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FINAL FACTORY-SIDE MEASUREMENTS OF THE NEXT SC CH-CAVITIES FOR THE HELIAC-PROJECT*

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Abstract

The upcoming FAIR project (Facility for Antiproton and Ion Research) at GSI will use the existing UNILAC (UNIversal Linear ACcelerator) and SIS18 as an injector to provide high intensity heavy ion beams at low repetition rates [1]. As a consequence a new superconducting (sc) continous wave (cw) heavy ion Linac is required to provide ion beams above the coulomb barrier to keep the Super Heavy Element (SHE) physics program at GSI competitive on an international level [2, 3]. The fundamental Linac design comprises a high performance ion source, the High Charge State Injector (HLI) upgraded for cw-operation and a matching line (1.4 MeV/u) followed by a sc Drift Tube Linac (DTL). Four cryo modules each equipped with three Crossbar-H-mode (CH) structures [4] provide for acceleration up to 7.3 MeV/u. The first section of this ambitious accelerator project has been successfully commissioned and tested with heavy ion beam from the HLI in 2017 [5]. It comprises two sc 9.3-T solenoids and a sc 217-MHz CH-cavity with 15 equidistant gaps as a demonstrator. The construction of the next two sc 217 MHz 8-gap CH-cavities is nearly finished and final factory-site measurements will be presented.

STATUS OF THE CH-CAVITIES

Since December 2016 the next two sc 217 MHz CH-cavities (CH 1 and CH 2) for the new sc cw-Linac are under construction at Research Instruments (RI), Bergisch Gladbach, Germany. Both subsequent cavities have the same constant beta, as well as the same geometry. Compared to recent sc CH-cavities CH 1 and CH 2 is dedigned without girders and with stiffening brackets on each inclined end cap (see Fig. 1). This results in higher mechanical stiffness and reduces the pressure sensitivity. The design gradient is about 5–7 MV/m, which has to be achieved by eight accelerating cells. Its resonant frequency of 216.816 MHz is the second harmonic of the HLI-frequency. In Table 1 the main parameters of the first two 217 MHz CH-cavities are depicted.

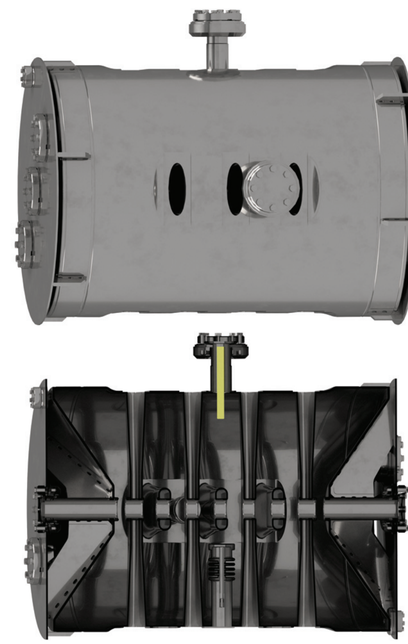

Figure 1: Layout of the SC 217 MHz CH-Cavity 2 and 3.

Table 1: Main Parameters of CH-Cavity 2 and 3

Parameter	Unit	
β		0.069
Frequency	MHz	216.816
Accelerating cells		8
Length ($\beta\lambda$-definition)	mm	381.6
Cavity diameter (inner)	mm	400
Cell length	mm	47.7
Aperture diameter	mm	30
Static tuner		3
Dynamic bellow tuner		2
Wall thickness	mm	3-4
Accelerating gradient	MV/m	5 - 7
E_p/E_a		5.2
B_p/E_a	mT/(MV/m)	<10
G	Ω	50
R_a/Q_0	Ω	1070

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PRESSURE SENSITIVITY

First intermediate measurements on CH 1 and CH 2 were conducted in spring and summer 2017. These measurements have been performed as soon as the stems had been welded into the cavity body while the end caps have been attached by threaded rods. Bead pull measurements as well as RF measurements of the external quality factor Q_e of preliminary power couplers, the frequency shift of static and dynamic tuners and mechanical measurements on the dynamic tuners have been performed during the fabrication process in 2017 [6, 7]. To estimate the pressure sensitivity and the influence on the frequency stimulated by the contraction of the cavity under cold conditions final factory-site measurements have been performed before the final surface preparation was implemented. The pressure sensitivity was investigated during gradual evacuation and ventilation of the cavity in steps of 50 mbar. The resulting frequency shift of CH 2 is shown in Fig. 2.

