EXPLORING POSSIBILITIES FOR ACTIVE MICROPHONIC COMPENSATION OF BNL SRF CAVITIES

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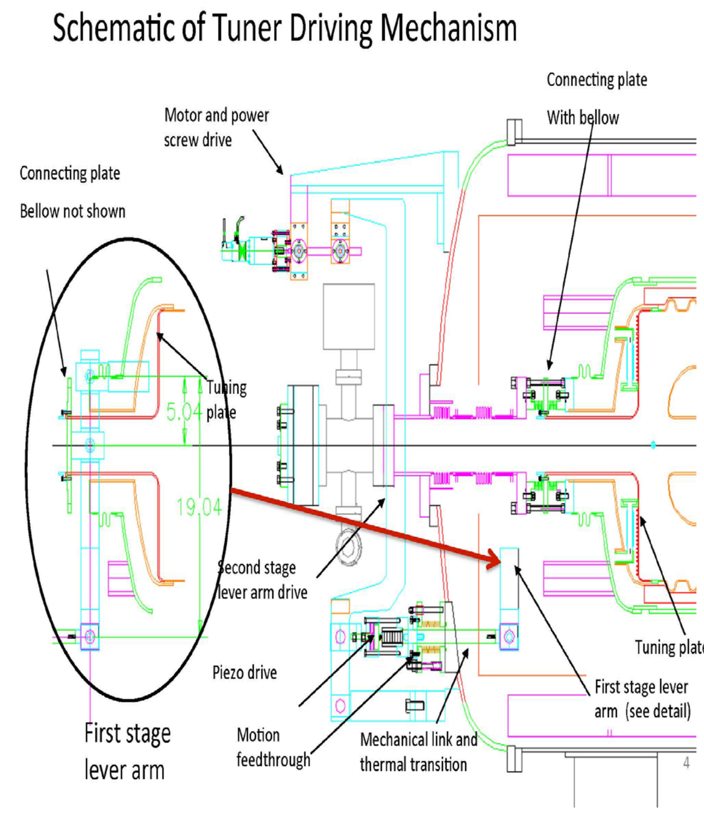
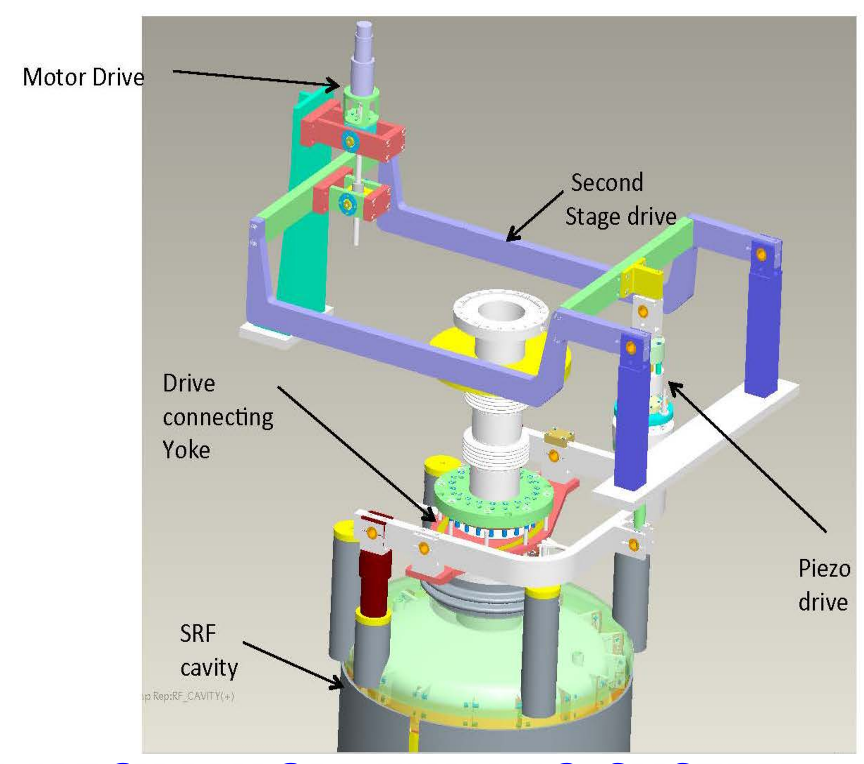
Abstract

