STUDIES ON TRANSPORTATION OF SUPERCONDUCTING RESONATORS AND BEAM POSITION MONITOR - QUADRUPOL UNITS FOR THE XFEL PROJECT

A. Schmidt, A. Matheisen, R. Bandelmann, H. Brueck, J. Schaffran,
Deutsches Elektronen Synchroton DESY, Hamburg, Germany.

Abstract

For the XFEL project industrial companies in Germany and Italy are in charge of the cavity fabrication and preparation. For the radio frequency acceptance test these cavities have to be transported to the DESY site in Hamburg without losing the performance. The XFEL Beam Position Monitor and Quadrupol Units (BQU) are completed in the DESY clean room. The cavities and the BQU are handed out in the status “ready for assembly” to the string assembly site at CEA Saclay in France. These components have to be transported without risk of damages or reduction of performance. To ensure that the transports over European routes do not influence the performance of cavities or are origin of particulates inside the BQU, individual transport boxes for super conduction cavities and transport fixtures for the BQU are designed and tested.

INTRODUCTION

The cavity fabrication and surface preparation for the XFEL project is contracted at two industrial companies, E. Zanon in Schio, Italy and Research Instruments in Bergisch-Gladbach, Germany. The assembly of the module strings, consisting of eight cavities and one BQU will take place in the cleanroom of CEA Saclay in France. For transports between these companies, standard trucks will be used. Some frequent transport distances will exceed 1000 km.

Test equipment for transportation studies on valuable goods can be found at the Institute BFSV in Hamburg Germany [#1]. Beside damage-free transportation, DESY has to ensure that the performance of resonators will not be influenced by these transportations. Commercial available transport cases as well as a special designed transport unit for BQU were studied on a test bench and during real transport to validate safe transportation procedures.

TRANSPORT CONDITIONS

For the XFEL in the 17GeV version 100 modules have to be assembled at CEA Saclay. 800 resonators in batches of up to four cavities need to be transported from Italy, respectively middle of Germany to the test bench at DESY as pay load. Batches of eight tested resonators and one BQU will be sent to CEA Saclay. For these transports a maximum of technical safety at a minimum of costs is required, On the test bench of the BFSV institute in Hamburg it was shown that cavities and accessories like High Q- or HOM antennas can be exposed individually to shock waves of up to 6 g without affecting the mechanical properties (geometry of the cavities) [1].

Transport Conditions

The cavities are handed to DESY in the status ready for acceptance test. The surface treatment by final EP or BCP flash [2] is completed at industry. The cavities are equipped with their Pick up antenna and HOM antennas that remain on the cavity in the module. For the vertical test at 2K a high Q test antenna is installed on the power coupler port (Fig. 1). These antennas, as well as the beam tube flanges, remain on the resonators until the string assembly.

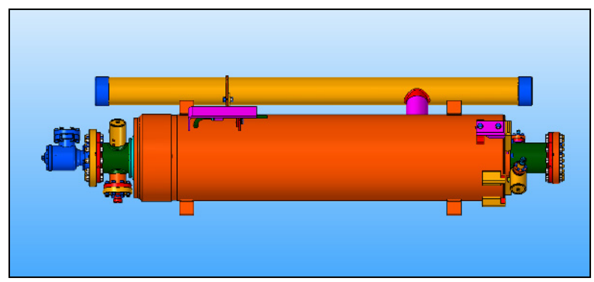

Figure 1: XFEL cavity in helium tank full equipped.

The BQU units are completed in the ISO 4 area of the DESY cleanroom (Fig. 2). A cleaning for ISO 4 clean rooms of the sophisticated BQU cannot be done in an economical way.

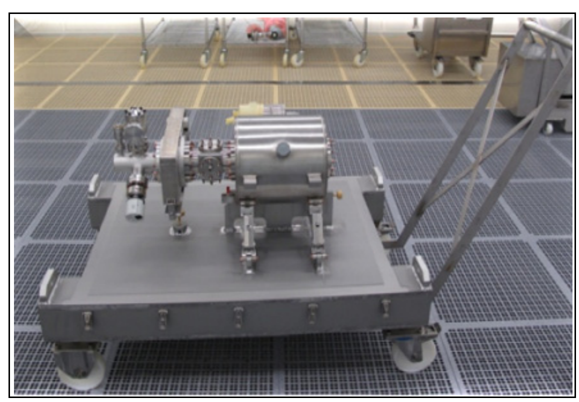

Figure 2: BQU completed inside ISO 4 cleanroom.

