SSR1 TUNER MECHANISM: PASSIVE AND ACTIVE DEVICE

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Introduction

In this paper we present the methodology adopted in designing the mechanism responsible for controlling the resonant frequency of Single Spoke Resonators of first type (SSR1). Such device is capable of compensating the effects of external perturbations, such as pressure fluctuations and microphonics, on the frequency of SSR1. The compensation is achieved through active responses via an actuation system and passive responses which are inherent to the elastic behavior of the overall system. The first experiences in the design, assembly, QA and testing are reported.
The tuning device for the SSR1 cavities of generation 3 (SSR1-G3) [2] has to operate only on one of the beam-pipe regions of the cavity and only generates forces directed towards the cavity (push only). The resonant frequency of the cavity is modified by adjusting the spacing between the cavity end-wall and the spoke. Controlling this gap allows to maintain the frequency near the nominal value of 325MHz.

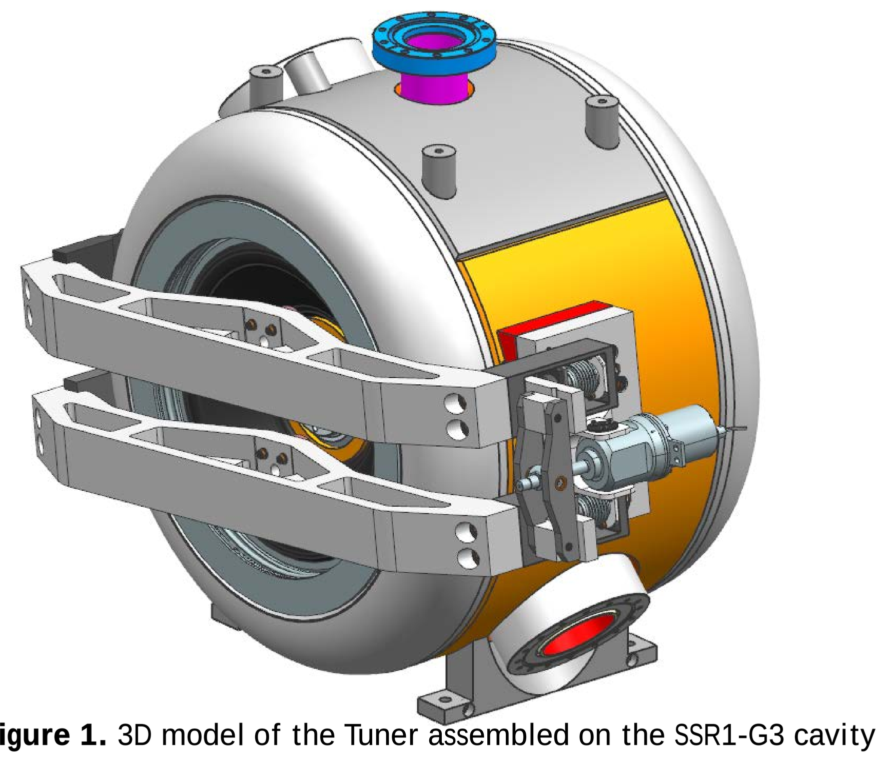


Figure 1. 3D model of the Tuner assembled on the SSR1-G3 cavity

Specifications → Conceptual design

Double lever Tuner

- Well known technology
- Adjustable mechanical advantage
- Piezos and motor in series
- Piezos away from the beam
- Estimated efficiency and stiffness
- Respect of the following maximum forces at the actuating components:

Parameter	Value
Stepper motor with gear box	
Max force	1300 N
Resolution	0.1 µm
Piezo	
Stroke (x_f) at 293 K	68 µm
Stroke (x_f) at 20 K	15 µm
Max operating force	2700 N
Min operating force	840 N

