VALIDATION OF THE 650 MHZ SRF CAVITY TUNER FOR PIP-II AT 2 K*

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MOPA27

FERMILAB-POSTER-22-151-TD

Introduction

- The SRF cavity tuner has three roles:
  - (1) It is needed for active microphonics compensation
  - (2) It is also used for moving the cavities to the nominal frequency after cooling to 2 K
  - (3) Lastly, it is used for protecting the cavity during pressure tests
- The double lever tuner will be used for both the $\beta = 0.61$ and $\beta = 0.92$ five-cell 650 MHz elliptical cavities, Fig. 1 shows the tuner installed
- The tuner specifications for the 650 MHz cavities are shown in Table 1

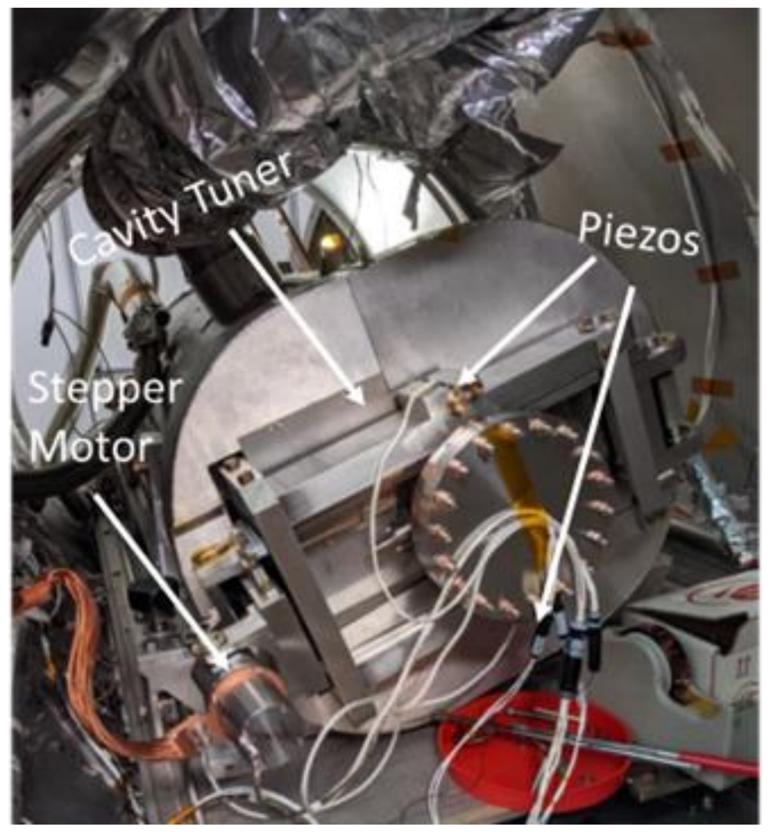

Figure 1: 650 MHz β_G=0.92 with tuner and other ancillaries inside the STC cryostat at the MDB facility in Fermilab.

- Both components were tested at 2 K operation
- The results shown are for both the $\beta = 0.61$ and $\beta = 0.92$ 650 MHz elliptical cavities

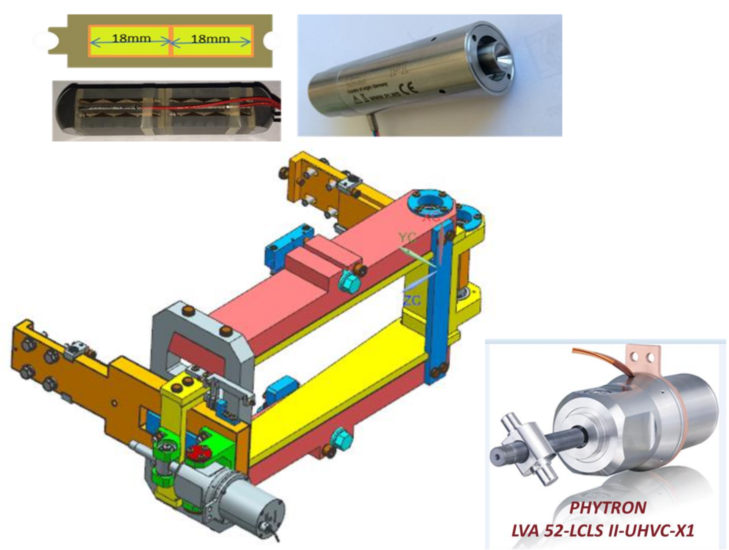

Table 1 : 650 MHz cavity and tuner specifications for different geometries.

