Motors/actuators SSR1 (325MHz) slow/coarse tuners

Piezoelectric actuators for SSR1 (325MHz) fine/fast tuner

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02/06/2012

Original Saclay I/TTF motor/actuator units

(with Phytron motor (VSS52.200.2.5-UHVC-X) /harmonics drive/M12X1mm CuBe shaft) designed for cavity/tuner with

k_{cavity}=3kN/mm & 1:20 tuner (1)

INFN Slim Blade Tuner used the same unit for cavity/tuner with:

k_{cavity}=6.5kN/mm & 1:10 tuner (4.5)

Proposed Tuner for SSR1 have parameters:

k_{cavity}=30kN/mm & 1:6 tuner (33) (1/2range ΔF)→ (20)

<u>Wide used Unit will not work for SSR1</u>

What Phytron can do for us?

- CM3 – Slim Blade Tuner
  - Are we OK with actuator which we have now?
- 650MHz tuner ?
- SSR1 tuner ?

- Phytron application engineer: “Phytron never used harmonics drive for product directed to be used at Vacuum and Cryogenic Temperature..”

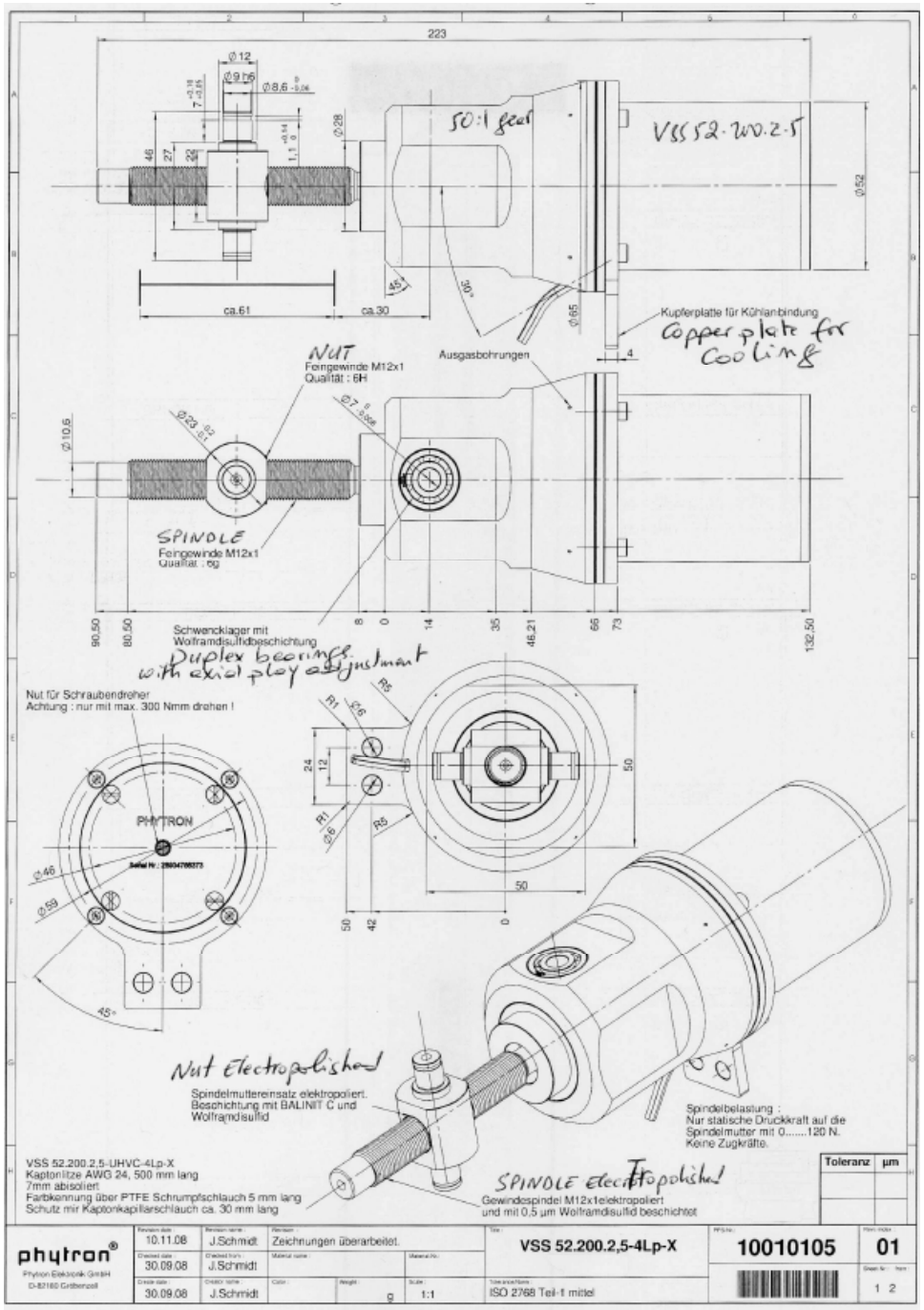
- From our limited experience: “ It is not smart to procure may mechanical parts from different vendors and do assembly of electro-mechanical system in-house”

