Bunch-by-bunch Feedback Studies at the Australian Synchrotron

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Our Goals

The Problem

In the recent operation it has been observed that vertical beam dynamics change dramatically when the in-vacuum undulator (IVU) gaps are closed. Robust operation of the existing bunch-by-bunch feedback setup in these conditions has proven elusive.

- Characterize the modified dynamics;
- Identify the limitation(s) in the feedback performance;
- Make it all work.

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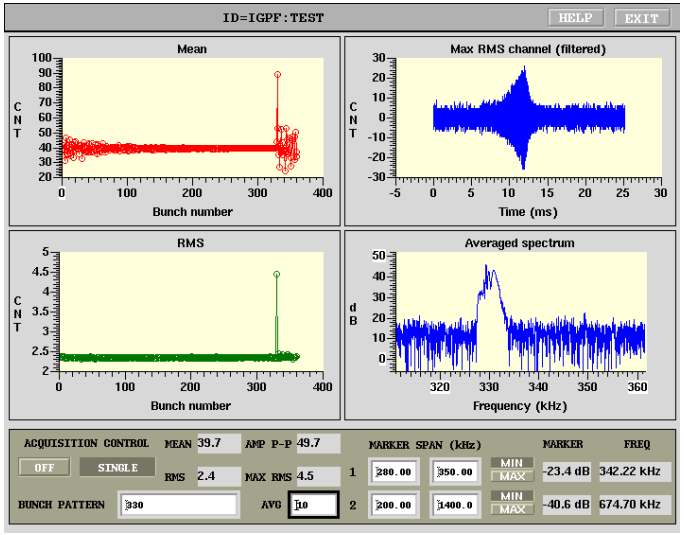
The Hardware

- We used Dimtel bunch-by-bunch feedback hardware for these studies;
- Combined front/back-end unit;
- Baseband processor.

Feedback Setup



- On the 20th in 3.5 hours we set up the hardware and timed it to the beam;
- Demonstrated single-bunch drive/damp;
- As well as multibunch grow/damp at 177 mA and vertical chromaticity of 3.5;
- Standard complex fitting fails due to tune modulation.

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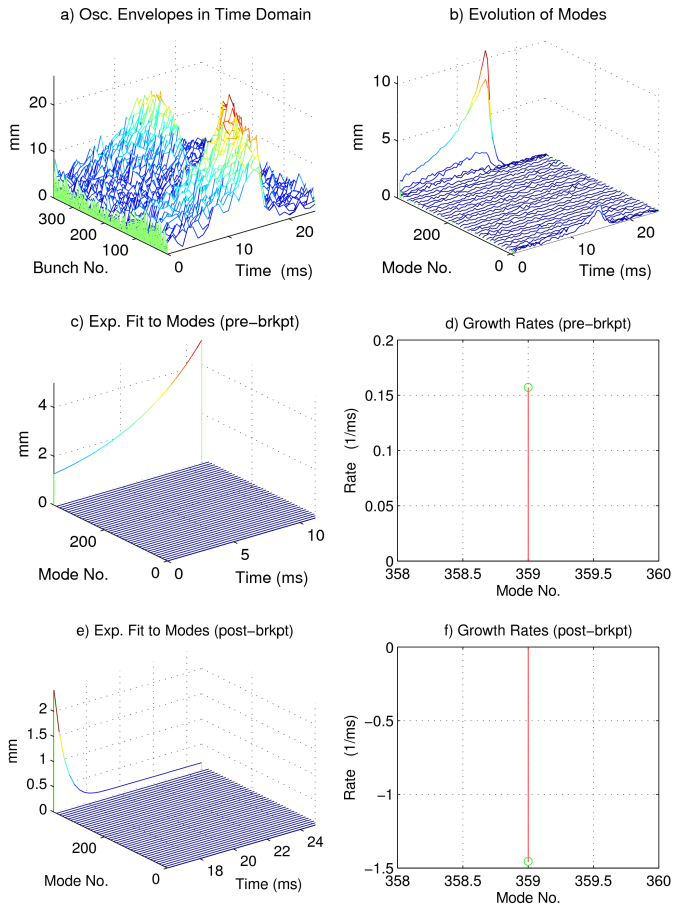

ASLS:jan2111/025111: Io= 176.7mA, Dsamp= 1, ShifGain= 2, Nbun= 360,
At Fs: G1= 26.3856, G2= 0, Ph1= 61.0894, Ph2= 0, Brkpt= 22300, Calib= 1.

