VERTICAL ELECTRO-POLISHING AT DESY OF A 1.3 GHz GUN CAVITY FOR CW APPLICATION

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Abstract

Superconducting gun cavities for cw operation in accelerators are under study. In 2003 a three-and-a-half cell gun cavity was chemically treated with buffered chemical polishing and tested successfully in a collaboration between Helmholtz-Zentrum Dresden-Rossendorf and DESY. For several years a 1.3-GHz 1.6-cell resonator has been under study, which has been built and tested at DESY and elsewhere. For further studies and optimization the gun cavity needed to be electro-polished, which was conducted at DESY for the first time using vertical electro-polishing. The technical set-up for the vertical electro-polishing and high pressure rinsing as well as the processing parameters applied and the adaptation of the existing infrastructure to the 1.6-cell geometry at DESY are presented.

INTRODUCTION

For CW accelerators several activities are ongoing to develop also superconducting (s.c.) gun cavities for CW application [1,2]. The Rossendorf 3.5 cells gun was prepared at DESY in 2003 by using buffered chemical polishing (BCP) acid in the chemical etching stand of the DESY cleanroom [3,4].

Another s.c. CW gun cavity under study now is the 1.6 cell, DESY Gun 2 16G2, developed in collaboration with TJNL. This 1.6 cells gun cavity has been surface treated by BCP and tested before at TJNL [5]. To study the benefit of EP the DESY horizontal electro polishing infrastructure [6] should be used for this test sequence.

EP SET UP FOR GUN CAVITY

The DESY EP facility is designed for horizontal electro polishing of single and 9 cell 1.3 GHz resonators of Tesla /XFEL type [6]. For horizontal EP the acid is injected into the cavities by nine holes in the centered aluminum electrode and exits on the two beam tubes of the cavity with nearly equal amount of volume. This allows having a homogenous distributed acid flow.

The gun 16G2 is made from one standard TESLA type end cell with beam tube with HOM coupler, power coupler port and a 0.6 cell of middle cell geometry. The 0.6 cell ends with a welded on back plate, made from RRR 300 Niobium. A center hole of 5 mm ID in this back plate allows inserting plugs with different surface coating for study. The inner surface of this 1.6 cell gun is about 10 dm².

The hydrodynamic resistivity of the five millimeter ID hole for the acid flow prevents any nearly homogenous flow distribution in horizontal position like for the single- and nine cell geometries polished so far at DESY. In addition the large back plate needs to be polished homogenously like the cells. Only in vertical position a well-defined acid flow and polishing of the end plate during the EP treatment could be realized for this application.

Modification on EP Bench

The beam tube geometry of gun 16G2 beam is of stand XFEL and TESLA end- cell geometry. This allows connecting the gun cavity at the reference ring of the beam tube to an existing single cell frame for cavity processing in the cleanroom. To realize vertical EP a frame work was build that can be positioned on the EP bench and allows turning the cavity by 180 degrees. The cavity frame is connected to the new frame work for vertical electro polishing (Fig. 1).

After EP the frame can be removed from the frame work and serves for handling, assembly of accessories and high pressure rinsing (HPR) of the cavity inside the cleanroom.

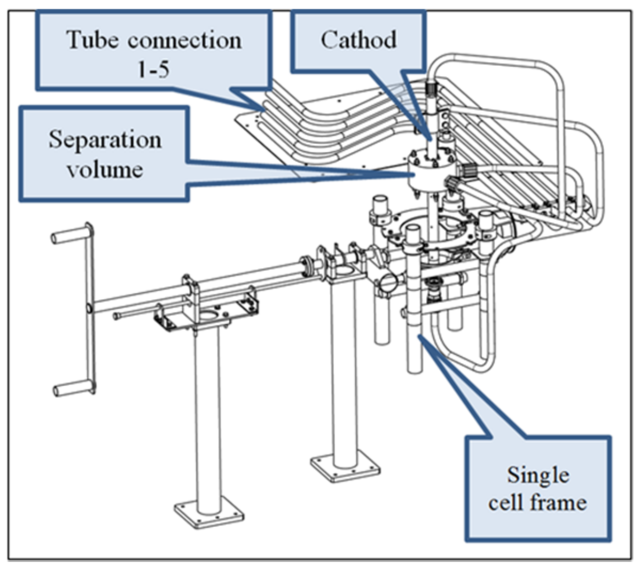

Figure 1: Design drawing of frame work for vertical EP.

Cables from the power supply are connected to the electrode on one side (cathode) and by a copper clamp (anode) directly to the stiffening ring between the cells. No current flows over the rotating bearings of the frame work. All piping's of the horizontal EP for acid charge and discharge, rinsing water and draining as well as exhausted gases of the horizontal EP set up are connected to the gun cavity as well. This allows using the same safety and processing software like qualified for horizontal EP.

