Bunch-by-bunch Feedback Studies at SPEAR3

Jeff Corbett[1], Don Martin[1], James Safranek[1], Jim Sebek[1], Dmitry Teytelman[2], et. al.

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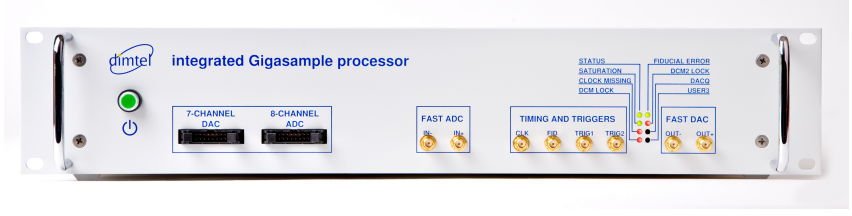
July 2, 2010

Outline

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.

Outline

Installed Units and Tests

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.

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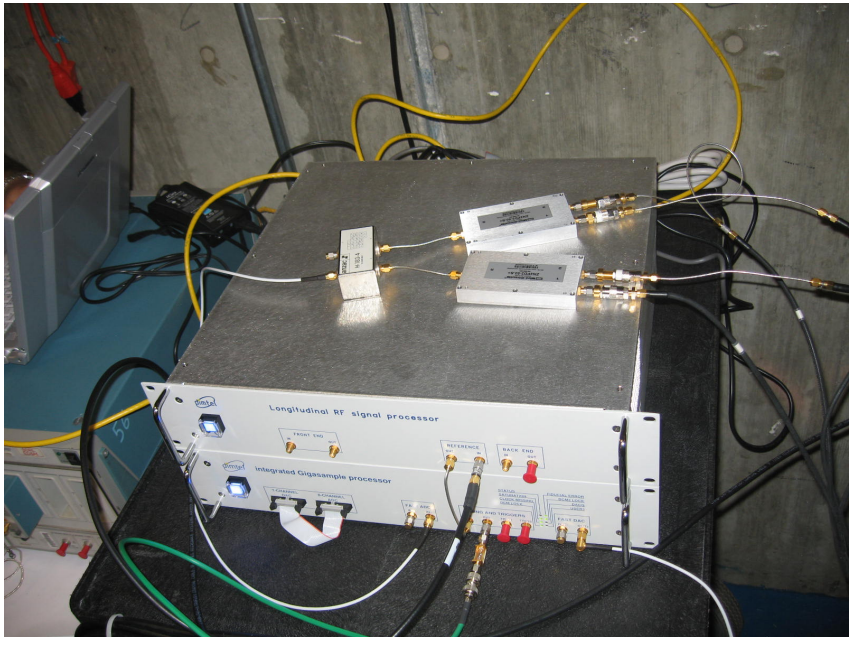
Experimental Setup

- 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.

Experimental Setup



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Experimental Program

- 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;
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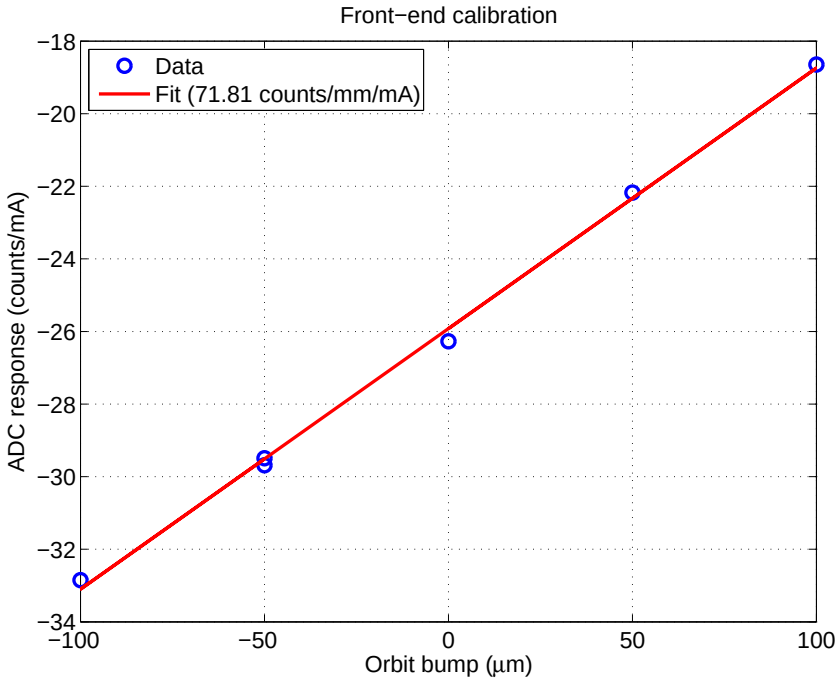
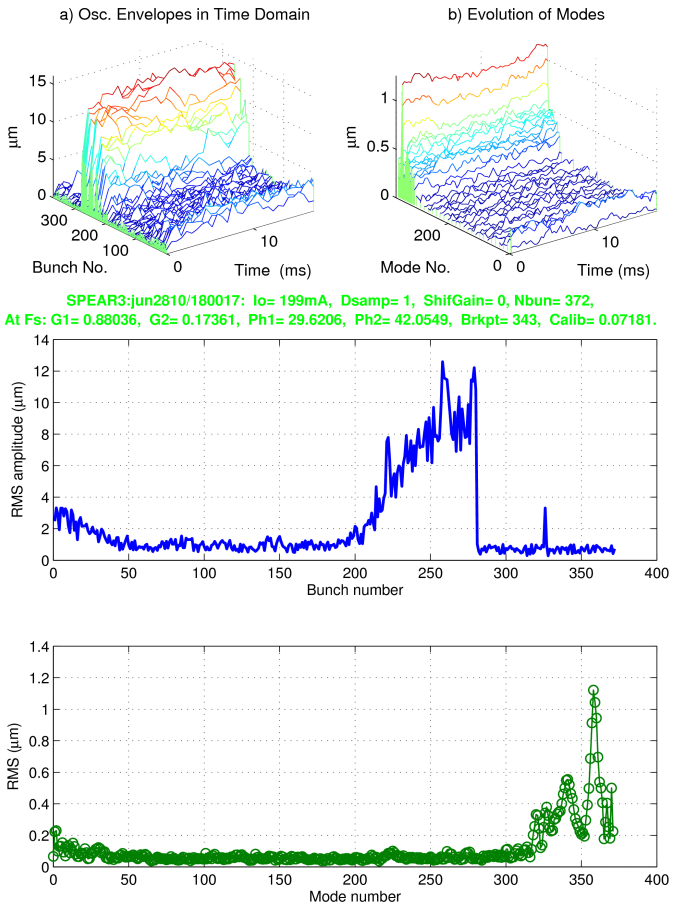
Front-end Calibration



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

Outline

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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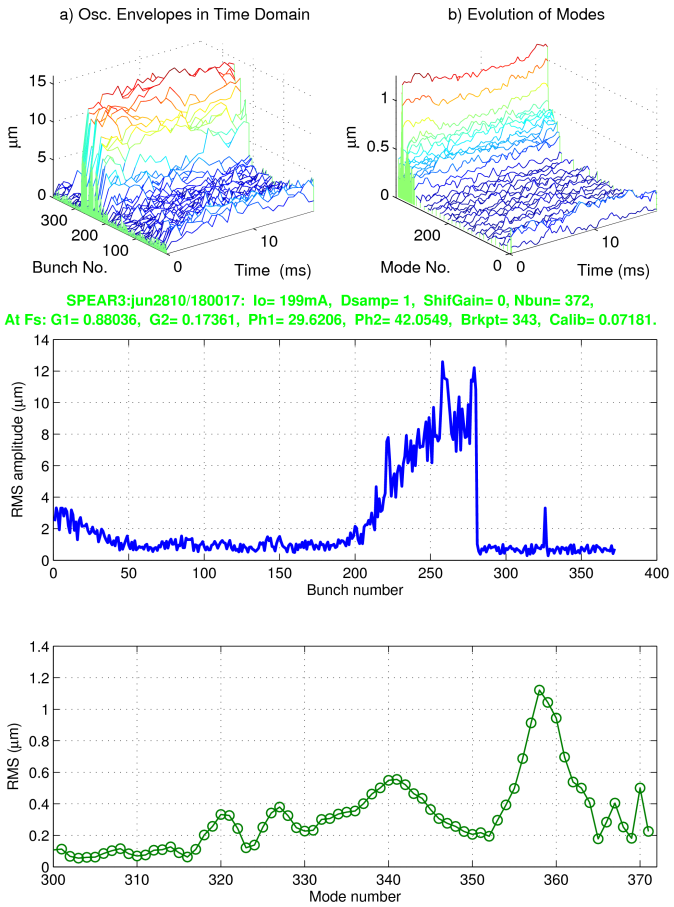

