SRF Cavity Active Resonance Control
Status of Work for LCSL II and PIP II Projects

Jermiah Holzbauer

Yuriy Pischalnikov

Samuel Smith

Warren Schappert

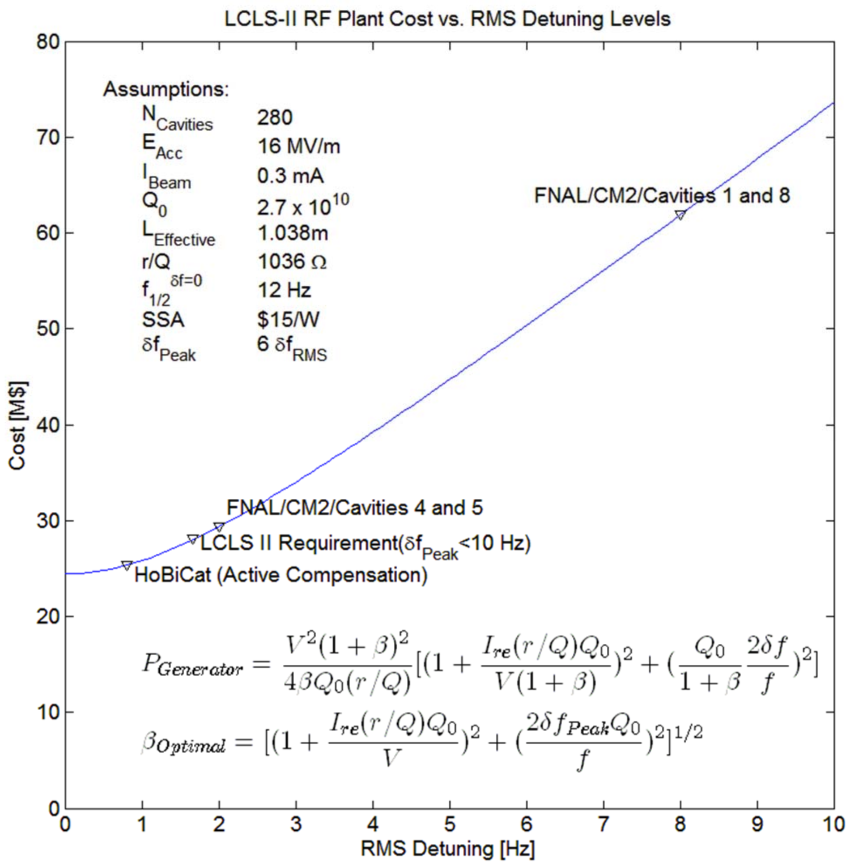
2015/07/27

SRF Cavity Vibrations

- SRF Cavities are manufactured from thin sheets of niobium to allow them to be cooled to superconducting temperatures
- The thin walls make the cavities susceptible to detuning by
  - Mechanical vibrations and
  - Fluctuations in helium pressure
- Detuned cavities require more power to operate

The Cost of Cavity Detuning

- If sufficient RF power is not available to maintain a constant gradient during the peak expected cavity detuning, the beam will be lost
- For machines employing very narrow bandwidth cavities, ERLs, XFELS, cavity detuning can be a major driver of the cost of the machine



Controlling Detuning

- Controlling detuning in narrow bandwidth cavities requires careful design of entire machine
  - Cavity design
  - Cryomodule design
  - Civil engineering
  - RF control
  - Active vibration compensation
- Active compensation alone may not work if other aspects ignored

