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#dziuba@iap.uni-frankfurt.de

Institute for Applied Physics
Max-von-Laue-Straße 1
D-60438, Frankfurt am Main, Germany

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

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Measurements on the Superconducting 217 MHz CH Cavity during the Manufacturing Phase*

F. Dziuba[#,1], M. Amberg[1,3], K. Aulenbacher[3,4], W. Barth[2,3], M. Basten[1], M. Busch[1], H. Podlech[1], S. Mickat[2,3]

[1]IAP University of Frankfurt, 60438 Frankfurt am Main, Germany
[2]GSI Helmholtzzentrum, 64291 Darmstadt, Germany
[3]Helmholtz Institute Mainz (HIM), 55099 Mainz, Germany
[4]KPH Mainz University, 55128 Mainz, Germany

Abstract:

Since in future the existing UNILAC (Universal Linear Accelerator) will be used as an injector for the FAIR (Facility for Antiproton and Ion Research) project, a new superconducting (sc) continuous wave (cw) linac at GSI is proposed to keep the Super Heavy Element (SHE) program at a competitive high level. In this context, a sc 217 MHz crossbar-H-mode (CH) cavity has been designed at the Institute for Applied Physics (IAP), Frankfurt University, and was built at Research Instruments (RI) GmbH, Germany. The cavity serves as a first prototype to demonstrate the reliable operability under a realistic accelerator environment and its successful beam operation will be a milestone on the way to the new linac. In this contribution measurements during the production process of the cavity as well as corresponding simulations will be presented.

Frequency during the Manufacturing Process

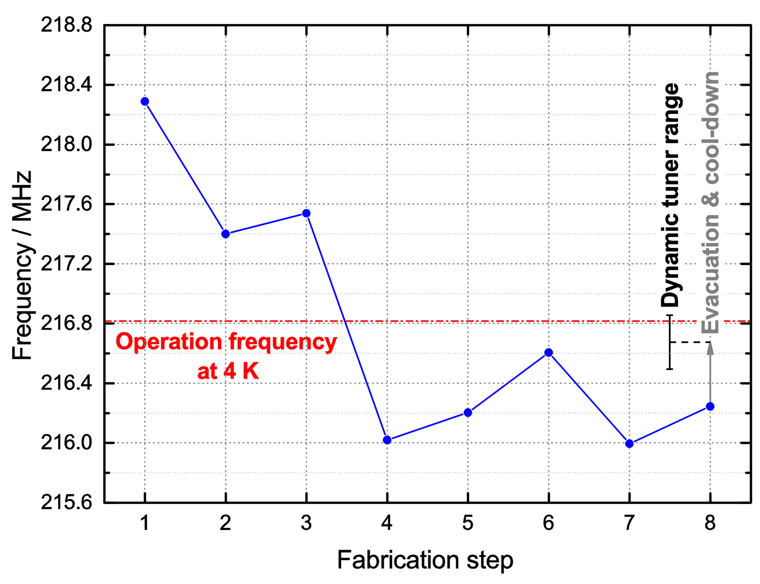

Figure 2: Measured frequency of the cavity during each fabrication step.

Several measurements have been performed during each fabrication step in order to compensate static frequency variations.

1. End caps with oversize
2. Four static tuners welded in
3. Left end cap welded on
4. Three static tuners welded in
5. Right end cap welded on
6. 50 µm BCP
7. Two static tuners welded in
8. 25 µm BCP

Evacuation of the Cavity

To study the cavity's resonance frequency change caused by evacuation and its pressure sensitivity, coupled structural – high frequency electromagnetic simulations have been performed with CST Studio Suite and validated by appropriate measurements.

Boundary conditions for simulations:

- Girders were chosen as a fixed support
- 1 bar pressure on the surface of the cavity walls was used as an applied load
- Assumption: self-supporting cavity during evacuation process