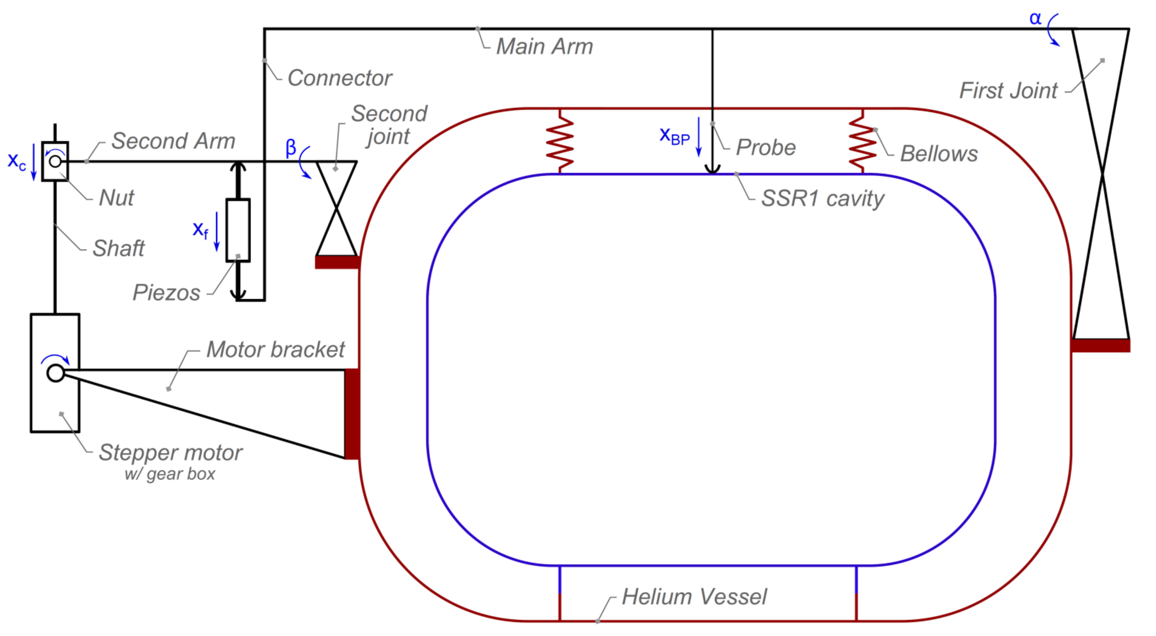


Figure 2. Schematic for the tuning system showing the cavity inside the helium vessel.

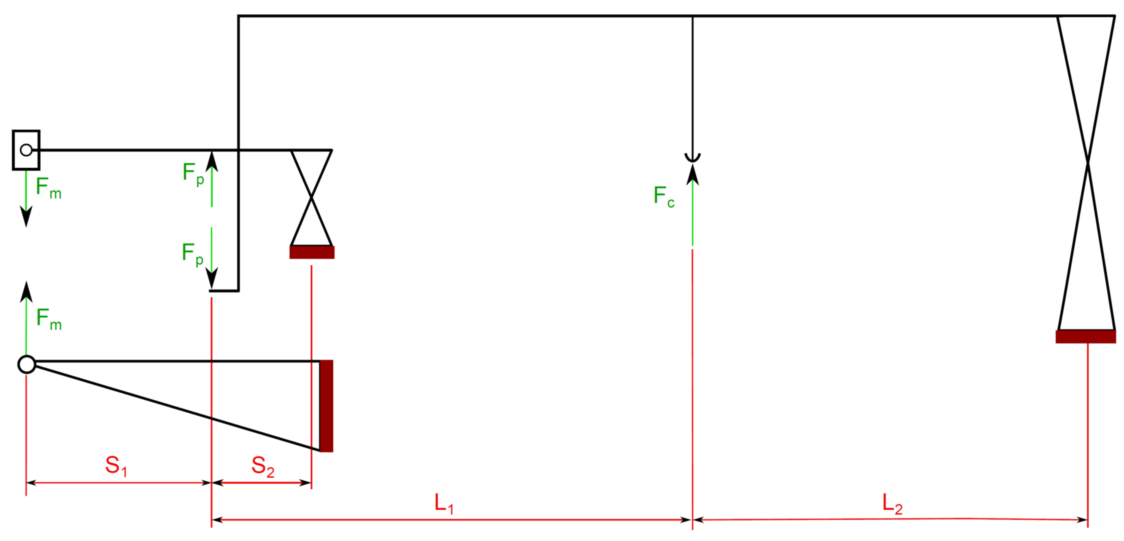
$$0 \le F_c \le k_{cav}\left(x_{BPc} + x_{BPf}\right) \simeq 7500\,\mathrm{N}$$

