LCLS-II AND HE CRYOMODULE MICROPHONICS AT CMTF IN FERMILAB

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Introduction

- The study of microphonics for the LCLS-II cryomodules was done at Fermilab in the cryomodule testing facility (CMTF) facility (see Fig. 1).
- Passive microphonics techniques were implemented in the cryomodule to reduce the effects of microphonics .
- Implementing these changes yielded a peak detuning below 10 Hz for 63 % of all cavities tested and an RMS detuning of less than 2 Hz for 60 % of all cavities tested. The results are shown in Figure 3 and 4.
- Note that these results could be unique to the CMTF environment. The supply pressure at SLAC will be lower and so will the inlet helium temperature.
- The detuning data was collected after a week of the cryomodule being cooled to 2 K since earlier data can be affected by thermalization effects.
- The cavities that have a peak detuning greater than 10 Hz have similar vibrations sources such as a 30 Hz source attributed to the Kinney vacuum pump. Other cavities are affected by cryogenics such as the 2.3 K supply pressure, harmonics, and Helmholtz mode of the helium vessel. The Helmholtz mode is affected by the liquid level inside the helium vessel.

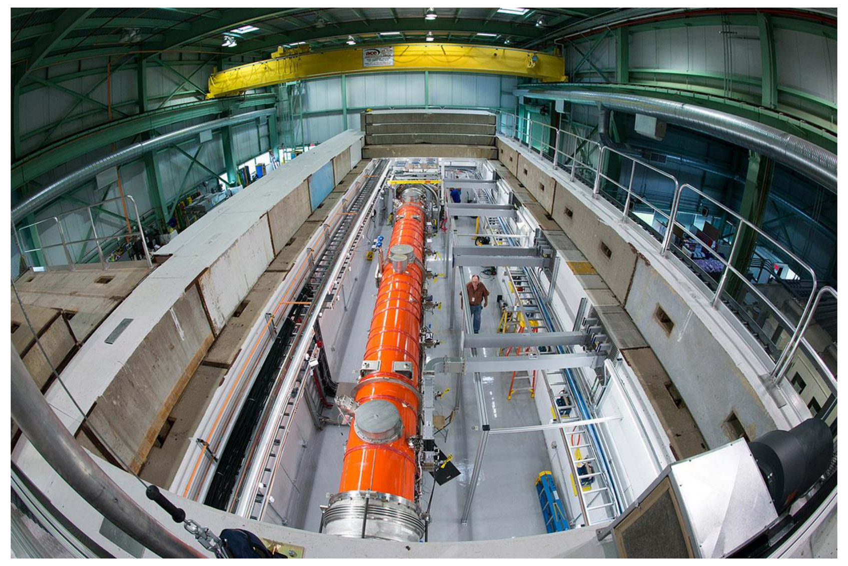

Figure 1: CMTF at Fermilab

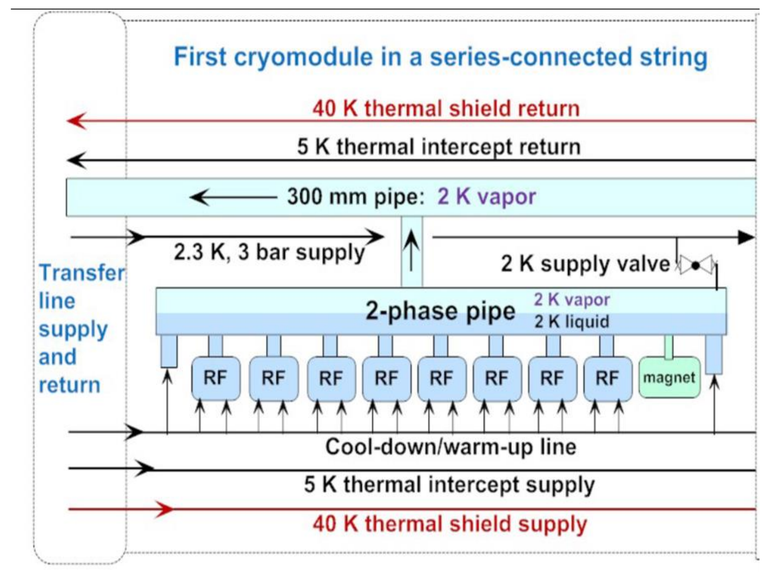

Figure 2: Cryogenic flow schematic of a 1.3 GHz LCLS-II cryomodule.