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EP Connection Head

For separation of H_2 gas (0.6 l/min) from the chemical reaction and the evaporation of hydrofluoric (HF) from the acid, a separation volume, made from PVDF, is added on top of the beam tube (Fig. 2).

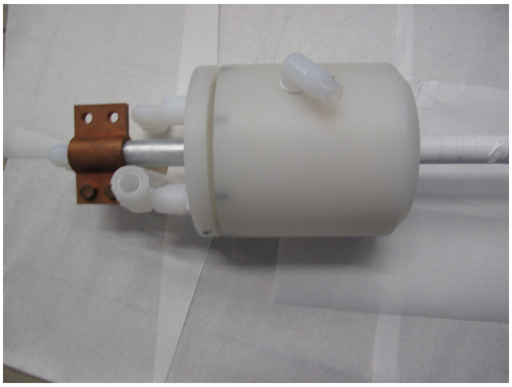

Figure 2: Separation volume for vertical EP with electrode installed.

The electrode is screwed to this separation volume. The bottom plate of the separation box (Fig. 3) guides the electrode in the center of the beam tube into the cavity and serves as counter bearing for the electrode and acid return line.

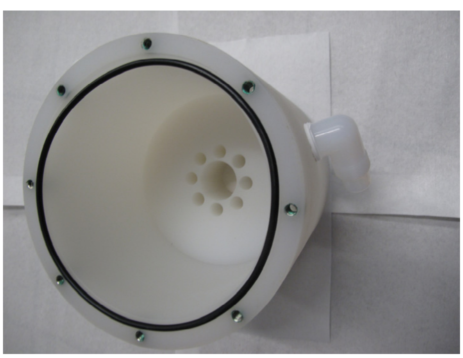

Figure 3: View into the separation box.

The acid feed line (pipe 1) is connected to the electrode while the N2 gas overlay (pipe 3), DI water rinsing pipe (pipe 5) and the connection to the gas scrubber (pipe 4) are connected to the cover plate made from PVDF (Fig. 3). The acid return line (pipe 2) is connected to separation box, about 80 mm below the cover plate (Fig. 4).

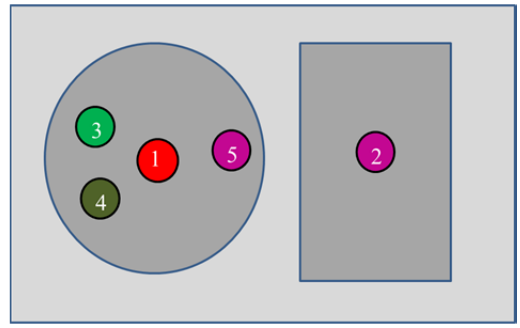

Figure 4: Left side: tube connection on top plate of separation box; right side: connection to separation box.

EP Electrode

Calculations, basing on the 9 cell EP data with 5.8 A/dm^2 [6] show that currents of 50 to 60 A for the 17 V processing voltage applied have to be expected. For safety reasons the power supply of the DESY EP facility was limited to 80 Amperes for this application.

The maximum power of about 1.4 KW at 80 A can easily be handled by the two times 12 KW heat exchanger cooling capacity of DESY EP set up. This allows stabilization of the acid temperature during gun cavity EP in vertical positon without overheating and active cooling of the cells.

Figure 5a: Electrode for 1.6 cell gun cavity EP.

The electrode of 30 mm OD is made from the same 99.99% pure aluminum as the electrode for the horizontal EP. Like in the horizontal case the iris region of the cell and the beam tubes is masked by Teflon tape to reduce removal rate there [7].

The back plate of the Gun cavity is located in the high magnetic field region and request same removal conditions as the equator regions of the normal cells. There for the end of the electrode facing towards the back plate is not masked.

The acid is injected to the cavity volume in two plains of injection holes. Six circular distributed injection holes of 4 mm ID each are located in each plain. At the end of the electrode (Plain 2) the injection holes are oriented under an angle of 30 degrees in respect to the back plate. This will force the acid flow towards the weld region of back plate and cell. The distance between center of back plate and end of electrode is 16 mm.