- Let experts do it… it will be more reliable and even less expensive system

Phytron Motor/Actuator for DESY/XFEL

Unit cost 3.9K$

(if you buy 100 or more)


223
Ø12
Ø9 h6
Ø8,6
Ø28
46
27
22
50:1 gear
VSS 52.200.2.5
Ø52
ca.61
ca.30
45°
30°
Ø65
Kupferplatte für Kühlanbindung
Copper plate for Cooling
4
NUT
Feingewinde M12x1
Qualität : 6H
Ausgasbohrungen
Ø10,6
Ø23
Ø7
SPINDLE
Feingewinde M12x1
Qualität : 6g
90,50
80,50
8
0
14
35
46,21
66
73
132,50
Schwencklager mit
Wolframdisulfidbeschichtung
Duplex bearings
with axial play adjustment
Nut für Schraubendreher
Achtung : nur mit max. 300 Nmm drehen !
PHYTRON
Ø46
Ø59
45°
R1
Ø6
R5
24
12
50
50
42
0
Nut Electropolished
Spindelmuttereinsatz elektropoliert.
Beschichtung mit BALINIT C und
Wolframdisulfid
Spindelbelastung :
Nur statische Druckkraft auf die
Spindelmutter mit 0.....120 N.
Keine Zugkräfte.
VSS 52.200.2,5-UHVC-4Lp-X
Kaptonlitze AWG 24, 500 mm lang
7mm abisoliert
Farbkennung über PTFE Schrumpfschlauch 5 mm lang
Schutz mir Kaptonkapillarschlauch ca. 30 mm lang
SPINDLE Electropolished
Gewindespindel M12x1elektropoliert
und mit 0,5 µm Wolframdisulfid beschichtet
Toleranz
µm
phytron®
Phytron Elektronik GmbH
D-82160 Gröbenzell
10.11.08
J.Schmidt
Zeichnungen überarbeitet.
30.09.08
J.Schmidt
30.09.08
J.Schmidt
g
1:1
VSS 52.200.2,5-4Lp-X
ISO 2768 Teil-1 mittel
10010105
01
1 2

Motor Part number	VSS 52.200.2.5-UHVC-X
Description	Cryogenic stepper motor actuator, designed for 4K
Motor section	
Motor Resolution	200 full steps/rev.
Detent torque at motor shaft	~10 mNm (torque with power off)
Holding torque at motor shaft	~160 mNm at 1A and ~390 mNm at 2.5A
Run torque at motor shaft at 300 Hz half step	~120 mNm at 1A and ~300 mNm at 2.5A
Phase current	2.5 Amps. (50% or less is sufficient to produce 120N ouput)
Winding Resistance at 20C	0.7 Ohms +/- 20%
Winding Inductance at 20C	2 mH +/- 20%
Gear ratio	50:1 (integrated in the motor)
Linear output	
Push force	0 to 120 N
Screw	M12x1 (1 mm pitch). Electropolished and coated
Nut	M12x1, electropolished
Travel	48 mm
Bearings	ball bearings Quality P5
Output shaft	Duplex bearings with preload adjustment
Magnetic Flux	NSSN rotor. Low flux leakage version
Cooling	mounted copper plate for cooling mount
Lubrication	Dry
Start current of motor at -196C	~200 mA
Stall current at of motor at -196C	~170 mA
Start current of actuator at -196C	~240 mA
Stall current of actuator at -196C	~160 mA

- Tests performed at Phytron

  Detent torque, Holding torque, run torque, resistance, inductance, start and stall currents of motor and complete actuator, high voltage test, tolerances at 77K, preload of motor bearing, life test

Phytron Life Test

Requirement was for 800 spindle revolutions.

Life Test

Setup was built to simulate the application as shown in picture.

Setup placed in the vacuum chamber and cooled to 77K.

First: Actuator ran for 1600 revs = 16 million full steps.

Second: Actuator held in-vacuum non-operating for 3 months. Then started to check if it would run.

Third: Actuator sent to customer for additional test of 50 million full steps until failure.

Conclusion: Motor operated successfully for 6500 spindle turns which is 8 times more that the required value.

(6500 spindle turns ==65Msteps)

Actuator returned to us for inspection and found no problems except that it required a current of 500-700 mA instead of 200 mA originally used. This current is still below the nominal current.