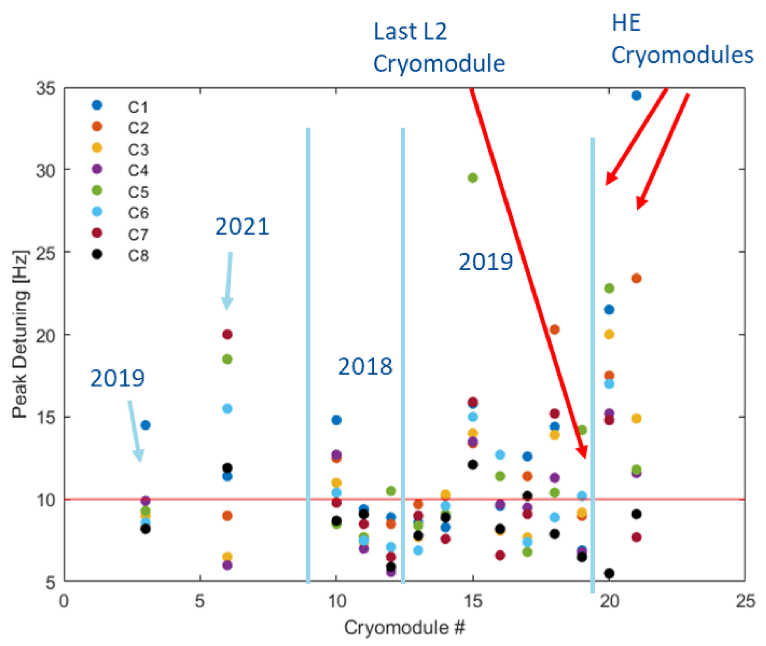

Figure 3: Cavity peak detuning of all 8 cavities from cavities tested from 2018 until 2022. These include cavities from LCLS-II and HE. The cavity peak detuning specification is 10 Hz.

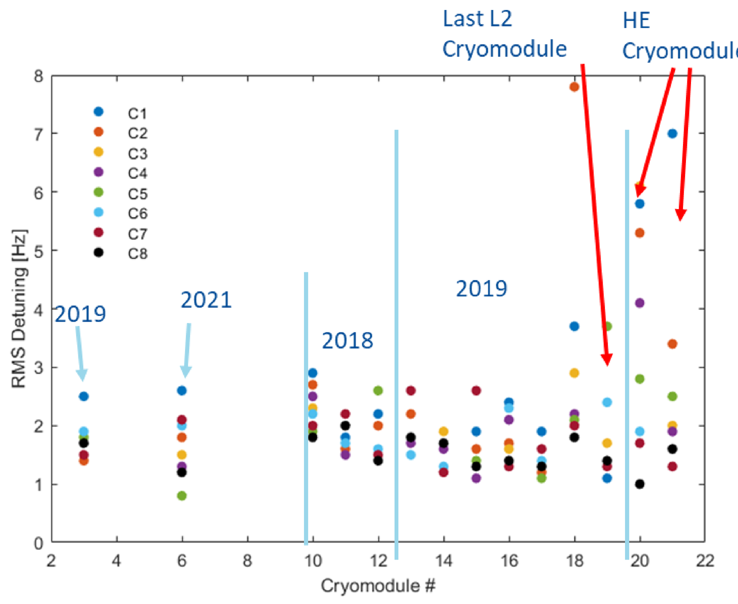

Figure 4: RMS cavity detuning from 2018 to 2022. These include cavities from LCLS-II and HE.