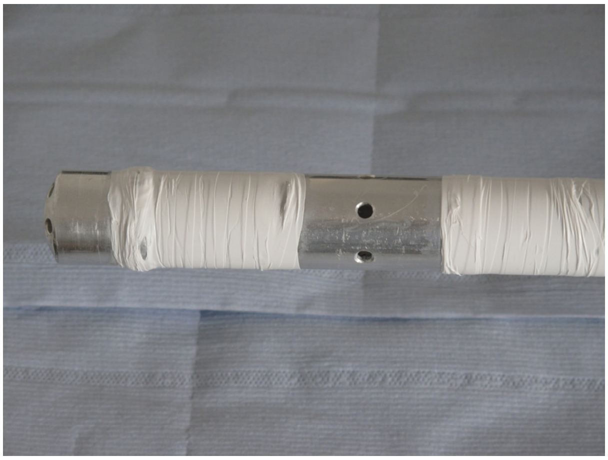

Figure 5b: View on acid injection holes and masking of electrode for 1.6 cell gun cavity vertical EP.

The voltage drop over the 5 mm ID connection to the plug will cause etching instead of polishing [8] of the inside of the hole. The reduction of the RF voltage when plug is installed is of the order of 0.6 percent (Fig. 6) of the acceleration voltage (0.2 MV/m at 33 MV/m acceleration gradient) resp. magnetic field of 35 Gs at 33 MV/m. Due to this reduction it can be assumed that the surface roughness caused by the etching effect in the plug hole will not influence the RF performance significantly.

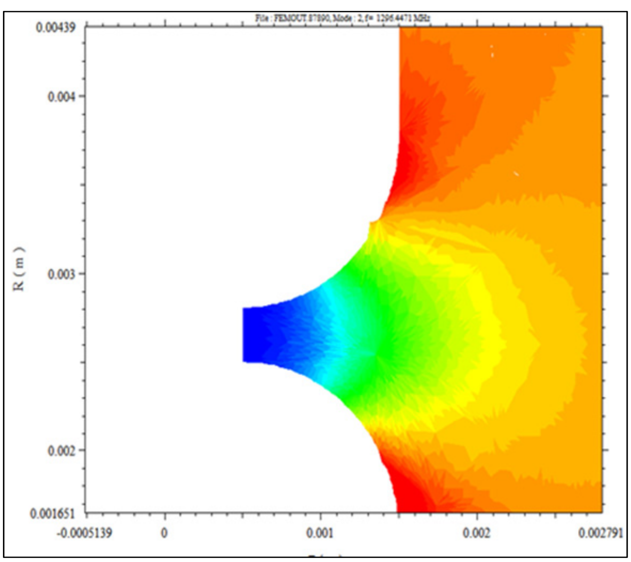

Figure 6: Contour of the electrical field amplitude at plug.

Ep Processing of the Gun Cavity

The steering of the EP was done in manual mode because no software and parameters for gun cavities was in hand. The EP process was set to 17 V constant voltages and a constant N2 gas overlay of 30 l/minute. For safety reasons the power supply of the DESY EP facility was limited to 80 Amperes.

In the first processing cavity 16G2 was polished for two hours in vertical position. The maximum current of 73 A and oscillation of -1 and +7 amperes was reached at 30 °C acid outlet temperatures with an acid flow rate of 8 l/min (Fig. 7) after one and a half hour. During the second vertical Ep of one hour length the maximum current of 72 A and oscillations from – 1 to + 2 amperes established at 30 °C with the acid flow rate set to 8 l/min (Fig. 8).

After removing cavity from vertical EP set up, gun cavity followed the same procedures of cleaning to enter cleanroom and rinsing to 18 MΩcm, as in use for EXFEL and Tesla cavities [9].

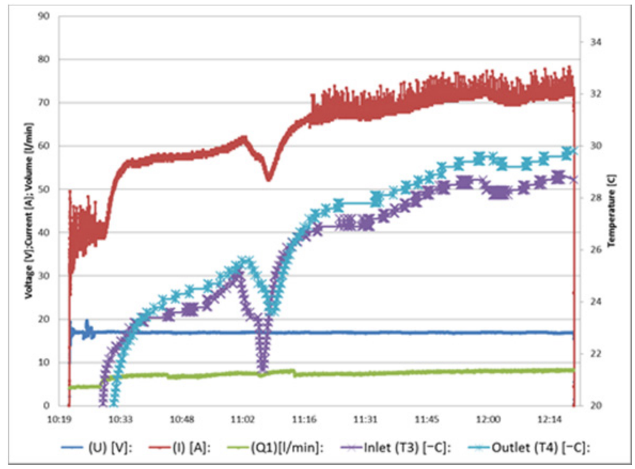

Figure 7: Data of 1st vertical EP on 16G2.

The DESY gun cavity 16G2 had to be treated twice at DESY. After first EP processing it was noticed, right in front of the HPR stand, that the alignment of the cavity in the frame needs to be readjusted to surely prevent collision of HPR nozzle and iris. This misalignment was notice after cavities was drained already in front of the HPR stand. During the readjustment of the gun cavity it could not be excluded that parts of the surface started to dry before HPR after EP was started. The result of the first RF measurement showed high field emission (Fig. 10) after the first EP processing and supports this assumption.

