CC2

as unique (for FNAL)

testing facility for

"SCRF Cavities Resonance Control Tasks"

Brief Summary of CC2 test

from

Resonance Control Group

Presented by

Y.Pischalnikov & W.Schappert

CC2 Test Objectives

- To Develop and Test (with real cavity) Prototype Resonance Control System for NML Cryomodule#1 facility:
  - » Hardware
  - » Firmware
  - » Software
  - » Control Algorithms
- To Gain experience to control Resonance of SCRF cavity working with Eacc up to 28MV/m
- Give "a real life stress-test" to different CC2/HTS subsystem (LLRF, HLRF, Cryo, etc…)
- To perform tests (collect data) for future SCRF cavity projects (HINS,…)

Two System Developed, Commissioned and Tested with Real Cavity (CC2)

- First System is Prototype of NML CryoModule#1 Piezo Control System:

  Phase Detector System based on I/Q demodulator (AD8333 chip) + NI PXI ADC (as data logger) + NI PXI FPGA (as Piezo stimulus DAC) +NI PXI Processor (LabView + FPGA Module)

- Second System is Resonance Control R&D System:

  Lyrtech Fast ADC (104 MHz) as a Phase Detector+ NI PXI ADC (as data logger) + NI PXI FPGA (as Piezo stimulus DAC) +NI PXI Processor (LabView + FPGA Module+VHDL)

Resonance Control Goal:

Control SCRF Cavity Resonance Frequency
at 1.3GHz within +/-10Hz
during 800us FLAT-TOP part of RF pulse.

(This is simple-just to control length of 9-cell (1m long) cavity within +/- 3nm)

1. Lorentz Force Detuning (LFD);

2. Microphonics Detuning:

Residual (from previous RF pulse) Cavity Vibration (5Hz (10Hz?)repetition);

Cryo-system induced fluctuation

LiqHe bath pressure fluctuation (4K (HINS) & 2K) (10s mHz)
Mechanical vibration trough cryo-piping (~10s Hz)

