FAST TUNER PERFORMANCE FOR A DOUBLE SPOKE CAVITY

N. Gandolfo, S. Bousson, S. Brault, P. Duchesne, P. Duthil, G. Olry, D. Reynet, IPN, Orsay, France
C. Darve, M. Lindroos, ESS, Lund, Sweden

Abstract

IPN Orsay is developing the low-beta double Spoke cavities cryomodule for the ESS. In order to compensate resonant frequency variations of each cavity during operation, a deformation tuner has been studied and two of them have been built. The typical perturbations are coming from LHe saturated bath pressure variations as well as microphonics and Lorentz force detuning (LFD). In this paper, the tuner performance of the double Spoke cavity is presented.

INTRODUCTION

The ESS spoke cryomodule is designed to include two cavities. These cavities require a tuning solution to prevent several kinds of undesirable shift and perturbations well identified to interfere with the resonant frequency during beam operation. The largest ones come from manufacturing, preparation and cooling down phases and can shift the resonant frequency. While it is possible to anticipate them, a relatively small incertitude still exists within a range of few tens of kilohertz. Another type of perturbations will come from RF high field which generates Lorentz forces on the cavity walls thus shifting the resonant frequency very quickly at each beam acceleration pulse. In order to compensate these two very different types of perturbations, a deformation tuner has been designed including an association of one stepper motor for a large tuning stroke capability and two piezoelectric actuators for the fast tuning compensation. The tuning principle is to apply a pulling force on one cavity wall from four fixation points of the LHe tank to the beam tube flange (Fig. 1).

Figure 1: View of the tuner equipping the ESS double spoke cavity.

TEST SETUP

Since the double spoke cavity is still under construction, a sequence of room temperature tests has been planned with the tuner on a triple spoke cavity (Fig. 2) which nearly meets the same relevant mechanical parameters (Table 1).

Figure 2: Photo of the tuner assembled on a triple spoke cavity.

Table 1: Cavities parameters

	Wall stiffness	**Sensitivity**
Triple spoke (computed)	19 kN/mm	166 kHz/mm
Triple spoke (measured)	16.2 kN/mm	151 kHz/mm
Double spoke (computed)	20 kN/mm	128 kHz/mm

Since two prototypes have already been built, some characterization steps have been conducted twice in order to compare performances of each tuner on the same cavity.

SLOW TUNER CHARACTERIZATION

Slow Tuner Range

Maximum cavity elongation (for ESS double Spoke cavity) at low temperature without exceeding the niobium elastic limit has been evaluated at 1.28 mm (Fig. 3).

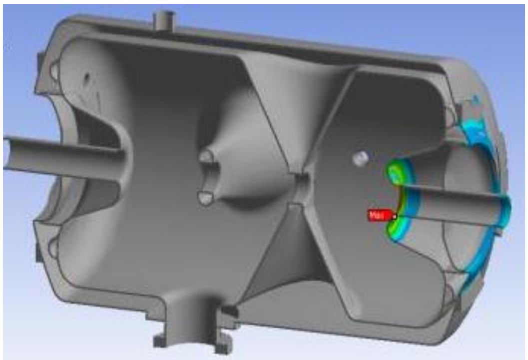

Figure 3: Cavity simulation determined 1.28 mm maximum deformation [1].

Nevertheless, the effective tuner stroke has been defined at 1 mm maximum to keep a security margin from permanent deformation of the cavity (Fig. 4). Also, it is important to consider a minimum effective deformation in which the deformation control will suffer from some non-linearity.

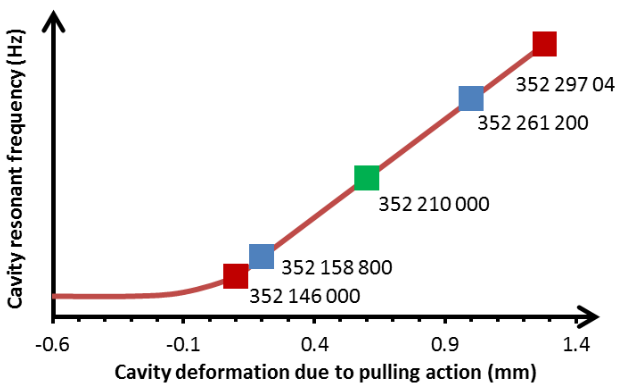

Figure 4: Slow tuner range specification, the green dot represents the nominal set point and the blue dots indicate nominal range of operation. Red dots are ultimate value of operation.

