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VERTICAL ELECTRO POLISHING OF SUPERCONDUCTING SINGLE- AND MULTI CELL GUN RESONATORS

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Abstract

At DESY activities on surface treatment of superconducting RF gun cavity resonators at 1.3 GHz are ongoing. Due to the small opening on the endplate for insertion of cathodes, no reasonable acid flow can be realized with the existing set up for horizontal electro polishing. To benefit from electro polishing of Niobium surfaces, an adapter to the existing horizontal electro polishing bench at DESY was set up and is in operation now. Vertical EP was applied on 1.3 GHz SRF gun resonators with 1.6 and 3.5 cell geometry. Work flow, process conditions as well as test results of gun cavities treated so far at DESY are described.

INTRODUCTION

The development of superconducting RF gun cavities for CW application is still ongoing. The DESY set up for vertical EP was modified to treat different types of 1.3 GHz SRF gun and normal cavities up to a length of 3.5 cells. In 2003 the Rossendorf 3.5 cells SRF gun was prepared at DESY by using buffered chemical polishing (BCP) in the chemical etching stand of the DESY cleanroom [1,2]. In a new approach, a Rossendorf 3.5 cell SRF gun was prepared by using the vertical EP set up for rinsing with HF and for an EP procedure in 2016.

EP SET UP FOR DIFFERENT RF GUN CAVITIES

The first setup of the vertical EP for 1.6 cell SRF gun resonators (Fig. 1) was built on the DESY system [3], which is designed for horizontal electro polishing of single and 9 cell 1.3 GHz resonators of Tesla /XFEL type [4]. 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 (Fig. 2).

The second RF gun cavity which was installed to the DESY set up was the Rossendorf 3.5 cells SRF gun with a center hole of 14 mm ID at the end of the cavity (Fig. 3). The hydrodynamic resistivity of the 14 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. Only in vertical position a well-defined acid flow and polishing of the SRF gun cavity during the EP treatment could be realized for this application.

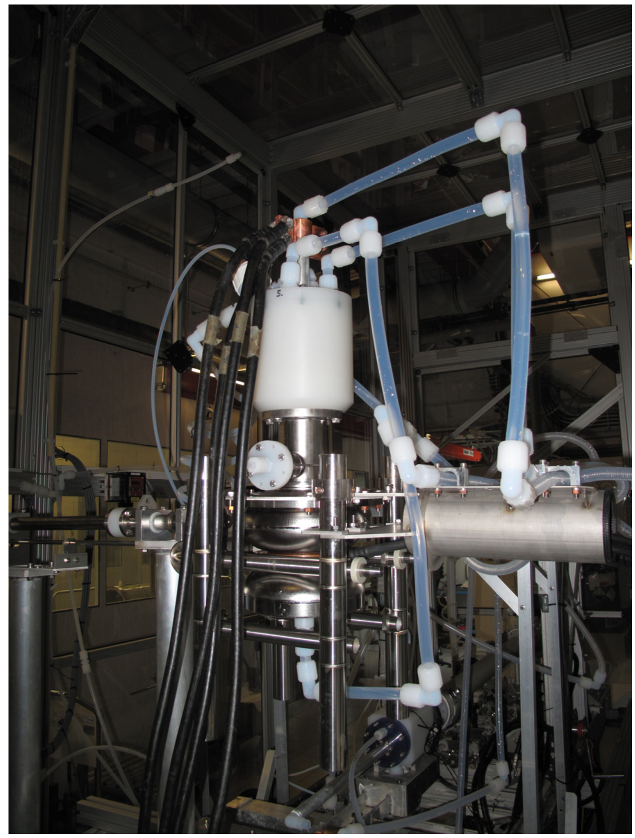
Figure 1: 1.6 cells SRF gun installed in the DESY EP set up.

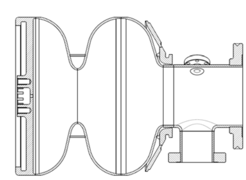
Figure 2: 1.6 cells SRF gun.

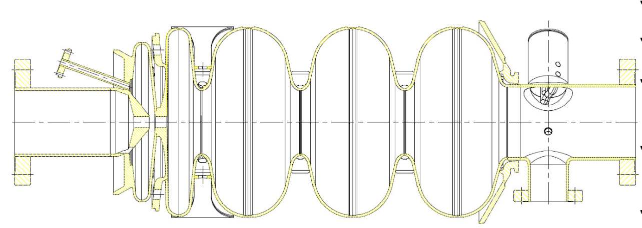
Figure 3: 3.5 cells SRF Rossendorf gun.

