13th Int. Particle Acc. Conf. IPAC2022, Bangkok, Thailand JACoW Publishing
ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-TUPOTK009

DEVELOPMENT OF SUPERCONDUCTING CH CAVITY PREPARATION AT IAP*

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Abstract

Goethe University (GU), Gesellschaft für Schwerionenforschung (GSI) and Helmholtz Institut Mainz (HIM) work in collaboration on the Helmholtz Linear Accelerator (HELIAC). A new superconducting (sc) continous wave (cw) high intensity heavy ion linear accelerator (Linac) will provide ion beams with maximum duty factor up to beam energies of 7.3 MeV/u. The acceleration voltage will be provided by sc Crossbar-H-mode (CH) cavities, developed of Institute for Applied Physics (IAP) at GU. Cavity preparation is researched and optimized towards widely used elliptical multicell cavities. A standardized preparation protocol for CH cavities is researched in collaboration between GU, GSI and HIM on a 360 MHz 19 gap CH prototype. Compared to baseline measurements, a 120°C 48 hour bake produced higher maximum gradient, decreased intrinsic quality factor and a shorter cavity conditioning phase. As a critical preparation step, High Pressure Rinsing (HPR) with ultra pure water will be performed at HIM and is currently in preparation. HPR cycles were successfully tested on a CH dummy with a new nozzle layout that is optimized towards CH cavity geometry.

BASELINE MEASUREMENTS

Coupler Re-Design

Cavity preparation is performed on a 360 MHz 19 gap CH prototype. The cavity was stored for over ten years with inserted nitrogen gas. After first examination, the cavity had a different coupler installed than in past measurement. A new coupler for an expected intrinsic quality factor of 7×10^8 [1] was necessary for the following cold tests at 4K. Therefore, dummy couplers of different coupling strength were build and measured in the clean room at Frankfurt university. Simulations and measurements at room temperature resulted in an intrinsic quality factor of $Q_0 = 4300$. Stem length differs in 1.5 mm increments and three different coupler head pieces were build, see Fig. 1. An ideal coupling strength was found for a dummy coupler length of 128.5 mm with a quality factor of 3.16×10^8. Confirmation measurement of the final coupler of 128.3 mm length resulted in a quality factor of 2.97×10^8.

Figure 1: Dummy parts on the right were tested to achieve critical coupling strength at room temperature. Center dummy components are of similar dimensions to the previously installed coupler on the left and were used to determine the required length adjustment.

Cold Test

Cold tests at 4K were performed with the newly installed coupler. RF parameter results of all referenced tests in this proceeding are summarized in Table 1. An intrinsic quality factor of $Q_0 = 10^9$ and coupling strength $\beta = 2.6$ were measured during low level tests. This put the quality factor of the new coupler to 3.69×10^8 which varies from room temperature measurements. The coupler reacts very sensitive to small displacements. Cooldown to 4 Kelvin from room temperature could have led to displacement by thermal shrinkage. Subsequent power test showed a diminished maximum electrical field compared to 2007 measurements, with a drop from 8 MV/m to 3 MV/m. Intrinsic quality factor decreases at an electric field of $E = 3\,\mathrm{MV/m}$ with the onset of field emission. Analysis via Fowler-Nordheim equation delivers an amplification coefficient greater than $\beta = 3500$ compared to 2007's $\beta = 240$. This increase suggests an accidental insertion of particles. Possible causes are a short ventilation of the cavity during the prolonged storage time period or the dummy coupler tests and installation.

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* Work supported by BMBF Contr. Nr. 05P21RFRB2, HGS-HIRe and HFHF

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Table 1: RF Parameter Results

Paramter	**2007**[1]	**Baseline**	**Post Bake**
Q_0	7×10^8	10^9	8×10^8
β	4.5	2.6	1.5
Q_L	1.2×10^8	2.7×10^8	3.2×10^8
$E_{a,max}[MV/m]$	7	3.7	4.4

120° C 48H BAKE

Bake Setup

As first preparation step a 120° C 48h bake was performed at IAP. The bake setup can be seen in Fig. 2. The cavity was heated with three heatbands to 120°. Two layers of aluminium foil allowed for a more evenly distributed temperature. Temperature was monitored with three platin temperature sensors and a thermal imaging camera. Temperatures were confined in a span from 113° to 132°. A pumping station supplied a cavity vacuum of 2.1×10^{-7} Bar at room temperature. During the bake a rise to 5×10^{-6} Bar with a subsequent descent to 3×10^{-7} Bar over the course of the treatment. After cooldown, the cavity reached a vacuum pressure of 2.5×10^{-8} Bar and was prepared for the next cold test at 4 Kelvin.

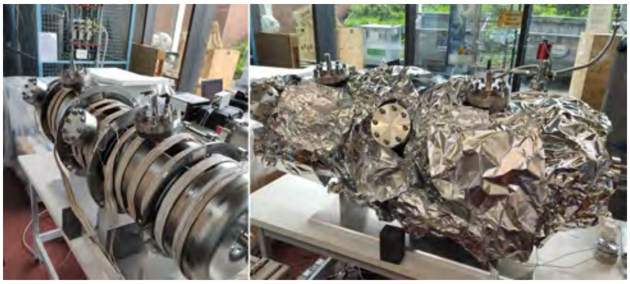

Figure 2: Installation of heating bands on the left. Three heating bands of 5 m length were attached to the cavity. Two layers of aluminium foil were wrapped around the cavity to ensure proper convection.

