COMMISSIONING THE LCLS-II LLRF SYSTEM IN THE LERF CRYOMODULE TEST FACILITY

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Abstract

The JLAB Low Energy Recirculating Facility, LERF, has been modified to support concurrent testing of two LCLS-II cryomodules. The cryomodules are installed in a similar fashion as they would be in the L1 section of the LCLS-II linac, using all of the LCLS-II hardware and controls for cryomodule cryogenics, vacuum, and RF (SSA and LLRF). From the start, it was intended to use LCLS-II electronics and EPICS software controls for cryomodule testing. In effect the LERF test facility becomes the first opportunity to commission and operate the LCLS-II LINAC hardware and software controls. Specifically it is an excellent facility to test the performance and commission all facets of the LLRF system. This poster presents the trials, tribulations and successes of the LLRF system as it was commissioned and used for cryomodule tests.

CRYOMODULE, RF AMPLIFIERS, & LLRF RACK

RF SYSTEM

Features

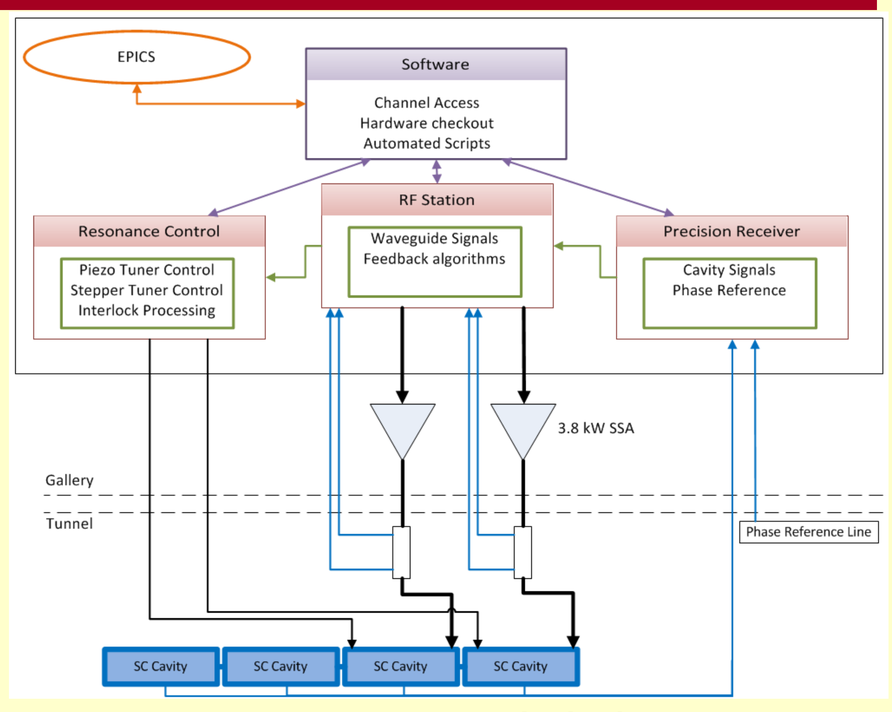
The LERF replicates the RF system in the L1 section of the LCLS-II Linac

High Power RF

- 16 four kW solid state amplifiers tested to 4 kW
- 50 dB dual directional couplers
- Isolator with load tested to 4 kW

Low Level RF

- Each rack controls four cavities
- Single LLRF System/cavity
- Resonance
  - Coarse: Stepper motor
  - Fine: Piezo Tuner
- Cavity Interlocks
- Cavities tested and operated in SEL and SELAP (GDR)



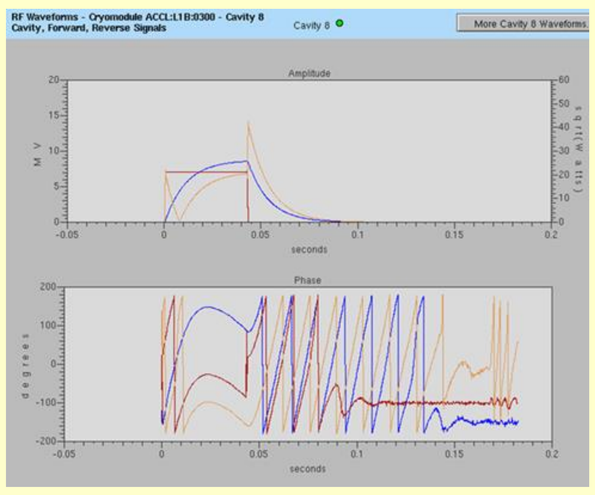
LCLS-II RF System Block Diagram

Mode	Description
SEL (Self Excited Loop)	RF system tracks the cavity frequency in open loop, no phase or amplitude regulation
SELA (Amplitude)	RF system tracks the cavity frequency while maintaining cavity amplitude with feedback loop parameters
SELAP (Phase)	RF system runs at nominal frequency while maintaining cavity amplitude and phase. GDR equivalent.
Chirp	Frequency sweep over 100 kHz within one waveform to quickly measure detune over wide range. Used only during characterization
Pulsed	Pulsed RF
Tone	Open loop forward power without tracking frequency. Used for system calibration and testing by experts
Integrator (on)	Piezo tuner feedback loop enabled. Tunes cavity based on RF detune calculation

