Commissioning Results - HER
Longitudinal Feedback

J. Fox, D. Anderson, B. Cordova-Grimaldi, H. Hindi, R. Larsen, S. Prabhakar, D. Teytelman, A. Young

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September Results

I. System Architecture and Status report
   • HER, (LER processing) Systems installed, ready, tested
   • EPICS User Interface, MATLAB analysis codes

II. Summary from last June

III. Single Bunch Studies
   • Front End, Back End Timing
   • Bunch to bunch isolation
   • Beam power spectra for positive/negative feedback

IV. Multi-bunch Studies
   • 12 bunch pattern
   • 194 bunch pattern
   • 291 bunch pattern
   • 2 RF configurations (2 vs 3 klystrons)

V. Conclusions and suggestions for further study
System block diagram

BPM

Beam bunches

Kicker structure

Power amp

Timing & Control

Low-pass filter

A/D Down sampler

DSP

Hold-Buffer D/A

QPSK modulator

Kicker oscillator 1.125 GHz Phase-locked to ring

Master Oscillator phase-locked at 6 RF of cavity

Ext

500 MHz

3.2 \times 10^9 \text{ macs/sec}
Longitudinal Feedback System Components

Multiprocessor architecture fully implements ALS/DAFNE/PEP-II requirements. Scalable, flexible architecture for up to 8192 bunches with up to 500 MHz sampling rates.

- DSP processor - VME card, 4 AT+T DSP 1610s
- VME interface - Bus master for data distribution
- Downsampler - 500 MHz A/D and VXI Sequencer
- Hold Buffer - 500 MHz D/A and VXI Ring Buffer
- Timing - VXI oscillators (476, 2856, 1071 MHz)
- Front-end - Comb Generator with 2856 MHz
- Phase Detector - 600 MHz IF bandwidth

Back-end - AM modulator transfers baseband kick to 1125 MHz QPSK’ed carrier (1 - 1.25 GHz) - 1500 W GaAs power amps with drift tube type kickers

Software - VxWorks operating system with EPICS-based graphical control interface
IR-4 Installation
BASE BAND TRANSFER FUNCTION

NETWORK
A: REF
10.00
\[ \text{dB} \]
B: REF
600.0
\[ \text{deg} \]
O MKR
0
\[ \theta \]
10 009.500 Hz
T/R
-85.7754m
\[ \text{deg} \]
002

\[ \text{MAXIMUM AT } \frac{1}{2} \text{SWAP} \]

DIV
10.00
\[ \text{DIV} \]
200.0
\[ \text{START} \]
STOP
200 000 000 Hz
\[ \text{RBW}: 1 \text{ KHz } \text{ST}: 12.8 \text{ sec RANGE: R= 0, T= 20dBm} \]
RBW= 1 KHZ

FILTER TRANSFER FUNCTION
Longitudinal motion at 4160 Hz

Kicker 2 timing sweep, 9/7/97

Delay, ps

Longitudinal motion at 4160 Hz
System Diagnostics

diagnostics in operation at ALS

Off-line tests (memorics, DSP, etc.)

Fake beam signal, mux in system oscillator

On-line - automated kicker timing

front end calibration

bunch rms motion (noise floor)

Bunch current monitors

Grow-damp growth rates

Modal excitation and analysis codes

injection transient diagnostic

EPICS based operator panels - thermal monitors

System Oscillator level monitors

rms beam motion - rms kick detectors

programmable trip points for status notification
Beam response to a single-bunch drive excitation using MILMEGA amplifier

$10^{-3}$
ALS Measurements

System in operation at full 400 mA current

Single Bunch studies
  frequency domain - stability

Multi-Bunch studies
  narrowband modal transfer functions
  narrowband time-domain grow-damp sequences
  multi-modal Grow-Damp sequences
  FFT synthesized Pseudo-beam spectra
  RMS noise studies
  Current monitors
  injection transient studies

undulator Spectrum/Optical Beam Profiles

Exploration of system performance (kicker gain vs. frequency, gain limits) - operation with optimal control filters (e.g. LQG and L1 optimal filters)
Time Domain Snapshots and Modal Analysis

Basic Idea - Use memory in DSP to record bunch motion for many (1K) turns, manipulate DSP processing during this interval under software or external trigger control

Example - Grow/Damp Transient

START - with feedback on (filter #1), stable beam

On trigger, begin recording all bunch data, turn feedback off (filter #2).