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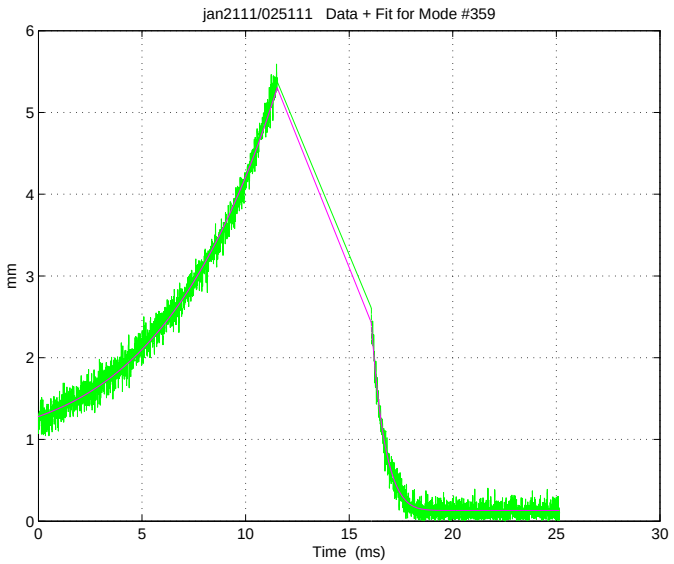

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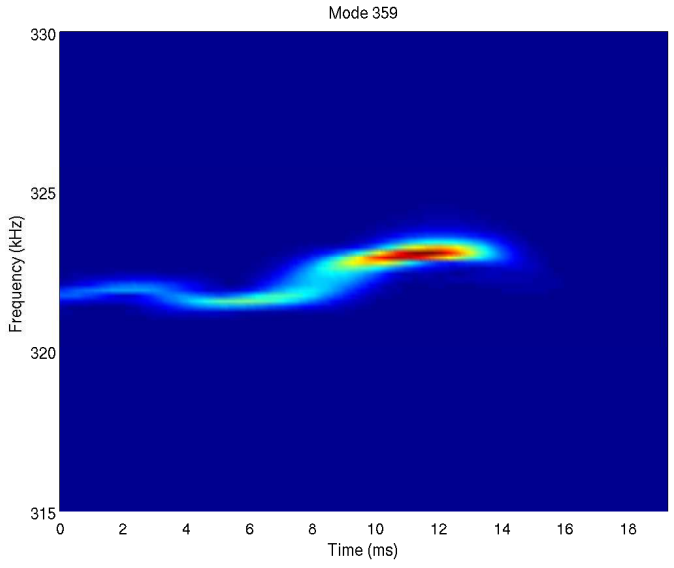

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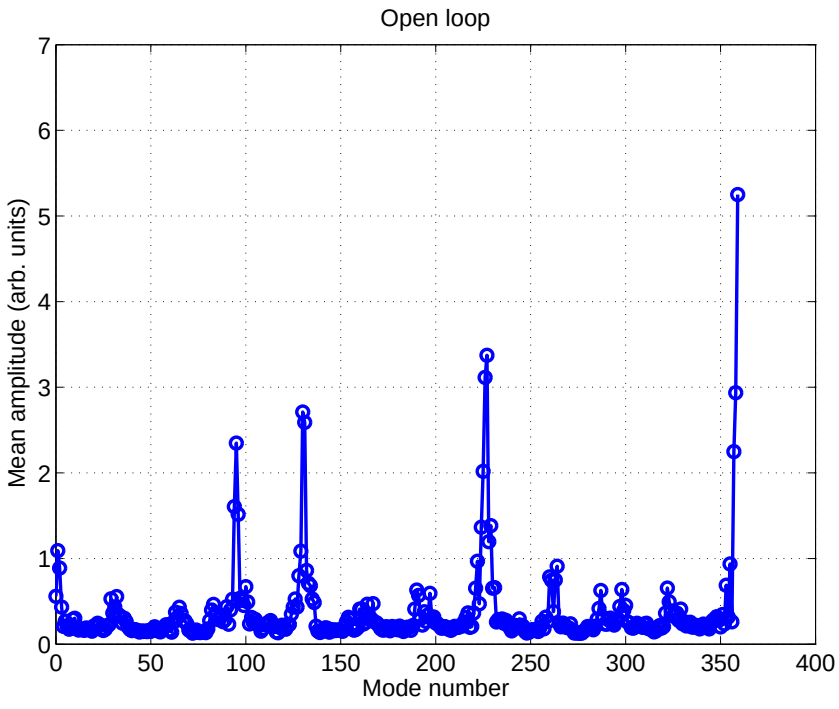
Closing the Gaps



- At 160 mA and chromaticity of 3.4 we closed the gaps;
- Open-loop spectrum shows two groups of modes:
  - Resistive wall around 359 (-1);
  - Mode 227, most likely driven by an HOM.
- Closing the feedback loop we suppress RW, but not the HOMs.

