FIRST RF MEASUREMENTS OF THE SUPERCONDUCTING 217 MHz CH CAVITY FOR THE CW DEMONSTRATOR AT GSI*

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Abstract

Presently, a superconducting (sc) 217 MHz Crossbar-H-mode (CH) cavity [1] is under construction at Research Instruments (RI), Bergisch Gladbach, Germany. Among the horizontal cryomodule and two sc 9.5 T solenoids the cavity is the key component of the cw demonstrator at GSI. To show the operation ability of sc CH cavity technology under a realistic linear accelerator environment is one major goal of the demonstrator project. A successful beam operation of the demonstrator will be a milestone regarding the continuing advanced sc cw linac project [2] at GSI for a competitive production of Super Heavy Elements (SHE) in the future. The fabrication status as well as first rf measurements at room temperature of the 217 MHz CH cavity are presented.

CW DEMONSTRATOR PROJECT

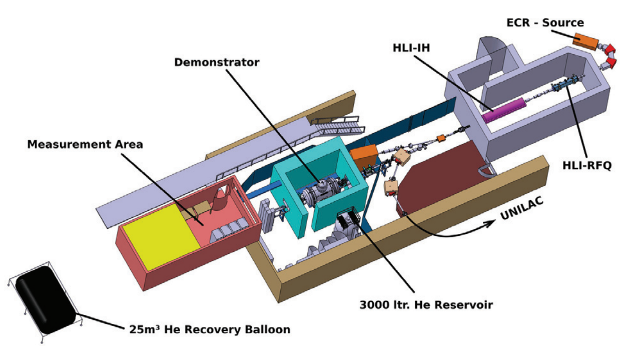

Figure 1: Future test environment at GSI using the existing HLI as an injector for the cw demonstrator.

The successful acceleration of a beam with the cw demonstrator, which consists of two sc 9.5 T solenoids and a sc 217 MHz CH cavity mounted in a horizontal cryomodule, will be a milestone realizing a new sc cw linac to keep the SHE program at GSI competitive on a high level. The 1.4 AMeV GSI High Charge State Injector (HLI) will serve as an injector to run first beam tests. Figure 1 shows the future test environment at GSI.

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LAYOUT OF THE CAVITY

Since June 2012, the sc 217 MHz CH cavity [3] (see Fig. 2) for the cw demonstrator project is under production at Research Instruments (RI) GmbH, Bergisch Gladbach, Germany. The cavity has a design gradient of 5.1 MV/m which will be achieved by 15 equidistant arranged accelerating cells. For the related beam dynamics layout the special EQUUS (EQUidistant mUlti-gap Structure) [4] code was used. Nevertheless, the production of the cavity is almost finished. Its delivery to the IAP for first cold tests with low rf power is expected in December 2014. Table 1 summarizes all main parameters of the cavity. The cavity will be equipped with a 10 kW cw power coupler which is currently under development at the IAP, a titanium helium vessel, several flanges for surface preparation and a frequency tuning system. Figure 3 shows the current fabrication status of the cavity and the setup of the following rf measurements.

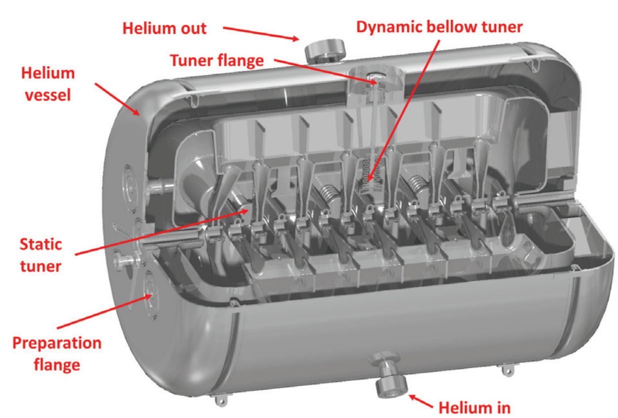

Figure 2: 3D-model of the sc 217 MHz CH cavity.