The need to mitigate microphonic induced detuning in Superconducting Radio Frequency (SRF) Cavities is of critical importance when trying to achieve a very high degree of cavity field regulation given limited amounts of RF power. At the Collider Accelerator Department (C-AD) at Brookhaven National Lab, we recently started exploring various approaches/methods for microphonic compensation using a piezo-electric tuner on two of our SRF cavities. We used our digital low level RF controller to measure piezo to cavity tuning transfer functions using multiple types of stimuli, and obtained a Matlab Simulink model that represents the system. In addition, we designed and implemented a compensator for the first mode in one of the cavities and demonstrated closed loop operation, validating the accuracy in our model. Here we summarize our work so far and plans for future design and implementation of a more comprehensive method of microphonic compensation for both cavities.

Schematic of Tuner Driving Mechanism

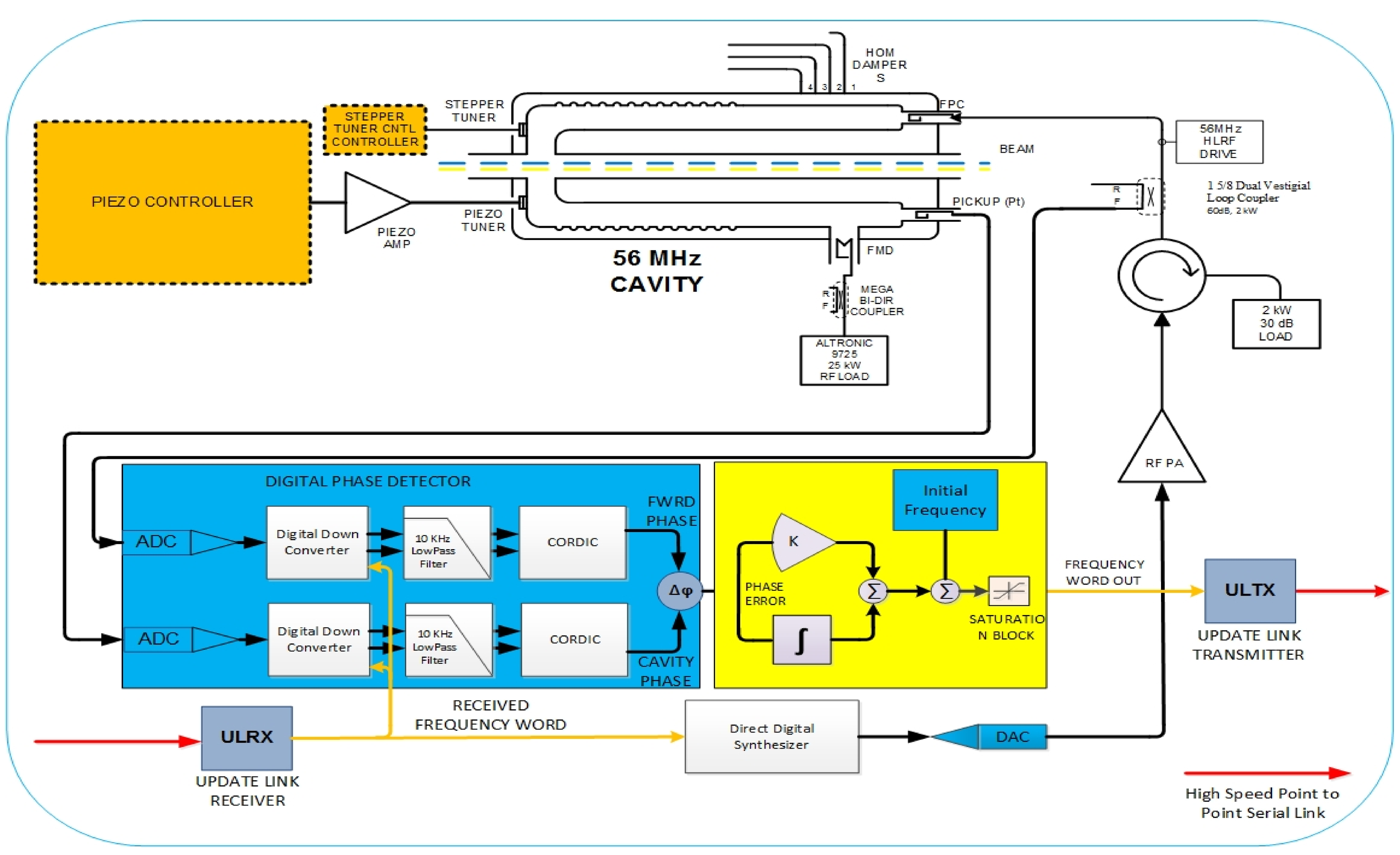


Mechanical Tuner Assembly (Vacuum chamber is not shown)



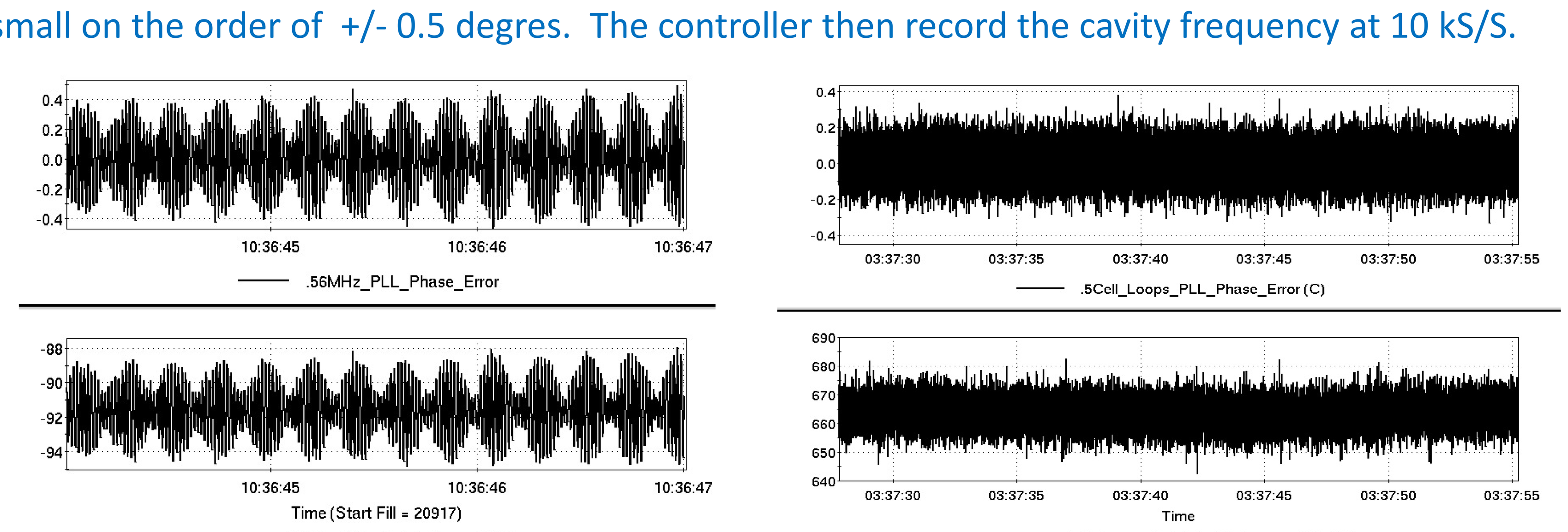
BNL 56 MHz SRF CAVITY MECHANICAL TUNING SYSTEM