$$T_m = \frac{L_1 + L_2}{L_2} \cdot \frac{S_1 + S_2}{S_2} = 6.5$$

$$T_p = \frac{L_1 + L_2}{L_2} = 2$$

$$0 \le F_m \le \frac{F_c}{T_m} = 1150\,\mathrm{N}$$

$$0 \le F_p \le \frac{F_c}{T_p} = 3750\,\mathrm{N}$$



$L_1 = 350mm,\ L_2 = 350mm,\ S_1 = 67mm,\ S_2 = 30mm.$

Figure 3. Scheme of force acting on the Tuner.

Design and optimization

Key Design

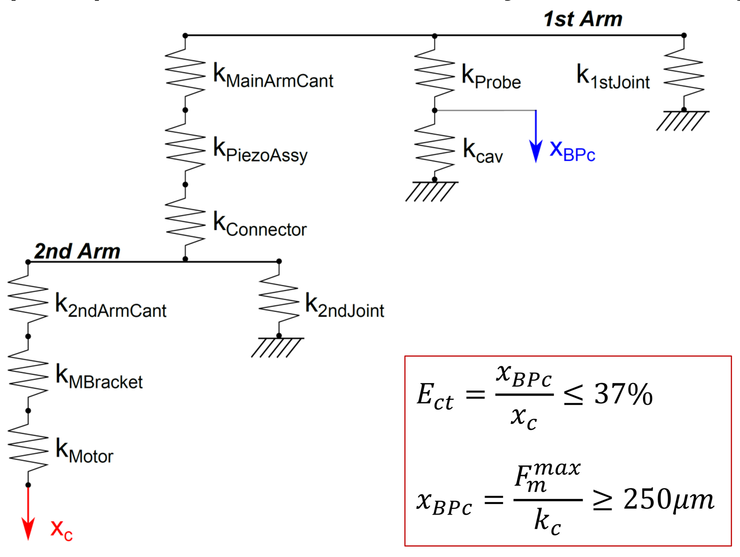
Operating mode

Coarse tuning
$\Delta f_c \ge 135\,kHz \rightarrow x_{BPc} \ge 250\mu m$
*Active compensation for **uncertainty** due to **cooldown**, **preload** the system*

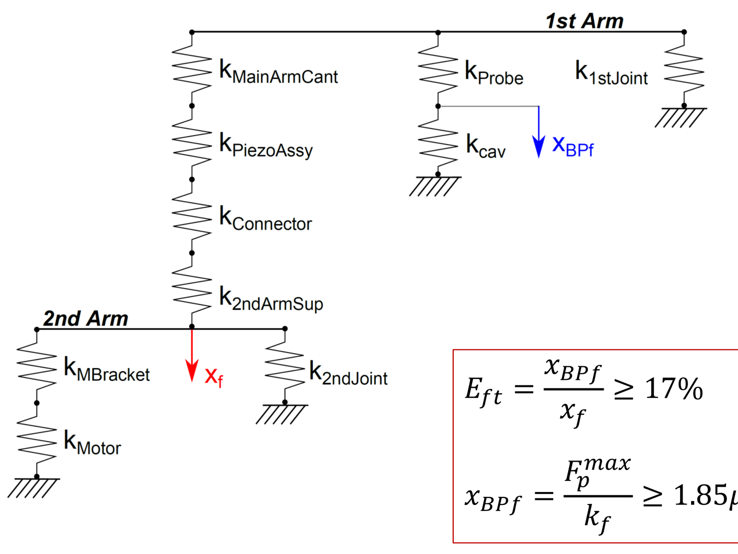
Fine tuning
$\Delta f_f \ge 1\,kHz \rightarrow x_{BPf} \ge 1.85\mu m$
*Actively compensate the frequency shifts due to **microphonic***

Passive tuning
$k_{pass} \ge 30\,N/\mu m$
*Passively minimize the **pressure sensitivity** of the cavity*