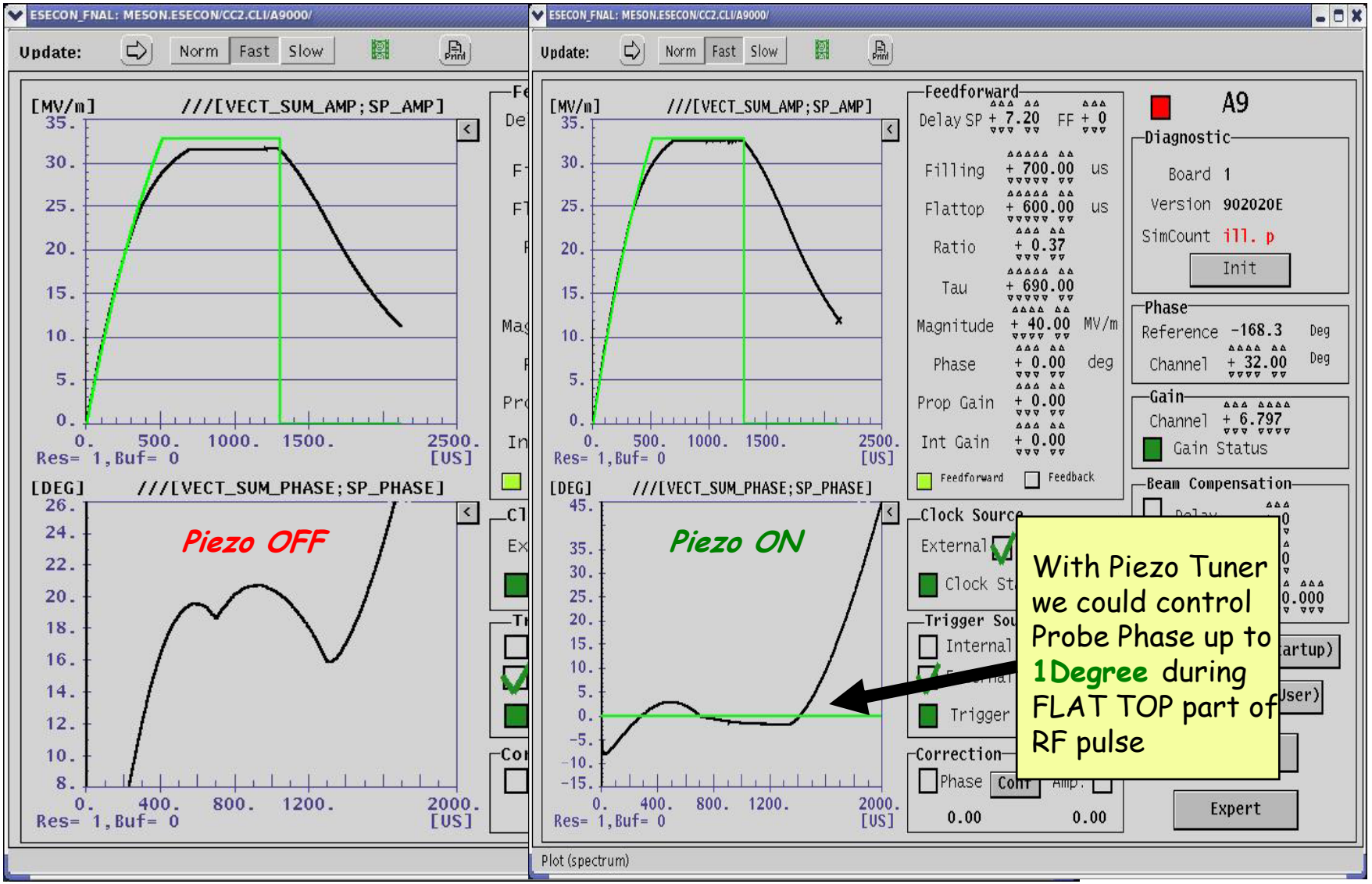
Mechanically induced fluctuation

Pumps, motors, etc. (~1-30Hz)

Summary of CC2 Tests Accomplishments

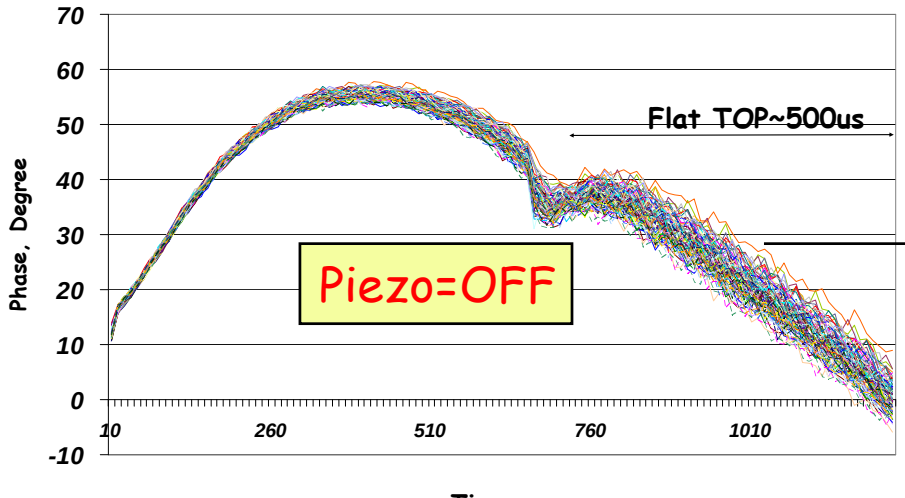
- **Lorentz Force Detuning Compensation**
  - Worked with Open & Close loop cavity control (RepRate=1-5Hz);
  - With Eacc = 27MV/m and RepRate=5Hz continuously (~72Hours) run cavity with LFD compensation ;
  - Study in-details compensation algorithm with "standard" sine-wave stimulus Piezo pulse;
  - Developed newest algorithm with "optimized" stimulus Piezo pulse;
  - Developed algorithm for automatic pre-detuning of cavity during LFD compensation procedure;
  - Used technique for on-line calculation LFD during RF pulse.
  - Implement technique to correct Phase and Amplitude of Forward Power (taking into account contamination from Reflected Power)