RF MEASUREMENTS

Intermediate rf measurements during the production process of the cavity have been performed at room temperature to determine the frequency shift of the static tuners in order to adjust the cavity to its design frequency successively. Furthermore, the electric field distribution on the beam axis as well as the external quality factor Q_e of preliminary couplers for cold tests with low rf power have been evaluated. To validate the performed measurements

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Table 1: Design Parameters of the 217 MHz CH Cavity

β		0.059
Frequency	MHz	216.816
Accelerating cells		15
Inner length	mm	690
Inner diameter	mm	410
Cell length	mm	40.8
Aperture	mm	20 (18)
Accelerating gradient	MV/m	5.1
Energy gain	MeV	2.97
Static tuner		9
Dynamic bellow tuner		3
U_a ($\beta\lambda$ definition)	MV	3.12
E_p/E_a		7.0
B_p/E_a	mT/(MV/m)	5.2
R_a/Q_0	Ω	3320

Figure 3: Current status of the cavity with temporarily attached end caps (top), measurement setup (bottom).

the CST MicroWave Studio [5] code was used. During the first stage of production the end caps have been temporarily attached to the cavity. The end caps as well as the end drift tubes are provided with an oversize. Reducing this oversize is a further opportunity to influence the cavity's frequency. The cavity's frequency during the production process is represented in Figure 4:

(a) end caps temporarily attached to the cavity, both end caps and end drift tubes with oversize, no static tuners welded into the cavity

(b) four static tuners welded into the cavity

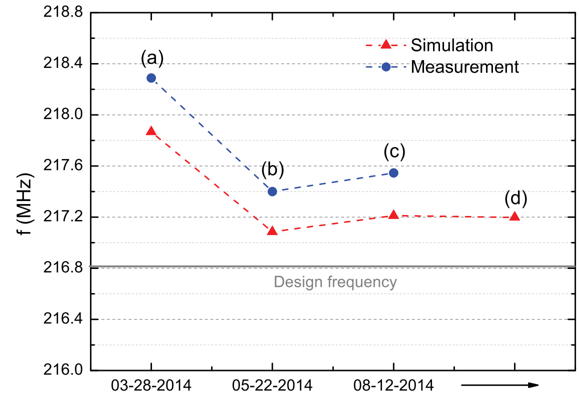

Figure 4: Frequency of the sc 217 MHz CH cavity during the production process.

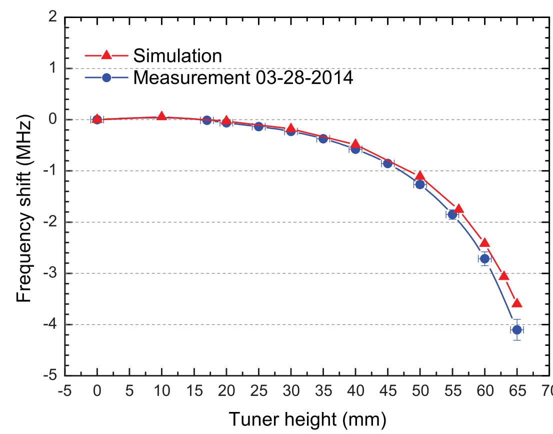

Figure 5: Measured frequency shift of nine static dummy tuners in comparison to the simulation.

(c) left end cap and drift tube without oversize, both end caps temporarily attached to the cavity

(d) left end cap welded to the cavity, right end cap temporarily attached to the cavity

The difference between simulations and measurements is about 300 kHz which shows that the numerical simulations are very precisely. Figure 5 illustrates the measured frequency shift Δf of nine static dummy tuners made of brass for different tuner heights in comparison with the simulation. As one can see, the measurements show a good agreement with the simulation. The total frequency shift is roughly 100 kHz higher than expected. In terms of the large frequency gain of $\Delta f \approx 4$ MHz the design frequency of the cavity can be reached easily. The cavity will be completed step by step during the next months while the frequency will be adjusted to its design value with the remaining static tuners. Several bead pull measurements have been performed to investigate the electric field distribution along

