Development and Performances of Spoke Cavity Tuner for MYRRHA Linac Project

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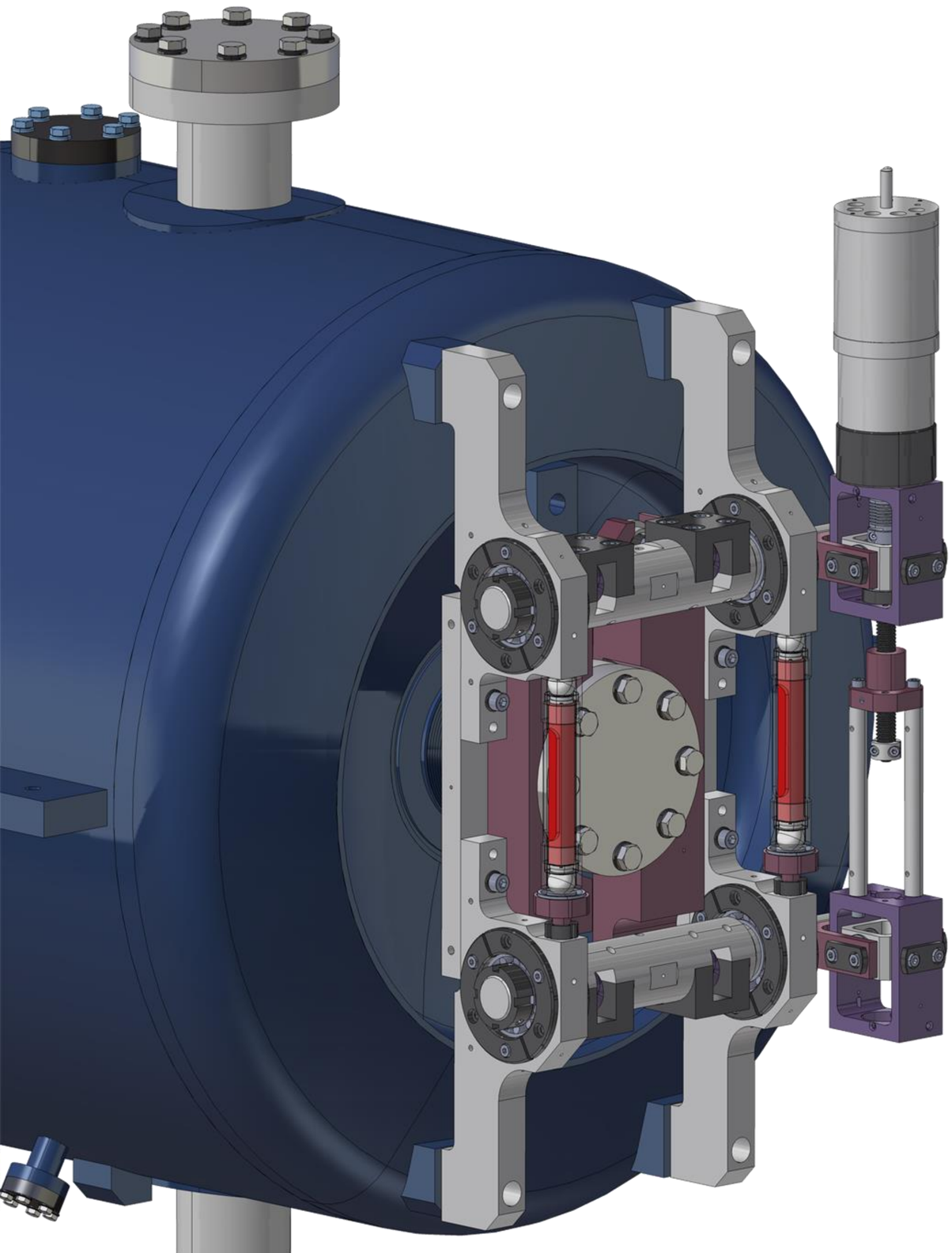
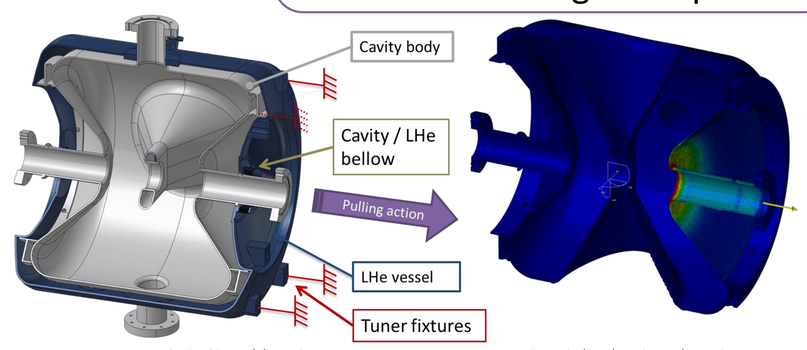
In the framework of the Multi-purpose hYbrid Research Reactor for High-tech Applications (MYRRHA) 100 MeV linac construction, a fully equipped prototype cryomodule is being developed. In order to control the resonance frequency of the cavities during operation, a tuner has been studied with the specific requirements: high degree of reliability and high tuning speed. This paper reports the design consideration and the first performances measurement in vertical cryostat test at an early stage of the prototyping phase.