To use this vertical EP set up for different types of TESLA shaped SRF gun cavities the DESY set up had to be adapted.

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Modification on Vertical EP Set Up

The 3.5 cells Rossendorf SRF gun is significantly longer and, because of the helium vessel, considerably heavier than the 1.6 cells DESY SRF gun. The vertical EP set up bench has to be adapted in order to be able to also polish these resonators.

The height of the pivot point is fixed, so the EP bench frame had to be modified to make the rotation of the gun possible (Fig. 4). Due to the higher weight of the 3.5 cells SRF gun, the frame also had to be reinforced.

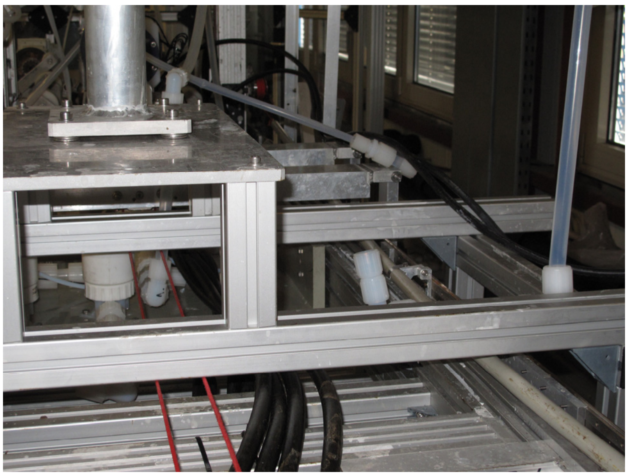

Figure 4: Adapted EP bench frame.

Modification on Rotatable Fork

The previous rotatable fork was suitable for single cell cavity frames only (Fig. 5). The higher weight of the 3.5 cells SRF gun as well as another required fork width for the cavity frame made the construction of an adjustable fork necessary. This new fork is suitable for all 1.3 GHz resonator types up to 3.5 cells and the associated frames (Fig. 6).

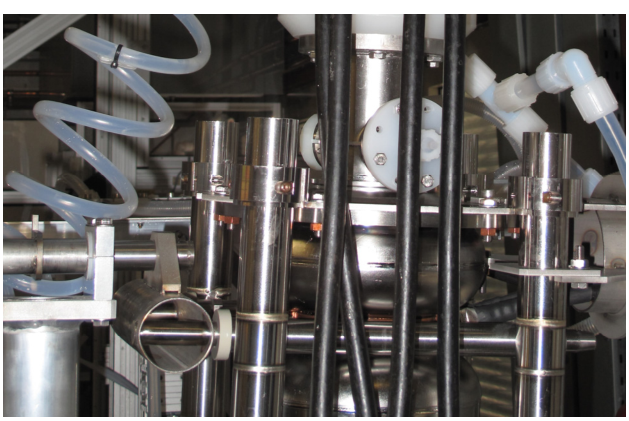

Figure 5: Old version of the rotatable fork.

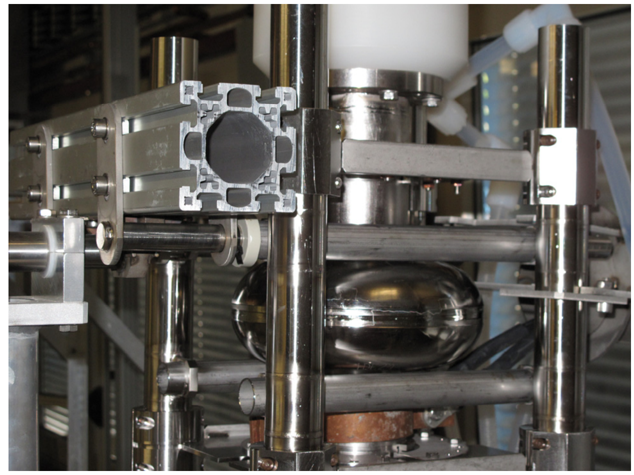

Figure 6: More stable and flexible fork.

