THE SC CW LINAC DEMONSTRATOR – 1ST TEST OF AN SC CH-CAVITY WITH HEAVY IONS

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Abstract

The superconducting (sc) continuous wave (cw) LINAC Demonstrator is a collaboration project between GSI, the Helmholtz Institute Mainz (HIM), and the Institute for Applied Physics (IAP) at the Goethe University Frankfurt. The aim is a full performance test of a 217 MHz sc Crossbar H-mode (CH) cavity, which provides gradients of 5.1 MV/m at a total length of 0.69 m. In addition the Demonstrator comprises two 9.3 Tesla sc solenoids. The configuration of a CH-cavity embedded by two sc solenoids is taken from a conceptual layout of a new sc cw LINAC with nine CH-cavities and seven solenoids. Such an accelerator is highly desired by a broad community of users requesting heavy ion beam energies in the Coulomb barrier range. A successful test of such an sc multigap structure is an important milestone towards the proposed cw-LINAC.

THE SC CH-CAVITY

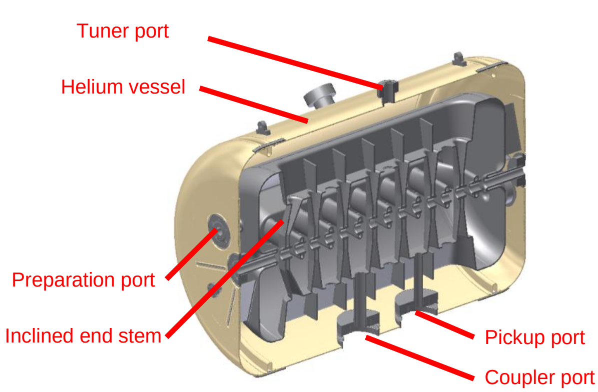

Figure 1: The 217 MHz sc CH-cavity.

The sc CH-cavity is the key component of the Demonstrator project. Four sc CH-cavity types were and are developed at the IAP so far:

(1) A first prototype of a 360 MHz sc CH-cavity (β=0.1, 19 gaps) was tested at the IAP successfully. In vertical rf-tests maximum gradients of up to 7 MV/m at Q_0-values between 10^8 and 10^9 were achieved [1, 2].
(2) The delivery of a 325 MHz sc CH-cavity (β=0.16, 7 gaps) is imminent [3]. The site acceptance test at RI, Germany is in progress. First rf-tests at room temperature were successful.
(3) The cavity designed for the cw-LINAC Demonstrator project (β=0.06, 15 gaps) is operated at 217 MHz (fig.1). Its general parameters are listed in table 1.
(4) The cold part layout of the 17 MeV injector of the MYRRHA (Multi-purpose hybrid research reactor for high-tech applications) project should comprise 176 MHz cavities [4].

THE SC CW LINAC DEMONSTRATOR

Although the results of the warm and cold rf-tests of the 360 MHz cavity at the IAP were very promising, for a proof-of-principle on the sc CH-cavities tests under real operational conditions must be passed. That is the aim of the Demonstrator project. At the GSI High Charge Injector (HLI) a 217 MHz sc CH-cavity should be operated with heavy ion beam.

The project is financed by HIM mainly and is supported by the Accelerator Research & Development (ARD) program of the Helmholtzgemeinschaft (HGF).

Table 1: General parameters of the sc CH-Cavity designed for the cw-LINAC Demonstrator.

β		0.059
max A/Q		6
Frequency	MHz	217
Gap number		15
Total length	mm	690
Cavity Diameter	mm	409
Gap length	mm	40.8
Aperture	mm	20
Effective gap voltage	kV	225
Voltage gain	MV	2.97
Accelerating gradient	MV/m	5.1

The Demonstrator is the first section of the proposed sc cw-LINAC (cp. Future Applications). It is a cryostat housing the cavity, which is embedded by two superconducting solenoids (fig. 2). A study has been worked out which provided a concept to load the cryostat with the solenoids and the cavity as well as to align the three components to the beam axis [5].