Actual version of the prototype design

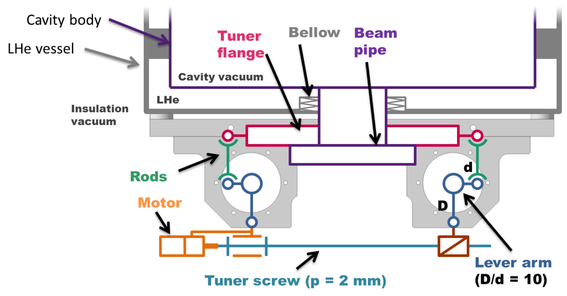
Active tuning concept



Cavity 3D model cut view — *Tuner induced strain on the cavity*

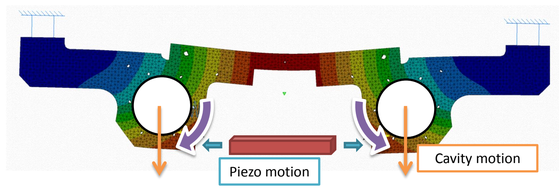
Cavity/tuner parameters	Unit	Value
Frequency sensitivity	kHz/mm	180
Stress sensitivity	MPa/mm	367
Stiffness	kN/mmm	15
Cavity bandwidth	Hz	160
Motor resolution	Step/rev	200
Gearhead ratio		6.25:1
Roller screw pitch	mm	2
Lever arm ratio		20
Displacement resolution	µm/step	0.08
Frequency resolution	Hz/step	< 14.5

The tuner is mounted on the liquid helium vessel which is welded on the cavity body (rigid connection). Then it pulls the cavity beam pipe flange along the beam axis. Maximum force applied is 13.1 kN and corresponds to a deformation of 0.87 mm and a frequency shift of 158 kHz. The mechanical system is composed from several elements : a **roller screw** system driven by a **stepper motor** acts on a **double lever arm** mechanism to provide a significantly reduced displacement of the **cavity flange**. Additional information on the cryomodule integration of the tuner and cavity can be found on MOP098 H. Saugnac.



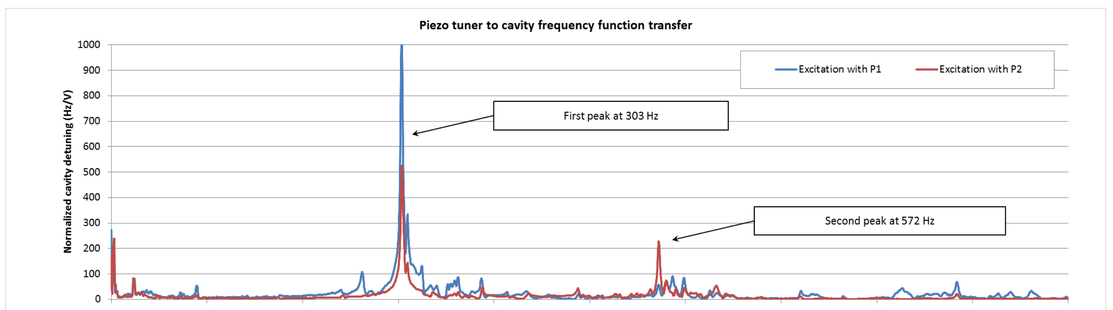
Slow tuner kinematic principle

Two piezo actuators have been inserted in the main frame of the tuner. They provide an small additional displacement to the cavity which can be very fast in order to compensate vibrations and to provide some help into the fast detuning/retuning scenario (fault tolerance strategy).