CC2 LFD Compensation
Eacc=27MV/m RepRate=5Hz Open Loop

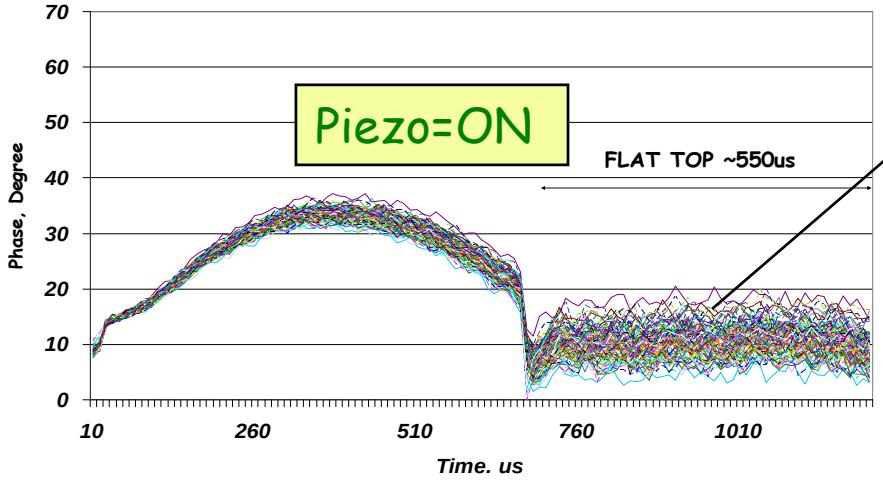


CC2 LFD Compensation
Eacc=27MV/m RepRate=5Hz Close Loop

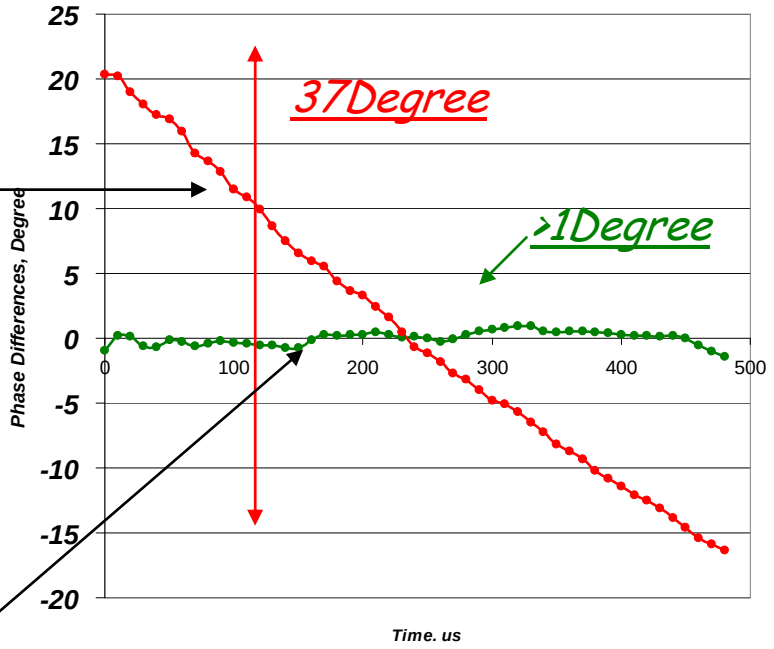
Ph(Forw)-Ph(Probe) during RF pulse



Ph(Forw-Ph(Probe) during RF Pulse



Phase(Probe-Forward) during Flat Top of RF Pulse vs time

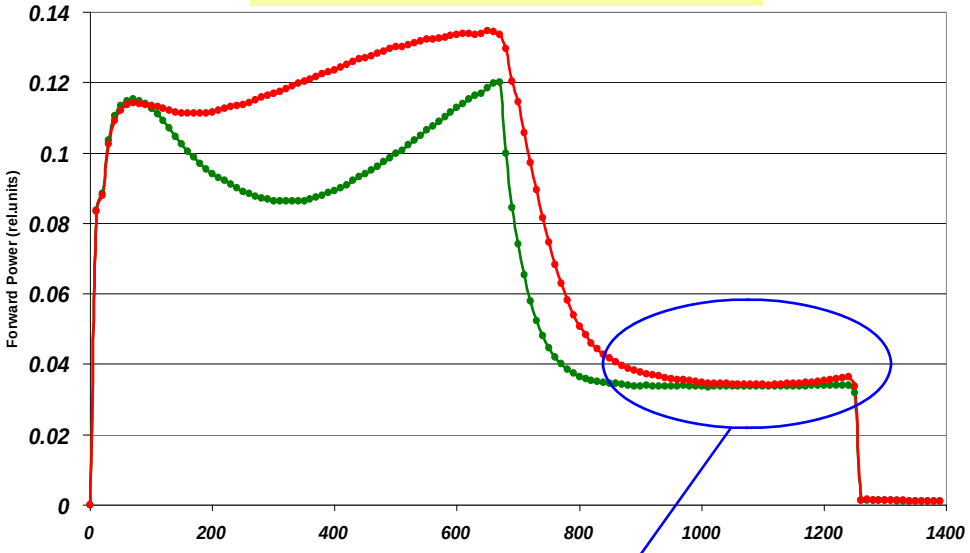


Compensation of LFD during Flat Top (500us) From 165Hz to 4Hz

