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INFRASTRUCTURE FOR SUPERCONDUCTING CH-CAVITY PREPARATION AT HIM

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Abstract

A superconducting cw LINAC for heavy ions is currently under development at GSI in Darmstadt and HIM in Mainz. This Linac is based on 217 MHz multigap bulk niobium Crossbar H-mode RF-cavities. In order to treat and prepare RF-cavities with such a complex geometry a new cleanroom facility has been already built at the Helmholtz-Institut in Mainz. All tools and machines inside the cleanroom can handle cavities up to 750 mm in diameter and up to 1300 mm in length. In its ISO-class 6 and 4 zones, respectively it features a large ultrasonic and conductance rinsing bath, a high pressure rinse (HPR) machine and a vacuum oven. The HPR cabinet has an inside clearance of 1.3 m. The cavities sit on a rotating table, while the rinsing wand moves vertically up and down. Due to the crossbar structure of the RF-cavities the HPR device allows for off axis-rinsing in their quadrants. For RF testing a 52 m^2 (4 × 13 m^2) concrete shielded area with sufficient liquid helium supply is located next to the cleanroom and the cryo-module assembly area.

INTRODUCTION

In order to keep the GSI-Super Heavy Element program (SHE) [1] at Darmstadt competitive, the construction of a superconducting cw-Linac, Helmholtz Linear Accelerator (HELIAC) [2], is envisaged. For this linac the ions will be accelerated in 217 MHz multi gap bulk niobium Crossbar H-mode RF-cavities. In 2017 the first beam acceleration using such a 15 gap sc cavity was successfully demonstrated at GSI. Helium and argon ion beams at different charge states were accelerated up to the design beam energy and the design gradient of 5.1 MV/m could be exceeded, while a maximum average beam intensity of 1.5 pμA (25% duty factor) was achieved [2]. The cavity was tested in a short demonstrator cryo-module housing the cavity and two sc solenoids. Assembly of the cold string has been accomplished in a small ISO-class 4 cleanroom at GSI in Darmstadt. For the HELIAC it is foreseen to assemble 3 CH-cavities, 2 sc solenoids and a sc re-buncher cavity in a 5 m long standard cryo-module. The complete linac comprises four of such cryo-modules, while the cavity design (length) has to be adapted with increased beam energy. It is planned to assemble the 4.5 m long cold-strings at the new HIM-cleanroom [3], which offers sufficient space for assembly, surface preparation capabilities under the necessary clean condition (ISO class 4).

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SRF-INFRASTRUCTURE AT HIM

The cleanroom is located in the experimental hall at the HIM-lab. It includes a mounting rail, allowing the assembly and sealing of full cavity strings under ISO-class 4 conditions. Outside the cleanroom - in front of the doorway to the ISO 6 area - sufficient space is available for mounting a cavity cold-string into a cryo-module. Right next to this area in the same hall a concrete shielded area for RF testing of superconducting cavities is located. Its inner dimensions of 4 × 13 m^2 offers adequate space for cryo-modules and further instrumentation. Liquid helium is supplied by a cryogenic transfer line from the liquifier of the neighbouring Institute for Nuclear Physics [4]. While HELIAC cavities will be operated at 4 Kelvin, a subatmospheric compressor station can be used to lower the pressure of the helium bath down to 16 mbar in order to lower the temperature down to 1.8 K. In a first step single CH-cavities will be tested in a short horizontal cryo-module, the demonstrator module which has been used for the first beam testing at GSI in Darmstadt. The shielded area is also allocated for RF testing of the fully mounted HELIAC cryo-modules before they will be transferred to GSI.

The cleanroom is divided in an ISO-class 6 and an ISO-class 4, both on a double floor. Together with its greyroom and air locks, the cleanroom covers an area of 155 m^2. A facility for ultrahigh purity water is located in the basement of the HIM building. It produces, when needed, up to 2.5 m^3 deionized (DI) water per hour with a conductivity of less than 1 μS/cm. 5200 l of this DI water are stored in a buffer tank . For all applications performed in the cleanroom an additional purification process lowers the conductivity down to 0.056 μS/cm, a 0.2 μm particle filter ensures for sufficiently high quality of the water.