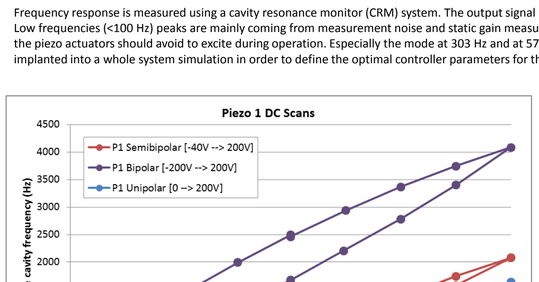


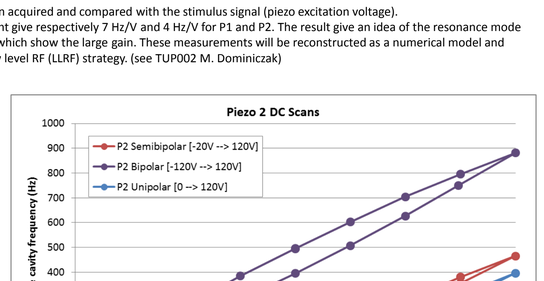
Fast tuner kinematic principle

Fast tuner tests (at 2K)

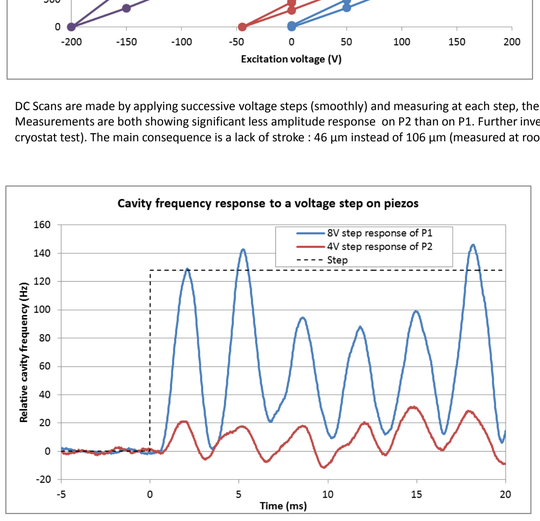


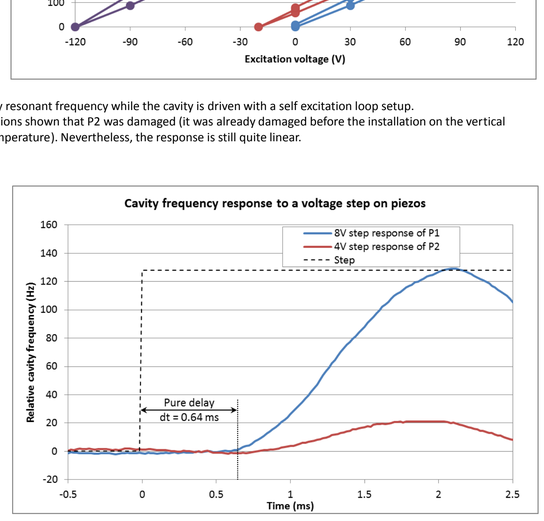
Frequency response is measured using a cavity resonance monitor (CRM) system. The output signal is then acquired and compared with the stimulus signal (piezo excitation voltage).
Low frequencies (<100 Hz) peaks are mainly coming from measurement noise and static gain measurement give respectively 7 Hz/V and 4 Hz/V for P1 and P2. The result give an idea of the resonance mode the piezo actuators should avoid to excite during operation. Especially the mode at 303 Hz and at 572 Hz which show the large gain. These measurements will be reconstructed as a numerical model and implanted into a whole system simulation in order to define the optimal controller parameters for the low level RF (LLRF) strategy. (see TUP002 M. Dominiczak)





DC Scans are made by applying successive voltage steps (smoothly) and measuring at each step, the cavity resonant frequency while the cavity is driven with a self excitation loop setup.
Measurements are both showing significant less amplitude response on P2 than on P1. Further investigations shown that P2 was damaged (it was already damaged before the installation on the vertical cryostat test). The main consequence is a lack of stroke : 46 µm instead of 106 µm (measured at room temperature). Nevertheless, the response is still quite linear.



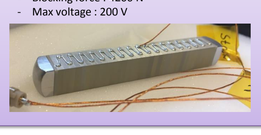


Pure delay has been measured using the same setup than for the transfer function. It is defined as the time between the beginning of a piezo action (voltage step on the piezo amplifier) and the beginning of the cavity frequency rising. It is imputed to the time travel of the acoustic wave from the piezo actuator to the cavity through the different mechanical parts of the tuner. The measurement of this parameter is also used to describe the numerical model of the tuner for simulation purpose.

