PRODUCTION PROCESS FOR THE EUROPEAN XFEL RE-ENTRANT CAVITY BPM

C. Simon#, C. Boulch, P. Carbonnier, P. Contrepois, P. Daniel-Thomas, F. Eozenou, Y. Gasser, F. Gouit, O. Napoly, J. Novo, C. Servouin CEA-Saclay/DSM/Irfu, Gif sur Yvette, France
J. Kruse, D. Noelle, M. Schalwat, S. Vilcins- Czvitkovits, DESY, Hamburg, Germany
N. Rouvière, J.-P. Prestel, CNRS, IN2P3, Orsay, France

Abstract

As In-Kind contributor to the E-XFEL project, CEA is committed to the procurement of around one third (31) cold beam position monitors (BPM) of the re-entrant RF cavities type and to the assembly on the Saclay site of the 101 cryomodules of the superconducting linac. Each cryomodule is equipped with a beam position monitor connected to a quadrupole at the high-energy end of the cavity string. The industrial process of those BPMs, used in an ultra-clean environment at cryogenic temperature, includes several steps and involves a quality control in collaboration with industrial partners. This paper describes the different steps of the re-entrant cavity BPM fabrication process: machining, copper coating, thermal treatment, EB welding, cleaning and mounting in clean room on the quadrupole. Problems encountered and the lessons learnt will be also reported.

INTRODUCTION

The European XFEL [1] is an X-ray free electron laser user facility currently under construction in Hamburg, Germany. This accelerator has a superconducting 17.5 GeV main linac based on the TTF technology and is composed of 101 cryomodules including the injector module. Each module includes a string of eight 1.3 GHz RF cavities, followed by a BPM connected to a superconducting quadrupole. As In-Kind contributor to the E-XFEL project, CEA is committed to the integration on the Saclay site of the 101 cryomodules [2] as well as to the procurement of the magnetic shielding, superinsulation blankets and 31 cold re-entrant cavities beam position monitors (BPM). The others cold BPMs will be button BPMs and are not discussed here [3].

These re-entrant BPMs cavities have been studied and prototyped at CEA [4]. They are composed of two parts of stainless steel welded together to form a resonator. The production of the re-entrant cavities has been transmitted to a company named Gavard & Cie which is in charge of mechanical fabrication. Pickups and RF re-entrant BPM cavities are provided by the CEA/Saclay and sent to DESY to be mounted on the quadrupole inside an ISO4 cleanroom.

In this paper, the industrial process is reported with a description of different steps. In addition, difficulties met during production are discussed. Design and architecture of the re-entrant BPM electronics, developed by a collaboration of CEA/Saclay/Irfu, DESY and PSI, are not discussed here [5].

#claire.simon@cea.fr

GENERAL DESCRIPTION

In the XFEL accelerator modules, 31 cold re-entrant cavity BPMs will be installed. Independent of the type, all cold BPMs will have a common mechanical interface and the same specifications presented in Table 1.

Table 1: Cold BPM Parameters

Parameter	Value
Beam pipe diameter	78 mm
Length	170 mm
Single bunch resolution (RMS)	50 µm
Operation range for maximum resolution	± 3 mm
Transverse Alignment Tolerance (RMS)	300 µm

The re-entrant BPM will be connected to a cold quadrupole at the high-energy end of the cavity string as illustrated Fig. 1.

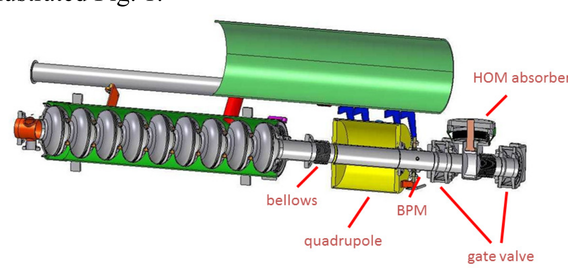

Figure 1: Layout of the XFEL cryomodule downstream end.

The length of this BPM is 170 mm to respect constraints imposed by the cryomodule and its aperture is 78 mm (see Fig. 2). It is composed of two parts, in stainless steel, welded together by electron beam welding (EB). Flanges are machined out of the same blocks to get the alignment tolerances. The alignment is done by dowel pins with respect to the cold magnet.

Each antenna, which is a combination of stainless steel, molybdenum and alumina Al_2O_3 ceramic brazed, is mounted on the cavity via a CF16 flange. They have to pass cryogenic shocks and to fulfil the conditions of Ultra High Vacuum (UHV). They have been manufactured by SCT (Société des Céramiques Techniques) [6]. Four copper-beryllium radio-frequency contacts are also welded in the inner cylinder of the cavity to ensure the electrical conduction between the feedthrough inner conductors and the cavity.

