Overview of the Application Piezoelectric actuators for SRF cavity tuners*

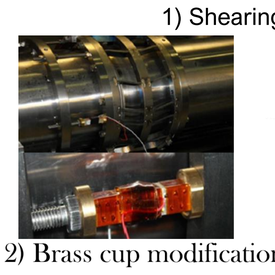
Y. Pischalnikov†, ***Fermilab, Batavia, IL, USA***

Abstract

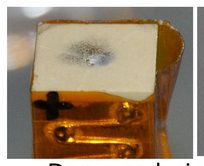
Large SRF Linacs and HEP experiments require accurate frequency control, which is achieved using cavity tuners typically actuated by the piezoelectric ceramic stacks. The piezoelectric ceramic stacks became “standard” components of the SRF cavity tuner and, depending on the application, could be operated in the different environment: in air, at cryogenic temperature, in vacuum, and submerged in liquid helium. Different applications place different requirements on the piezo actuators, but the important parameters, common to all applications, are the lifetime and reliability of the actuators. Several R&D programs targeting the development of reliable piezo actuators are reviewed in this contribution.

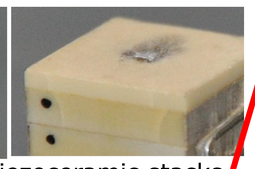
Design of the fast Tuners/ Mechanical integrations of the piezoelectric stack into tuner

1) Shearing Forces applied to piezostack

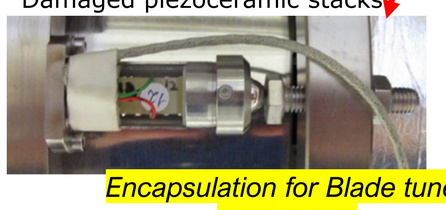


2) Brass cup modifications

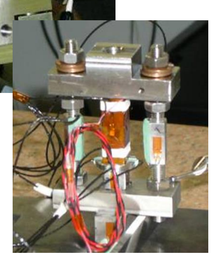




Damaged piezoceramic stacks

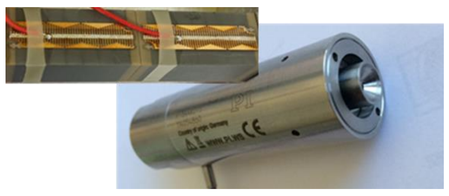


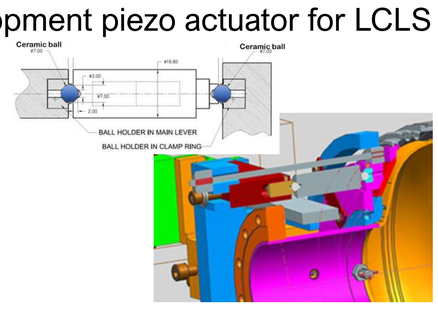
Encapsulation for Blade tuner CM2/ILCTA



Using strain gages to measure shearing/bending forces on the piezo stack

Collaboration with PI… Development piezo actuator for LCLS II





Encapsulated piezo actuator P-844K075 (LCLS-II). Inset: Two PICMA piezo-ceramic stacks (10×10×18 mm) butted together, that are installed inside the stainless-steel capsule.

Two ceramics balls, that used to interface the slow tuner frame and the cavity, help to prevent build-up of shearing forces on the piezo actuator.

For LCLS II HE project actuator P-844K075 must work with preload 6-7kN (when blocking forces for this unit just 3.8kN)

Piezo ceramics offer compressive strength well above 200MPa. P-844K075 actuators equipped with PICMA stacks 10*10mm2 can take at least 20kN pressure without been destroyed.

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.

CONCLUSION

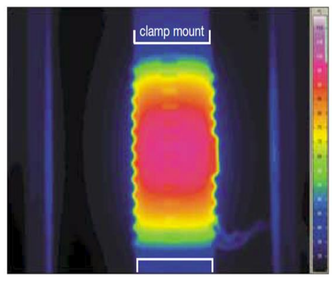
Longevity of the modern piezoelectrical actuators can easily cover 20-30 years, that is typical lifetime of SRF linac. To preserve this longevity, tuner’s designers must follow the main recommendation of the piezo vendors during process of integration piezo stack into SRF cavity tuner. Collaboration with applications engineers from piezo production companies will help to deliver reliable tuner design.

FNAL/PI joint R&D program led to development P-844K075 actuator, that successfully deployed at LCLS II and will be used in PIP II and LCLS II HE.

