LCLS-II TUNER ASSEMBLY FOR THE PROTOTYPE CRYOMODULE AT FNAL

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Abstract

The tuner design for LCLS-II has been thoroughly verified and fabricated for used in the LCLS-II prototype modules [1,2]. This paper will present the lessons learned during the installation of these tuners for the prototype module at FNAL, including installation procedures, best practices, and challenges encountered.

TUNER COMPONENTS QC AND PREPARATION STEPS BEFORE INSTALLATION INTO CM

SRF cavity tuners frames arrived from vendor pre-assembled (Figures 1, 2). As the first Quality Control (QC) step tuner frame installed on the cavity/He vessel mock-up" frame (Figure 2). As preparation step for installation on the cavities string tuner frame dis-assembled on three large components (Figure 2).

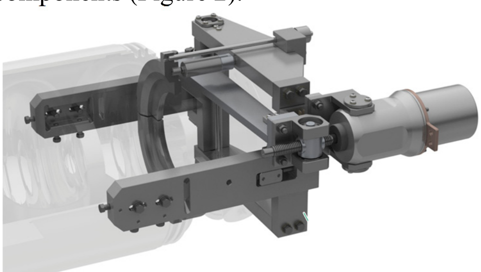

Figure 1: 3-D model of LCLS II tuner.

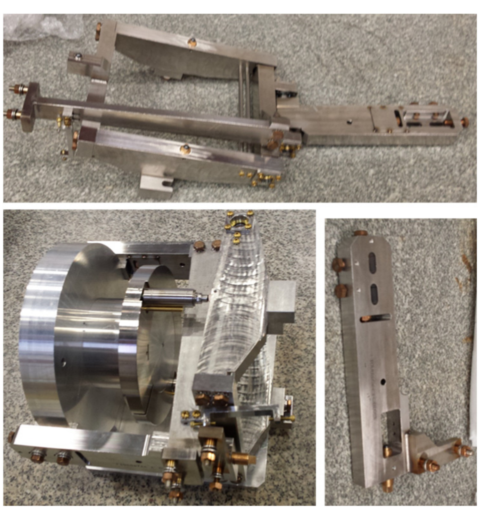

Figure 2: Tuner frame assembled on the aluminium fixture. Partially disassembled tuner before installation on pCM.

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The electromechanical actuator LVA 52-LCLS II-UHVC-X1 (and two limit switches) [1, 2] terminated to rad-hard Hypotronics connectors at FNAL (Figure 3). Each actuator tested at FNAL before installation on the tuner. For production cryomodule Phytron, Inc will terminate motor and limit switches wires to 9 pin Hypotronics connectors. Company will also conduct details test of each actuators (including testing each units at LN2 temperature).

The 16 piezo-actuators P-844K075 [1, 2] were terminated to rad-hard Hypotronics connectors and tested at FNAL before to be install on prototype cryomodule (pCM). Each piezo-capsule has two 10*10*18 mm^3 piezo-stack and following parameter was measured for each 19 mm long piezo-stack: capacitance, dissipation factor, stroke for V=60 V.

For production cryomodule Physik Instrumente (PI) will supply piezo-capsules already terminated to connector and tested. Protocol for testing agreed between PI and LCLS II project.

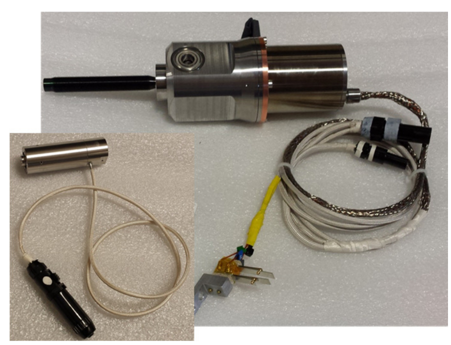

Figure 3: Active components of the tuner: electromechanical actuator and piezo-capsule.

TUNERS INSTALLATIONS AND CHALLANGES

Tuners installed many times on the single dressed cavity but installation on the cold mass was much challenging adventure: tight space, significant amount of the other cavity components.

Our previous experience reflected into travellers / tuner installation procedure. It roughly divided into several steps (Figure 4):

1. Removing safety brackets (that protect cavity during previous production steps)
2. Installation on the He vessel right tuner arm and main levers around beam pipe (Figure 4 (A))
3. Installation on the He vessel tuner left arm and connecting together left and right side of tuner (Figure 4 (B))

4. Installation of stepper motor (electromechanical actuator and limit switches) (Figure 4 (B))
5. Adjustment of the actuator's traveling nut position and limit switches
6. Installation and preloading both piezo-capsules (Figure 5) by compressing cavity on 40-50 kHz (Figure 4 (C))
7. Installation of the safety rods
8. Tightening all screws (including set-screws) with specify torque and applied cryogenic glue to set-screws