ISBN 978-3-95450-141-0

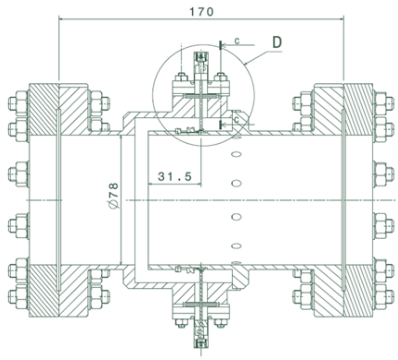

Figure 2: Drawing of the re-entrant cavity BPM.

FABRICATION PROCESS

Two prototypes have been produced by different companies and a pre-series of one + six units has been ordered to validate the process. The 30 BPMs have been machining together but EB welding is done in series of 6.

Gavard & Cie is in charge of machining and the whole of market of re-entrant BPM under the supervision of the CEA. Major aspects of going to industrial production of re-entrant BPM are summarized in Table 2.

Table 2: Fabrication Process of Re-entrant Cavity BPM

Process	**Carried out by**
Firing 950° for 2 h	Industry
Machining of feedthroughs	Industry- Specialist of brazing
Machining of two parts composing the RF cavity	Industry
Cu plating	Industry
Vacuum firing	Industry
US bath	Industry
RF contacts welding	Industry
EB welding	Industry
Final machining	Industry
Cleaning + RGA + leak test	CEA
N2 shocks on feedthroughs + leak test	Industry + CEA
RF measurements	CEA
Packing to transport to DESY	CEA
Final cleaning + RGA	DESY
Mounting	DESY

Stainless steel material has been ordered according the DESY specifications. In order to avoid hydrogen outgassing, a heat treatment at 950 °C for 2 hours according the UHV specifications is applied to the two already machined parts, composing the BPM cavity. Since it is connected to a cold magnet, the BPM will be at a temperature close to the 4 K level and will be mounted in a clean room. For an effective cleaning, twelve holes of 5 mm diameter are drilled at the end of the re-entrant part.

To check the machining, Three-Dimensions (3-D) and roughness (Ra) measurements are carried out at the manufacturer.

Copper Coating

To reduce the cryo-losses, a 12 µm thick copper coating is deposited on the inner beam pipe. A thickness of 1 µm of Nickel is used to do the adhesion with the stainless steel. This copper coating is carried out by electro deposition in an acid bath by Protec [7]. Before to validate this process, several tests have been done:

- adhesion test by thermal shock
- desorption measurement
- electrical resistivity measurements and RRR calculation

Special tools (Fig. 3) have been manufactured to protect the parts no copper plating and to avoid the using of resin mask which is prohibited in a clean environment.

Figure 3: Copper coating BPM tools.

After the copper coating process, thickness measurement is done on each piece.

To check the copper surface and test the contact of copper and steel, pieces are put in an Ultra-Sonic (US) bath with ultrapure water and a vacuum firing at 300 °C for one hour is carried out. The acceptance is done by visual check inspection.

Weldings

Aspit [8] is in charge of weldings. Four RF contacts in CuBe are welded on the re-entrant part.

The two parts composing the BPM are mounted together with a special tool (Fig. 4) using some cupped washers to keep, during the Electron Beam (EB) welding, a coaxiliaty around 50 µm between the two blocks. During the welding, measurement with an electronic comparator is done.

Figure 4: BPM mounted with its equipment used during EB welding.

Checking and Acceptance Tests

The industry is responsible up to the delivery of BPMs to Saclay. There, some acceptance tests are performed:

- Visual Inspection
- Leak test
- Residual Gaz Analysis (RGA). Acceptance criteria are given by the Ultrahigh-vacuum conditions [9]
- RF measurements as shown Fig. 5

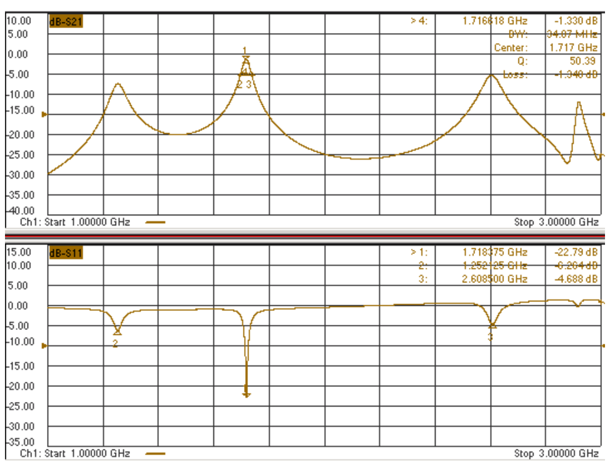

Figure 5: RF characteristics.

The RF measurements are done in laboratory and are presented in Table 3.

Table 3: BPM RF Characteristics

	Frequency (MHz)	Q_{ext}
	Measured in lab.	Measured in lab.
Monopole mode	1253	23.5
Dipole mode	1720	50.5

Frequencies of monopole and dipole modes of twelve first BPMs have a difference around 2 MHz maximum and the variation of the quality factor is well in specification.