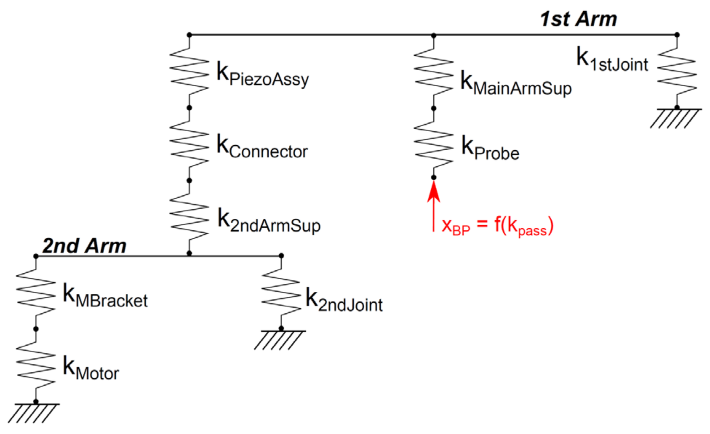
- Lumped parameter model to systematically balance the chain of stiffness and void weak link



$$E_{ct} = \frac{x_{BPc}}{x_c} \le 37\%$$
$$x_{BPc} = \frac{F_m^{max}}{k_c} \ge 250\mu m$$

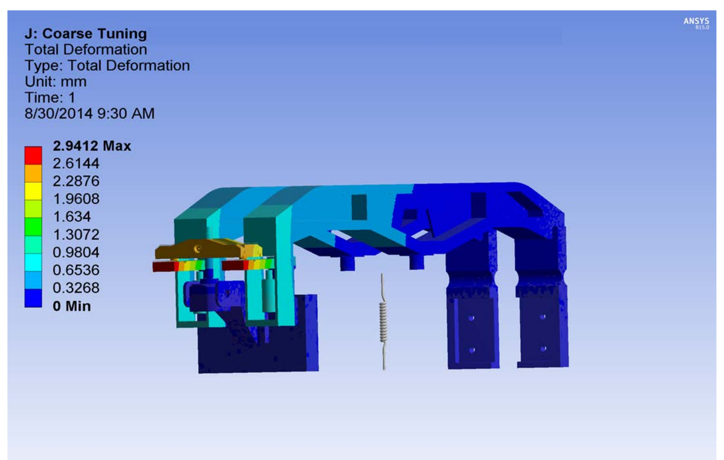


$$E_{ft} = \frac{x_{BPf}}{x_f} \ge 17\%$$
$$x_{BPf} = \frac{F_p^{max}}{k_f} \ge 1.85\mu m$$

