STRING ASSEMBLY FOR THE EU-XFEL 3.9 GHZ MODULE AT DESY

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Abstract

For the injector of the EU-XFEL one so-called 3.9 GHz module is required. This special module houses eight 3.9 GHz s.c. cavities, a beam position monitor and a quadrupole package. The cavities were fabricated and vertically tested as an in-kind contribution to the EU-XFEL by INFN Milano collaborators. The power couplers have been fabricated and conditioned by FNAL. The string assembly took place inside the ISO 4 cleanroom at DESY. A seven meter long alignment and assembly girder for this special string assembly has been designed and fabricated at DESY. The girder facilitates the assembly of the 3.9 GHz resonators with alternating power coupler orientation in ISO 4 cleanrooms. For redundancy and fast action on problems during string assembly, the DESY high pressure rinsing system (HPR) has been modified on the basis of the INFN Milano design for this 3.9 GHz application. The HPR has been qualified by four 3.9 GHz resonators, tested at INFN Milano. The integration of the cavities into Helium vessels, power coupler coupling factor and the power coupler assembly at DESY is qualified by one cavity that has been equipped with Helium tank and a power coupler and tested horizontally.

INTRODUCTION

In 2008 a first 3.9 GHz module [1] was set up for the FLASH accelerator at DESY. Also for the EU-XFEL accelerator, currently under installation, the benefit of higher efficient bunch compression should be applied [2]. As an in kind contribution from INFN Milano a 3.9 GHz module, housing 8 resonators, a beam position monitor and quadrupole magnet unit (BQU) was designed. Fabrication and testing of superconducting resonators as well as manufacturing of the module cold mass and vessel took place under responsibility of INFN. The BQU adapted to the 3.9 GHz cryostat geometry, is taken from the XFEL series production [3]. The setup of the 3.9 GHz cavity string and its integration in the module is done at the DESY Hamburg, as a joint collaboration between INFN Milano and DESY Hamburg [4]. The existing DESY infrastructure developed for 1.3 GHz modules was modified and adopted to the needs of the smaller 3.9 GHz resonators and cryostat.

ADAPTATION OF CLEAN ROOM HARDWARE

In the DESY cleanroom the handling of cavities is based on the usage of cavity frames, lifters and manipulators. These components are designed for 1.3 GHz nine cell resonators of TESLA shape. For the 3.9 GHz string and module assembly, this infrastructure needed to be adapted to the different size of the 3.9 GHz resonators. Ensuring a smooth 3.9 GHz string assembly as well as to provide a reprocessing capability for surface treatment and cleaning during the production and during string assembly most of the existing infrastructure needed to be modified.

Frame for Cavity with and without Tank

For 3.9 GHz cavities without helium tank (undressed cavities) the existing frames from 1.3 GHz single and triple cell treatment were modified. Here only the connecting plate between the frame and the reference rings of the 1.3 GHz cavities needed to be redesigned and exchanged (Fig. 1)

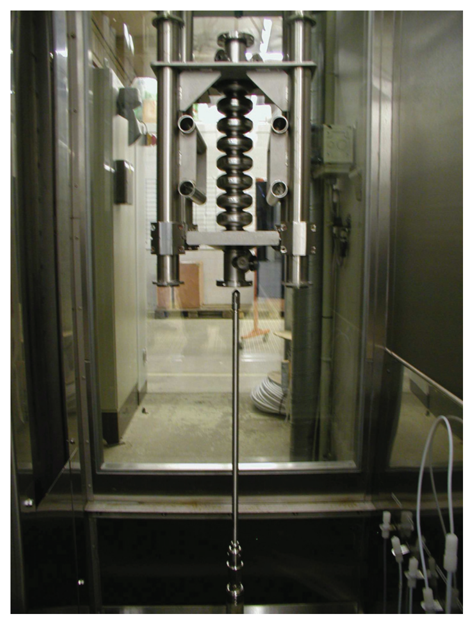

Figure 1: Undressed 3.9 GHz cavity in modified frame during high pressure rinsing.