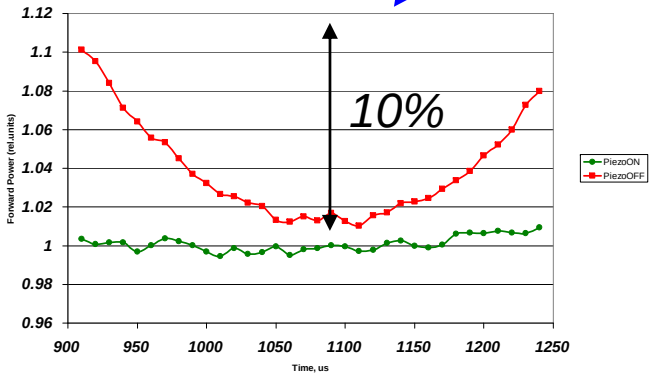
1Degree~4Hz

CC2 LFD Compensation
Eacc=27MV/m RepRate=5Hz Close Loop

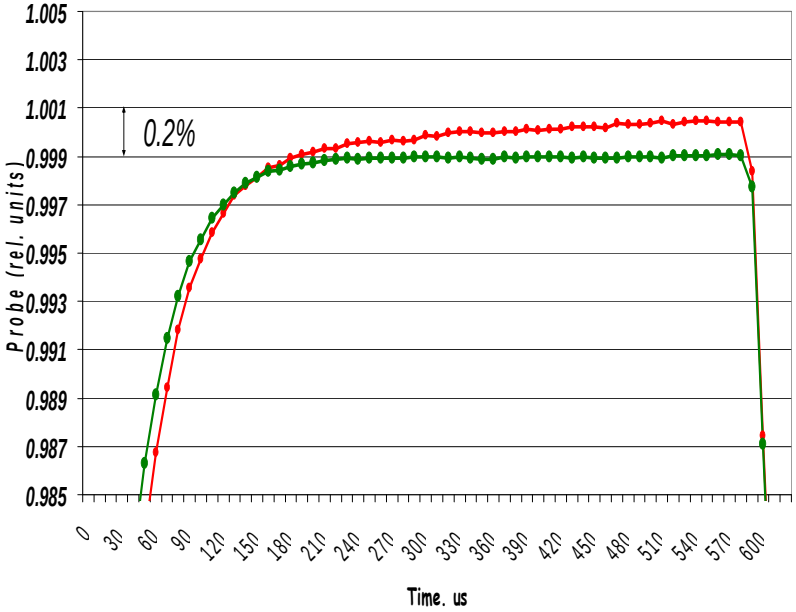
Forward Power during RF pulse



Forward Power during last 350us of FlatTop



Probe Power during RF pulse



Issue:
Contamination of Forward Power signal (Amplitude and Phase) with Reflected Power must to be taking into account