During the test, this non-linear phase which correspond to the moment from getting mechanical contact between the tuner and the cavity until it is fully connected last over 15 kHz equivalent to a 0.1 mm cavity wall deformation. After what a very linear sensitivity appears with a ratio of 0.88 Hz/step (Fig. 5).

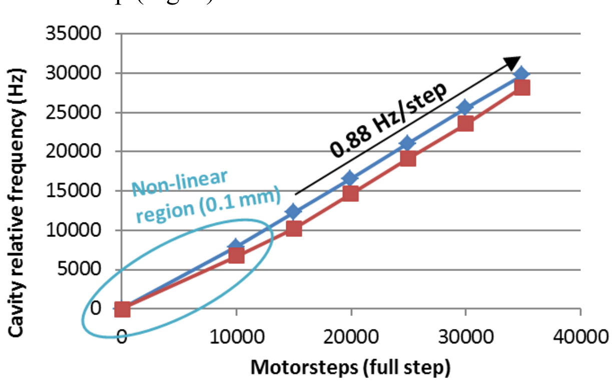

Figure 5: Cavity resonant frequency versus motor action, one curve per tuner tested.

In order to not reach the niobium yield strength, the maximum displacement was limited to 0.2 mm of cavity deformation. Further low temperature tests will confirm the possibility to achieve the 100 kHz nominal tuning stroke.

Tuner Stiffness

While applying an effort to the cavity, part of the displacement is lost in the tuner itself.

Part by part static analysis has been made during the design study to prevent any weak zone to absorb a large part of the displacement but in reality, interface element such as ball bearing or spherical joint lower the estimated value with some incertitude.

During the test, knowing the real cavity stiffness, the measured displacement and the applied displacement by the tuner, its stiffness has been indirectly estimated. Around half of the displacement seems lost by tuner deformation (Fig. 6), thus it is almost as stiff as the cavity wall 16.2 kN/mm.

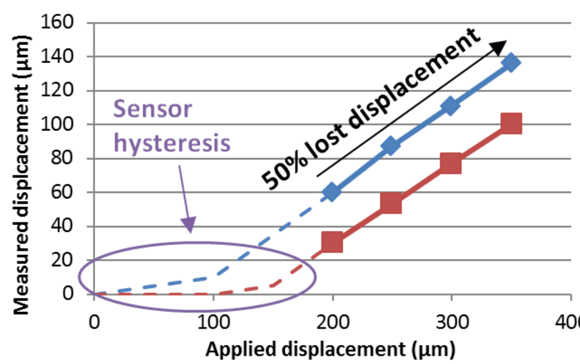

Figure 6: Displacement measurement over limited tuner range, one curve per tuner tested.

Motor Hysteresis

Repetitive back and worth motions have been applied to check the motor hysteresis at very low speed. Results show a quite small hysteresis of 12 Hz when applying a 1 µm back and worth displacement (Fig. 7). This result is encouraging but must be confirmed in a more realistic test at low temperature.

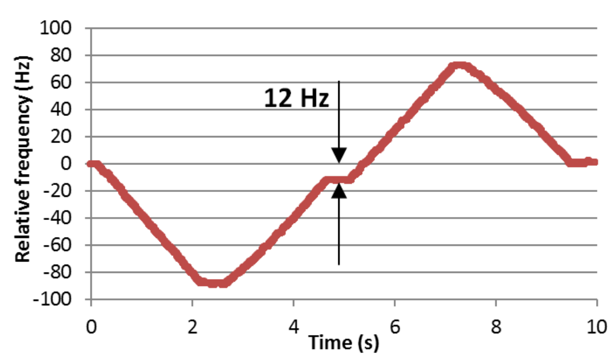

Figure 7: Cavity resonant frequency shift over a very slow and small motor motion of twice 1 µm amplitude.

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FAST TUNER CHARACTERIZATION

Piezo Tuner Principle

Two independent actuators are placed inside two parts that serve as rigid lever arm (Fig. 8). The purpose of the rigid lever arms is to reduce the forces induced by the slow tuner action to the piezo actuators, but it will also reduce the fast tuning stroke.

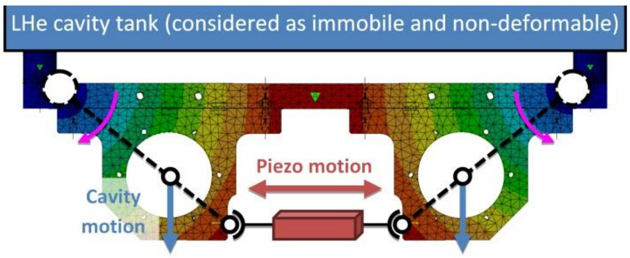

Figure 8: Displacement vector simulation result when the piezo actuators are solicited: red field points the highest value while blue field means no motion.