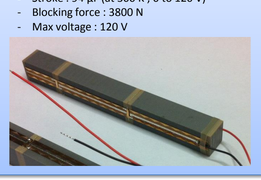
Actuators specifications

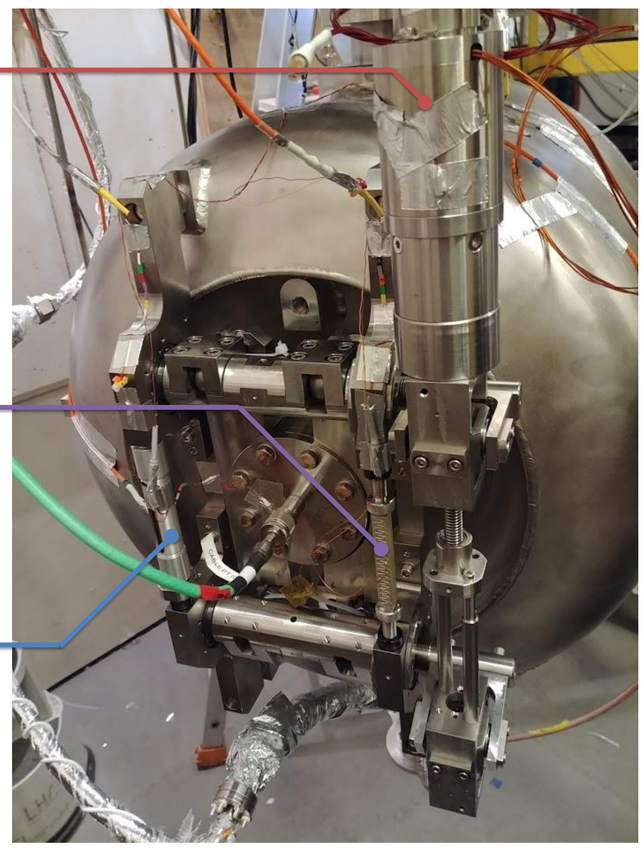
Motor :
- Manufactured by Phytron
- Nominal speed : 100 rev/min
- Max speed : 600 rev/min
- Overall dimensions (øxL): ø57 x 119 mm
- Weight : 1.7 kg
- Nominal current : 0.6 A (up to 1.2 A max)
- Planetary gear head with 6.25:1 ratio
- Radiation tolerant up to 10^6 J/kg
- Vacuum and cryogenics compatible

Piezo 1 (P1) :
- Manufactured by CTS (Noliac)
- Dimensions : 72x10x10 mm
- Capacitance : 13.9 µF (at 300 K)
- Measured capacitance : 3.87 µF (at 26.85 K)
- Stroke : 115.5 µF (at 300 K ; 0 to 200 V)
- Blocking force : 4200 N
- Max voltage : 200 V

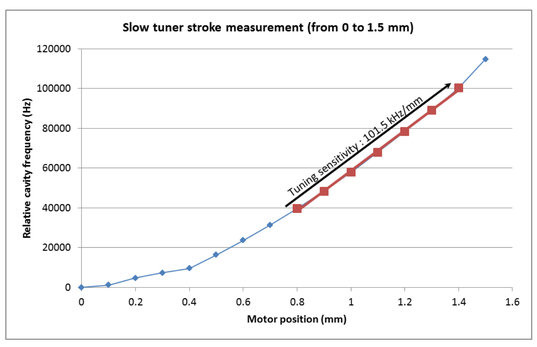


Piezo 2 (P2) :
- Manufactured by Physik Instrumente
- Dimensions : 90x10x10 mm
- Capacitance : 32 µF (at 300 K)
- Measured capacitance : 3.80 µF (at 20.7 K)
- Stroke : 94 µF (at 300 K ; 0 to 120 V)
- Blocking force : 3800 N
- Max voltage : 120 V

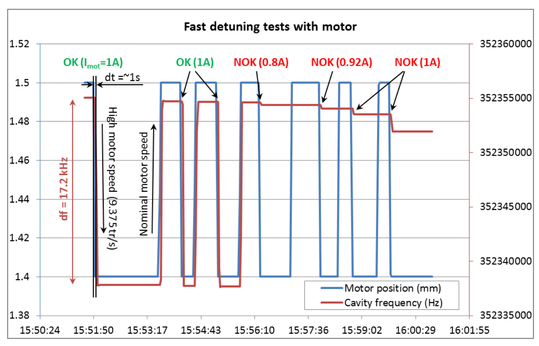




Slow tuner tests (at 2K)



Slow tuner measurements consist of exploring the whole tuner range from 0 (when the tuner is not yet connected to the cavity) to 1.5 mm (when the tuner is strongly connected to the cavity). From 0.2 to 0.4 mm the tuner is not fully connected to the cavity, this zone should not be used during operation because of strong non linearity, backlash issue and piezo response which would not be optimal.



One of the project requirement ask to be able to detune the cavity of 14 kHz is 1 second. This requirement can be satisfied if the motor can reach a speed of 9.375 turn/s.
Several tests have been done to verify this by releasing the cavity at this speed, sometimes it worked and sometimes not. More studies will be lead to understand and improve those results.