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FIRST MEASUREMENTS OF THE NEXT SC CH-CAVITIES FOR THE NEW SUPERCONDUCTING CW HEAVY ION LINAC@GSI

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Abstract

In the future the existing GSI-UNILAC (Universal Linear Accelerator) will primarily be used to provide high power heavy ion beams at a low repetition rate for the FAIR project (Facility for Antiproton and Ion Research). To keep the ambitious Super Heavy Element (SHE) physics program at GSI competitive a superconducting (sc) continuous wave (cw) high intensity heavy ion Linac is highly desirable to provide ion beams at or above the coulomb barrier [1]. The fundamental Linac design composes a high performance ion source, a new low energy beam transport line, the High Charge State Injector (HLI) upgraded for cw, and a matching line (1.4 MeV/u) followed by the new sc-DTL Linac based on CH-cavities [2] for acceleration up to 7.3 MeV/u. The construction of the first demonstrator section has been finished in the 3rd quarter of 2016. It comprises the first crossbar-H-mode (CH) cavity with two sc 9.3 T solenoids and has been successfully tested at the end of 2016 [3]. Currently the next two sc 8 gap CH-cavities are under construction at Research Instruments (RI). First intermediate measurements during the fabrication process as well as the latest status of the construction phase will be presented.

LAYOUT OF THE CAVITY

Since December 2016 the next two sc 217 MHz CH-cavities for the new sc cw-Linac are under construction at Research Instruments, Bergisch Gladbach, Germany. They are the next milestone after the successful RF test of the demonstrator cavity at GSI [3] and the first successful beam operation at GSI-High Charge Injector (HLI) [4]. Both subsequent cavities have the same constant beta, as well as the same geometry. The revised design (see Fig. 1) without girders and with stiffening brackets potentially reduces the pressure sensitivity and expedites the fabrication process. The design gradient is about 6 MV/m, which has to be achieved by 8 accelerating cells. Its resonant frequency is the second harmonic of the HLI at GSI, Darmstadt. In Table 1 the main parameters of the first two 217 MHz CH-cavities are depicted.

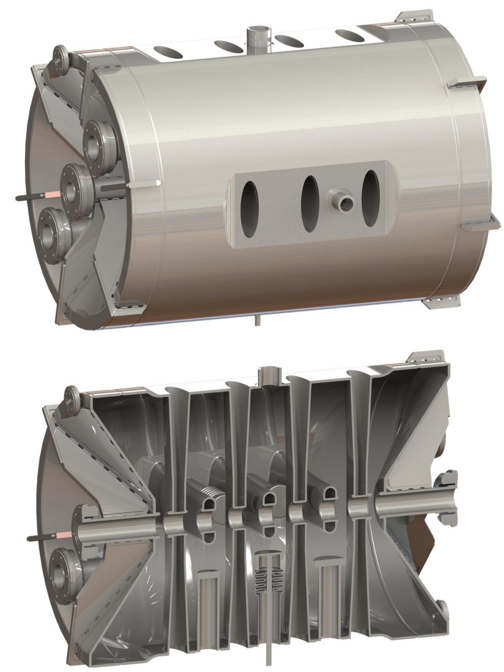

Figure 1: Layout of the sc 217 MHz CH-cavity 2 and 3.

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	6
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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INTERMEDIATE RF MEASUREMENTS

First measurements for each cavity can be performed after the stems and both dynamic tuners have been welded into the cavity body. The end caps are temporarily attached to the cavity by threaded rods so that bead pull and RF measurements can be performed. The internal structure of the CH-cavity with stems and dynamic tuners as well as the setup for the presented RF measurements is shown in Fig. 2.

Second Rf measurements take place when the end caps are welded onto the cavity body and the cavity is closed. First intermediate RF measurements have been performed on both cavities, while second RF measurements could be performed only on the first one up to know. The measurements include the electric field distribution along the beam axis (Fig. 3), the frequency shift of the static (Fig. 4) and dynamic tuners (see figures at the end of the next section: Fig. 7 to 10), as well as the external quality factor Q_e of preliminary input couplers [5]. To validate all performed measurements several simulations with CST Microwave Studio [6] have been performed and can be reviewed in [7, 8].

Figure 2: Internal structure (top), measurement setup with temporarily attached end caps (bottom).

Several bead pull measurements have been performed during the first measurement campaign, where only the stems and dynamic tuners are welded into the cavity body, to investigate the electric field distribution along the beam axis. Figure 3 shows a comparison of measurement and simulation.