Maury Tigner:ERL 2015

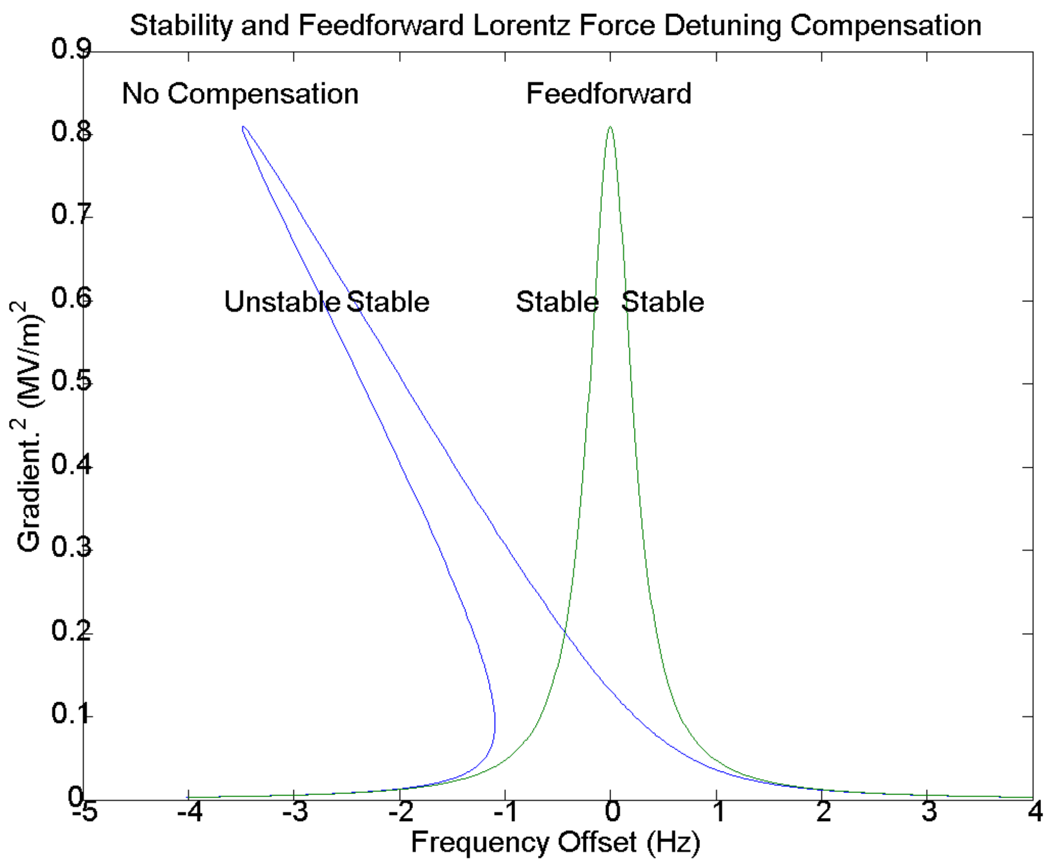
R&D for mitigation

•Large scale-up risks need mitigation by excellent, full scale, machine modeling including realistic error distributions derived from real hardware prototypes and putative specifications

•Phase and amplitude control challenges are multidimensional here we mention only one i.e. vibration induced detuning of the very high Q cavities. Successful mitigation will require great attention to the vibration source(s) and design of the cryomodules for favorable transfer functions - source to cavity. Enough prototypes needed to assure robustness of design. RF and beam measurements in R&D loop can both help.

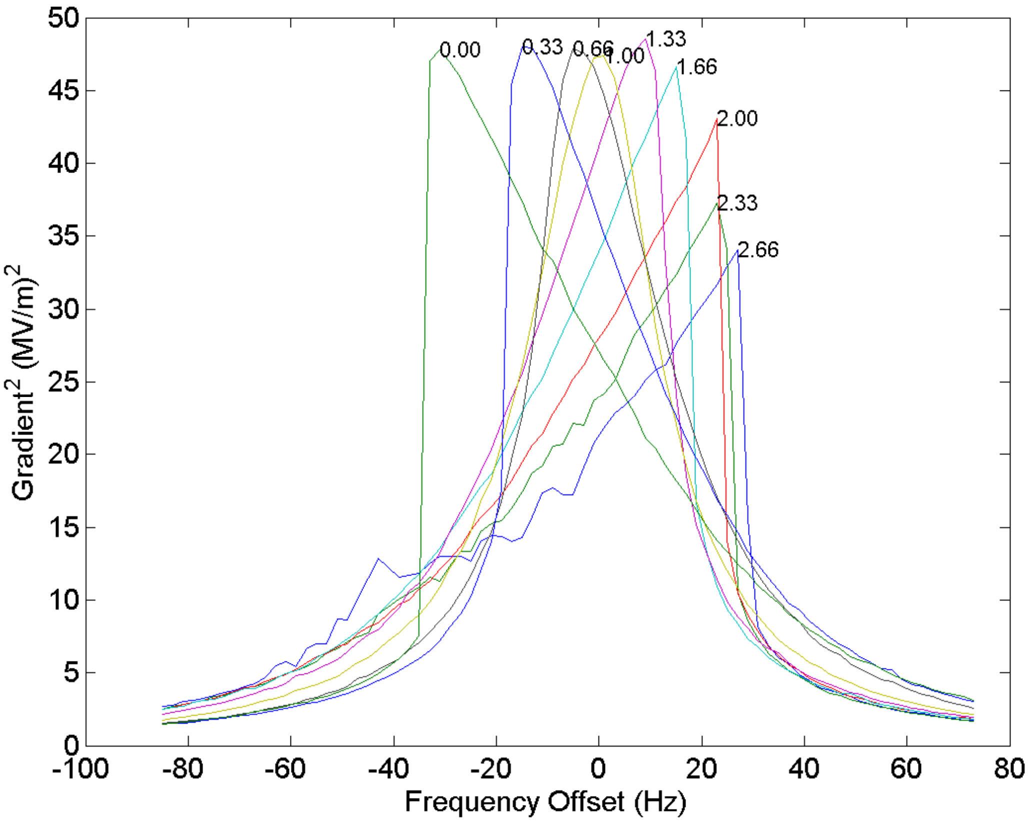
Ponderomotive Instabilities

- Lorentz force detunes cavity
- If detuning is more than several bandwidths cavities can become unstable
  - Small perturbations can cause the cavity field to suddenly crash to zero



