ILC FAST TUNER R&D PROGRAM at FNAL

Status Report
CC2 Piezo Test Preliminary Results

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(on behalf of the FNAL FAST TUNER Working Group)
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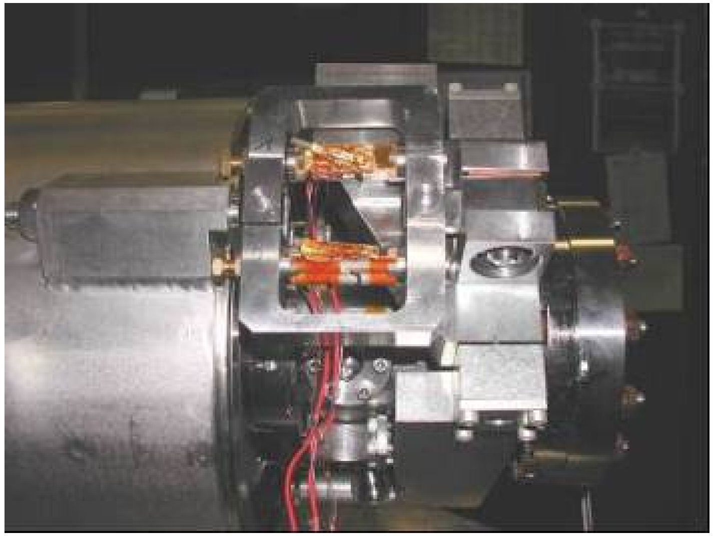
Outline

- CC2 Piezo Tuner
- Preload Changes Measurements
  - Interaction with stepping motor
  - During cooldown
- Static Piezo Tuning Range Test
- Cavity Mechanical Resonances Measurement
- Piezo Test as a Vibration Sensor (CW and Pulsed)
- Piezo Test as an Actuator (Detuning Compensation)
- Piezo Test as a Dual Device (Sensor+Actuator)
- Summary

CC2 Piezo Tuner: Problems and R&D Plan

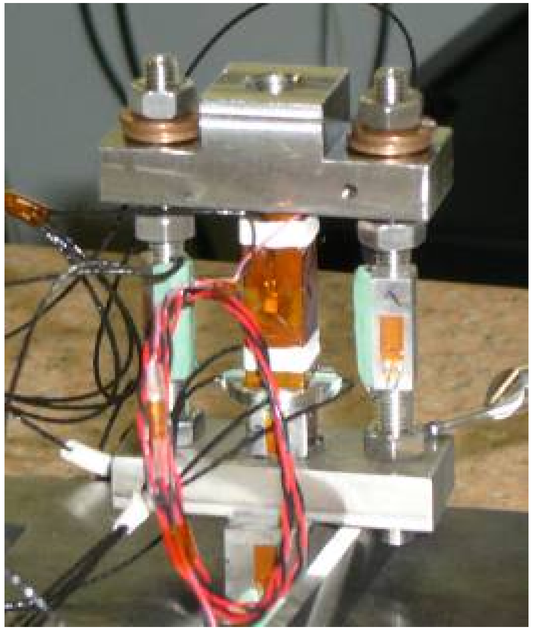


The current dual-piezo DESY bracket design does not work due to preload loss after cooldown and interaction with stepping motor action to bring the cavity to 1.3 GHz (excessive, unknown pulling force applied to piezo assembly)

The plan for CC2 test at SMTF is to go back to the simpler single-piezo DESY design, perform mechanical modeling, and add diagnostics instrumentation (strain gauges, RTD, capacitance measurements) to understand preload changes

CC2 Piezo Tuner
(showing diagnostics instrumentation)

