SRF 2021
28 June 2021 – 02 July 2021

SRF CAVITY TUNERS FOR 3.9 GHZ CRYOMODULES FOR LCLS-II PROJECT*

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Abstract

Fermilab conducted testing of three 3.9 GHz cryomodules for the LCLS-II project that will operate in continuous wave mode. Several cavities faced problems with fast-tuner operations after cooldown to 2 K and tuning the cavities to 3.9 GHz in cryomodule 2. All the piezo actuators were in working conditions, but the slow tuner ranges required to stretch some of the cavities to the operational 3.9 GHz frequency were too small to deliver the required preload on the piezos. This behavior can be attributed to several factors: setting the initial warm cavity frequency during production too high, pressure tests of the warm cryomodule could have changed cavity frequency; and the small bending and twisting of the cavity-tuner system during the cooldown and warmup of the cavities. A decision was made to inelastically retune the warm cavities to decrease the unrestrained frequency by 130-500 kHz, this was done via the slow tuner. The major challenge was to conduct this procedure without disassembling cryomodule and without any access to the tuner and cavities systems. The results for this retuning method of three 3.9GHz cryomodules will be discussed.

Slim Blade Tuner

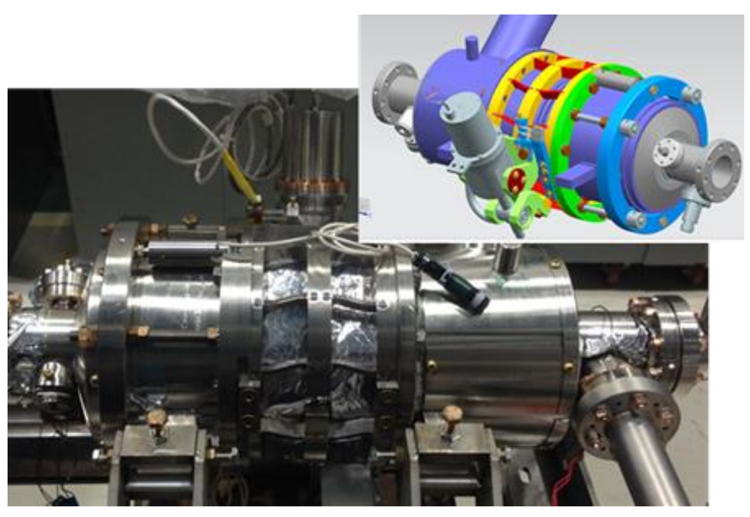

Figure 1 : Slim blade tuner installed on a 3.9 GHz cavity.

The slim blade tuner is installed coaxially on the cavity helium vessel. The tuner can compress and stretch the cavity via the slow/coarse frequency component. Compression of the cavity decreases the frequency while stretching the cavity increases the frequency. The slow-coarse component consists of a Phytron stepper motor which is also used for the 1.3 GHz cavities. The second frequency tuning component consists of two piezo actuator encapsulations used for fast-fine frequency compensation which can only stretch the cavity. The slim blade tuner and the two components are shown installed on the 3.9 GHz cavity in Fig. 1.

Operation at 2 K

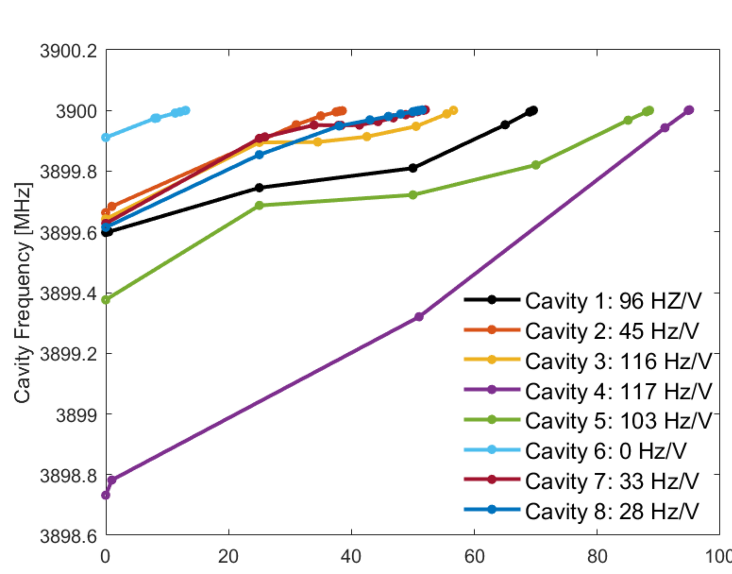

Figure 2: Slow tuner operation to set the cavity to the nominal frequency of 3.9 GHz in CM 2.