The measured field distribution corresponds very well to the simulations. Due to the fact that the end caps have still an extension of 5 mm the field in the first and last gap is still below the design value. The frequency shift of each static tuner was verified with dummy tuners made from brass that

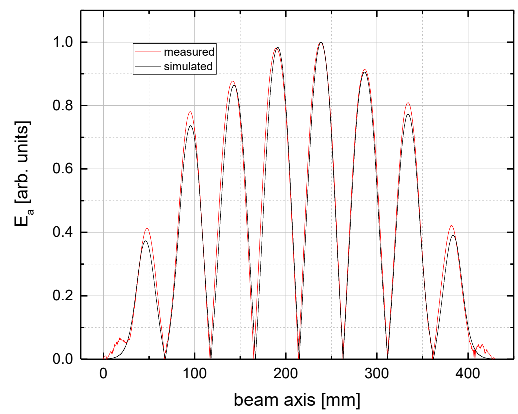

Figure 3: Measured and simulated electric field distribution along the beam axis.

could be positioned at different heights inside the cavity by brass mounts [5]. The cavity is equipped with three static tuners positioned orthogonal to the stems no. 2, 3 and 6. Tuner 2 and 3 are equipped with additional tunerheads to increase the tuning range, whereas tuner 6 has no tunerhead for installation after the cavity is closed. Figure 4 shows the measured and simulated frequency shift Δf of each tuner.

Tuner 3 has a total frequency shift of ca. 1.5 MHz, whereas for tuner 2 and 6 the shift is in the range of 1 MHz. The total frequency range of $\Delta f \approx 3.5$ MHz ensures that the design frequency of each cavity can be reached.

MECHANICAL MEASUREMENTS ON THE DYNAMIC BELLOWTUNERS

The dynamic tuning concept of each CH-cavities is based on two dynamic bellowtuners oriented orthogonal to stem no. 4 and 5. The scope of these bellow tuners is a frequency shift of about 250 kHz with a tuning stroke in the order of 1 mm. First measurements at RI company should provide information about the frequency shift depending on the tuning stroke and the tuning force. The measuring setup consisted of a baseplate with a movable platform that could be mounted to the tuner rod. The baseplate was attached by threaded rods and a counteplate to the cavity body to provide a fixed base. The platform at the tuner rod was guided with linear ball bearings along aluminium rods which guaranteed a smooth and stable motion. A dial gauge was mounted between both plates to measure the tuning stroke which could be applied by either a trapezoidal thread spindle or the use of weights on the tuner platform itself. By that we could gain information about the frequency shift through the tuning stroke and the applied tuner force. Figure 5 shows both options of the measuring setup.

The yield strength of niobium at 295 K is a factor of 8 to 10 lower compared to 4.5 K [9]. To prevent the bellow tuners from any plastic deformation or mechanical damage during the first measurements under room temperature several simu-

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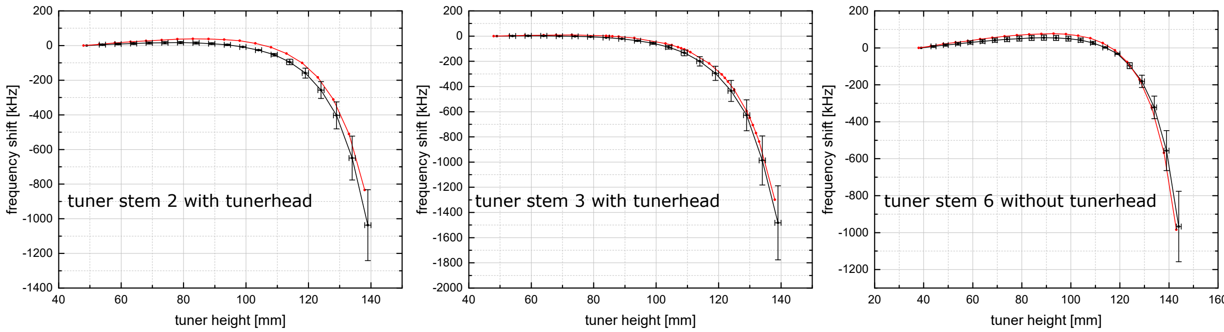

Figure 4: Measured and simulated frequency shift of each static dummy tuner.