Cryogenics Induced Microphonics

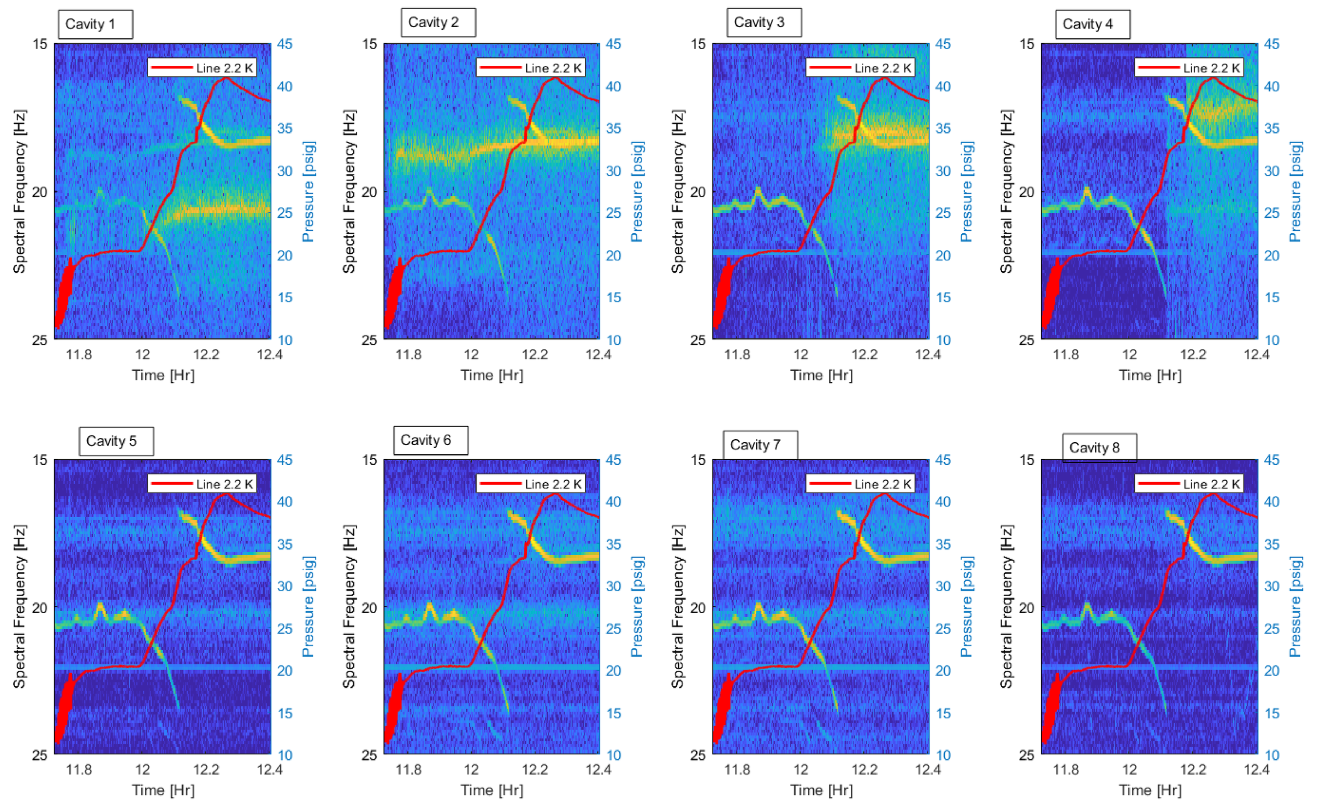

Figure 5: Spectrogram of the cavities in vCM showing the transition of 20 Hz vibration to 18 Hz by changing the supply pressure of the 2.3 K line.

- All cavities tested shown in Figures 3 and 4 have 18 Hz or 20 Hz vibrations
- This vibration was studied by changing the supply pressure of the 2.3 K line.
- The supply pressure was varied from 10 psig to 40 psig in the verification cryomodule (vCM HE).
- The results show that the 20 Hz vibration transitions to an 18 Hz vibration. The nominal supply pressure is 33 psig, at around 25 psig the 20 Hz vibration changes to 18 Hz.
- In this data acquisition the 18 Hz vibration becomes stable once the nominal pressure is reached. In other cases it is the 20 Hz vibration
- In some of the cavities the 18 Hz vibration can also lead to harmonics as shown on the spectrograms in Fig. 6 and Fig 7.

