LCLS II Cavity Tuner

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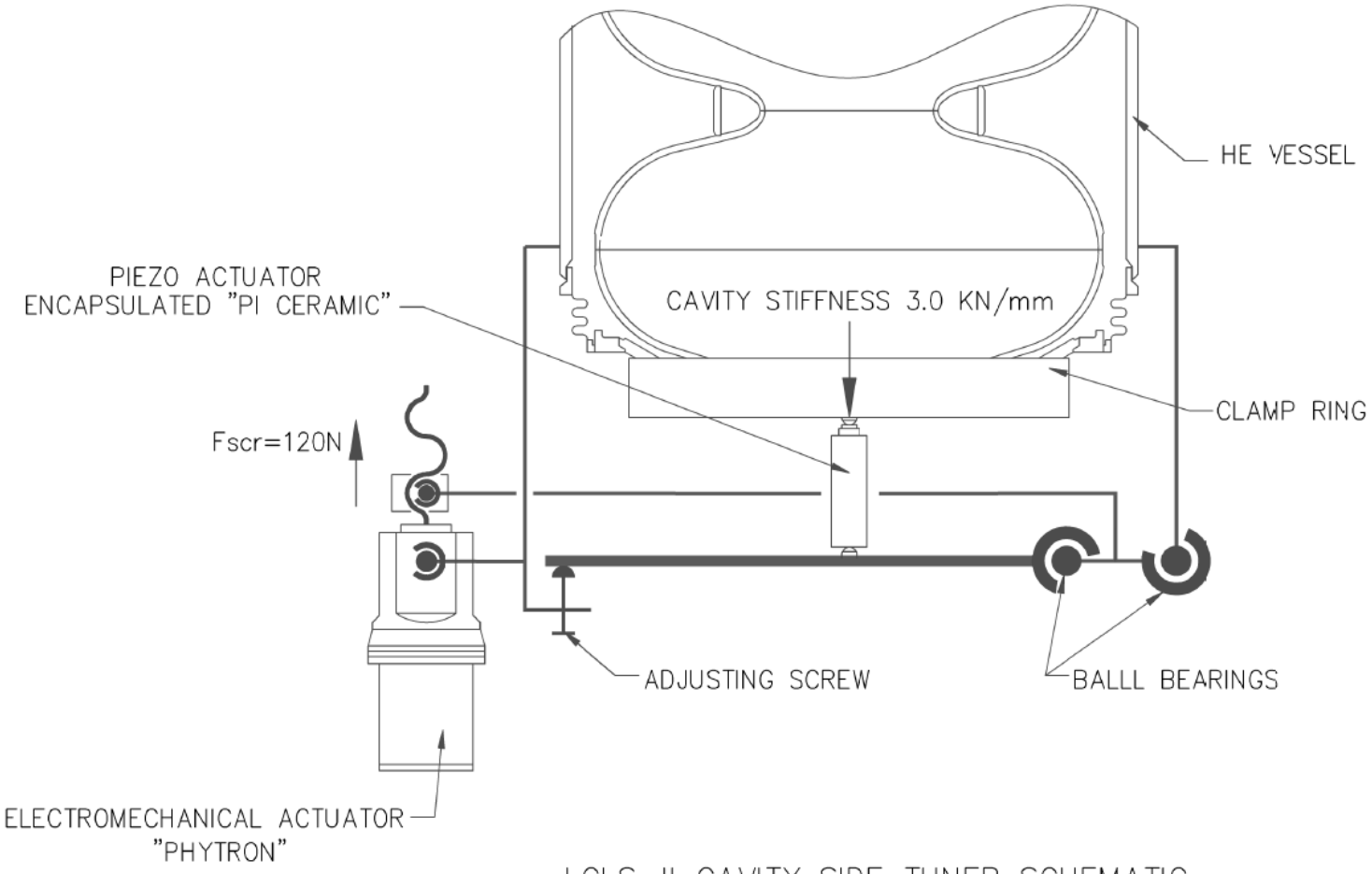
Presented by Yuriy Pischanikov
at LCLS II Dressed Cavity Review
April 15, 2014

Tuner Functional/ Technical Requirements Specs

Parameters	*Value*
Cavity Frequency	1.3GHz
Cavity bandwidth	30Hz
Cavity elongation tuning	340Hz/um
Cavity Spring Constant	3N/um
Slow Tuner cavity freq. range	**250kHz**
Slow Tuner dimentional range	740um
Slow/Coarse tuning resolution	20Hz
Fast Tuner cavity freq. range	**1KHz**
Fast Tuner dimentional range	3um
Fast Tuner tuning resolution	**1Hz**
Fast Tuner stroke resolution	3nm
Fast Tuner response bandwidth	5kHz
Min. tuner stiffness	**30N/um**
Min. tuner mechanical resonance	5kHz
Tuner operating condition	insulated vacuum T=20-60K
Slow Tuner / electromechanical lifetime (20years)	1000 spindle rotation
Fast/piezo Tuner lifetime range	$5*10^9$ pulses