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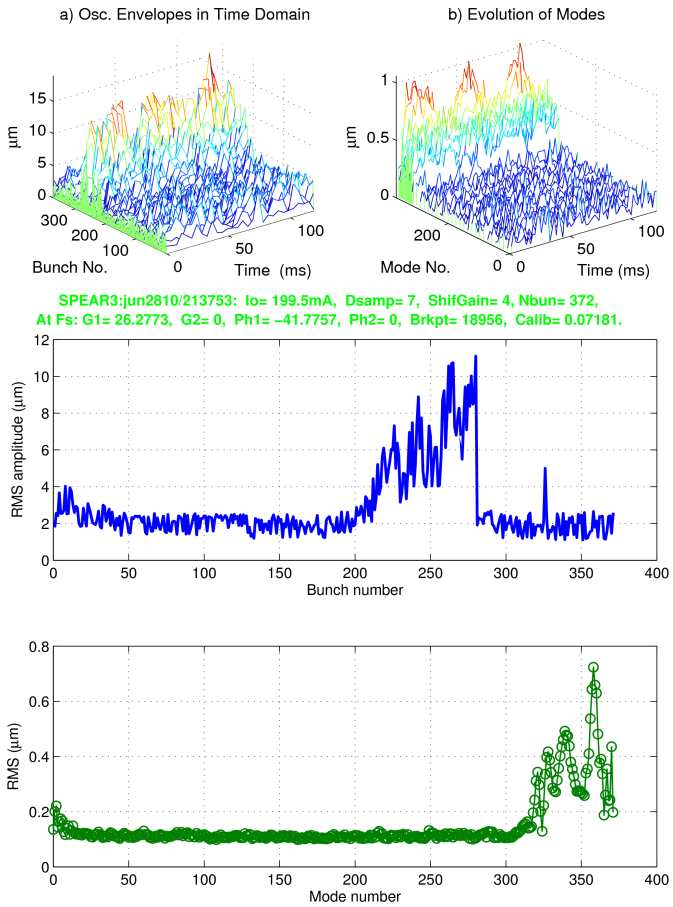

- Same fill pattern, longer (120 ms) data set;
- Amplitudes of modes centered at 18 MHz (mode 358 or -14) are beating at roughly 25 Hz;
- Modal spectrum is the same as in the short set.

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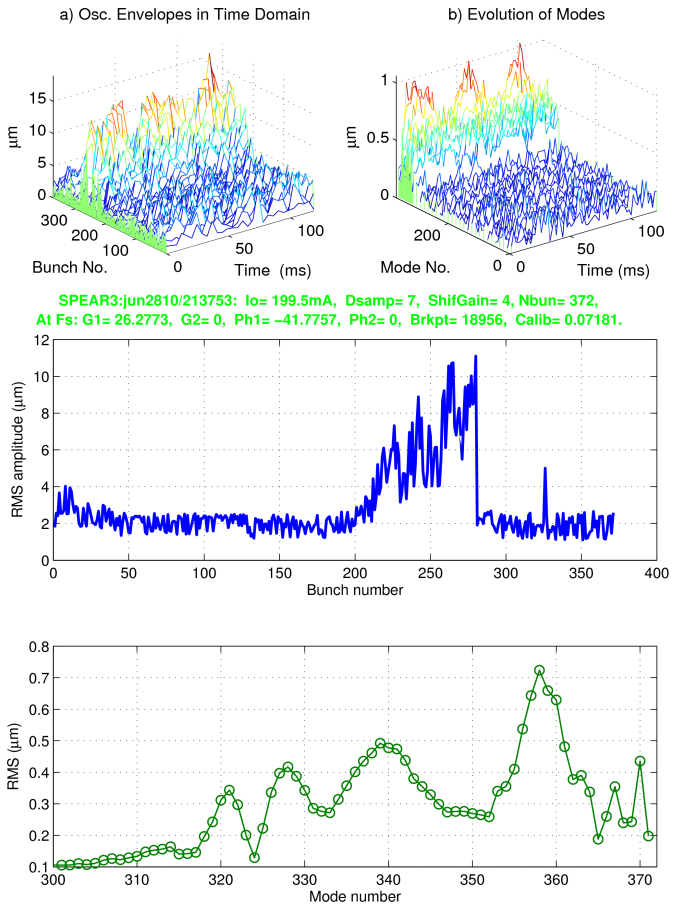

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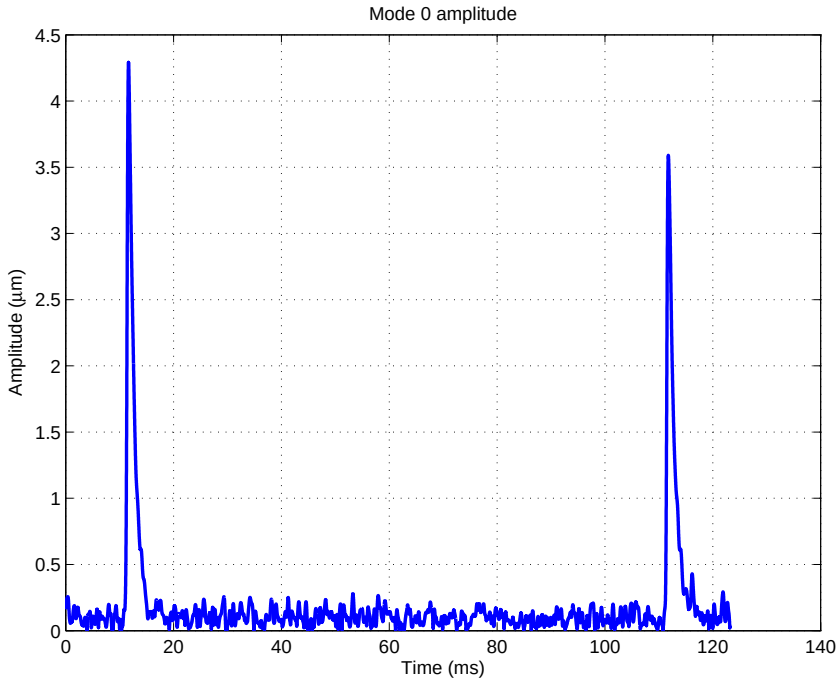
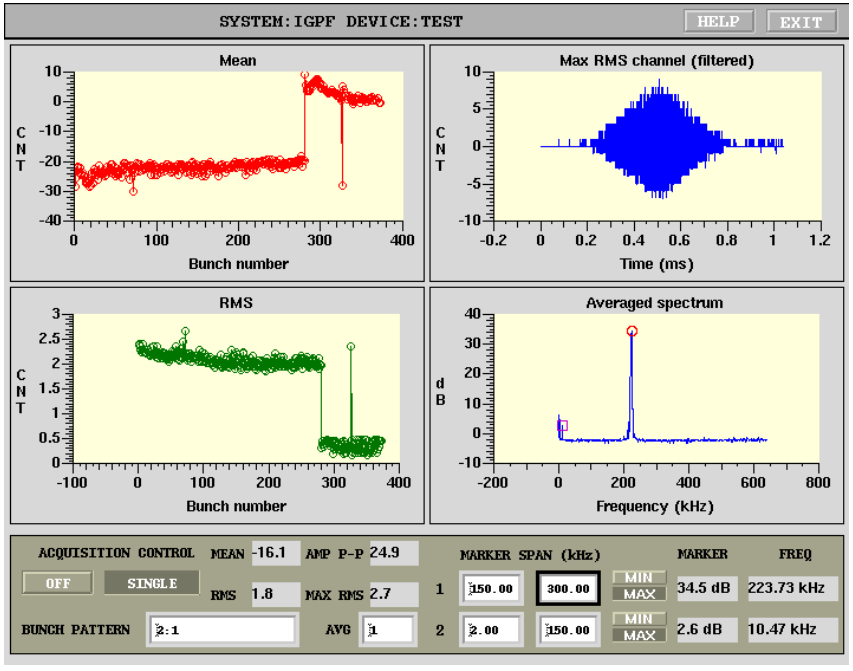
Injection Transients



