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REFURBISHMENT OF SRF CAVITIES AND HOM ANTENNA COATING STUDIES FOR THE MAINZ ENERGY-RECOVERING SUPERCONDUCTING ACCELERATOR (MESA)*

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Abstract

The commercial available cryomodules of the ELBE/Rossendorf-type, produced by Research Instruments (RI), found use in various superconducting accelerators. Requirements for the cryomodules changed in the last two decades. In particular, this was the case for the Mainz Energy-Recovering Superconducting Accelerator (MESA), so the so-called MESA Enhanced Elbe-type Cryomodule (MEEC) was produced by RI to fulfil the specific requirements for MESA. In addition, an ELBE-type cryomodule from the decommissioned Accelerator and Light In Combined Experiments (ALICE) from Daresbury, United Kingdom[1], was gifted to us. The ALICE module needs a refurbishment to fulfill the requirements for MESA. Therefore, the investigation of a possible use as a spare cryomodule started as well as a study for using coated HOM antennas. This includes a clean room treatment with a high pressure rinse (HPR). The existing clean room structure at the Helmholtz Institut Mainz (HIM) will be used for this purpose. Through corona regulations it was not possible to perform a HPR with the ALICE cavities till now, but an injector cavity from the S-DALINAC could be refurbished successfully in 2021.

INTRODUCTION

Currently, a cryomodule of ALICE [1] is under refurbishment at the Institut für Kernphysik at the Johannes Gutenberg-Universität Mainz. This Module contains two 1.3 GHz TESLA/XFEL-type cavities like the MESA MEEC [2] modules. It is planned to test Higher Order Mode (HOM) antennas with a coating of better superconductors, like Nb_3Sn and NbTiN at a later stage. With further modification, the ALICE module will finally become a spare cryomodule for MESA. These modifications include an upgrade of the tuner, HOM antennas and Helium port. It is expected that coated HOM antennas allow better damping of HOMs and thus enable the transport of more beam current.

MESA Layout

Figure 1 shows the lattice of MESA [3]. The injector includes the Small Thermalised Electron Source at Mainz (STEAM), MESA Low Energy Beam Apparatus (MELBA) and MilliAMpere BOoster (MAMBO) and accelerates the polarised and unpolarised electrons up to an energy of 5 MeV. The two superconducting cryomodules drive the main accelerator and provide an energy gain of 100 MeV for MAGIX in the energy-recovering (ER) mode and 150 MeV for the P2 and BDX in the beam dump mode. Table 1 compares the key parameters of ALICE and MESA. The cryomodules are similar as they are both based on the ELBE/Rossendorf design [4]. Since MESA is planned to run in the ER mode with a factor of 100 higher beam currents, it is necessary to refurbish the ALICE module and modify it for the use in MESA.

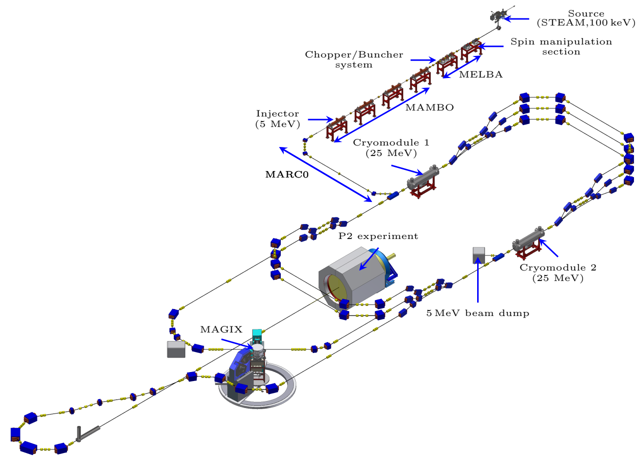

Figure 1: MESA lattice with a normal conducting injector and superconducting main accelerator. Two superconducting cryomodules prepare the electron beam for the experiments by MESA.

Table 1: Comparison of the Key Parameters of ALICE and MESA

Parameter	MESA	ALICE
Q_0	1.25×10^{10}	5×10^9
Field gradient	12.5 MV m^{-1}	12.9 MV m^{-1}
Beam current (ERL)	1(10) mA	13 µA
RF Frequency	1.3 GHz	1.3 GHz
Cavities	9-cell XFEL/TESLA	9-cell XFEL/TESLA

REFURBISHMENT OF SRF CAVITIES

Clean Room Infrastructure at HIM

For the clean room treatment of the Niobium cavities the existing clean room infrastructure at HIM is used. It contains

