MICROPHONIC ANALYSIS OF THE SC 325 MHZ CH-CAVITY*

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

Abstract

Since the walls of superconducting (sc) cavities are kept very thin to support the cooling process, even small mechanical disturbances can detune the cavity. One of the main sources of detuning a cavity is microphonics. These low-frequent vibrations caused by e.g. vacuum pumps are transferred to the cryostat and excite mechanical resonances of the cavity which may lead to frequency shifts larger than the bandwidth. To determine the mechanical resonance frequencies of the sc 325 MHz CH-cavity (Crossbar-H-Mode) simulations with ANSYS Workbench have been performed in a first step. Additionally, microphonics measurements were taken at room temperature in the cryo-lab of the IAP, Frankfurt University. Furthermore, the deformation of the cavity walls and the resulting frequency shift due to cooling down the cavity have been measured. A comparison between simulation results and the measured values is presented on this paper.

INTRODUCTION

The sc 325 MHz CH-cavity has been developed at the Institute for Applied Physics (IAP), University of Frankfurt, for future beam tests at GSI, Darmstadt (see Fig. 1) [1]. It is designed and optimized for high power applications, consists of 7 accelerating cells and has a design gradient of 5 MV/m. Its frequency is the third harmonic of the UNILAC at GSI, Darmstadt. Table 1 shows the main parameters of the 325 MHz CH-cavity.
The complete 325 MHz CH-cavity is produced of niobium sheets with a thin wall thickness of 3 mm. To control the effects of appearing mechanical deformations of the cavity walls due to e.g. microphonic and cool down effects and the caused fluctuation of the cavity resonance, coupled structural mechanical and rf simulations are essential.
This paper presents the comparison between simulation results and measurements of microphonic and cool down effects of the sc 325 MHz CH-cavity.

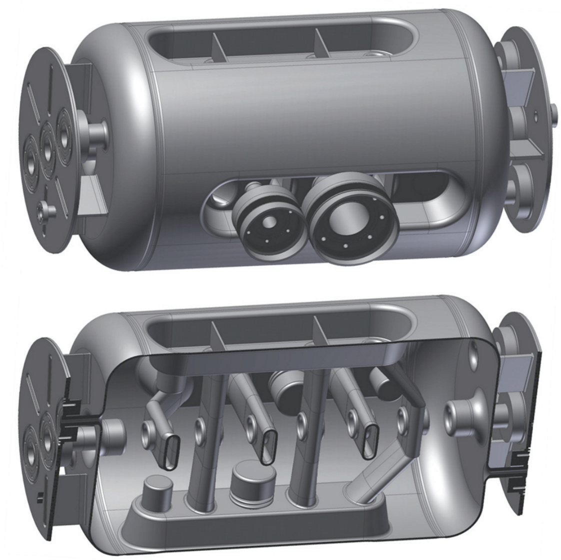

Figure 1: Layout of the sc 325 MHz CH-cavity [1].

Table 1: Specifications of the 325 MHz CH-cavity

Parameter	Unit	
β		0.16
Frequency	MHz	325.224
Length ($\beta\lambda$-def.)	mm	505
Cavity diameter	mm	347.4
Wall thickness	mm	3
Accelerating gradient	MV/m	5
E_p/E_a		5.1
B_p/E_a	mT/(MV/m)	13
G	Ω	64
R_a/Q_0		1248
R_aR_s	kΩ^2	80

MICROPHONIC EFFECTS

Superconducting cavities have to accomplish strict mechanical requirements to assure a stable operation. Even small mechanical deformations of the cavity shape may lead to a frequency shift in the range of several hundred Hz. One of the major sources of detuning a cavity is microphonics. External vibrations caused by e.g. vacuum pumps are transferred by the cryo-system and excite the mechanical natural frequencies of the cavity.

Simulation Results

During the design process it is important to increase the frequencies of the mechanical resonant modes of the cavity. With the simulation software ANSYS Workbench it is possible to determine the natural frequencies and the corresponding oscillation modes of the cavity [2]. In the case of the sc 325 MHz CH-cavity the two lowest eigenfrequencies were predicted to be about 160 Hz and 227 Hz, respec-

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

ISBN 978-3-95450-122-9

tively, which means that the 325 MHz CH-cavity is a stiff structure (see Fig. 2). To validate the simulation results microphonics measurements have been carried out.

