STATUS OF THE SUPERCONDUCTING CW DEMONSTRATOR FOR GSI*

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

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

Abstract

Since the existing UNILAC at GSI will be used as an injector for the FAIR facility a new superconducting (sc) continuous wave (cw) LINAC is highly requested by a broad community of future users to fulfill the requirements of nuclear chemistry, especially in the research field of Super Heavy Elements (SHE). This LINAC is under design in collaboration with the Institute for Applied Physics (IAP) of Frankfurt University, GSI and the Helmholtz Institut Mainz (HIM). It will consist of 9 sc Crossbar-H-mode (CH) [1] cavities operated at 217 MHz which provide an energy up to 7.3 AMeV. Currently, a prototype of the cw LINAC is under development. This demonstrator comprises the first sc CH cavity of the LINAC embedded between two sc solenoids mounted in a horizontal cryomodule. One important milestone of the project will be a full performance test of the demonstrator by injecting and accelerating a beam from the GSI High Charge State Injector (HLI) in 2014. The status of the demonstrator is presented.

THE SUPERCONDUCTING CW LINAC DEMONSTRATOR

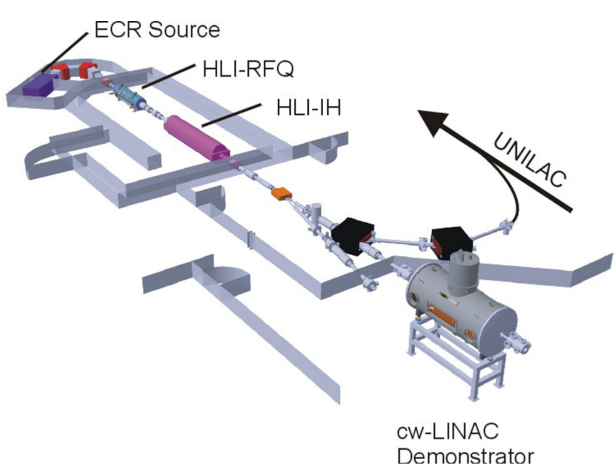

Figure 1: Demonstrator setup with the High Charge Injector at GSI.

The demonstrator will be the first section of the new sc cw LINAC at GSI. It will be operated at 217 MHz which is the second harmonic of the existing 1.4 AMeV GSI HLI. A test of the sc 217 MHz CH cavity, which is the key component of the project, under real operational conditions is the main aim of the demonstrator [2, 3]. It is planned to run a full performance test by injecting and accelerating a beam from the HLI in 2014. Figure 1 shows the cw demonstrator setup and the HLI.

STATUS OF THE SC 217 MHZ CH CAVITY

The sc 217 MHz CH cavity for the cw LINAC demonstrator (see fig. 2) will consist of 15 accelerating cells at a total length of 690 mm while the maximum gradient is 5.1 MV/m. Furthermore, the cavity is designed with the special EQUUS (EQUidistant mUlti-gap Structure) beam dynamics [4].

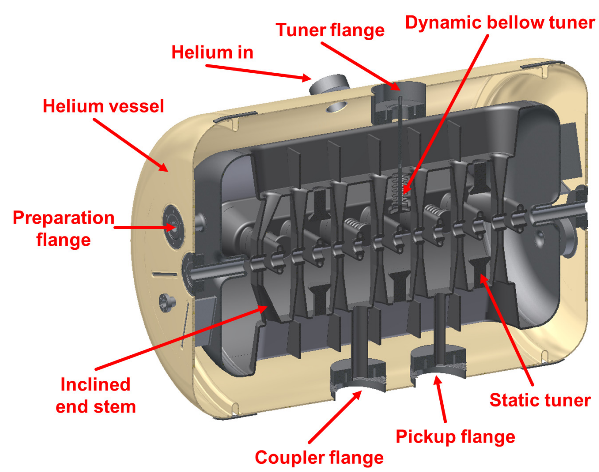

Figure 2: Side view of the sc 217 MHz CH cavity for the cw demonstrator at GSI.

The rf design of the cavity is finished. All main parameters of the cavity are shown in table 1. In June 2012 the production of the cavity has started at Research Instruments (RI) GmbH, Bergisch Gladbach, Germany. It is scheduled to be delivered to the IAP in 2013.

The cavity will be equipped with all necessary auxiliaries like a 10 kW cw power coupler, a titanium helium

* Work supported by HIM, GSI, BMBF Contr. No. 06FY7102
† dziuba@iap.uni-frankfurt.de

ISBN 978-3-95450-122-9

Table 1: Main parameters of the 217 MHz CH-cavity

β		0.059
Frequency	MHz	216.816
Accelerating cells		15
Total length	mm	690
Cavity diameter	mm	410
Cell length	mm	40.8
Accelerating gradient	MV/m	5.1
U_a ($\beta\lambda$ definition)	MV	3.12
E_p/E_a		6.4
B_p/E_a	mT/(MV/m)	5.4
R_a/Q_0	Ω	3320

vessel, several preparation flanges and a frequency tuning system. Since matching the design frequency during the fabrication and the operation process of a sc CH cavity is a serious challenge, the tuning will be done by capacitive static and dynamic tuners positioned between the stems.