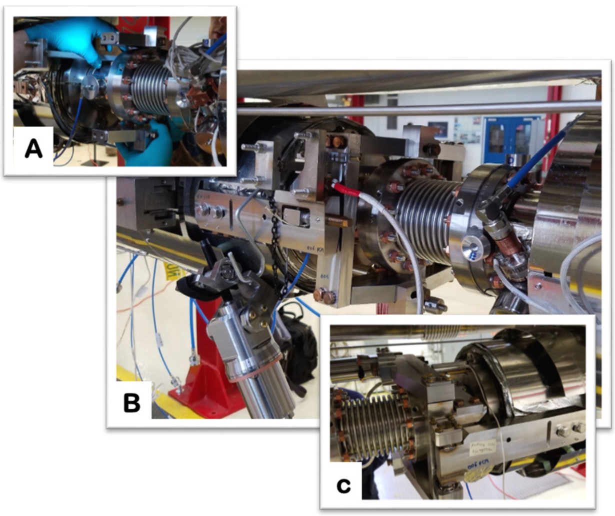

Figure 4: Assembly of the tuner on the pCM. (A)- Right arm of the tuner attached to He vessel lug and tuner's levers mounted around beam-pipe. (B)- Tuner frame assembled. Process of installation of the stepper motor and limit switches. (C)-Tuner assembled (safety rods not installed).

Overall tuners installation into FNAL pCM went without significant problems. One of the factor that contributed into smooth installation of the tuners on pCM was development specialized tools & fixtures. There were several issues that will be addressed for incoming production cryomodules. Small modifications into tuner design already done.

Several tuner assembly issues will be taking into consideration and resolve for production cryomodule:

1. Tuner design with assumption that distance between He Vessel lugs used to mount tuner will machine with small tolerance. Several cavity has quite significant tolerances that create issues with tuner assembly. Major impact was on the piezo capsules alignment. Misalignment of the piezo can built shearing forces that will compromise lifetime of the piezo-stack.

2. Cavity magnetic shielding endcap for pCM designed and fabricated without taking into consideration that tuner lever arms need to move close to cavity split ring. As result, tuner range was limited to 400 kHz (instead of 600 kHz) and complicated stepper motor setup procedure.

3. Procedure for setting up "max, "zero" and "min" position for traveling nut/ tuner lever and limit switches trigger arm was time-consuming and complex. Increasing range of tuner range to 600 kHz for production cryomodule (by modifying design of cavity magnetic shield) will simplify setting of "max/zero/min" positions on the tuner trigger arm. The screws on trigger arms will short limit switches to the ground (Figure 6) that is adding complication for stepper motor operations. In the production cryomodule screws will have insulated cup made from G11 to avoid short to the ground.

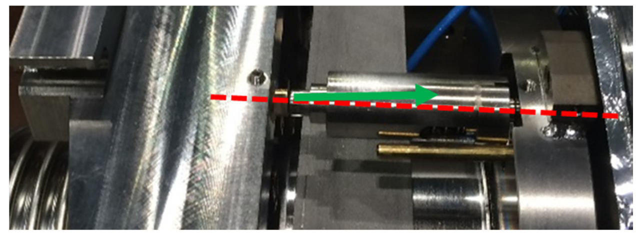

Figure 5: Picture of the top piezo-capsule. Red line – axis of piezo. Green line – direction of the forces on the piezo capsule.

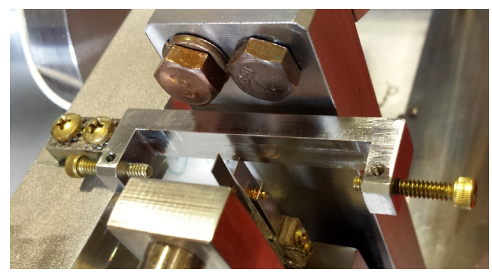

Figure 6: Picture of the limit switches and trigger arm with screws that will trip switches.

By design tuner can only compress cavity and tune cavity frequency lower value. During our tuner design verification program we tested several dressed (with tuner installed) cavities at HTS [1]. Tests shown that during transition of the warm (N2 back-filled) cavity to cold (2 K) cavity additional compression of the cavity by tuner will be in the range of 300 µm (or 100 kHz). This compression can be explained by different thermo-contraction of the components the cavity/He Vessel/tuner system. Taking into account additional 40-50 kHz cavity preload by piezo-capsule through tuner installation process cool-down to 2 K will compressed cavity on 450 µm (or 150 kHz). It is meant that tuner can "back-up" or release compression of the cavity on ~300 µm (or ~100 kHz) without compromising cavity/tuner system performance. It can be important in case when after cool-down cavity will be "landed" with frequency below 1.3 GHz (Figure 7, cavity #1). During installation "zero" position of the tuner arm can be selected to allow motor to "back-up" to increase frequency of the cavity. For the pCM we divided 400 kHz tuner range in two portions: (1) to compress cavity ~ -330 kHz and (2) to "back-up" ~+70 kHz.