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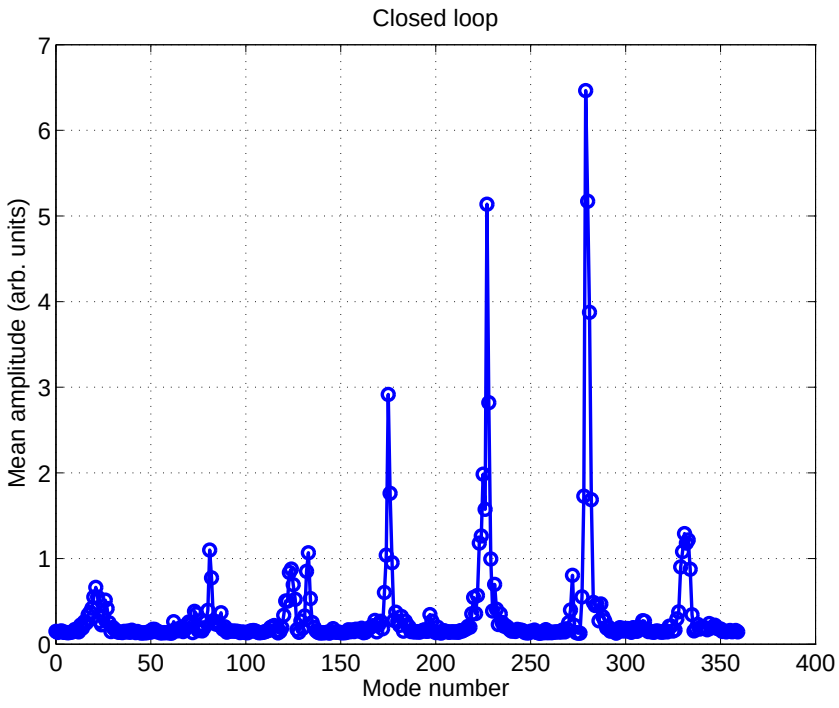

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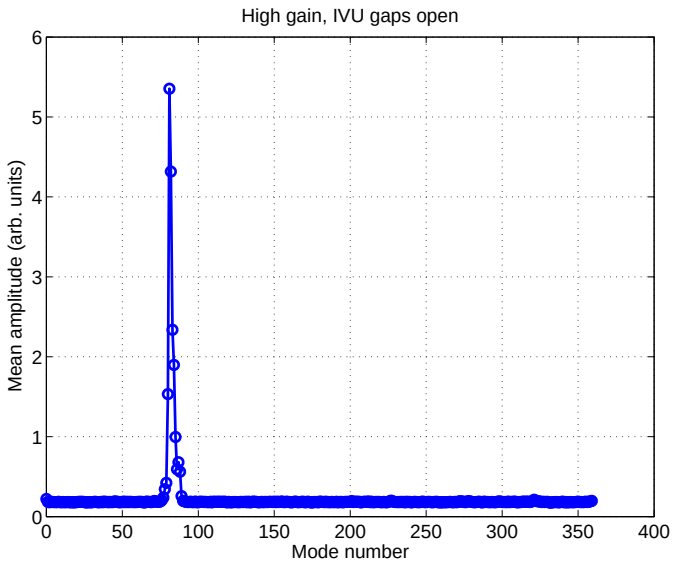
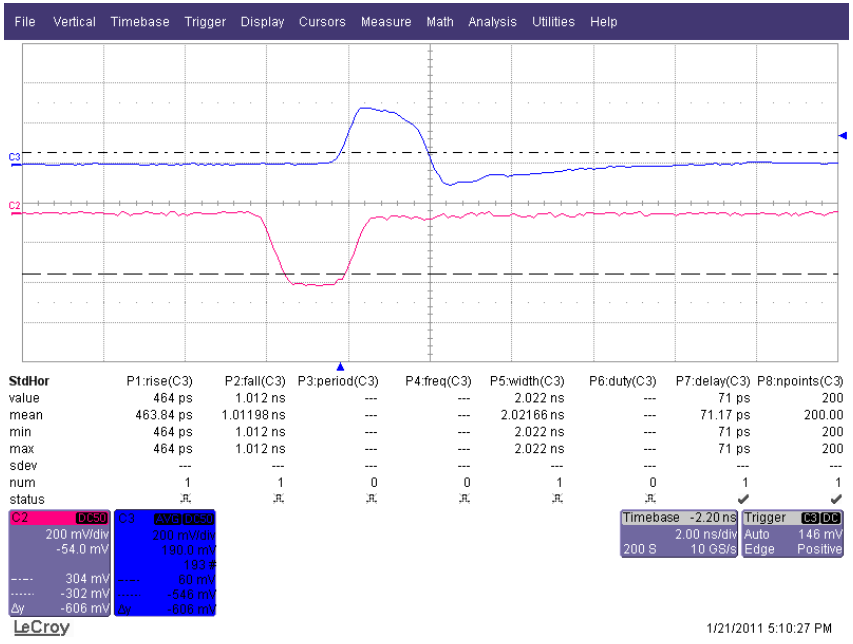
Feedback Gain Limit