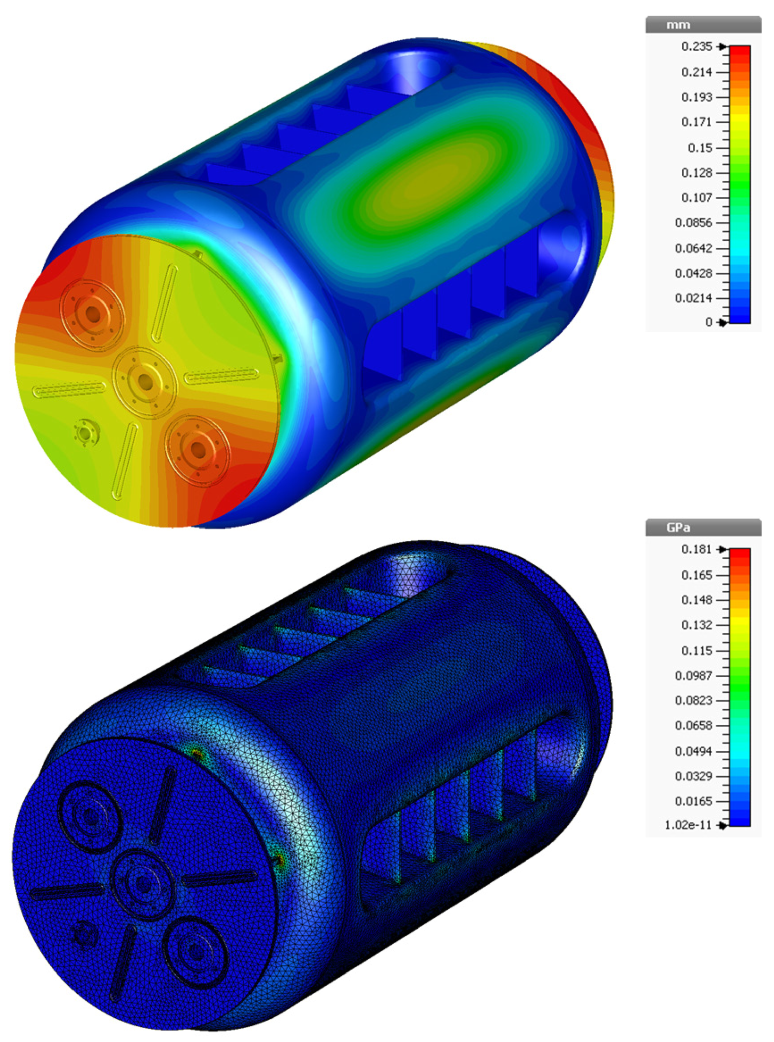

Figure 5: Maximum deformation (top) and von Mises stress (bottom) of the cavity due to the evacuation process.

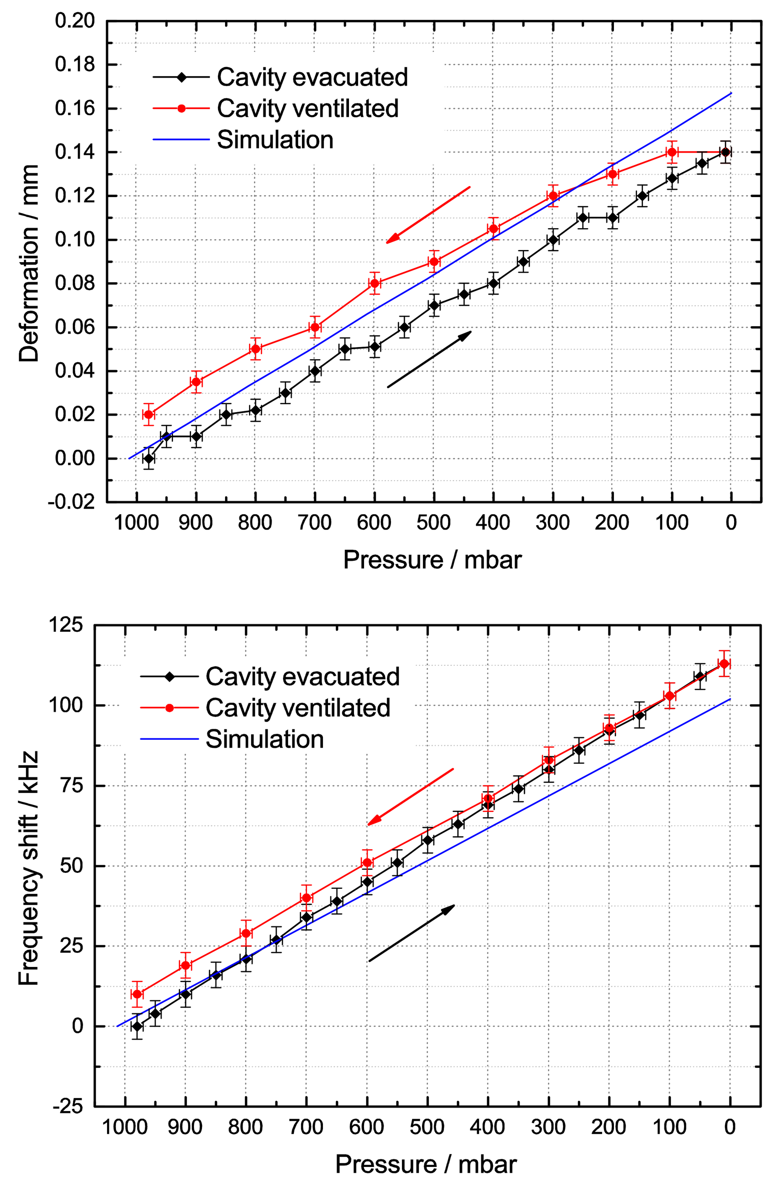

Figure 6: Measured deformation of the cavity wall (top) and related frequency shift (bottom) due to evacuation.