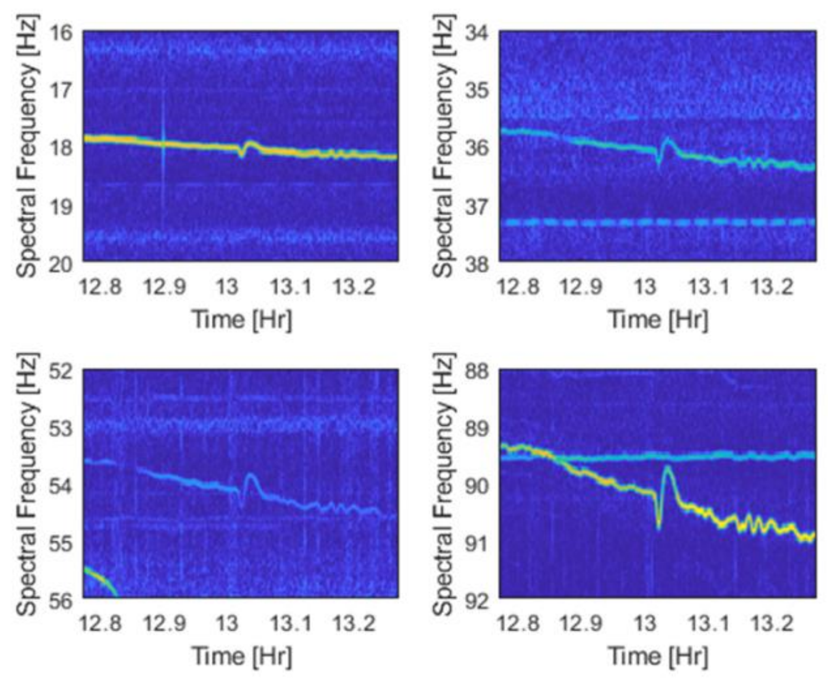

Figure 6: Spectrograms showing harmonics observed in cavity 7 in CM 15, the fundamental mode occurs at 18 Hz.

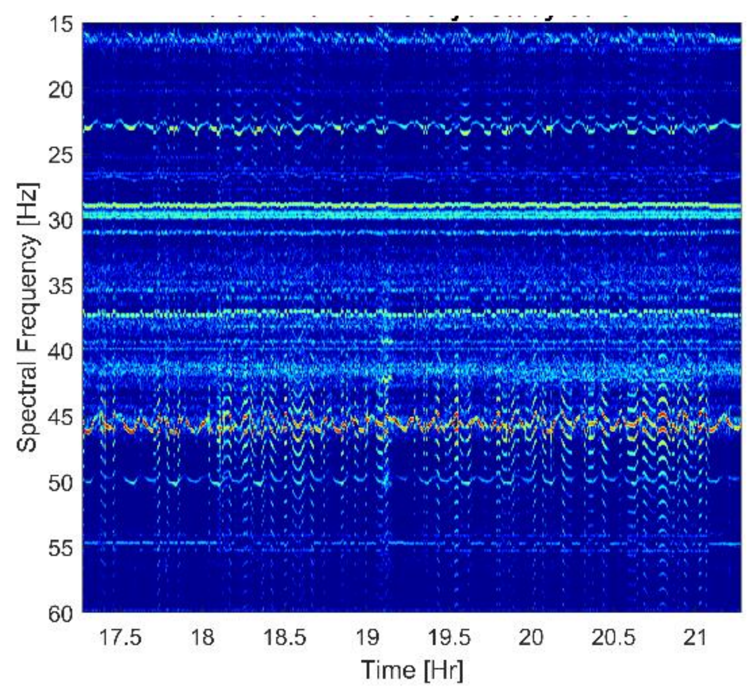

Figure 7: Spectrogram of cavity 5 in CM15 showing the harmonics with fundamental frequency of 23 Hz and higher order frequency of 46 Hz. .