CC2 LFD Compensation results

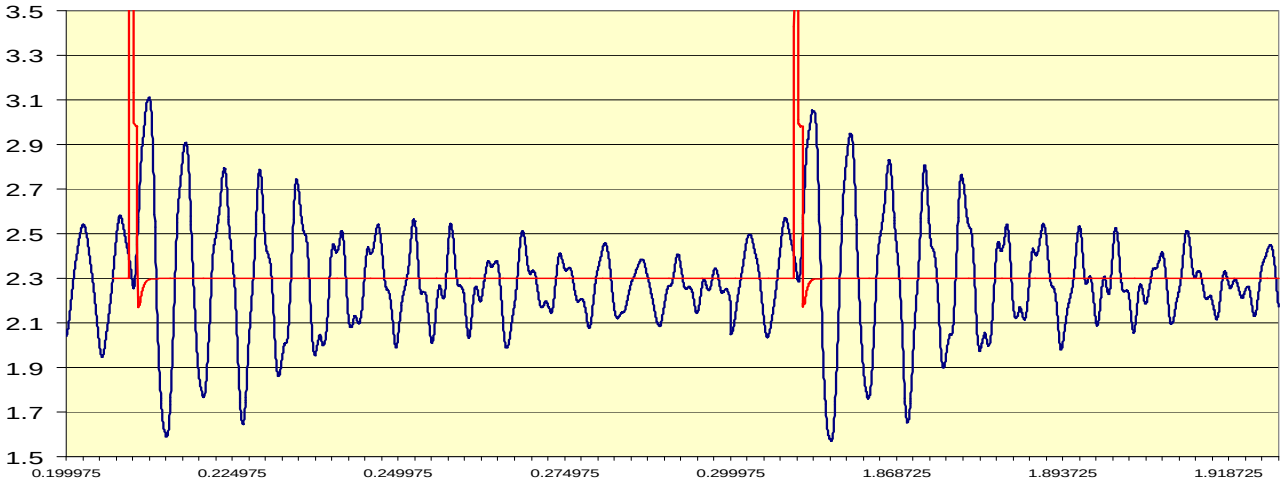
- Our LFD Compensation System could control (flatness) Resonance frequency of SRF Cavity (running at Eacc>27MV/m) within 4 Hz during FLAT TOP part of RF Pulse.
  - *(FF for Piezo Stimulus Pulse and FB for Piezo Bias Voltage to pre-detune cavity during LFD compensation + slow change of Resonance (pressure?))*
- Only **30%** (36V) of all range of Piezo Voltage (120V) has been used for CC2 running at 27MV/m .
- *Residual vibration of CC2 (when it run at RepRate=5Hz) contributed to overall stability of SRF Cavity (see below)*

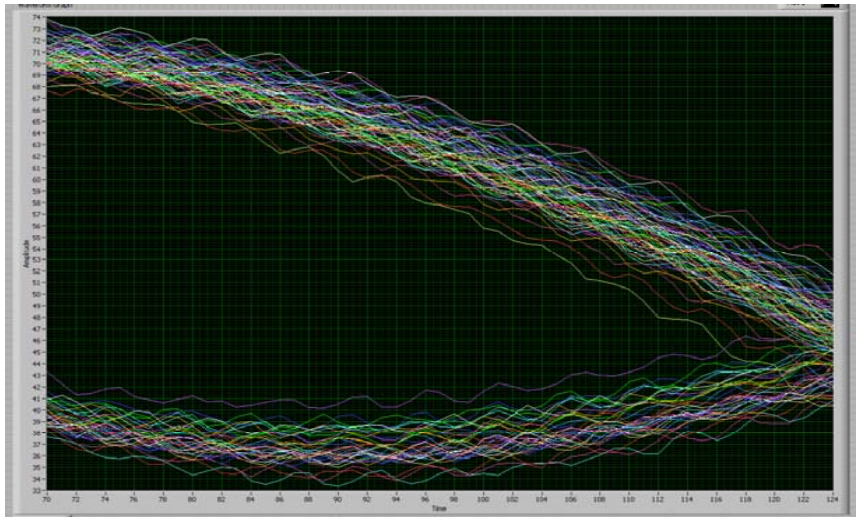
Summary of CC2 Tests Accomplishments

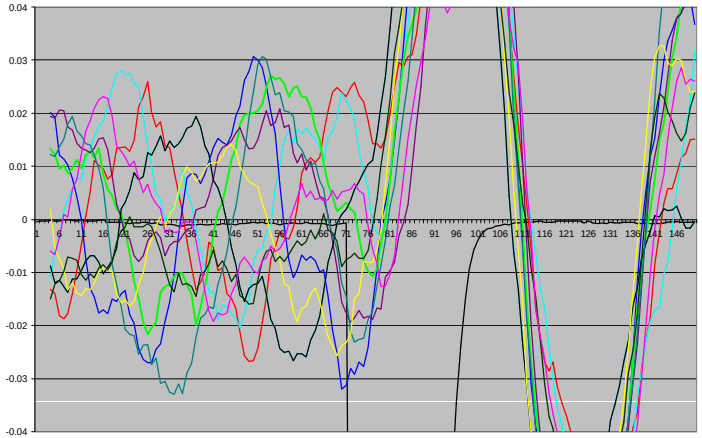
- **Microphonics Detuning Compensation**
  - Study effect of Cavity Residual Vibration on Resonance Stability at different repetition rates ;
  - Compensation of Cavity Resonance shift from He Gas pressure fluctuation (4K) & 2K – Slow Control of DC Voltage on Piezo ;
  - Up to 15db compensation for persistent mechanical vibration (range 10-200Hz) at CW mode;
  - Compensation of microphonics "between RF pulses" using Accelerometers as an error signal;

