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

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ABSTRACT

The PIP-II linac will include thirty-six β_G=0.61 and twenty-four β_G=0.92 650 MHz 5-cell elliptical SRF cavities. Each cavity will be equipped with a tuning system consisting of a double lever arm tuner consisting of a slow tuner for coarse frequency tuning and a piezoelectric actuator for fine frequency tuning. One cavity equipped with an SRF tuner has been tested in the horizontal test stand at Fermilab. Results of testing the cavity-tuner system will be presented.

INTRODUCTION

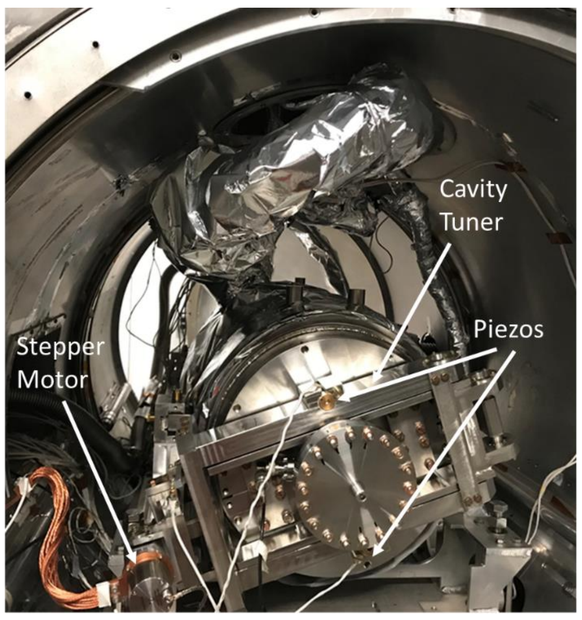

Figure 1: 650 MHz β_G =0.90 with tuner and other ancillaries inside the STC cryostat at the MDB facity in Fermilab.

The prototype HB 650 cryomodule (CM) will have a mix of the β_G= 0.92 and legacy β_G =0.90 cavities. The legacy cavity was jacketed first and was tested in the horizontal configuration. The cavity was placed in the recently upgraded cryostat at the Meson Detector Building (MDB) at Fermilab, pictured in Fig. 1. This double lever arm tuner will be used for both the HB and LB 650 MHz elliptical cavities. The tuner specifications for the HB and LB 650 MHz cavities are shown in Table 1. The SRF cavity tuner has three roles. It is needed for active microphonics compensation. It is also used for moving the cavities to the nominal frequency after cooling to 2 K.

Lastly, it is used for protecting the cavity during pressure tests. There are two components to the tuner, one is the slow and coarse frequency tuning component consisting of a stepper motor. The other is the fast and fine frequency tuning component composed of piezoelectric actuators.

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

	$\beta_G = 0.9$	$\beta_G = 0.92$	$\beta_G = 0.61$
Cavity Stiffness [kN/mm]	20	5	4
Cavity Tuning Sensitivity [Hz/μm]	180	150	240
Tuner System Stiffness [kN/m]	≥ 40	≥ 40	≥ 40
Lowest Mechanical Resonance of Cavity-tuner System [Hz]	>100	>100	>100
Slow Tuner Frequency Range [kHz]	100	200	200
Stepper Motor Resolution [Hz/step]	≤ 1	≤1	≤1
Slow Tuner Hysteresis [Hz]	≤ 100	≤ 100	≤ 100
Piezo Tuner Frequency Range (at 120 V) [kHz]	1.2	1.2	1.2
Piezo Tuner Resolution [Hz]	<0.5	<0.5	<0.5

SLOW AND COARSE FREQUENCY COMPONENT

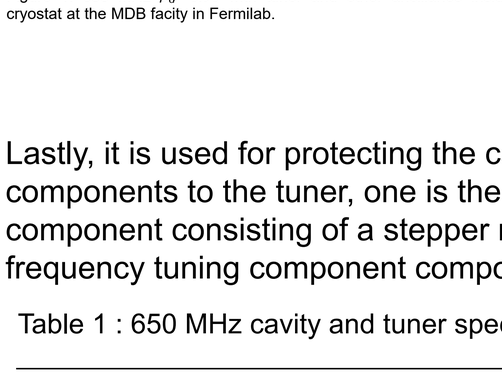

Figure 2: Tuner operation after cooldown to 2 K and further compression to demonstrate the range of the tuner

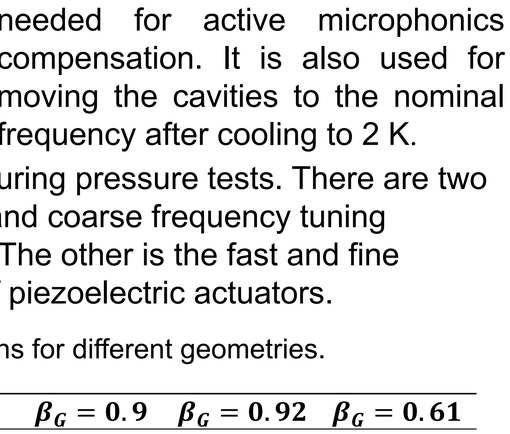

Figure 3: Short step hysteresis of the stepper motor.

