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CRYOGENIC TESTS OF THE SUPERCONDUCTING BETA=0.069 CH-CAVITIES FOR THE HELIAC-PROJECT*

M. Basten[1,†], K. Aulenbacher[3,4], W. Barth[2,3], M. Busch[1], F. Dziuba[3], V. Gettmann[3], M. Heilmann[2], T. Kürzeder[3], M. Miski-Oglu[3], H. Podlech[1], M. Schwarz[1], S. Yaramyshev[2]

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

Abstract

In the future the existing UNILAC (UNIversal Linear Accelerator) at GSI will be most exclusively used as an injector for FAIR to provide short pulse high intensity heavy ion beams at low repetition rates [1]. A new superconducting (sc) continuous wave (cw) high intensity heavy ion Linac should provide ion beams with max. duty factor above the coulomb barrier for the Super Heavy Element (SHE) program at GSI. The fundamental Linac design comprises a low energy beam transport (LEBT)-section followed by a sc Drift Tube Linac (DTL) consisting of sc Crossbar-H-mode (CH) structures for acceleration up to 7.3 MeV/u [2, 3]. After the successful test and commissioning of the first demonstrator section with heavy ion beam from the HLI in 2017 [4], the next two sc CH-structures have been constructed and the first one has been extensively tested at cryogenic temperatures at the Institute for Applied Physics (IAP) at Goethe University Frankfurt (GUF). The results of the final cold test of the first CH-structure as well as the next steps realizing a new sc cw heavy ion LINAC at GSI will be presented.

INTRODUCTION

The construction of two sc 217 MHz CH-cavities (CH 1 and CH 2) for the new advanced demonstrator started in December 2016 and was finished in March (CH1) and September 2018 (CH2). During the construction phase several factory side measurements have been performed to monitor crucial parameters like frequency and the tuning concept [5, 6]. Both cavities have the same geometry and the same constant beta profile. Compared to recent sc CH-cavities both cavities are designed without girders and with stiffening brackets on each inclined end cap (see Fig. 1) aiming for increased mechanical stiffness and reduced pressure sensitivity. Each cavity is equipped with two dynamic bellow tuners to adjust the frequency accordingly during operation. The design gradient is 5.5 MV/m, which has to be achieved by eight accelerating cells. In Table 1 the main parameters of the first two 217 MHz CH-cavities are depicted.

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† Basten@iap.uni-frankfurt.de

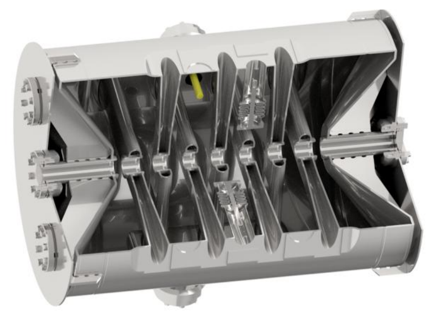

Figure 1: Layout of the sc 217 MHz CH-cavity CH1/CH2.

Table 1: Main Parameters of CH-cavity CH1/CH2

Parameter	Unit	Value
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
Design Accelerating gradient	MV/m	5.5
E_p/E_a		6
B_p/E_a	mT/(MV/m)	<10
G	Ω	50
R_a/Q_0	Ω	1070

EXPERIMENTAL SETUP

After the delivery of CH1 to GUF in March 2018, cavity preparations have been started for the first test at 4.2 K in a vertical cryostat at IAP. The cavity has been equipped with eight temperature probes, 60 Thermo-Luminescence-Dosimeters (TLD's) and two piezo elements (see Fig. 2). The TLD's around the cavity surface record the x-ray-spectra generated inside the cavity during high field levels to observe possible sources of field emission. The piezo elements can be used as actuator and sensor to analyze the mechanical eigenfrequencies of the cavity. The RF measurement setup

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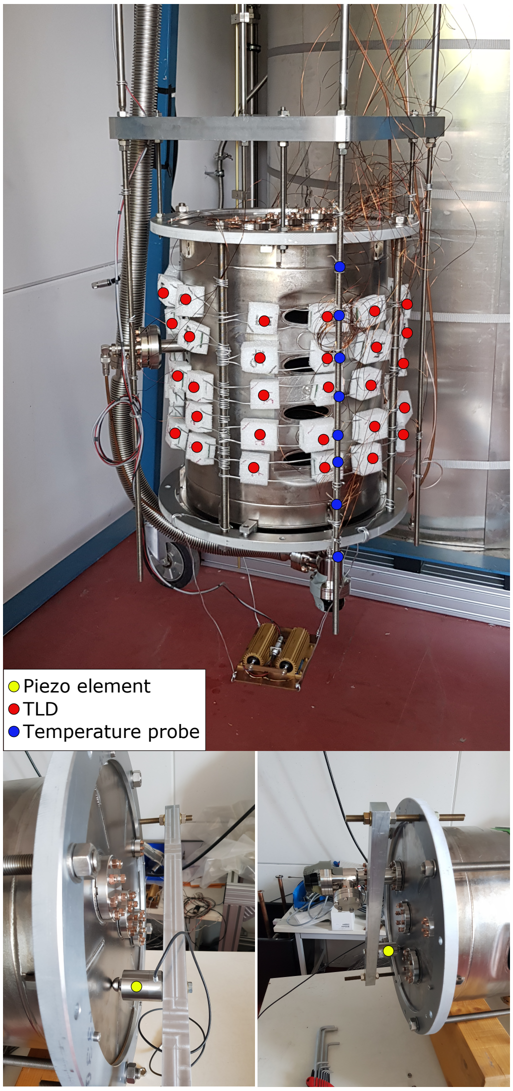

