TESTS OF THE EXTENDED RANGE SRF CAVITY TUNERS FOR THE LCLS-II-HE PROJECT

C. Contreras-Martinez†, T. Arkan, A. Cravatta, B. Hartsell, J. Kaluzny, T. Khabiboulline, Y. Pischalnikov, S. Posen, G. Romanov, JC. Yun Fermilab, Batavia, IL, USA † ccontrer@fnal.gov

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Introduction

- For multi-energy operation in the LCLS-II-HE linac the tuners were modified to meet the off-frequency operation (OFO) specification of **1299.535 MHz.**
- In the case of OFO operation 62 % of the cavities must tuned to 1299.535 MHz.
- Tuning from 1.3 GHz to OFO must be done approximately twice a month, this level of operation pushes the tuner and cavity to new thresholds which test the longevity of both.
- Recent results demonstrate that the cavity and tuner can achieve these requirements.

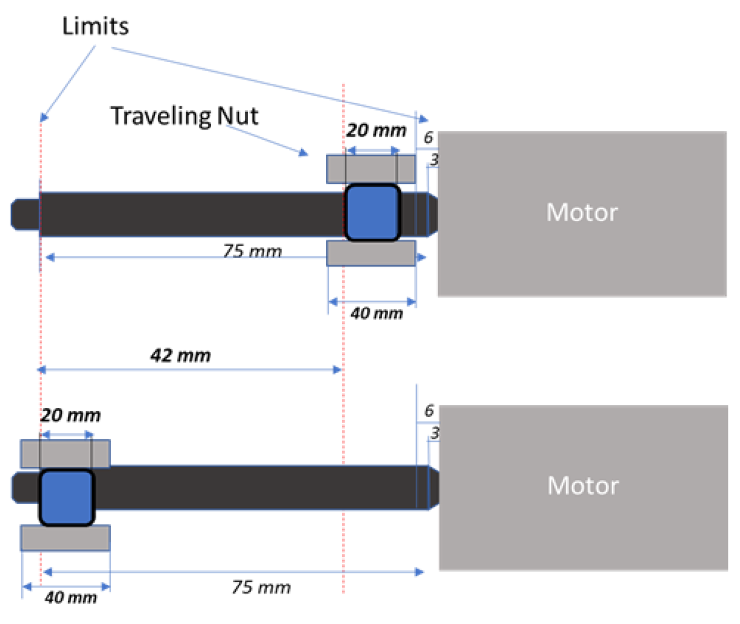

Figure 1: Motor shaft schematic showing the traveling range in mm. the traveling nut is connected to the tuner arm which is responsible for compressing the cavity.

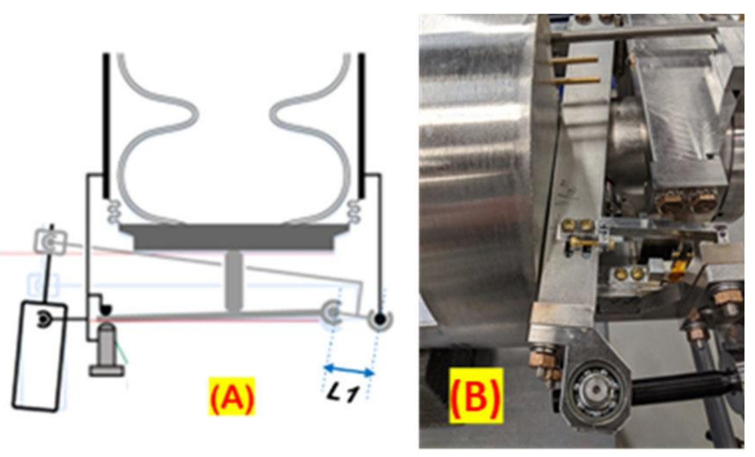

Figure 2 : Diagram of the tuner

Cavity Frequency Tuner

- The tuner must be able to compress the cavity by **715 kHz** which is roughly 3 times large range than the LCLS-II tuners.
- The LCLS-II-HE tuners were modified from the LCLS-II design by decreasing the tuner lever ratio from 1:20 to 1:16. The length of the motor arm was also increased by 7 mm. A Full description and discussion of these changes are presented in [2].
- These modifications changed the motor sensitivity from 1.4 Hz/step to 1.84 Hz/step.
- In the case of cavity 1 the total range of movement is 39 mm (assuming no other interference) and for the rest of the cavities it is 42 mm.
- The shaft screw is made of titanium, and the shrinkage rate of the 75 mm shaft is only 0.11 mm from room temperature to 2 K. Using this simple and simplified shrinkage for cavity 1 gives a tuning range of 717.6 kHz and for the rests of the cavities it is 772.8 kHz.