- Even with the gaps open there was a problem;
- Typically in the transverse plane the feedback achieves very fast damping times, down to 30 turns;
- In the ASLS the gain limit was low by at least 24 dB;
- Raising the gain above the limit excited a group of high-frequency (112 MHz) modes.

Hardware Issues Found



- A bad connection of the amplifier output cable;
- A 400 MHz low-pass filter after the amplifier with strong ringing at 250 MHz;
- Improperly terminated SMA connector on the vertical hybrid output;
- Anaren hybrids with a messy Δ response.

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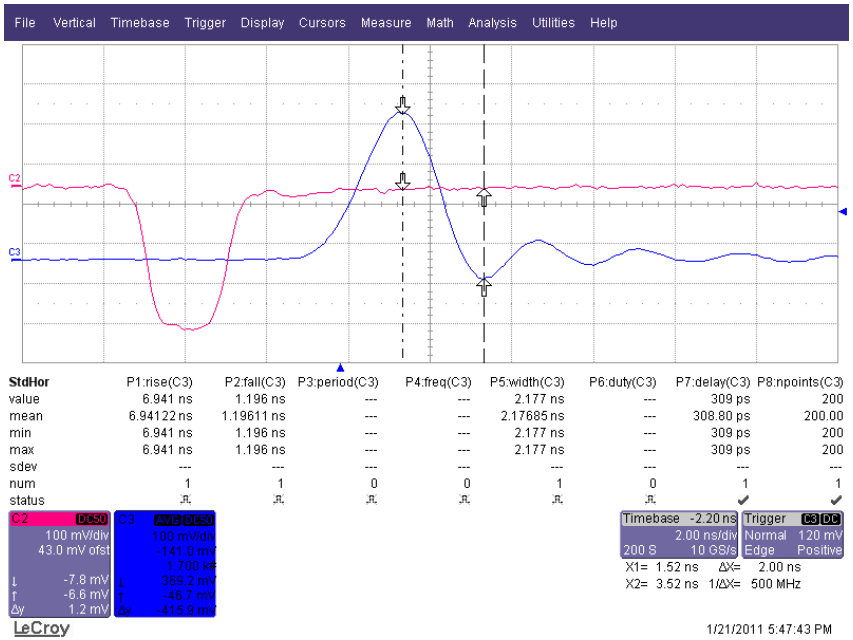

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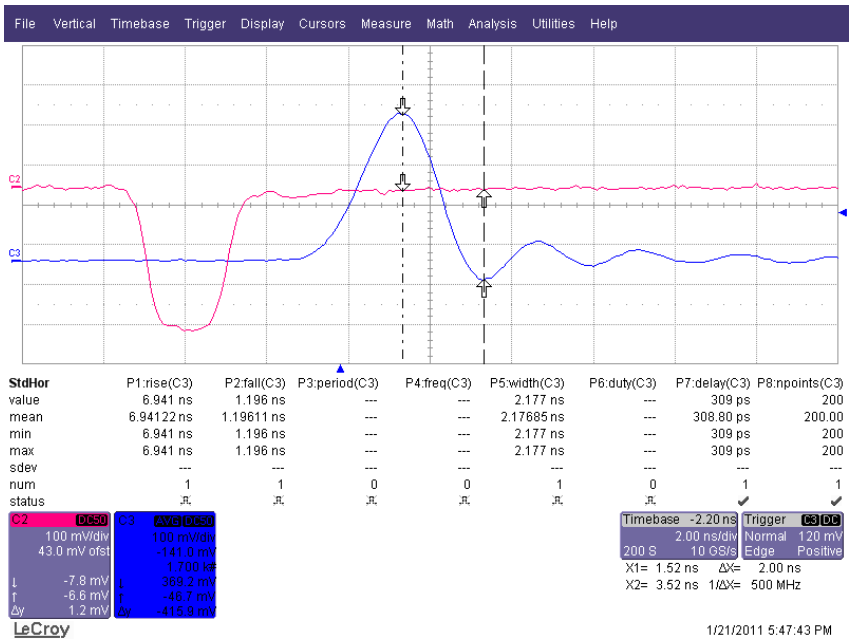

