THE FAST PIEZO-BASED FREQUENCY TUNER FOR SC CH-CAVITIES*

M. Amberg †, K. Aulenbacher, Helmholtz-Institut Mainz (HIM), 55099 Mainz, Germany
M. Busch, F. Dziuba, H. Podlech, U. Ratzinger, IAP Frankfurt University, 60438 Frankfurt, Germany
W. Barth, V. Gettmann, S. Mickat, GSI Helmholtzzentrum, 64291 Darmstadt, Germany

Abstract

Superconducting structures are very susceptible to external influences due to their thin walls and their narrow bandwidth. Even small mechanical deformations caused by dynamic effects like microphonic noise, pressure fluctuations of the liquid helium bath or Lorentz-Force-Detuning can lead to resonance frequency changes of the cavity which are much larger than the bandwidth. To compensate the slow and fast resonance frequency variations during operation a compact frequency tuner prototype equipped with a stepper motor and a piezo actuator has been developed at the Institute for Applied Physics (IAP) of Frankfurt University. In this paper, the tuner design and the results of first room temperature measurements of the tuner prototype are presented.

INTRODUCTION

To guarantee a stable operation a new dynamic frequency tuner for sc CH-cavities [1] has been developed at the IAP. This tuner consists of an inner and an outer part: dynamic bellow tuners are welded into the girders of the cavity which react on frequency variations by changing their height. The tuner drive consisting of a slow stepper motor and a fast reacting piezo actuator is mounted on top of the helium vessel and provides slow and fast tuning by pushing or pulling the dynamic bellow tuner (see Fig. 1).

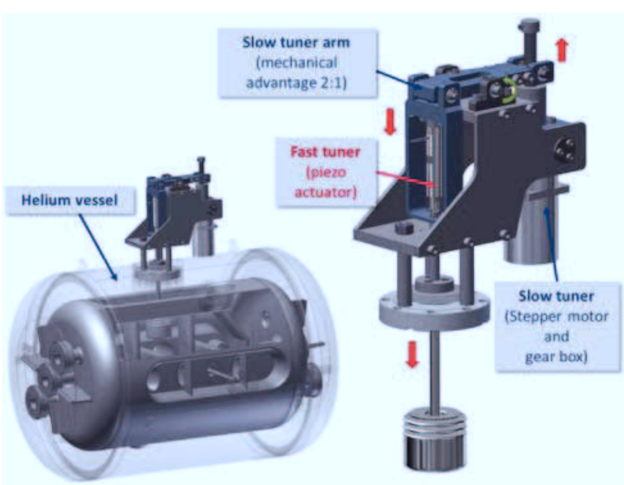

Figure 1: Tuner drive mounted on top of the helium vessel (left) and complete frequeny tuning system including the dynamic 3-cell bellow tuner (right).

DYNAMIC BELLOW TUNER

For the sc 325 MHz and 217 MHz CH-cavities [2] [3] which are currently under first tests and under construction, respectively, a new dynamic frequency tuning concept has been worked out. Additionally to the cylindrical static tuners, several dynamic capacitive bellow tuners are welded into the girders to act against slow and fast frequency variations by changing their height of up to ±1 mm. The goal of the slow tuners, driven by stepping motors, is to readjust the frequency changes caused by cavity cool-down to 4.2 K and evacuation effects. In addition, one of these slow tuners is based on a fast reacting piezo actuator to compensate frequency changes due to microphonic excitations and Lorentz Force Detuning. This tuning device including slow and fast dynamic bellow tuners is sufficient for frequency tuning during beam operation. The final design of a 3-cell bellow tuner for the sc 325 MHz CH-cavity is shown in Figure 2 [4].