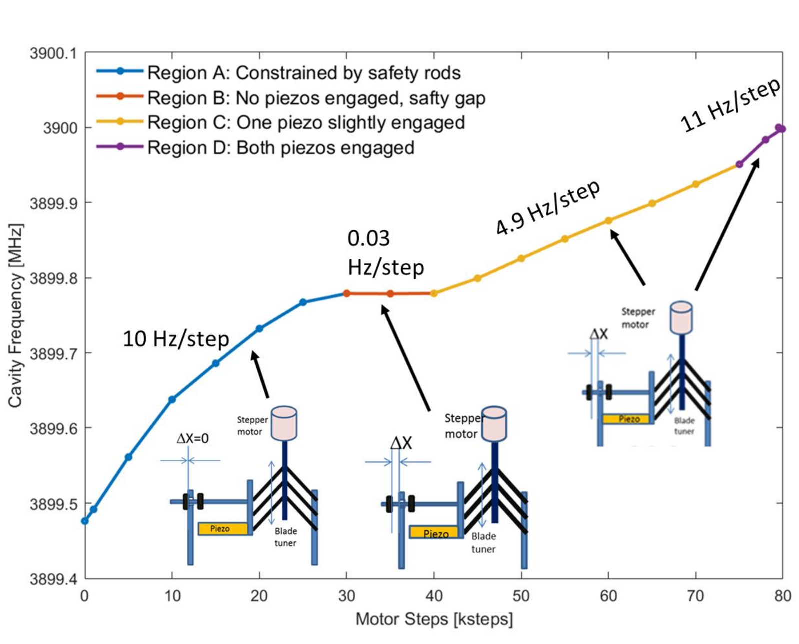

Figure 3: Frequency detuning the cavity with stepper motor tested at 2 K. Three regions are observed: region A has none of the piezo engaged and cavity frequency changes due to release of compression from the safety rods; region B is the position when cavity unrestrained with the tuner (both components: safety rod & piezo do not engage with cavity); region C is when one of the two piezo encapsulations is engaged; and region D is the position when cavity stretched by tuner through both piezo actuators.

- The expected frequency sensitivity for the piezos is 100 ±20 Hz/V if both piezos are engaged.
- During testing of cryomodule (CM) 2 cavity 6 had no response to the piezo stimulation. Additionally, cavities 2, 7, and 8 had only one piezo actuator engaged since their frequency sensitivity was below 100 Hz/V as shown in Fig 2.
- The low-frequency sensitivity was not due to an electrical wiring fault
- Based on the results from Fig. 2 all the cavities except cavity 4 have a high unrestrained frequency.
- Since the unrestrained frequency is high the tuner does not have enough space to transition to region D where both piezos are engaged (See Fig. 3).
- This can be resolved by inelastically tuning the cavities to shift the unrestrained frequency
- To tune the cavity unrestrained frequency down the stepper motor on the tuner was used. This was an unconventional use of the tuner since it was designed to stretch the cavity.

Inelastic Retuning

Table 1: Cryomodule 2 warm cavity frequencies. The original frequency $f_{original}$ and the frequency f_{tuned} after tuning the cavities inelastically is given. The inelastic tuning is given by $\delta f = (f_{original} - f_{tuned})$.

CM 2	$f_{original}$ [MHz]	f_{tuned} [MHz]	δf [kHz]
Cav. 1	3893.434	3893.299	135
Cav. 2	3893.531	3893.271	260
Cav. 3	3893.457	3893.287	170
Cav. 4	3892.573	3892.814	-241
Cav. 5	3893.191	3893.22	-29
Cav. 6	3893.743	3893.274	469
Cav. 7	3893.491	3893.297	194
Cav. 8	3893.454	3893.245	209

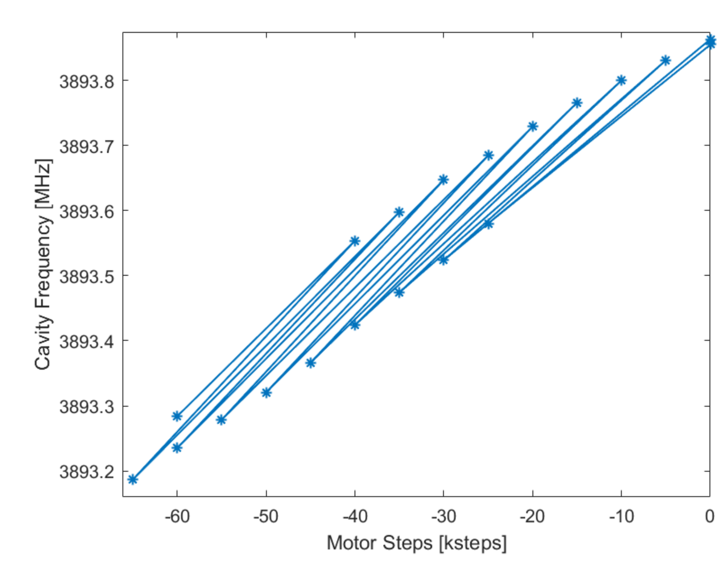

Figure 4: Inleastic tuning of cavity 6 with stepper motor.