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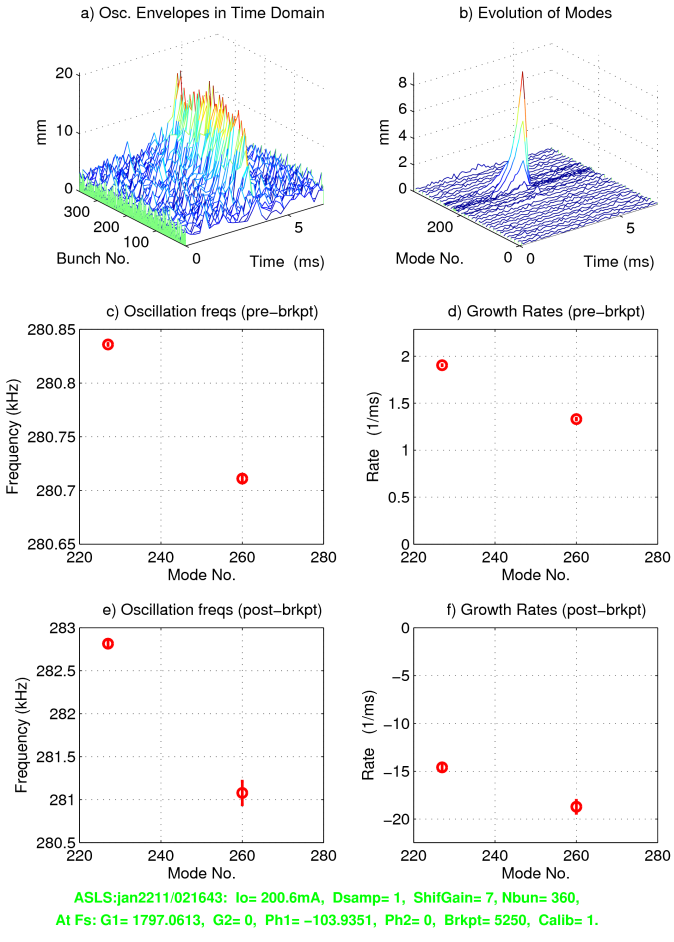
Feedback Timing Improvements

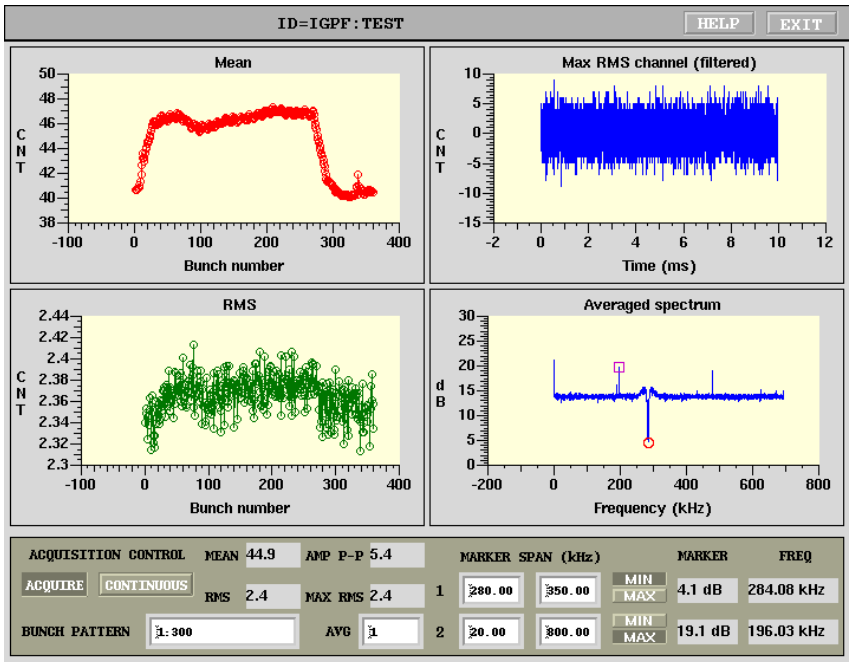
- Transverse front end operates as an amplitude detector;
- As a result it is tempting to set up the front end to maximize the peak value of the detected signal;
- The above works well when the beam has some offset from the electrical center;
- When the beam is well centered, must optimize sensitivity to transverse motion rather than static offset.

Nominal Current with Gaps Closed



- Grow/damp at 200 mA and vertical chromaticity of 1;
- Two fast modes: 227 and 260;
- Growth rates 10$\times$ the resistive wall rates;
- Achieved damping of 40 ms^{-1} (25 ms or 35 turns).