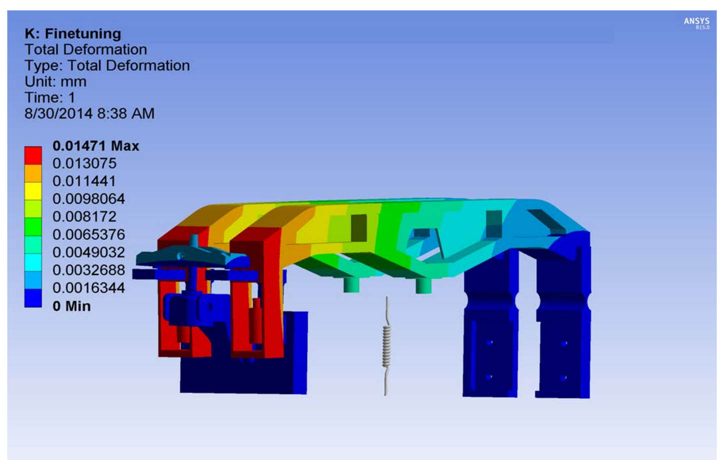


$$k_{pass} = \frac{F_{BP}}{x_{BP}} \ge 30\,N/\mu m$$

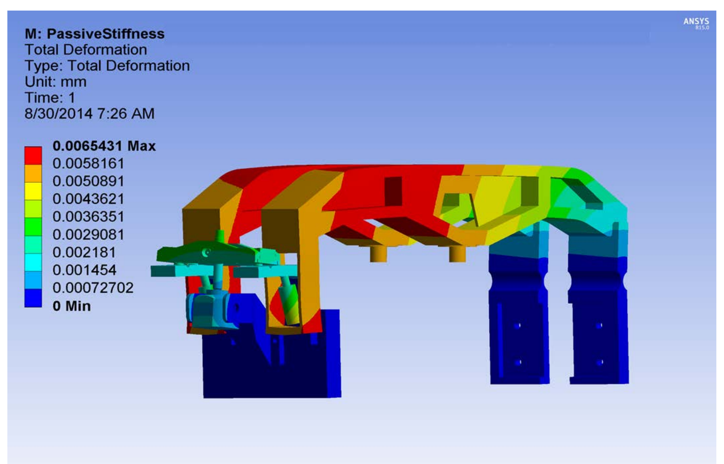
- FE analyses to simulate the three operating conditions and verify the value of stiffness and efficiency



$$E_{ct} = \frac{x_{BPc}}{x_c} = \frac{260}{2500} = 10.4\% \le 37\%$$
$$x_{BPc} = \frac{F_f^{max}}{k_c} = 260\mu m \ \ge 250\mu m$$



$$E_{ft} = \frac{5.30\mu m}{15\mu m} = 35\% \ge 17\%$$
$$x_{BPf} = \frac{F_p^{max}}{k_f} = 5.30\mu m \ge 1.85\mu m$$



$$k_{pass} = \frac{F_{BP}}{x_{BP}} = 40\,N/\mu m \ge 30\,N/\mu m$$

Low hysteresis

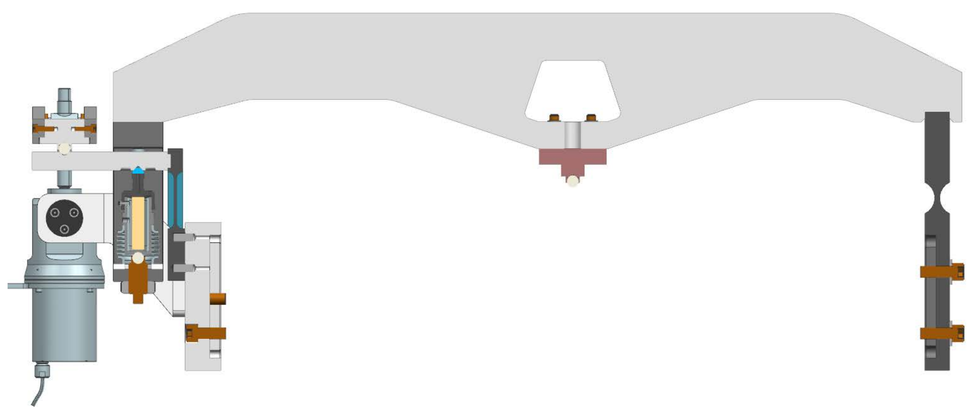


Figure 4. Simple contacts and flexible joints were adopted in order to predict their behavior and minimize sources of hysteresis.

Reliability and maintainability

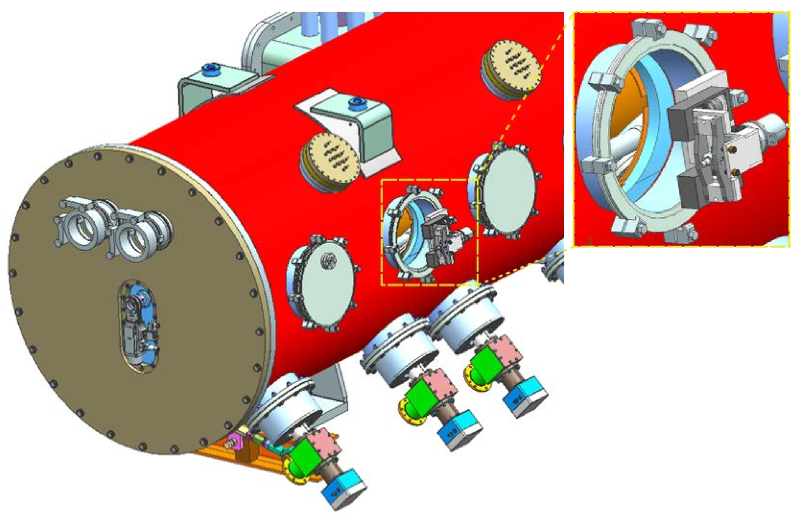


Figure 5. Actuating components assembled on a removable cartridge that can be removed from the cryomodule by dedicated access ports