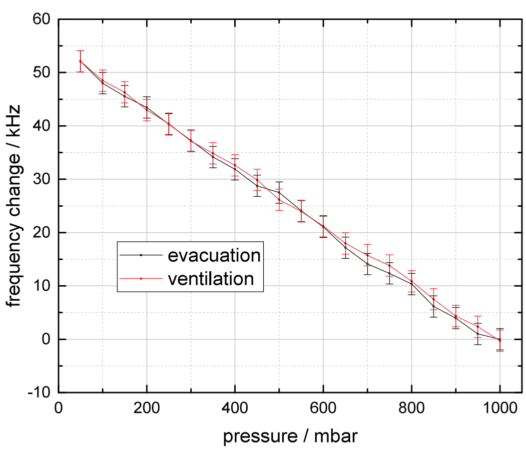

Figure 2: Pressure sensitivity of CH 2 during evacuation and ventilation.

The resulting frequency shift of CH 2 was found to be $\Delta f \approx +57$ Hz/mbar during the evacuation and $\Delta f \approx +51$ Hz/mbar during the ventilation process. The change of ϵ_r inside the cavity should result in a frequency change of $\Delta f \approx +63.6$ Hz. With respect to this the pressure sensitivity of the cavity could be estimated for $\Delta f \approx$ -9.8 Hz/mbar. The simulations performed with CST Microwave Studio [8] indicate a frequency change of $\Delta f \approx +4.6$ Hz/mbar. For this we expect (compared to the simulations) a frequency abatement by roughly $\Delta f \approx$ -10 kHz during the evacuation process.

SURFACE PREPARATION

The chemical surface preparation (**B**uffered **C**hemical **P**olishing, BCP) has been performed carefully in three 50 µm steps, while the resulting frequency shift was monitored. To compensate the unequal surface erosion due to a rise of the acid composition from the bottom to the top of the cavity, the cavity was rotated between each single step. Fig. 3 shows the total frequency change as well as the frequency change for each 50 µm BCP step for CH 1 and 2.

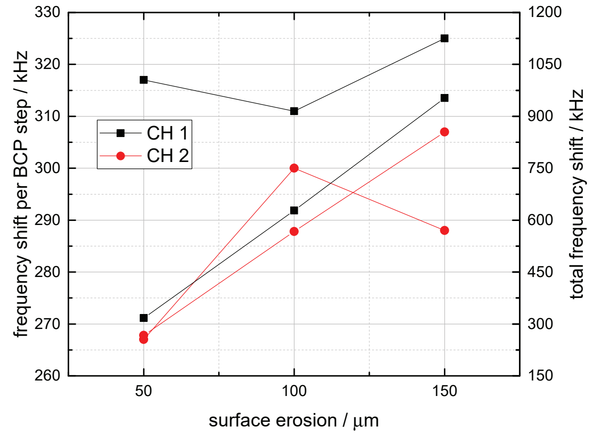

Figure 3: Frequency change for each 50 µm BCP step as well as the total frequency change for CH 1 and CH 2.

Obviously the frequency shift and the resulting surface erosion on CH 1 is more reproducible as on CH 2. Nevertheless we could estimate the frequency sensitivity of each cavity depending on the surface erosion per µm. To predict the influence of the cavity contraction under cold conditions on the resonance frequency a factory site cold test with liquid nitrogen was performed with both CH cavities. The temperature as well as the resonance frequency have been recorded once per minute for CH 1 and once per second for CH 2. The temperature was measured with several thermal sensor distributed over the cavity body. Fig. 4 shows the evolution of the average temperature and the resonance frequency of CH 1 and 2 over time, whereas Fig. 5 shows the frequency change depending on the average temperature.

The evolution of the resonance frequency as function of the average temperature was compared with contraction values from literature resulting in an increasing resonance frequency. At an average temperature of 95 K the measured frequency change of CH 1 was approximately +293.5 kHz, which is $\approx$ 13% more than estimated in [9]. For CH 2 the measured frequency change at an average temperature of 84 K was approximately +308 kHz, which is $\approx$ 12% more than stated in [9]. The difference between these results arises through the complex geometry of the CH-cavity compared to the contraction values of niobium probes stated in [9]. With these measurements we expect a frequency change of $\approx$ +350 kHz for both CH cavities at a temperature of 4 K.