Required Specs from Fermi

- Max. linear travel
- Linear resolution in mm
- Max. push force
- Max. non-operating pull force
- Linear speed
- Years of operation (in spindle revolutions)
- Vacuum level
- Temperature
- Drawing of system (3D preferred if possible)

Required Specs
for 1,3GHz Slim Blade Tuner
(draft)

- Max. linear travel **(25mm)**
- Linear resolution in mm **($300*10^{-6}$mm ==20Hz)**
- Max. ~~push~~ force **(PULL 1500N)**
- Max. non-operating ~~pull~~ force **(PUSH 4500N)**
- Linear speed **(100steps/sec)**
- Years of operation (in spindle revolutions) **(2000)**
- Vacuum level (10^{-6})
- Temperature (40K)
- Drawing of system (3D preferred if possible)

Required Specs (Motor/actuator unit)
*for **325MHz** and 650MHz (?)*
(draft)

- Max. linear travel **(5mm)**
- Linear resolution in mm **1) 25nm; 2) 250nm**
  - **(2Hz→(1um/250)*6→25nm)**
    - ✓ for shaft with 1mm pitch $\Delta \sim 10^{-2}$ Degree
      - ✓ == 1/4step (50:1 gear & 200step/rev)
      - ✓ == 2step (100:1 gear &500step/rev)
  - **(20Hz→250nm)**

- Max. push force **(PULL 3000N)**
- Max. non-operating pull force
- Linear speed (100steps/sec ?? 50steps/sec)
- Years of operation (in spindle revolutions) **(1000==4Msteps)**
  - **5+5 rev. for our T-cycle; 2 T-cycle per year *20years=400 revolutions**
  - **NO fine tuning of the cavity with slow tuner…** excessive microphonics will trip cavity
- Vacuum level (10^{-6})
- Temperature (40K)
- **Drawing of system (3D preferred if possible)**

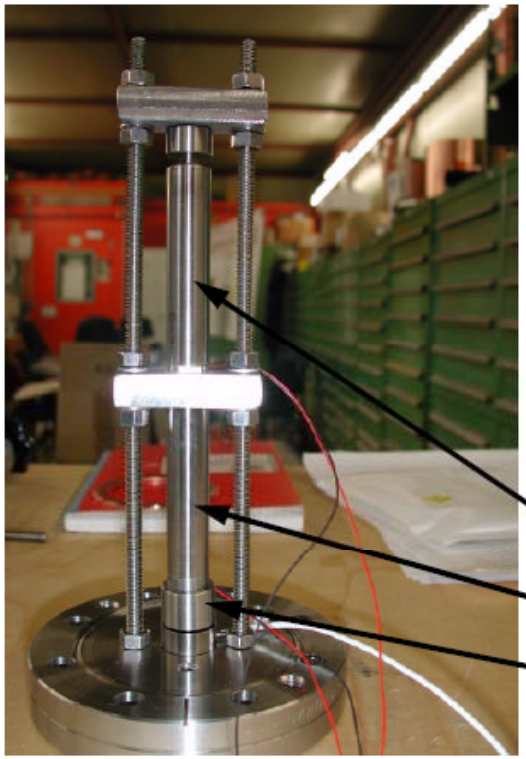
Required Specs (Motor/actuator unit)
for **325MHz** and 650MHz (?)

- Max. linear travel **(5mm)**
- Linear resolution in mm **[1) 25nm; 2) 250nm]**
- Max. ~~push~~ pull force **(2000N)**
- Max. non-operating ~~pull~~ **push** force **(2000N)**
- Linear speed (100steps/sec ?? 50steps/sec???)
- Years of operation (in spindle revolutions) **(1000)**
- Vacuum level (10^{-7} mbar)
- Temperature (40K)
- **Drawing of system (3D preferred if possible)**