Table 3: Cavity under evacuation.

Evacuation	Simulated	Measured
Deformation end cap / mm	0.23	0.35
Deformation wall / mm	0.17	0.14
Max. stress / MPa	30	–
Δf (incl. ϵ_r) / kHz	102	113
df/dp / Hz/mbar	38	49

Layout of the Cavity

Presently, the fabrication of the sc 217 MHz CH cavity is finished except for the helium vessel. The cavity has a design gradient of 5.5 MV/m which will be achieved by 15 equidistant accelerating cells at an effective length of 612 mm. It is equipped with nine static and three dynamic frequency tuners, a 10 kW cw power coupler and several flanges for surface preparation.

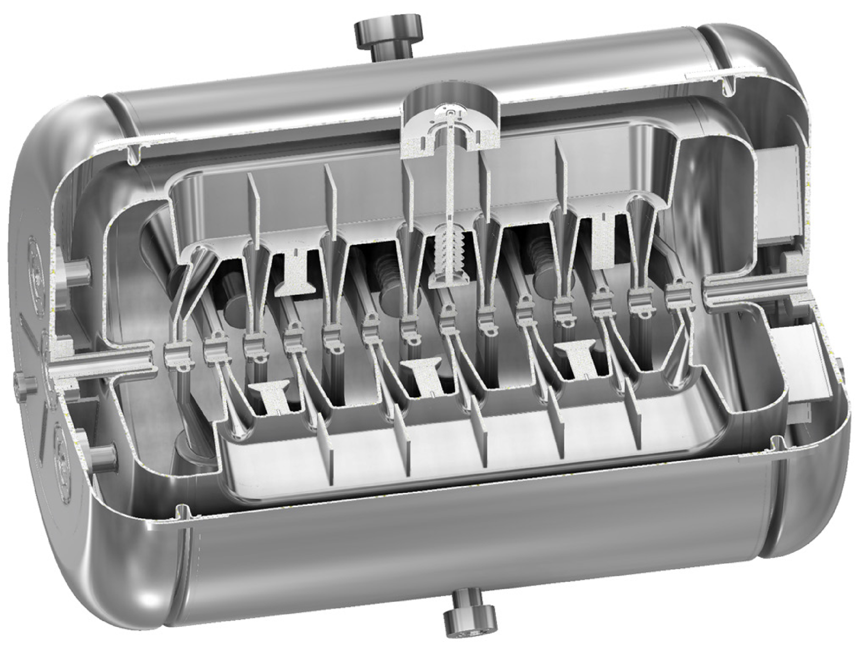

Figure 1: Layout of the sc 217 MHz CH cavity.

Table 1: Parameters of the cavity

β		0.059
Frequency	MHz	216.816
Accelerating cells		15
Effective length ($\beta\lambda$)	mm	612
Diameter	mm	490
Tube aperture	mm	18 / 20
Wall thickness	mm	4
Dynamic tuner		3
Static tuner		9
ΔW	AMeV	0.5
G	Ω	52
R_a/Q_0		3236
E_a	MV/m	5.5
U_a	MV	3.4
E_p	MV/m	34.6
E_p/E_a		6.3
B_p	mT	31.3
B_p/E_a	mT/(MV/m)	5.7

Cavity Cool-Down

Caused by cooling down from 293 K to 4 K the cavity shrinks symmetrically in all dimensions. The thermal shrinkage and the related frequency shift has been determined by the total linear contraction from room temperature to the indicated temperature.

To validate the expected behaviour the cavity has been cooled down with LN_2 while the frequency change was measured.

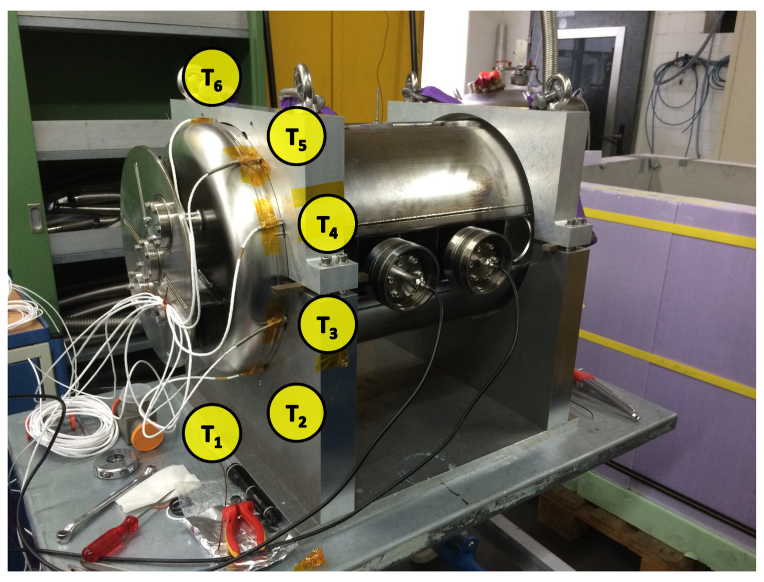

Figure 3: Setup with six temperature sensors to measure the frequency shift during cool-down with LN_2.