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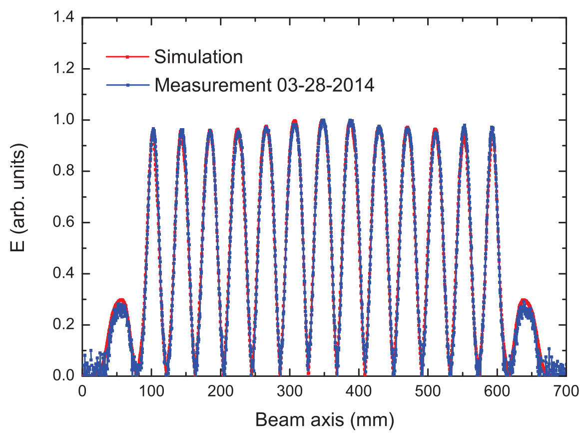

Figure 6: Measured electric field distribution along the beam axis at a dummy tuner height of 60 mm.

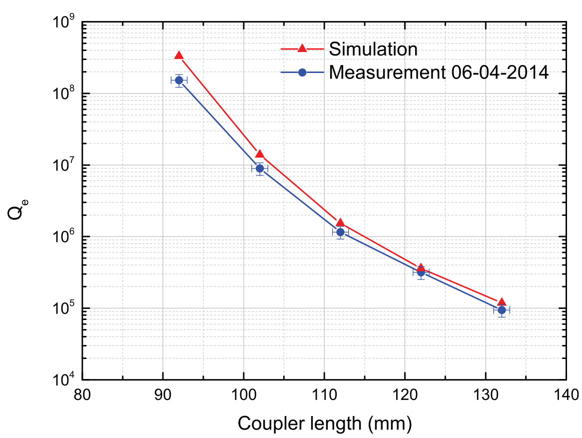

Figure 7: Measurement of the external Q factor depending on the coupler length for a coupler tip of 12.2 mm diameter.

the beam axis for different positions of the static tuner dummies. In Figure 6 the electric field along the axis is shown for a dummy tuner height of 60 mm which is close to their final estimated working point. The expected behavior of the field corresponds to the measurements very well. Since the end caps and the end drift tubes are provided with an oversize the field in the last gaps is about 50% below the design value. After removing the oversize and welding the end caps to the cavity the field will be increased and the whole distribution becomes more homogeneous. For first performance tests and especially for rf conditioning at 4 K the cavity should be overcoupled. Therefore, the coupler respectively Q_e has to be adjusted accordingly. Assuming that the intrinsic quality factor Q_0 of the cavity is about $8 \cdot 10^8 - 1 \cdot 10^9$ at the temperature of liquid helium, the value for the coupling coefficient should be

$$\beta_e = \frac{Q_0}{Q_e} \approx 8 - 10$$

with $Q_e \approx 1 \cdot 10^8$. In this context Q_e was measured in transmission

$$Q_e = Q_0 \left(\frac{1 - |S_{11}|^2 - |S_{21}|^2}{|S_{21}|^2} \right)$$

depending on the coupler length and various coupler tips with different diameters. The diameter of the outer conductor is 28 mm while the inner conductor has a diameter of 12.2 mm which is given by the 50 Ω termination. A suitable coupling strengths can be reached with a short coupler equipped with a tip which has the same diameter as the inner conductor (see fig. 7).

SUMMARY & OUTLOOK

The production of the sc 217 MHz CH cavity has started in June 2012 at Research Instruments and is almost finished. Several rf measurements during the production process have been carried out at room temperature to hit the cavity's operation frequency. Since the results are very promising, the design frequency can easily be reached. The remaining welding jobs will be completed during the next few months. Further measurements have been done to estimate preliminary coupler dimensions for conditioning the cavity at 4 K with low rf power. More measurements concerning the pressure sensitivity, the thermal shrinkage and the frequency shift of the dynamic bellow tuners will be done very soon. Recently, the delivery date of the cavity to the IAP is estimated for December 2014. First performance tests and rf conditioning of the cavity are planned at the end of 2014.

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