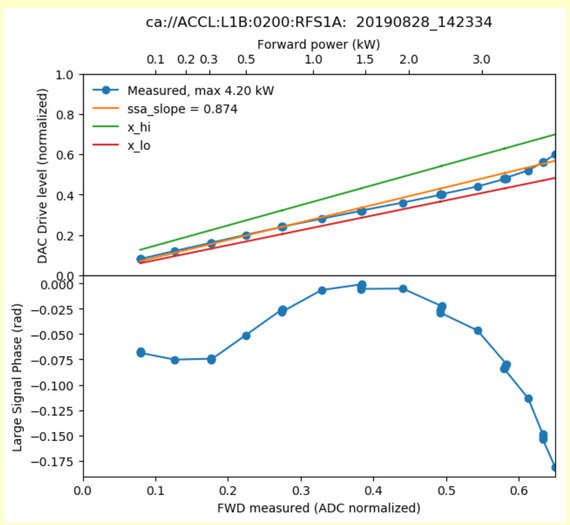
RF START UP/CALIBRATIONS

RF Start Up Calibrations

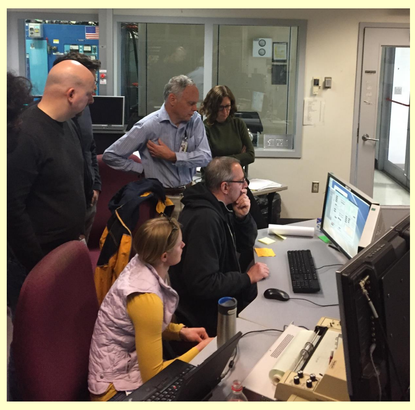
- SSA Calibration
- Frequency Chirp
  - Determines cavity frequency
- Pulsed SEL Calibration
  - Loaded Q
  - Cavity scale factor (gradient)
- Ramp to Target Gradient in SEL Mode
- 8pi/9 Frequency



LLRF EPICS Waveform Screen Showing a Gradient Calibration from the Emitted Power

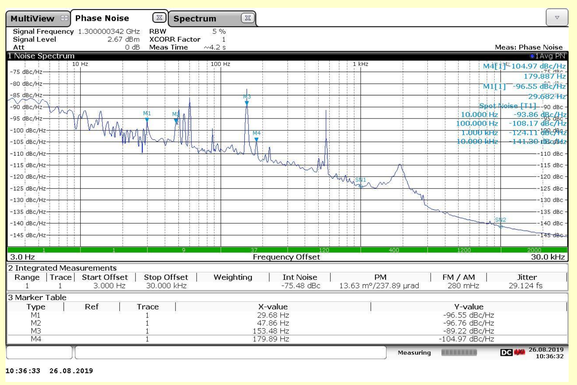


Solid State Amplifier Gain Curve

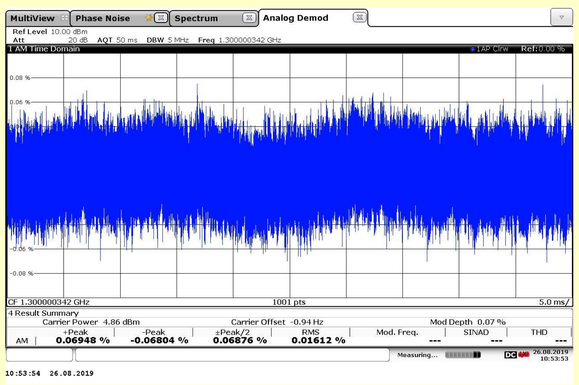


LLRF Experts Assisting with Cryomodule Commissioning

"OUT-OF-LOOP" RF SYSTEM PERFORMANCE



Phase noise plot of the cavity field signal in GDR. RMS. Phase error is 0.013º. Phase noise was limited by the LO source.