Nine static tuners will be adapted accordingly during the fabrication to hit the design frequency. At a maximum height of 65 mm the frequency shift range of the static tuners is 3.6 MHz. Additionally, three slow bellow tuners (see fig. 3), driven by stepping motors control the frequency of the cavity during operation. They will readjust frequency changes and pressure effects at 4.2 K. Furthermore, two of these bellow tuners are connected to fast reacting piezo elements to compensate limitations like microphonics and Lorentz-Force-Detuning (one in operation, one in spare). The expected frequency shift range for one fast tuner during operation is ± 50 Hz/μm.

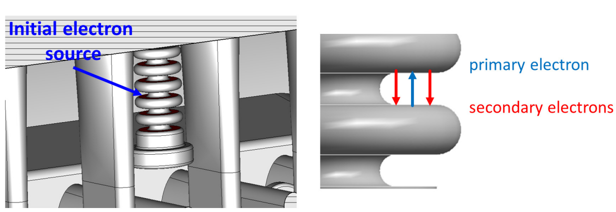

Figure 3: Final design of the 6-cell bellow tuner with the initial electron sources for the multipacting analyses.

To determine the geometry of the bellow tuners several mechanical, rf and multipacting simulations have been performed with ANSYS Workbench, CST MICROWAVE STUDIO and CST PARTICLE STUDIO. The gaps of the bellows are critical spots for multipacting. Figure 3 shows the final geometry of the 6-cell bellow tuner with a gap width of 3.5 mm and the initial electron sources for the multipacting analyses. For the simulations 12000 initial particles were chosen while the energy of the initial electrons has been varied from 2 to 5 eV with an kinetic spread of 50%. The simulated secondary emission yield (SEY)

$$\langle \mathrm{SEY} \rangle = \frac{\text{Total number of secondaries}}{\text{Total number of hits}}$$

for different accelerating gradients is shown in figure 4 as an example for an initial electron energy of 3 eV. As all simulations show, the effect of multipacting does not appear in the tuner gaps.

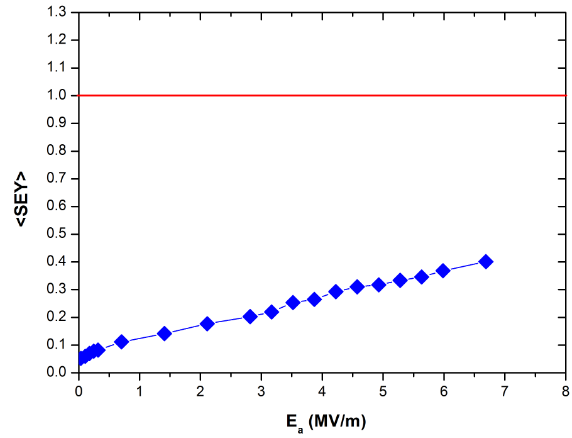

Figure 4: Simulated secondary emission yield for different accelerating gradients at an initial electron energy of 3 eV.

THE HORIZONTAL CRYOSTAT

For the planned beam tests at the GSI HLI a new horizontal cryostat is needed which houses the two sc solenoids and the sc CH cavity (see fig. 5). The final design phase of the cryostat is in progress at the moment. It is going to be built by Cryogenic Limited, London, United Kingdom and scheduled to be delivered in 2014. In comparison to a first concept study [5] the material of the vacuum vessel was changed from stainless steel to aluminum due to cost-efficient production.

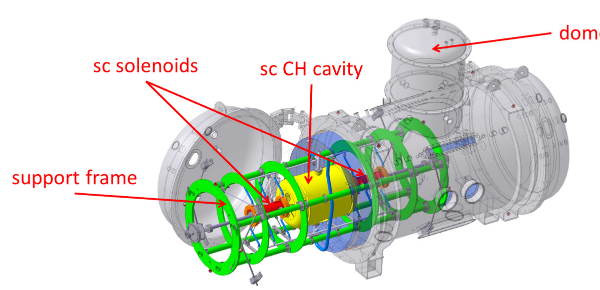

Figure 5: Layout of the horizontal cryostat close to the final design. In the center of the support frame the cavity (yellow) is embedded by two sc solenoids (red).

The main design criteria for the new cryostat are:

- modular design, universally usable - tests of various types of solenoids and CH cavities with different lengths and diameters
- various flanges for assembling options
- a dome for electrical supplies with a reservoir for cryogenic liquids
- a measuring system to control the positions of the cold masses on the beam axis

Furthermore, the LHe reservoir will have a flow rate of 100 l/h while the estimated losses of the cryostat are roughly 2 l/h.