- All the cavities were first warmed up to room temperature to be inelastically deformed to lower the unrestrained frequency.
- During this tuning, the pressure inside the beamline was 2×10^{-11} torr, the insulating vacuum of the cryomodule and the cavity helium vessel pressure was set to 1 atm with back filled nitrogen gas.
- The cavities were compressed iteratively to reach a lower frequency value.
- The results for retuning of cavity 6 are shown in Fig. 4. During this procedure, the motor temperatures were being monitored and all had temperature increases less than 20 K.
- During this inelastic compression of the cavity each of the 9 frequency modes of the cavity were also recorded to ensure the field flatness of the cavity would be within the project's specifications.

Results of Retuning

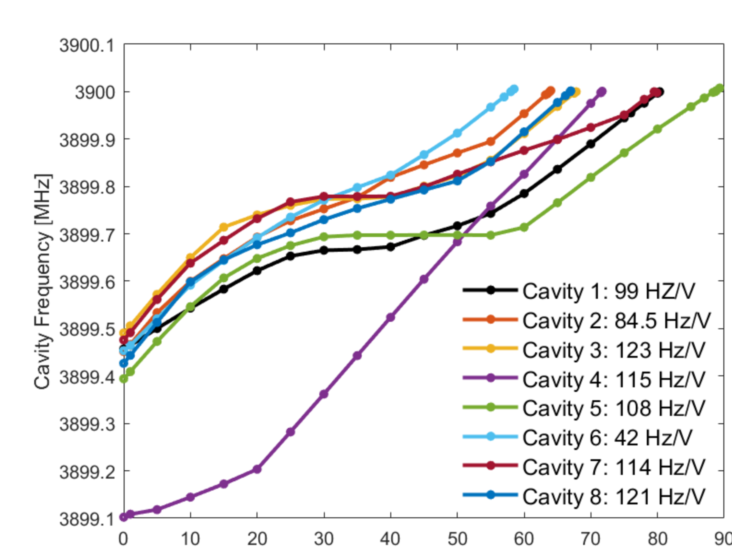

Figure 5: CM 2 cavity tuner operation after retuning cavity frequency of cavities 1,2, 6, 7, and 8. The piezo frequency sensitivities are given next to the cavity.

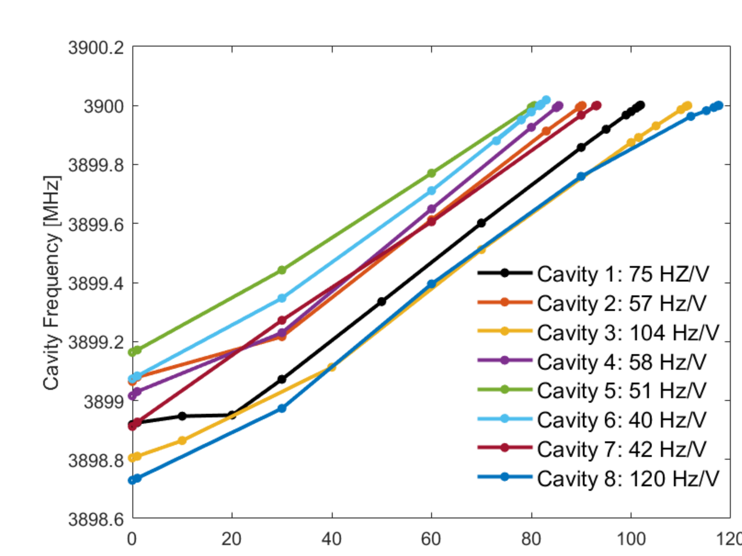

Figure 6: CM 3 cavity tuner operation after retuning.

- The results of tuner operation in CM 2 after tuning are shown in Fig. 5.
- A piezo frequency sensitivity improvement was observed for cavities 2, 6, 7, and 8. Cavities 2, 7 and 7 all reached both piezo engagement with the tuner.
- The compression of the cavities for CM 3 was larger and the results of the tuner operation are shown in Fig. 6. In this case only cavities 1, 3, and 5 have both piezos engaging. The other cavities have only one piezo engaging.
- It is possible that during this large deformation the tuner or cavity was also deformed which caused only one piezo engaged.

Conclusion

During operation of the 3.9 GHz cryomodule it was discovered that one of the cavities had no piezo engagement after 100 V were applied. This was attributed to the initial frequency after cooldown being too close to 3.9 GHz. Since the slim blade tuner has safety gaps in the safety rods the motor spindle displacement was not enough for the piezo to be engaged. This was resolved by inelastically deforming the cavities with the slim blade tuner inside the cryomodule. This retuning of the cavities successfully engaged at least one of the two piezo actuators. For the cavities that only one actuator was engaged this can be attributed to deformations of the tuner or the cavity.

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. Additional support provided by award number DE-SC0018362 and Michigan State University.

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