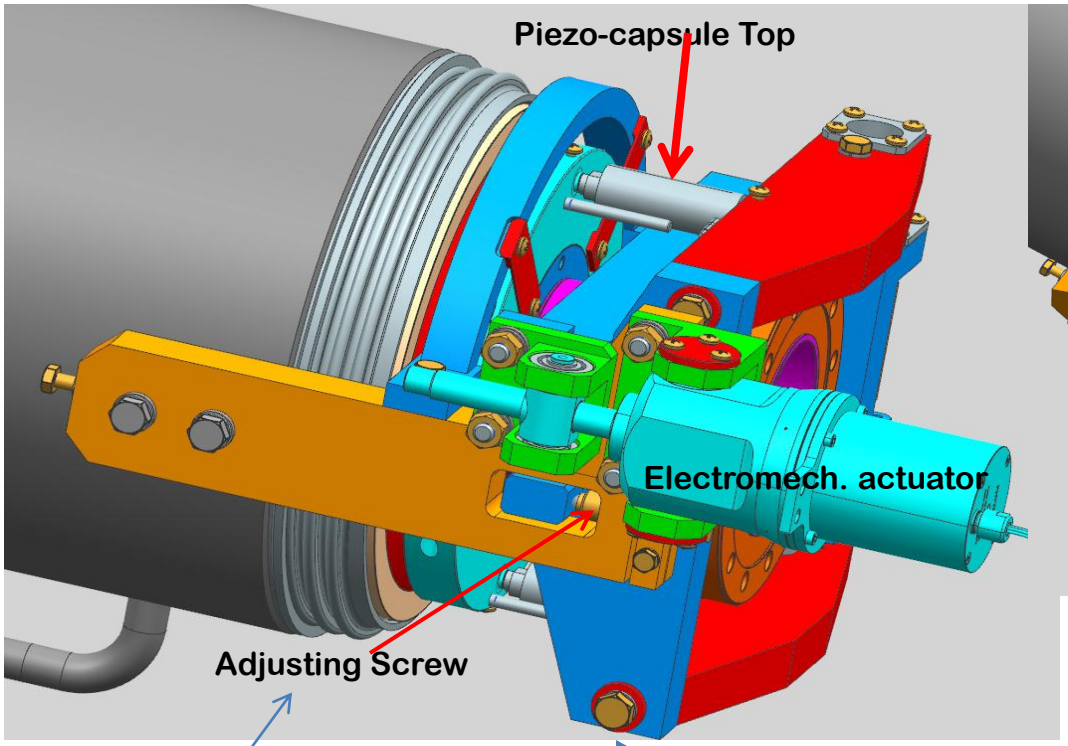
LCLS II Tuner Schematics

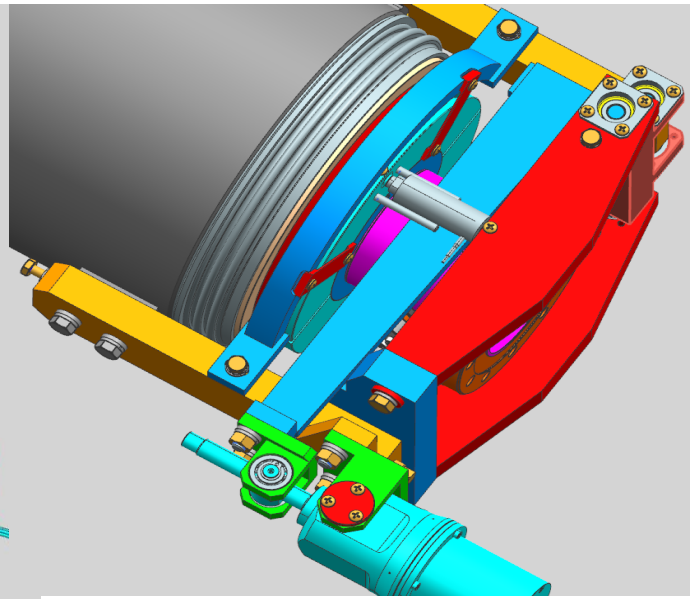
- Slow/Coarse Tuner is double lever tuner (close to design of the SACLAY 1)
- Coarse Tuner ration 1/20 (Saclay 1 ~ 1/17)
- Fast Tuner - two piezo installed close to flange of cavity /translation of the stroke from piezo directly to the cavity