After N turns, turn feedback back on (filter #1), continue recording bunch data

After N+M turns, stop recording data, keep feedback on

GO TO START

The data is read from the DSP dual-port memory via the VSB bus without interacting with the feedback process, and analyzed off line -
Time Domain Transient Measurement Flowchart

- Normal operation feedback on filter #1
  - Trigger event
  - N turns recorded
  - Switch to filter #1

- Switch to filter #2
  - Begin data recording
  - M turns recorded

- STOP acquisition
  - Tell host to read data from the dual-port through the VSB bus
oct2896/2235: Io = 238.8 mA, Dsamp = 22, ShiftGain = 2, Nbun = 320, Gain1 = 0,
Gain2 = 1. Phase1 = -140. Phase2 = -140. Brkpt = 496. Calib = 21.2 cnts/ mA-deg.
apr0996/2303: lo= 127mA, Dsamp= 22, Shift Gain= 3, Nbun= 320, Gain1= 0, Gain2= 1, Phase1= -200, Phase2= -200, Brkpt= 480, Calib= 21.2 cnts/mA-deg.
Oscillation Envelopes in Time Domain

Evolution of Modes

Exp. Fit to Modes (pre-brkpt)

Growth Rates (pre-brkpt)

Exp. Fit to Modes (post-brkpt)

Growth Rates (post-brkpt)

feb2796/2104: lo= 147.9mA, Dsamp= 21, Shift Gain= 3, Nbun= 320.
Damping Rate vs Gain

JAN30 '96: Expt. Data & Linear Fit

Damping Rate Due to FB

Feedback Gain

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a) Osc. Envelopes in Time Domain

b) Evolution of Modes

c) Exp. Fit to Modes (pre-brkpt)

d) Growth Rates (pre-brkpt)

e) Exp. Fit to Modes (post-brkpt)

f) Growth Rates (post-brkpt)

125 bunches, spacing of 2

jun1797/0014: Io = 29.5mA, Dsamp = 14, ShifGain = 7, Nbun = 276, Gain1 = 0,
Transient Analysis- Observations

Complementary to narrowband frequency domain detection (e.g., tuned receiver) - both allow measurements of growth/damping rates.

Advantage of transient technique - speed. All modes measured in a single several millisecond transient - as apposed to several hundred or thousand individual narrowband sequential measurements. Does not require steady-state system.

Directly applicable to transient excitations, such as injection transients- study of modal amplitudes, distributions helps size power amplifier.

Related to transfer function measurements - in which one bunch may be driven, and responses recorded for entire ring. Measurements of HOM’s, wake fields directly (as sampled by subsequent bunches).

Excellent quick control room check on operation of accelerator and feedback - non-destructive, essentially invisible to users. Directly quantifies feedback gain margin - allows check on nominal operating parameters.
Single Bunch Studies

Front End, Kicker Timing

Bunch to Bunch signal isolation

Power Spectra

- Open Loop
- Negative
- Positive Feedback

System timed up in 2 hours using Autotim utility

Presence of Klystron-driven 60 Hz harmonics roughly 35 - 40 dB above broadband noise floor (as from last June)

Maximum gain limited by presence of 60 Hz lines causing feedback channel saturation
Single bunch spectrum with 2 RF stations, 9/12/97 6:15
Single bunch spectrum with 3 RF stations, 9/14/97 10:32
Longitudinal phase detector spectrum, 9/8/97, 4:15pm

Phase detector output, dBV

-90  -85  -80  -75  -70  -65  -60  -55

Frequency, Hz

4050  4100  4150  4200  4250

Positive

Open loop

Negative
12 bunch fill, 9/8/97 15:00

RMS motion, counts

Bunch number

140 142 144 146 148 150 152 154 156 158 160
Bunch 1 spectrum, 12 bunch fill, 9/8/97 15:00
Bunch 2 spectrum, 12 bunch fill, 9/8/97 15:00

Bunch phase motion

Frequency, Hz
Multi-Bunch Spectra

in three filling patterns (12, 194 and 291 bunch)

The 194 bunch pattern has non-uniform (injection into 8/10 bunch spacing) fill - noted as potential problem by M. Sullivan during injection. He was right.