CLEANROOM EQUIPMENT

Personnel enters the ISO 6 room through an air lock, where cleanroom clothes will be put on. Objects, for example RF-cavities, will be brought in by a different air lock via the grey room. In this air lock wet pre-cleaning with a high pressure washer is possible. To enter the ISO 4 area every person has to go through the next air lock including an air shower. For objects another air lock has to be used. The HPR cabinet can be loaded from the ISO-class 6 and unloaded from the ISO-class 4 and thus serves as an air lock as well. Figure 1 shows the cleanroom with its major installations. The typical transfer paths for objects are illustrated.

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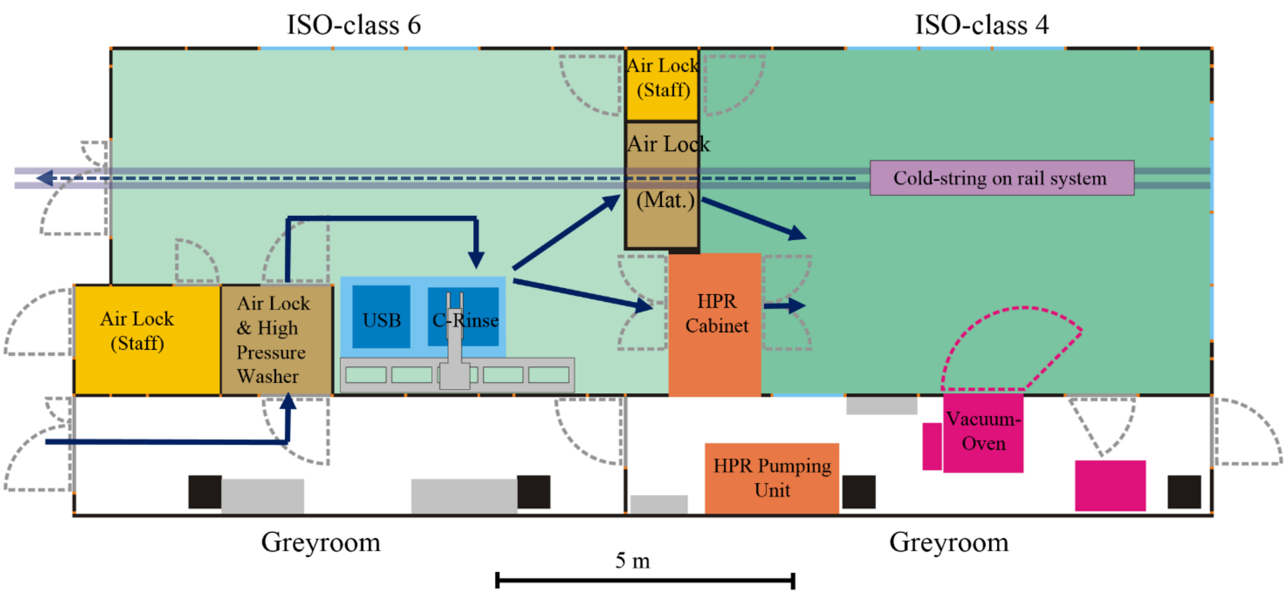

Figure 1: Sketch of the HIM-cleanroom. The ISO-class 6, -class 4 and greyroom areas are shown, as well as the different features such as air locks for personnel and objects, large ultrasonic (USB) and conductance rinsing (C-Rinse) baths with their crane, a high pressure rinsing (HPR) cabinet, vacuum oven and mounting rail for cold-string assembly and transportation. Typical transfer paths for objects and material (blue arrows) are depicted.