Cold Test

Compared to the baseline measurements, the conditioning time was shortened to two days from five days. This suggests that bake recipes of this type could be a useful treatment option for multipacting reduction. Low level measurements showed a decrease in intrinsic quality factor to 8×10^8 from 10^9. The electic field limit increased slightly to 3.6 MV/m from 3 MV/m with an onset of field emission at 3 MV/m.

HPR PREPARATION

One of the most important surface treatment options of sc cavities is the High-Pressure-Rinse with ultra pure water. Treatment will be performed in collaboration with HIM in Mainz.

Nozzle Layout

The 360 MHz CH prototype can only be rinsed through the beam line. For this reason, the standard nozzle layout of 15° spray angle is not optimal to cover critical areas where field emission could occure. These areas with high electrical field were identified via CST RF simulations [2] and include all drift tube, stem and girder surfaces, see Fig. 3. CST RF eigenmode simulations scale electromagnetic field inside the cavity to 1 J of field energy. The simulations have been scaled to the electric field of the highest performance in 2007 with $E_a = 7$ MV/m. A critical field of 10 MV/m has been chosen, at which a given surface is considered to be susceptible to field emission. As stated above, all surfaces of stems, drift tubes and girder satisfied the condition. Optimal coverage is achieved with two different spray angles of 27° and 69°. The 27° nozzle was custom made and successfully tested with a CH dummy cavity at HIM. The 69° spray angle is covered by a conventional flat fan spray nozzle.

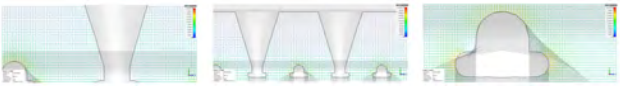

Figure 3: CST simulations of the 360 MHz CH prototype. Left view shows a close-up of the electric field in the stem area is shown. Center view shows an overview of cavity geometry for high electric field surfaces. Right view shows a close-up of the field distribution for drift tube surfaces.

HPR Setup at HIM

Cleanroom at HIM consists of different sections with different ISO-classifications [3]. Through a material air lock, the pre-cleaned cavity is brought into cleanroom 1 with ISO-class 6 , where the cavity is further cleaned with two ultrasonic baths and flanges are dismantled. The HPR cabinet with ISO-class 4 is located between cleanroom 1 and cleanroom 2 with ISO-class 4. The cavity is placed on top of a rotating table that is adjustable on three points. The wand moves vertically during rinsing programs and water pressure up to 100 Bar is supplied by the system from SPEC. After HPR treatment the cavity is placed into cleanroom 2, where the cavity dries under laminar flow and is reassambled.

CH Dummy Cavity Test

Geometric parameters of the CH prototype include an aperture of 25 mm and length of 1050 mm. These dimensions combined with the wand diameter of 14 mm cause the HPR treament to be challenging. The decision was made to practice on a CH dummy cavity of same aperture. All parts of the dummy were cleaned in either an ultrasonic bath or by hand before the assembly in cleanroom 1. The wand showed an offset from the center of the beam axis, see Fig. 4. During table rotation, a slight cavity precession due to a cavity tilt was observed. HPR cycles up to 100 Bar of water pressure were successfully tested. Wand vibrations visibly increase during rinses of the drift tubes. For 90 Bar the maximum vibration amplitude was observed to be smaller than 1.1 mm.

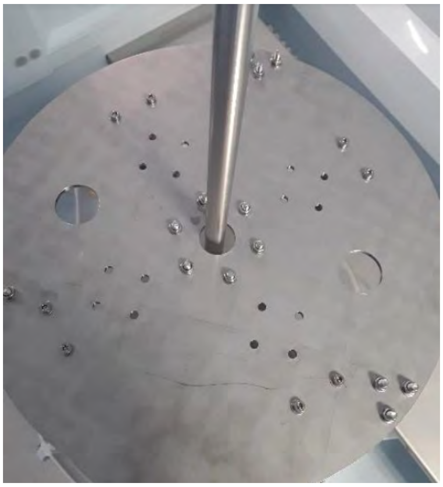

Figure 4: CH dummy cavity during first inspection prior to tested HPR cycles.

OUTLOOK

HPR of the 360 MHz cavity is currently in preparation. A cleanroom mount was developed and build by IAP. The mounting system was installed to the cavity and went through a series of minor adaptations. The cavity was cleaned in the ultrasonic bath of cleanroom 1. It was decided to dismantle before ultrasonic cleaning, due to unknown contamination inside the blind holes of all flanges. Conductivity sink was used to finish the pre-cleaning process before first alignment tests inside the HPR cabinet. The wand was placed closely to the top of the cavity as reference. Cavity precession was not noticeable under rotation, but the wand showed displacement from center. The cavity is currently stored in cleanroom 2 and wand adjustment will be performed after this conference.

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