Cavity Frequency History

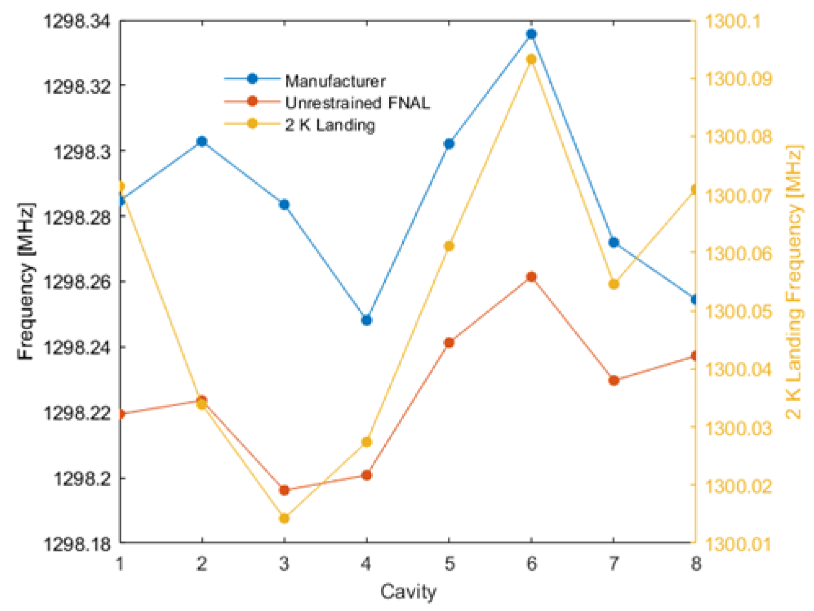

Figure 3: Cavity history of the vCM cryomodule. The frequency measured by the manufacture, unrestrained at FNAL, and the 2 K landing frequency are shown.

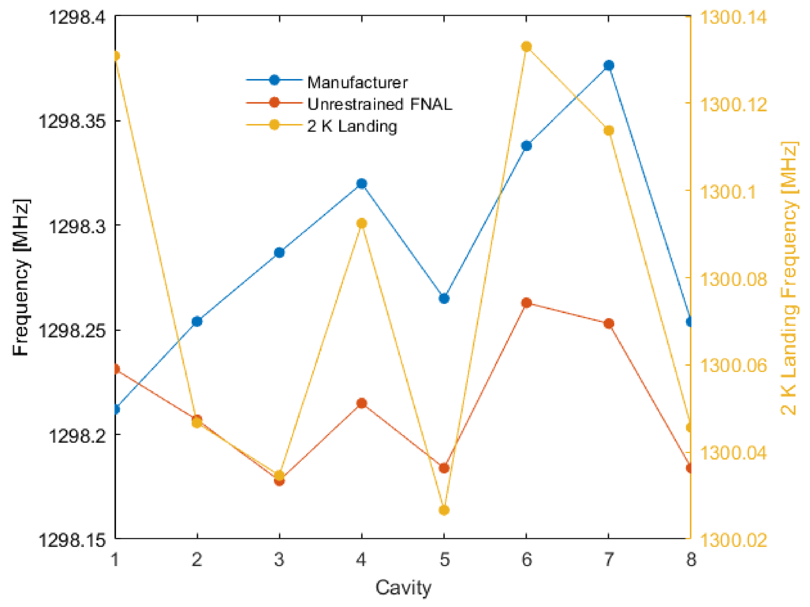

Figure 4: Cavity history of the CM 1 cavities.

- Another way to reach the full range of the OFO operation is to decrease the $f_{2k\ Landing}$.
- 95 % of the cavities tested had a $f_{2k\ Landing}$ of 250 kHz or less
- The cavity history for these two cryomodules is shown in figures 3 and 4.
- The frequency measurements are done at different pressures and temperatures. There are three regions where the pressure will affect the cavity frequency. These are the pressure outside the helium vessel (P_{out}), the pressure in the cavity helium vessel ($P_{HeVessel}$), and in the cavity beam line ($P_{BeamLine}$).
- The frequency measured at the manufacturer site: T=293 K , $P_{HeVessel}$ = 1 atm , P_{out} = 1 atm, and $P_{BeamLine}$ = Vacuum.
- Unrestrained frequency at FNAL: T=293 K , $P_{HeVessel}$ = 1 atm , P_{out} = 1 atm, and $P_{BeamLine}$ = Vacuum.
- 2 K landing frequency: T=2 K , $P_{HeVessel}$ = 23 Torr , P_{out} = Vacuum, and $P_{BeamLine}$ = Vacuum.