EP Cathodes

For each type of resonator, a cathode adapted to the corresponding length of the cavity is required. The cathodes of 30 mm OD are made from the same 99.99% pure aluminum as the cathode for the horizontal EP. Like in the horizontal case the iris regions of the cells and the beam tubes are masked by Teflon tape to reduce removal rate at the areas with the smallest distance between the niobium surface of the cavity and the cathode [5]. The back plate areas of the Gun cavities are located in the high magnetic field region and request the same removal conditions as the equator regions of the normal cells. Therefore the end of the cathodes facing towards the back plate areas is not masked (Figs. 7 and 8).

Figure 7: Cathode for 1.6 cell gun cavity EP.

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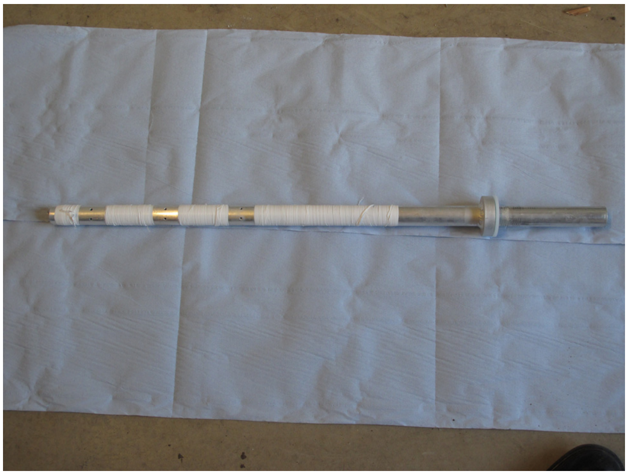

Figure 8: Cathode for 3.5 cell SRF gun cavity EP.

For the 1.6 cells SRF gun the acid is injected to the cavity volume in two plains of injection holes. For the 3.5 cells RF gun there are four plains of injection holes. Six circular distributed injection holes of 4mm ID each are located in each plain. At the end of the cathode 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 plates and end of cathodes is 16 mm.

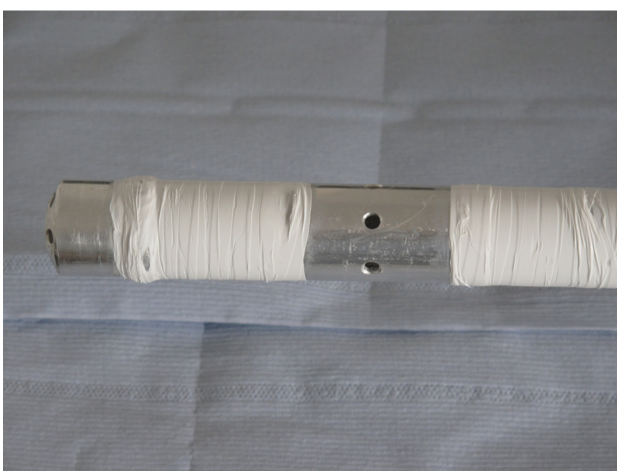

Figure 9: view on acid injection holes and masking of cathode for 1.6 cells SRF gun cavity vertical EP.

Ep Processing of the SRF Gun Cavities

The process control of the EP has to be done in manual mode because no software and parameters for SRF gun cavities are in hand. The EP process is set to 17 V constant voltage and a constant N2 gas overlay of 30 l/minute.

The processing of 16G2 was the third EP at DESY on this cavity and was performed to clean the resonator to replace the plug. During the third vertical EP of one hour length the maximum current of 78 A and oscillations from – 2 to + 3 amperes established at 30 °C with the acid flow rate set to 7.5 l/min.

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 [6].

The Rossendorf RF gun 3RG2 was, after an etching process in 2003 and a HF rinsing process with our vertical EP set up in 2016, polished for the first time at DESY for an hour. During this EP process the current starts at 17V with 80 amperes and a low acid in let (T3) temperature of 17°C. After warming up the acid up to 31°C the process runs smoothly with a current between 188 and 154 amperes. Due to the temperature curve the acid flow rate rises from 6 l/min after 20 minutes to 8 l/min (Fig. 10).