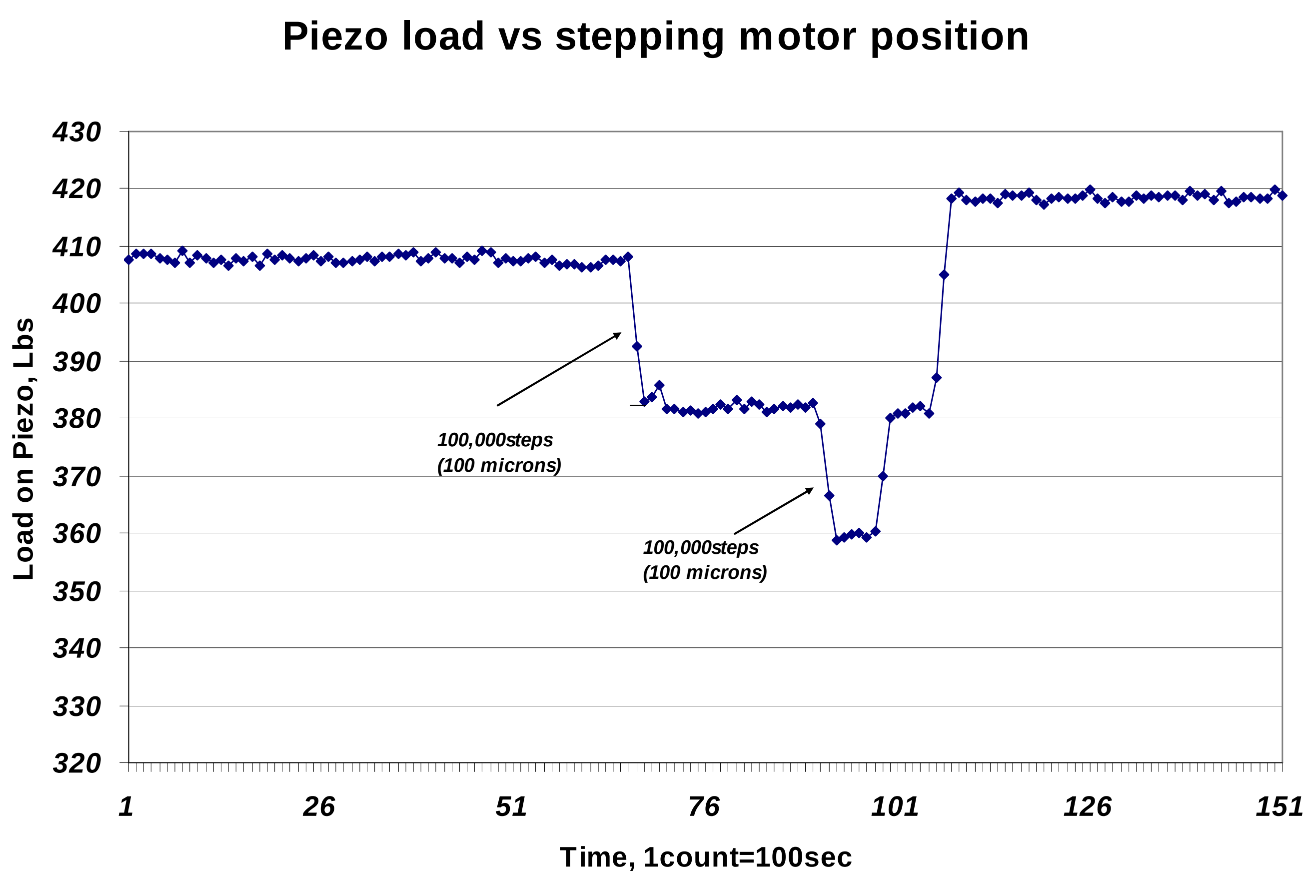
Calibrated "Bullet" Strain Gauge Sensor to measure preload changes during cooldown and stepping motor operation



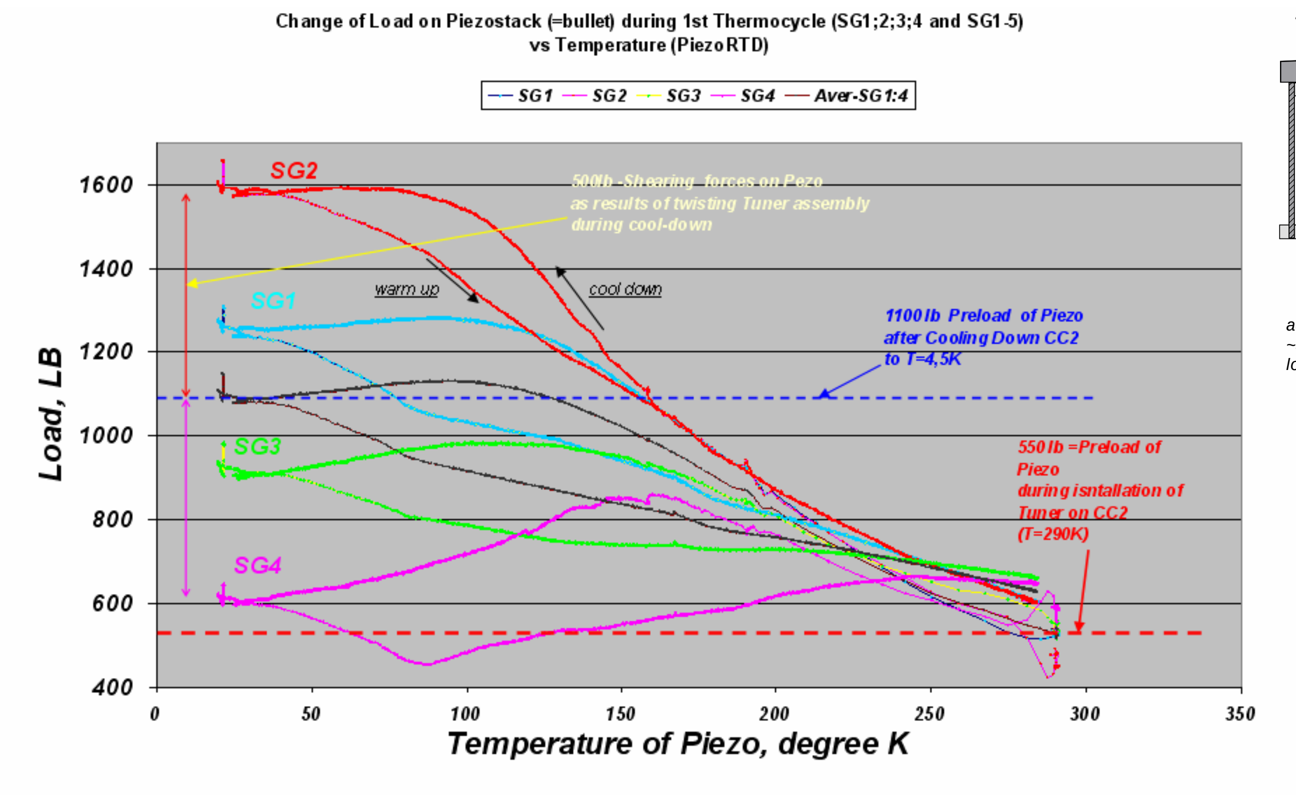
CC2 Piezo assembly instrumentation:

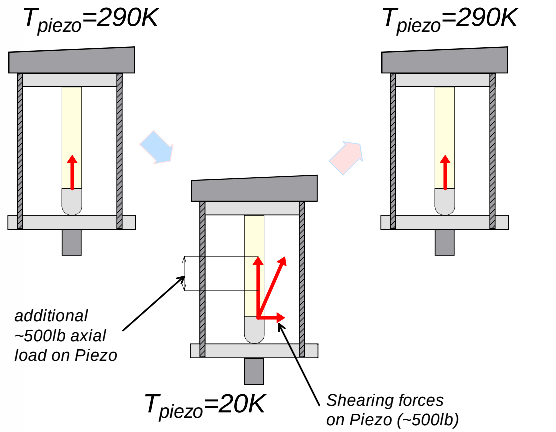
- **11 strain gauges**
- **2 RTDs**

Piezo Tuner Test –Preload Changes due to interaction with stepping motor (measured at room temperature only)

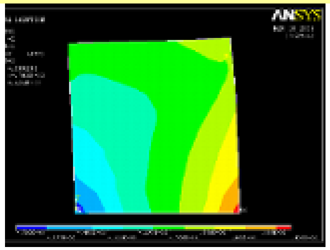


Piezo Tuner Test –Preload Changes During Cooldown

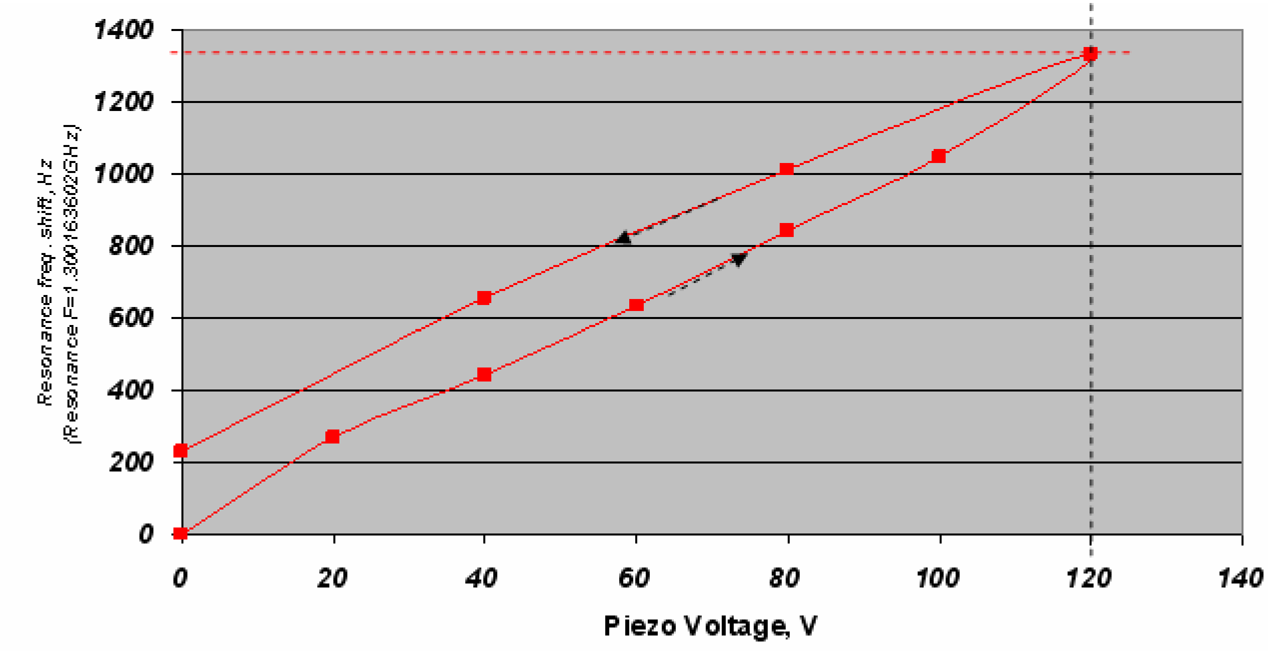




ANSYS model shows bullet deformation using SG readings input

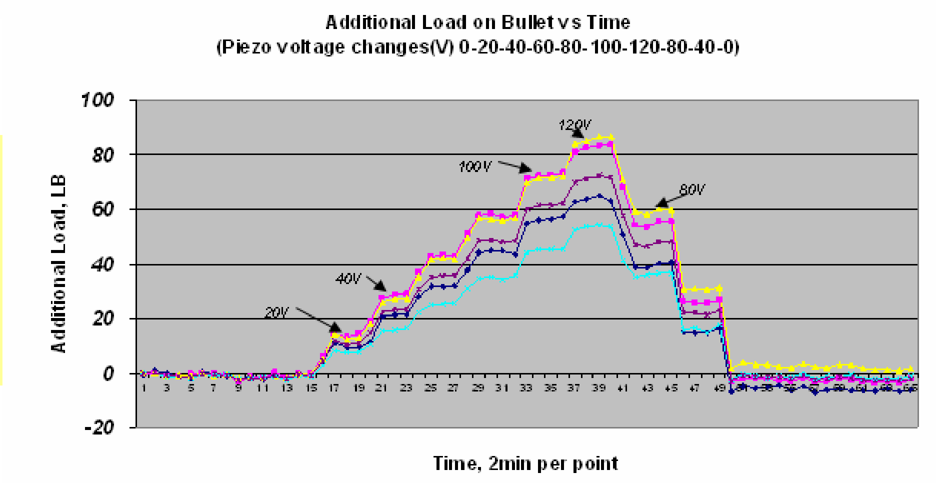


Piezo Tuner Test –Static Tuning Range



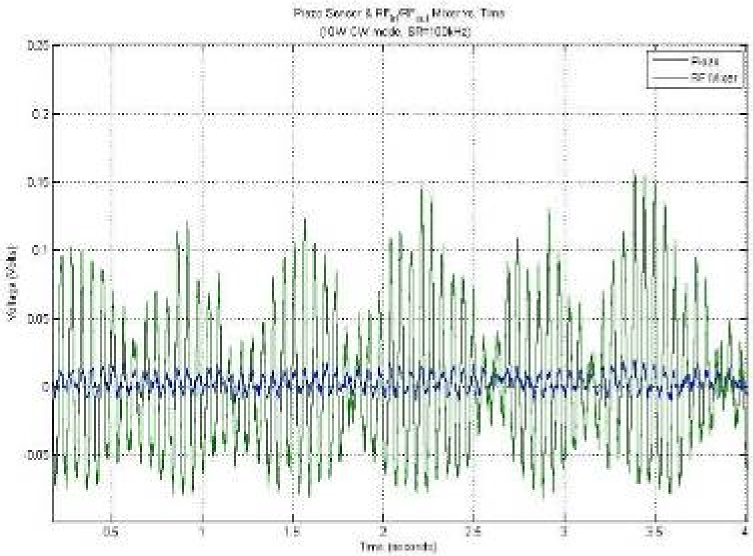