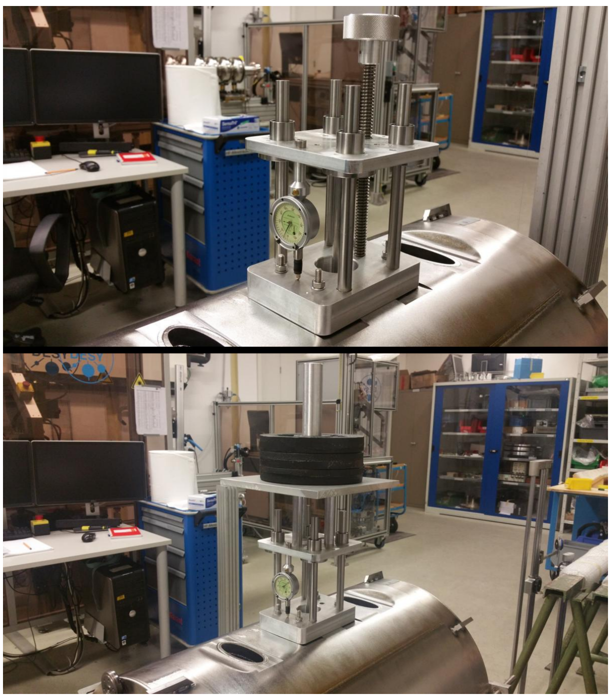

Figure 5: Tuning stroke induced by trapezoidal thread spindle (top), Tuning stroke induced by tuner force through weights (bottom).

lations have been performed to evaluate the estimated tuning stroke and Von-Mises-Stress depending on the tuning force. 70 MPa was defined as an upper threshold which limited the mechanical range of the bellow tuners under warm conditions to $\Delta x = \pm 0.3$ mm (see Fig. 6).

At first the trapezoidal thread spindle was used to induce the tuning stroke on each bellow tuner. The measured frequency shift averaged $\Delta f \approx -183 \pm 9$ kHz/mm for the bellow tuner at stem no. 4 (see Fig. 7) and $\Delta f \approx -124 \pm 8$ kHz/mm for the bellow tuner at stem no. 5 (see Fig. 8). The simulated frequency shift was $\Delta f \approx -140$ kHz/mm for the bellow tuner no. 4 and $\Delta f \approx -130$ kHz/mm for the bellow tuner no. 5.

The results are in good accordance for bellowtuner no. 5, but show a slight difference for tuner no. 4. Probably the mechanical stability of the tuners is decreased by multiple welding seams, so that the simulations can only estimate

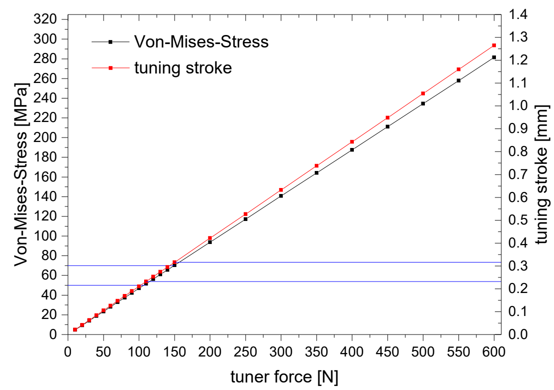

Figure 6: Simulated Von-Mises-Stress and tuning stroke depending on the tuner force.

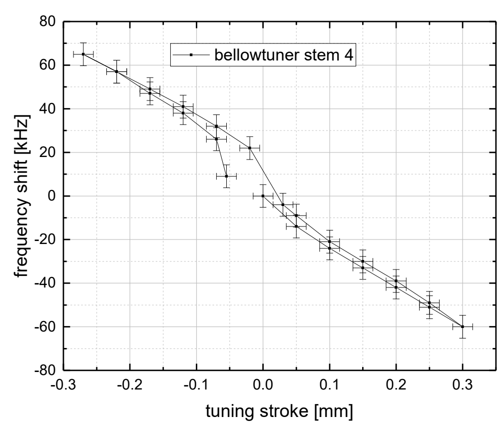

Figure 7: Measured frequency shift for bellowtuner No. 4.

the true deformation. Additionally the bellow tuners are very sensitive to deformations overall wich results in a slight hysteresis effect. Due to the fact that the measured frequency shifts are above the simulated ones, it is still easy to reach the design frequency shift of about 250 kHz to operate the cavity save at the design frequency. After these measurements the trapezoidal thread spindle was removed and a platform with a centering pin for weight plates was installed to validate the