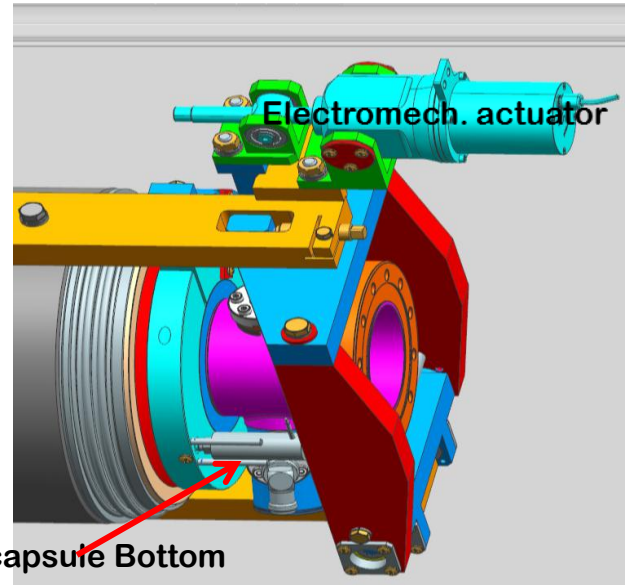


LCLS II Tuner

- Electromechanical actuator & piezo can to be replaced through special port





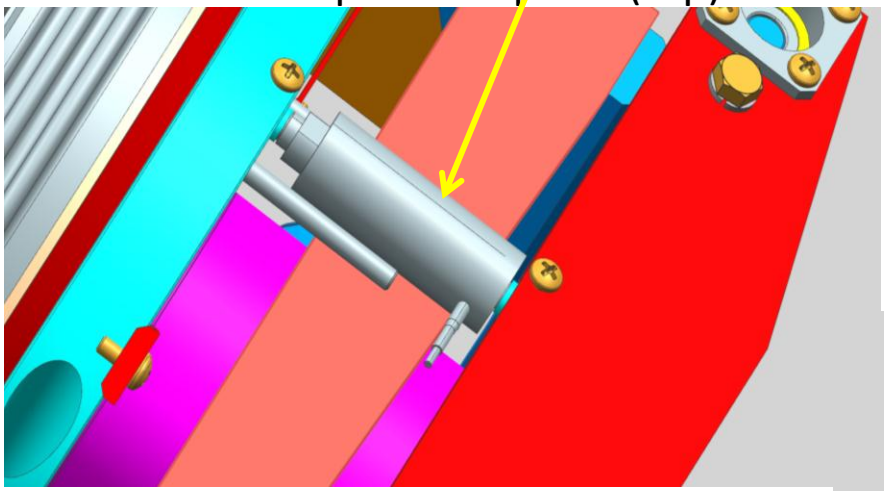


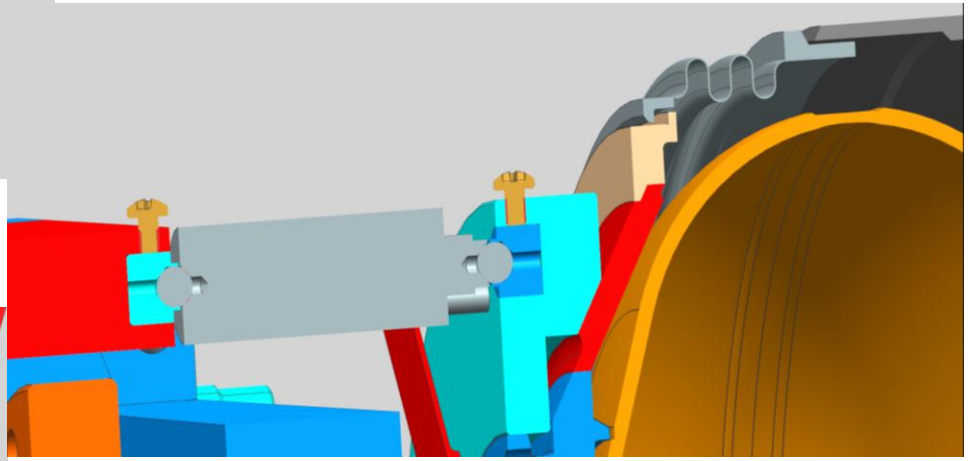
Adjusting Screw to unload piezo-capsule for replacement (in case of failure)… capsule can be replaced through special port

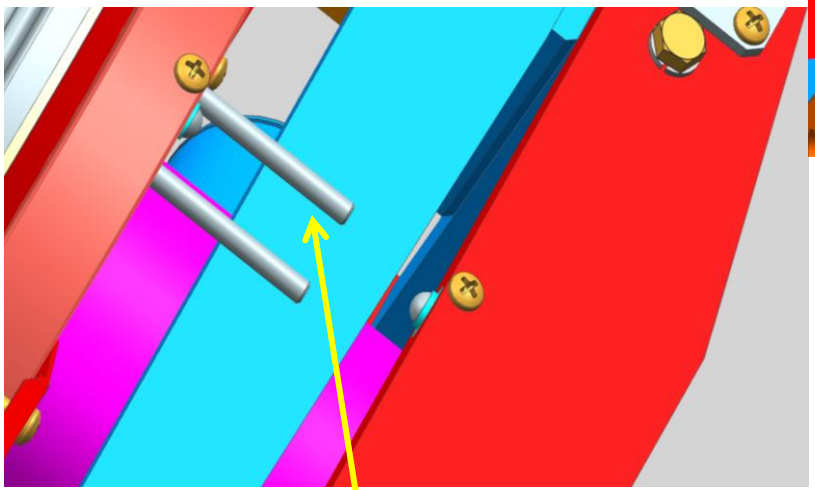
Tuning mechanism to uniformly preload piezo-capsule during initial assembly.

Details of Fast Tuner design

Encapsulated piezo (top)

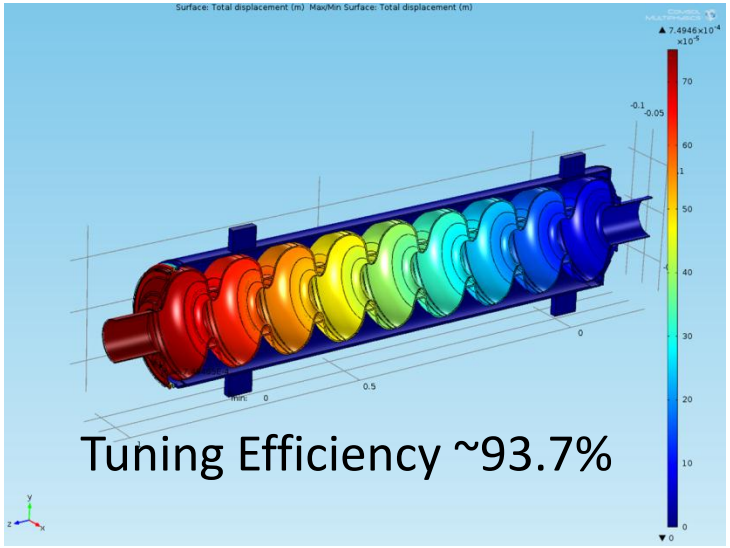






Horizontal support rods – to help replace piezo capsule through special port

Tuner Simulation (by Ivan Gonin)