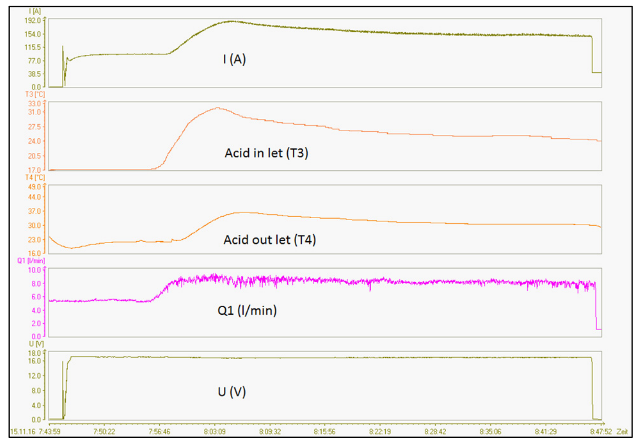

Figure 10: Data of 1st vertical EP on 3RG2

Work Flow After Vertical EP

The work flow applied after vertical EP was identical to the one applied to standard European XFEL nine cell cavities [5]. For high pressure rinsing (HPR) of the SRF gun cavities the HPR stand 1 was in use, which supports the cavity frame from the bottom side. As done for single cell application the adapter frame for HPR of 1.3 GHz single cell cavities was installed here for the 1.6 cells SRF gun. For the 3.5 cells SRF gun a new frame was needed to use the HPR stand (Fig. 11). After EP and installation of accessories in ISO 4 cleanroom, the SRF guns were 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 Parameters for SRF Gun Cavities HPR Rinse

Parameter	1.6 cells setting	3.5 cells setting
Pressure	100 bar	100 bar
Rotation speed	445.000 [deg/min]	445.000 [deg/min]
Vertical speed	11.000 [mm/min]	11.000 [mm/min]
Water consumption	≈ 750 l / hour	≈ 750 l / hour
Processing time	37 min / pass	50 min / pass

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Figure 11: SRF Gun cavity 3RG2 installed to HPR stand.

TEST RESULTS

In contrast to the test result after the second EP (33.4 MV/m acceleration gradient), the test result after the third EP was bad. Only 10 MV/m with a very low Q_0 was achieved (Fig. 12). It is assumed that the material thickness has become so thin after many treatments that the necessary mechanical stability is no longer given. DESY is currently building two new resonators for further studies.

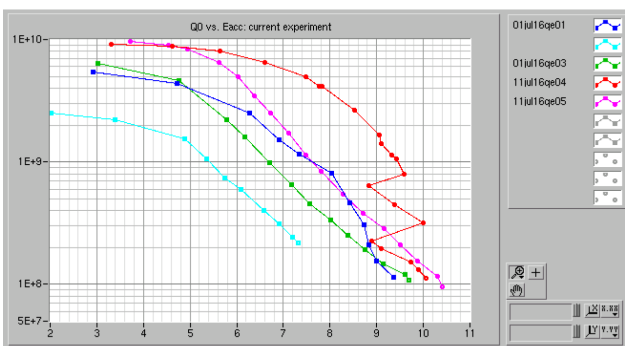

Figure 12: Test results of SRF Gun cavity 16G2 after third vertical EP.

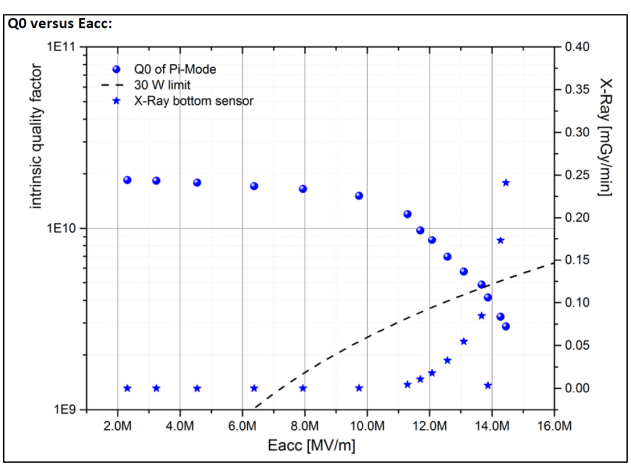

Figure 13: Test result of the SRF gun cavity 3RG2.

The first test of the SRF gun cavity 3RG2 showed strong field emission loading of 0.24 mGy/min and limitation by quench at 14.5 MV/m. Most probably this quench was inducted by the field emission (Fig. 13). After the test it could not be ruled out that a defective cable could have influenced the test. A new test will take place in august 2017.

SUMMARY

At DESY a vertical electro polishing set up for superconducting 1.6 and 3.5 cells SRF gun cavities was built and adapted to the existing horizontal EP facility. Vertical EP was done without active cooling of the cavity installed. The work flow of surface treatment, as established for nine cell European XFEL type cavities was applied to the SRF gun cavity as well.

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

The test of the 3RG2 showed a bad result and will be redone in August.

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