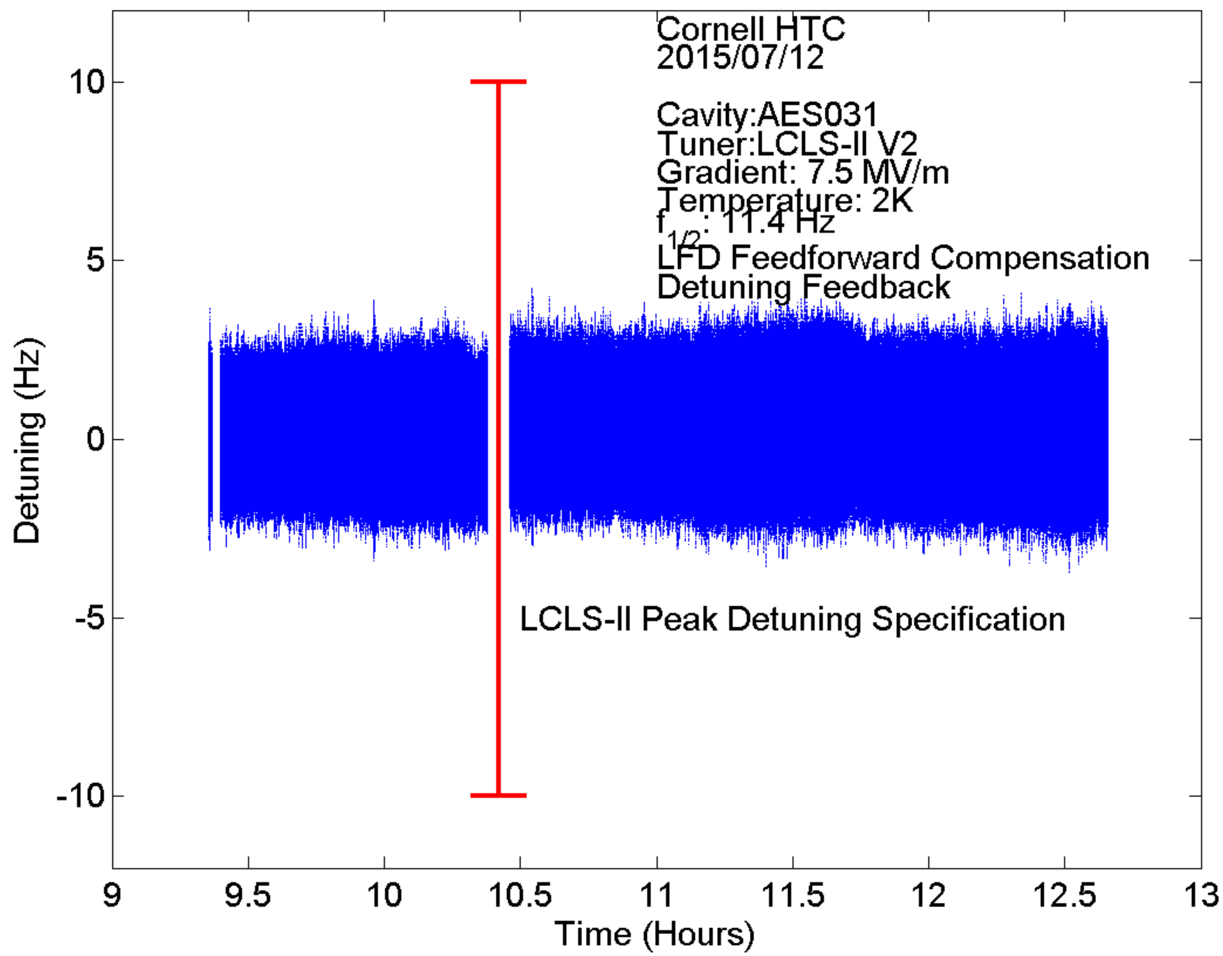
Feed-Forward LFD Compensation

- Possible to remove the instability using piezo feed-forward tied to cavity square of gradient
  - Previously shown for SSR1 spoke resonator
  - Now demonstrated for multi-cell elliptical cavities



