THE SC CW-LINAC DEMONSTRATOR – FIRST SECTION OF A SC CW-LINAC

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Abstract

The realisation of the first section of a new superconducting (sc) continuous wave (cw) LINAC is planned in 2013. The project is called "cw LINAC Demonstrator" and is financed by the Helmholtz Institute Mainz (HIM). The aim is a "full performance test" at GSI-HLI of a new 217 MHz sc CH-Cavity which is designed by the Institute of Applied Physics (IAP) of the University Frankfurt [1, 2].

According to an engineering study for the cryostat, a frame has been designed to support the cavity embedded by two sc solenoids. A nuclotron -suspension analog to the SIS-100 Magnets for FAIR is used, which nearly prevents the displacement of the components on the frame while cooling down. Another challenge is to reduce the magnetic field of the solenoid from 9.3 T to 50 mT at the cavity within some centimeters by moveable compensation -coils.

This and other technical solutions in the cryogenic environment of the Demonstrator are presented.

INTRODUCTION

Since 1990 the High Charge Injector (HLI) is in service to provide Super- Heavy- Element (SHE) experiments (SHIP and TASCA) with beam at GSI. It comprises a 14 GHz ECR, an RFQ, and an IH anti-parallel to the UNILAC. In 2005 an upgrade program for the HLI was defined to make the HLI cw-capable [3, 4]. Straight forward to this injection line the Demonstrator should be assembled for a "full performance test" with beam.

In order to use these favourable conditions it is planned to adjust the test environment, with the cryostat, a 3000ltr. Helium reservoir, a radiation protective shield, the beam diagnostics and other supply units in this area (Fig.1). In order to solve the physical, technical, and assembling requirements some solutions are presented to accomplish the components (solenoids, cavity, supporting frame) and keep the needed tolerances. Another challenge is the detection of the displacements of the components while cooling down.

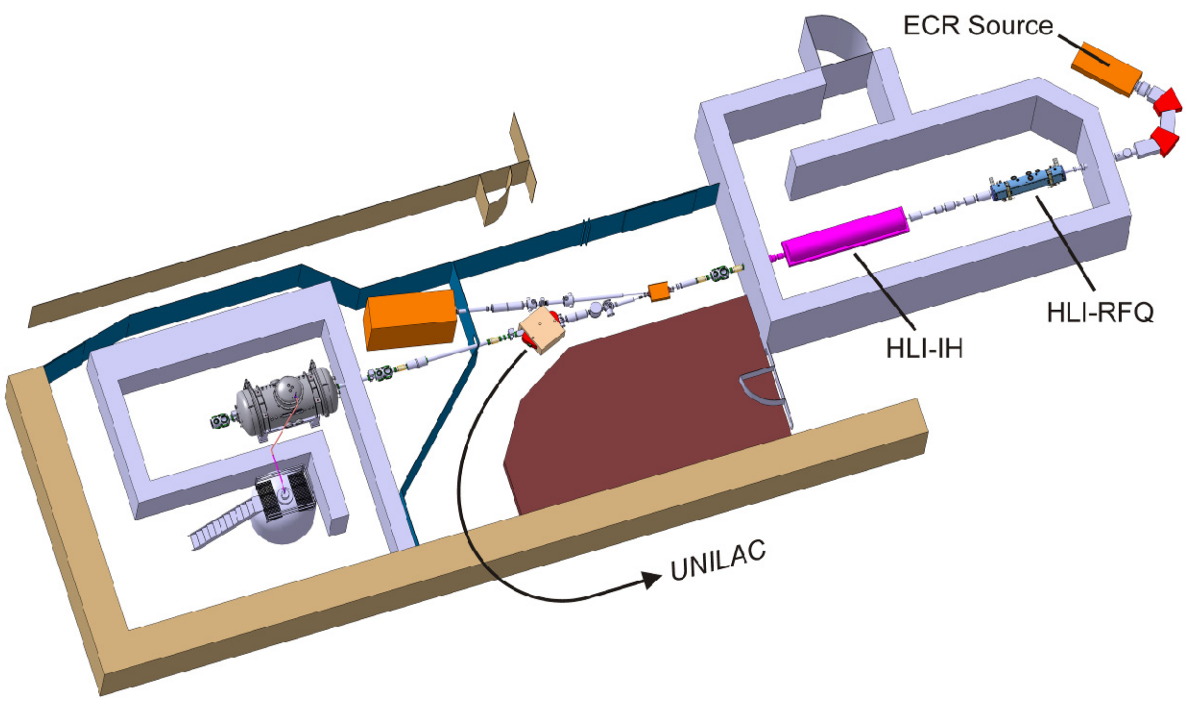

Figure 1: The future layout of the GSI accelerator facility with the cw-LINAC Demonstrator integrated in the existing High Charge Injector (HLI).