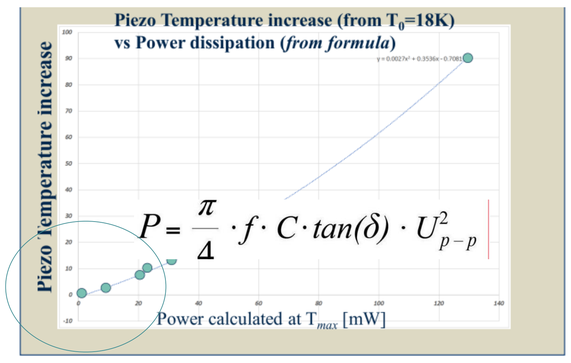
Novel piezo actuator P-844K093 developed for high dynamic rate operation. Copper foam heat transfer tech-niques resolved piezo overheating problems. Prototype actuator from lithium niobite piezoceramic demonstrated good potential for SRF tuner’s application.

Recommendations for selection of the piezo actuator for “warm” tuner’s is presented.

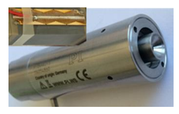
Heating piezo actuator, when operated inside insulated vacuum at high Vpp and high dynamic rate (RF-pulse mode/LFD Compensation)

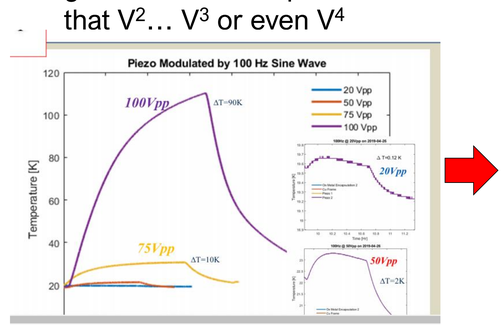


Thermal image of the dynamically cycled piezo actuator, clamped at its ends. Environment: ambient air convection. Notice the cooling effect at the end faces due to the clamping mounts [76].



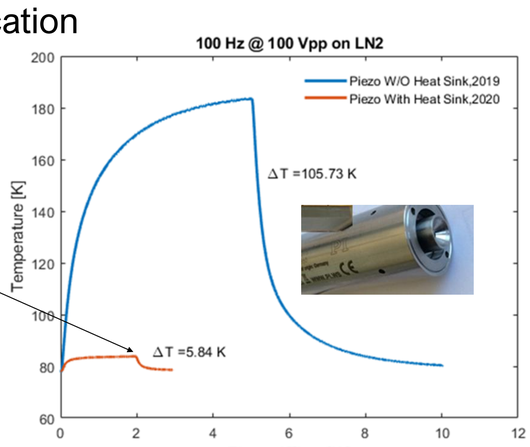
At large Vpp (around 100V) power dissipation growth faster that predicted formula /faster that V^2… V^3 or even V^4

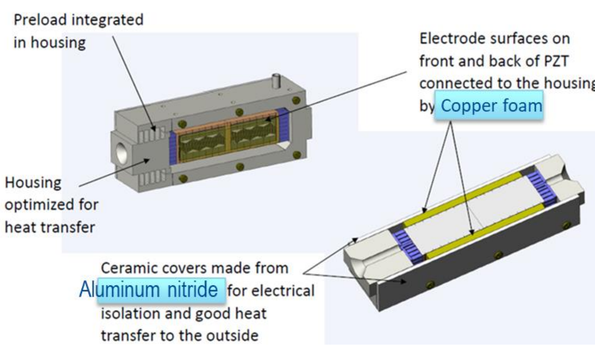


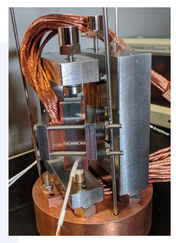


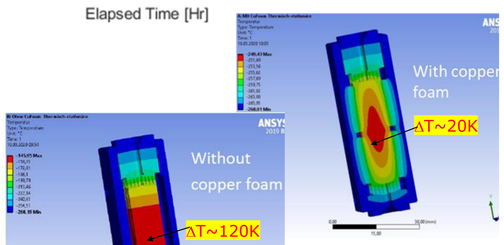
Newest PI piezo actuator for high amplitude and high dynamic rate application

Design concept for a dynamic actuator in cryogenic applications (updated)









Simulation of heating of piezo with and without copper foam in contact with the ceramic (courtesy of PI)

Piezo actuator from Lithium niobate *LiNbO3*

V= -500V to +500V
Stroke = 3um

	PIC 050	PIC 255/252
Material	$LiNbO_3$	PZT
Length [mm]	36	18
Cross-section [mm^2]	100	100
Stroke (300 K) [μm]	3	18
Stiffness [N/μm]	195	200
Blocking Force (300 K) [N]	585	3600
Curie Temperature [K]	1423	623
Density ρ [g/cm^{-3}]	5	7.80
Relative Permittivity ϵ_{33}/ϵ_0	28.7	1750

As predicted, FNAL tests demonstarted very small (☐T <1K) changes in actuator temeprature when run with sinewave at 200Hz and Vpp=1000V. Lithium niobate actuators could be good alternative to “standard” PZT actuators for high dynamic rate operation in cryogenic/vacuum enviroment.

OPERATION OF PIEZO ACTUATORS AT AMBIENT ENVIROMENT