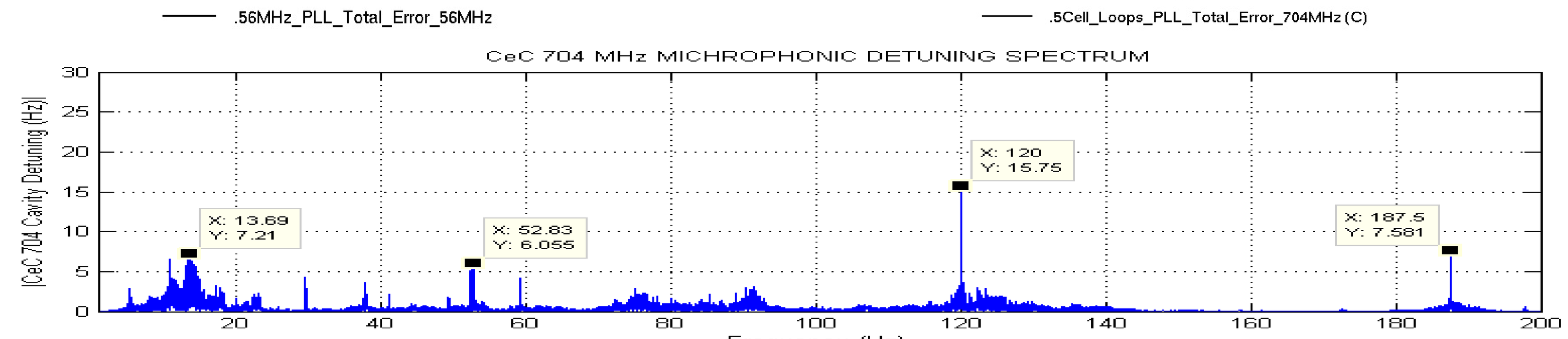
The BNL 56 MHz superconducting RF cavity is a quarter wave resonator that operates at 4.4 K with a quiet helium source to isolate the cavity from the environmental acoustic noise [1]. The cavity typical operating Q_{ext} is ~6e6 with a half bandwidth of about 60 Hz. Frequency tuning is achieved by two stages of simple lever arm mechanical tuner [2]. The piezo tuner has a range of 60 Hz and is installed in the first of the two stages.

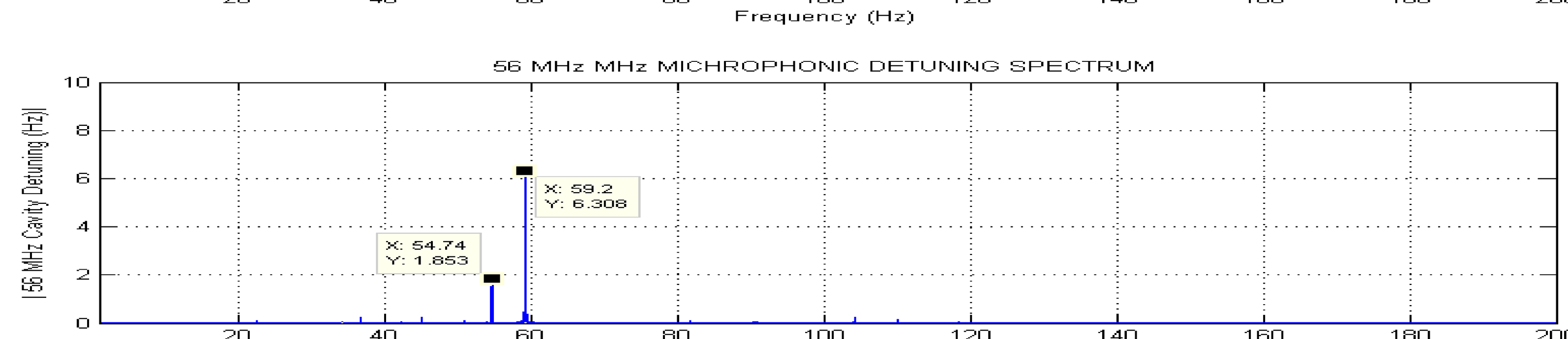


PHASE LOCKED LOOP USED FOR MICHROPHONICS MEASUREMENT

We used our digital low level controller to drive the cavity with a phase locked loop (PLL) enabled. The loop is setup with high proportional and integral gains to keep the tuning phase error very small on the order of +/- 0.5 degrees. The controller then record the cavity frequency at 10 kS/S.