The Demonstrator comprises two superconducting solenoids and the 217 MHz sc CH-cavity and is the first section of the future sc cw-LINAC, which allows the acceleration of highly charged ions with a charge to mass ratio of 1 to 6 at 1.4 MeV/u from the upgraded HLI. The proposed cw-LINAC is designed with nine sc CH-cavities and seven sc solenoids [5, 6].

CW-LINAC-DEMONSTRATOR

The Cryostat

The demonstrator is the first section of the cw-LINAC with a superconducting CH-cavity embedded by two superconducting solenoids (Fig. 2, 3).

A study has been worked out how to mount the components in a cryogenic environment operating at a temperature of 4.4 Kelvin and a pressure of less than 0.5 bar. As a result the cryostat itself has a cylindric shape with an inside length of 2200mm, an inside diameter of 1120mm (Tab.1), and caps to both sides. In order to allow assembling and servicing, it will be possible to open the caps. The cold-warm-transitions which are mounted at these caps are connected to the cold beam pipe with an aperture of 30mm. The inner surface of the cryostat is coated with a μ-metal layer to suppress external magnetic fields. The thermal isolation will be assured by evacuating the cryostat in combination with a pipe-shaped nitrogen shield. Layers of super isolation on the outer side of the shield should keep the static thermal losses smaller than 10 Watt additionally. An external reservoir (250 ltr.) of liquid nitrogen for the thermal shield and an external liquid helium reservoir (3000 ltr.) supplying the cavity and the solenoids will be placed at the area nearby the demonstrator (Fig.1). A 25 m³ gas-balloon will store the used warm helium gas from the demonstrator and is already installed at GSI. The gas is bottled with an existing compressor and later reprocessed in a condenser.

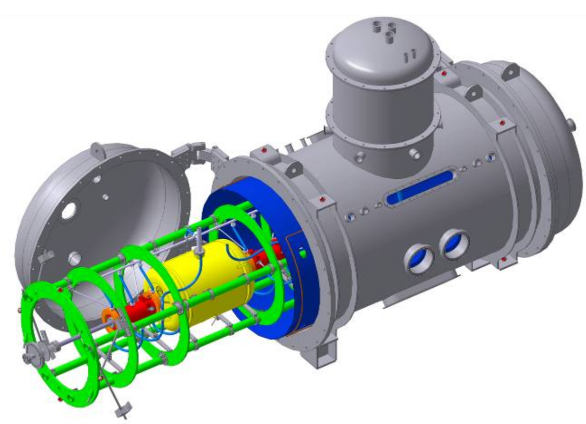

Figure 2: The cryostat of the cw-LINAC Demonstrator with the supporting frame (green) and the CH-cavity (yellow) in its centre embedded by two sc solenoids (red-orange).

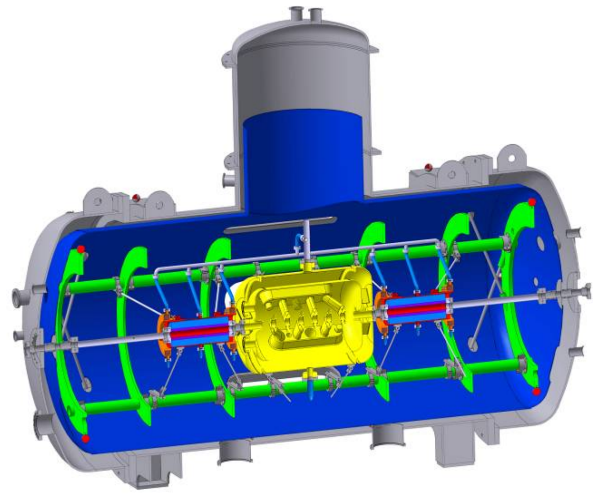

Figure 3: Sectional view of the cryostat. On the top space for a reservoir of liquid helium as well as of liquid nitrogen is reserved.

The sc CH-cavity

The sc CH-structure is the key component and is designed by IAP. The structure is an issue of actual research and development [1, 2]. A first prototype of a 360 MHz sc CH-cavity (β=0.16, 19 gaps) was tested at the IAP successfully. A second cavity operated at 325 MHz is fabricated presently.