	$\beta_G = 0.92$	$\beta_G = 0.61$
Cavity Stiffness [kN/mm]	5	4
Cavity Tuning Sensitivity [Hz/μm]	150	240
Tuner System Stiffness [kN/m]	≥ 40	≥ 40
Lowest Mechanical Resonance of Cavity-tuner System [Hz]	>100	>100
Slow Tuner Frequency Range [kHz]	200	200
Stepper Motor Resolution [Hz/step]	≤1	≤1
Slow Tuner Hysteresis [Hz]	≤ 100	≤ 100
Piezo Tuner Frequency Range (at 120 V) [kHz]	1.2	1.2
Piezo Tuner Resolution [Hz]	<0.5	<0.5

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics

Slow & Coarse Tuner Component

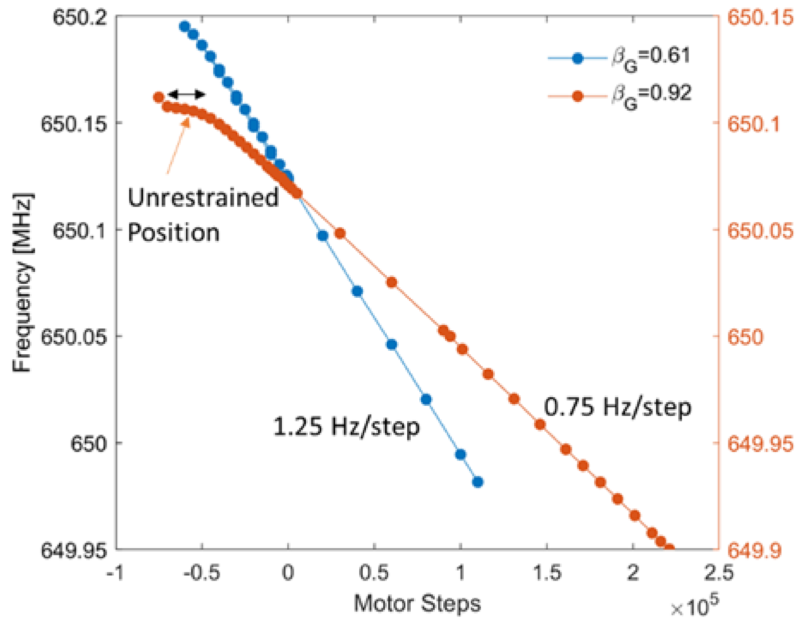

Figure 2: Tuner operation after cooldown to 2 K. The left axis corresponds to the β_G = 0.61 cavity and the right to β_G=0.92 cavity.

- This frequency at 2 K before tuning is called 2 K landing frequency ($f_{2\ K\ Landing}$)
- The slow coarse tuner has three regions of operation.
  1. The first region is when the tuner can stretch the cavity via the safety rods, in this region piezos are not engaged, this region is not used during operation.
  2. The second region is the unrestrained region where the cavity frequency changes slightly or not at all. This region is caused by the safety gap setup at room temperature. The piezos are not engaged, hence the small frequency change.
  3. The last region has both piezos in contact and is used for normal operation

Table 2 : Measured figures of merit of the 650 MHz cavity tuner.

	$\beta_G = 0.92$	$\beta_G = 0.61$
$f_{2\ K\ Landing}$ [MHz]	650.070	650.124
$f_{unrestrained}$ [MHz]	650.107	TBD
Measured piezo preload [kHz]	37	TBD
Unrestrained gap [μm]	100	TBD
Motor Steps to 650 MHz	93333	99200
Motor Sensitivity [Hz/Step]	0.75	1.25
Motor Range [kHz]	212	214
Piezo Sensitivity [Hz/V]	-24	-36

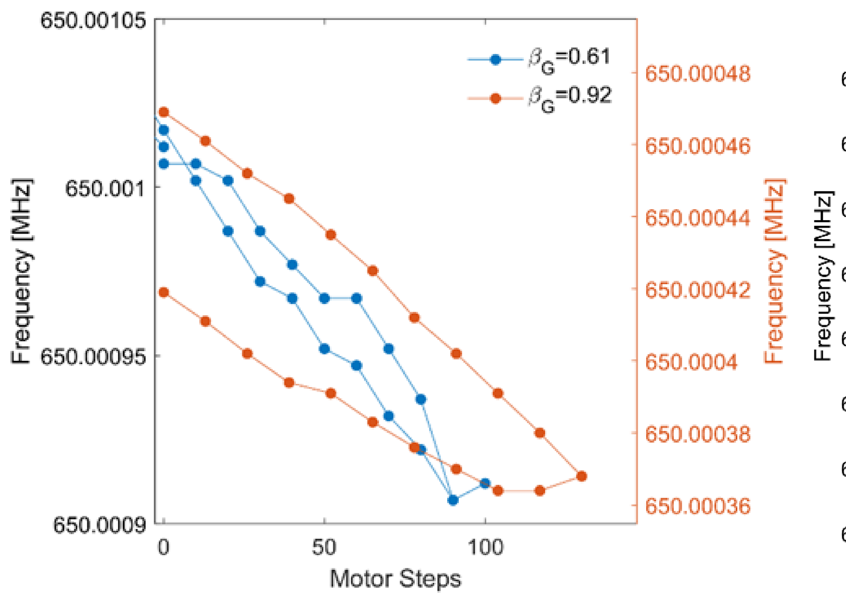

Figure 3: Short step hysteresis of the stepper motor for both cavity types.

