Bunch-by-bunch Feedback Studies at SPEAR3

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July 2, 2010
Outline

1 System overview
   - Introduction
   - Operating experience
   - SPEAR3 setup

2 Measurements
   - Calibration
   - Open-loop Measurements
   - Closed-loop Measurements
   - High Current Studies
iGp Highlights

- A 500+ MHz processing channel.
- Finite Impulse Response (FIR) bunch-by-bunch filtering for feedback.
- Control and diagnostics via EPICS soft IOC on Linux.
- External triggers, fiducial synchronization, low-speed ADCs/DACs, general-purpose digital I/O.
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Commissioned systems

- **DAΦNE**: 4 systems, transverse;
- **ALS**: 1 system, longitudinal;
- **Photon Factory**: 3 systems, longitudinal and transverse;
- **Duke SR-FEL**: 2 systems, longitudinal and transverse;
- **CesrTA**: 3 systems, longitudinal and transverse;
- **BEPC-II**: 2 systems, longitudinal;
- **TLS**: 1 system, transverse;

Demonstrated in DELTA, ELSA, ANKA, MLS, KEKB.
## Installed Units and Tests

### Commissioned systems

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Experimental Setup

- Three elements:
  - Front-end;
  - Baseband DSP;
  - Back-end.
- Modified ENI 525LA amplifier (25 W, 0.7-350 MHz);
- Tune excitation striplines;
- Passive front-end computes the difference of upper and lower buttons.
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June 28, 2010
- Started hardware setup and parasitic timing one hour before the shift;
- At 5:55pm we completed the timing and captured a few parasitic data sets;
- Around 6:30pm we connected the power amplifier and started back-end timing;
- Loop closed at 8pm;
- Made a number of grow/damp measurements at 200 mA, explored chromaticity dependence.

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- Continued the measurements during high-current studies (400–450 mA);
- Stabilized the beam in both vertical and horizontal planes;
- Calibrated front-end sensitivity.
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Front-end Calibration

- Set up orbit bumps near the feedback BPM;
- ADC signal for bunch $n$ is $\nu_n = g_{fe} \times y_n \times i_n$;
- Computed front-end gain of 71.8 counts/mm/mA.
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Single Bunch Train

- First open-loop data set taken at 18:00;
- Bunches 1–280 and 326 are filled;
- Vertical coupled-bunch oscillations are seen;
- Oscillation amplitude rises along the bunch train;
- Several peaks in the modal spectrum, centered at 18 and 41 MHz.
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Same fill pattern, longer (120 ms) data set;

- Amplitudes of modes centered at 18 MHz (mode 358 or -14) are beating at roughly 25 Hz;
- Modal spectrum is the same as in the short set.
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Injection Transients

- 120 ms record acquired during injection;
- Amplitude of mode 0 (all bunches move in phase) shows injection transients;
- Can extract information on injection bump closure from such measurements.
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Waveform Panel

- Updates at 1 Hz
- Uses data from all bunches over many turns.
- Four waveforms:
  - Mean;
  - RMS;
  - Bunch with largest RMS;
  - Averaged spectrum of all bunches.
System overview

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Drive/damp measurement;
Feedback is positive for first 450 $\mu$s, then negative;
Clearly exciting the beam;
Large betatron line in the spectrum at 223.7 kHz
Grow/Damp Measurement

- Grow/damp measurement at 200 mA;
- Very good damping of low-frequency modes;
- Feedback somewhat reactive — tune shift of 120 Hz between open and closed-loop;
- Growth rate of $0.22 \text{ ms}^{-1}$, damping rate of $1.8 \text{ ms}^{-1}$. 

SPEAR3:jun2810/210354; Io=199.5mA, Dsamp=1, ShflGain=4, Nbuns=372,
At Fs: G1=27.0558, G2=0, Ph1=−14.953, Ph2=0, Brkpts=10000, Calib=0.07161.
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Closed-loop Motion vs. Feedback Gain

- **Open-loop measurement:**
- Feedback on — damping 17 modes;
- Increase the gain — 15 more modes are damped;
- Double the gain — little change;
- Stripline bandwidth is around 20 MHz;
- With proper setup we can roughly double the control range.
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Horizontal Instabilities

- **Open-loop measurement:** horizontal plane;
- **Mode -1** — typical resistive wall motion;
- **Vertical plane** is dominated by mode 354 (-18).
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Dual-Band Filter

- Created a dual-band filter with negative feedback response in both horizontal and vertical planes;
- Matlab tool generates filter coefficients matching desired gains and phases at the two betatron tunes;
- Fully suppressed horizontal motion.
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Vertical Grow/Damp

- Six trains of 47 bunches separated by 15 bunch gaps;
- Open-loop amplitudes reach 35 $\mu$m;
- Non-exponential growth — consistent with smaller fill-pattern gaps.
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We have successfully demonstrated feedback control of transverse coupled bunch instabilities in SPEAR3.

- There is strong evidence of ion-driven instabilities in the vertical plane at 200 mA and above;
- Resistive wall instabilities in the horizontal plane show up around 450 mA;
- We have demonstrated diagnostic capabilities of the iGp and correlated the measurements with existing instrumentation;
- Further measurements would benefit from better striplines and amplifiers.
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