Lorentz Force Detuning and Microphonics

RECENT PROGRESS AT FERMILAB CONTROLLING LORENTZ FORCE DETUNING AND MICROPHONICS IN SUPERCONDUCTING CAVITIES [1]

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Outline

- Overview
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- Helium Bath Pressure Control
- Microphonics Compensation
- References

Overview

- Superconducting RF cavities have thin walls (<= several mm) that can be distorted by:
  - forces from electromagnetic fields inside the cavity – Lorentz Force
  - Fluctuations of pressure in the surrounding helium bath
  - Mechanical vibrations driven by external sources
- More RF power is required to maintain the accelerating gradient as the cavity detunes changing the resonant frequency (increasing capital and operating costs).
- Piezo actuators can limit detuning to a small fraction of the cavity bandwidth

Lorentz Force Detuning Control

- Timing, amplitude, width and bias level of the piezo drive signal are chosen to cancel the detuning due to Lorentz Force
- Control algorithm
  - The measured response is used to automatically calculate an appropriate compensation waveform and adapt that waveform to changing cavity operating conditions
- Tailor the piezo drive waveform to the mechanical response of the cavity
- Tested: 9 cell 1.3GHz elliptical cavities with bandwidth ~200Hz

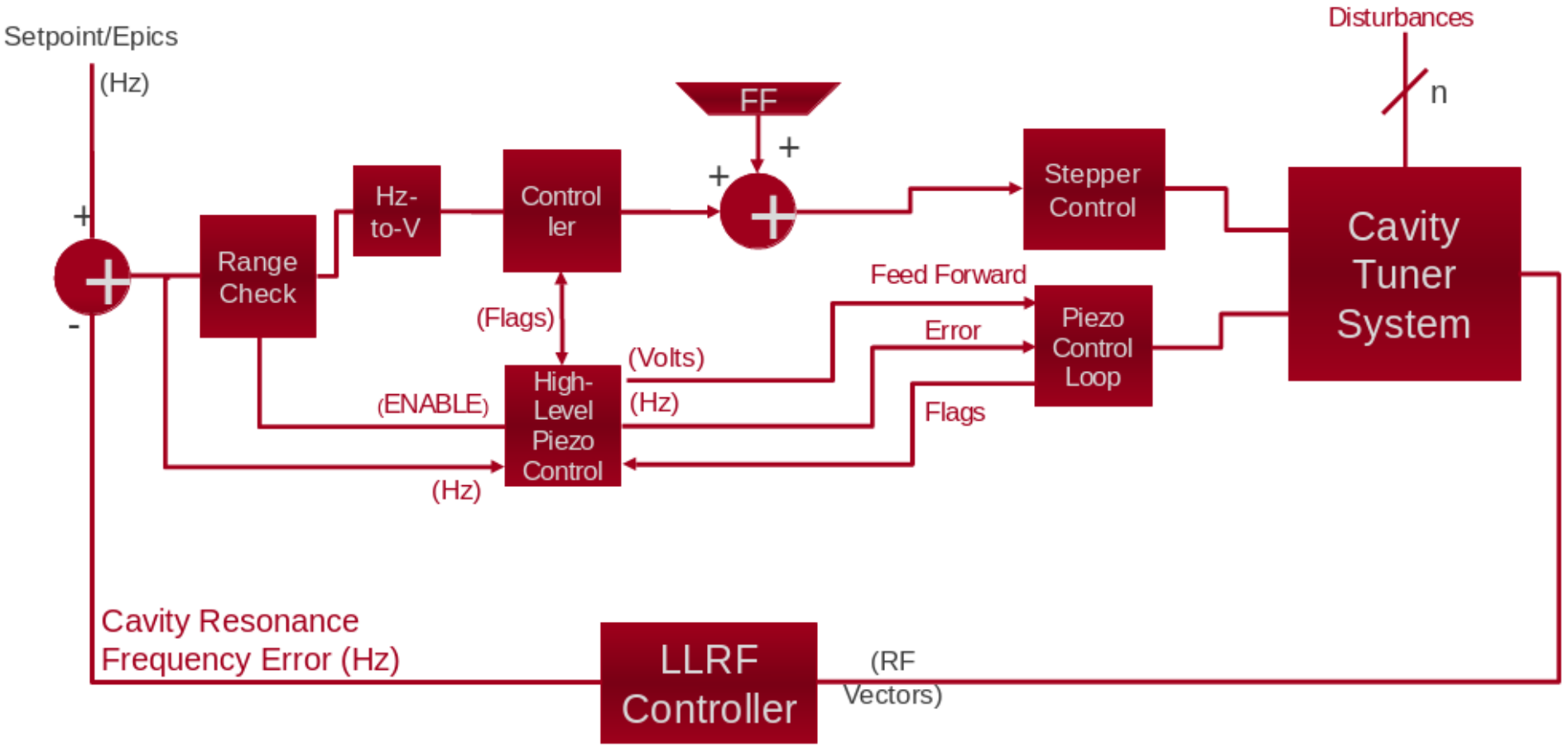
Lorentz Force Detuning Control

$$F_l(t) \propto E_{acc}^2(t) \longrightarrow \Delta f_l(t)$$

$$F_c(t) \longrightarrow \Delta f_c(t)$$

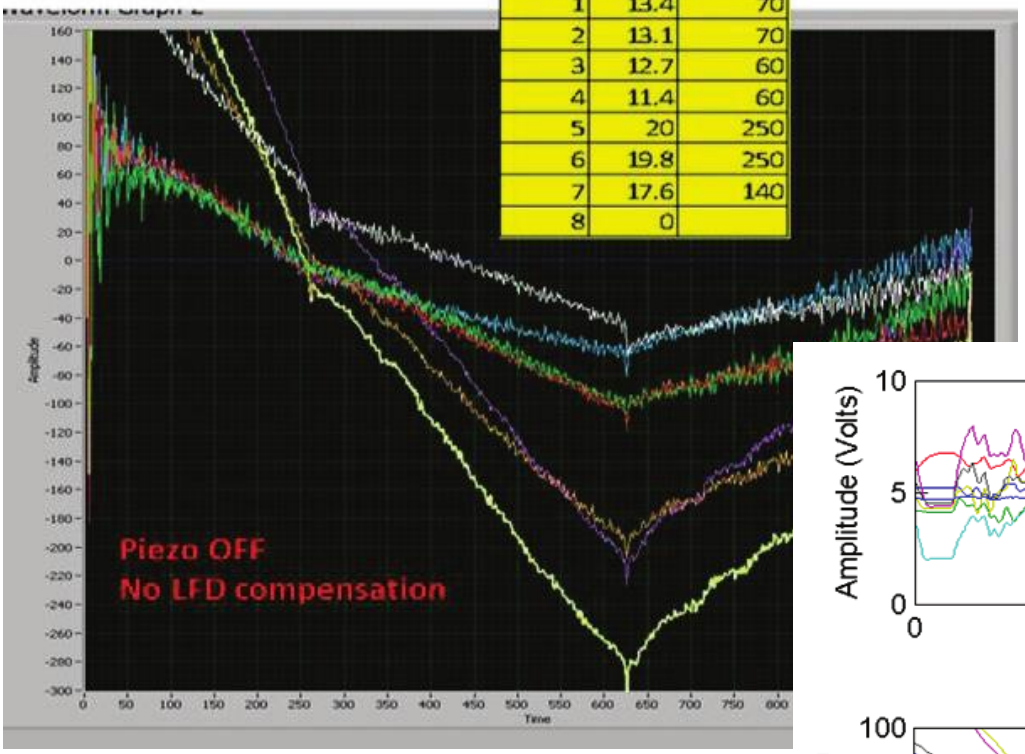
$$\Delta f_c(t) = -\Delta f_l(t)$$

Lorentz Force Detuning Control

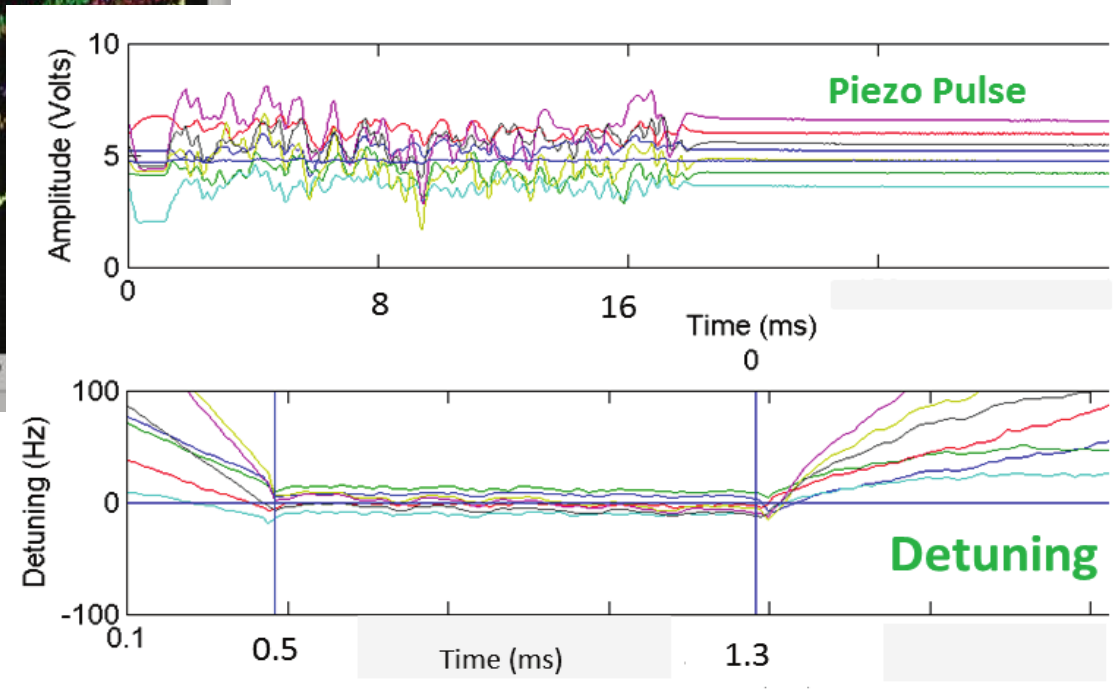


Lorentz Force Detuning Control

Cavity	Gradien	LFD_Flat
1	13.4	70
2	13.1	70
3	12.7	60
4	11.4	60
5	20	250
6	19.8	250
7	17.6	140
8	0	