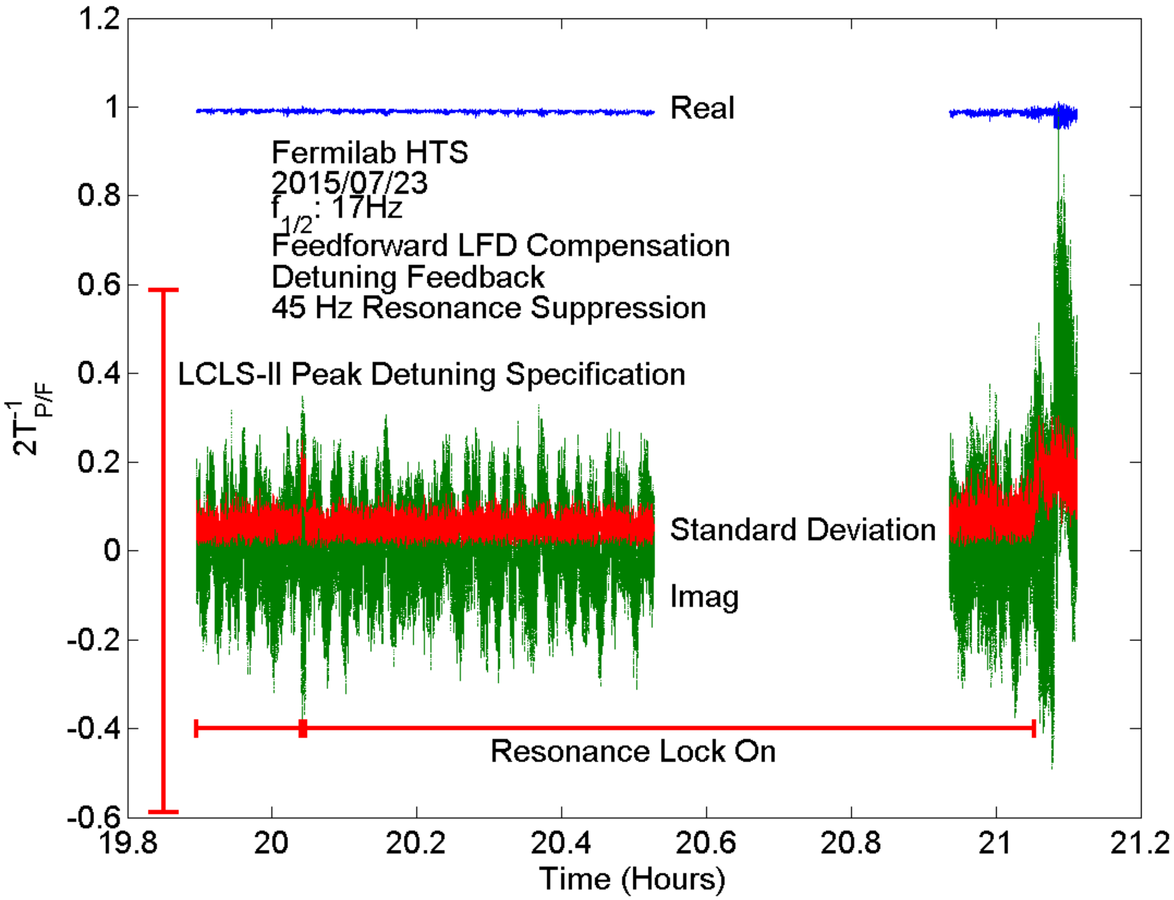
Cornell HTC

- Narrow bandwidth cavity
- Very stable cryogenic system
- Gradient lower than LCLS-II
  - HOM overheating
- 60 Hz component not yet understood



Individual Resonance Suppression

- Possible to suppress individual mechanical resonances
  - Apply band-pass filter to detuning
  - Feed filter output back to the piezo 180º out of phase



Looking Forward

- Large volumes of data collected over last several months will require time to fully analyze but initial assessment is positive
  - STC
  - Cornell HTC
  - Fermilab HTS
- Collected full cavity characterization data that can be used to construct realistic simulator (LBNL/Fermilab)
- Single cell cavity now installed in Fermilab VTS 3 will also facilitate development and testing of software and firmware
- Dynamic tuner performance successfully validated
- Still features in the data that are not fully understood
- Still serious concerns about test time available
  - May already be too late to feed results back into design
  - Only limited resonance control capability likely to be available during upcoming cryomodule tests

Conclusion

- Controlling microphonics requires optimization of the entire machine design
  - Active compensation will be required but
  - Active compensation alone may not be sufficient
- Tuner dynamic performance successfully validated
- Ponderomotive instabilities successfully controlled using feed-forward piezo compensation in both spoke resonators and in multi-cell elliptical cavities
- Cavity resonance frequency successfully stabilized the against helium pressure variations in both Cornell HTS and Fermilab HTS
- Individual cavity resonance line successfully damped using filtered feed-back
- Considerably more work required before work on prototype production active compensation systems could even commence
- Continued progress requires access to cold cavities for further testing
  - No cavity ⇔ No Progress
  - Cold cavity ⇔ Progress