Figure 2: Vertical string with cavity in a support frame equipped with TLD's, temperature probes and piezo elements.

comprises of an RF generator, a 50 W broadband amplifier, an RF control system, several power meters, scopes, network analyzers and a piezo amplifier.

MEASUREMENT RESULTS

After the assembly of the cavity string into the vertical cryostat the liquid nitrogen shield was partially filled to precool the cavity, directly followed by a rapid cooldown with liquid helium down to 4.2 K. Avoiding hydrogen related Q-disease the temperature change was in the range of 1.8 K/min. After cooldown to 4.2 K the mean residual pressure inside the cavity came down to 5×10^{-10} mbar by using a turbo-molecular and an ion getter pump. After several days of RF conditioning at various power levels and sweep times, all multipacting barriers could permanently be surmounted and the RF performance of the cavity could be determined. Figure 3 shows the resulting Q_0 vs. E_a curve of the vertical (test

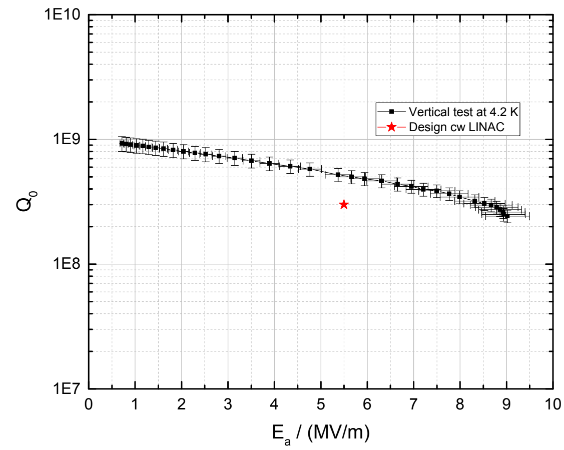

Figure 3: Q_0 vs. E_a curve at 4.2 K.

without helium vessel). The maximum Q-value at low field levels (Q_0^{low}) was approx. 1.02×10^9 and a maximum gradient of 9 MV/m corresponding to 3.32 MV voltage could be reached. The unloaded Q-value Q_0 dropped down to 2.43×10^8 at this field level which is near to the external Q_e-value of the input power coupler of 1.68×10^8. The design Q-value of 3×10^8 is reached at an gradient of 8.52 MV/m, which is 55% more than the design gradient of 5.5 MV/m. The main measurement results of the first RF test at 4.2 K are summarized in Table 2.

Table 2: Main Results of the First RF Test of CH1 at 4.2 K

Parameter	Unit	Value
Q_0^{low}		$1.02 \cdot 10^9$
Q_e^{low}		$1.68 \cdot 10^8$
R_s	nΩ	48.4
R_{BCS}	nΩ	12.6
R_{mag}	nΩ	9.78
R_0	nΩ	26.02
E_a	MV/m	9
U_{eff}	MV	3.32
Q_0^{high}		$2.43 \cdot 10^8$
Q_e^{low}		$1.68 \cdot 10^8$

FIELD EMISSION

Due to technical limitations, High Pressure Rinsing (HPR) could be performed only along the beam axis of the cavity. A new HPR installation in the new laboratories at the Helmholtz-Institute in Mainz will allow rinsing of each quadrant of the cavity in the next future. To determine if there are still impurities on the inner surface it is necessary to evaluate the power consumption inside the cavity P_c^{total} depending on the accelerating gradient E_a. The total power loss P_c^{total} comprises of ohmic losses P_c^{ohmic}, expected with a constant

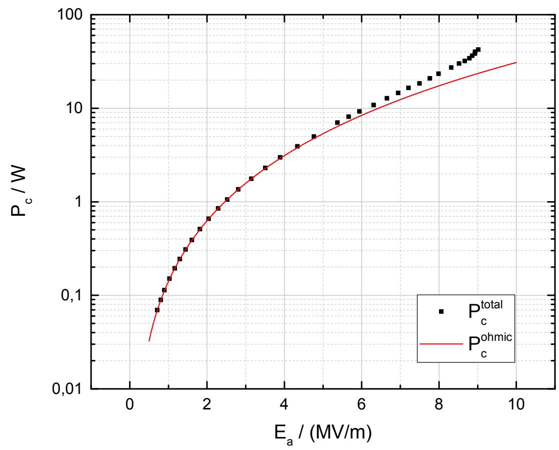

Figure 4: Total losses P_c^{total} as well as pure ohmic losses P_c^{ohmic} inside the cavity depending on E_a.