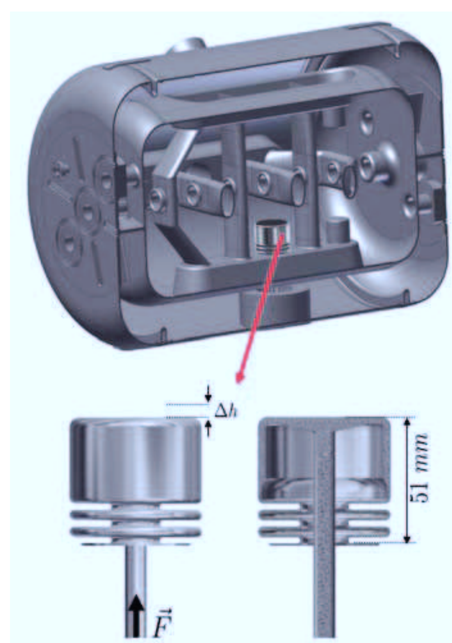

Figure 2: Dynamic 3-cell bellow tuner for the sc 325 MHz CH-cavity.

RF simulations of the sc 325 MHz CH-cavity with CST Microwave Studio [5] show that a frequency shift of around 130 kHz/mm is achievable for each of the two bellow tuners at a working point of 51 mm tuner height. To validate the RF simulation results first room temperature measurements regarding the frequency shift of the bellow tuners have been performed. Preventively, the mechanical range of the bellow tuners was limited to $\Delta x = \pm 0.15$ mm because of the

* Work supported by HIM, GSI, BMBF Contr. No. 05P12RFRBL
† amberg@iap.uni-frankfurt.de

appearing material stress. The measured frequency shift averaged Δf =-125 kHz/mm for tuner 1 and Δf = -118 kHz/mm for tuner 2. The measurement results of the frequency change show a good agreement with the simulated values (see Fig. 3).

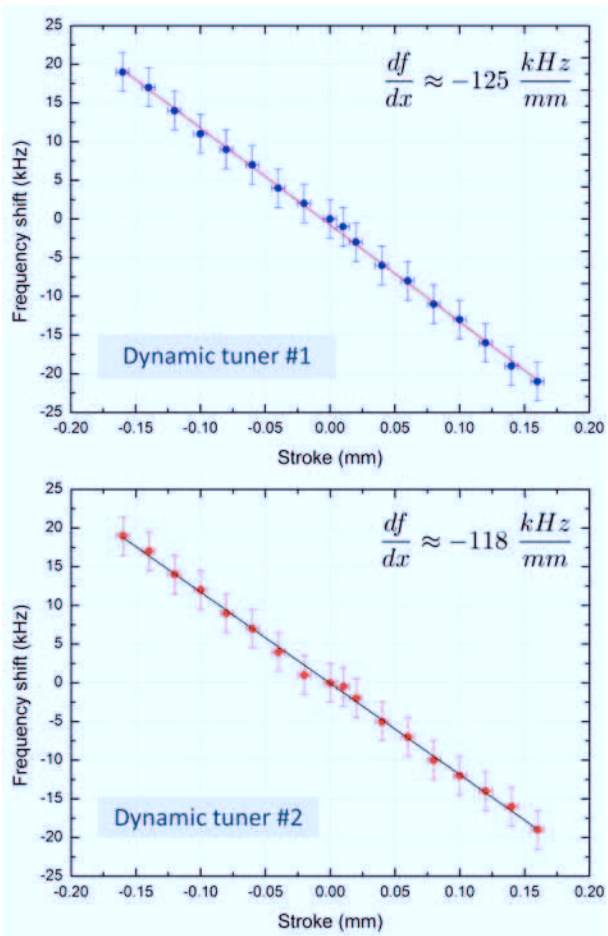

Figure 3: Measured frequency shift of the dynamic bellow tuners for the sc 325 MHz CH-cavity.

TUNER DRIVE

To change the height of the dynamic bellow tuners a novel frequency tuner drive concept has been developed. The tuner drive system provides slow and fast tuning by pushing or pulling the dynamic bellow plunger inside the cavity. For a coarse match of the frequency at 4.2 K a stepper motor moves the dynamic bellow plunger via a lever arm around ± 1 mm. Furthermore, a fast reacting piezo actuator housed in a piezo frame will be driven by the control system to compensate the dynamic frequency variations which are already mentioned above. The piezo actuator deflects the bellow plunger around ± 6 μm.
In Figure 4 the major elements of the frequency tuner are shown. The outer part of the tuner works at liquid nitrogen temperature and under vacuum, therefore special materials and treatments are necessary under these conditions.

