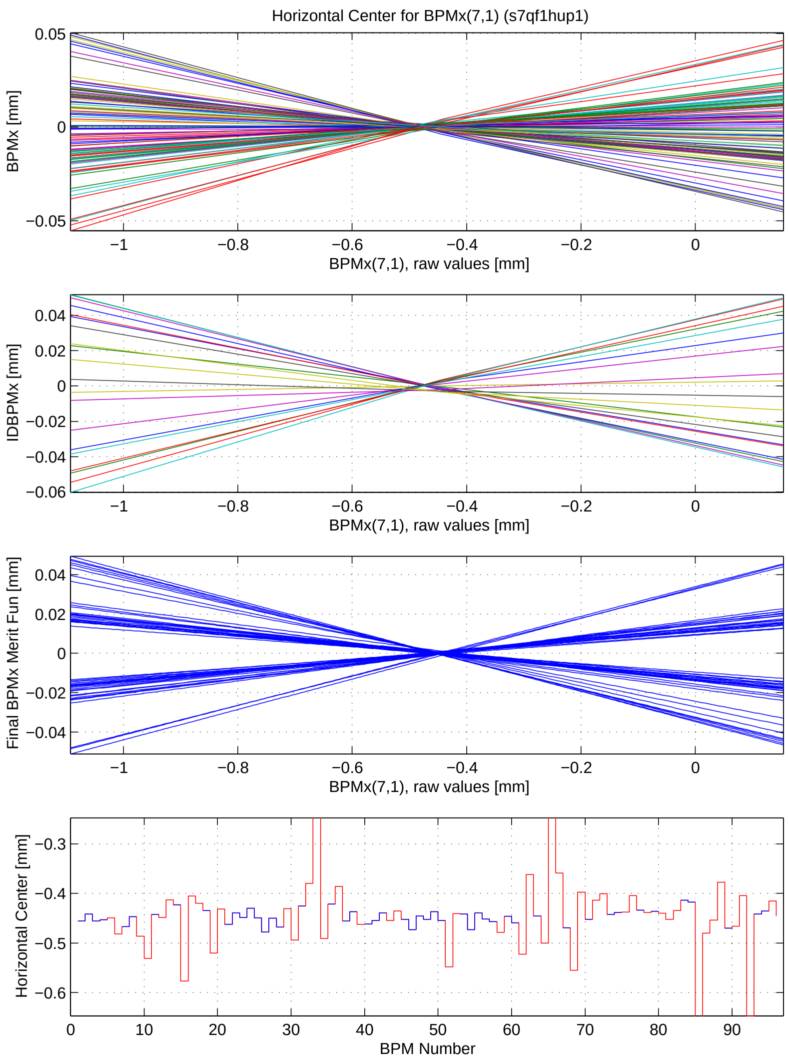
w/ ID Compensation
April 12, 2000: w/ Orbit Correction
w/ Slow Orbit Feedback