Tuners to OFO

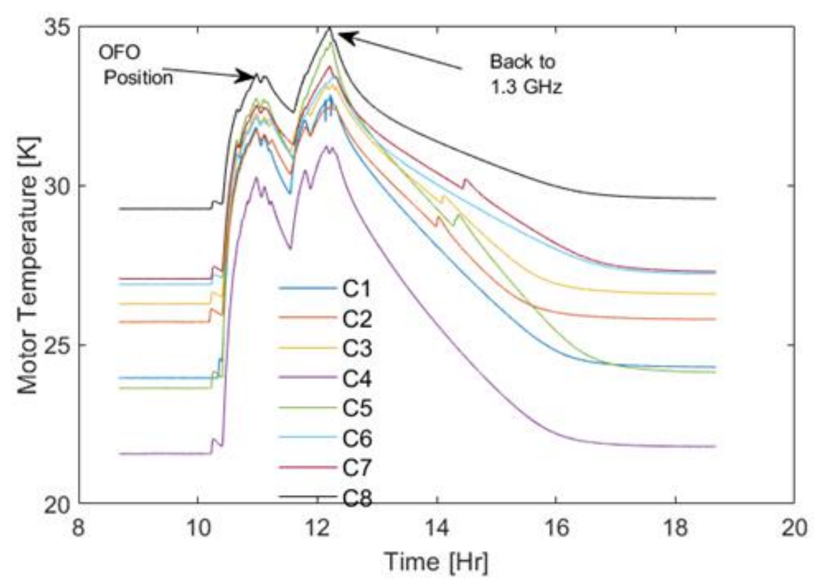

Figure 5: Motor temperatures during operation to OFO and returning to 1.3 GHz

Table 1: Steps required to tune the cavity to 1.3 GHz since the 2 K landing frequency

Cavity	vCM Steps to 1.3 GHz	CM1 Steps to 1.3 GHz
1	40125	73500
2	18875	26360
3	7768	19700
4	14885	52325
5	34145	15212
6	52330	77320
7	30300	63245
8	39500	25727

Table 2: Steps required to tune the cavity to OFO frequency. This is the total number of steps since the 2 K landing frequency.

Cavity	vCM OFO Steps	$vCM\ f_{OFO}$ $[MHZ]$	CM1 OFO Steps	$CM1\ f_{OFO}$ $[MHZ]$
1	258000	1299.533	335977	1299.535
2	258000	1299.536	290695	1299.535
3	258000	1299.535	284445	1299.535
4	258000	1299.535	316605	1299.535
5	258000	1299.533	280037	1299.535
6	258000	1299.545	356820	1299.533
7	258000	1299.535	325595	1299.533
8	258000	1299.535	287682	1299.534

- After all the cavities are tuned to the nominal frequency of 1.3 GHz the OFO operation can begin. The total number of steps from the 2 K landing frequency to the OFO set point is given in Table 2.
- For the vCM only a fixed number of steps was set, this was done as a precaution. No limit switches were tripped during this larger motor movement.
- For CM1 the number of steps needed to reach OFO was larger, this was due to the larger 2 K landing frequencies. During OFO operation none of the limit switches were tripped for CM1.
- It took a total of 1.5 hours to bring all cavities from 1.3 GHz to the OFO setpoint and then back to 1.3 GHz. The stepper motor temperatures were monitored, during this time the motor temperatures were only warmed up by 11 K (see Fig. 5).
- This showed that the copper heat sink attached to the stepper motor body can handle the heat load generated by the motor.

Conclusion

- Two LCLS-II-HE cryomodules were tested at FNAL. It was demonstrated that both cryomodules were able to bring all cavities to the OFO range.
- During this large frequency detuning of the cavities the stepper motor was operated for roughly 1.5 hours. During this operation, the motor only warmed up by 11 K from the nominal value when it was static.
- No limit switches were tripped, and the 62 % specification to bring cavities to OFO was met.

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