- 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.

Outline

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.

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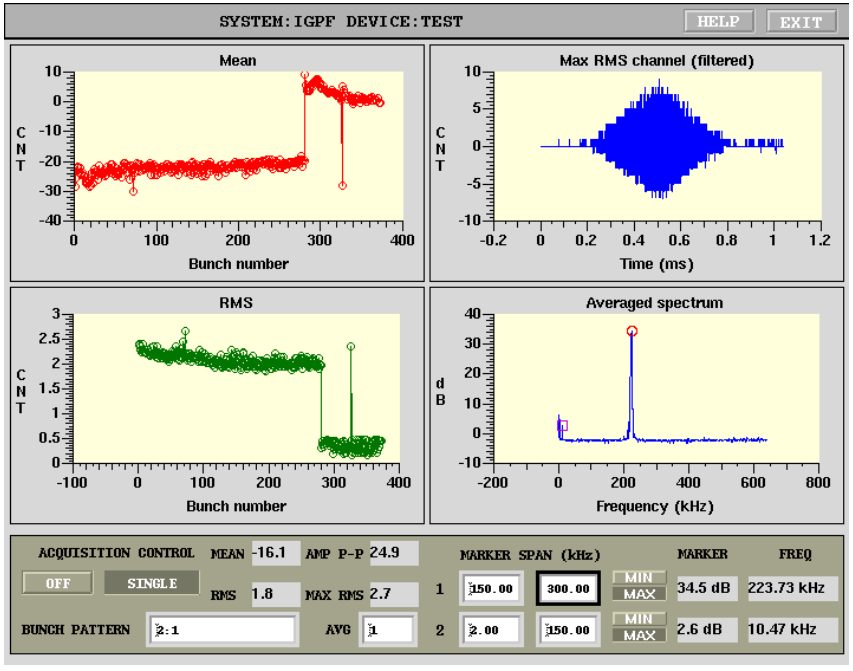

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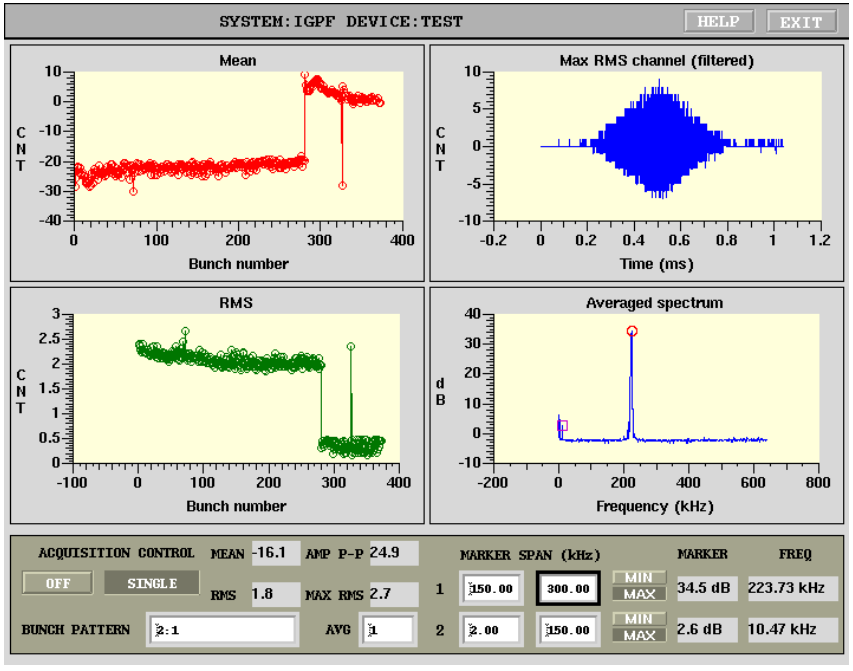

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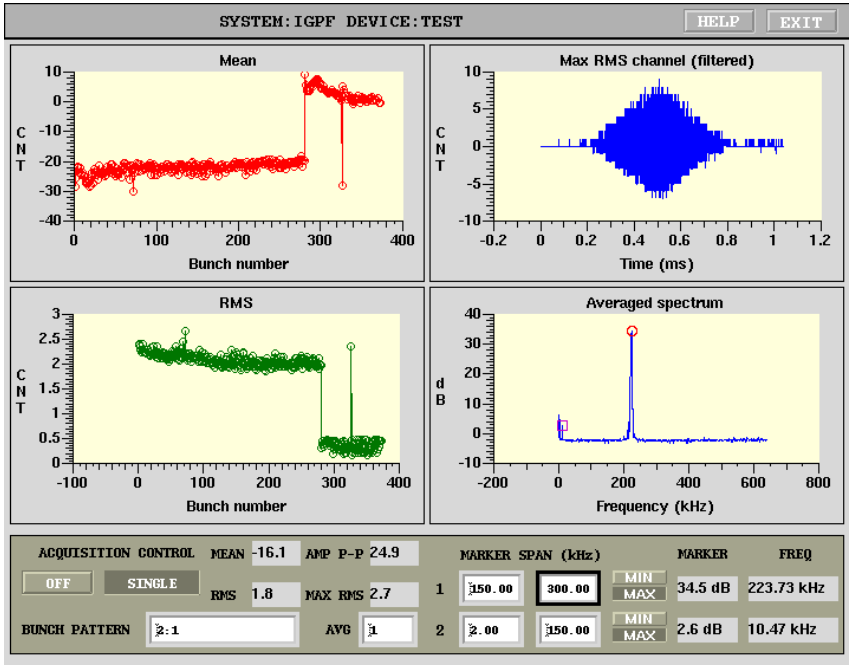