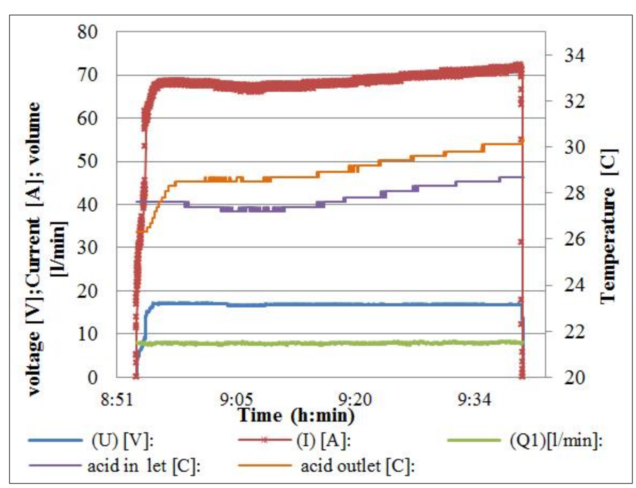

Figure 8: Data of 2nd EP of 16G2.

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For the second treatment the alignment was cross checked and a test installation to HPR took place before cavity is installed to the vertical EP set up. The second preparation was done without any interruption in the processing.

Work Flow after Vertical EP

The work flow applied after vertical EP was identical to the one applied to stand EXFEL nine cell cavities [7]. For high pressure rinsing (HPR) of the gun cavity the HPR stand 1 was in use. As done for single cell application the adapter frame for HPR of 1.3 GHz single cell cavities was installed here for height adjustment (Fig. 9). After EP and installation of accessories in ISO 4 cleanroom, the gun 16G2 is HPR rinsed six times with the stand HPR nozzle head for 1.3 GHz resonators and parameter settings as shown in Table 1.

Table 1: HPR Parameter for Gun Cavity HPR Rinse

Parameter	setting
Pressure	100 bar
Rotation speed	445.000 [deg/min]
Vertical speed	11.000 [mm/min]
Water consumption	≈ 750 l / hour
Processing time	37 Min / pass

During preparation of 16G2 for test two of the lead coated plug was installed during the six passes of HPR. It was found that the HPR at 100 bar leads to erosion of the lead coating, even without direct impact of the HPR water jet. Remaining coating after HPR at 100 bar was still sufficient for the test.

Figure 9: Gun cavity 16G2 installed to HPR stand.

TEST RESULTS

The Gun cavity 16G2 was tested in the vertical insert of DESY hall 3 at 1.79 K with beam tube side facing down wards and the back plate facing towards top plate of cryostat. Radiation sensor was installed to the top plate of the cryostat about 4 m away from back plate.

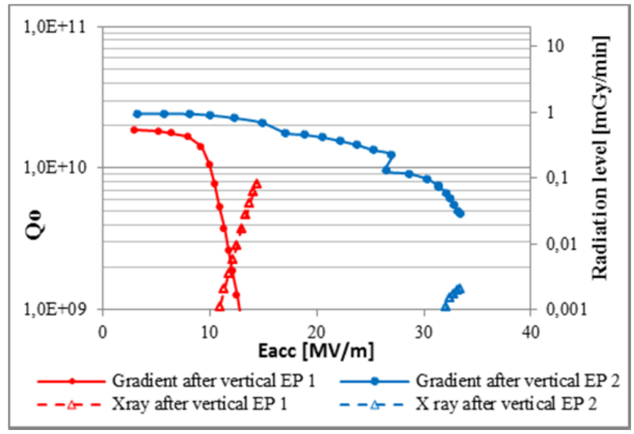

Figure 10: Test results of Gun cavity 16G2 after 1st and 2nd vertical EP.

In test one strong field emission loading of $8*E^{-2}$ mGy/min and limitation by quench at 14 MV/m was found. Presumably this quench was induced by the field emission (Fig. 10), which most probably resulted from residues of drying during the long time delay between draining and start of HPR (see EP processing of the gun cavity)

After retreatment of one hour vertical EP the cavity recovered and reached 33.4 MV/m acceleration gradient (Fig. 10) with low field emission loading of $2*E^{-3}$ mGy/min measured on top plate of the cryostat.

SUMMARY

At DESY a vertical electro polishing set up for superconducting 1.6 cell gun cavities is build and adapted to the existing horizontal EP facility. Vertical EP was done without active cooling of the installed cavity. The work flow of surface treatment, as established for nine cell EU-XFEL type cavities was applied to the gun cavity as well.

The DESY gun cavity 16G2 was polished twice. An acceleration gradient of 33.4 MV/m was reached after debugging the infrastructure and optimization of process flow in the second treatment.

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