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COMMISSIONING OF DEMONSTRATOR MODULE FOR CW HEAVY ION LINAC@GSI

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Abstract

The cw – Linac – demonstrator is a prototype of the first section of the proposed cw-LINAC@GSI, comprising a superconducting CH-cavity embedded by two superconducting solenoids. The sc CH-structure is the key component and offers a variety of research and development. The beam focusing solenoids provide maximum fields of 9.3 T at an overall length of 380 mm and a free beam aperture of 30 mm. The magnetic induction at the fringe is minimized to 50 mT at the inner NbTi-surface of the neighboring cavity. The fabrication of the key components is finished, as well as the cold performance testing of the RF cavity. The cryostat is ready for assembling and the test environment is completely prepared. After successful testing of the RF-Power coupler, the components have been assembled to the suspended frame under cleanroom conditions. Alignment, assembly, under cleanroom condition issues will be presented.

CW LINAC DEMONSTRATOR

Table 1: Main Parameters

CH-Cavity		
β		0.059
max A/Q		6
Resonance Frequency	MHz	217
Gap number		15
Total length	mm	690
Cavity Diameter	mm	409
Aperture	mm	20
Effective gap voltage	kV	225
Accelerating gradient	MV/m	5.1
Cryostat		
Inner length	mm	2200
Inner diameter	mm	1120
Material		Al
Operating temperature	°K	4.4
Operating pressure above atmosphere	bar	< 1
Solenoids		
Aperture	mm	30
Total length	mm	380
Max. field	T	9.3
Nominal current	A	110

The demonstrator project kick-off at GSI was in 2010, which was followed by design studies for the key components as the 217 MHz CH cavity, two sc solenoids, and the cryostat itself. Meanwhile the fabrication is completed. The main parameters are listed in Table1.

The concept of a suspended support frame, which carries the cavity embedded by two sc solenoids, is followed (Fig.1) [1]. The support frame as well the accelerator components are suspended by eight tie rods each in a cross-like configuration (nuclotron suspension) balancing the mechanical stress during the cooling-down and warm up (Fig.2). This way the components will always stay within the tolerance limits related to the beam axis (long. ±2mm, trans. ±0.2mm).

The cryostat has been loaded at the RF and cold test in summer 2016. The cryogenic systems as well as all mechanical tasks were solved for the final beam test.

Figure 1: The cw demonstrator comprising a CH-cavity embedded by two solenoids on a support frame, which hang into the cryostat.

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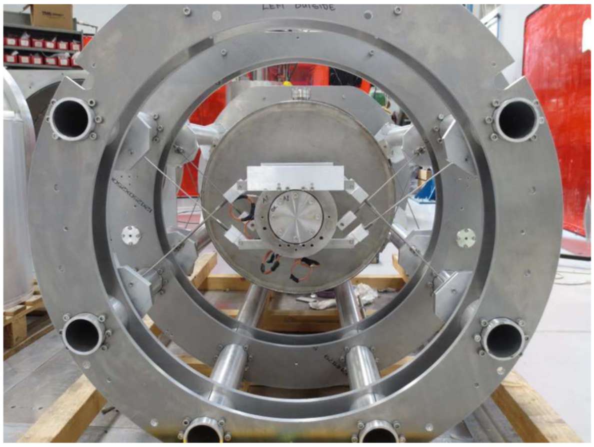

Figure 2: Detailed view of tie rods in a cross-like configuration.

The beam focusing solenoids provide a maximum field of 9.3 T. The main coil is made out of NbSn and the compensation coils made out of NbTi are shielding the maximum magnetic field down to 30 mT within 10 cm. The solenoids are connected to LHe pots inside the cryostat by copper tapes allowing dry cooling.

The CH cavity is cooled with LHe directly using a He jacket out of titanium. The manufacturer is Research Instruments (Germany). After a high pressure rinsing (HPR), and a final performance test at 4K with low rf power @ IAP, Frankfurt was performed [2].

Three piezo tuners are manufactured at GSI to tune the cavity while operating with beam. Therefore a tuner dummy was tested at IAP [3].

The three 5 kW cw power couplers were delivered in August 2016. For conditioning a cavity out of aluminum was fabricated at GSI, and a setup of two couplers connected to the test resonator was operated [4].

Figure 3: 5 kW power coupler screwed on cavity and cryostat.

