SUPERCONDUCTING CH CAVITIES FOR HEAVY ION ACCELERATION*

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

To demonstrate the operation ability of superconducting (sc) Crossbar-H-mode (CH) [1] cavity technology a 217 MHz structure of this type is under development at the Institute for Applied Physics (IAP) of Frankfurt University. The cavity has 15 accelerating cells and a design beta of 0.059. It will be equipped with all necessary auxiliaries like a 10 kW power coupler and a tuning system. Currently, the cavity is under construction. Furthermore, this cavity will serve as demonstrator for a sc continuous wave (cw) LINAC at GSI. The proposed cw LINAC is highly requested to fulfill the requirements of nuclear chemistry and especially for a competitive production of new Super Heavy Elements (SHE) in the future. A full performance test by injecting and accelerating a beam from the GSI High Charge State Injector (HLI) is planned in 2014. The current status of the sc CH cavity and the demonstrator project is presented.

CW LINAC DEMONSTRATOR

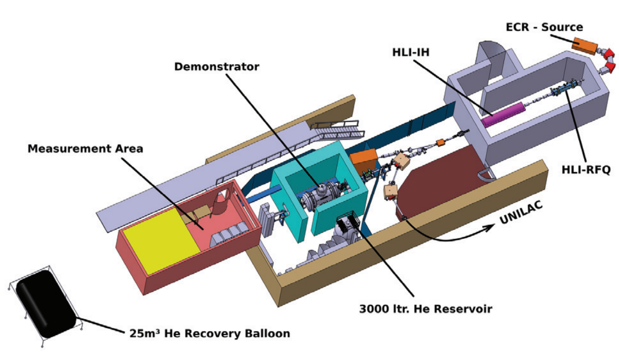

Figure 1: Future test environment at GSI using the existing HLI as an injector for the cw demonstrator.

The successful beam operation of 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 the new sc LINAC to keep the SHE program at GSI competitive on a high level [2]. Moreover, this demonstrator will be the first section of the entire LINAC. The 1.4 AMeV GSI HLI will serve as an injector to run first beam tests. Figure 1 shows the future test environment at GSI.

THE SC 217 MHZ CH CAVITY

At present, the sc 217 MHz CH cavity for the cw LINAC demonstrator [3] (see fig. 2) is under production at Research Instruments (RI) GmbH, Bergisch Gladbach, Germany. The production of the cavity has started in June 2012 and it is scheduled to be delivered to the IAP in September 2013 for first cold tests with full rf power. Nevertheless, the cavity will consist of 15 accelerating cells which provide a maximum gradient of 5.1 MV/m. Regarding the beam dynamics design of the cavity the special EQUUS (EQUidistant mUlti-gap Structure) code was used [4].

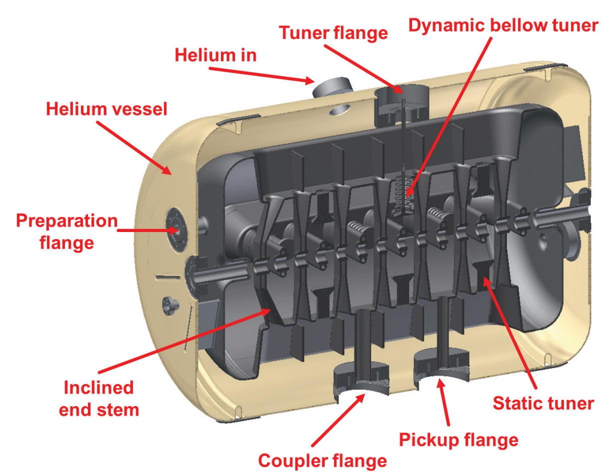

Figure 2: The sc 217 MHz CH cavity for the cw demonstrator at GSI.

All main parameters of the cavity are shown in table 1. The cavity will be equipped with a 10 kW cw power coupler, a titanium helium vessel, several flanges for surface preparation and a frequency tuning system. In figure 3 the current fabrication status of the dynamic bellow tuners and the stems is shown.

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† dziuba@iap.uni-frankfurt.de

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Figure 3: Production status of the dynamic bellow tuners (top), the straight stems (middle), and the inclined end stems (bottom).

Table 1: Main 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

HORIZONTAL CRYOMODULE

The final design of the new horizontal cryomodule, which houses the two sc solenoids and the sc CH cavity for the beam tests at the GSI HLI, is completed (see fig. 4). It is going to be built by Cryogenic Limited, London, United Kingdom and scheduled to be delivered in 2014. Contrary to a first concept study [5] the material of the vacuum vessel, the support frame as well as the thermal shield was changed from stainless steel to aluminum due to cost-efficient production. At the same time the whole cryostat was longitudinal shortened from 2600 to 2200 mm to keep its mechanical stability.