Cavity resonance frequency increase as a function of Piezo Tuner static voltage. Total static tuning range ~ 1300 Hz, corresponding to a CC2 length change of ~ 6.5 microns

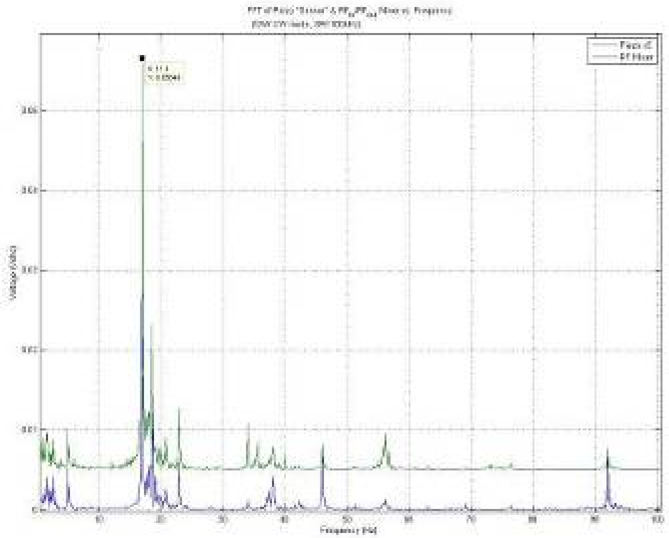
Piezo load increase for different piezo voltages measured by bullet strain gauges. The average increase for 120 Volts is ~ 60 lbs.



Piezo Test as a Vibration Sensor – CW mode

Piezo Tuner & RF Mixer Measurement of CC2 @10W CW Mode





There is a good correlation between the Piezo Tuner and the RF Mixer in the time domain.

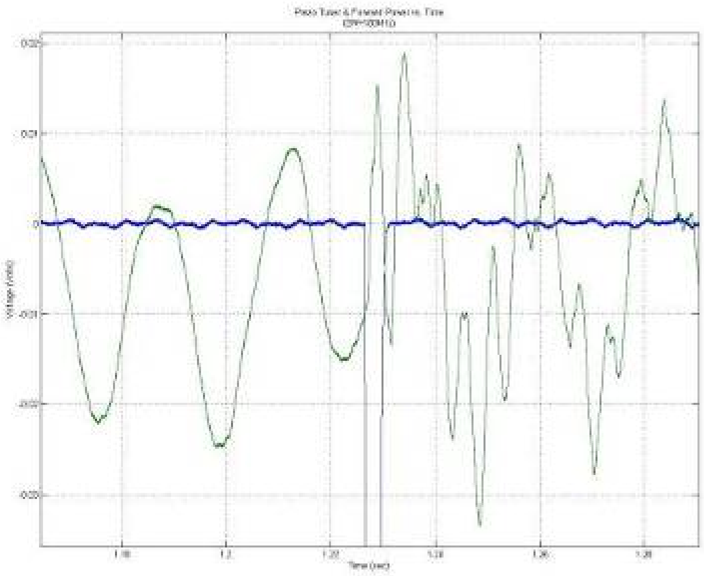
An FFT of the Piezo Tuner and the RF Mixer signals show close agreement in the frequency domain.