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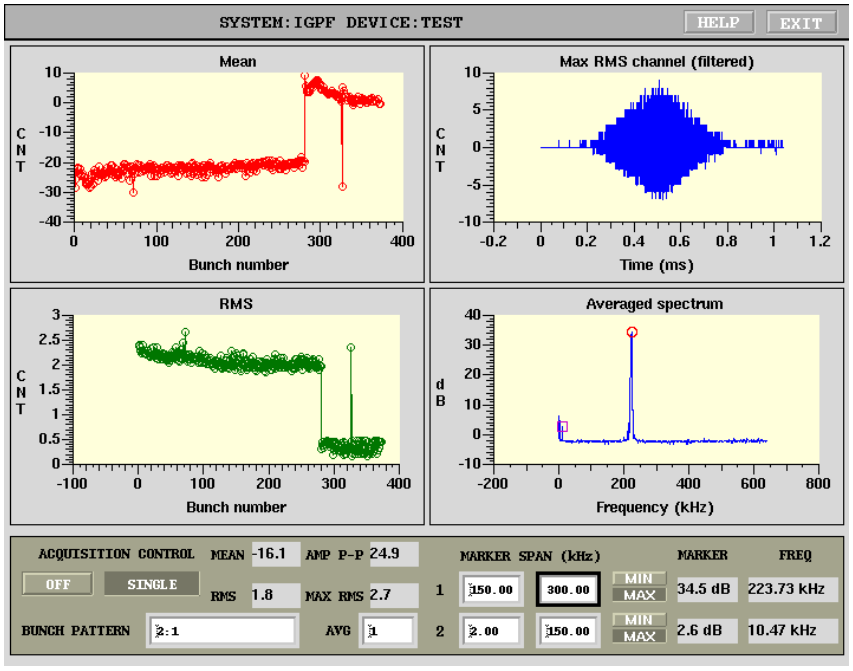
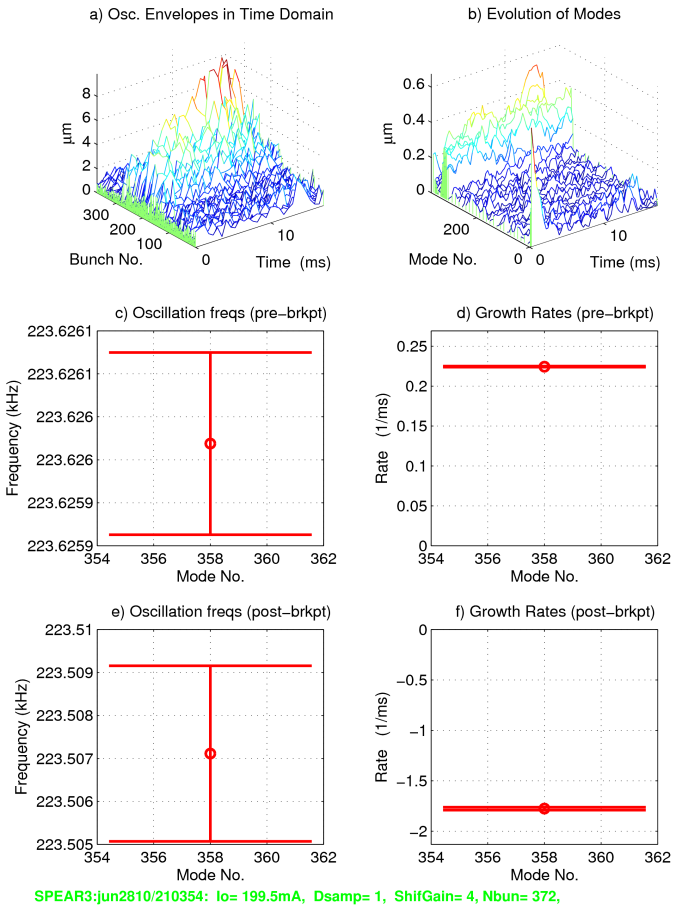


- Drive/damp measurement;
- Feedback is positive for first 450 μs, then negative;
- Clearly exciting the beam;
- Large betatron line in the spectrum at 223.7 kHz

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 ms^{-1}, damping rate of 1.8 ms^{-1}.

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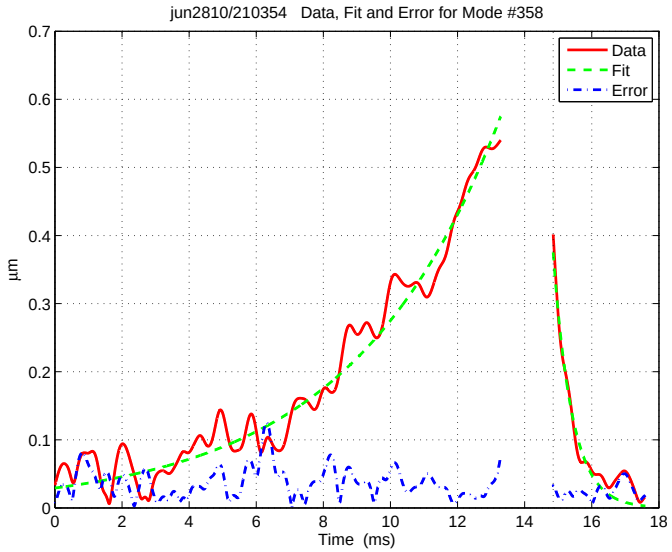

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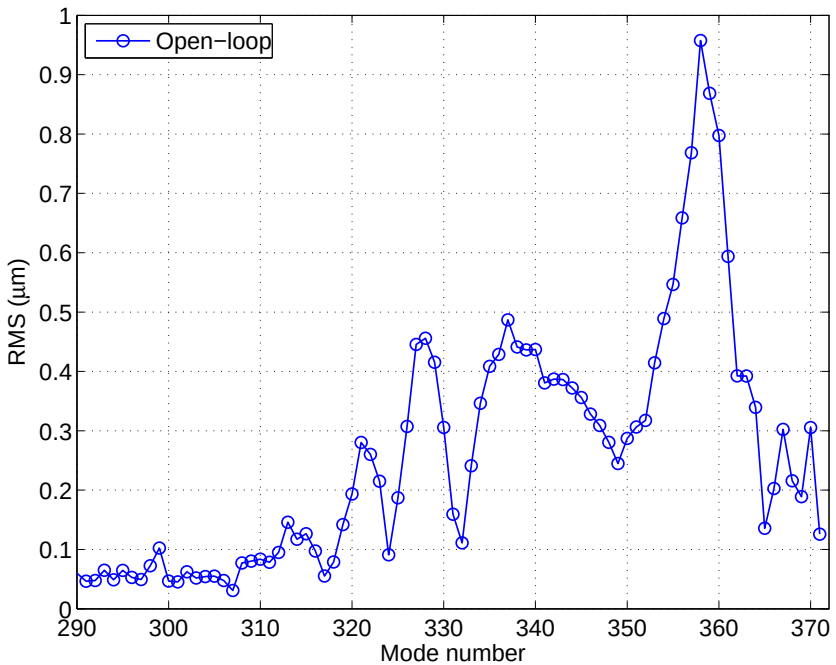
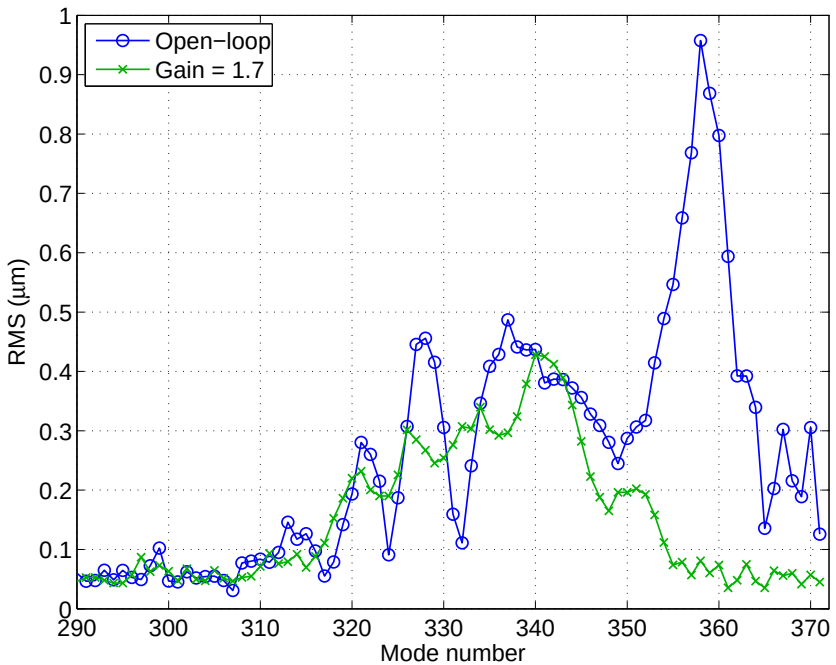
Closed-loop Motion vs. Feedback Gain



- 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.