The 3.9 GHz resonators are tuned by blade tuners where the Titanium bellows, needed for the tuning of the resonator, is located in the middle of the Helium vessel [5]. In addition the smaller diameter of the Helium vessels and thereby the shorter distance between the tank brackets as well as the long Helium pipe connection tubes does not allow to make use of the 4 post frames, that are in use for the 1.3 GHz cavity activities. At the HPR 2 system [6] the positioning of frame and HPR is made by four guide pins on a locating plate. A new frame for the 3.9 GHz cavities dressed with the Helium vessel was designed, with two long and two short posts allowing installation on the HPR 2 (Fig. 2).

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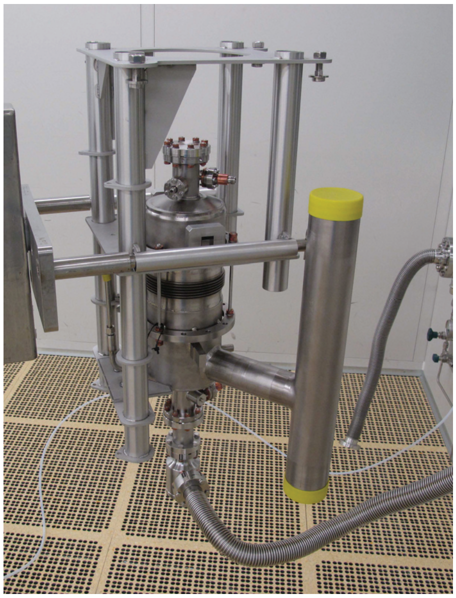

Figure 2: 3.9 GHz cavity dressed with helium tank in frame during leak check.

Adaptation of HPR Stand No. 2

The most critical point for the adaptation of 3.9 GHz cavities to the HPR at DESY was the diameter of the spraying-head. The HPR nozzles head in use for 1.3 GHz has a 40 mm outer diameter, while the 3.9 GHz beam tube and iris diameter is only 35 mm. The HPR nozzle head was re-designed by using the HPR nozzle head geometry developed and tested at the LASA laboratory of INFN Milano.

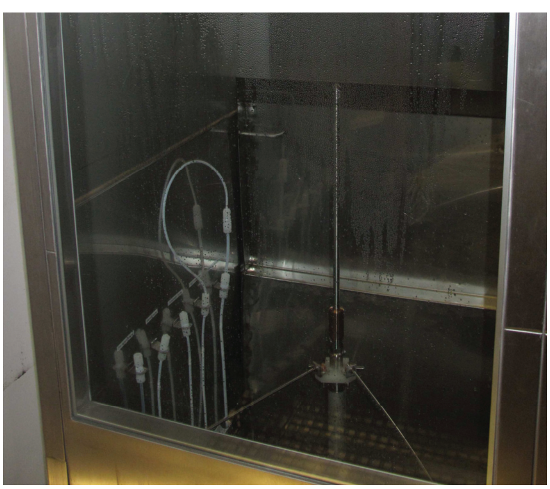

Figure 3: HPR extension for adaptation 3.9 GHz cavities.

With a cavity length of 506 mm and max distance of 8.5 mm between spraying cane and iris of cavity a very precise alignment is required in order not to mechanically damage the cavity surface. The HPR 2 in use for the 3.9 GHz cavity has a fixed spraying cane and water is pressurized by a turbine, resulting in very low vibrations of the cane. The nozzle adapted to the 3.9 GHz diameters replaces the 1.3 GHz HPR head and extends the spraying cane by 640.5 mm to a total length of 2256 mm.

To improve stability of the HPR the cane connection between 1.3 GHz cane and the extension for the 3.9 GHz nozzle is linked to a special framework fixed at the HPR housing (Fig. 3). The six nozzles of 0.2 mm outer diameter (OD) are installed at the top of the cane extension.