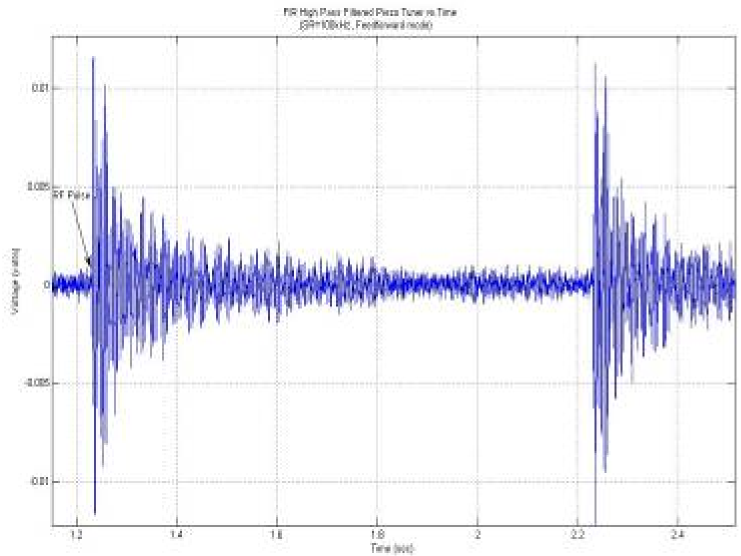
Piezo Test as an Actuator – Cavity Mechanical Resonances

- Cavity powered in CW mode (10 W)
- RF instrumentation provided to continuously monitor cavity detuning
- Piezo tuner was driven with a sinewave
- Sinewave frequency swept between 1 Hz and 400 Hz at constant amplitude
- **Two strong mechanical resonances detected: ~ 180 Hz and ~ 220 Hz.**
- At these resonance frequencies, vibrations could be felt on the cryostat outer shell!

Piezo Test as a Vibration Sensor – Pulsed mode

PIEZO TUNER RESPONSE & FORWARD POWER OF CC2 IN FEEDFORWARD MODE



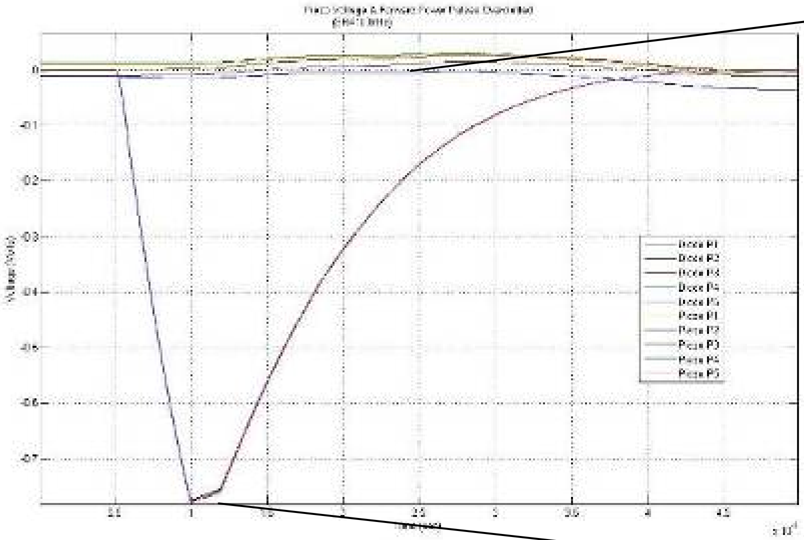


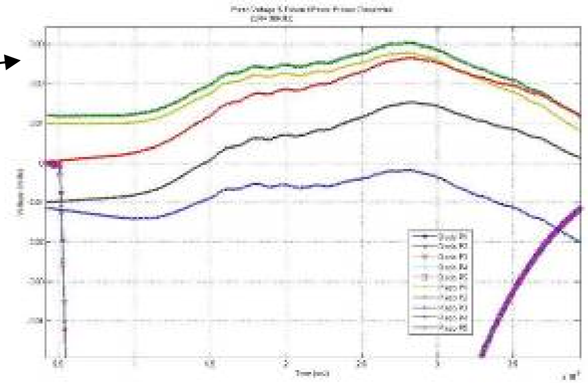
A close-up of the piezo response shows a ~42Hz oscillation just before the RF pulse occurs. The pulse excites a main cavity mechanical resonance of ~ 180 Hz.

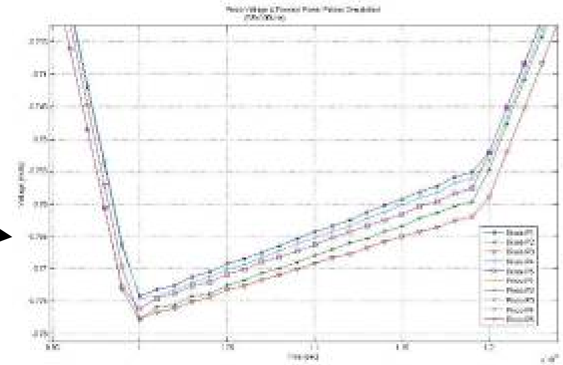
The Piezo Tuner data is filtered with a high pass FIR filter to remove <150Hz noise. The decay of the 180Hz cavity vibration after the RF pulse is ~0.7sec.