Beam Resonance Spectral Notch



- Within the feedback loop one can normally observe a notch at the beam resonance;
- An easy way to provide parasitic true-tune readout at 1–2 Hz;
- High chromaticity produces additional notches/peaks due to the synchro-betatron resonances.

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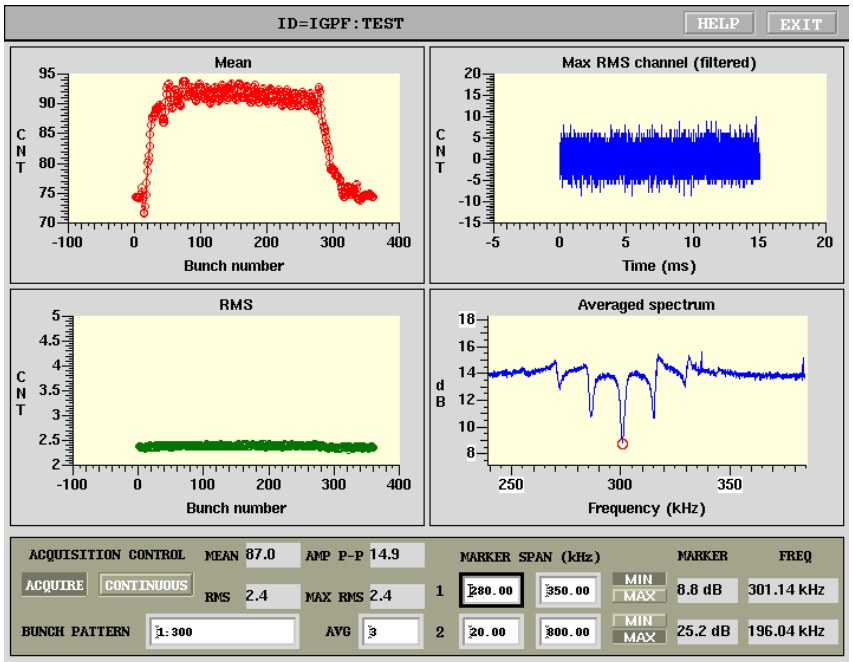

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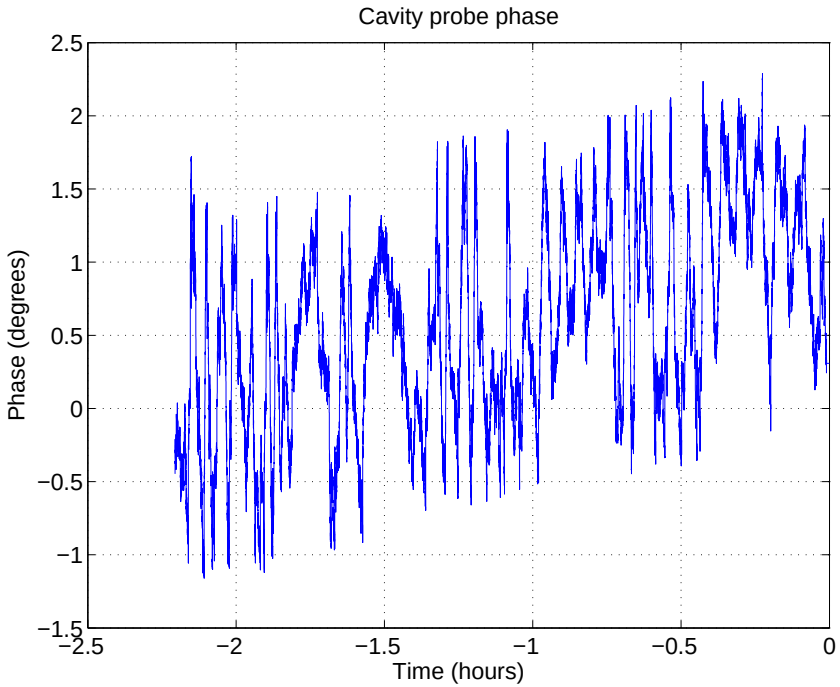
A Vector Voltmeter

- LLRF prototype: 6 input and 4 output channels;
- Connected to master oscillator reference;
- Monitoring cavity probe, forward, and reflected signals.