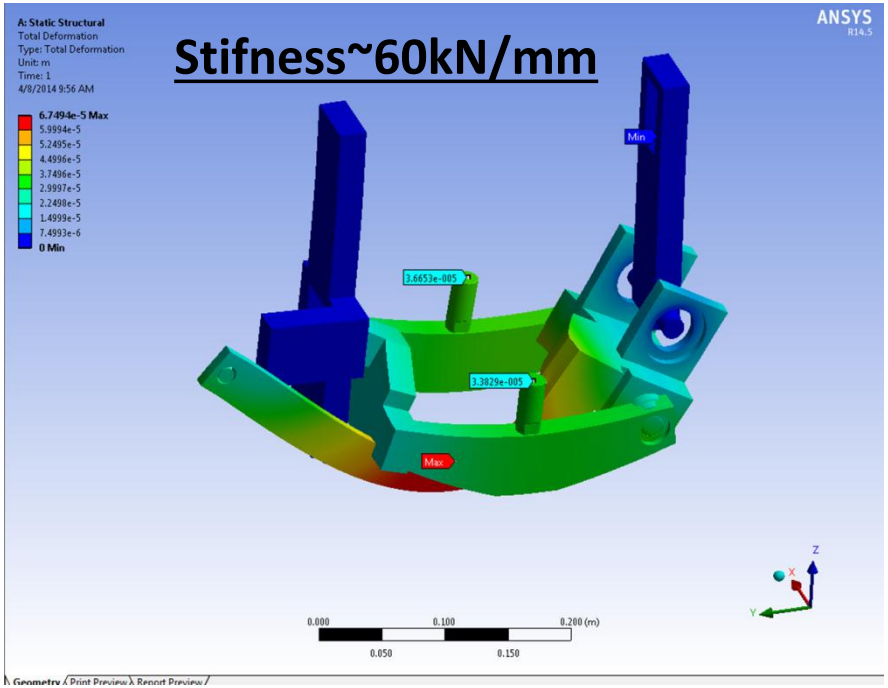


9-CELL CAVITY+HV+Conical Flange +Bellows

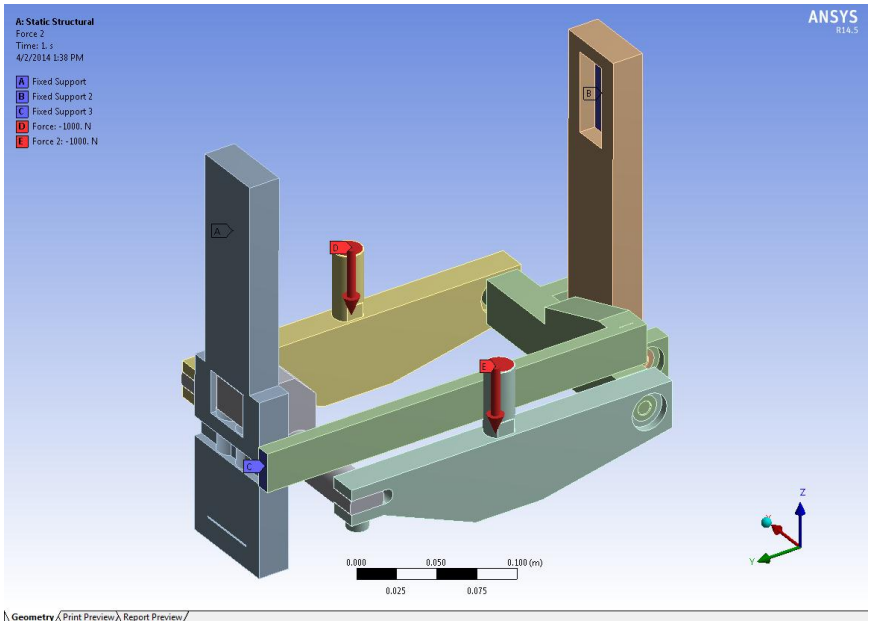
E=293K/2K, t=2.8mm, F=3200N,

ΔL~0.750/0.669mm

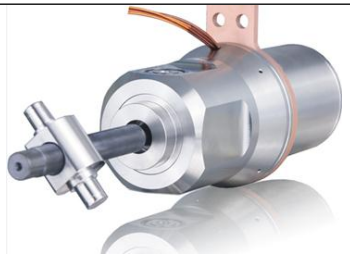
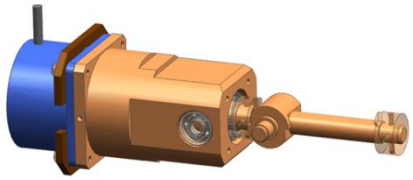
K~4260/4780 N/mm



SIMPLIFIED MODEL OF LEVER TUNER



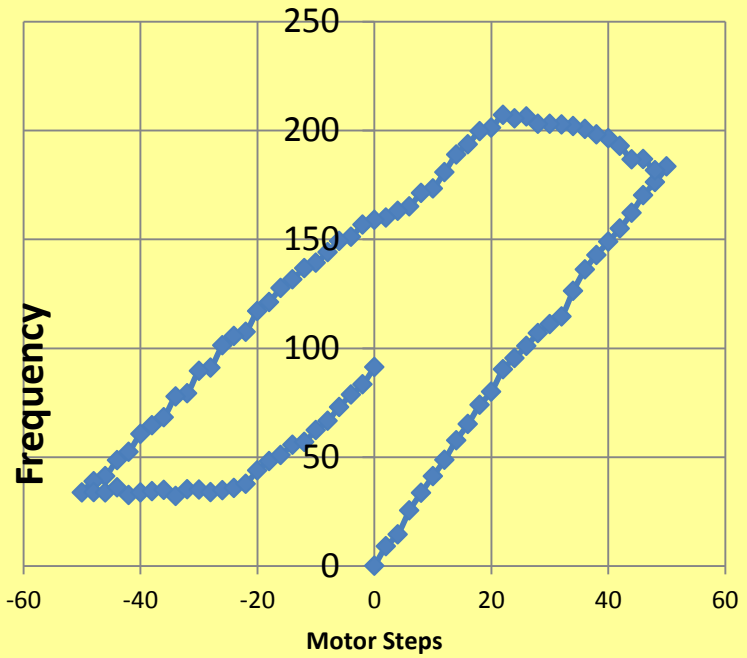
Electromechanical Actuator
(for coarse tuning)