Detuning of several hundreds of Hz

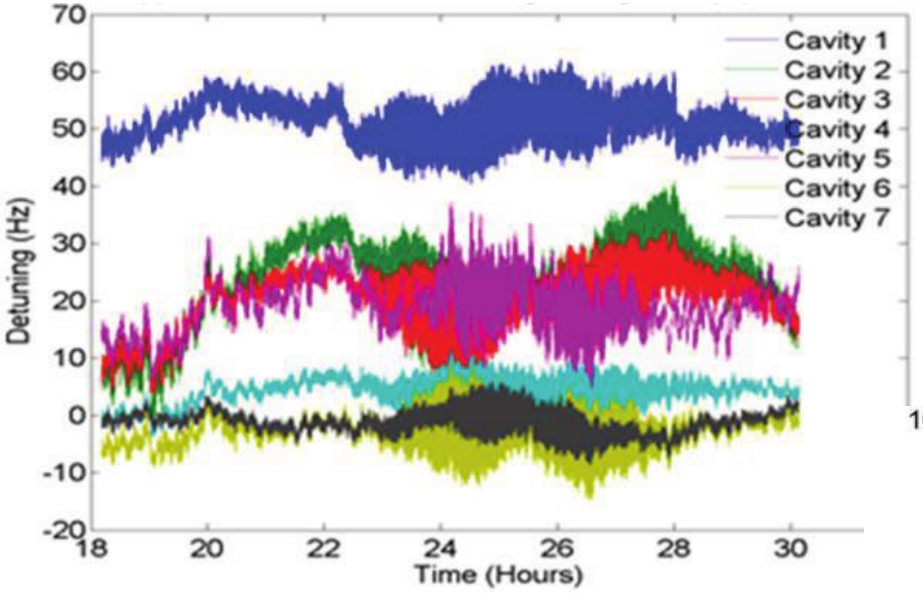


Control limits the detuning to ~10Hz

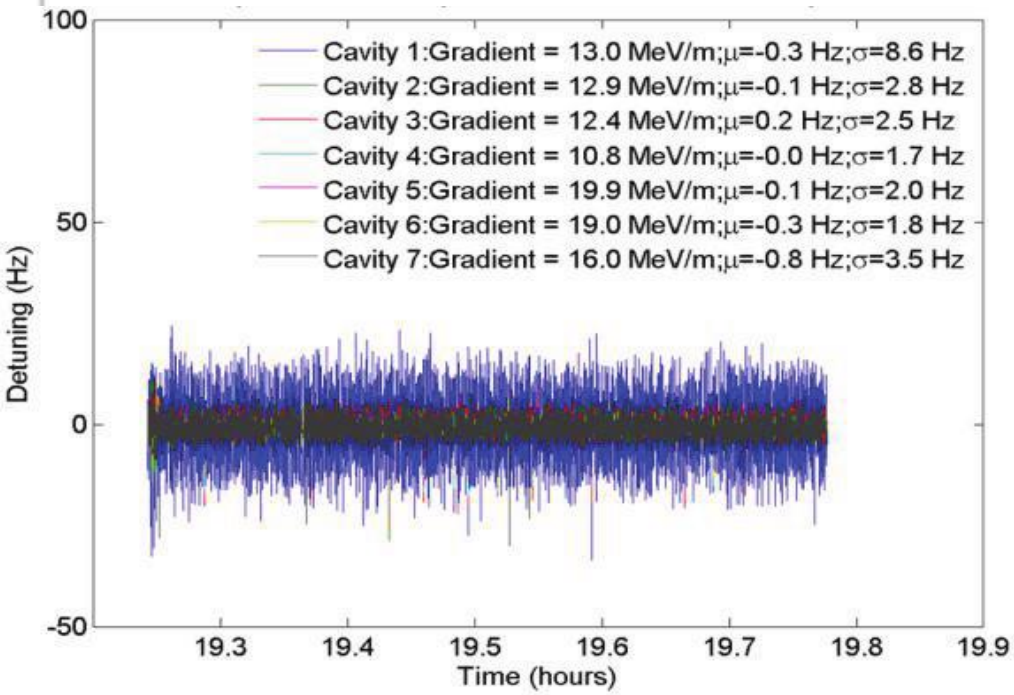
Helium Bath Pressure Control

- Monitor cavity resonance frequency
- Adaptively adjusts the DC bias on the piezo actuator