Cavity Monitoring



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- Cavity voltage;
- Forward power;
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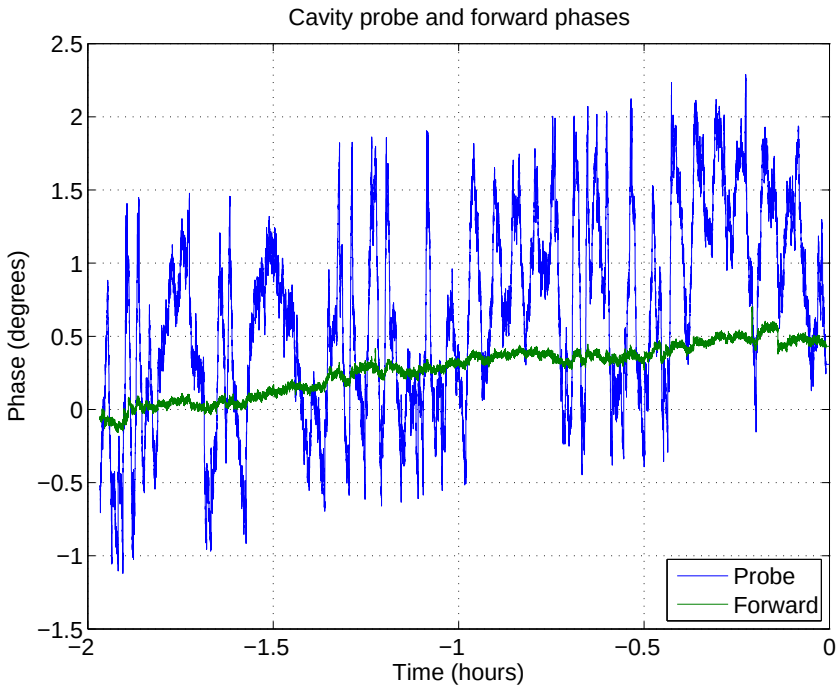

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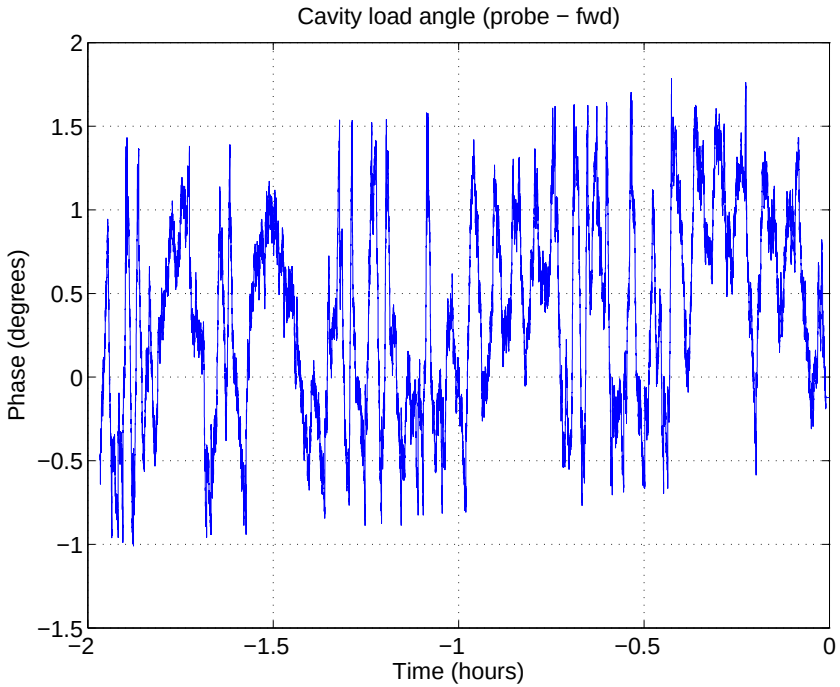

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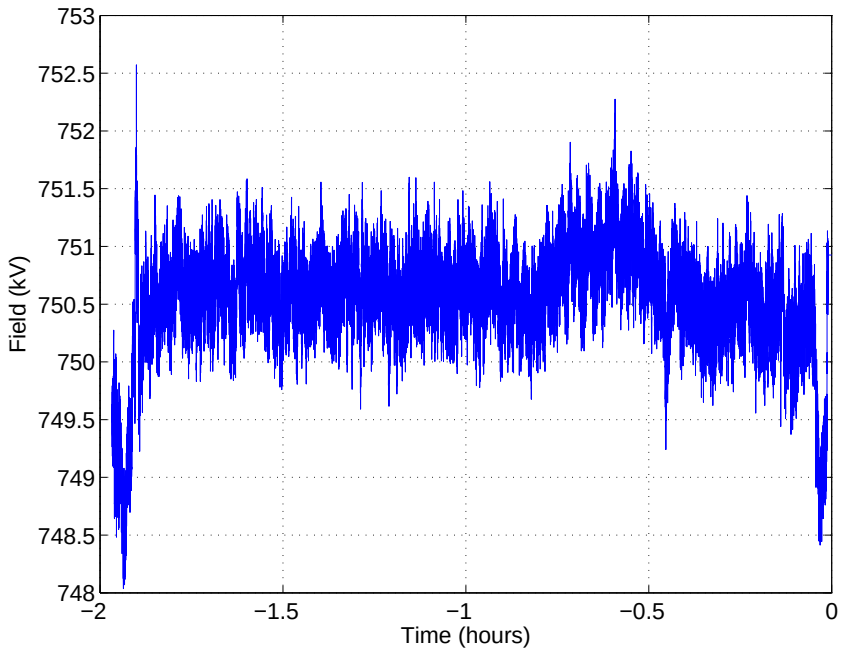