Piezo Test as a Vibration Sensor – Pulsed mode

PIEZO TUNER RESPONSE & FORWARD POWER OF CC2 IN FEEDFORWARD MODE

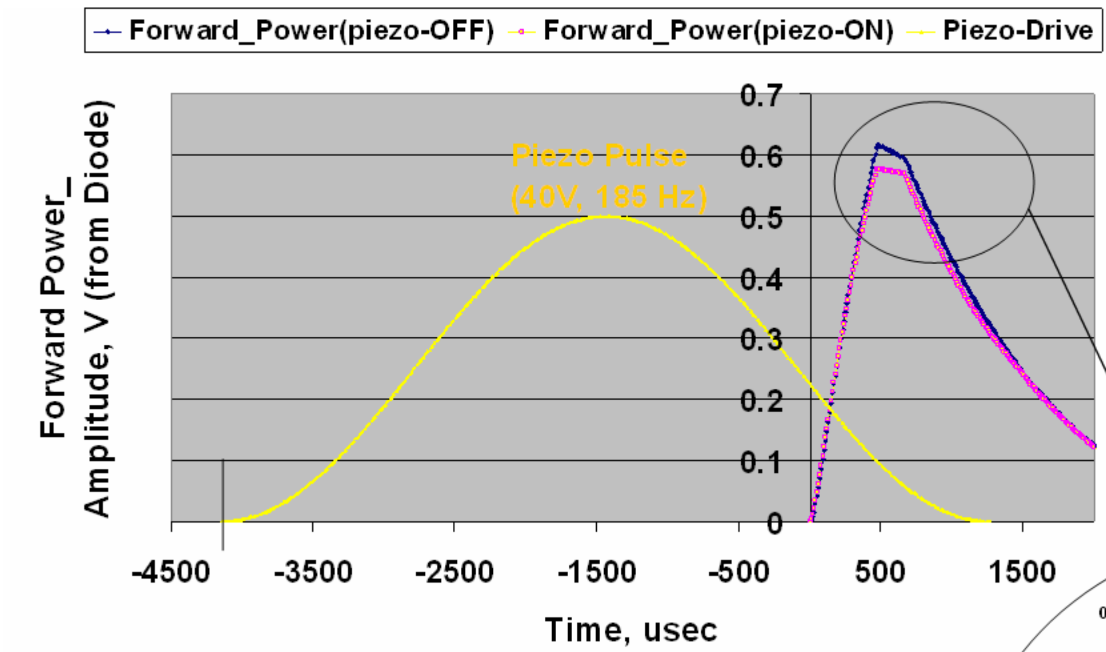






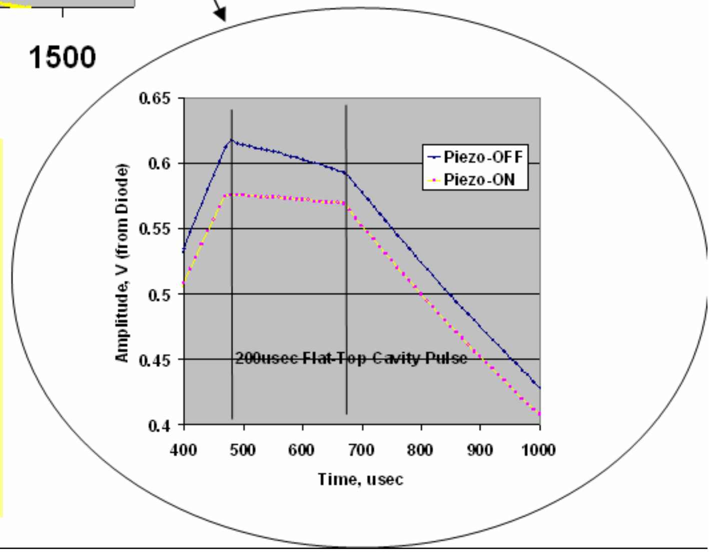
The Piezo Tuner and Forward Power data during the RF pulse of five pulses are over-plotted.
The spread of the cavity responses are due to the 42Hz vibration. Good correlation between the spread of forward power measured by the diode detector and the cavity response measured by the Piezo Tuner.

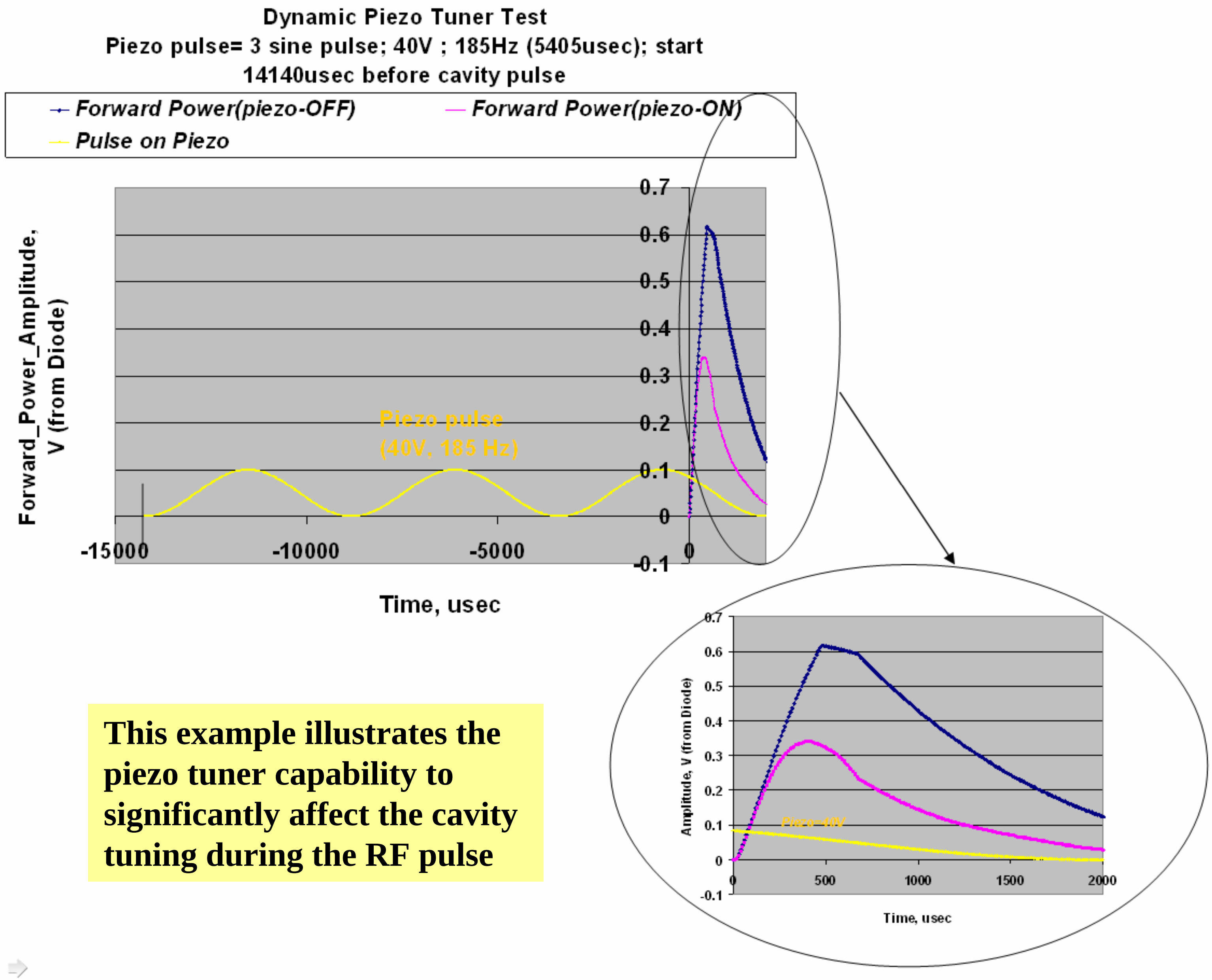
Piezo Test as an Actuator – Detuning Compensation