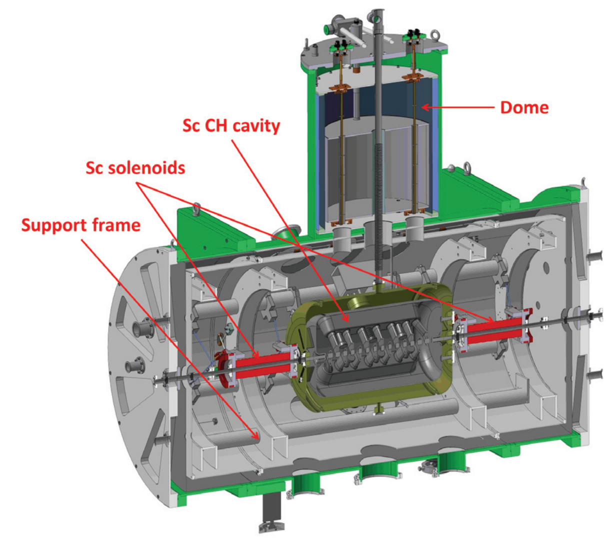

Figure 4: Final design of the new horizontal cryomodule for the cw demonstrator.

The main design criteria for the new cryostat are:

- modular design, universally usable - tests of various solenoids and CH cavities with different lengths
- three part cryostat for easy assembling
- various flanges for assembling options
- dome for electrical supplies with a reservoir for cryogenic liquids
- measuring system to control the positions of the cold masses on the beam axis
- support frame adjustable from outside
- nuclotron suspension with tie rods to all components
- dry cooled solenoids

Table 2 shows the main design parameters of the cryostat. Furthermore, the flow rate of the LHe reservoir will be 100 l/h while the estimated losses of the cryostat are about 2 l/h.

In order to fulfill the requirements from the beam dynamics the transversal / longitudinal tolerance of the cold mass has to be kept between ± 0.2 / ± 2 mm. Reaching this tolerance while cooling down will be a serious challenge.

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Regarding this, several thermal and mechanical simulations have been performed with CST MPHYSICS STUDIO to analyze the behavior of the cryostat's support frame and the tie rods under a cryogenic environment [6]. Figure 5 shows the sc 217 MHz CH cavity and the two sc solenoids mounted on the support frame of the cryostat. The cold masses will be assembled to the frame in the clean room of the IAP. Afterwards, the fully equipped frame will be inserted into the cryostat with a trolley (see fig. 6).

Table 2: Design parameters of the cryostat

Inner length	mm	2200
Inner diameter	mm	1180
Material tank		aluminum
Insulating vacuum	mbar	$< 1 \cdot 10^{-5}$
Leaking rate	mbar l/s	$1 \cdot 10^{-9}$
Max. system pressure	bar	< 0.5
Operation temperature	K	4.4
Temperature thermal shield	K	77
Trans. / longit. tolerance	mm	± 0.2 / ± 2
Max. static losses (stand by)	W	< 10

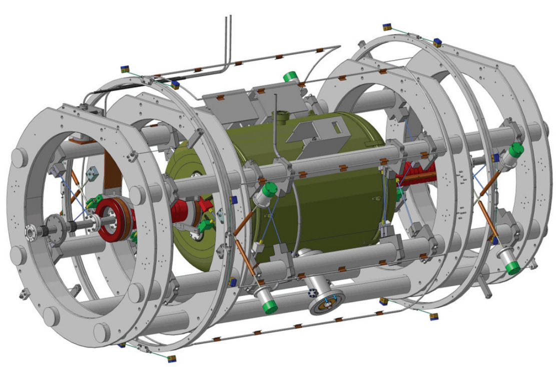

Figure 5: Superconducting 217 MHz CH cavity and two superconducting 9.5 T solenoids mounted in the support frame of the cryostat.

SUMMARY & OUTLOOK

In 2012 the 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. In addition to this, the 217 MHz rf amplifier (solid state, 5 kW cw with an upgrade option to 10 kW) for the cavity was delivered to the IAP and successfully tested.

The rf design as well as the mechanical analyzes of the sc 217 MHz CH cavity were completed and its fabrication has started in June 2012 at Research Instruments. Several components of the cavity like the stems with the drift tubes, the dynamic bellow tuners, and the coupler and pick up flanges are completed already. Recently, the delivery date of the cavity is estimated for September 2013.

Furthermore, the final design of the horizontal cryostat and the sc 9.5 T solenoids is completed as well. The production of the cryostat and of the solenoids will start during the next months at Cryogenic Limited.

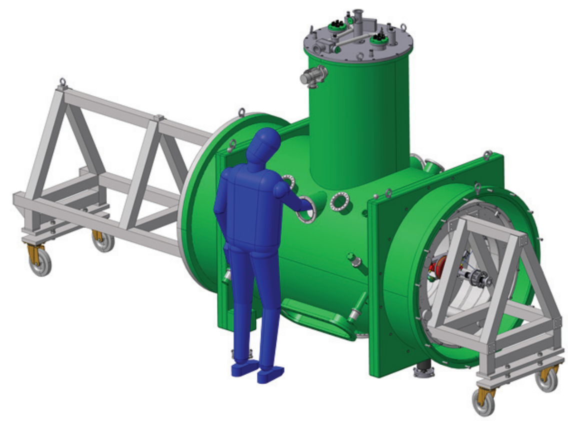

Figure 6: Mounting scheme of the cold masses.

The delivery of all main components is expected for 2013/14. After the assembling of the cold masses under clean room conditions and first rf and cold test at the IAP, a full performance test with beam at the HLI is foreseen in 2014. Nevertheless, a successful beam test of the demonstrator is a big milestone on the way to the proposed sc cw LINAC and consequently to the SHE program at GSI.

ACKNOWLEDGMENT

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