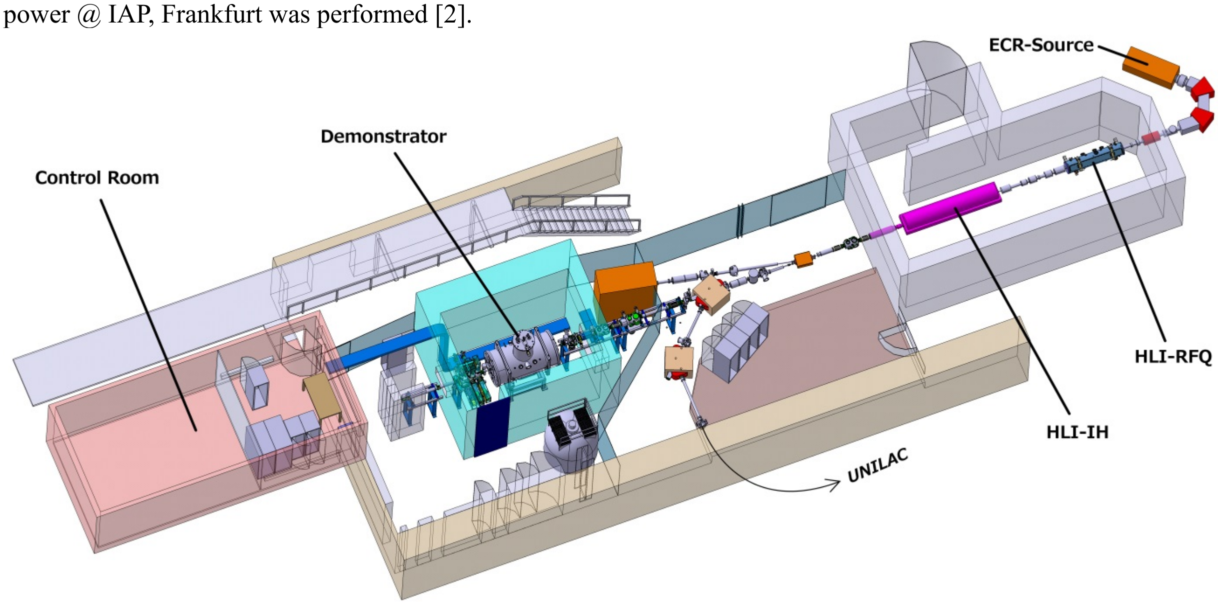

Figure 4: 3D layout of the GSI High Charge State Injector (HLI) with the new cw-LINAC Demonstrator environment

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BEAM TEST SETUP AT GSI HLI

Commissioning of the Demonstrator was finished in April 2017 at the GSI HLI, which operates at 108 MHz (Fig. 4). A new beam line in straightforward direction to the HLI, which transports the beam to the new radiation protection shelter locating the demonstrator, was designed regarding beam dynamics simulations [1]. In a beam measurement complain in 2015 the demonstrator cryostat confirmed the beam dynamic simulations and the aspired positioning of the components in the beam transport line [5].

An emittance measurement device, four phase probes, beam current transformers, and a bunch shape monitor are installed to fully characterize the beam [6, 7].

The 3000 ltr. Reservoir and the 12 kW amplifier for the 108MHz Rebuncher in the beam line is already in place

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and already for mounted. A flexible 13m long helium pipe is connected to the demonstrator cryostat. The exhaust helium gas is connected to a 25m³ recovery balloon and later liquefied and brought back.

To be able to mount the demonstrator string under cleanroom conditions, and also for future service of other applications, an existing ISO 8 cleanroom at GSI was upgraded to ISO 4 in 2016 (Fig. 5). Therefor the floor was completely renewed, the existing artificial ventilation was re-worked, and an area of laminar flow units was installed in the cleanroom to reach ISO 4. To connect the whole string, the pre-assembled support frame stayed two days in the cleanroom before the final connection between cavity and solenoids under laminar starts, to ensure as far as possible that no particles arrives the beam interior.

Figure 5: Upgraded cleanroom ISO 8 to ISO 4

After successful mounting of the components and a final leak test the parts were aligned applying a laser tracking system to the axis of the support frame within a tolerance less than 0.1 mm. A previous cold test with a cross-hair camera system showed a maximum longitudinal movement of the components of less than 0.2 mm.

TIMETABLE

Table 2: Timeline

	cw-LINAC – Demonstrator-Project
2010	Kick-off at GSI Tendering of demonstrator components
2011	Delivery of LHe-supply and rf-amplifier Ordering of cavity, solenoids, cryostat Assembly of test area @GSI started
2015	Delivery of cavity 1st tests (warm + cold) at IAP
2015	Delivery of solenoid and cryostat
2016	Cleanroom Upgrade
Jun 2017	Full performance test at GSI HLI

BEAM TEST / OUTLOOK

The CH-Cavity accelerated first time heavy ion beam to an energy of 1.85 MeV/u. While the cavity was operated in cw-mode, a maximum average beam intensity of 1.5 pμA has been achieved, limited by the pulse intensity of the injector and its maximum duty factor of 25%. Detailed tests and evaluation is scheduled.

The achieved beam commissioning of the demonstrator is a major milestone towards the cw-LINAC at GSI. Especially the GSI Super Heavy Elements (SHE) program benefits highly from such a dedicated accelerator. As a next step the extension of the demonstrator to a string of three 217 MHZ CH-cavities, a rebuncher cavity, and two solenoids is proposed and already defined by beam dynamic simulations to be placed in a dedicated cryomodule. [8, 9, 10].

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