- A total of 10^8 steps were required to compress the cavity to 650 MHz which is shown in Fig. 2. An additional 10^8 steps were implemented to measure the range of the tuner and verify that no limit switches would be tripped during the movement.
- The total range measured from this compression was 120 kHz, this is higher than the specification given in Table 1 for the $\beta_G = 0.9$ value of 100 kHz.

SLOW AND COARSE FREQUENCY COMPONENT

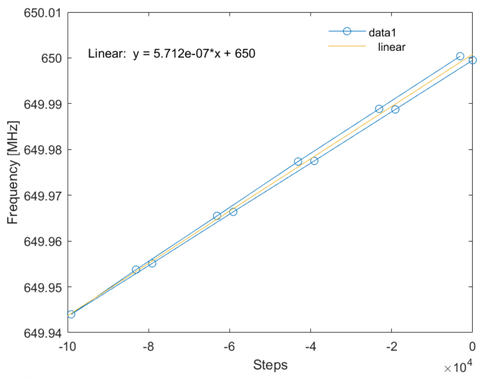

Figure 4: Large step stepper motor hysteresis.

- In the short-range hysteresis with increments of 200 steps, the difference between the compression and relaxation sweep is 30 Hz, as shown in Fig. 3. The sensitivity of the tuner in this range is 0.58 Hz/step also within the specification given in Table 1.
- In the long-range hysteresis with a span of 10^8 steps, shown in Fig. 4, the sensitivity is 0.57 Hz/step. These values demonstrate that the stepper motor can tune the cavity to 650 MHz and has a large range

FAST AND FREQUENCY TUNING COMPONENT

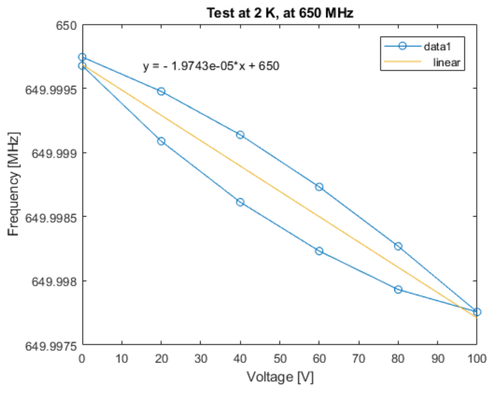

Figure 5: Piezo hysteresis of both capsules with 20 V intervals.

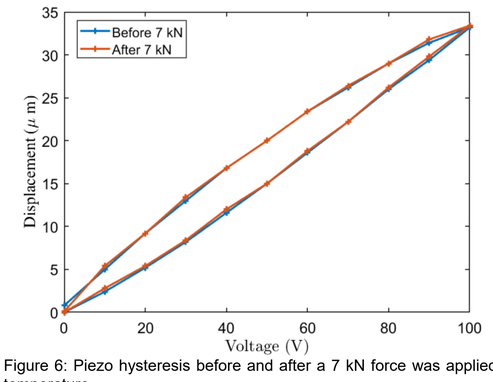

Figure 6: Piezo hysteresis before and after a 7 kN force was applied at room temperature.

- The piezo displacement was studied on the 650 MHz cavity at 2 K, with results shown in Fig. 5.
- At 100 V on both piezo capsules, the cavity frequency shift was -1.97 kHz, this is higher than the specification given in Table 1.
- Frequency sensitivity is 19.7 Hz/V. The piezo can be modulated by small increments such in voltage in mV achieving a piezo resolution of 0.5 Hz or less.
- The expected detuning from microphonics of the cavity operated in CW mode is on the order of 5-50 Hz.
- The $\beta_G = 0.9$ cavity has a stiffness of 20 kN/mm. It is expected that the load on the piezos will be 7 kN, which is roughly double the blocking forces at 3.8 kN.
- A room temperature test was therefore performed on the piezo displacement before and after a 7 kN force was applied to check for depolarization.
- Results shown in Fig. 6 demonstrate that this does not affect the piezo stroke displacement. The results show that the piezo can operate in high stress environments.

CONCLUSION

- The results show that the slow-coarse range for the $\beta_G = 0.9$ cavity is 120 kHz.
- The hysteresis for the slow tuner is 30 Hz, within specifications shown in Table 1. The fast-fine component test yielded a response of 19.7 Hz/V. This gives a large range for compensation of microphonics for CW operation and compliments slow tuner compensation with for fine frequency adjustment.
- Results after application of 7 kN longitudinal force demonstrated that the piezo stoke displacement is not affected.
- Thus, the double lever tuner is capable of operation in the PIP-II linac by exceeding the specification of the PIP-II project.

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