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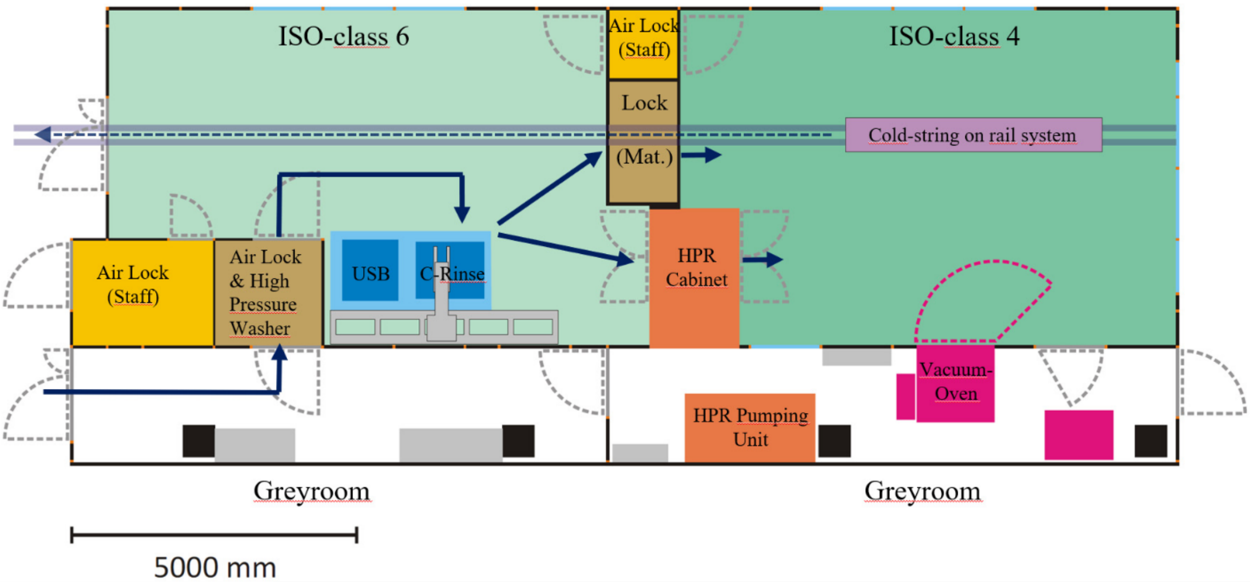

Figure 2: Sketch of the clean room infrastructure at HIM [5].

two clean rooms from different ISO classes (see Fig. 2). The first clean room fulfills the requirements for the ISO 6 class. Here the cavities are cleaned from the outside in an ultrasonic bath and brought into the HPR. The cavity leaves the HPR from clean room 2 which fulfills the ISO 4 requirements. In this room the cavity can dry after the HPR and be prepared for the next steps.

Clean Room Handling

For testing the the cleanroom handling and HPR performance a 3 GHz 6-cell cavity from S-DALINAC accelerator [6] at TU Darmstadt, Germany, has been tested first. The cavity from Darmstadt was brought into the clean room through the material entrance where the outer surface got coarse cleaning. The cavity was then brought through robot arms to the ultra sonic bath system (USB), (see Fig. 3). Here the outside of the cavity got cleaned in an ultrasonic bath, which was heated up to 40 °C and contained Tickopur as a cleaning solvent. After 30 minutes in the active ultra sonic bath the cavity was brought into the ultra pure water rinse. Here was measured the electric conductivity of the out flowing water monitored. When a value between 0.055 – 0.1 μS cm^{-1} of the electrical conductivity of the out flowing water was reached one could state that the outer surface is particle free. Then the cavity was ready for the inner surface treatment with the HPR. The HPR receipt includes pre-rinse, scrub-rinse and post-rinse. The pre-rinse and post-rinse cycles have a pressure of 20 bar. The scrub-rinse uses a pressure of 95 bar to clean the inside of the cavity. During the HPR the conductivity of the out flowing water was monitored again to identify when the surface was particle free. In the following the cavity was brought in clean room 2 and dried there for 2 days. The cavity was then wrapped up in the clean room and prepared for the transport back to Darmstadt. At Darmstadt, the cavity was installed back into the accelerator.

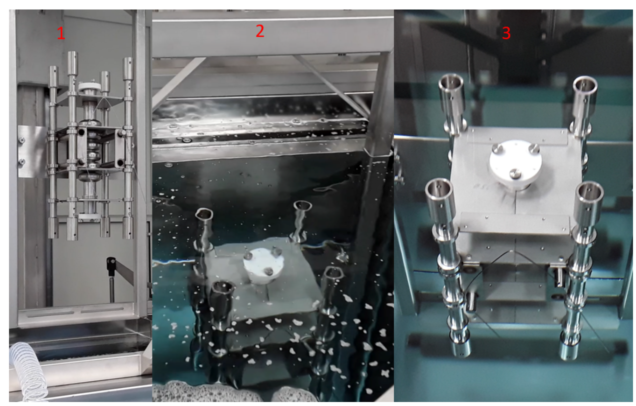

Figure 3: 1. cavity on the robot arm of the USB system; 2. cavity in the active USB; 3. cavity in the ultra pure water rinse.