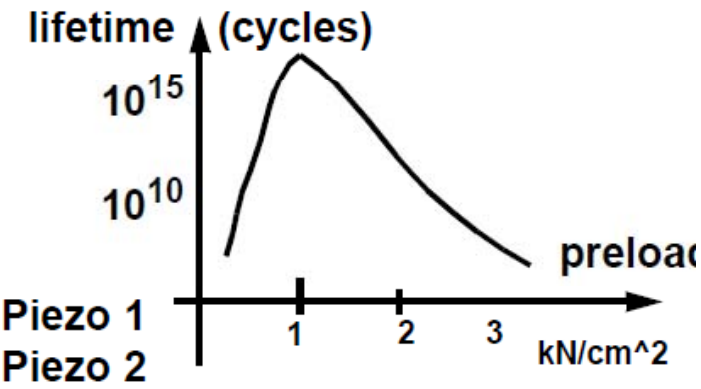
PIEZOELECTRIC ACTUATORS

30kN*(0.3mm)=9kN/2=4.5kN – forces on the piezoactuators

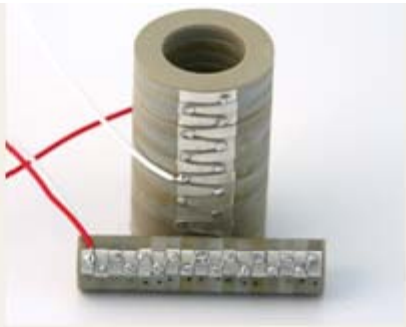
Measurement of Mechanical Preload



Lifetime of piezo depends strongly on mechanical preload. Optimum around 1 kN/ cm^2.



Noliac Piezoactuators



Specifications on standard Noliac SCMAR's:

Product Name	Outer Diameter	Inner Diameter	Height	Max. Voltage	Free Stroke	Blocking Force
	[mm]	[mm]	[mm]	[V]	[µm]	[N]
SCMAR01	6	2	4-60	200	2.6 - 74	1000
SCMAR02	8	3	4-80	200	2.6 - 100	1700
SCMAR03	12	6	4-120	200	2.7 - 157	2670
SCMAR04	15	9	4-150	200	2.7 - 197	4530
SCMAR05	20	12	4-200	200	2.9 - 282	8000

itions on standard Noliac multilayer piezo SCMAP's:

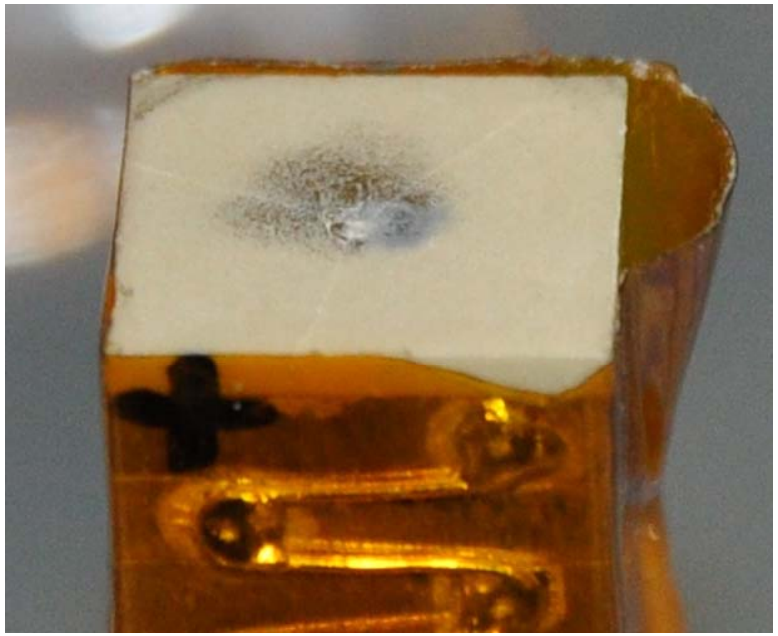
duct me	Length	Width	Height	Max. Voltage	Free Stroke	Blocking Force
	[mm]	[mm]	[mm]	[V]	[µm]	[N]
AP01	3	3	4-30	60	2.3 - 32.8	360
AP02	5	5	4-50	60	2.7 - 63.8	1000
AP03	3	3	5-30	150	4.2 - 39	360
AP04	5	5	5-50	150	4.6 - 73	1000
AP05	7	7	4-70	150	2.9 - 100	1960
AP06	3	3	4-30	200	2.8 - 39	360
AP07	5	5	4-50	200	2.9 - 71	1000
SCMAP08	7	7	4-70	200	3.0 - 103	1960
SCMAP09	10	10	4-100	200	3.0 - 149	4000
SCMAP10	3	3	4-30	200	1.7 - 24	290
SCMAP11	5	5	4-50	200	1.9 - 46	800
SCMAP12	2	2	4-20	120	2.4 - 21	160