Helium Bath Pressure Control



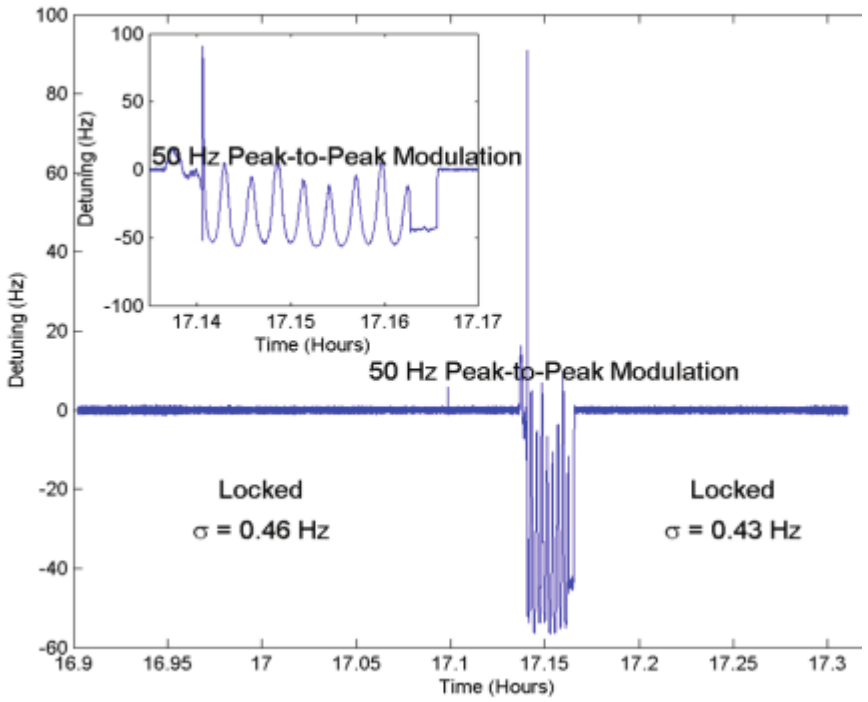
Cavity resonance frequency detuning of several tens of Hz

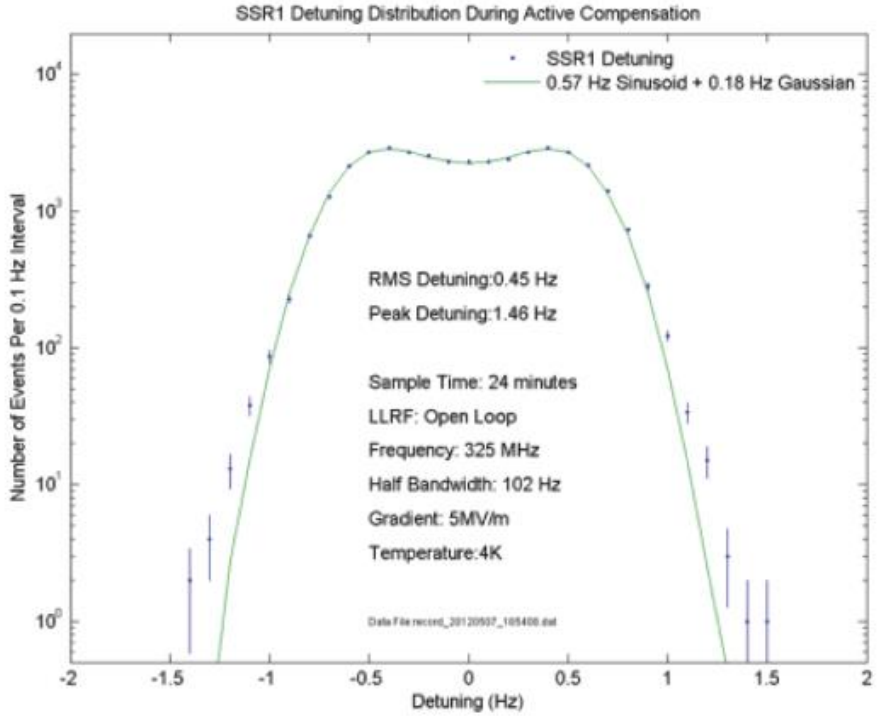


Control limits the long term drift to less than 1Hz

Microphonics Compensation

Control off: Cavity tracks the He bath pressure
Control on: RMS detunning 0.45Hz. Peak detunning 1.46Hz





References

[1] W. Schappert and Y. Pischalnikov, “Recent Progress At Fermilab Controlling Lorentz Force Detuning And Microphonics In Superconducting Cavities” IPAC 2013, Shanghai, China.
[2] L. Doolittle et al., “THE LCLS-II LLRF SYSTEM” IPAC 2015, Richmond, USA.
[3] M. Liepe et al., “Dynamic Lorentz Force Compensation with a Fast Piezoelectric Tuner” IPAC 2001, Chicago, USA.