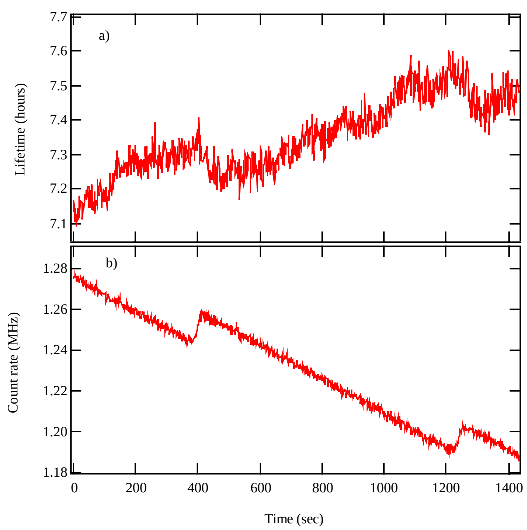


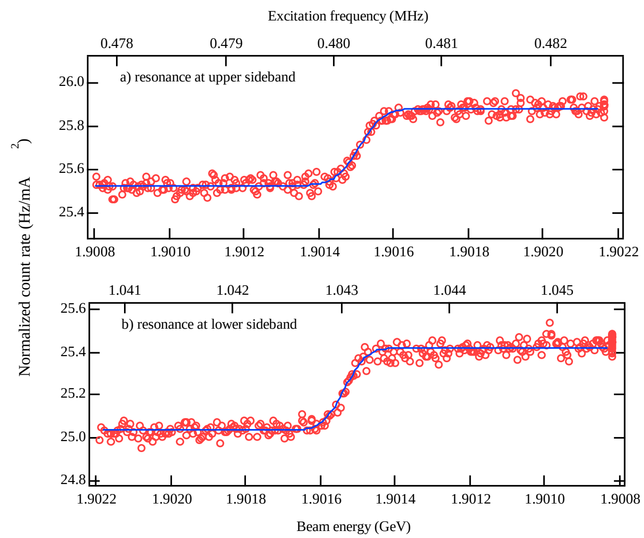
Beam based alignment

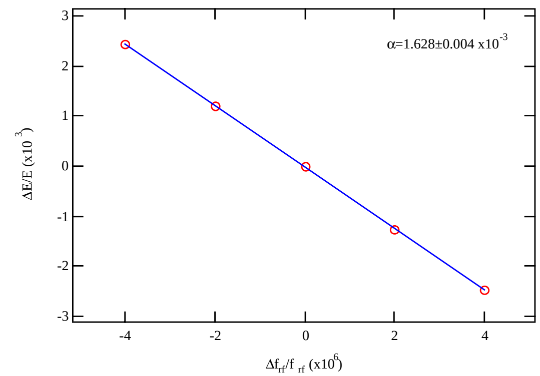


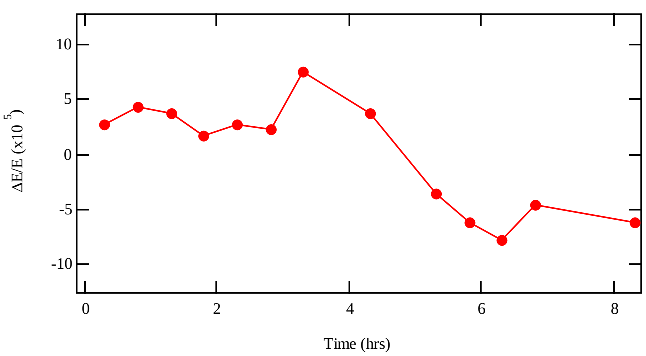
- All quadrupoles at ALS allow beam based alignment
- Automated computer routine – is performed regularly
- Main problem are C-shaped magnets and hysteresis; solution: directional sweep
- Offsets are fairly significant (rms of 300-500 microns) but very stable
- Beam based alignment only necessary after hardware changes or realignment
- Information from orbit response matrix analysis (with and w/o sextupoles) is in good agreement

Energy calibration (resonant depolarization)









- High precision measurement of beam energy is relatively simple at low energy light sources like ALS
- Allows some conclusions about long term orbit/magnet/ground plate stability
- Implemented rf-frequency feedback at ALS and verified it with energy measurements

User requirements – Impact of improvements

Most users at the ALS are happy with current level of orbit stability

Two examples of experiments that currently are the most sensitive:

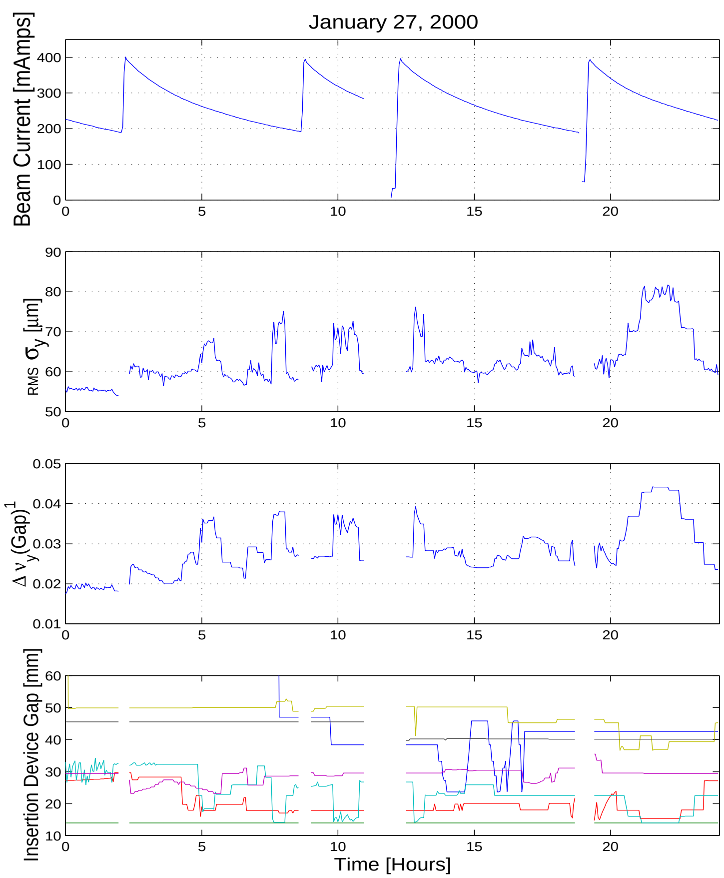
- Micro focusing beamlines on bending magnets (e.g. Micro XAS, especially in combination with molecular environmental science samples, i.e. dirt); problem is that sample is very inhomogenous and small source motion causes the spectrum to change significantly. I_0 normalization does not help!
- Dichroism experiments (i.e. on EPUs) measuring very small polarization asymmetries; orbit motion can cause small shifts of the photon energy out of the monochromator, resulting in fake asymmetries.