Microphonics

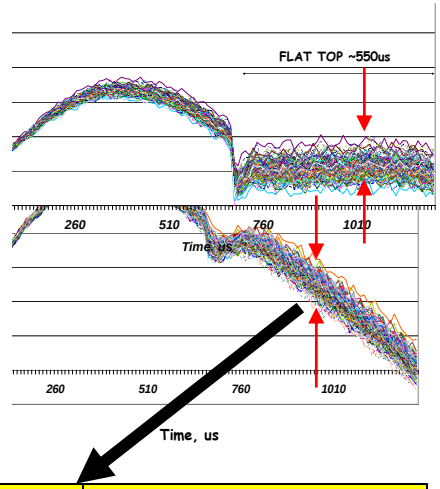
Effect of Cavity Residual Vibration on Resonance Stability at different repetition rates



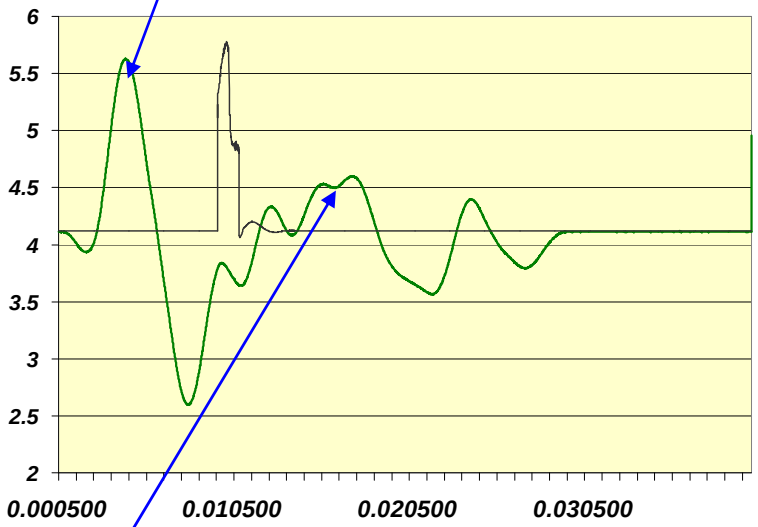




Standard vs Optimized Piezo Stimulus Pulse



LFD compensation part of Piezo Pulse



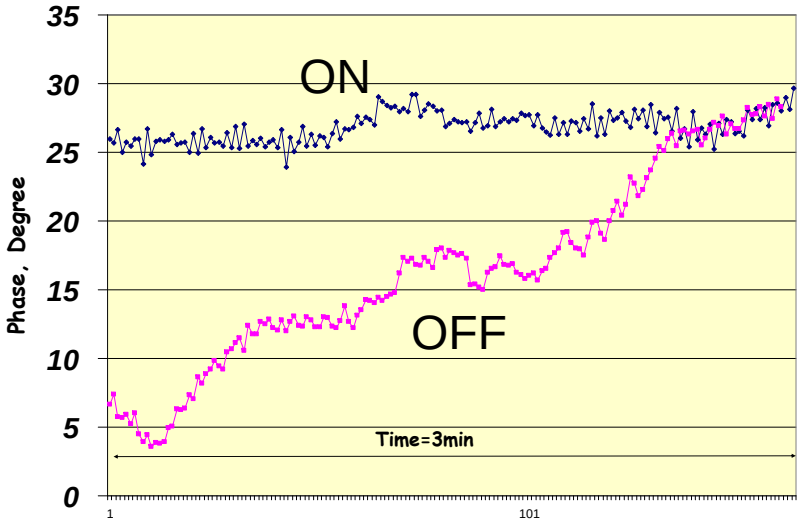
Residual Vibration compensation part of Piezo Pulse