Cavity gradient was only ~ 15 MV/m → not enough Lorentz force detuning. Therefore, an artificial slope was introduced by the LLRF system and we attempted to compensate it with the piezo.

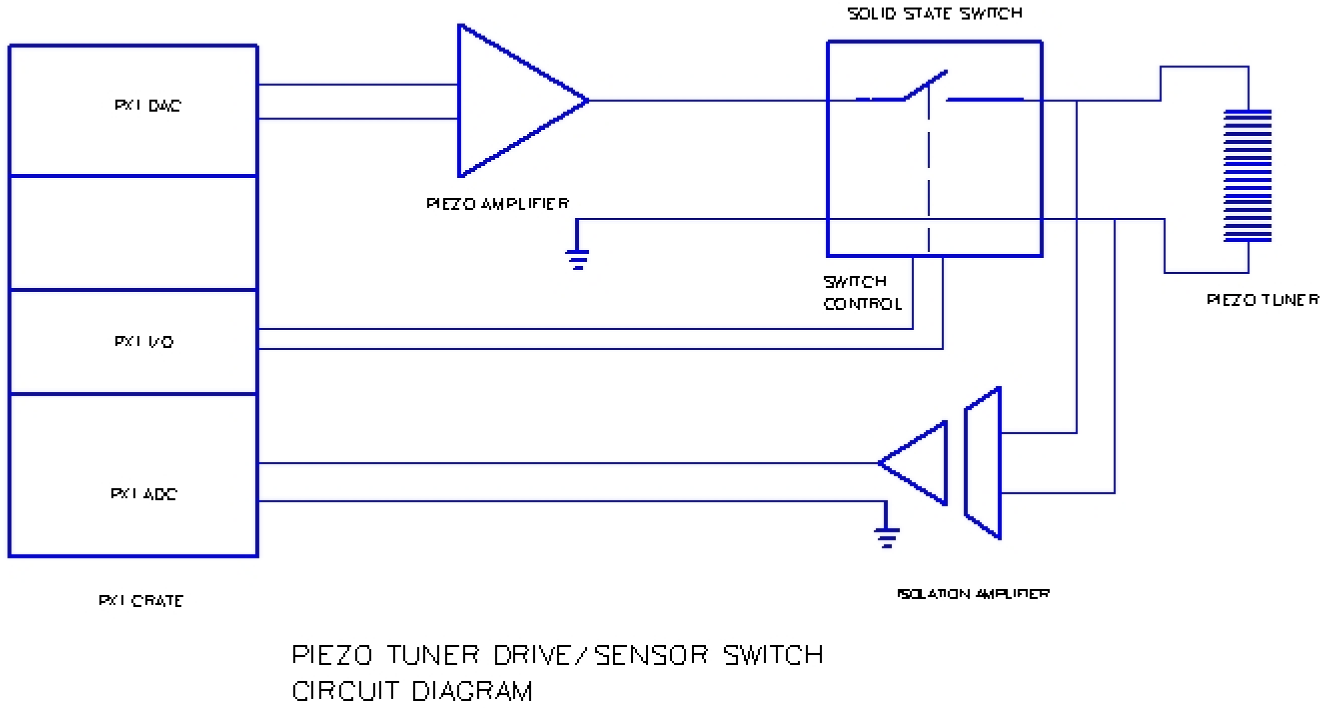
By pulsing the piezo, and manipulating the pulse amplitude, frequency, and phase it was possible to change the flat top slope and approximately correct for the artificial detuning. We only had a few minutes to perform this test! Further optimization possible by changing the piezo pulse amplitude, frequency, and phase.