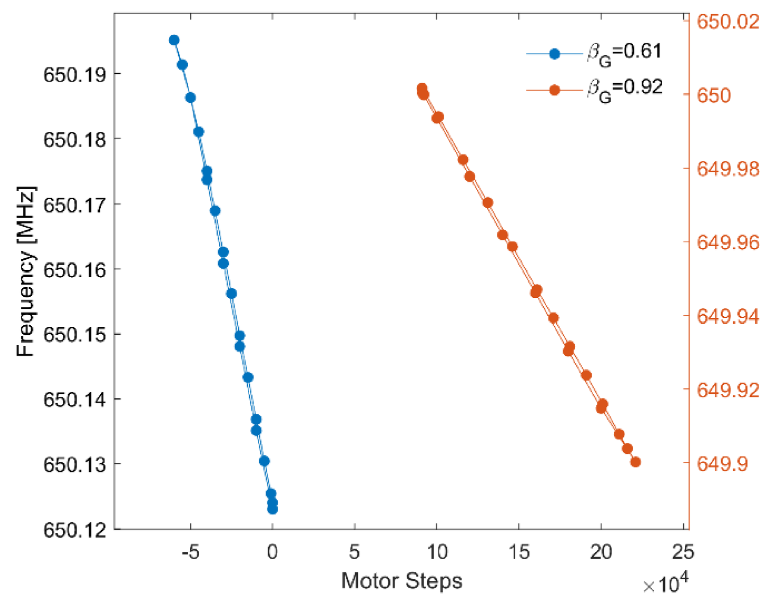

Figure 4: Large step stepper motor hysteresis.

- The hysteresis of the stepper motor was tested by first operating it in short step increments and then in large step increments
- In the short-range hysteresis with increments of 10 steps, the difference between the compression and relaxation sweep is 30 Hz, as shown in Fig. 3 for both cavity types. The 30 Hz value of the slow tuner hysteresis is consistent with the stepper motor actuator backlash measured with the LCLS-II tuner. This is also within the hysteresis specification given in Table 1
- The sensitivities of the tuner in this short range are given in Table 2 and are within the specification given in Table 1. In the long-range hysteresis a span of 10^8 steps was used, and results are shown in Fig. 4. These values demonstrate that the stepper motor can tune the cavity to 650 MHz and has a large range.

Fast & Fine Tuner Component

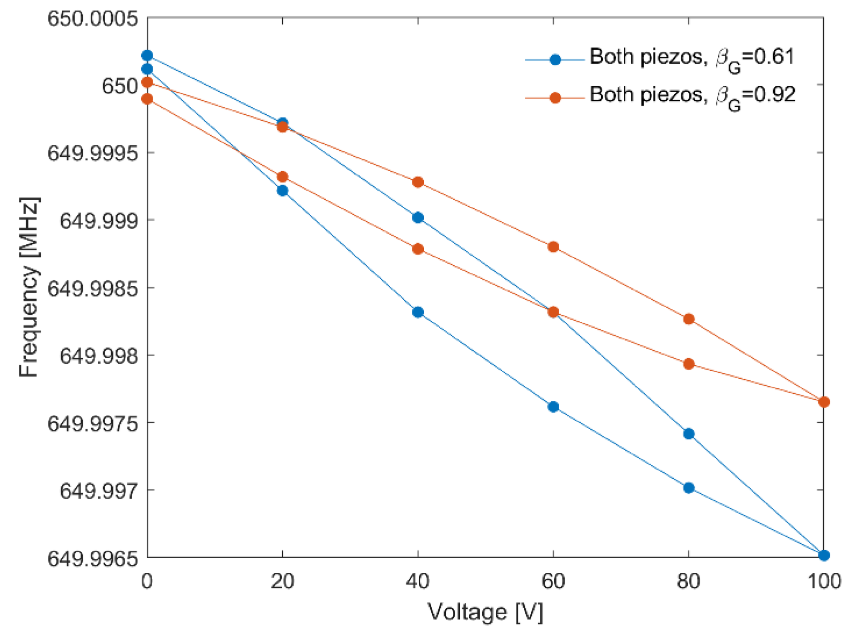

Figure 5: Piezo hysteresis for both types of cavities with 20 V intervals, both piezos were used.

- The tuner consists of two piezo capsules which contact the cavity. The piezo actuator can expand by 34 ± 2 μm when 100 V is applied at room temperature.
- At 2 K and 100 V on both piezo capsules, the cavity frequency shift was -2.4 kHz for β=0.92 and -3.6 kHz for β=0.61
- The piezo can be modulated by small increments such as 15 mV, this achieves a piezo resolution of 0.5 Hz meeting the specification given in Table 1.
- The temperature of the piezo can be estimated to be in the range of 95 to 105 K, based on motor temperature and capacitance which was 5.8 μF.

Conclusion

- The results show that the slow-coarse range for the is 212 kHz for β=0.92 and 214 kHz for β=0.61
- The hysteresis for the slow tuner is 30 Hz which is within specifications shown in Table 1
- The fast-fine component test yielded a response of -24 Hz/V for β=0.92 and -36 Hz/V for β=0.61
- This gives a large range for compensation of microphonics for CW operation and complements slow tuner compensation with fine frequency adjustment
- All specifications were met