Picture	Name	Motor	Gear Box	Spindle&Nut	Forces (freq. range with assumption 3N/um (not 4.7N/um)	Longevity
	LCLS II (DESY)	Phytron 1.2A	planetary gear (ration 1:50)	Stainless Steel M12*1	120N *(250kHz)*	tested in vacuum at 77Kfor 6500 turns (6,5XFEL lifetimes) current go from 0.2A to 0.7A
	PIP II (FNAL)	Phytron 1.2A	planetary gear (ration 1:50)	Titanium M12*1	+/- 1300N *(2,5MHz)*	tested in ins. vacuum at HTS for 5000 turns (5 XFEL lifetimes). In the force range +/- 1500N. Motor run with current 0.7A
	XFEL	Sanyo	Harmonics Drive (ration 1:100)	CuBe (safety issues) M12*1	?N *(200kHz)*	tested in insulated vacuum at HTS for 3000 turns (3 XFEL lifetimes).

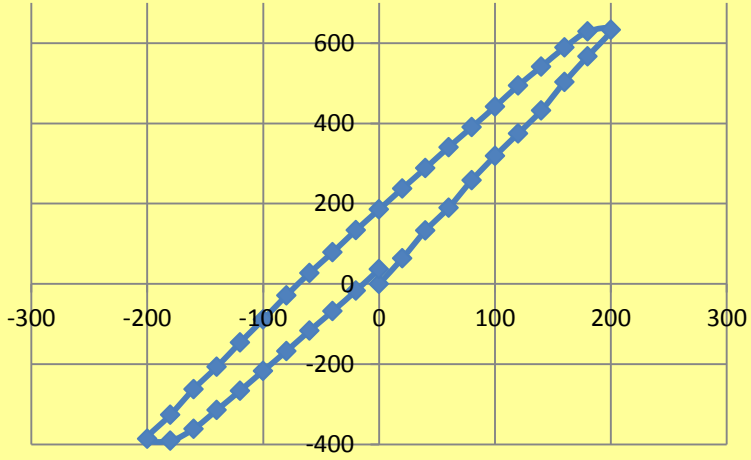
LCLSII actuator best choice. PIP II actuator is choice #2… XFEL is choice #3. For first 2 cryomodule Phytron is ready to supply LCLS II or PIP II (16-20 units). Can we have XFEL actuator for independent tests????

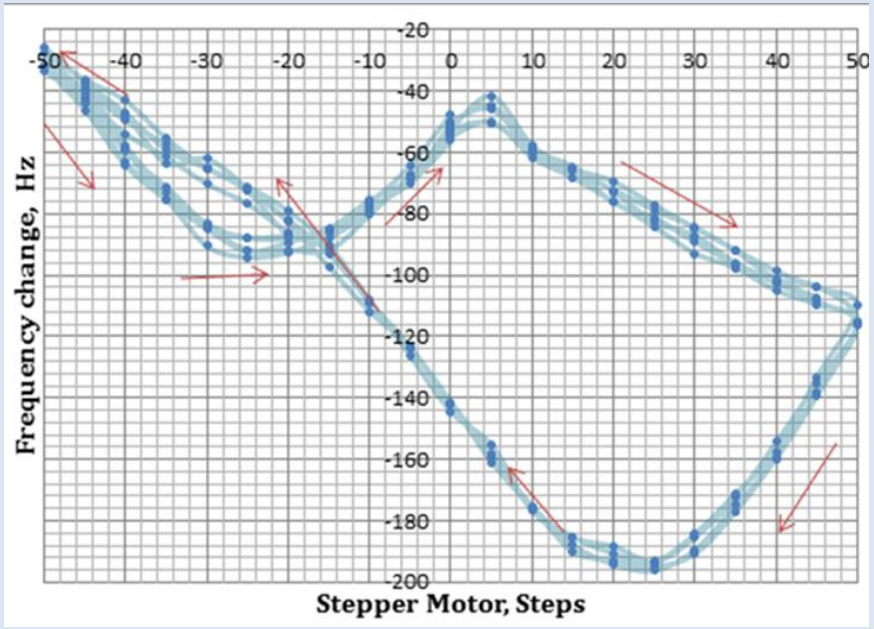
Slow (coarse) Tuner Hysteresis

FNAL's CM2 Blade Tuner (tested at HTS)