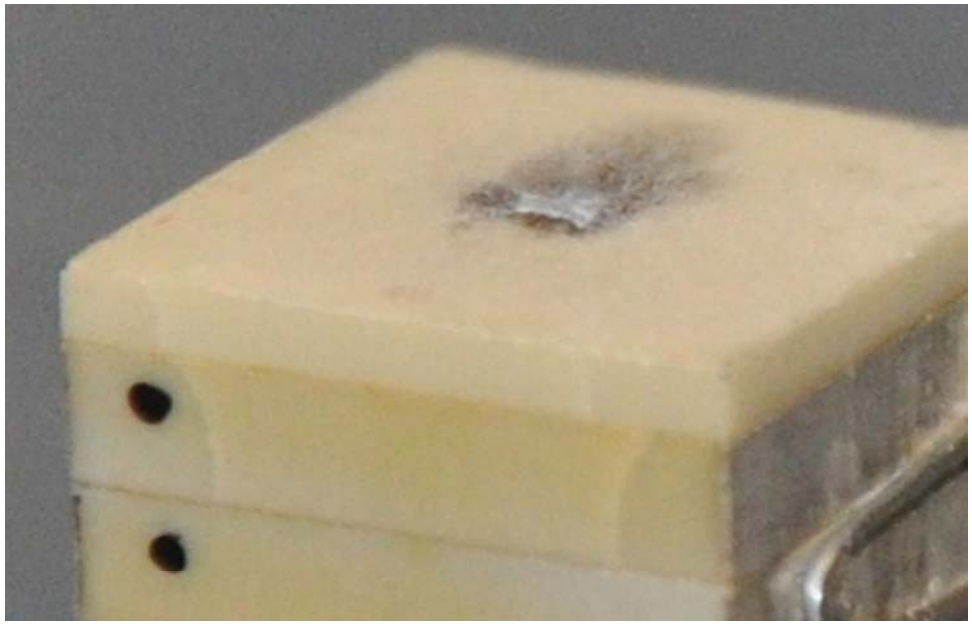
Fine/Fast Tuner Stroke requirements

- If we need 1kHz fine tuning range of the Piezo Tuner → required 1um stroke at beam-pipe.
- 1:2 fine tuner ration and 50% efficiency requirements to piezo stroke 5um at 20K (or ~10-20um at 300K)
- Length of Noliac piezo ➔ 20-30mm (C=22uF)

Piezo tuner failure at S1-G (cavity C2)

as a result of large shearing forces on piezo and bump in the center of the brass cup