This example illustrates the piezo tuner capability to significantly affect the cavity tuning during the RF pulse

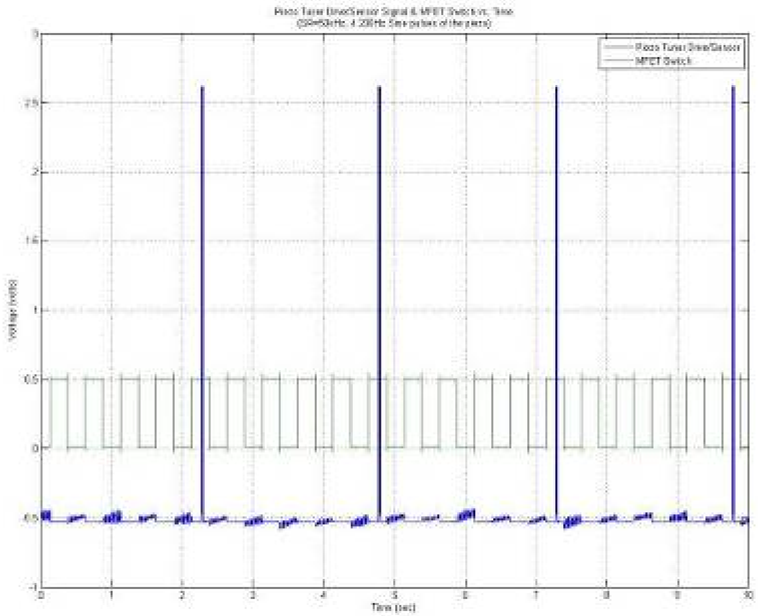
Piezo Test as a dual device: sensor + actuator



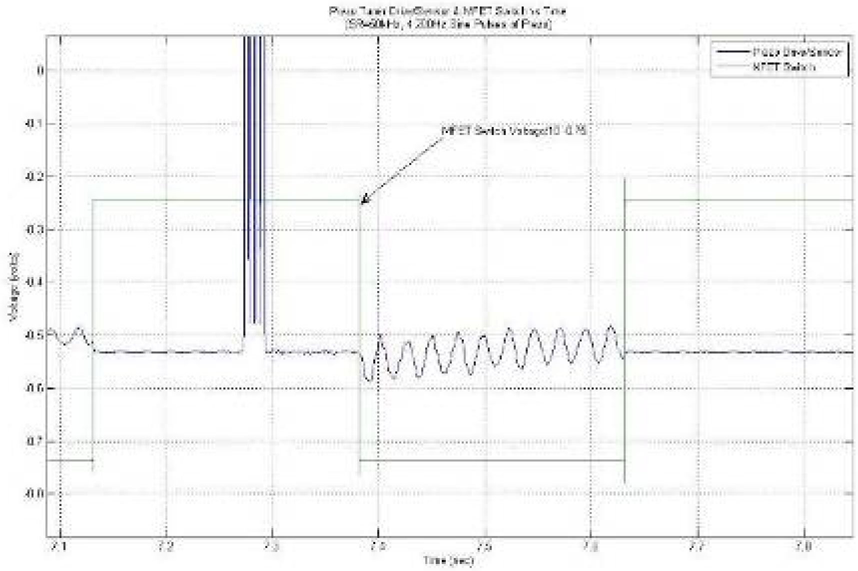
The Piezo device is periodically switched from Actuator Mode to Sensor Mode using a solid state switch operated with a square wave at 2 Hz. In the tuner mode the Piezo is pulsed at 200Hz for 4 cycles.

Piezo Test as a dual device: sensor + actuator

Piezo Switched Between Cavity Tuner and Sensor



This plot shows the solid state switch open and close signal (in green) plus the voltage from the piezo (in blue). Piezo is in actuator mode when the switch signal is high, and in sensor mode when it is low.



A close-up of the Piezo signal with the solid state switch shows the 4 200Hz cycles when in Tuner mode, and then a smooth transition to the sensor mode where it is measuring the cavity vibration. The 42 Hz microphonics component can be clearly seen when the piezo functions as a sensor.

Summary

- We have a working piezo tuner in CC2
- The bullet strain gauge instrumentation was successful in measuring piezo preload changes and bending forces during cooldown
- The static piezo tuning range is 1,300 Hz (~ 6.5 microns of cavity motion)
- Two strong mechanical resonances were identified by driving the cavity with the piezo: one around 180 Hz, and the other around 220 Hz.
- A strong ~ 42 Hz microphonics component was detected by both the piezo and the RF system. This microphonics component was not always present, and its source has not been identified yet.
- There is good correlation between piezo vibration measurements and CW RF detuning
- In pulsed RF mode, the piezo signal clearly shows excitation of the 180 Hz mechanical mode, which takes about 0.7 seconds to decay.
- Pulsing the piezo just before the RF pulse showed that the piezo is capable of changing the flat top slope. Unfortunately, the gradient was not high enough to have significant Lorentz force detuning. However, the potential of the piezo tuner to compensate was demonstrated. Also, driving the piezo with multiple pulses near a mechanical resonance shows a large tuning effect caused by the piezo action during the RF pulse.
- A promising method of using a solid state switch to quickly toggle the piezo function as sensor or actuator was demonstrated. This method could offer additional possibilities of using the piezo for microphonics and Lorentz force detuning compensation.
- More piezo testing is being planned for the next CC2 cooldown to 1.8 K.