CONCLUSION

Several factory-site measurements have been performed to estimate all influences on the resonance frequency and to determine the final BCP preparation on each CH cavity reaching the design frequency. Additionally the first BCP-steps have been performed for both cavities in 50 µm steps to evaluate the reproducibility of the BCP treatment

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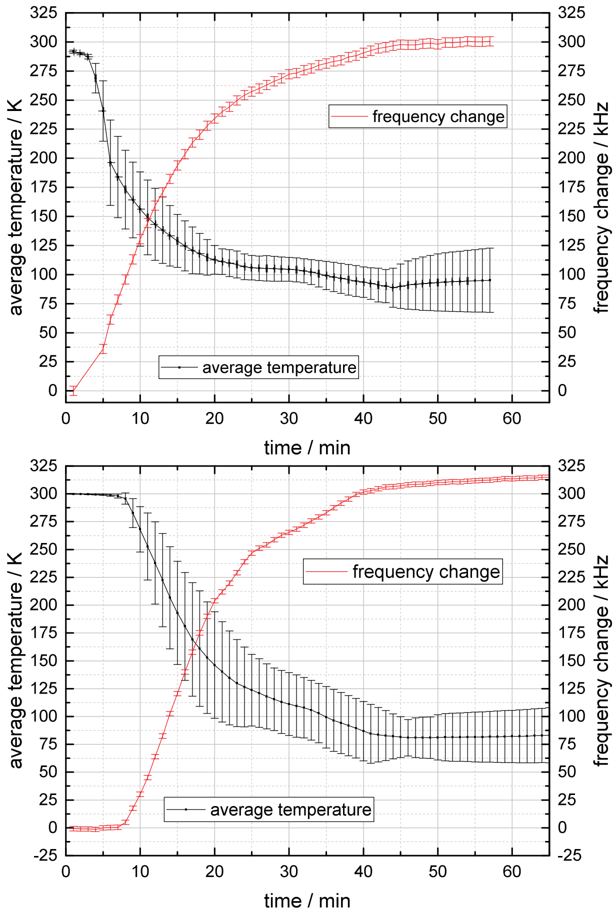

Figure 4: Resonance frequency and average temperature of CH 1 (Top) and CH 2 (Bottom) during the preliminary cold test.

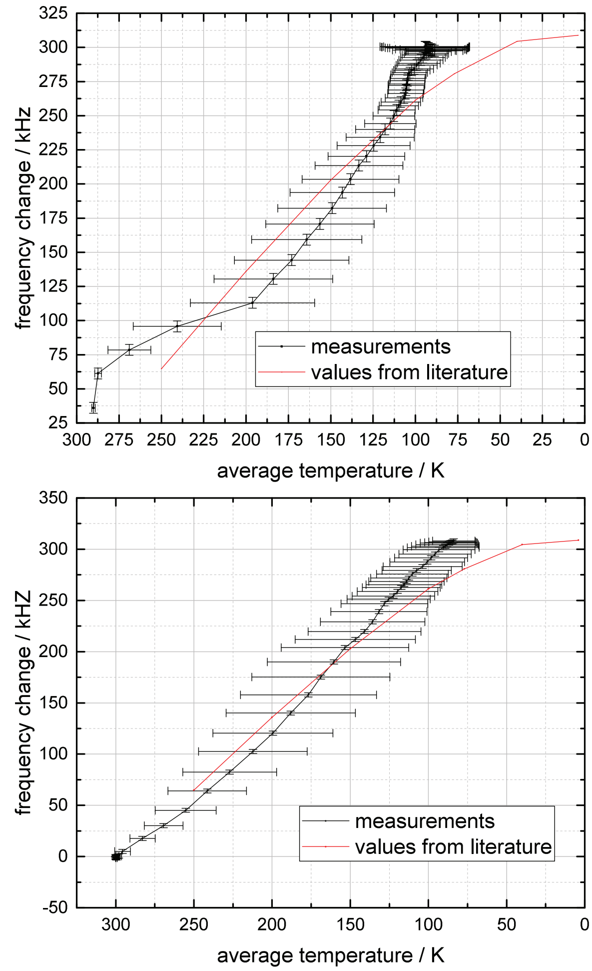

Figure 5: Frequency change depending on the average temperature of CH 1 (Top) and CH 2 (Bottom) during the preliminary cold test compared to [9].

as well as the frequency sensitivity (depending on the surface erosion per µm) of each cavity. With these results the necessary final BCP treatment to reach the design frequency of 216.816 MHz was evaluated for each cavity. The final surface preparation of CH 1 was finished in March 2018 and the cavity was successful delivered to the Institute for Applied Physics (IAP) at the Goethe University of Frankfurt (GUF), where the first cryogenic power tests at 4 K in a vertical cryostat will be performed in May 2018. After the successful commissioning under cryogenic conditions the final surface preparation on CH 2 has to be performed directly followed by vertical commissioning at the IAP at GUF. So far all intermediate measurements were successful and the desired resonance frequency of CH 1 could be reached through the final BCP surface treatment.

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