		RepRate=1Hz	RepRate=5Hz
Piezo OFF		σ=5 Hz	σ=12 Hz
Piezo ON	Standard Pulse		σ=12 Hz
Piezo ON	Optimized Pulse		σ=8 Hz

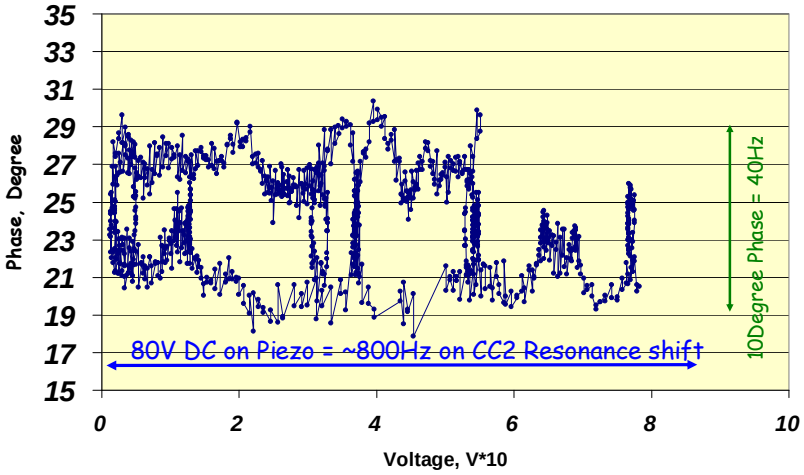
Microphonics

Compensation of Cavity Resonance shift from He Gas pressure fluctuation (4K) & 2K FB loop regulate Piezo DC bias (100Vpiezo=1000Hz); for SSR1-HINS Cavities

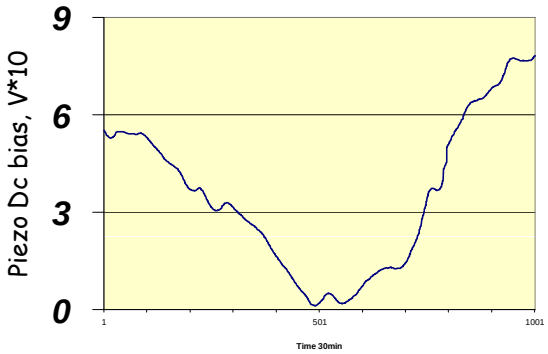
CC2 Phase VS time with/without FB loop



Cavity Phase VS DC bias on Piezo (on FB loop)