Closed-loop Motion vs. Feedback Gain



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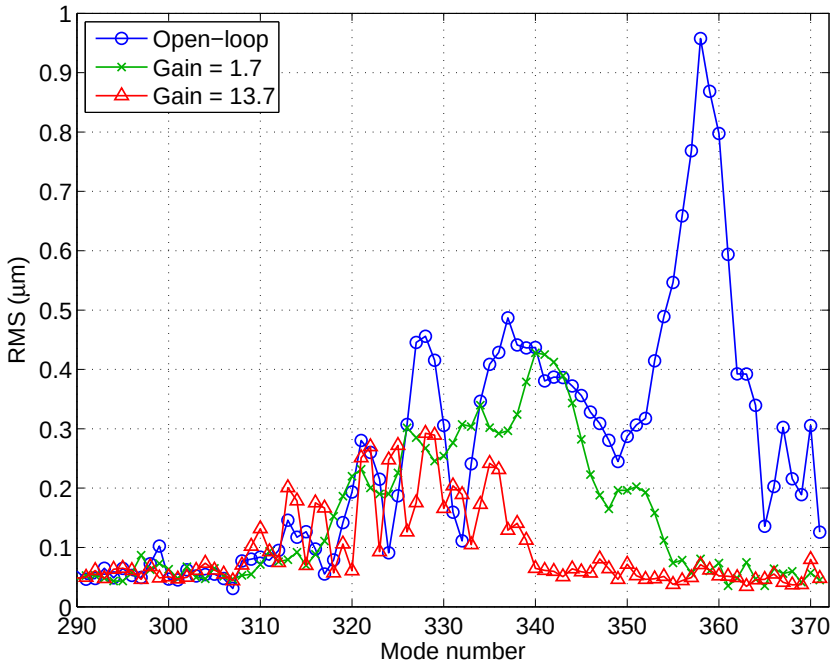

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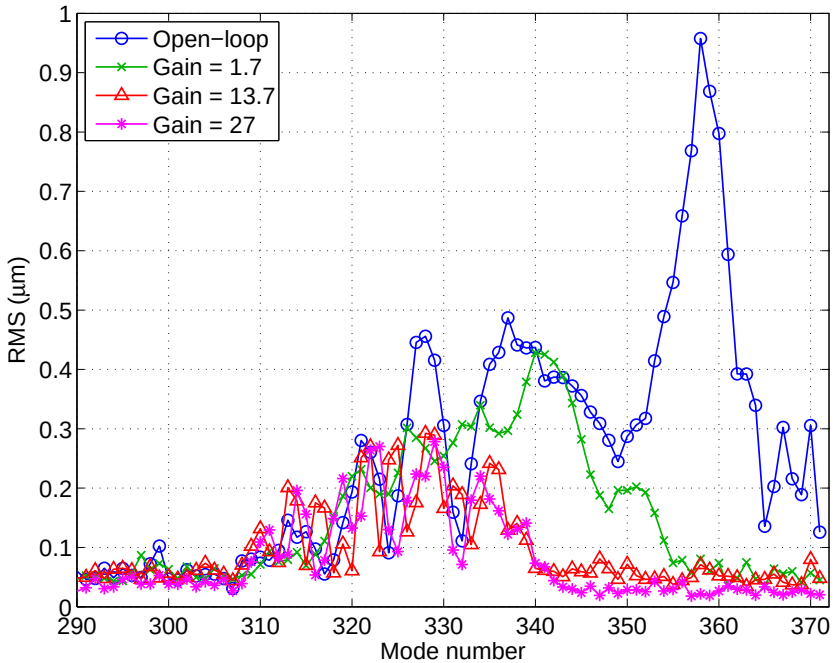

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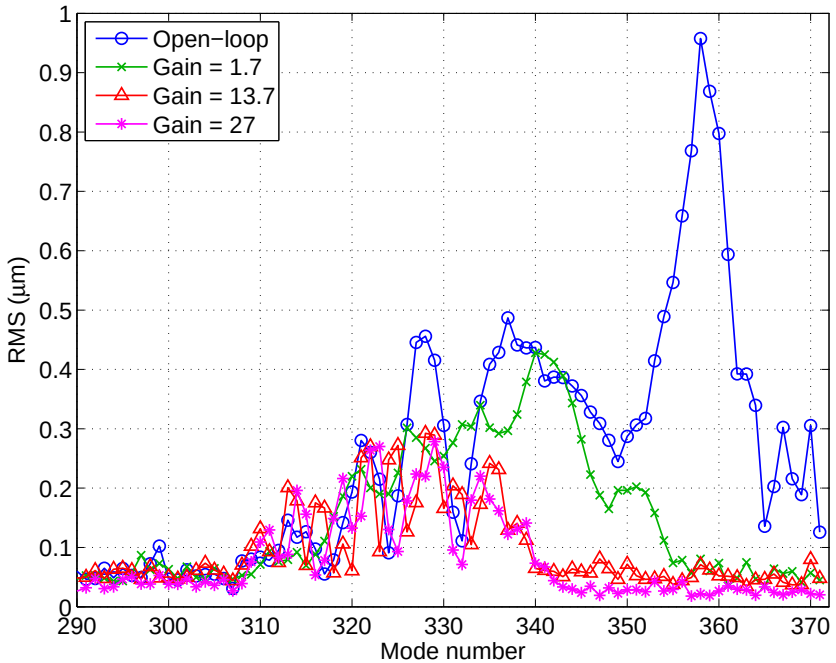

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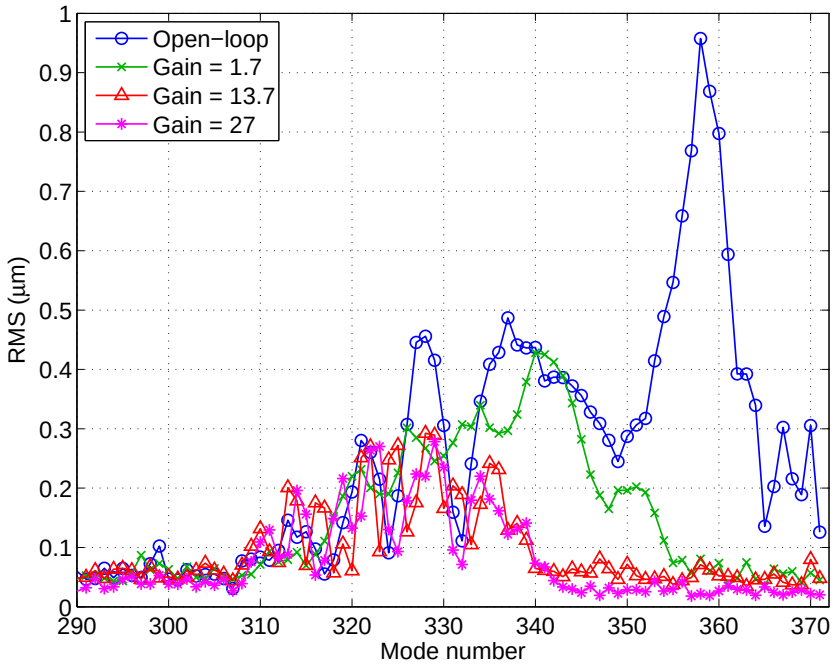