The cavities frequency (calculated and measured) after FNAL pCM cool-down to 2 K presented on the Figure 7 [3]. Frequency of the "non-restrained" cavity at 2 K calculated by adding ΔF=2.35 MHz to the measurements of the frequency for "warm/open to air/ non-restrained" dressed cavity. This value (ΔF=2.35 MHz) came from DESY and FNAL experience with 1.3 GHz 9-cell elliptical cavities. On the Figure 7 presented frequency of "restrained by tuner" cold cavity that is different from "non-restrained" cavity on the ΔF=-150 kHz. Differences between calculated and measured values are 10-77 kHz (Figure 7). Measurements with FNAL pCM confirmed that frequency of the cavity at 2 K could be predicted quite well using measurements of "warm dressed cavity".

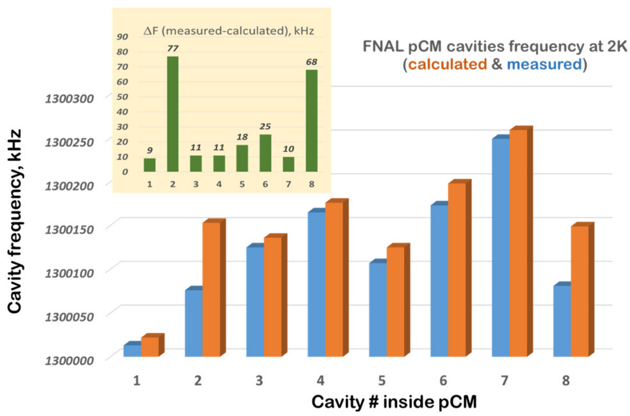

Figure 7: The FNAL pCM cavities frequency measured at 2 K (blue) and calculated based on warm cavities frequencies and measurements of tuner performance at HTS. Insert: difference between measurements and predictions.

QC OF THE TUNER AFTER INSTALLATION

After tuner assembled on the each cavity designated set of tests of the slow (stepper motor) and fine (piezo) tuner performed (Table 1).

Cavity/tuner system connected to NWA and frequency of the cavity monitored during any periods when cavity can be compressed or stretched. Stepper motor run on 10 ksteps (or 15 ksteps) and return back to "zero" position. Operator visually monitor direction of the motor and actuator spindle rotation. The 10 ksteps on the stepper is one full turn of the spindle. One full spindle turn must compress or stretch cavity on 50 μm (or +/-15 kHz frequency shift). Summary of the test presented on Table 1. Right after assembly tuner loaded by piezo-capsule just on ~45 kHz (or 500 N). 500 N is quite low load on the tuner. It is preferable during slow tuner tests to compress cavity (like cavity #1 and #8) instead of decreasing preload (cavity #2-7). Important to emphasise that maximum allowable for warm cavity range is ~600 μm. During slow tuner tests cavity will compressed on 200 μm.

Piezo operation tested by applying V_{dc}=60 V on (a) the both top and bottom piezos and on (2) just one piezo (Table 1). For V_{dc} =60 V expected stroke from both piezo-capsule is 18-20 μm and corresponding cavity frequency changes must be ~6 kHz (for one piezo expected ~3 kHz).

Table 1. Summary of the QC Test of the Slow and Piezo Tuner after Installation of the Tuners on the pCM

#	Cavity ID TB9#	F_{before}	Stepper Motor, [ksteps]	F after	ΔF, [kHz]	ΔF/step, [Hz/step]	ΔF, [kHz] 60V Vpplied to Both Piezo	ΔF, [kHz] 60V Applied to One Piezo
1	AES021	1297.77	-15	1297.74	-24	1.6	-5	-3
2	AES019	1297.83	10	1297.84	12	1.2	-5	-3
3	AES026	1297.88	10	1297.89	10	1.0	-5	-2
4	AES024	1297.92	10	1297.93	12	1.2	-5	-3
5	AES028	1297.86	10	1297.87	12	1.2	-5	-2
6	AES016	1297.93	10	1297.94	11	1.1	-5	-2
7	AES022	1298	10	1298.01	11	1.1	-6	-2
8	AES027	1297.83	-15	1297.81	-22	1.5	-5	-3
	Target				-15	-1.50	-6	-3

CONCLUSION

Eight tuners designed at FNAL for LCLS II 1.3 GHz elliptical cavity successfully installed on the FNAL pCM. Procedures and tools developed during tuner design verification program were used in real production environment. Several small tuner frame modifications that come out from pCM experience already incorporated into production set of the tuners. Program for testing tuners assembled on CM established.

FNAL pCM cool-down and tuners were tested [3]. Tuners performance into pCM met technical requirements specifications.

REFERENCES

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