# EXTENDED RANGE SRF CAVITY TUN FOR LCLS-II HE PROJECT*

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***Abstract***
The off-frequency detune method is being considered to be applied in the LCLS-II-HE superconducting linac to produce multi-energy electron beams for supporting multiple undulator lines simultaneously [1]. To deliver off-frequency operation (OFO) requirements for SRF cavity tuner must be changed. Tuner design modifications and results of the testing new tuner installed on the single dressed cavity and eight cavity/tuner system, deployed in verification cryomodule (vCM), will be presented.

SRF tuners, that will be deployed into LCLS-II-HE linac, must be capable to bring 100% cavities to operational frequency 1.3GHz and at least 62% of the cavities of the linac need to be retuned to 1.299,535kHz ($F_{OFO}$=1.3GHz-465kHz) [6]. One more demanding requirement is regularity of cavity re-tuning from 1.3GHz to $F_{OFO}$=1.3GHz-465kHz. It must be done approximately twice a month, that will be required exceptional longevity for SRF cavity tuner.

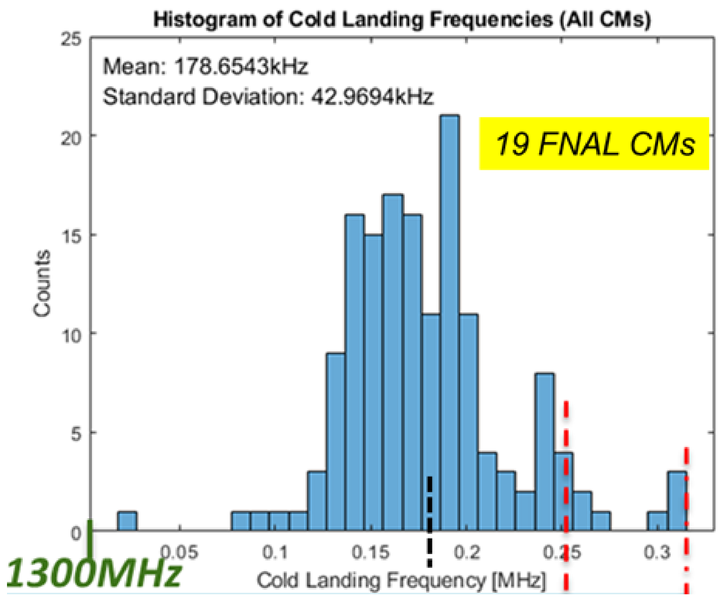
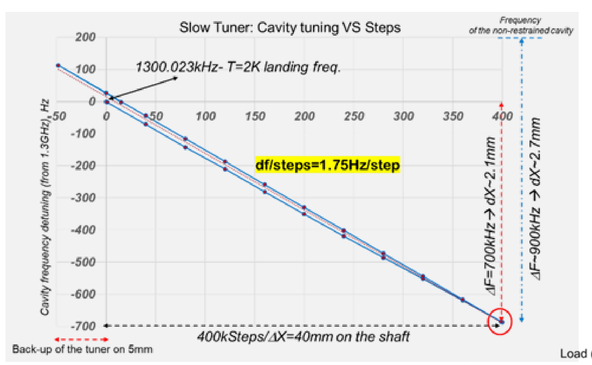


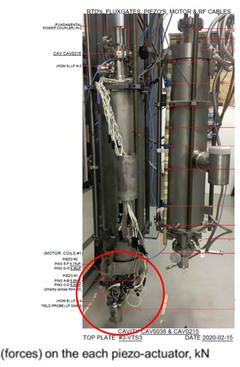

Figure1: Distribution of the values F $_{T=2K\_Landing}$ for 152 cavities assembled into 19 FNAL's cryomodules. Mean value is 1.3GHz+178kHz.

LCLS-II-HE slow tuner range ~465kHz+200=665kHz
Tuner range must be increase **~2.5 times….**
With cavity compression ~885kHz/330kHz/mm~2.7mm

## TESTING OF THE MODIFIED TUNER

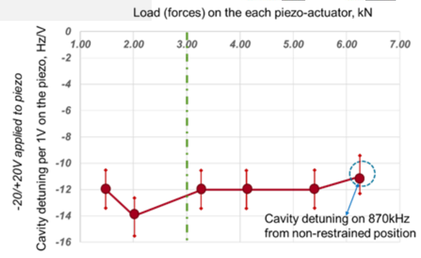
1. Test at VTS… cavity/tuner submerged into LHe