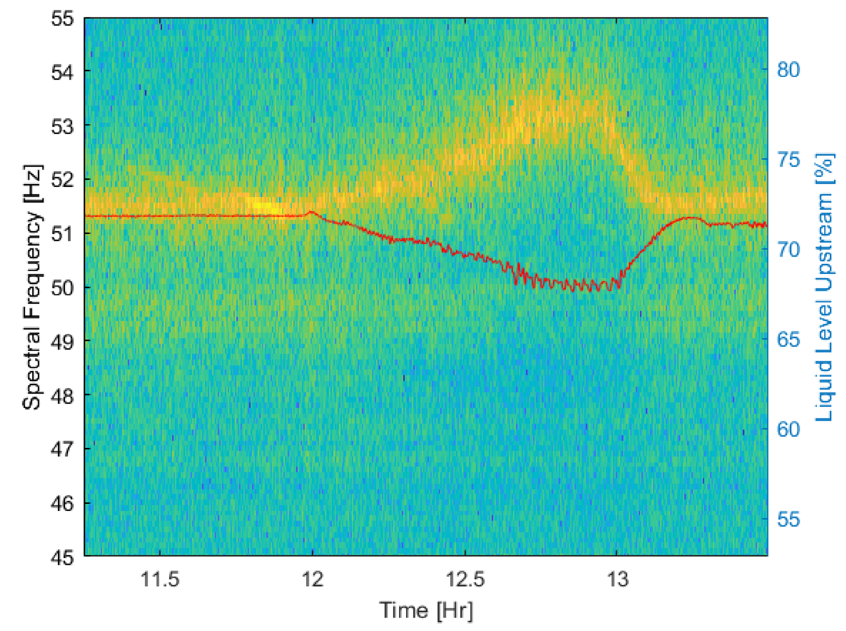

Figure 8: Liquid level variation for Helmholtz mode in cavity 1 CM21. The liquid level is correlated with the 51.5 Hz mode.

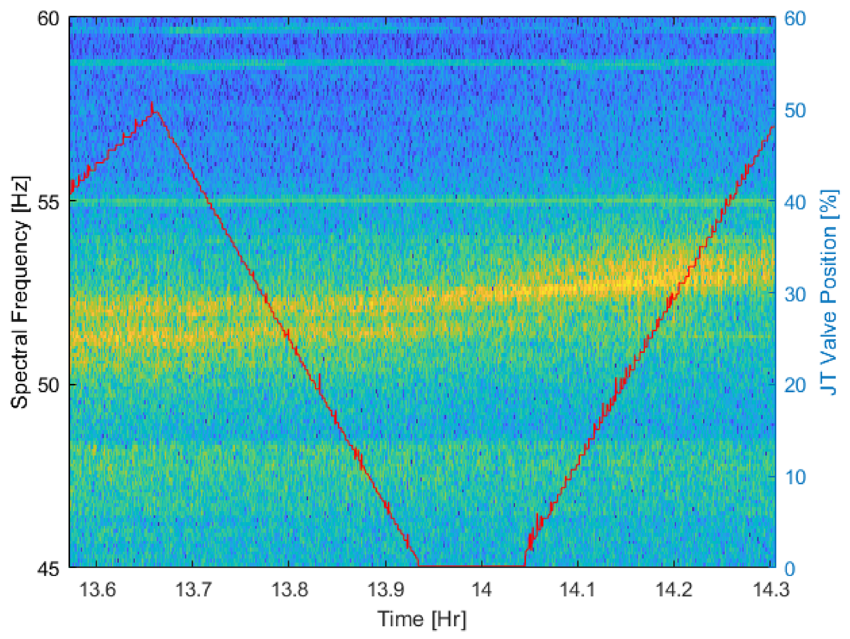

Figure 9: Spectrogram showing the effects of closing and opening the JT valve on the 51.5 Hz Helmholtz mode.

- Figure 6 shows data for CM15, the fundamental mode occurs at 18 Hz with higher order modes of 36 Hz, 54 Hz, and 90 Hz. The small blip at around hour 13 is due to the supply pressure for the 2.3 K line.
- Figure 7 shows the data for CM15, the fundamental mode is 23 Hz and the higher order mode is 46 Hz. The 23 Hz line is correlated with the 2.3 K supply pressure line.
- A prominent vibration in the LCLS-II and HE CMs is due to 48 Hz to 51.5 Hz mode. This vibration is cavity dependent, in cavity 1 the vibration is 51.5 Hz and in cavity 8 it is 48 Hz.
- This difference in frequency is due to the liquid level of the cavity, the cryomodule is tilted and cavity 1 has a lower liquid level than cavity 8.
- The effects of the liquid level on the 51.5 Hz vibration in cavity 1 are shown in Fig. 8.
- This effect is caused by the Helmholtz mode of the cavity liquid helium vessel. The Helmholtz mode can only occur in the superfluid phase of helium.
- Figure 9 shows that the JT valve does not affect this vibration

Conclusion

The LCLS-II cryomodules changed their design to reduce the effects of microphonics. These changes were also implemented for the cryomodules in LCLS-II HE. Despite these passive mitigation techniques the cavities still experience frequency detuning caused by residual microphonics. An analysis of the frequency detuning of 112 cavities along with multiple cryogenic parameters was made for 14 cryomodules. The results discussed demonstrate that cryogenic parameters such as liquid helium level and supply helium pressure variation affect the frequency detuning.

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