Once the acceptance tests validated, the re-entrant BPM is sent to DESY to be assembled with the quadrupole.

Preparation and Mounting

At DESY, BPMs are cleaned in an ultra-sonic bath, rinsed by ultra-pure water and controlled by vacuum leak check and RGA by DESY MDI group. Cleaning and assembly of components requires cleanliness of UHV conditions as well as condition of particle free surfaces.

They are pre-assembled and mounted, by MKS group, with the quadrupole unit in an ISO4 cleanroom. HPR (High Pressure Rinsing) and RGA are carried out on the unit. Then, feedthroughs are mounted on the BPM and a test, to check the contact between the CuBe spring and the antennae pin is done with an ohmmeter.

After assembling, the BPM Quadrupole Unit (BQU) is put in a special box made for a transport under ISO4 conditions and for being able to absorb shocks during the transport to CEA Saclay where it will be mounted on the string cavity [10].

INDUSTRIAL FABRICATION

During the industrial process, several difficulties occurred:

On the prototypes, the coaxiality was around 70 µm while a coaxiality around 50 µm was asked. A special tool was made to equip the BPM during the EB welding and to guarantee a coaxiliaty in the specification.

Concerning the copper coating some problems appeared:

- On the first prototype, varnish was used to protect parts no copper coating. Even with a good cleaning, some black particles stayed. That's why a special tool was made to avoid the use of resin.
- On the second prototype: a problem is occurred during the HPR. After the HPR, drying is done "naturally" (no drying with compressed air is used). Due to the oxidation, some black marks have been seen on the copper coating. Copper coating was damaged. Some added tests have been carried on others BPMs to check the copper coating but no problem occurred. We didn't understand what happened.

On the prototypes, some problems are appeared during the mounting of antennae. If there isn't touch between the antennae and the RF contact, RF characteristics can be modified. This contact need to be checked with an ohmmeter.

Around 10 % of the feedthroughs production has a black area on the flange where a graphite frame was used during the brazing. Hypothesis is that some of them underwent cementation (carburation). The analysis of those pickups confirmed that carbon elements were more abundant in the "black" part. After, the cleaning of those feedtroughs with a detergent ElmaClean 115C, black traces are appeared on the flange where the graphite frame was mounted. A machining and etching were done to remove black parts then by a cleaning in an US bath with ethanol.

On the first prototype, frequencies shifted by around 10 MHz in comparison with the simulation results and the

ISBN 978-3-95450-141-0

measurements done on the re-entrant BPM installed on the FLASH linac [5]. This difference could be due to the cavity geometry. That's why on the next ones, tolerances were tightened and RF measurements are used in the quality control process of the series.

FABRICATION

Several prototypes have been manufactured by different companies to qualify them. To avoid different problems, a strict control is carried out for the different steps during the fabrication process.

In 2009, one first prototype has been installed in a prototype cryomodule.

Since the first prototype, CEA Saclay received thirteen BPMs, seven BPMs are already mounted on quadrupole and are in a BQU. Four BPMs are already mounted in a cryomodule. Figure 6 shows a re-entrant BPM mounted on the cavity string.

Figure 6: Re-entrant BPM mounted in an XFEL cryomodule.

CONCLUSION

Strict quality control has to be carried out for the different steps to receive BPMs within the performances. The mostly of problem are now solved and the mounted in the BQU can continue. Several BPMs are already mounted in some BQU and on cryomodules. Production of re-entrant BPM will be finished at the end of September.

ACKNOWLEDGMENT

We thank our colleagues of MDI and MKS groups from DESY for their support and their fruitful discussions. We would like to thank the different companies with which we worked on this project and find new solutions to improve the fabrication process. We, also, wish to acknowledge our colleagues from CEA Saclay for their advices and their help on this project.

REFERENCES

[1] E. Vogel et al., "Integration of the European XFEL accelerating modules", SRF 2013, Paris France 2013.

[2] C. Madec et al., "The Challenge to Assemble 100 Cryomodules for the European XFEL", SRF 2013, Paris, France 2013.

[3] D. Lipka et al., "Button BPM Development for the European XFEL", DIPAC'11, Hamburg, Germany, 2011.

[4] C. Simon, et al., "Performance of a reentrant cavity beam position monitor", Physical review special topics – accelerators and beams 11, 082802 (2008).

[5] C. Simon et al., "Status for the re-entrant cavity Beam Position Monitor for the XFEL project", BIW10, Santa Fe, United States.

[6] Société des Céramiques Techniques, http://www.sct-ceramics.com/

[7] Protec, http://www.protec-groupe.com/

[8] Aspit, http://www.aspit.fr/

[9] U.Hahn, K. Zapfe, General DESY UHV Guidelines for Vacuum components, DESY Report, Vacuum 005/2008.

[10] M. Schalwat et al., "Set up of production line for XFEL beam position monitor and quadrupol units for cavity string assembly at CEA", SRF13, Paris.