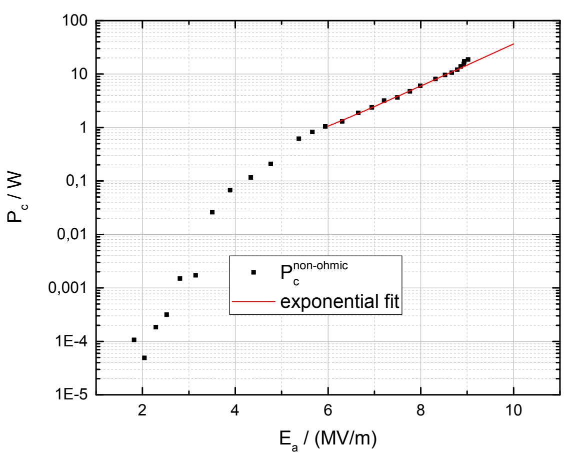

Figure 5: Non-ohmic losses $P_c^{non-ohmic}$ inside the cavity depending on E_a.

Q-value, and non-ohmic losses $P_c^{non-ohmic}$ e.g. field emission. Figure 4 shows P_c^{total} as well as P_c^{ohmic} while Fig. 5 shows $P_c^{non-ohmic}$, depending on E_a. Both figures show increased non-ohmic losses from $E_a = 5\,\mathrm{MV/m}$ which indicates the activation of a field emitter. But even at high field gradients the additional losses induced by the field emission are still low considering the fact that the HPR treatment could only be performed along the beam axis. This can also be seen in the corresponding Fowler-Nordheim plot shown in Fig. 6. It illustrates the enhancement factor $\beta_{FN} = 84.3$ of the electric fields on the surface of the field emitter an indicates how pointed it's geometry is. The corresponding maximum electric field E_p is in the range of 4.6 GV/m at the maximum accelerating gradient of $E_a = 9\,\mathrm{MV/m}$.

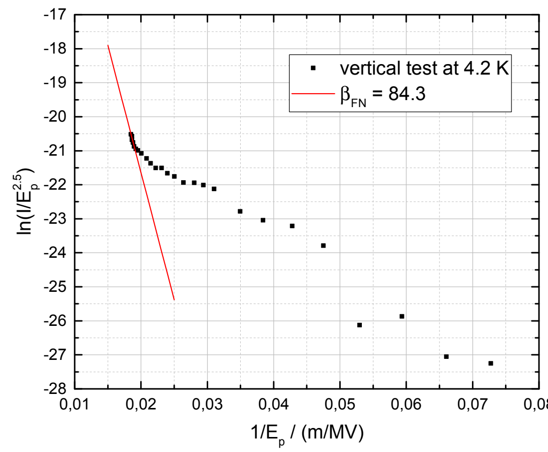

Figure 6: Fowler-Nordheim plot for the first RF test at 4.2 K.

SUMMARY & OUTLOOK

The first test with low level RF power of CH1 at 4.2 K at IAP was successful and has shown a very promising gradient of 9 MV/m. Although the surface preparation could only be done along the beam axis, field emission started at high gradients above 5 MV/m and the field enhancement factor was in the range of $\beta_{FN} = 84.3$ only. The next step is the first cryogenic test with CH 2, to compare the results with CH 1 as well as a possible test at 2 K with both cavities. Additionally an improved surface preparation to be performed at the Helmholtz-Institute in Mainz on both cavities is foreseen when the construction of the laboratories is finished to improve the surface conditions even further.

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REFERENCES

[1] W. Barth *et al.*, "High brilliance uranium beams for the GSI FAIR", *Phys. Rev. ST Accel. Beams*, vol. 20, 050101, 2017.

[2] W. Barth *et al.*, "Further investigations for a superconducting cw-Linac at GSI", in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 2197-2200. doi:10.18429/JACoW-IPAC2017-TUPVA055

[3] H. Podlech *et al.*, "Superconducting CH structure", *Phys. Rev. ST Accel. Beams*, vol. 10, 080101, Aug. 2007.

[4] W. Barth *et al.*, "First high intensity heavy ion beam tests with a superconducting multi gap CH-cavity", *Phys. Rev. ST Accel. Beams*, vol. 21, 020102, 2018.

[5] M. Basten *et al.*, "First measurements of the next sc CH-cavities for the new superconducting cw heavy ion LINAC@GSI", in *Proc. SRF'17*, Lanzhou, China, July. 2017, paper TUPB022, pp. 433-436.

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[6] M. Basten *et al.*, "Final factory-side measurements of the next sc CH-cavities for the HELIAC-Project", in *Proc. IPAC'18*, Vancouver, Canada, April 2018, pp. 943-945. doi:10.18429/JACoW-IPAC2018-TUPAF088