SPEAR3 Photon Beamline Stability from Ground Motion and Injection Transients

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BES Light Sources Beam Stability Workshop

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- Beam position monitor electronics
- Accelerator tunnel floor stability

Earth tides: 20”+ motion

A. Lunar tidal forcing: this depicts the Moon directly over 30° N (or 30° S) viewed from above the Northern Hemisphere.

B. This view shows same forcing from 180° from view A. Viewed from above the Northern Hemisphere. Red up, blue down.

Hydrostatic Leveling System, G. Gassner
Horizontal

PSD (mm²/Hz)

$10^{-1}$

$10^{-2}$

$10^{-3}$

$10^{-4}$

$10^{-5}$

$10^{-6}$

$10^{-7}$

$10^{-8}$

$10^{-9}$

$10^{-10}$

hours

orbit feedback off

with orbit feedback

Frequency (Hz)

10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 10⁰ 10¹ 10² 10³ 10⁴ 10⁵

13SU, next to cast wall

Displacement (µm)

Days - from Feb12 - Apr16, 2010

Y. Yan
Hydrostatic Leveling System

31 sensors
Measure water level in $\frac{1}{2}$ filled PVC pipe
Measure $\sim$40 micron daily floor motion = 5x e-beam size.
What’s driving tunnel floor?

Experiments
- White paint
- Mylar
- Insulation

LCLS undulator tunnel is stable
PEP-X (under ground) should also be stable
Diagnosed SPEAR3 tunnel floor motion

- SPEAR3 tunnel floor moving 10’s of microns, diurnal motion
- Priority identified by 2011 review
Mitigated SPEAR3 Tunnel Floor Motion

- DOE AIP funding
- Tunnel insulation installed 2012
- Up to x10 motion reduction

It's insulated now.
Top-off stored beam perturbation

- **peak-to-peak/FWHM:**
  - horizontal = 6
  - vertical = 100
  - IDs FWHM_{x,y} = (1.0,0.022) mm

- **damping time:** 5 msec

- **repetition rate**
  - booster: 10 Hz
  - top-off interval: 5 minutes

Measured turn-by-turn oscillations of beam:

- (Oscillations at $\beta_x = 3.5$ m, $\beta_y = 12.5$ m)
  - y, peak-peak = 1.1 mm
  - x, peak-peak = 2 mm
  - 3 msec
Stored beam kick vs. bump amplitude

Septum x-section

High Permeability Silicon Steel (dimensions in mm)

Central Orbit

5.00 DC Bump

17.00 AC Bump

2.5

1.7

2.00 Injected Beam

5.00

3.00

Septum Wall Thickness

1010 Steel Pole

5-pole magnet, cancels septum leakage fields

Septum bump coupling

Required corrector field profile

Integrated field [G*cm]

ByL

BxL

kicker bump amplitude [mm]

Septum x-section

Measurements

BPM oscillation amplitude [mm]

BPM

x

y

orbit shift from septum

SPEAR3 MAC Review I

January 12, 2011
**SPEAR 3 Top-Off Injection Transient**

- Vertical transient from septum magnet leakage field corrected:

  ![Vertical transient graph]

  
  CORB9V + 2 skew quads

  
  ~20 µm pk-pk

- Horizontal transient from injection kicker bump through sextupoles reduced by adjusting middle kicker pulse width:

  ![Horizontal transient graph]

  SPEAR bunch pattern

  one turn 780 nsec

  SPEAR 3 Kicker Waveforms (superposed)
Beam-based injection bump matching

- Measure horizontal and vertical oscillations of stored beam as a function of bunch number kicked.
- Vary 2 kicker strengths, kicker timing, and kicker pulse widths to minimize $x$.
- Vary 2 skew quadrupoles plus septum 5-pole corrector to minimize $y$.

$x_{\text{peak}} = 114 \text{ um}$

$y_{\text{peak}} = 14 \text{ um}$

$x_{\text{osc.}} / \text{beam size} = 0.8$

$y_{\text{osc.}} / \text{beam size} = 0.8$
SPEAR injection kickers, first kicks

- Initial pulses narrower
- Increases stored beam kick
- Improvements under way
The robust line optimizer

Step 1: bracketing the minimum with noise considered.
Step 2: Fill in empty space in the bracket with solutions and perform quadratic fitting. Remove any outlier and fit again. Find the minimum from the fitted curve.

Global sampling within the bracket helps reducing the noise effect.

RCDS is Powell’s conjugate method* + the new robust line optimizer.

*however, since the online run time is usually short, it is important to provide good an initial conjugate direction set which may be calculated with a model.
Kicker bump match for low-alpha (3/26/2013)

Use RCDS code.
Minimize rms orbit deviation for the first 30 turns with 8 parameters.
Kicker bump match automation, July, 2018

Use BxB feedback to measure oscillations in individual bunches. Calculate average oscillation amplitude (or rms) and use it as the objective function. Kai had to adjust BRAM gain to trigger BxB data output when the kickers are fired (if signal is too low, no output update).

Kicker bump matching using MBF detector

Before optimization

After optimization
Longitudinal oscillations

- Electron bunch length is 20 psec rms
- Electron bunches vary in arrival time by 1 to 3 psec rms
  - Primary frequencies: 10 kHz, 60*n Hz
- Vary in energy by 0.5 to 1.5e-4 (ΔE/E)