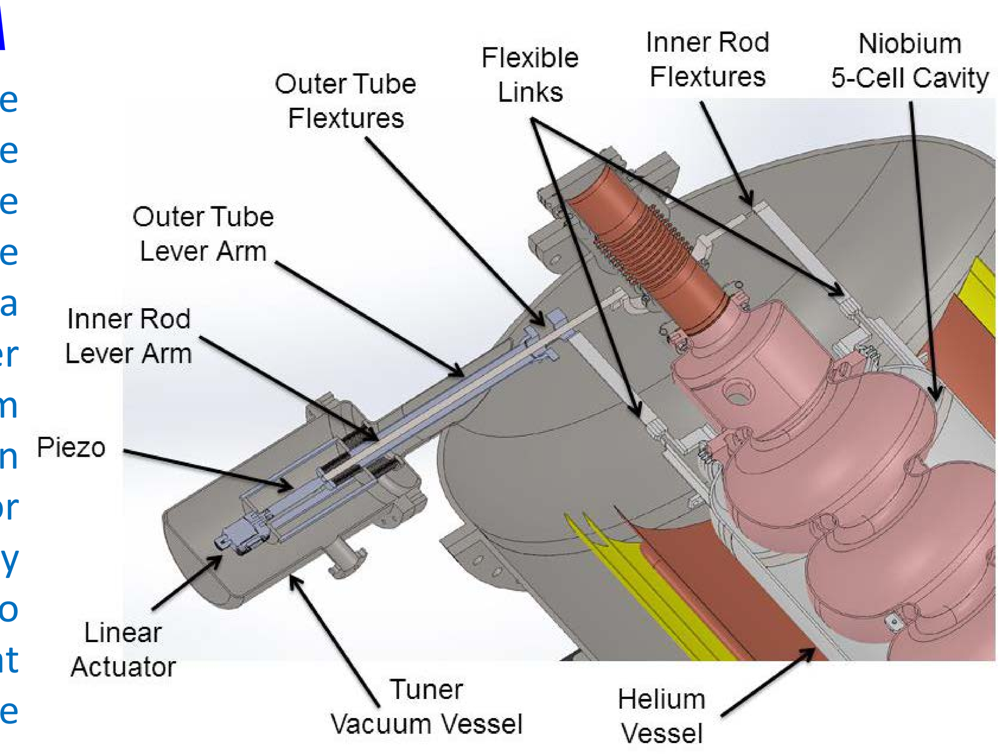


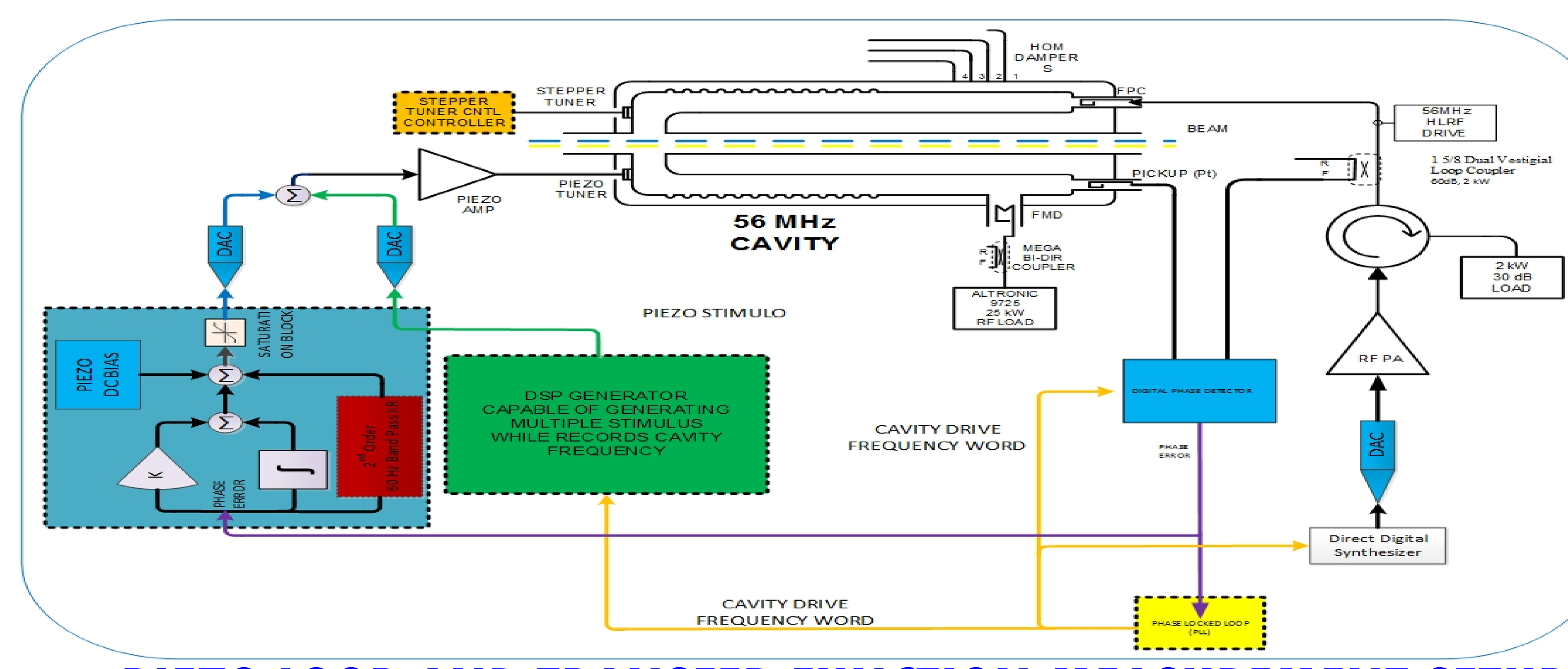
MICROPHONICS SPECTRUM

We used Matlab to compute the FFT of the cavity microphonic detuning. The system allows us to measure microphonic detuning frequency up to 5 kHz.

704 MHz 5-CELL SRF CAVITY MECHANICAL TUNING SYSTEM

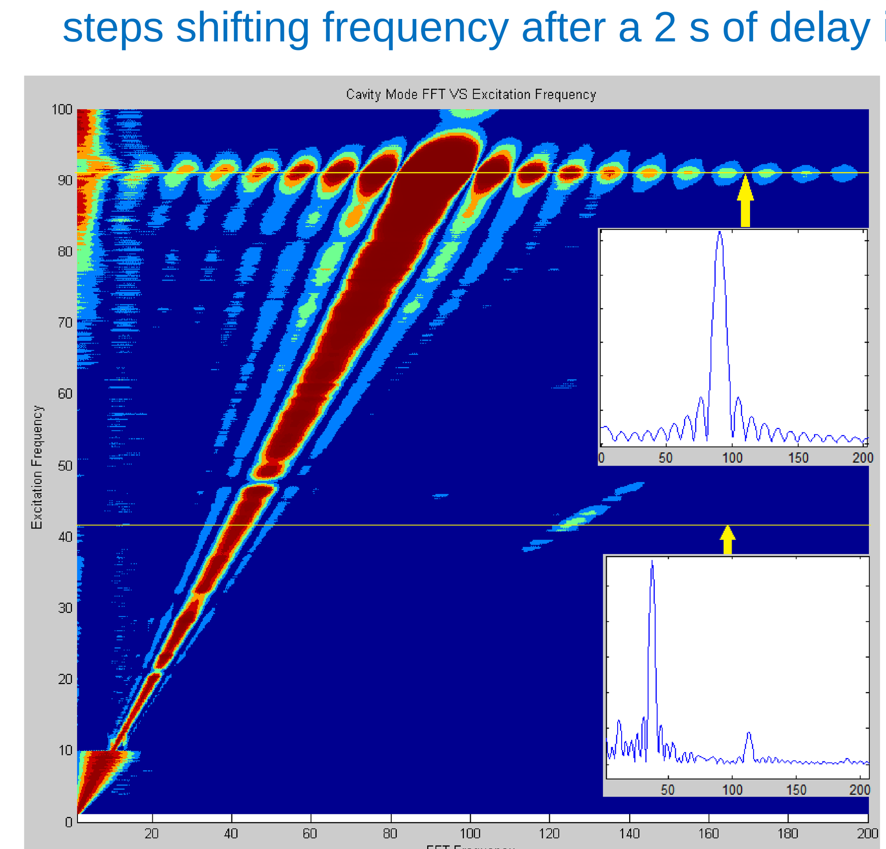
The 704 MHz SRF cavity was installed in the Coherent Electron Cooling Proof of Principle (CeC PoP) experiment developed for the Relativistic Heavy Ion Collider (RHIC)[3]. The cavity typical operating Q_{ext} is 1.5e7 with a half bandwidth of about 23 Hz. The tuner mechanism consists of an inner rod lever arm and an outer tube lever arm that move in opposite directions, using the linear actuator or the piezo[4]. This mechanical frequency tuning system was designed with a piezo electric actuator with high resolution that provides for fast tuning of the cavity. The piezo tuner range for this system is ~50 Hz.