Results at the S-DALINAC

After cleaning and integration back into the accelerator. The quality factor Q_0 was measured in-situ. The performance stability of the cavity increased compared to the measurement before the HPR at the cost of a lower value of Q_0. In Fig. 4 the results of both measurements are shown. Before the HPR was performed, the accelerating field was limited to 2.3 MV m^{-1} through a quench of the cavity. The quality factor of the cavity reduced from $(1.5 \pm 0.2) \times 10^8$ to $(4.6 \pm 0.2) \times 10^7$ for unclear reasons after the HPR. The cavity reached the designed field gradient with an increased power dissipation into the cryostat. The HPR could remove the source of the field e mitter. The cavity is operating at S-DALINAC successfully since re-integration.

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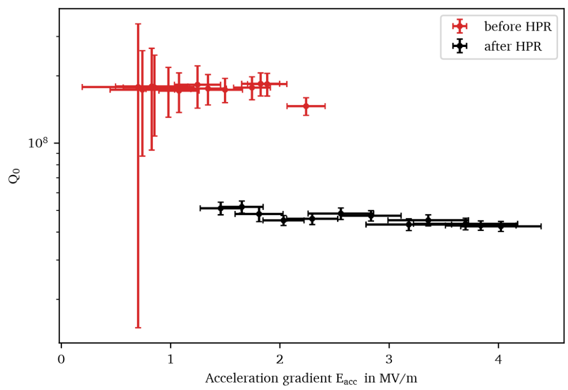

Figure 4: In-situ measurements of the quality factor at different accelerating field gradients. The quality factor before HPR was stable till 2 MV m^{-1} and quenched afterwards. After the HPR the quality factor was overall reduced, but higher field gradients were achieved. The field emitter which caused the quench was removed through the HPR [7].

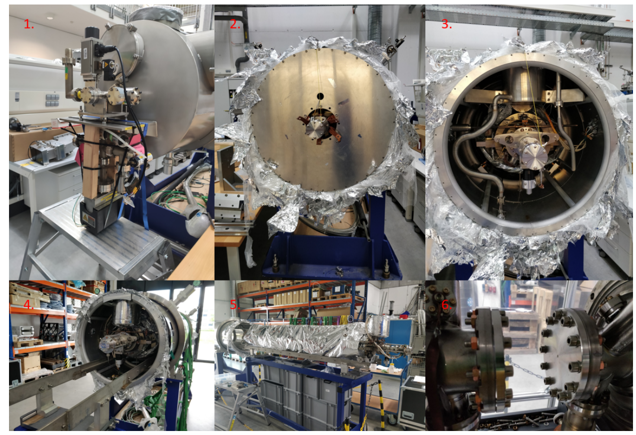

Figure 5: Steps of disassembling a cryomodule: 1. Fully equipped end cap; 2. Removed end cap and cut super isolation foil; 3. Opened shield; 4. Installed rail system; 5. Coldstring on the mounting rag and covered with super isolation foil; 6. Separated cavities.

Status of the ALICE Module

Before the ALICE cavities can receive a clean room treat-ment, they need to be unmounted from the cryomodule (see Fig. 5). This process includes the following steps:

Table 2: Steps of Disassembling the ALICE Cryomodule

Step	Description
1	The outer shell has to be freed from beam guide accessories, Helium and Nitrogen port and RF-power coupler
2	The end caps have to be removed
3	The shield has to be opened
4	The nitrogen shield has to be disassembled
5	Installation of the rail system to remove the coldstring
6	Remove the bellow which connects the cavities
7	Remove the tuning system from the cavities and install blind flanges by power coupler, antennas and cavities
8	Installation of the transport cage for clean room treatment

At the moment one cavity is at the last two steps, while the other cavity needs an acetone treatment to clean oil residuals from an oil leak into the Helium vessel.

HOM ANTENNA COATING STUDIES

In a later stage of MESA it is planned to have a beam current of 10 mA in continuous wave mode. Nb HOM antennas were tested at the CEBAF (Continous Electron Beam Accelerator Facility) [8] with XFEL/TESLA 1.5 GHz cavities and showed that the critical temperature of Nb was reached by a heat load of 43 mW. Since the cooling power for the HOM antenna is limited to 1.25 W, simulations with CST of the heat distribution are ongoing. First result of the simulations are that the pure Nb HOM antennas can heat up over the critical temperature of Nb. If the antenna heats up above its critical temperature, a quench of the whole system would be triggered. A possible solution are coatings with higher T_C superconductors like Nb_3Sn [9] and NbTiN [10, 11]. They have higher critical field, currents and temperatures. Simulations of the coated HOM antennas can provide an estimation of the performance gain of the coated antennas. The coating will be done with our research cooperation partners from University Hamburg and TU Darmstadt which both have the needed sputtering systems and experience which are necessary for the coatings.

CONCLUSION & OUTLOOK

With the cavity from Darmstadt, it could be shown that a surface refurbishment of SRF cavities with the existing clean room at HIM could be performed successfully. However, the drop of the quality factor cannot be explained right now and is part of ongoing research. A following HPR in the next maintenance phase could improve the quality factor but this would imply decommissioning of the successfully running S-DALINAC injector. The refurbishment of the ALICE cavities is ongoing and the first HPR will be performed soon. The simulation for the HOM antennas show the need for coated antennas. The coated antennas will be tested first at the ALICE cavities after their refurbishment.

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