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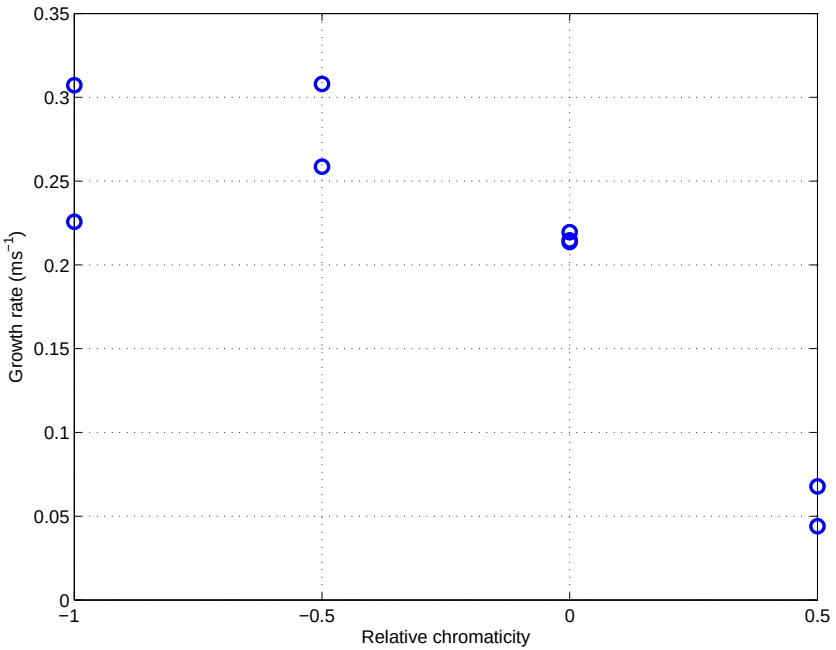
Growth Rates vs. Chromaticity



- Measured mode 359 growth rates vs. chromaticity; ;
- Clear drop with increased chromaticity, as expected.

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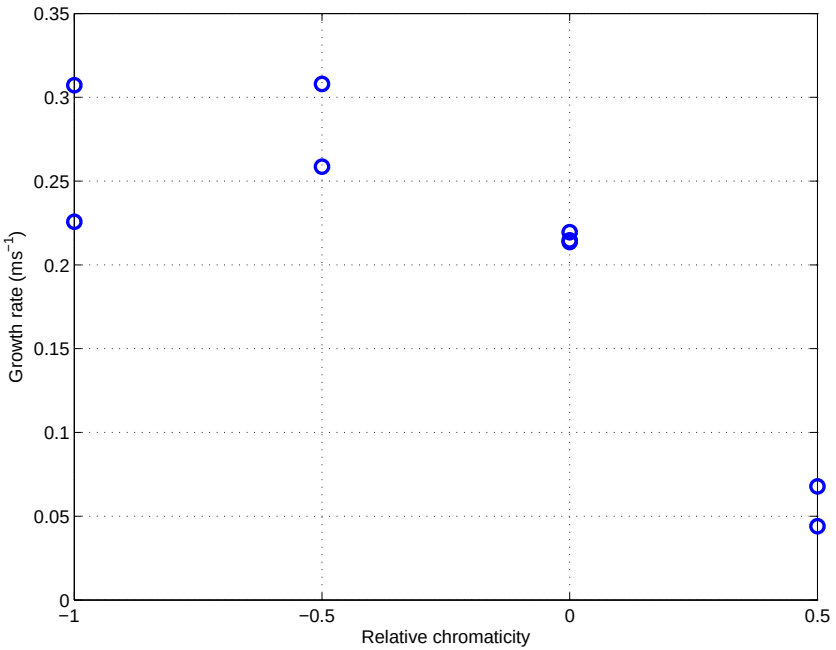

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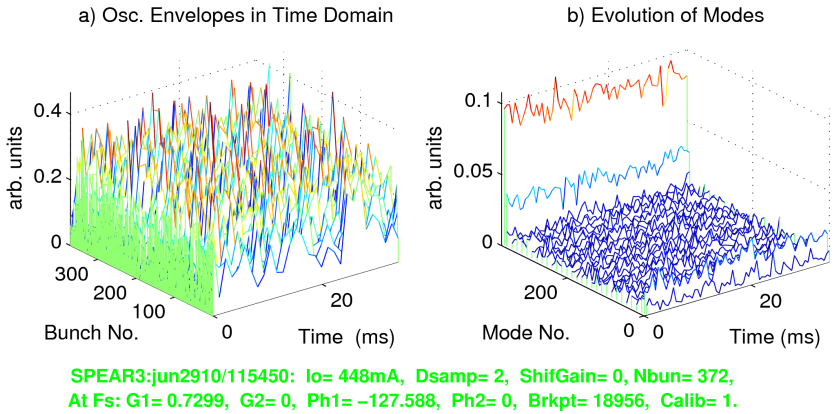

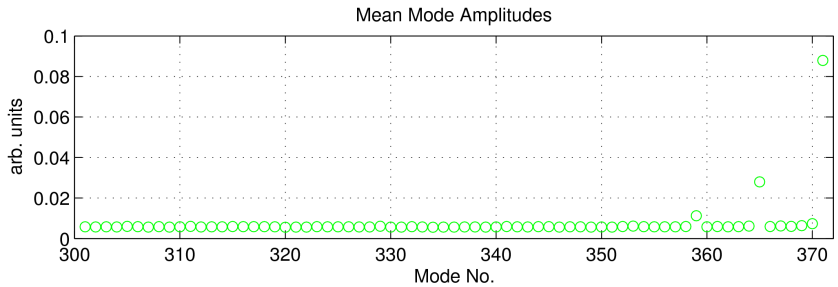

- Open-loop measurement: horizontal plane; ;
- Mode -1 — typical resistive wall motion;
- Vertical plane is dominated by mode 354 (-18).

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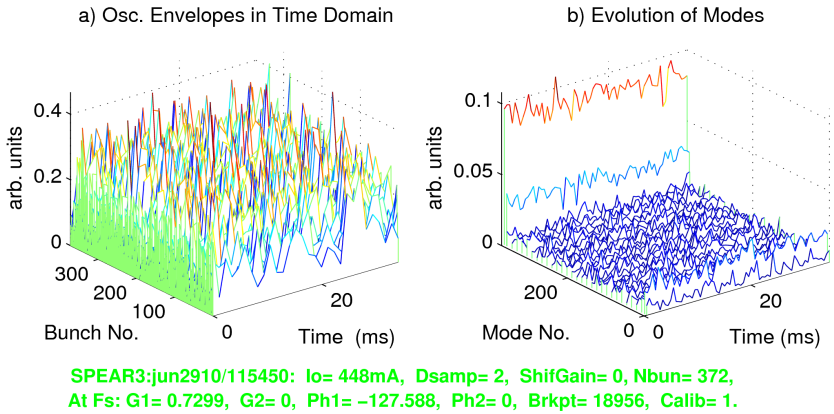

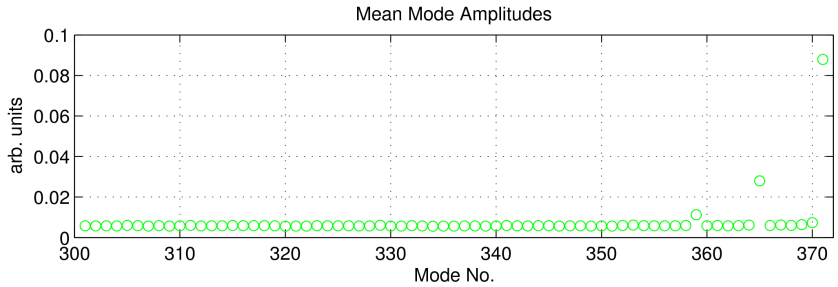

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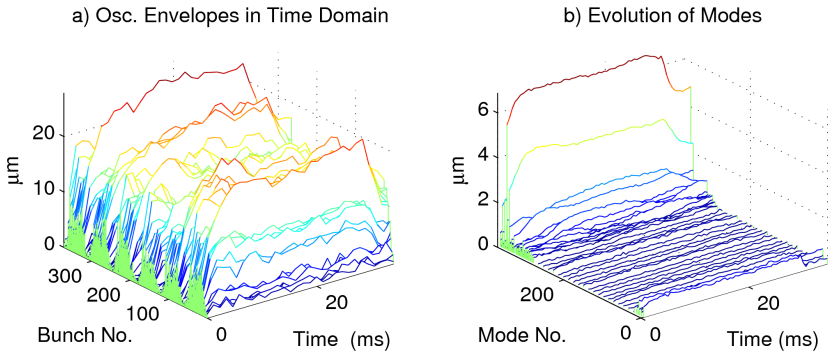