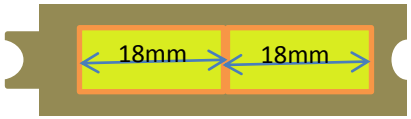
Planetary Gear Box 1:50

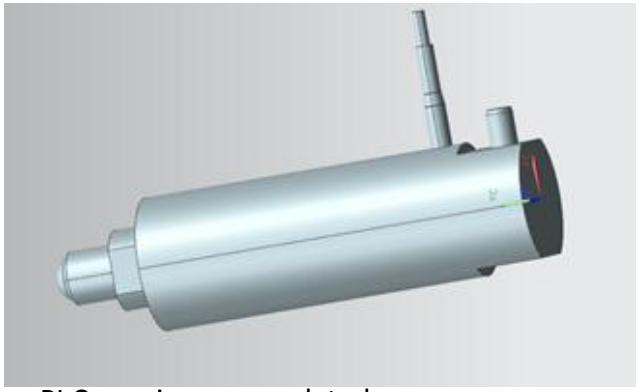




Harmonics Drive Gear Box with 1:100

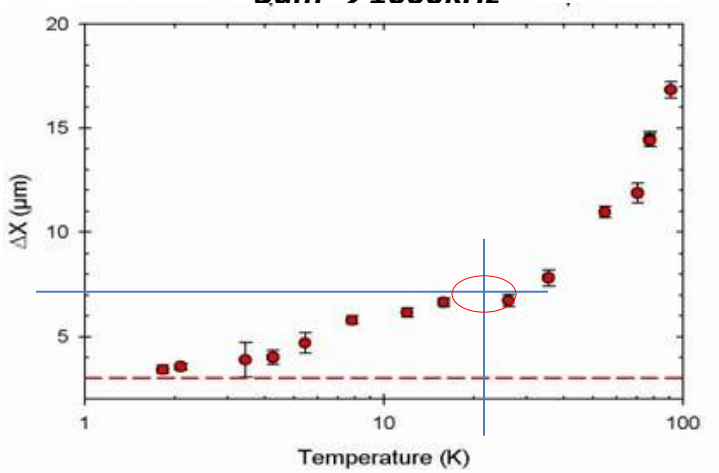
FAST (piezo) Tuner
(4 piezo – 2 run + 2 spare)
2 at the Top and 2 at the Bottom





PI Ceramics encapsulated
preloaded piezo
As a basis for LCLS II fast tuner
Required small modifications of
the body.

Stroke from one piezo (L=18mm) at 20K
~ 3um →1000kHz



Forces on piezos from Tuning Cavity
250kHz → 2.5kN → 1.2kN
(per piezo or 30% of blocking forces)
Optimal piezo preload ~ 50% of blocking → 1800N

Table #1. Technical characteristics for P-888.50 at Room Temperature

Dimensions A*B*L (mm)	Nominal Travel Range (0-100V)	Max. displacement (0-120V)	Blocking Forces	Stiffness	Electrical capacitance	Resonance Frequency
*mm*mm*mm*	*um*	*um*	*N*	*N/uF*	*uF*	*kHz*
10*10*18	**16**	**18**	**3600**	**200**	**6.0**	**70**

PI Ceramics agreed to make modification of "standard" capsule according our specs; install two separate piezo inside capsule; adjust preloading to our specs (correct preload at 20K)

Summary

- FNAL finalized design of Tuner for LCLS II (as a basis used SACLAY I design)
  - *Special attention paid to reliability of electromechanical actuator and piezo tuner*
  - *Fast tuner will have 4 piezo (2*2) to increase reliability (even one piezo will be able to tune for 500Hz)*
  - *Cost effective design/selection of the components*
    - *Negotiation with PI Ceramic; Noliac; PiezoMechanics*
    - *Negotiation with Phytron*
    - *Communication with DESY – exploring XFEL solutions*
  - *Piezo translate stroke directly to flange of the cavity (SSR1 experience) / to achieve sub-nm stroke → ~1Hz cavity tuning sensitivity*

Summary II

- Components reliability testing program start at FNAL
  - *Piezo Reliability at cold environment (HTS; IB1-VTS;VMTF; Stand3)*
  - *Piezo Radiation hardness study*
  - *Stepper motor/gear/spindle tests at cold-insulated vacuum environment*

- Tuner prototype testing program
  - *First prototype test in August-September at HTS*