After upgrades to the slow orbit feedback (arc sector, chicanes) and the EPU feed-forward, both types of experiments are currently OK with the orbit stability. But orbit jitter shows up as noise in some measurements (relatively short data taking time for each point of spectrum) and experimental techniques are progressing towards measuring smaller effects.

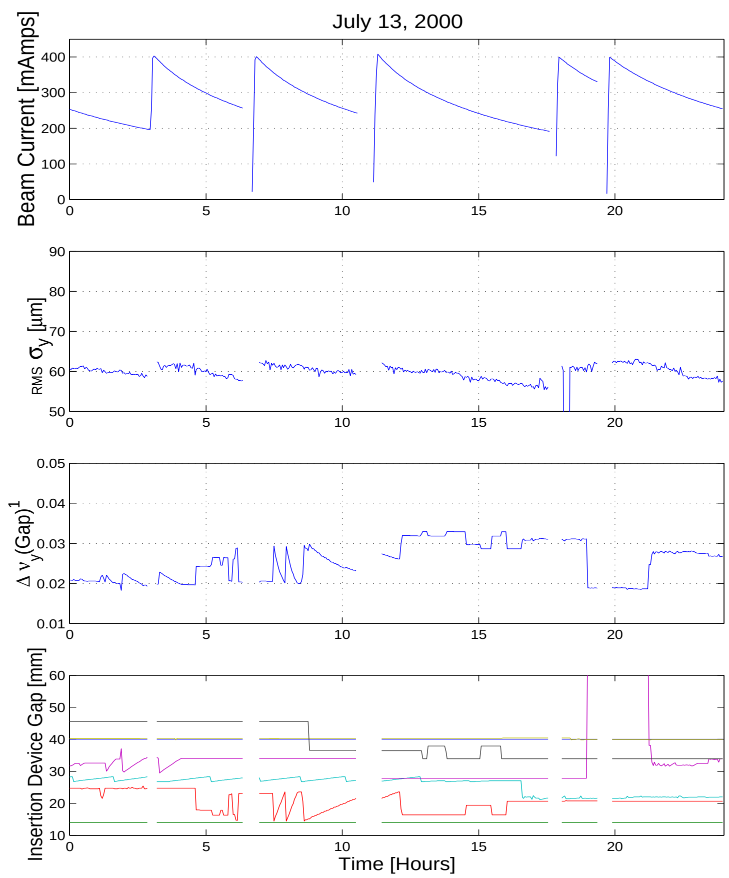
Also: Compensation of beam size variation will introduce orbit errors …

DAILY BEAM SIZE VARIATIONS WITH AND WITHOUT SLOW TUNE FEED FORWARD

Beamsize stability is nearly equally important to orbit stability; requires active correction which can be a significant noise source for the orbit! Fast beamsize feed-forward (EPU) can require a fast orbit feedback.