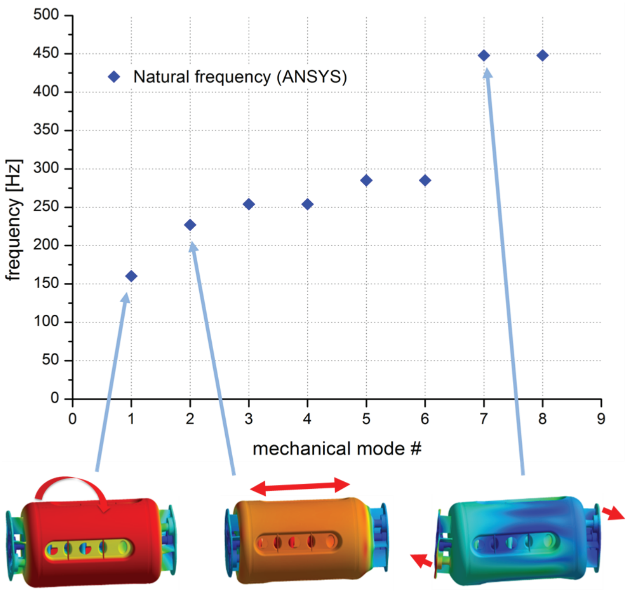

Figure 2: Simulated natural frequencies and three of the corresponding oscillation modes of the sc 325 MHz CH-cavity.

Measurements

The microphonic effects of the sc 325 MHz CH-cavity have been measured at room temperature in the environment of the cryo-lab at the IAP. To excite the natural frequencies of the cavity a voltage was applied to a piezo actuator which was installed on one end cap (see Fig. 3).

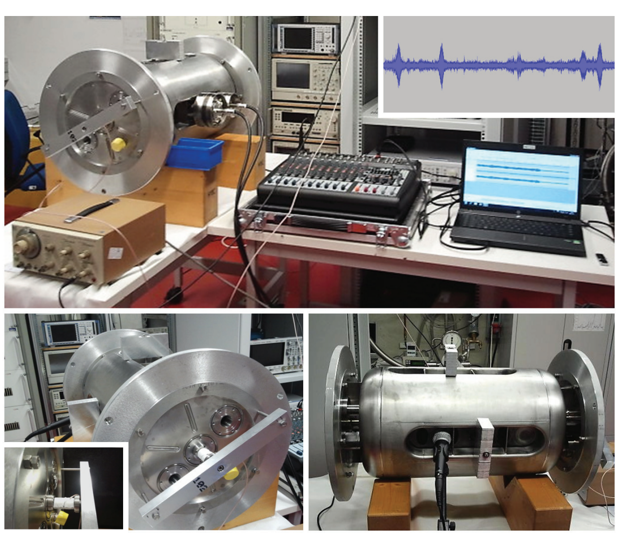

Figure 3: Test setup for microphonics measurements in the environment of the cryo-lab at the IAP, University of Frankfurt.

In a first measurement the piezo actuator was controlled by a sinusoidal signal sweeping over a frequency range between 0 Hz and 700 Hz. To approve the measured results we used a second method of measurement where the piezo was excited by a white noise signal comprising all frequencies between 16 Hz and 20 kHz. To analyze the response of the cavity to the excited vibrations a microphone was used as a detector.

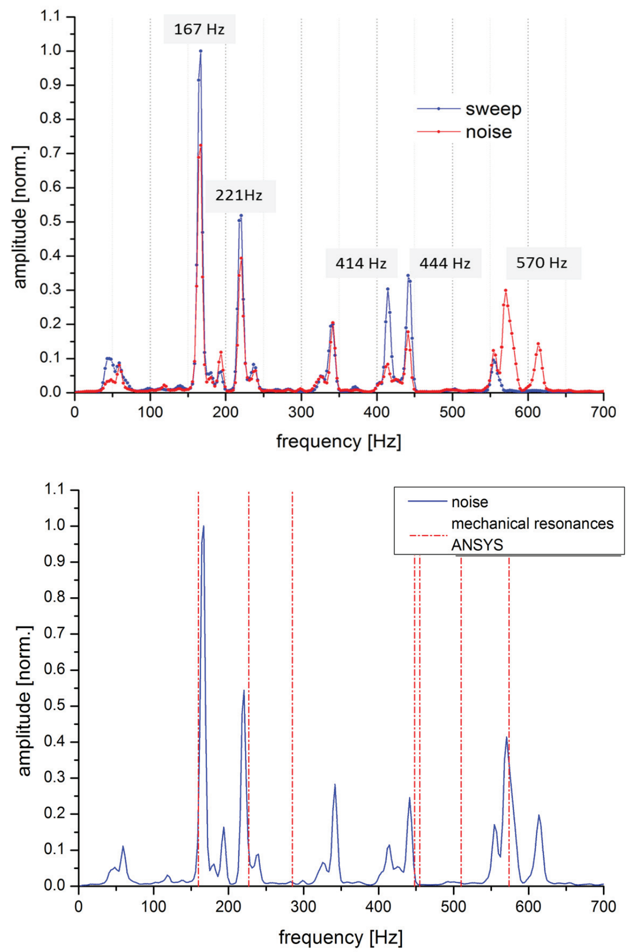

Figure 4: Comparison between sweeping method and white noise technique (top) and between measurements and ANSYS simulation results (bottom).

As can be seen in figure 4 there was a good agreement between the two methods of measurements as well as between the ANSYS simulation results and the measured data. Most of the simulated natural frequencies fall within not more than 20 Hz of the measured frequencies.