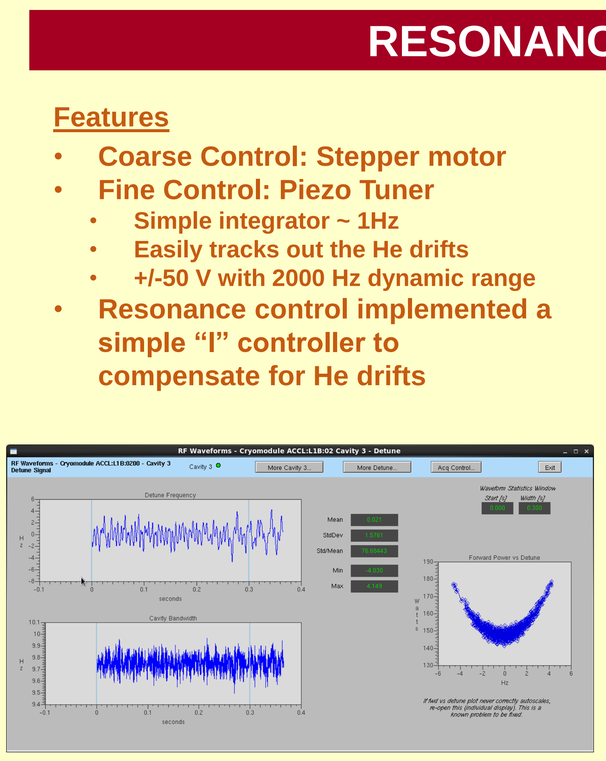


Amplitude error of the cavity field signal in GDR. RMS. Error is 0.016%.

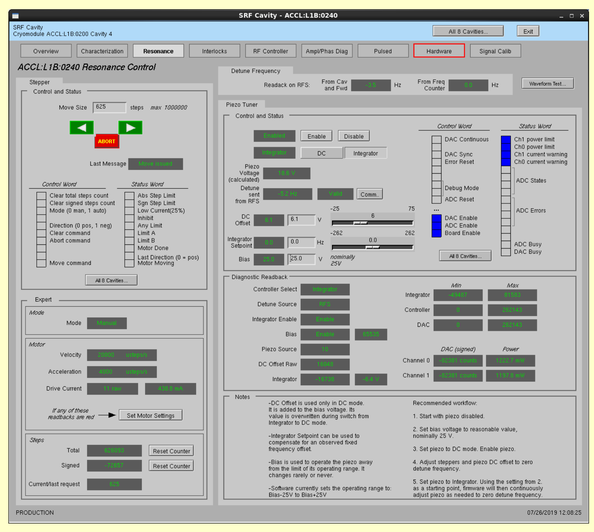
RESONANCE CONTROLS

Features

- Coarse Control: Stepper motor
- Fine Control: Piezo Tuner
  - Simple integrator ~ 1Hz
  - Easily tracks out the He drifts
  - +/-50 V with 2000 Hz dynamic range
- Resonance control implemented a simple "I" controller to compensate for He drifts



Waveforms showing cavity active detuning while in SELAP (GDR)

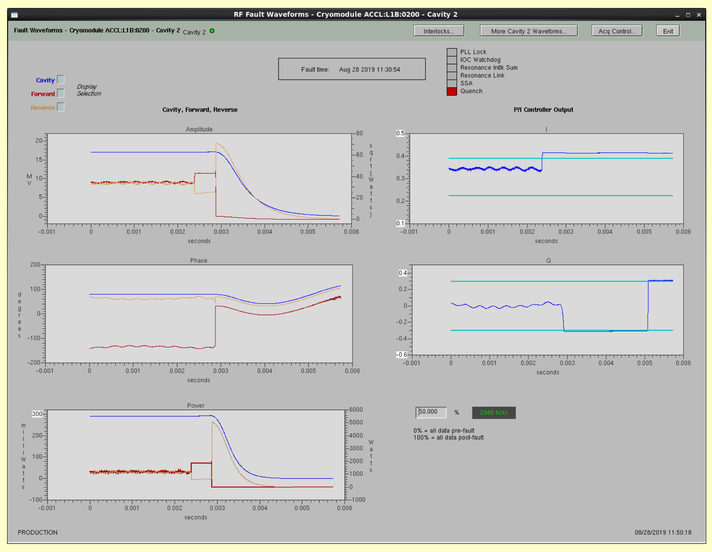


Resonance control screen for stepper motors and piezo control

Resonance system is Active Resonance Control (ARC) ready. This has been tested at FNAL.

RF INTERLOCKS

- All fault information embedded into firmware
- Enables fast response and fault waveform capture
  - Quench detection
  - SSA permits
  - IOC watchdogs
  - Stepper tuner temperatures
  - Limit switch status
  - Coupler temperatures
  - Vacuum status
  - Cryo-system summary



Cavity Quench Fault Waveforms

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