- Multi-rms plots showing injection current distribution
- Mode zero spectra, noise

Pseudo-Beam Spectra

- Technique to observe all 1746 normal modes
- almost all "modes" are aliased mode zero (barycentric) motion from RF excitation

A hint of true asymmetric sidebands at modes 926*Frev, 1280*Frev - first evidence of multi-bunch modes seen 9-12 (mode 3) - these lines are stable at currents achieved to date

9-14 shift first CLEAR EVIDENCE of UNSTABLE coupled-bunch mode (mode -1 at 190 mA)
High Resolution Beam Spectrum

Construction of “Pseudo-Beam Spectrum” from time domain data

Obtained from FFTs of longer time records

Frequency resolution - 70 Hz

250 MHz span in 14 ms

Time transients are 12 ms long............concatenate each turn to create a 1-d data sample N bunches x M turns long -

Information in the Pseudo-Beam Spectrum

- Synchrotron tune shifts
- Growth/damping rates (including stable modes)
- Steady state noise excitation spectrum
- Eigenstructure of asymmetric beam (due to non-uniform charge fill and gaps)
Mutibunch fill, 9/8/97, 16:22
Phase (deg)

Phase (deg)

Phase (deg)

Phase (deg)

Frequency (kHz)

Frequency (kHz)
Peak Values of Synchrotron Sidebands (upper – lower)
Motion of bunch 2 for a 291 bunch fill, 9/12/97 6:15

Bunch 2 spectra: positive feedback – red, negative feedback – green
FIRST TRUE UNSTABLE COUPLED BUNCH MODE (-1)

D. TEITELMAN
a) Osc. Envelopes in Time Domain

b) Evolution of Modes

sep1497/1559: Io = 207mA, Dsamp = 6, ShifGain = 2, Nbun = 290, Gain1 = 1, Gain2 = -1, Phase1 = -30, Phase2 = -30, Brkpt = 496, Calib = 20 cnts/MA-deg.
PEP-II Longitudinal Feedback
9/15/97

Current status

System is timed up and operational
Multiple FIR filters (4 to 12 taps) are available
System was able to drive mode 3 ~30 dB above the noise floor at 183 mA in positive feedback mode
Measured unstable mode -1 at 207 mA (9/14/97)

Experimental plans

Optimize FIR filters to control mode -1 around instability threshold (190 - 200 mA).
Measure mode -1 growth and damping rates.
Mode excitation/damping experiments (modes 3, -38, others) using single-tone drive.
Summary and for Next Shift

HER Longitudinal System ready - performance and gain limited by presence of 60 Hz driven harmonic linacs.

Measurements of modal growth/damping rates possible under these commissioning conditions

Majority of all beam motion due to RF excitation - a tiny projection onto several possible true multi-bunch modes - all except mode -1 stable at achieved currents (up to 200 mA)

Future Shifts -

Calibration of front-end channel (quantification of phase excursions, modal amplitudes, bunch by bunch current)

operation at higher (unstable currents)

Measurements of growth/damping rates, gain vs. frequency.

Continuation of our commissioning plan
Commissioning Plans for September

Continuation of front end calibration for nominal bunch charge. Required to quantify modal amplitudes and per bunch charge. Study of gap transients, synchronous phases

Operation at higher currents - control/measurement of uniform fills (unstable and stable). Quantification of expected modes, growth rates - comparison with simulations.

Study of system noise floor, systematic signal level optimization for nominal bunch currents.

Testing, development of several FIR and LQG feedback filters - trade-offs of noise vs. damping rate, required kicker power

Beam transfer function measurements - comparison with system simulations

Kicker-amplifier frequency response tests (modal damping rate measurements)

Routine operation of the LFB system from the control room, remote use of the diagnostic hardware and software features. Training of PEP-II operators