COOL DOWN

Mechanical and rf simulations have been performed with ANSYS Workbench and CST MicroWave Studio, respectively, to predict the shrinkage and the resulting frequency shift of the cavity due to cool down to 4.2 K [3]. The simulation results of the cavity cool down show that the maximum displacement is around 0.9 mm, which will lead to a frequency shift of about 460 kHz. The maximum von-Mises stress was found to be 42 MPa, which is still acceptable compared to the yield stress of niobium (see Fig. 5).

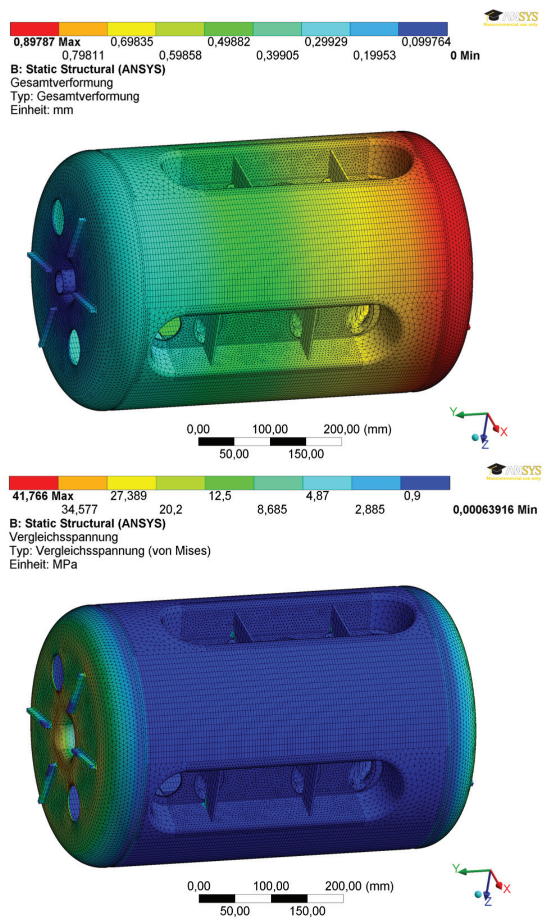

Figure 5: Displacement of the cavity walls caused by cool down (top) and appearing von-Mises stress (bottom).

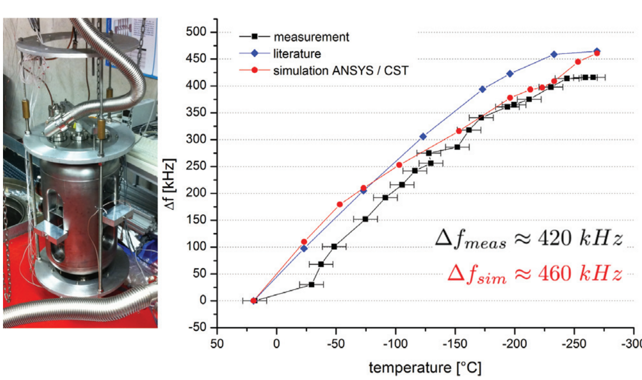

Figure 6: Prepared cavity before cool down (left) and comparison between simulated and measured frequency shift due to cool down (right).

The first cold test of the sc 325 MHz CH-cavity has been performed in December 2012. Figure 6 shows the prepared cavity before the test in the vertical cryostat (left) and the comparison between the simulated and measured frequency shift as a function of the temperature (right). The measured frequency shift is around 420 kHz which is close to the simulated value.

SUMMARY & OUTLOOK

Microphonics measurements of the sc 325 MHz CH-cavity were carried out at room temperature. A comparison between the measured data and the simulation results was made. The simulation software ANSYS Workbench is a useful tool to determine mechanical resonance frequencies and corresponding oscillation modes during the design process of a cavity. In 2013 it is planned to perform further microponics measurements at cryogenic temperatures. Moreover, a dynamic frequency tuner prototype including a stepper motor and a piezo acutator for the sc 325 MHz and sc 217 MHz CH-cavities [4] is presently under construction. The first tuner tests will start in the middle of 2013.

ACKNOWLEDGEMENT

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

REFERENCES

[1] M. Busch, H. Podlech, M. Amberg, F. Dziuba, U. Ratzinger, W. Barth, Status Of The 325 MHz sc CH-Cavity at IAP Frankfurt, in Proc. of IPAC'11, San Sebastian, Spain, p. 265-267 (2011).

[2] ANSYS is a registered trademark of SAS IP Inc., www.ansys.com

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

[4] F. Dziuba, M. Amberg, K. Aulenbacher, W. Barth, M. Busch, H. Podlech, U. Ratzinger, S. Mickat, Status of the Superconducting CW Demonstrator for GSI, in Proc. of LINAC'12, Tel Aviv, Israel, p. 639-641 (2012).

ISBN 978-3-95450-122-9