The INFN designed nozzle head with 6 sapphire nozzles of 0.2mm OD consumes about 100 l/hour ultra-pure water (UPW), while the minimum volume that has to pass the HPR turbine is approximately 1m3/ hour. Three additional nozzles are installed at the baseline connection of the HPR extension and the existing HPR cane to match the minimum flow requested by the pump and the flow at the nozzle. Rotation speed and vertical speed of HPR are set to the same impact time of the HPR water jet on the niobium surface as it is being in use for the 1.3 GHz cavities (Table 1).

Table 1: Parameter Setting for High Pressure Rinsing of DESY HPR 2 for 1.3 and 3.9 GHz Cavities

Parameter	1.3 GHz	3.9 GHz
Cavity iris diameter ID	78 mm	35 mm
HPR head OD	40 mm	18 mm
No of nozzles	8	6
Nozzle diameter	0.4	0.2
Water consumption	700l/hour	100 l /hour
Adaptation to minimum water flow of HPR turbine	none	additional nozzles 1* 1.0 mm 1* 0.6 mm 1* 0.4 mm
Rotation speed cavity	2000 Deg. /min	7200 Deg. /min
Vertical speed nozzle head	11 mm /min	22 mm /min
Process time for 6 times HPR	6h	2h 20min

QUALIFICATION OF HPR

Ten cavities manufactured and surface treated at industry (E.Zanon) were delivered to INFN right after chemical etching (BCP) [7]. Installation of accessories (HOM coupler antennas, pick up antenna and High-Q RF antenna) before final HPR and RF test at 2K was performed at the INFN labs [8]. The final HPR rinse of six resonators took place at INFN, while four cavities (3HZ004; 3HZ009; 3HZ011; 3HZ012) were sent to DESY for final HPR treatment in order to shorten the cavity preparation times. During incoming inspection of cavity 3HZ004 at DESY it was fond that cavity vacuum was vented to several 100 mbar but even with very carefully leak checking no leak could be detected.

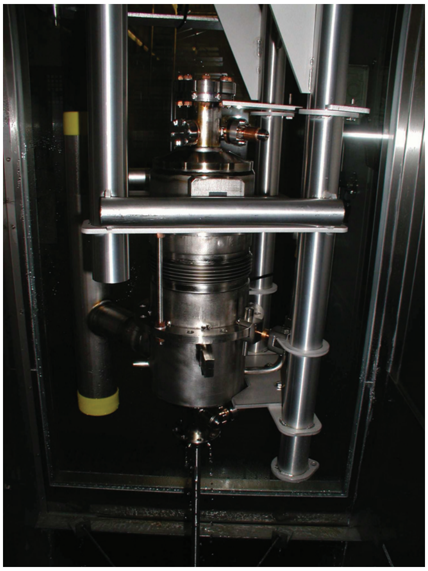

Figure 4: dressed 3.9 GHz cavity during HPR.

The four cavities for qualification of the DESY HPR system were HPR rinsed in six passes with 100 bar system pressure (Fig. 4), measured on the HPR outlet line. Cavities dried in the ISO 4 area of the DESY cleanroom for 12 hours and were handed back to INFN for vertical test after installing the pumping port, establish vacuum at <1E-7 mbar, leak checked and residual gasses analysis.

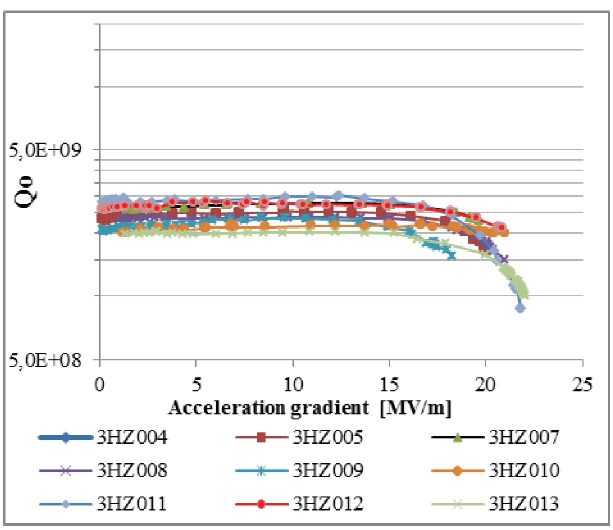

Figure 5: Q/E curve of nine 3.9 GHz resonators after HPR at INFN and DESY.