The unit is hermetically closed by a cover hood inside DESY ISO 4 area at DESY (Fig. 3). To ensure that the box will be free from differential pressure at any time, even when heated up during cleaning processes, an inline particle filter is connected to the hood.

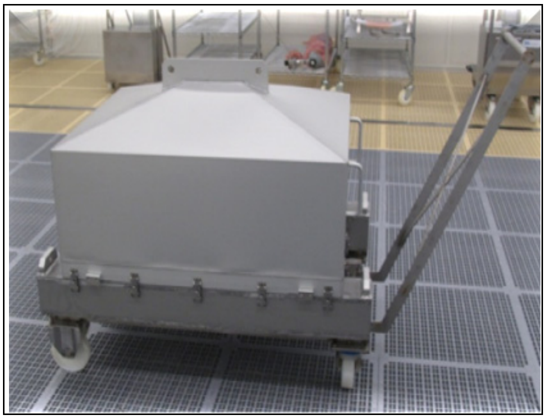

Figure 3: BQU located on a transport trolley and covered by transport hood.

This hood is cleaned in the CEA cavity washer [3] before hand over to ISO 4 area. After entering the ISO 4 region the transport hood is removed and the BPU is taken away from the transport frame.

Transport Boxes

Up to 40 cavity transport boxes will be needed to have a continuous flow of cavities at the different stations during the project time. For economic reasons the boxes are designed for payload transports on standard trucks. In collaboration with industrial company Amptown cases® [#2] these transport boxes for transport of cavities were developed (Fig. 4).

For easy loading the cavities into the box, the cavity will be held on a handling cart at the helium service pipe. They are lowered into the boxes and settled on the lower prism covered by felt. Horizontal positioning of the cavities inside the box during transport is reached by fixing the connecting tube between service pipe and helium tank in an adjustment sit on the lower prism. Closing the box presses the upper prism on to the Helium vessel and fixes the resonator.

Figure 4: View on the XFEL cavity packed into the transport case.

Sandwiches of different foams are glued on the box and fix the upper and lower prisms for damping (Fig. 5). These sandwiches were optimized according to the test results achieved on the test bench at BFSV.

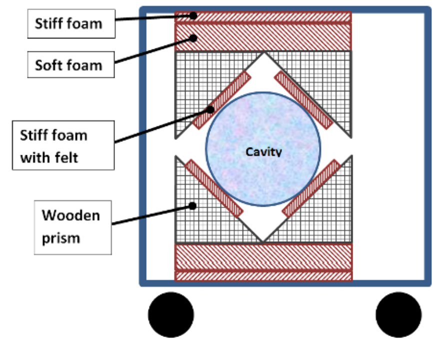

Figure 5: Foam concept of the transport case.

Transport Frame for BQU Transport

The transport units of BQU are limited to a maximum number of 100. The weight of more than 130 kg per BQU and the size of the transport hood covering the BQU do not allow using the foam based solution for the cavity transport. A transport frame, equipped with commercial designed steal wire dampers was built to hold the sealed BQU (Fig. 6). The absorbers are designed to absorb shocks corresponding to a drop down of 50mm height.

Figure 6: BQU transport frame with steel wire dampers.

TEST SEQUENCES

Several vibration and transport scenarios are available on the test bench at the BFSV institute:

- Constant ramping from 200 Hz down to 4 Hz allows studying resonances in the applied system.
- The transport on normal roads and with standard trucks can be simulated. An equivalent of 1200 km transport on road can be represented by a simulation of three ours and allows analysing the long-time behaviour of the transport units.
- Defined shocks of 4, 5 and 6 g in positive and negative direction allow defining the damping coefficient of the system under study.

The applied tests are standardized in various norms e.g. ASTM D4169; DIN EN 60068-2-6 or DEF STAN 00-35. A free amount of sensors allow analyzing the damping factors and the resonance spectra.