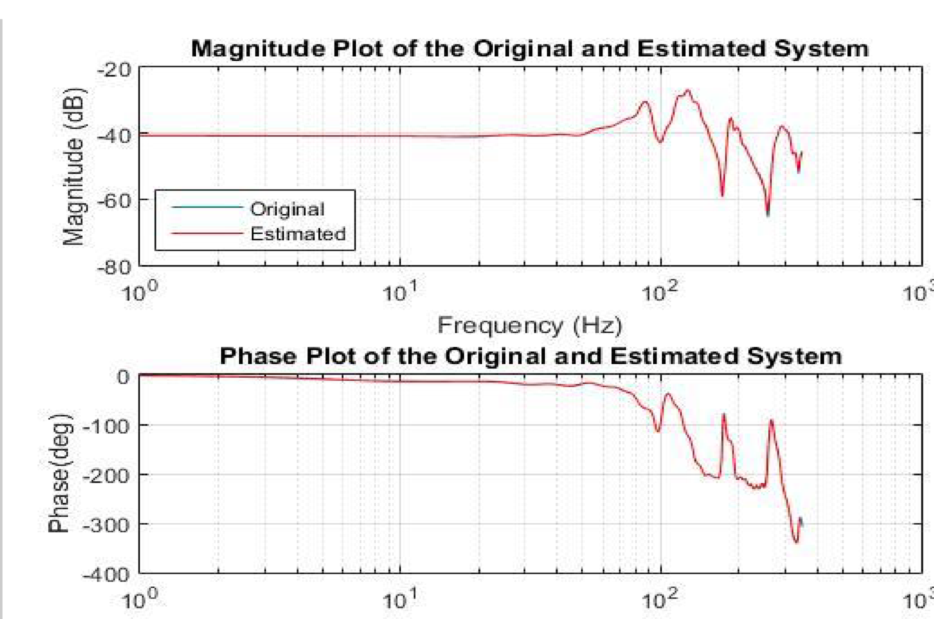
PIEZO LOOP AND TRANSFER FUNCTION MEASUREMENT SETUP

The setup shown above allowed us to measure an open or closed loop piezo to cavity tuning transfer function. We used our Low Level RF controller to drive the piezo with various kinds of stimuli while driving the cavity with a PLL loop. The DSP system simultaneously records cavity frequency data generated by the PLL and the corresponding piezo stimuli. The best transfer function was obtain by applying a sinusoidal signal in discrete frequency steps shifting frequency after a 2 s of delay in steps of 0.1 Hz.



TUNER FREQUENCY RESPONSE FOR 704 MHz CAVITY

Tuner transfer function response showing piezo drive frequency on the Y axis and cavity response on the X axis. The intensity of the response is indicated by color.



704 MHz PIEZO TO CAVITY TUNING TRANSFER FUNCTION

We processed the raw data using Matlab to compute the transfer function shown above. The same raw data was also used to obtain a Matlab Simulink model that represents the system. In addition, we designed and implemented a compensator for the first mode in one of the cavities and demonstrated closed loop operation, validating the accuracy in our model.

REFERENCES

[1] Q. Wu et al, "The First Operation of 56 MHz SRF Cavity in RHIC", IPAC 15, Richmond, VIRGINIA, May 2015 .
[2] C. Pai et al, "Mechanical Design of 56 MHz Superconducting RF Cavity For RHIC Collider", PAC11, New York, March 2011, TUP054, pp. 907 – 909.
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