- Tuner QA program

Additional Slides

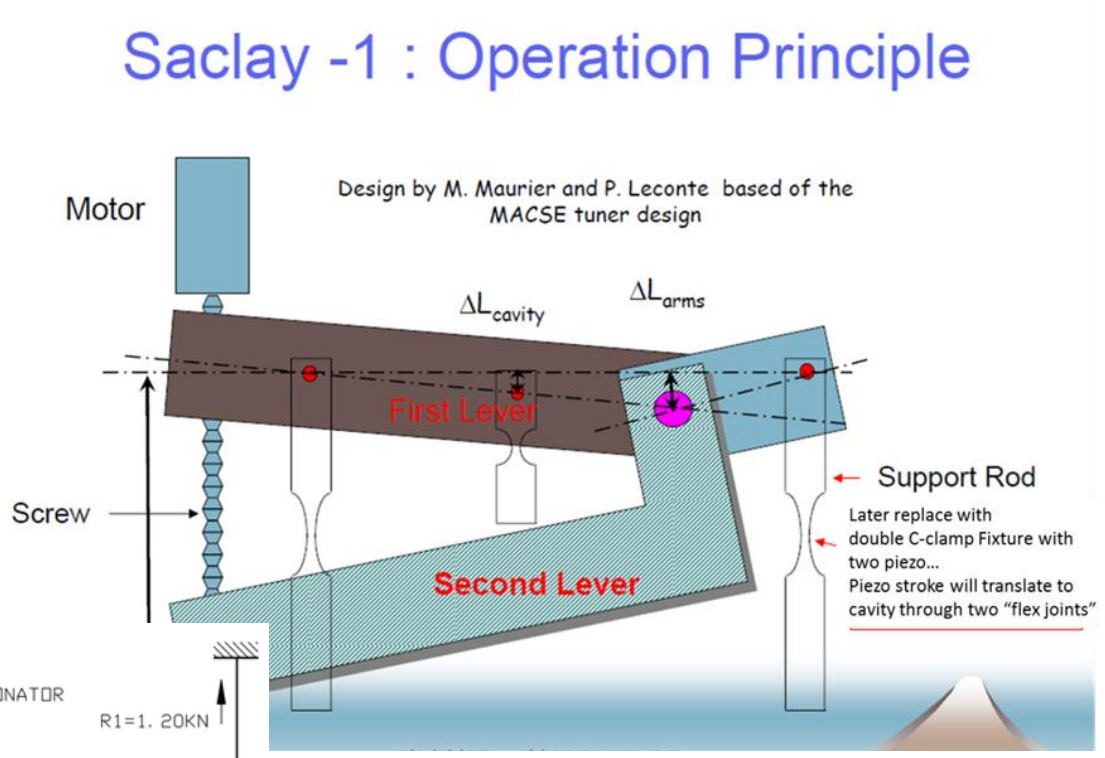
CM2 HTS

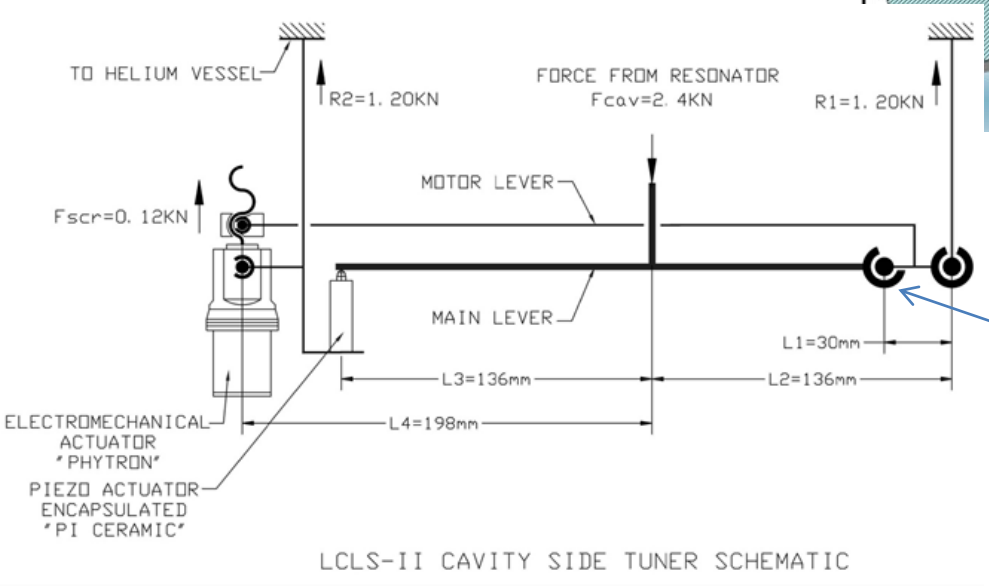
Table 1: Summary of cavity/tuner measured performance parameters

Cavity ID #	Frequency before tuner installation(MHz) 1bar, 300K	Frequency after cool-down (MHz) He -23torr, 2K	Slow Tuner slope (kHz/turn)	Piezo-to-Cavity Sensitivity, Hz/V	Dynamic LFD $Hz/s/(MV/m)^2$
ACC013	1297.385	1299.900	26.5	7.2	-970
AES009	1297.388	1299.813	31.2	2.7	-1240
ACCEL8	1297.321	1299.750	-	6.5	-860
AES010	1297.200	1299.793	27.9	8.5	-950
AES008	1297.175	1299.735	26.5	7.3	-1600
ACC016	1297.415	1299.899	28.1	10.5	-880
RI029	1297.106	1299.757	-	14	-650
AES007	1297.338	1299.791	26.3	10.4	-740
RI018	1297.417	1299.882	27.9	13	-740
Average	**1297.336**	**1299.813**	**27.8**	**9.7**	**-960**
σ	***0.116***	***0.065***	***1.7***	***2.8***	***295***

Issue of translation of the sub-nm stroke from piezo to cavity
(flex joint vs translation through bearing)

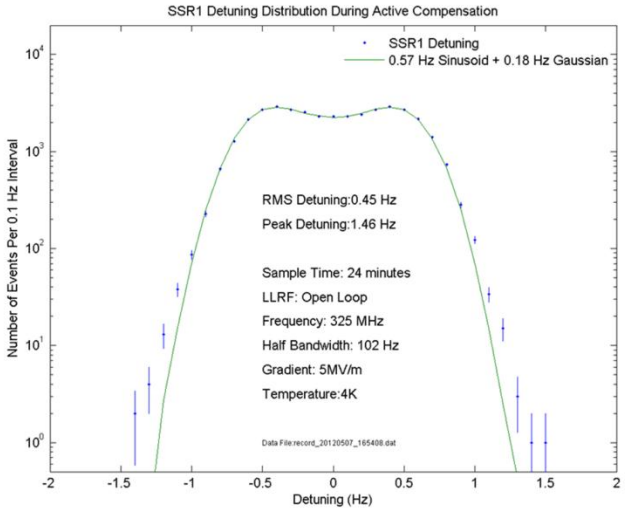
XFEL
Fast Tuning Resolution
10-20Hz (30-60nm)