The test sequences (Table 1) are started by analyzing the resonances of the system under study. In the next steps a transport simulation and single shock tests are carried out. At least another resonant search is done, to see if the simulations are harmful to the system and resonance shifts can be observed.

Table 1: Test sequences of transport study

Resonance search	200 Hz to 4 Hz
Transport simulation Truck / Trailer, Level II	Equivalent of 1200 Km in three hours
Single shock waves	+ - 4g; +- 5g; +- 6g
Resonance search	200 Hz to 4 Hz

This test sequence is applied for all simulation runs to optimize the damping capability of the boxes. For comparison a cavity without any damping elements was tested as well (Fig. 7 and 8).

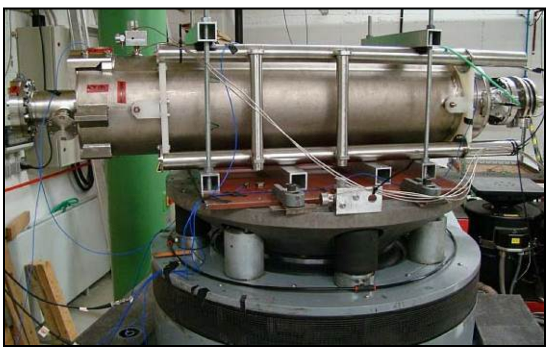

Figure 7: Cavity C24: installed into a handlings frame and fixed directly on the vibration table without any damping elements.

Figure 8: Cavity Z138 packed in transport case with different foam damping elements and rigged on simulator.

TEST RESULTS

Impact of Transport on Cavity Geometry

The analysis of mechanical deformations of resonators is made by comparison of fundamental mode frequency and variation of mode spectrum. For the measurements the resonators are tuned and a field profile of more than 96 % is established.

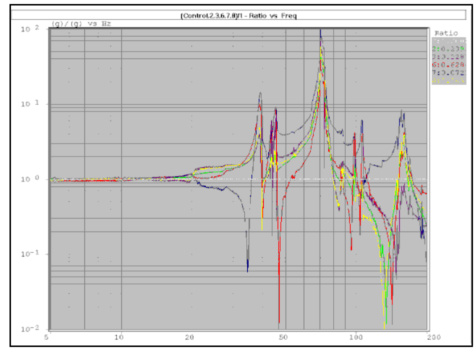

Figure 9: Resonance frequencies measured on cavity C24.

Cavity C24 -without any damping elements- showed sharp resonances at 40/45, 70, 110 and 180Hz (Fig. 9). A shock wave of 6 g impact resulted in a response resonance of the beam tubes of 14.8 g (short beam tube side) resp. 12 g at the cavity long beam tube side (Fig. 10). No changes in frequency or mode spectrum were observed, even when shock of more than 10 g are introduced to the cavity

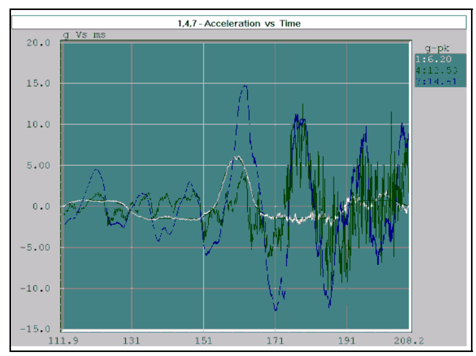

Figure 10: Damping and acceleration factor of cavity C24.

For the Cavity AC138 -packed into the optimized transport box- smooth resonances at 15Hz were dominating. Resonances at 55 and 70Hz were found as well but in a much more reduced form (Fig. 11). Shocks of 6 g strength were damped down to 2 g by the foam sandwich chosen (Fig. 12).

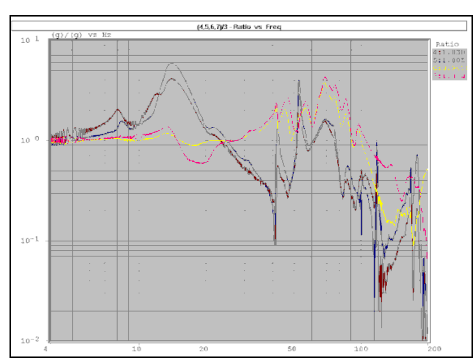

Figure 11: Resonance frequencies measured on cavity AC138.