Fast Tuning Stroke

Two types of piezos have been tested:

- 2 stacks of 50x10x10 mm from Noliac
- 2 stacks of 36x10x10 mm from Physik Instrumente

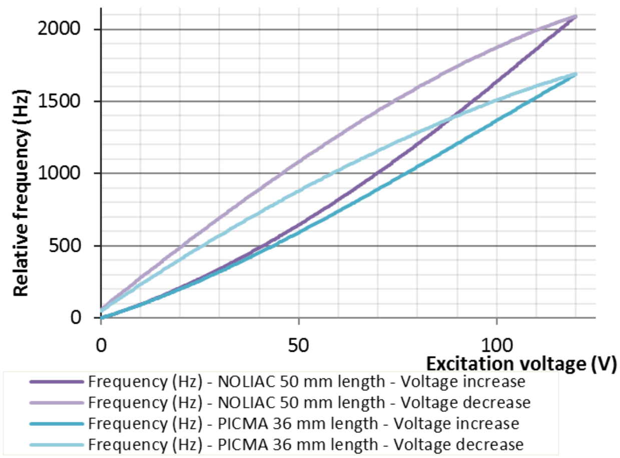

Figure 9: Fast tuner range measurement.

In order to compensate the Lorentz forces detuning on the ESS double Spoke cavity, the stroke requirement was 400 Hz [2]. The test showed that this requirement is fulfilled, however the available stroke will be reduced at low temperature, results must be confirmed at nominal conditions.

Tuner Transfer Function

The tuner transfer function (Fig. 10) has been found using a square wave excitation of 7.5V from both piezos (PICMA) and acquiring the phase between the forward and a transmit signal of the cavity at a fixed frequency near the cavity resonance. The phase measurement was performed using an AD8302 chip and the conversion was calibrated at 760 Hz/°.

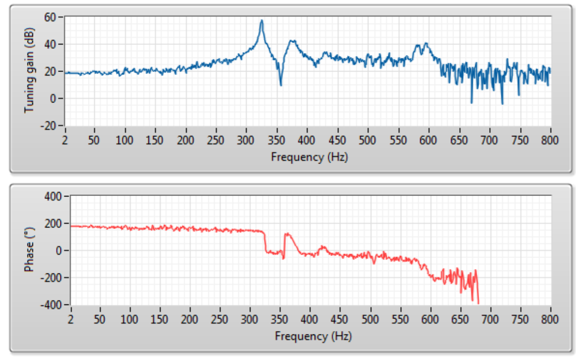

Figure 10: Tuner transfer function, the gain corresponds to the cavity detuning over dual piezo excitation (Hz/V).

Pure Delay

The pure delay is the time between the piezo signal command (sharp square wave) and the beginning of the frequency shift response. It has been measured in the order of 0.75 ms (Fig. 11). This delay comes essentially from the travelling of the acoustic wave from the actuators to the cavity walls and must be taking in account when using a closed control loop to regulate the cavity resonant frequency.

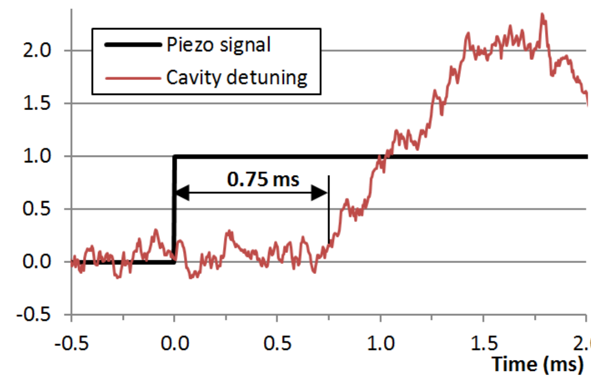

Figure 11: Detuning measurement (phase detection) normalized to the final square wave response value.

CONCLUSION

Two cold tuning systems have been fully characterized at room temperature. In term of optimization, there is some room to improve the tuner stiffness and the fast tuning stroke. A cold test must be performed in order to verify that performances will not degrade in nominal operation conditions.

REFERENCES

[1] P. Duchesne, S. Bousson, S. Brault, P. Duthil, G. Olry and D. Reynet, "Design of the 352 MHz, beta 0.50, double-spoke cavity", in *proceedings of SRF*, Paris, France, 2013.

[2] N. Gandolfo, S. Bousson, S. Brault, P. Duchesne, P. Duthil, G. Olry and D. Reynet, "Deformation tuner design for a double spoke Cavity", in *proceedings of SRF*, Paris, France, 2013.