The solenoids provide maximum fields of 9.3 T at an effective length of 290 mm and a free beam aperture of 30 mm. The fringe fields have to be reduced from the maximum field to 50 mT at the inner NbTi-surface of the neighbouring cavity. Based on the 9T solenoid design for the ISAC-II cryomodule [6] a coil configuration with two main coils and two bucking coils was assumed to fit the requirements at best (fig. 3). The calculations show that proper gradients can be achieved by using anti-windings. The general parameters of the solenoids are listed in table 2.

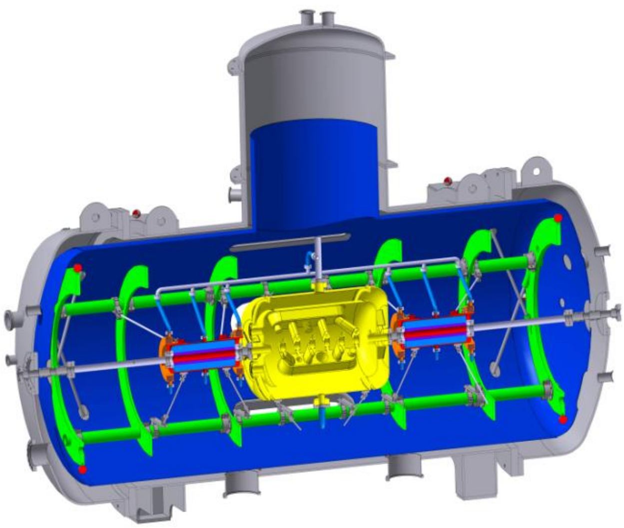

Figure 2: A scheme of the cw-LINAC Demonstrator shows the CH-cavity (yellow) in its centre embedded by two sc solenoids (red-orange). On the top space for a reservoir of liquid helium as well as of liquid nitrogen is reserved.

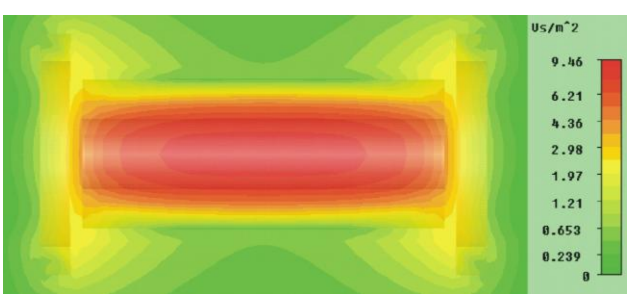

Figure 3: The solenoid field of the chosen coil configuration is calculated. Within the requirements the fringe field is shielded by the compensation coils.

The favoured location to setup the Demonstrator is in straightforward direction of the HLI at GSI (fig. 4). Two existing experiments at the HLI have to move since the space is needed for the demonstrator test environment including a new radiation protection cave.

The liquid helium (LHe) supply is covered by a 3000 ltr tank. The consumed helium is collected in a 25 m^3 recovery balloon and bottled by a compressor. In operation a consumption of 20 ltr LHe per hour is predicted.

Table 2: General parameters of the sc solenoids designed for the cw-LINAC Demonstrator.

max. field	T	9.3
B^2*l	Tm	24
effective Length	mm	280
Beam aperture	mm	30

For longitudinal matching the beam from the HLI to the demonstrator the existing buncher UN6 BB14 can be used. For transverse focusing an additional magnetic quadrupole doublet is needed. Moreover beam diagnostics like profile grids and an emittance measurement station have to be integrated in the beam line in front of and behind the demonstrator as well as phase probes for time of flight (TOF) measurements. For scheduling of the project see table 3.