All cavities passing the final HPR at INFN or at DESY fulfilled the specification (Fig. 5)and reached accelerating gradients between 20 and 22 MV/m with Qo values above $2*10^9$ at 2K [8]. No relevant levels of field emission loading were detected in the tests.

POWER COUPLER ASSEMBLY

Cavities of the 3.9 GHz mode are equipped with fixed power couplers, designed, fabricated and conditioned by the collaboration partner FNAL Batavia, IL, USA. In order to qualify the tank welding process, the final processing of the cavity in industry (the tank is welded after the vertical qualification tests [7]), the power coupler performance and also the power coupler assembly procedures, a horizontal RF took place in AMTF at DESY [9]. After final HPR and assembly of the accessories at INFN, cavity 3HZ010 was handed to DESY for power coupler installation inside ISO 4 cleanroom area.

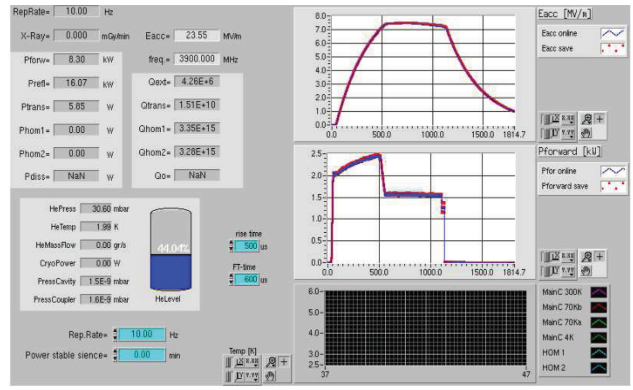

Figure 6: Screenshot of flat top power rise in vertical test for cavity 3HZ010 at 23.5 MV/m. Power scale Eacc in arbitrary values with scale parameter 7.5 = 23.5 MV/m.

The fixed power coupler cold part and a vacuum adaption line for the horizontal test bench were installed to the cavity in the DESY ISO 4 cleanroom. No HPR was applied between handover from INFN and installation of power coupler and pumping line for the horizontal test at AMTF. After completion of cleanroom activities cavity 3HZ010 was equipped with a blade tuner and installed to the test bench.

In the horizontal test (Fig. 6) the cavity fulfilled the requirements for the 3.9 GHz module application [9].

STRING ASSEMBLY PLATFORM

The under floor monorail system of the DESY cleanroom for 1.3 GHz cavity strings does not allow to put posts at a distance suitable for the 3.9 GHz cavity connections.

Figure 7: Assembly of cavity 3.9 GHz string for Module No.: X3M1.

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In addition the flexibility of the mono rail is too large for the tighter tolerances needed for the alignment of the beam tube flanges of NW 40 ID. A rigid girder platform, made from aluminium with two parallel cleanroom suitable side-mounted linear guidance systems have been designed and fabricated (Fig. 7). The girder was mounted on the standard string assembly posts used for 1.3 GHz string assembly with alternating orientation of power couplers from cavity to cavity [2].

Each cavity, the gate valve and the assembly tool for interconnecting bellows, are located on an individual carrier, attached to the parallel linear guidance system of the girder (Fig. 8). The cavity beam axis position of the 3.9 GHz cavities on that girder is set to the same height as the beam axis of the 1.3 GHz module assemblies. The beam quadrupole unit (BQU), containing a beam position monitor, with more than 100 Kg weight, has been positioned on the standard post unit of the 1.3 GHz module assembly fixtures (Fig. 9). Connection between the assembly platform and the BQU post is performed by a turn buckle connector on the bottom of the rail.