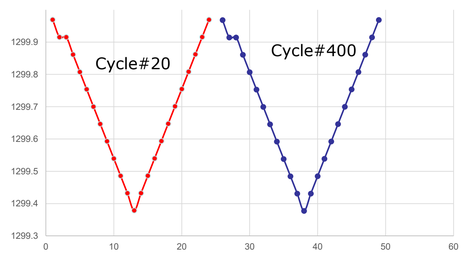



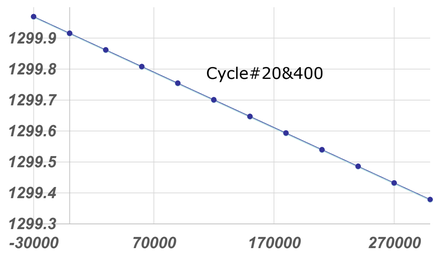
Load (forces) on the each piezo-actuator, kN

VTS test also provided information about parameters of the 9-cell elliptical cavity when compressed on quite significant stroke ΔX~2.7mm. VTS test demonstrated that cavity do not experience of any non-elastic deformations. **After two cycles of compression cavity on ΔF= 870kHz the cavity's field flatness changed less than on 0.01%**




2. ALT Tuner/dressed cavity at HTS by cycling cavity 625 times at T=2K & 4K.



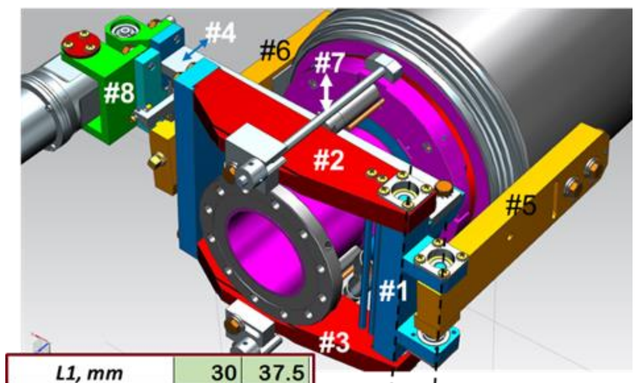

3. Testing of the tuners at vCM

Table 2: vCM cavity frequencies and number of the motor's steps required to bring cavities to 1.3GHz.

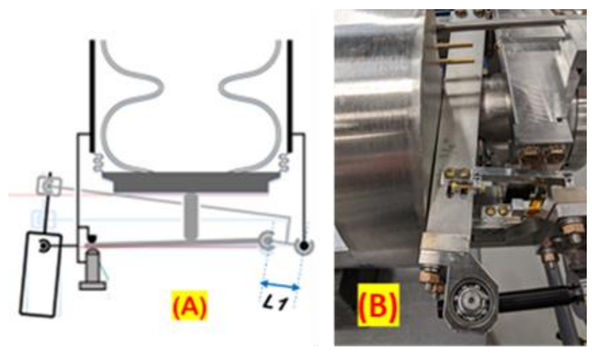
| cavity# | F $_{T=2K\_Landing}$ - 1.3GHz, [kHz] | Number of the motor steps required to tune cavity to 1.3GHz | Slow Tuner sensitiviy, [Hz/step] |
|---|---|---|---|
| 1 | 71 | 38730 | 1.83 |
| 2 | 32 | 17300 | 1.85 |
| 3 | 13 | 6460 | 1.97 |
| 4 | 28 | 14750 | 1.88 |
| 5 | 61 | 32950 | 1.84 |
| 6 | 93 | 54700 | 1.70 |
| 7 | 51 | 27780 | 1.84 |
| 8 | 69 | 37850 | 1.82 |
| | *52* | | ***1.84*** |

## TUNER MODIFICATIONS

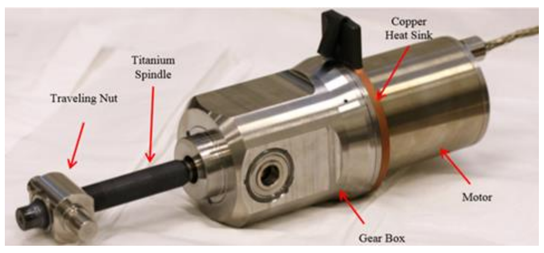
Two major tuner design modification have been introduced: (a) slow tuner lever ratio changed from **1:20 to 1:16** and (b) length of the tuner arms was **increased on 7mm**, allowing to shift tuner frame from cavity magnetic shielding and increase room for motor arm




| L1, mm | 30 | 37.5 |
|---|---|---|
| Tuner Ration | 20 | 16 |
| Hz/step | 1.4 | 1.8 |