The cavities for the cw-LINAC are designed to operate at 217 MHz and to provide gradients of 5.1 MV/m at a total length of 0.69 m.

Table 1: General Parameters of the sc cw-LINAC Demonstrator-Cryostat

Inside length	mm	2200
Inside diameter	mm	1120
Material	Stainless steel	1.4301
Insulation vacuum	mbar	<1×10^-5
Max. system pressure	bar	< 0.5
Operating temperature	K	4.4
Max. losses in stand-by	W	<10

The Supporting Frame

A supporting frame will carry the superconductive components with three drag-bars each in an angle of 120° transversally in order to balance the mechanical stress by pulling evenly. In this way the components are assumed to stay always within the tolerance limits related to the beam axis while cooling down. The components have to be adjustable with a longitudinal tolerance of ± 2 mm and transverse of ± 0.2 mm. To prevent displacements of the frame itself, a nuclotron–suspension analog to the SIS - 100 Magnets for FAIR is used. The maximum deflection of the frame by holding the components is limited to 1mm and has been confirmed by studies with the ANSYS code to be independent on the temperature.

The detection of the displacements of the components is not worked out finally. A study is pending to realize a measurement of deviations from the axis while cooling down.

The sc Solenoids

The solenoids provide maximum fields of 9.3 T along a effective length of ≈300 mm and a free aperture of 30 mm. The fringe fields have to be reduced from the maximum field to 50 mT at the entrance of the neighbouring cavity. Simulations show that the required gradients can be achieved by using compensation-coils (Fig. 4.), which are designed moveable in order to be able to access the cavity from outside, allowing the assembly and reaching a distance from the adjacent components of less than 63 mm [7]. The helium supply of the solenoids will be splitted in three separate and flux controlled paths to cool down the compensation- coils and the inner coils evenly. Because of mobility, all helium tubes have to be flexible.

Full Performance Tests at GSI HLI

For full performance tests with beam a test environment at the HLI (1.4 MeV/u) injector is favoured. The demonstrator will be connected straight ahead to the HLI (Fig.1). Beam diagnostics like profile grids and emittance measurements stations have to be integrated in the beam line in front and behind the demonstrator.

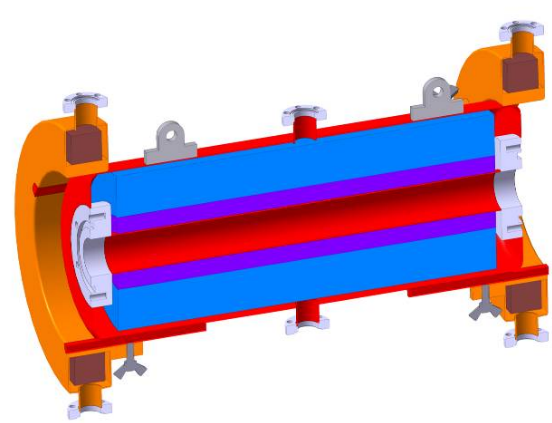

Figure 4: Sectional view of the Solenoid layout with moveable compensation-coils.

Status

The specifications of the solenoids and the cryostat with supporting frame are completed and in the tender procedure. The conceptual design of the cavity is already worked out and the order is placed to Research Instruments (RI) in Bergisch Gladbach, Germany. A 5 kW rf-amplifier is tested and has been delivered to GSI in May 2010. The 3000 l LHe-reservoir and the 25 m³ storage balloon for helium gas are also on site.

OUTLOOK

The main components of the demonstrator, like the cavity, the solenoid and the cryostat, are expected to be ordered in winter 2011 and be delivered in 2013. The assembly of the components under cleanroom conditions to a well-working system starts in 2012. First horizontal rf-tests of the system shall take place at IAP afterwards. Thus, full performance tests at GSI HLI are expected in 2013-2014 at earliest.

Successful full performance tests with beam will be a major milestone towards a sc cw-LINAC at GSI. The realisation of the proposed cw-LINAC is estimated in 2018 (Tab.2).

Table 2: Time Schedule

	CW-LINAC -DEMONSTRATOR
2010-2011	Ordering of the cryostat & solenoids, the cavity, the rf-amplifier, and the LHe-supply
2011-2013	Delivery of the components 1st tests (warm + cold)
2013-2014	Full performance test at GSI HLI
2017-2018	Commissioning "sc cw-LINAC"

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