THE SC CW-DEMONSTRATOR SCHEDULING

Table 3: Time Schedule

	cw LINAC Demonstrator Project
2009	Foundation of HIM Funding of the sc cw-LINAC Demonstrator
2010	Tendering of the Demonstrator's components
2011	Delivery of the LHe-supply and the rf-amplifier Ordering of the cavity Beginning of assembling the test facility at GSI HLI
2012	Ordering the solenoids and the cryostat
2013	Delivery of the cavity 1st rf tests (warm + cold) at IAP
2014	Delivery of the solenoids and the cryostat Commissioning of the Demonstrator at GSI Full performance test at GSI HLI

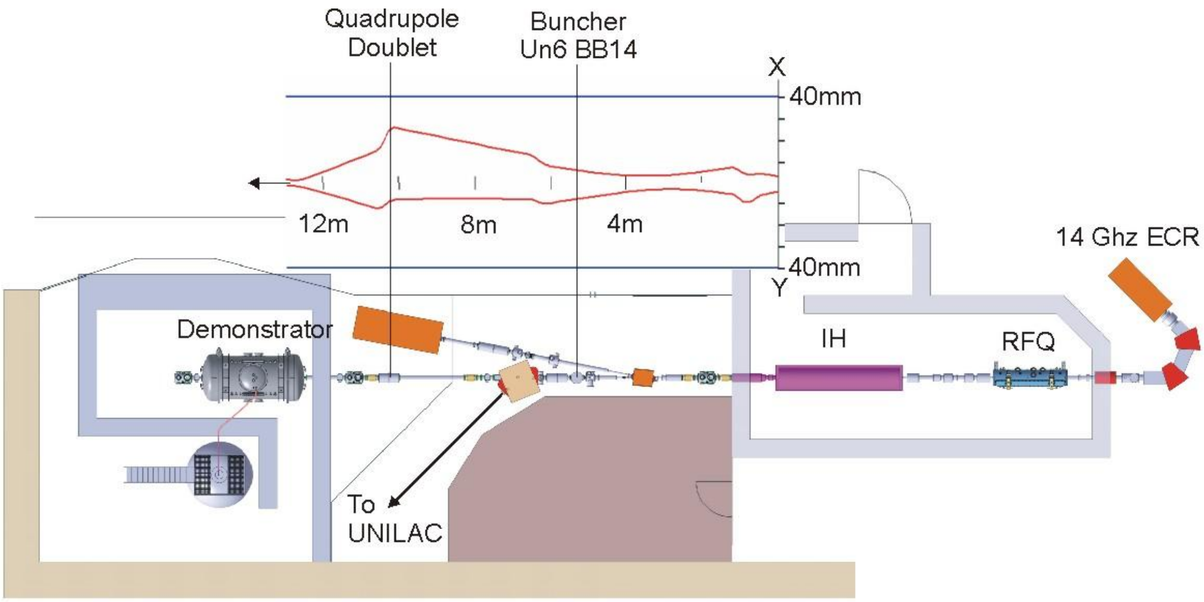

Figure 4: The existing 1.4 AMeV HLI should be used as the injector for the cw-LINAC demonstrator. In longitudinal plane the existing buncher UN6BB, in transverse plane an additional quadrupole doublet should be used to match the beam to the demonstrator.

FUTURE APPLICATIONS

Successful full performance tests with beam of the sc CH-cavity open a broad field of accelerator applications:

The first 360 MHz prototype was developed within EUROTRANS (European research program for the transmutation of high level nuclear waste in an accelerator driven system). In 2023 MYRRHA as an accelerator driven system (ADS) for transmutation of high level nuclear waste should be commissioned with four 176 MHz sc CH cavities [7].

As a future upgrade option for the GSI universal linear accelerator (UNILAC) an energy booster LINAC with six 325 MHz cavities is discussed [8].

Another application is the sc cw-LINAC, which is highly desired by a broad community of future users. Especially the Super Heavy Elements (SHE) program at GSI and at the Helmholtz Institute Mainz (HIM) benefits highly from such a dedicated accelerator [9].

A conceptual layout of the sc cw-LINAC was worked out [10], which allows the acceleration of highly charged ions with a mass to charge ratio of 6 at 1.4 AMeV from the upgraded HLI including a new source. An sc 28GHz ECR-source is under development at GSI. Nine superconducting CH-cavities operated at 217 MHz accelerate the ions to energies between 3.5 AMeV and 7.3 AMeV, while the energy spread should be kept smaller than ±3 AkeV. As beam focusing elements seven superconducting solenoids are applied. The first as well the follow-up proposal for the cw-LINAC was evaluated “excellent” by the HGF in 2011. Strong activities are in progress to receive a funding for the project.

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