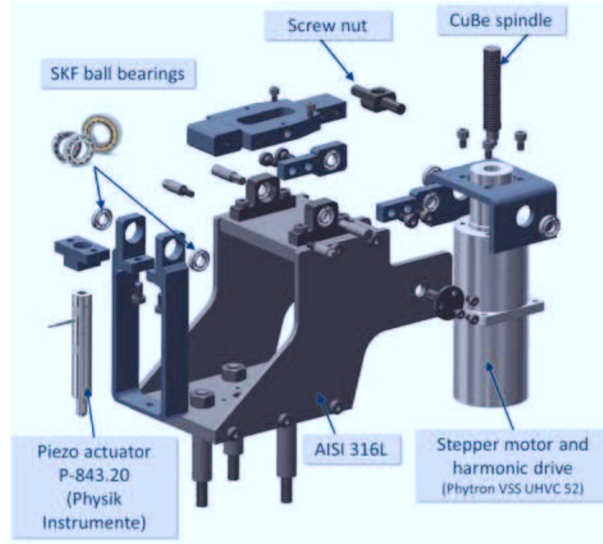

Figure 4: Main components of the frequency tuner drive system.

To validate the slow and fast tuning concept a frequency tuner drive prototype made of stainless steel was built at the workshop of the IAP. In first room temperature tests the mechanical stroke of a 1-cell bellow tuner made of niobium was measured with a precise probe indicator and an electronic height gauge, respectively. Figure 5 shows the achieved stroke as a function of the motor steps. The measurement results show a linear behaviour between the tuner stroke and the number of motor steps. Only small hysteresis effects of the slow tuning system have been detected (see Fig. 6 (top)).

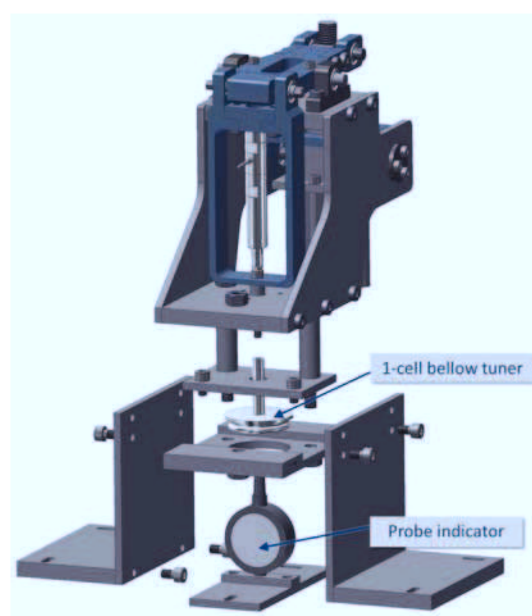

Figure 5: First frequency tuner prototype made of stainless steel including the dynamic 1-cell bellow tuner made of niobium.

ISBN 978-3-95450-142-7

In a second test the dynamic behaviour of the fast piezo driven tuner was measured at GSI, Darmstadt, using a Laser Doppler Vibrometer (LDV). The stroke of the 1-cell bellow plunger was measured as a function of the applied piezo frequency for various piezo voltages. The laser beam from the LDV was directed at the surface of the bellow plunger and the vibration amplitude and frequency were extracted from the Doppler shift of the reflected laser beam frequency due to the deflection of the bellow plunger.