In the ISO-class 6 area components and tools will be prepared and cleaned before they will be transferred to the ISO-class 4 area. Therefore, the main feature inside ISO-6 zone is a large ultrasonic bath. It has an immersion depth of approximately 1.4 m and a usable width of 750 mm × 750 mm. Ultrahigh purity water can be used together with a soapy detergent to remove any grease. During the process the water can be heated up to 80°C, while the liquid is pumped in a cycle through a particle filter removing all residual (pollute) particles, e.g. metal shavings. A crane unit, capable for a load of 300 kg allows to move objects to a conductance rinse bath of the same size, and after that to an unload/load position.

After ultrasonic cleaning objects can be brought through an air lock into the ISO 4 area, RF-cavities can enter the high pressure rinsing cabinet (Fig. 2) and have to be unloaded from the ISO 4 access side after the rinsing process. The cabinet and its pumping unit were commercially fabricated by Semiconductor Process Equipment Company (SPEC). Inside the cabinet the cavity is fixed on a rotating table, while the high pressure wand is moving up and down spraying ultrahigh purity water at 100 bar on the inner surfaces. Cavities of up to 1.3 m in length (and even longer if using a shorter table) and up to 1.3 m in diameter can be treated.

Wet objects are left in the laminar flow of the ISO-class 4 for drying, alternatively a large vacuum oven can be used to perform a more efficient drying procedure of vacuum surfaces. Its usable inner oven dimensions are 0.9 × 0.9 × 1.5 m^3, applying oil free vacuum pumps and filtered nitrogen for ventilation. During a 120°C bake out the cavity and furnace volume can be pumped separately on demand.

The final assembly of cold strings has to be executed in the ISO-class 4 area. All parts of the cold-string will be mounted on support tables which are sitting on a rail system in the cleanroom floor. Once the beam vacuum is closed, the entire string can be rolled back to the ISO-6 area and at last outside of cleanroom. Prior to this, leak tests can be performed in the ISO 4 or 6 areas.

Figure 2: HPR cabinet: View from ISO-6 access side for loading (left) and from ISO-4 for unloading (right). The lever with the wand is visible.

HPR ON CH-CAVITIES

The HPR is a key technology for preparation of SRF CH-cavities for the HELIAC. The first cavity in the project has been high pressure rinsed after fabrication at the vendor and tested in a vertical cryostat at Goethe University Frankfurt. Accelerating gradient E_a and Q_0 value both met the design values. After the helium mantel has been mounted and after the cavity was rinsed again, a second test could be performed. As a result the cavity performance was considerably enhanced, as shown in Fig. 3 [5]. Nevertheless, the cavity was rinsed by a nozzle moving up and down the beam axis so far. Due to its complex geometrical structure, not all surfaces in a CH structure (see Fig. 4), can

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be polished reliably when only spraying along the beam axis.

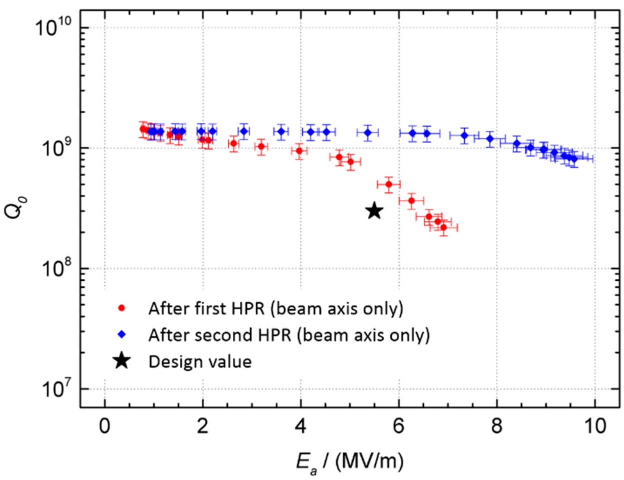

Figure 3: Measurements of Q_0 and E_a at a CH-cavity at 4 K; between first (red) and second (blue) test another HPR procedure has been performed [4].