Easy installation and handling

Conclusion and future work

Figure 6. Assemblies of encapsulated ceramic piezos.

The design of the Tuner is completed and it satisfies the specifications.
The first prototype of the tuner that was checked and assembled on a frame reproducing the tuner's supports of the cavity is shown in Figure 7. Preliminary tests at room temperature were performed in order to check the alignment of the parts, the symmetry of the loads in the two piezos and the deformation at the probes. Of course, more tests will be necessary to fully characterize its behavior and the respect of the specifications. The two encapsulated piezo assemblies were tested at room and cryogenic temperature. The strokes under different loading conditions were measured and it meets the performance declared by the vendor.
The effect of the passive tuning on SSR1-G3 has been tested at 2K [4] and an acceptable value of $df/dp = +4\,Hz/Torr$ was measured. A device with a passive stiffness of $k_{pass} = 40\ N/\mu m$ was in contact with the beam pipe.

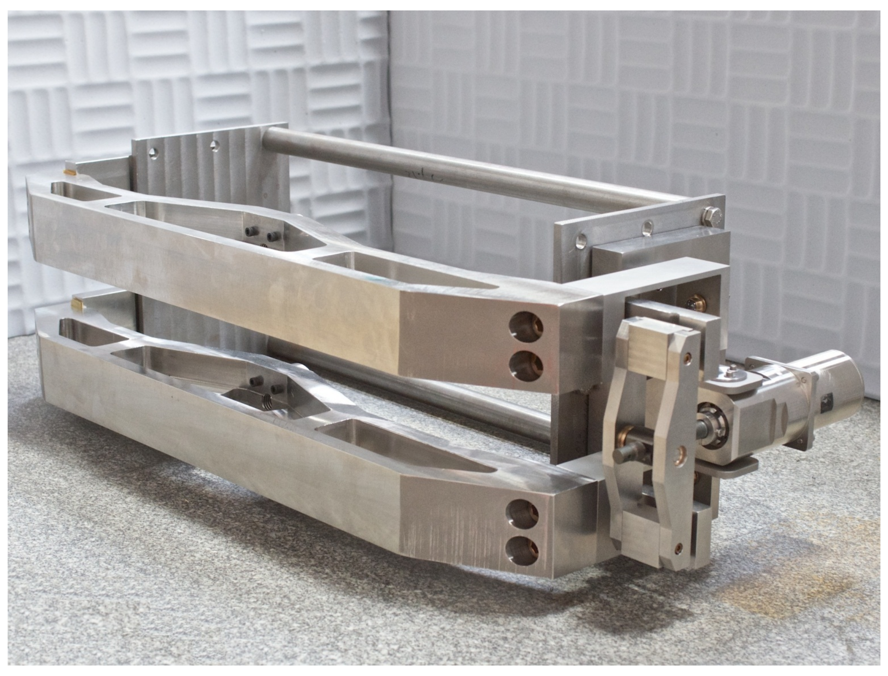


Figure 7. First prototype of the SSR1 double lever tuner.

References
[1] T. Nicol et al., "SSR1 Cryomodule Design for PXIE", PAC2013, Pasadena, California, THPMA09.
[2] L. Ristori et al., "Design of SSR1 Spoke Resonators for PXIE", IPAC2012, New Orleans, Louisiana, WEPPC057.
[3] Y. Pischalnikov et al., "A Tuner for a 325MHz SRF Spoke Cavity" SRF2009, Berlin, Germany, THPPO043.
[4] A. Sukhanov et al., "Result of cold tests of the Fermilab SSR1 cavities" SRF2009, Berlin, Germany, THPPO043.

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