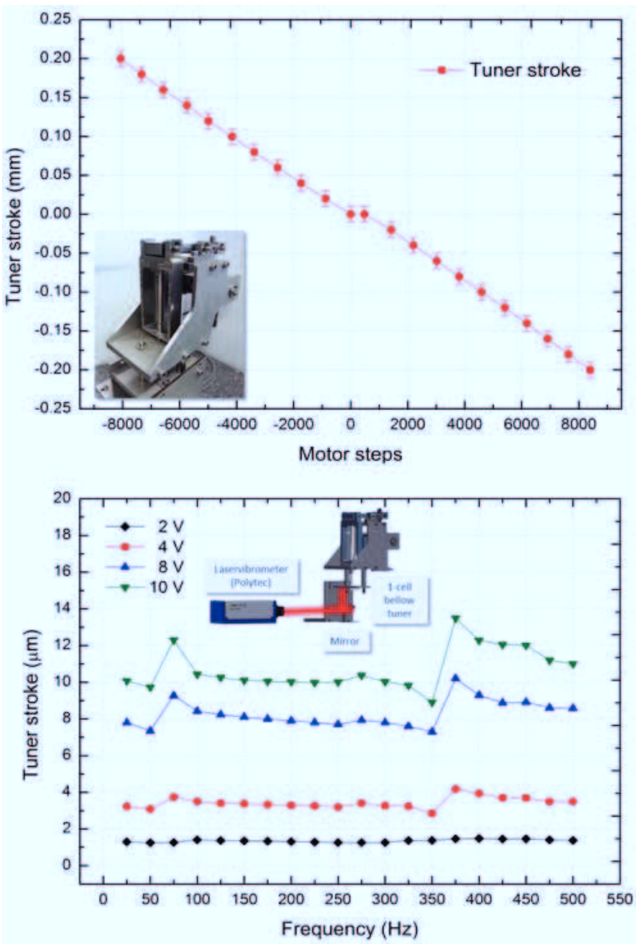

Figure 6: Measured tuner stroke as a function of the number of motor steps (top) and measurement results of the tuner stroke as a function of the applied piezo frequency for different operating voltages (bottom).

As shown in Figure 6 (bottom) especially for low piezo voltages the tuner stroke is constant for different piezo frequencies. At higher piezo voltages small mechanical resonance effects of the tuning device could have been detected at piezo frequencies in the range of 60-80 Hz and 360-380 Hz, respectively. The functional principle of the piezo-based frequency tuner has been validated experimentally.

SUMMARY & OUTLOOK

Room temperature measurements of the dynamic bellow tuners for the sc 325 MHz CH-cavity have been performed. A comparison between the measured data and the simulation results was made. A prototype of the novel frequency tuner drive including a slow stepper motor and a fast reacting piezo element has been worked out and built in the workshop of the IAP. First room temperature measurements have been carried out. In 2014/15 it is planned to test the dynamic frequency tuner prototype for the sc 325 MHz CH cavity under real operating conditions (vacuum, 4.2 K).

ACKNOWLEDGEMENT

This work has been supported by Helmholtz-Institut Mainz (HIM), Gesellschaft für Schwerionenforschung (GSI), BMBF contr. No. 05P12RFRBL and EU contr. No. 516520-FI6W. This work was (financially) supported by the Helmholtz International Center for FAIR within the framework of the LOEWE program (Landesoffensive zur Entwicklung Wissenschaftlich-Oekonomischer Exzellenz) launched by the State of Hessen.

REFERENCES

[1] H. Podlech, U. Ratzinger, H. Klein, C. Commenda, H. Liebermann, A. Sauer, Superconducting CH Structure, Phys. Rev. STAB 10, 080101 (2007).

[2] M. Busch, M. Amberg, F. Dziuba, H. Podlech, U. Ratzinger, Cold Measurements on the 325 MHz CH-Cavity, in Proc. of SRF'13, Paris, France, p. 890-892 (2013).

[3] F. Dziuba, M. Amberg, K. Aulenbacher, W. Barth, M. Busch, H. Podlech, U. Ratzinger, S. Mickat, Superconducting CH Cavities for Heavy Ion Acceleration, in Proc. of IPAC'13, Shanghai, China, p. 3794-3796 (2013).

[4] M. Amberg, K. Aulenbacher, M. Busch, F. Dziuba, H. Podlech, U. Ratzinger, W. Barth, S. Mickat, Structural Mechanics of Superconducting CH-Cavities, in Proc. of IPAC'11, San Sebastian, Spain, p. 268-270 (2011).

[5] CST Microwave Studio, http://www.cst.com