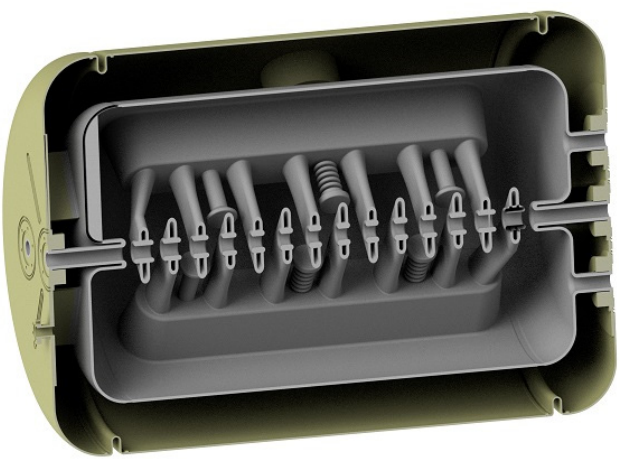

Figure 4: Sectional view of the first 217 MHz CH cavity for the cw linac at GSI; 10 cm off beam axis two openings from each side for additional rinsing of the four sector quadrants are available.

The HPR device, assembled at the new HIM lab, has been designed to open the possibility for cavity rinsing on and off axis. CH-cavities are equipped with two openings from each side (10 cm off beam axis) to rinse all four sector quadrants (Fig. 4). As a consequence for advanced off axis rinsing the cavity needs to be put 10 cm off centre on the rotating table. Thus the axis of rotation is fixed at the centre of the favoured quadrant, while the high pressure nozzle moves up and down. In Fig. 5 the rotation process is shown schematically: For rinsing of each quadrant, the cavity has to be relocated on the table and once it has to be turned around. Through the openings on the opposite side the water can flow out during the rinsing process. In the future it is envisaged that all CH-cavities will be rinsed along beam axis and in each of their sector quadrants. The effect on the cavity performance after those treatments is part of further investigations.

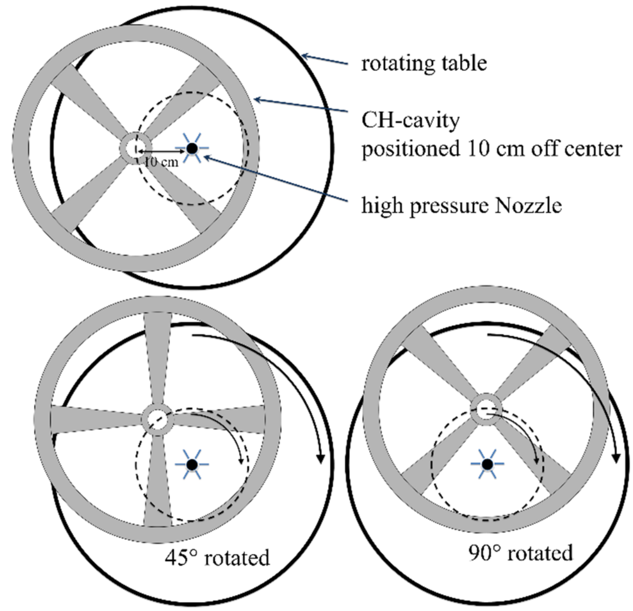

Figure 5: Schematic illustration of the high pressure rinsing process at one sector quadrant of a CH-cavity.

SUMMARY & OUTLOOK

Recently a new infrastructure for SRF R&D has been set up at the Helmholtz-Institut Mainz. Beside a radiation shielded test area, the main feature is a 155 m^2 cleanroom facility with its key components: An Ultrasonic bath and a conductance rinse, a High Pressure Rinsing device and a 120°C vacuum oven. Primarily it has been set up for the treatment of CH-cavities as they are needed for a new superconducting cw heavy ion linac (HELIAC) at GSI. Nevertheless, the equipment has been chosen to be suitable for a broad spectrum of SRF cavities, for instance 9 cell TESLA/XFEL type cavities.

In the next future all procedures inside cleanroom will be tested. Cleaning and assembly steps are scheduled to be tested with CH-cavity dummies first. Delivery of the next two CH-cavities [6] for the HELIAC project is scheduled for end of 2018.

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