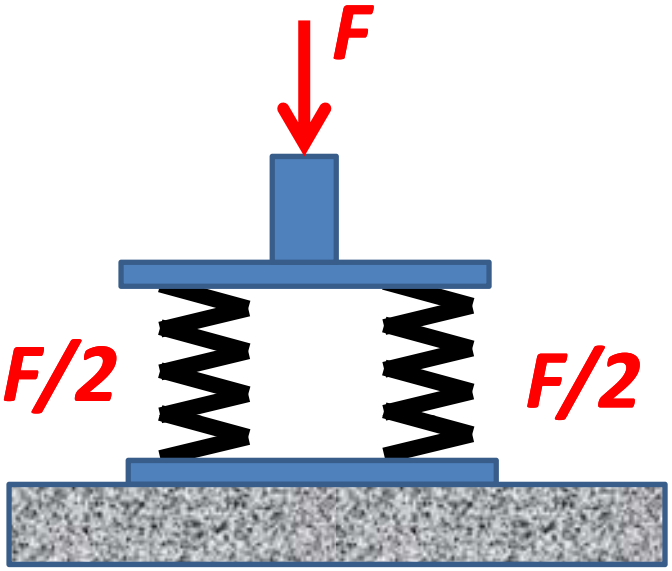


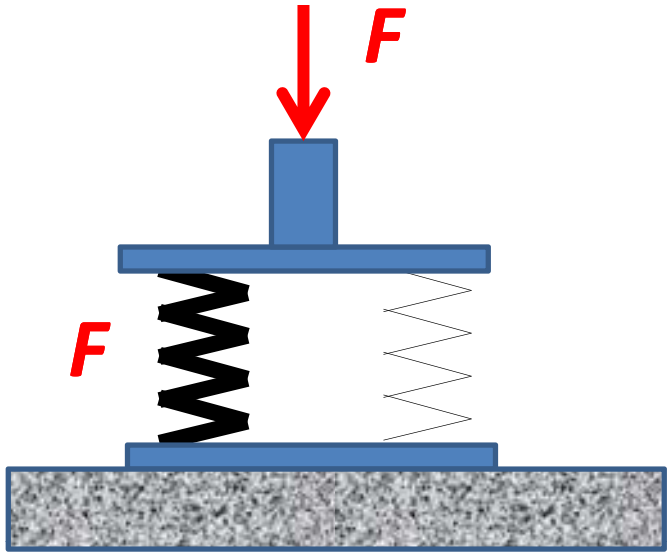


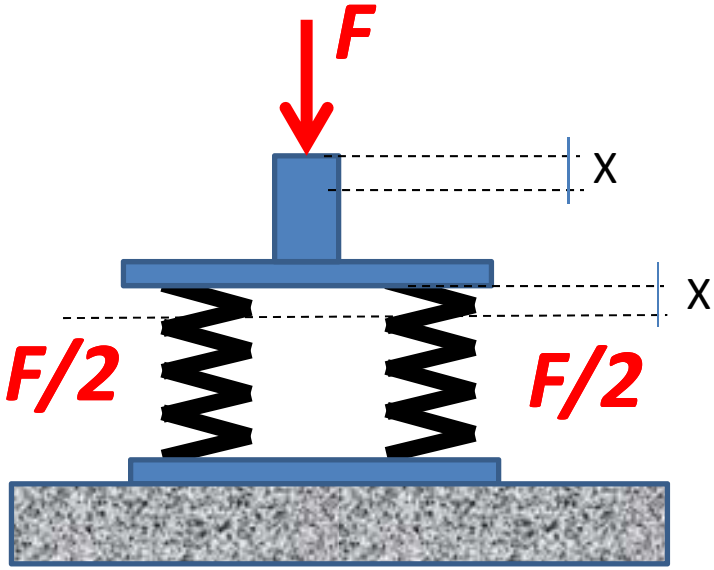
Post removal analysis revealed that coupler side piezo in C2 was significantly damaged with fractures found at one edge of the stack:

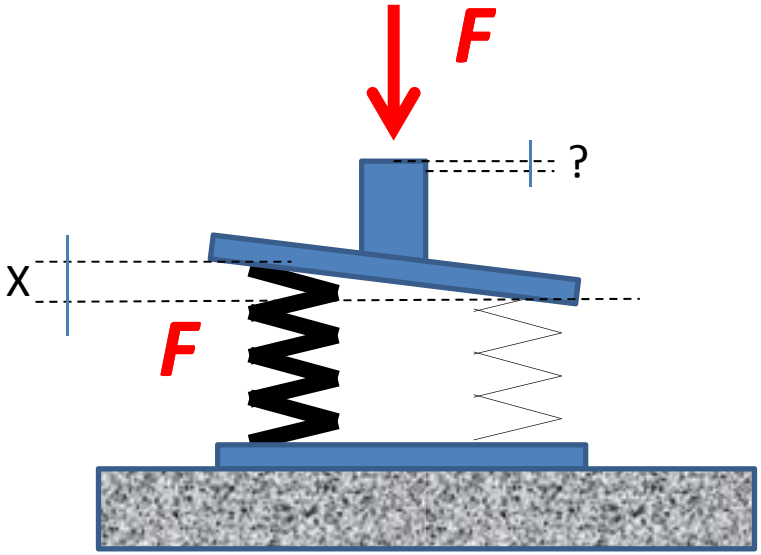
- **Cracks passing through electrical layers with possible sputtering of metal, thus explaining the systematic discharge at lower voltage.**
- **Integrity of piezo ceramic impaired, thus explaining the lack of piezo tuning efficiency observed (damaged stack acted, on the small range, as a soft element in series with the cavity)**

If one piezo damaged
(mechanical cracks AND/OR HV breakdown)