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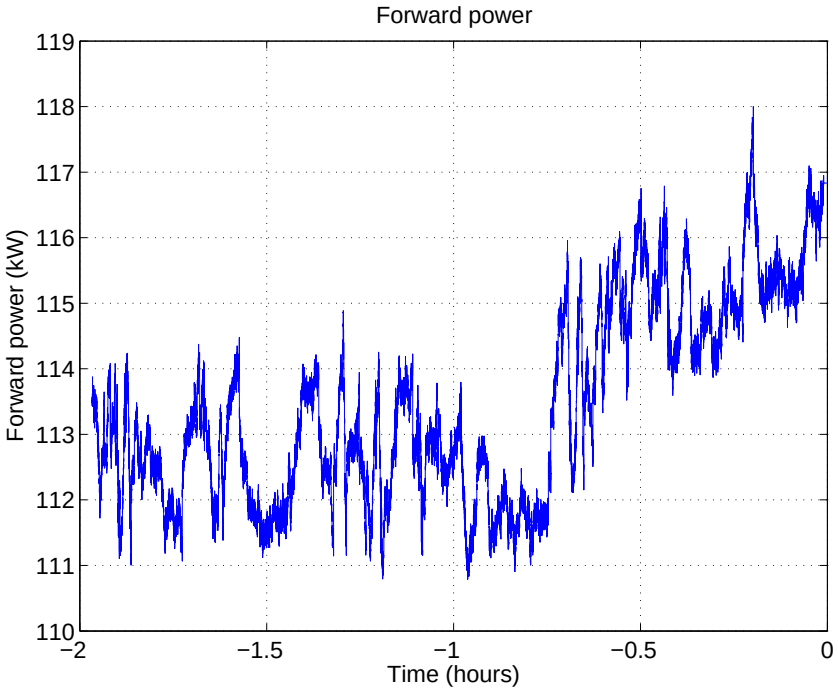

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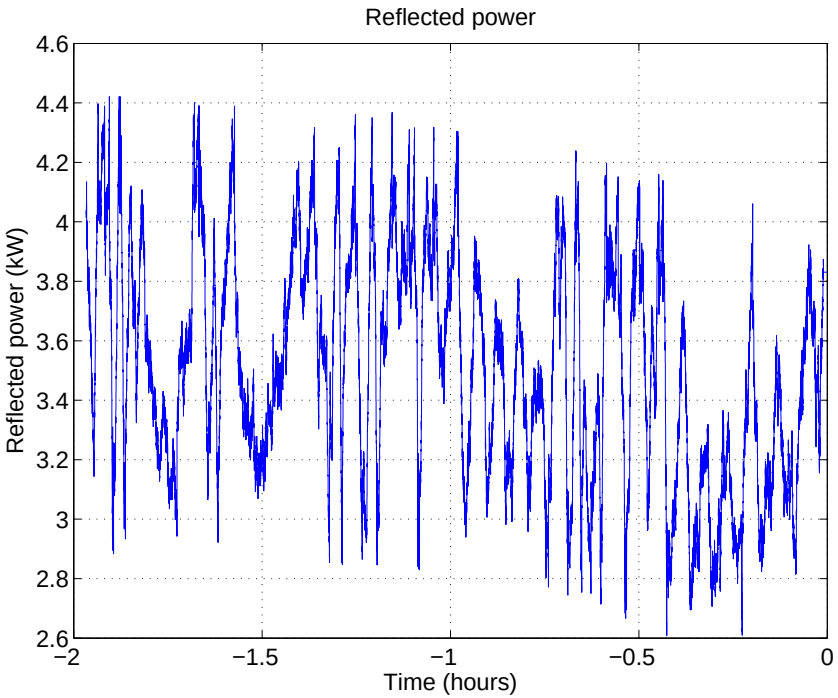

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