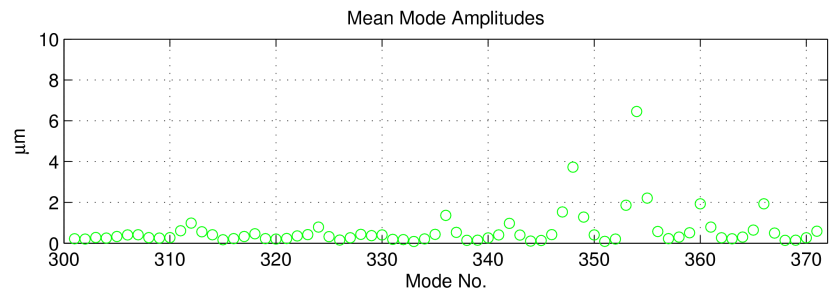

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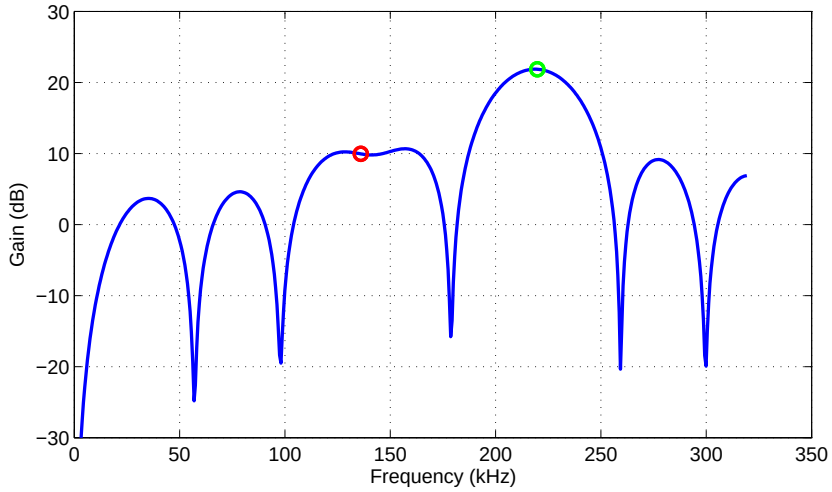
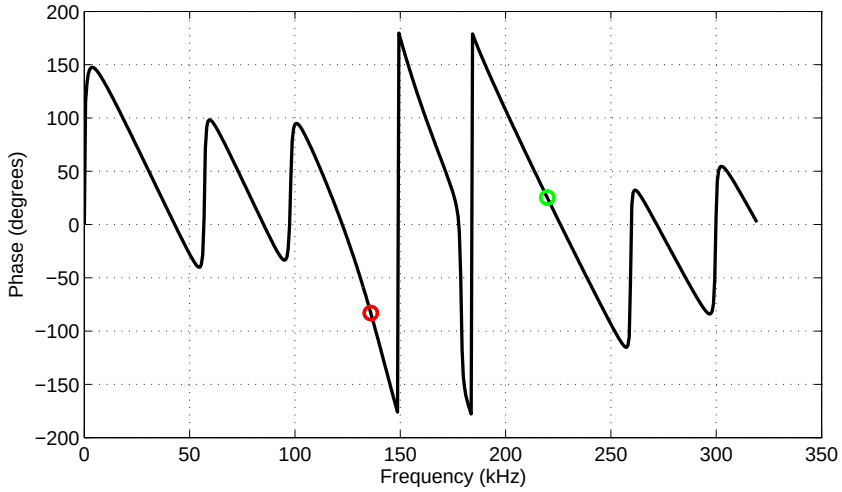
Dual-Band Filter





- 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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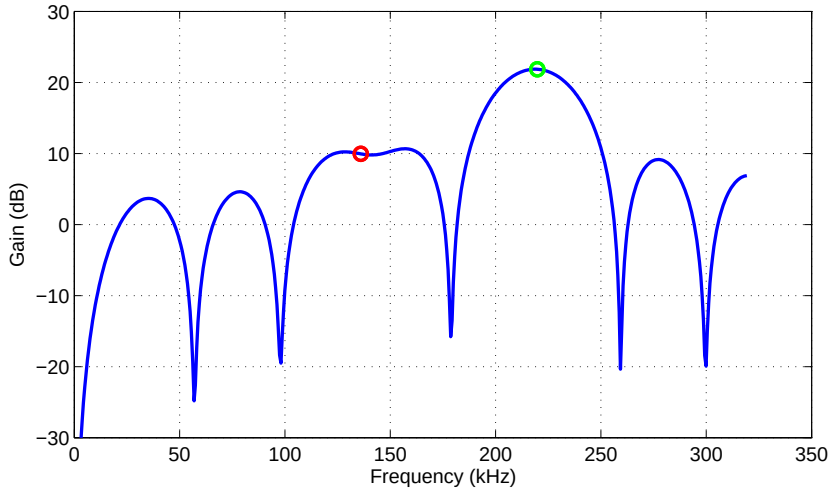

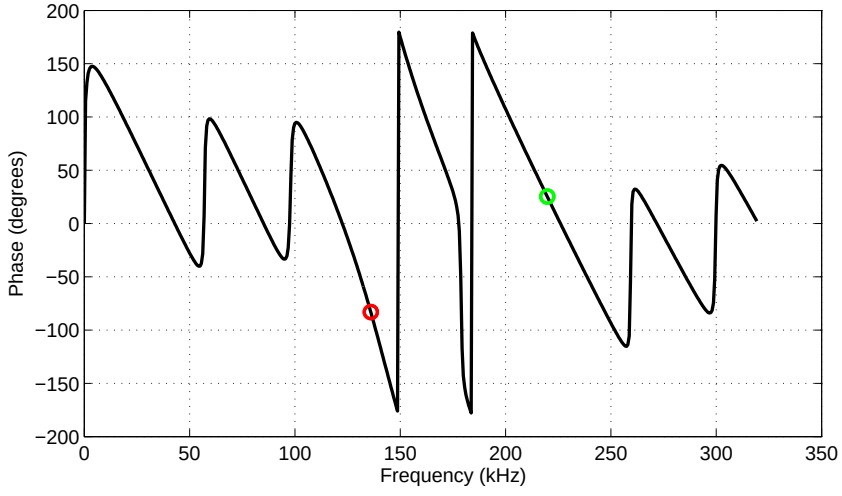

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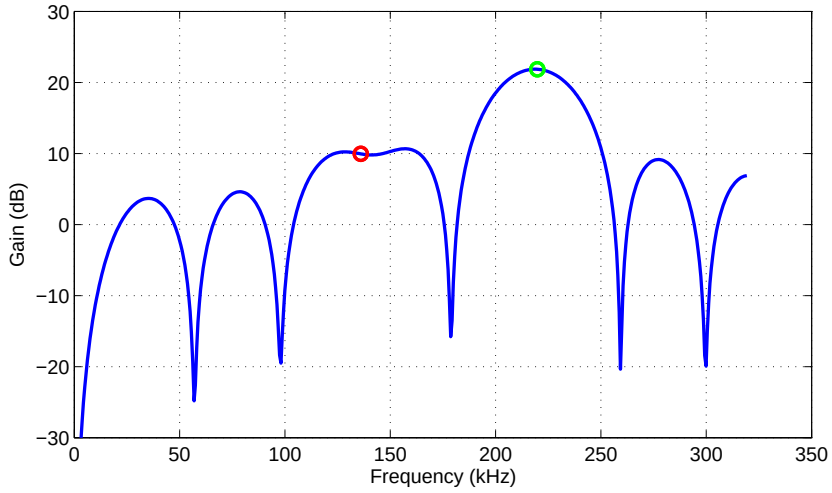