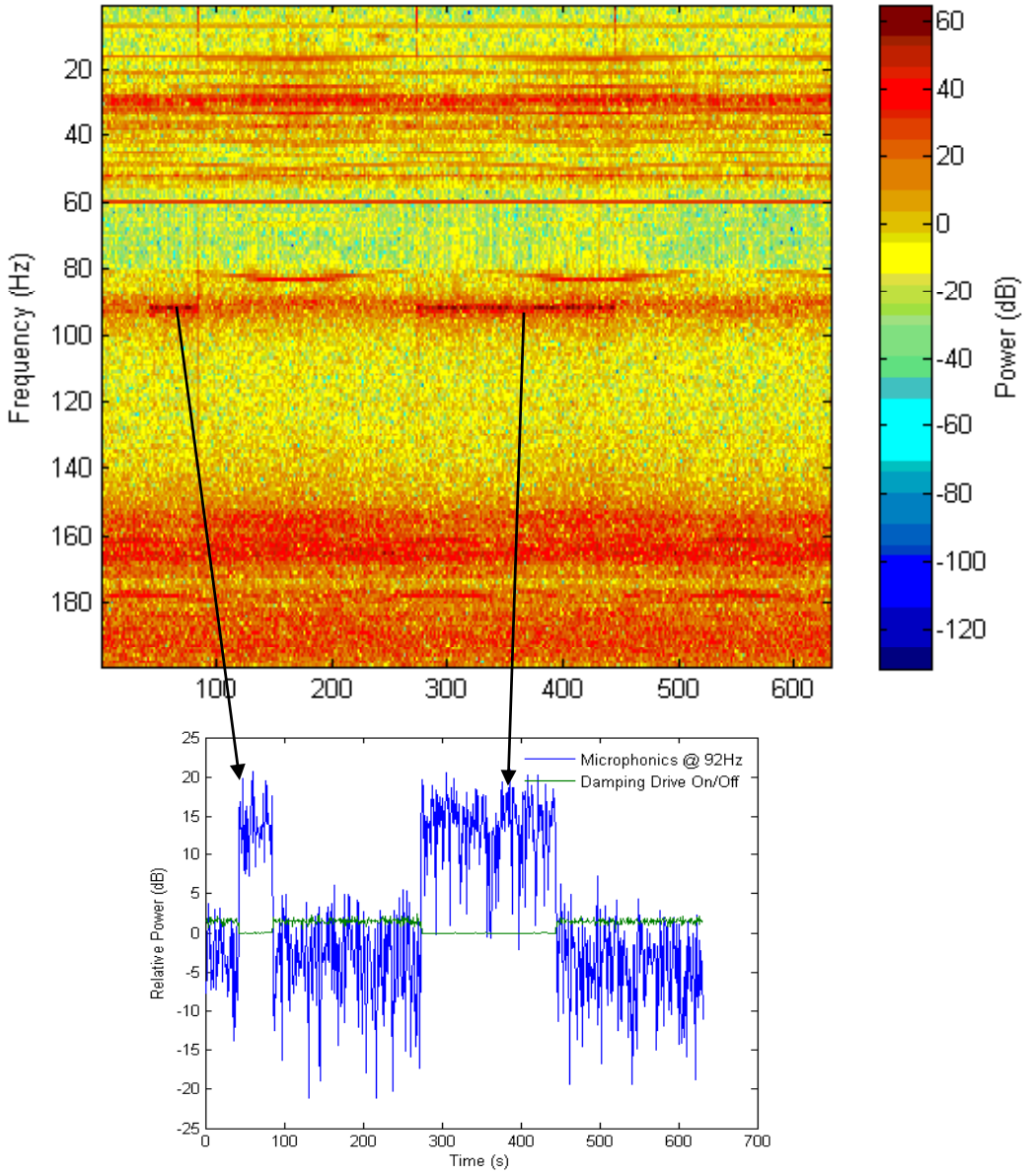


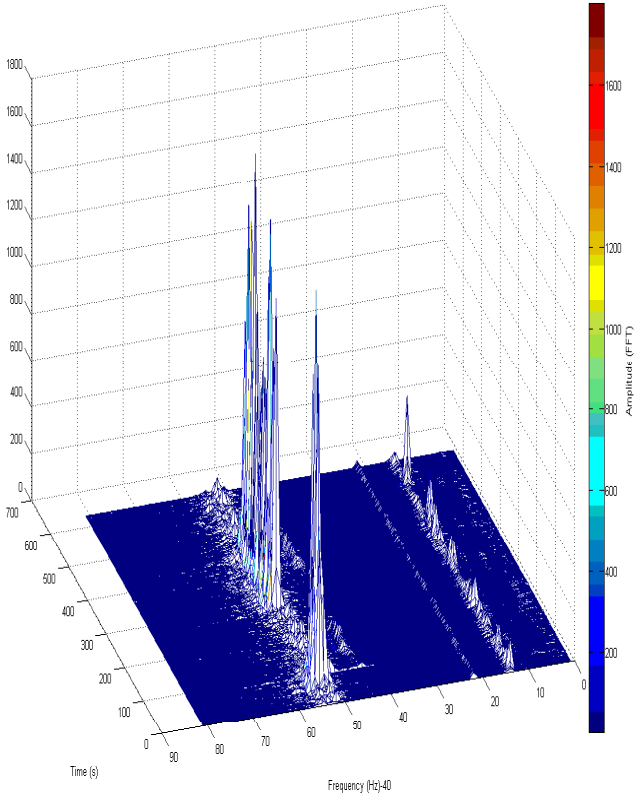
Piezo DC bias Voltage vs Time



Piezo DC bias FB loop suppress Cavity frequency swing from ~800Hz to 40Hz

Microphonics
compensation for persistent mechanical vibration Narrow Band Filter Bank;
Single 92 Hz Resonance Compensation (CW operation)





Summary

- We (Resonance Control Group) have first long (more than 1 day) access to High Gradient SCRF Cavity.
- We have accomplished major part of our R&D program. **Now we are ready to build Piezo Control System for NML (CM#1)** and we have a confidence in our efforts with incoming new projects: like SSR1(HINS), Blade Tuner for CM2, etc.
- **We learn a lot.**
- Thanks to all CC2 system's experts who support our program