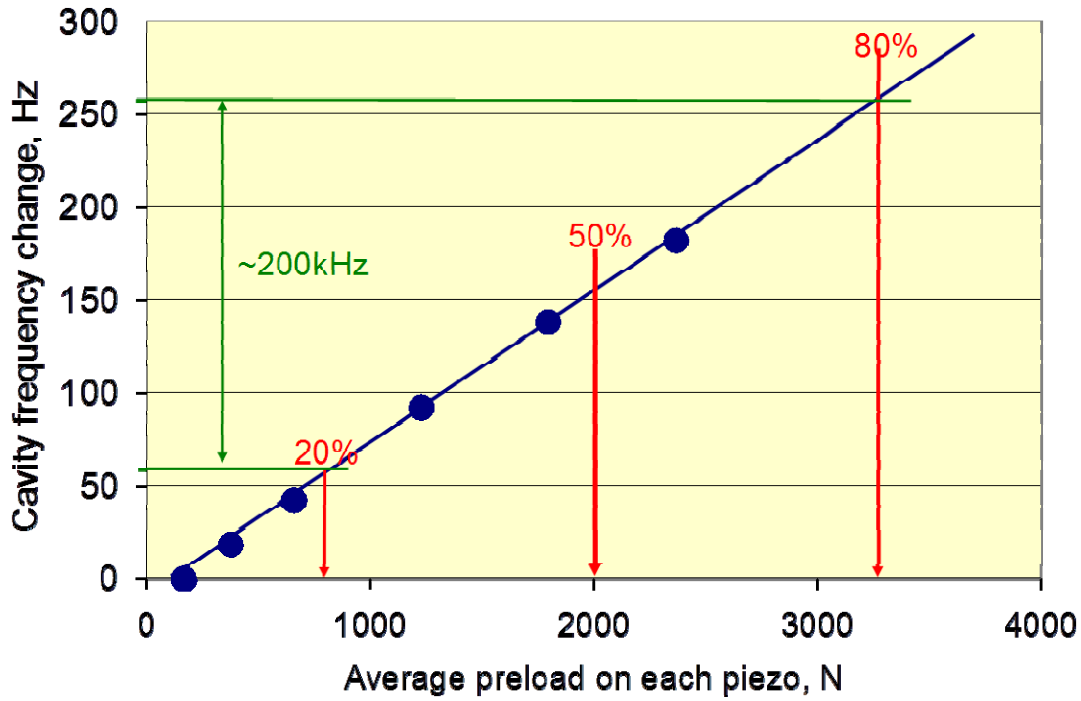


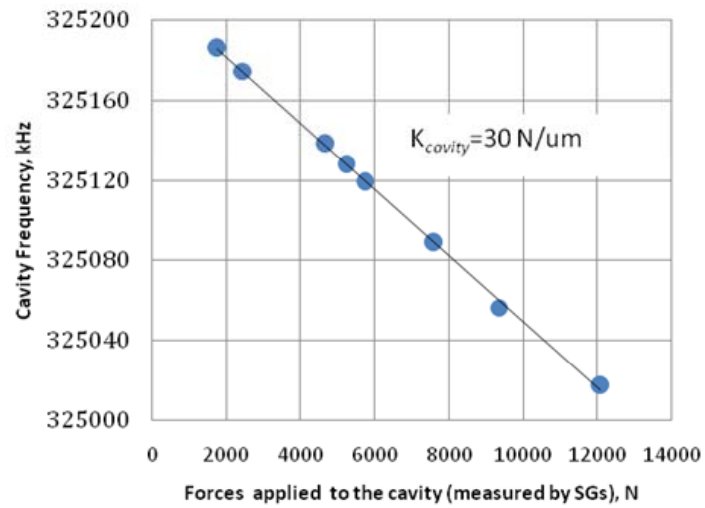


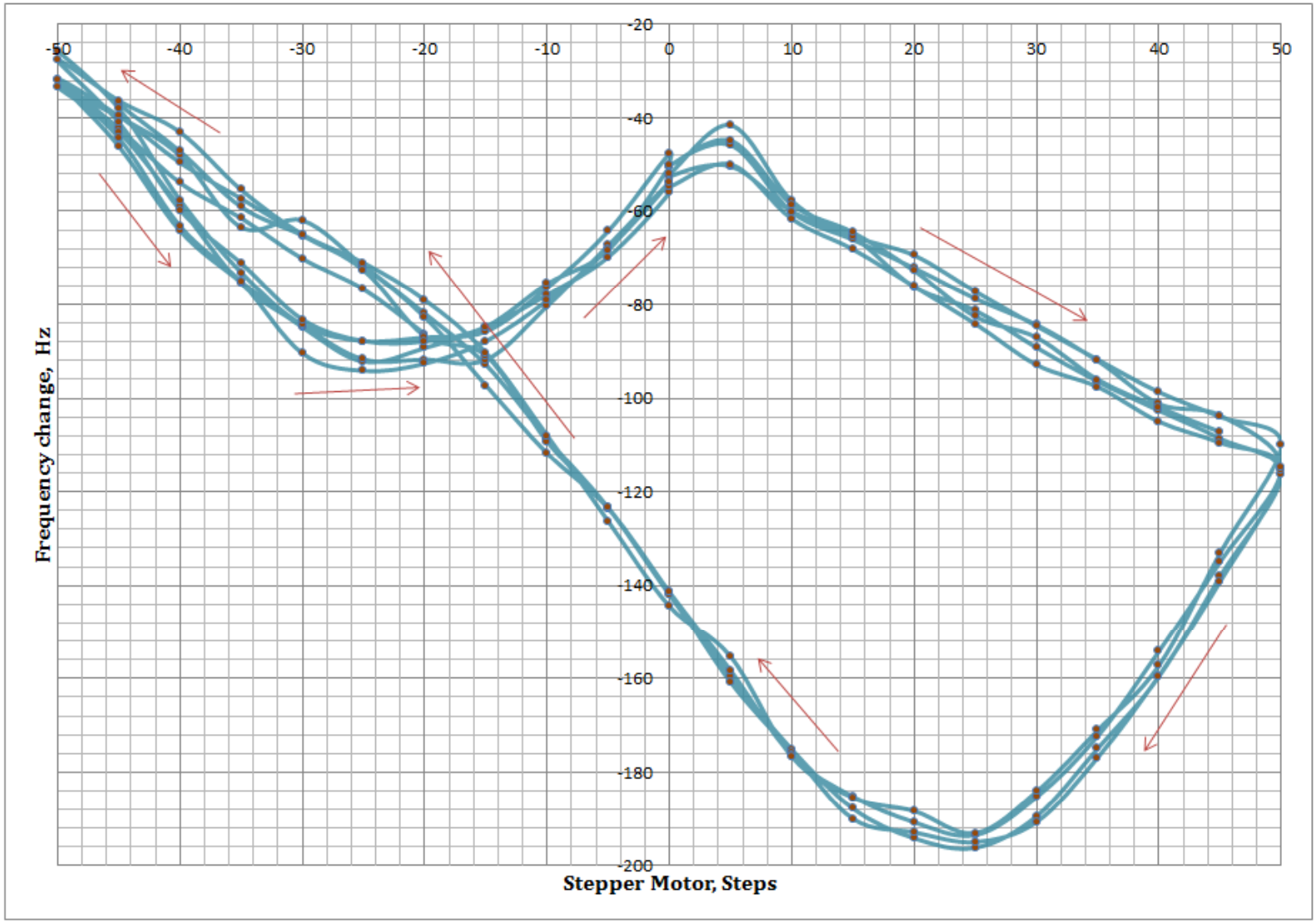
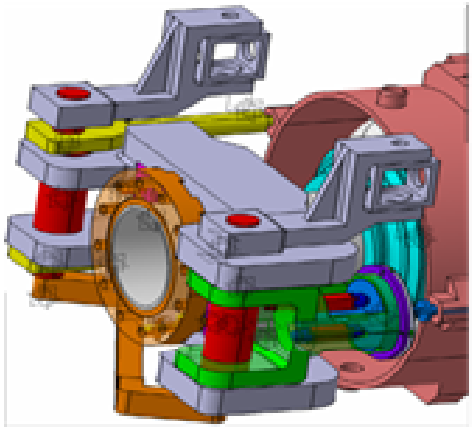
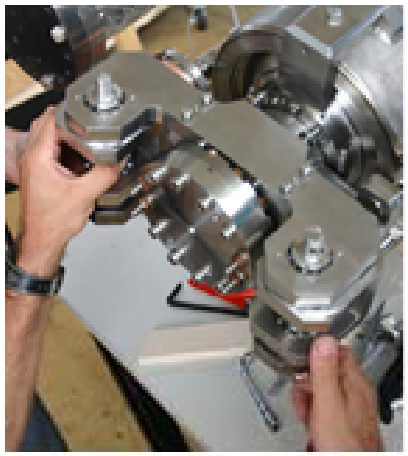
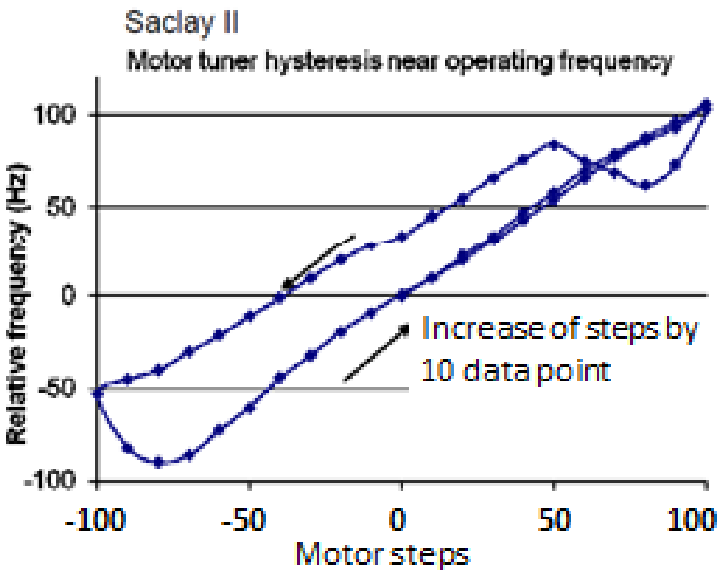
Summary

- SSR1 slow/coarse Tuner required new motor/actuator unit (work with Phytron to design/test new unit) - - probably it will be larger dimension/ weight (access port & replacement issues)
- SSR1 fast/fine Tuner required longer and stronger (larger cross-section) piezos…

  4 piezos instead of 2 ???


Cavity frequency change, Hz
300
250
200
150
100
50
0
0
1000
2000
3000
4000
Average preload on each piezo, N
~200kHz
20%
50%
80%


Cavity Frequency, kHz
325200
325160
325120
325080
325040
325000
0
2000
4000
6000
8000
10000
12000
14000
Forces applied to the cavity (measured by SGs), N
K_covity=30 N/um


-50
-40
-30
-20
-10
0
10
20
30
40
50
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Frequency change, Hz
Stepper Motor, Steps

Saclay - 2 : Cam & Lever