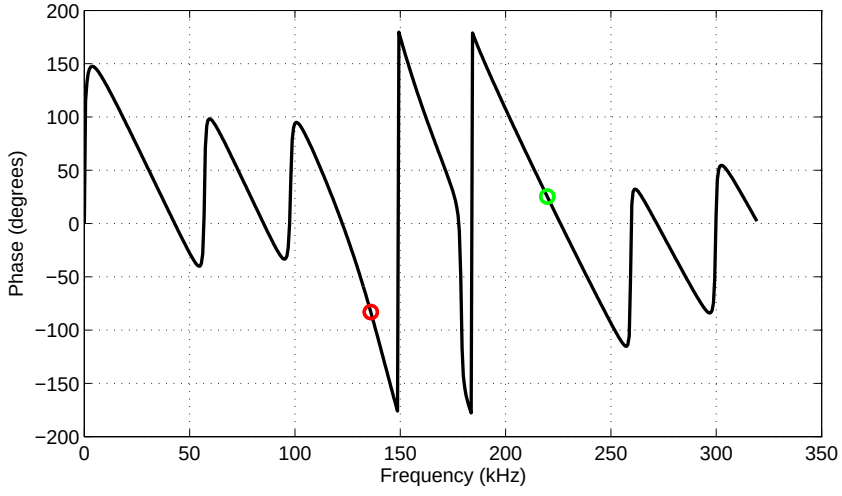

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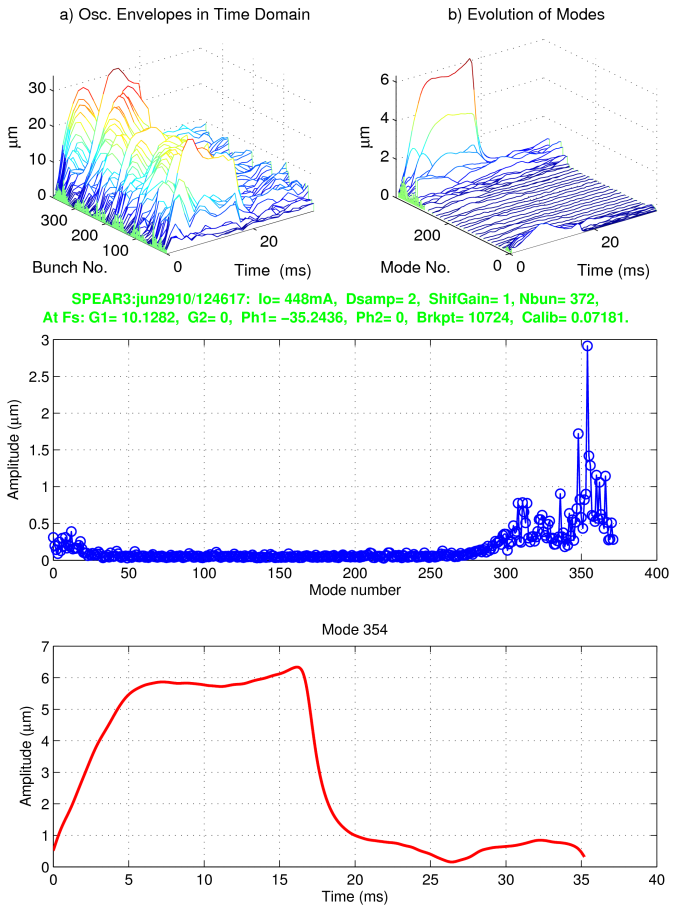

- Six trains of 47 bunches separated by 15 bunch gaps; ;
- Open-loop amplitudes reach 35 μm;
- Non-exponential growth — consistent with smaller fill-pattern gaps.

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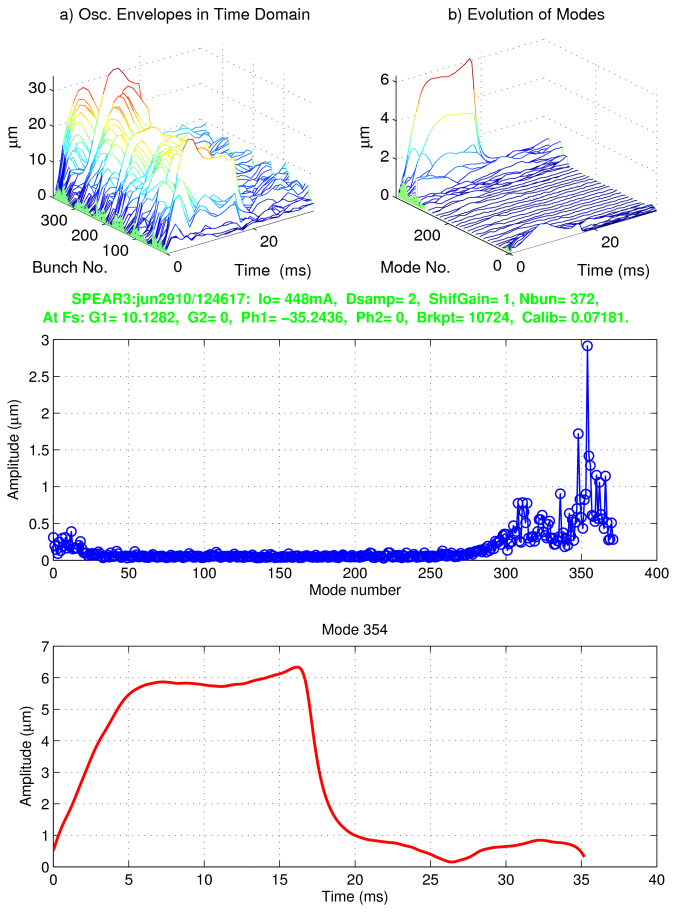

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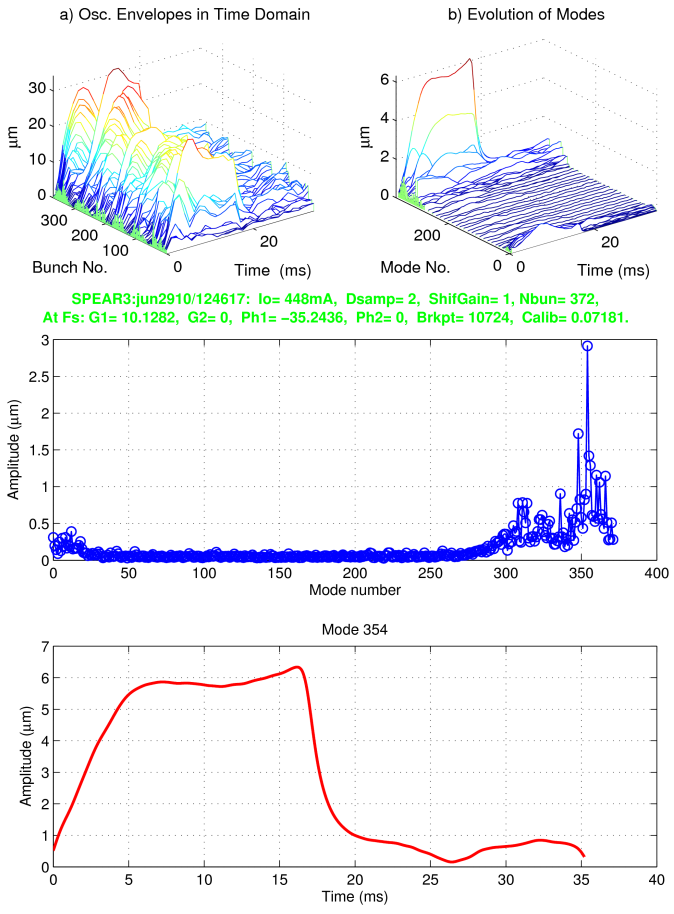

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Summary

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- 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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- 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.