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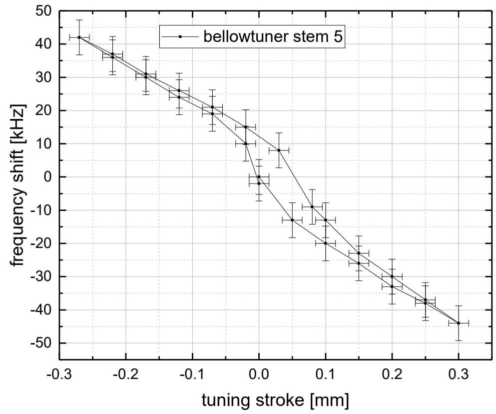

Figure 8: Measured frequency shift for bellowtuner No. 5.

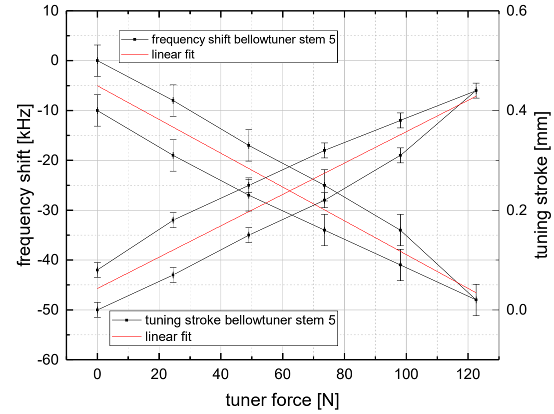

Figure 10: Measured tuning stroke for bellowtuner No. 5.

simulated tuner force. The measured tuning stroke averaged $\Delta x \approx 2.5 \pm 0.1\,\mu m/N$ for bellowtuner no. 4 (see Fig. 9) and $\Delta x \approx 3.2 \pm 0.4\,\mu m/N$ for tuner no. 5 (see Fig. 10). The simulated tuning stroke was $\Delta x \approx 2.1\,\mu m/N$ for each bellowtuner (see Fig. 6).

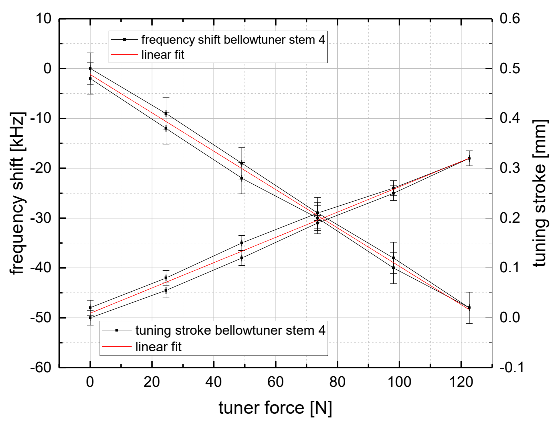

Figure 9: Measured tuning stroke for bellowtuner No. 4.

The measured frequency shift was in the range of $\Delta f \approx -0.39 \pm 0.01\,kHz/N \approx -156 \pm 10.2\,kHz/mm$ for tuner no. 4 and $\Delta f \approx -0.34 \pm 0.04\,kHz/N \approx -106 \pm 25.7\,kHz/mm$ for tuner no. 5. These values resemble in a good approximation the results from the performed measurements with the trapezoidal thread spindle.

CONCLUSION

The production of the next two sc 217 MHz CH-cavities for the new sc cw-LINAC at GSI has started in December 2016 at RI and will be finished at the end of 2017. First RF measurements as well as mechanical measurements on the dynamic bellow tuners during the production process have been performed on both cavities. It could be conducted that the design frequency can be reached without any restriction and that the dynamic tuning concept can guarantee the stable operation at the operating frequency of 216.816 MHz. Next measurements will be performed after the next welding steps to estimate the preliminary input coupler dimensions for conditioning the cavity at 4 K with low RF power. Additionally further RF measurements will take place after the first BCP-treatment to validate the simulated influence of RF-power dissipation on the resonance frequency. Measurements concerning the pressure sensitivity as well as the thermal shrinkage will be performed after the first successful BCP-treatment. Recently the delivery date of the first cavity is estimated for October 2017. First performance tests and RF conditioning are planned for the end of 2017.

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