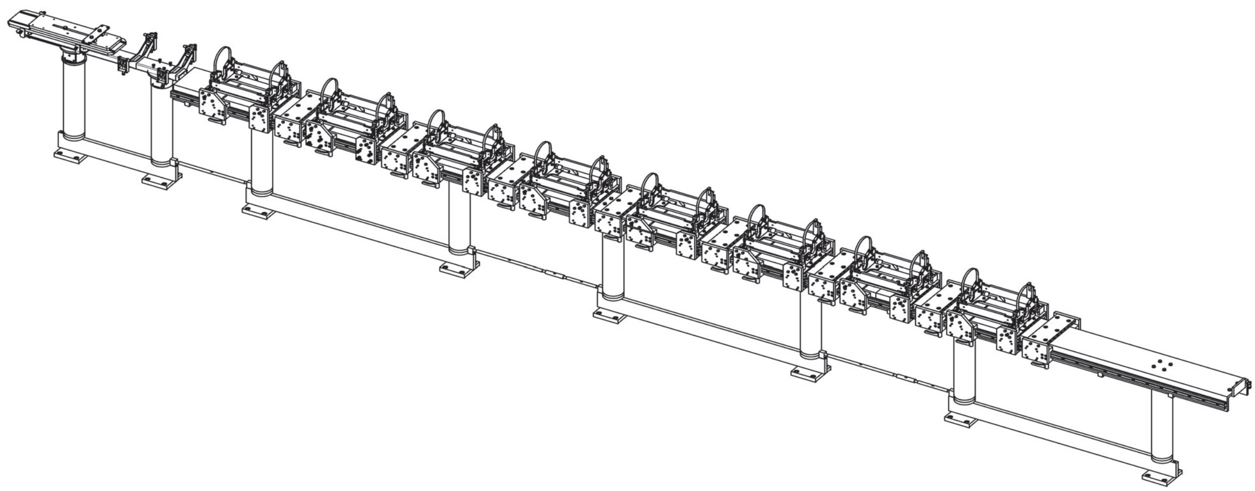

Figure 8: 3-D drawing of the assembly platform for eight 3.9 GHz resonators with alternating power coupler orientation.

Assembly of String X3M1

Due the alternating orientation of the power couplers two spare cavities were on place for rapid substitution in case of problems.

Before connecting the cavities to the string, they undergo an acceptance quality control. Two leaks were found on cavities 3HZ009 and 3HZ011 during this inspection. These cavities were retightened and HPR rinsed in parallel to the ongoing string assembly, to guarantee the continuous availability of two spare components during the operations.

Assembly started with the connection of gate valve to cavity 8 and was completed by the connection of the 3.9 GHz BQU to the string of eight cavities. During assembly it was found that space between bellows convolutions and bellows flanges was too tight to insert the studs after the bellows is positioned at the cavity flanges.

Figure 9: 3.9 GHz string with BQU on right hand side completed.

In contradiction to the standard work flow of module assemblies [10] the studs needed to be inserted to the cavity flanges before gasket and bellows flanges are moved towards the cavity.

Even with very precise alignment of bellow flange and cavity flange as well as very carefully handling, it could not be avoided that bellow flanges rub against the studs, with the potential of producing of particulates.

SUMMARY

At DESY a 3.9 GHz string with eight resonators, a beam position monitor and superconducting quadruple was assembled in the DESY cleanroom of hall 3. For this activity the infrastructure of the 1.3 GHz string assembly was modified. One HPR stand has been adapted to the geometry of the 3.9 GHz and successful qualified by four cavities.

One successful horizontal test of a fully equipped 3.9 GHz resonator took place to qualify the power coupler assembly procedures at DESY. A string assembly platform was manufactured to adapt the existing assembly infrastructure to the needs of 3.9 GHz string geometry. Completion of the first 3.9 GHz string with eight resonators and alternating power coupler orientation took place in June 2015 at DESY. The cryomodul installation for the EU-XFEL injector has started and the test of the completed module at 2K will take place in autumn 2015 in the injector of the EU-XFEL tunnel

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