## *Specification for stepper motor actuator*




| | LCSI II | LCLS II HE |
|---|---|---|
| Forces on the shaft/nut system to tune 95% of cavity to 1.3GHz, [N] | 270 | 340 |
| Forces on the shaft/nut system to tune 95% of cavity to 1.3GHz-465kHz, [N] | N/A | 690 |
| Longevity of the actuator/Number of the motor kSteps to tune cavity from 1.3GHz to "safe" position before warm-up (twice a year) during 20 years, [MSteps] | 7.2 | 5.6 |
| Longevity of the actuator/Number of the motor kSteps to tune cavity from 1.3GHz to "1,3GHz-465kHz" and back 20 times a year during 20 years, [MSteps] | N/A | 206 |
| Longevity for 20 years operation, [Msteps] | 7.2 | 210 |

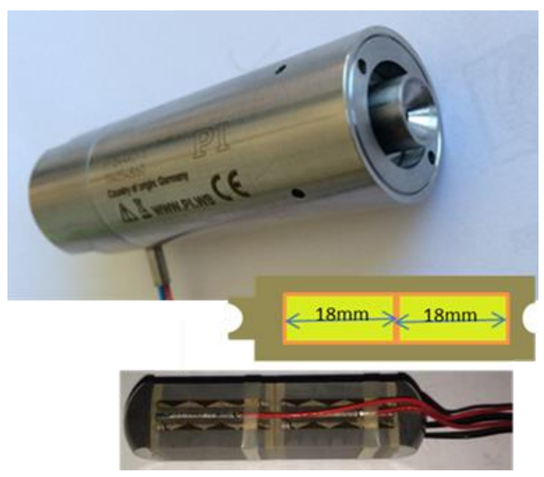
1300N specs

30 times!!!

ALT test at HTS with dressed cavity.
625 cycles … 2 X 600kHz each cycles ~1.5 lifetimes of LCLS II HE..
**No any degradation performances of the stepper actuator has been observed.**

## *Specification for piezo actuator*

*Piezo actuator will be preloaded on the* ***~6-7kN at OFO****… or 2 times larger forces than at LCLS II*




Piezo cross-section is 10X10mm2; blocking forces 3.8kN;internal preload 800N; stroke at RT ~36um; at LCLS-II/HE ~20Hz/V

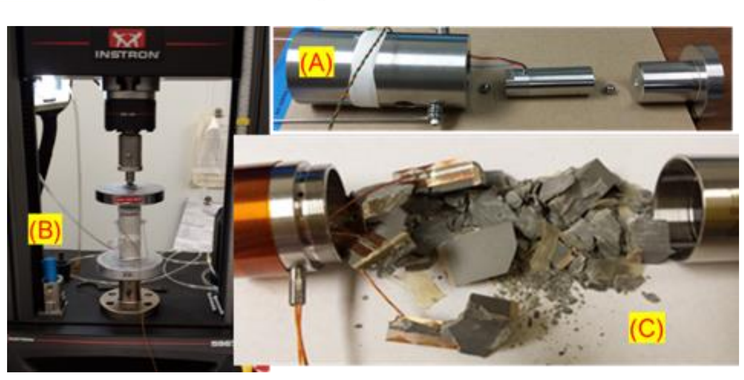



Figure: Destructive test of the piezo actuator. (A) Actuator installed inside heavy jig to minimize shearing force development and keeping piezo-ceramic at temperature T~80K during test at Instron (B). (C) Crushed pie-zo-ceramic stack. Actuator withstand forces **~28kN** before collapsed.

Piezo performances was not changed at 7KN preload. The same cavity tuning capability (20Hz/V) and predicted the same reliability level. After 625 cycles up to 6kN (ALT at HTS) there are no any piezo performances changes: piezo response still the same ~20Hz/V

## CONCLUSION

**LCLS II HE tuner is modification of the LCLS II tuner that addressed OFO requirements. Objectives were to introduce only necessary modifications of the proven to be reliable LCLS II design. To increase tuning range in 2,5 times tuner frame has two major changes: increase on 7mm the tuner arm's length and double lever ratio from 1:20 to 1:16. The modified tuner prototype was able to deliver OFO range without changing length of the stepper motor shaft and avoid interferences between cavity magnetic shield and motor arm. ALT testing at HTS demonstrated that Phyton stepper motor actuator operated for 400MSteps that is twice of required longevity of actuator for OFO. The PI encapsulated piezo actuators, used for LCLS II project, will be used for LCLS II HE. Testing tuner, when piezo preloaded at 6kN, that required to operate at OFO, demonstrated the same characteristics as at 3kN. ALT test at HTS confirmed that piezo performances do not changed after two piezo actuators were compressed up to 6KN 625 times. Based on the analysis performed by PI and FNAL experts we are expecting the same level of reliability of the P-844K075 actuator even at 6kN preload, as required by OFO. Multiple tests with extended range tuners installed on the dressed cavities demonstrated that tuner met LCLS-II-HE OFO specifications.**