Table 2: Design parameters of the cryostat

Inner length	mm	2200
Inner diameter	mm	1120
Material tank		Aluminum
Insulating vacuum	mbar	$< 1 \cdot 10^{-5}$
Max. system pressure	bar	< 0.5
Operating temperature	K	4.2
Temperature thermal shield	K	77
Max. static losses (stand by)	W	< 10

To investigate the behavior of the cryostat's support frame under a cryogenic environment, first thermal and mechanical simulations have been performed with CST MPHYSICS STUDIO. Therefore, three different temperature sources were added to a simple model of the cryostat and the cavity to run the stationary solver (see fig. 6). Figure 6 shows the 3D temperature distribution of the support frame with the suspension rods. Heat transfer caused by radiation was not considered in the simulations as well as insulating materials. The outer suspension rods of the support frame were fixed during the simulations. As the contour plots of figure 7 show, the total displacement in x and y direction is roughly 3 mm while in z direction a displacement of 10 mm appears.

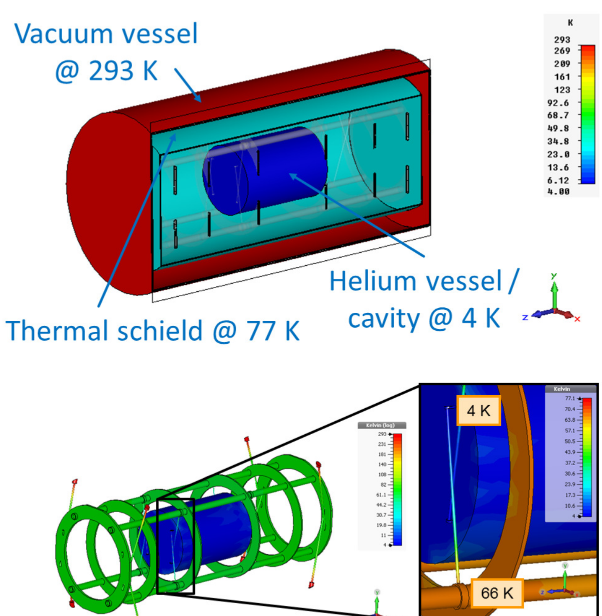

Figure 6: Temperature sources for the thermal stationary solver (top) and 3D temperature distribution of the support frame (bottom).

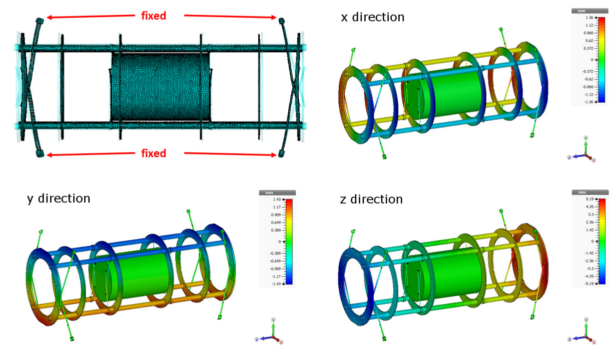

Figure 7: Deformed mesh of the support frame (scaling factor 10) and total displacement in x,y,z direction.

SUMMARY & OUTLOOK

First preparations were done to set up the cw LINAC demonstrator at the GSI HLI. A 3000 l LHe-tank as well as a helium recovery system have been delivered to GSI.

The rf design of the sc 217 MHz CH cavity is completed and its fabrication has started in June 2012 at RI. At present, the final design phase of the horizontal cryostat is in progress. The cryostat as well as the sc solenoids have been ordered from Cryogenic Limited.

The delivery of all main components is expected in 2013/14. After the assembling under clean room conditions and first rf test at the IAP, a full performance test with beam at the HLI is foreseen in 2014. Successful tests of the demonstrator are a fundamental step on the way to the proposed sc cw LINAC.

ACKNOWLEDGMENT

This work has been supported by Helmholtz-Institut Mainz (HIM) and Gesellschaft für Schwerionenforschung (GSI). This work was (financially) supported by BMBF Contr. No. 06FY7102 and by the HelmholtzInternational-Center for FAIR within the framework of the LOEWE program (Landesoffensive zur Entwicklung Wissenschaftlich-Ökonomischer Exzellenz) launched by the State of Hesse.

REFERENCES

[1] H. Podlech et al., Superconducting CH structure, Phys. Rev. STAB 10, 080101 (2007).

[2] S. Mickat et al., The sc cw-LINAC-Demonstrator - SRF Technology finds the way to GSI, in Proc. of SRF2011 (to be published), Chicago, USA (2011).

[3] F. Dziuba et al., Development of superconducting crossbar-H-mode cavities for proton and ion accelerators, Phys. Rev. STAB 13, 041302 (2010).

[4] S. Minaev et al., A Superconducting Energy Variable Heavy Ion Linac with Constant Beta, Multi-Cell Cavities of CH-Type, Phys. Rev. STAB 12, 120101 (2009).

[5] V. Gettmann et al., The sc cw-LINAC Demonstrator - an R&D project for SRF technology, in Proc. of SRF2011, Chicago, USA (2011).