Table 2: Cool-down of the cavity.

Cool-Down	Estimated	Measured
Long. shrinkage / mm	1.0	–
Trans. shrinkage / mm	0.6	–
Δf (at 4 K) / kHz	310	–
Δf (at 93 K) / kHz	268	298

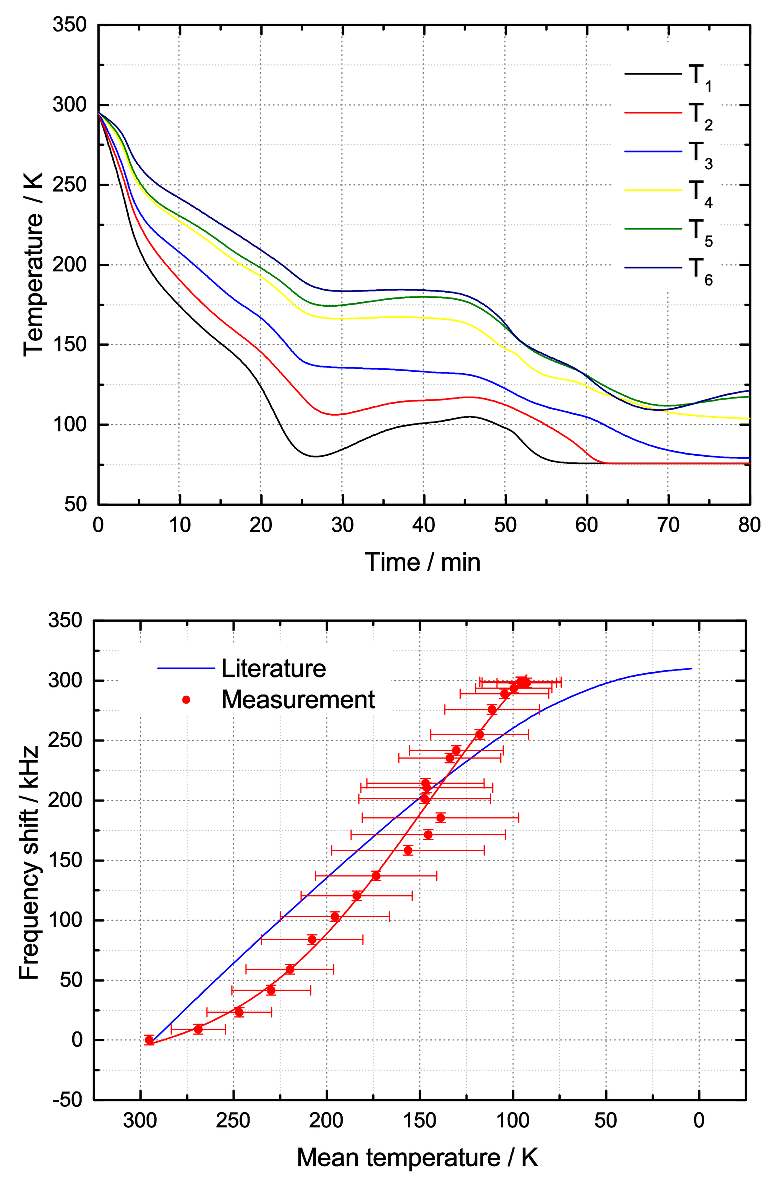

Figure 4: Measured temperature of six probes (top) and related frequency shift (bottom) under cool-down with LN_2. (Literature data after Jack W. Ekin, *Experimental Techniques for Low-Temperature Measurements, 2006)*

Summary & Outlook

The production of the sc 217MHz CH cavity is finished except for HPR treatment and the helium vessel. Several simulations have been carried out and validated by appropriate measurements during each fabrication step to analyse the cavity's behaviour considering different external influences. The performed measurements confirm the simulations and assumptions very well and the cavity's operating frequency could be reached within the range of the dynamic tuners. After the surface preparation the cavity will be delivered to the IAP for conditioning and first performance tests with low rf power. This is foreseen for the end of 2015. An additional BCP treatment of 25 m could be done afterwards to improve the performance of the cavity without leaving the operational frequency range.