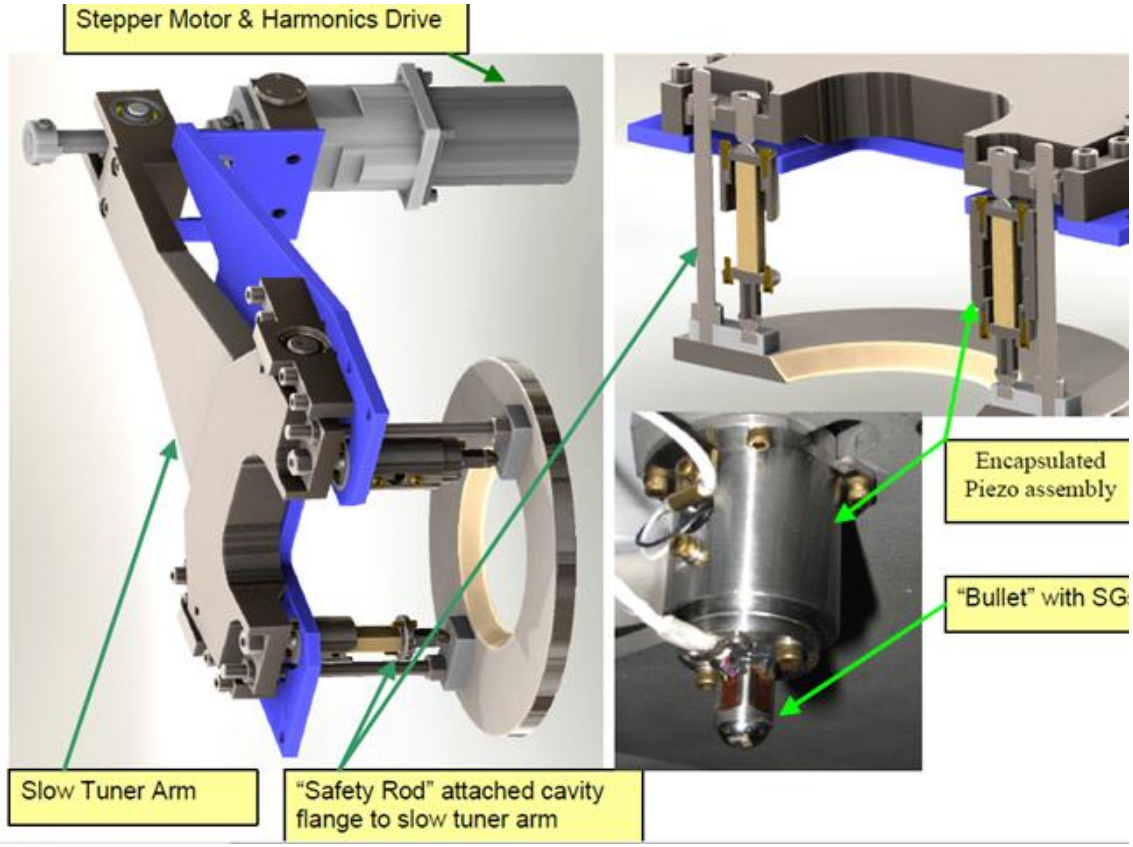




Previous LCLS II design…
Stroke from piezo translated to cavity through Main Lever & one bearing.
PI Ceramics experts expressed concerns: it will be challenge to reach 3 nm resolution

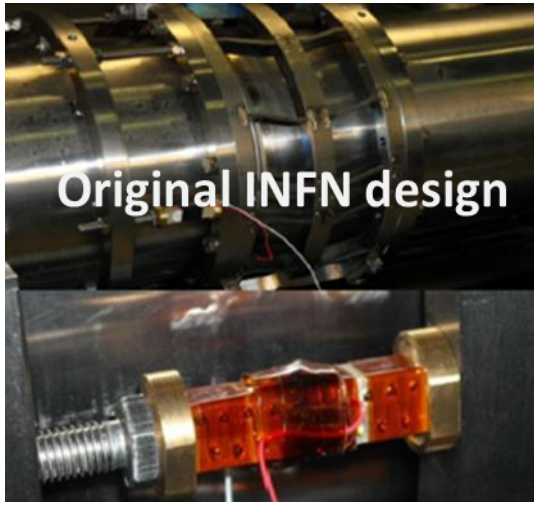
Issue of translation of the sub-nm stroke from piezo to cavity (direct translation – SSR1 Experience)



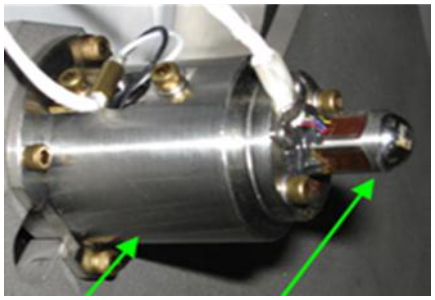


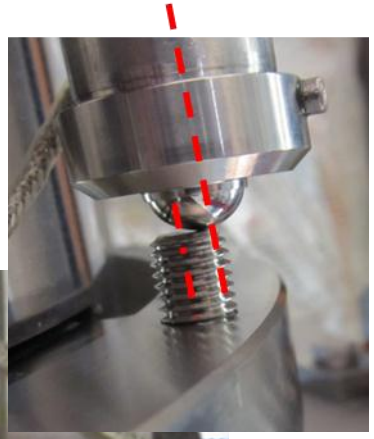
σ=1Hz → piezo tuning resolution ~ 2nm

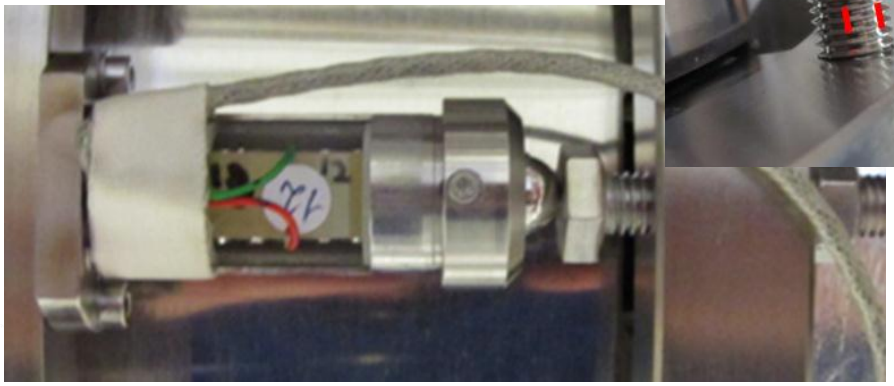
Shearing Forces & piezo tuner longevity (CM2 & S1 Global experience)



325MHz (Spoke Cavity)
Fast Tuner







1) Shearing Forces applied to piezostack