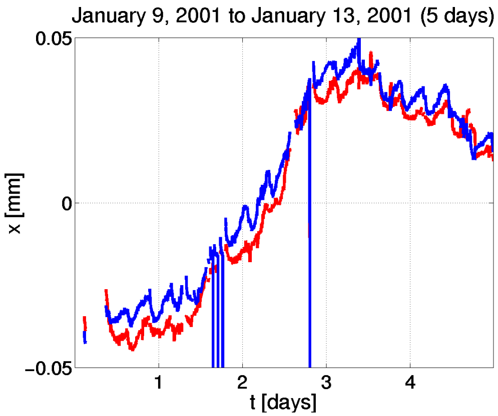


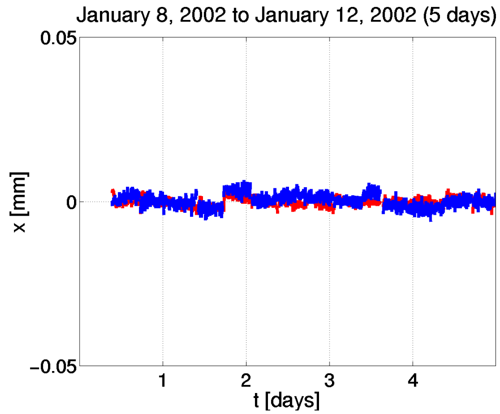
[1]W16 and EPU(4) longitidinal tune shifts are not included.

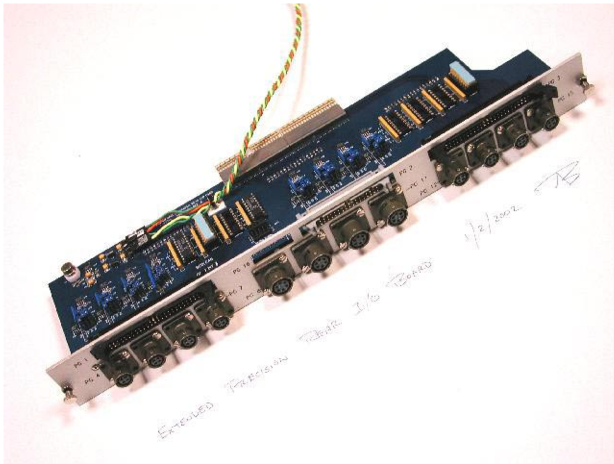


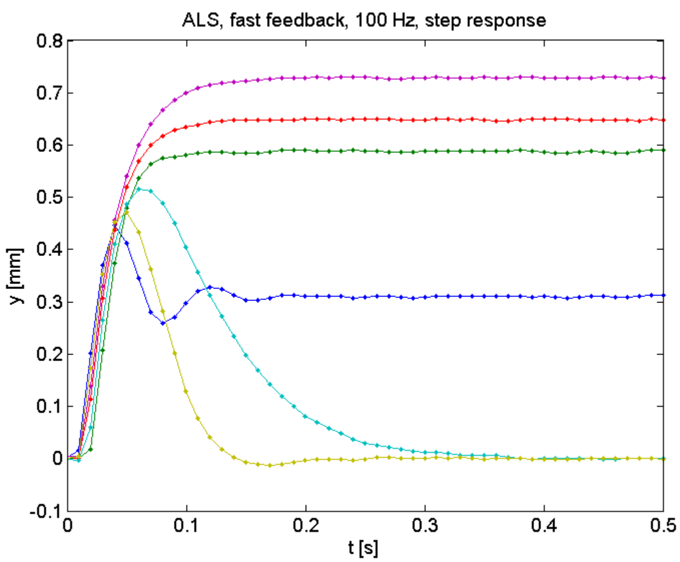
[1]W16 and EPU(4) longitidinal tune shifts are not included.

Recent upgrades









- RF-frequency feedback (significantly improved hor. orbit stability in arcs, energy stability)
- 20 Bit D/A converters (no digitization noise from SVD – mid term orbit stability now typically submicron)
- Start of commissioning of fast orbit feedback (standard hardware, 1 kHz update rate)

Summary

The ALS stability requirement of 1/10 the beam size is almost achieved

Obstacles:
• Vacuum chamber motion

For fast orbit jitter we try to get significantly below 1/10 of the beam size; Why? A) It seems achievable. B) It will reduce the signal noise for some very sensitive experiments (dichroism, micro focus), which have short data taking times at each spectral point.

How to get there:
•Vacuum chamber motion monitoring
• Faster control system (1 kHz global orbit feedback)
• More BPMs
• Even better storage ring temperature control
• Synchrotron light BPM