Mode spectrum measurements of cavity AC138 showed no significant changes before and after a vibration test.

Flanges, which were not properly tightened, started to loosen during transport simulations.

The box itself was not damaged during the tests and the hinges and wheels withstood the loaded forces.

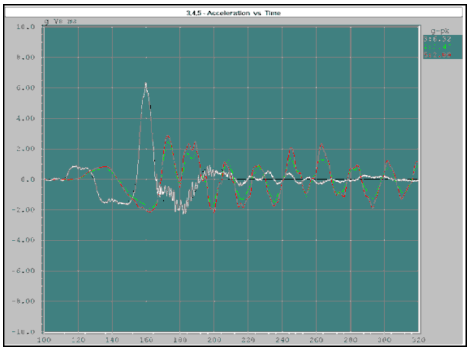

Figure 12: Damping and acceleration factor of cavity AC138.

RF Measurements

The acceptance test at DESY is the final acceptance level for XFEL cavities coming from industrial fabrication. One of the most import goals of the cavity transport investigations is the preservation of the cavity parameters (gradient and field emission levels). It had to be shown that the transport boxes allow transportation over 1000 km without influence on the cavity performance.

Cavity AC138 was qualified in the vertical acceptance test to 35 MV/m with field emission onset level at 21 MV/m. The radiation level of 1Exp -2 mGy/min is reached at 28 MV/M.

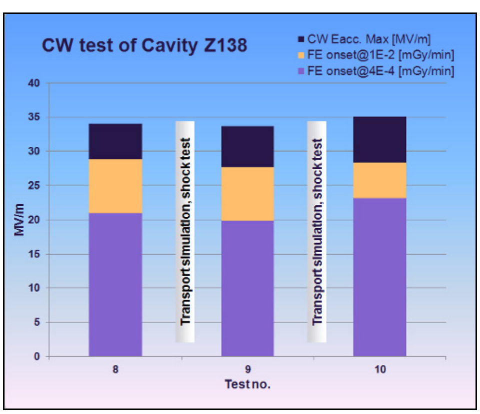

Figure 13: RF test results before, in-between and after transport tests.

The cavity, removed from the vertical insert and packed into a transport box, was tested according to the test sequences given in table 1. After each full cycle of transport test the cavity was measured in the vertical insert again (Fig. 13 and 14).

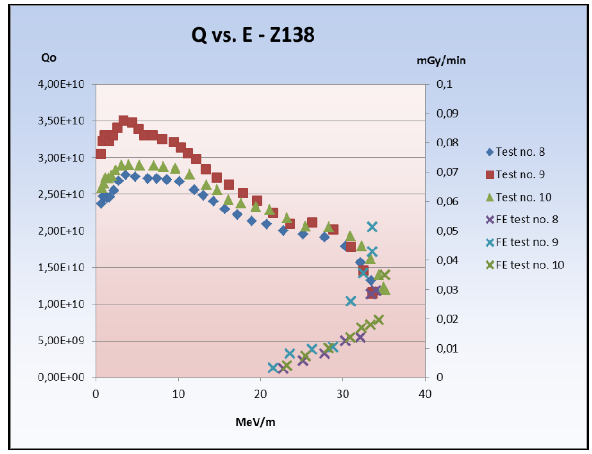

Figure 14: Q vs. E curve with Fe onset of test no. 8, 9 and 10.

After two complete test cycles no change in maximum acceleration gradient within the tolerances of the measurement was found. After the second test a slight improvement of the field emission onset level is seen even if the gradient of the radiation level at 1Exp-2 mGy/min did not change.

A fist set of nine cavities were transported in the transport boxes to CEA Saclay for the setup of module string PXFEL 3_1. On one cavity a leakage on a beam tube flange was detected after transport. Investigations are ongoing to understand the origin of this leakage.

CONCLUSION

Transport boxes for cavities and a transport system for Beam Position Monitor - Quadrupol units are developed. Investigations on mechanical impact of transport over long distances on XFEL like cavities are made. No influence on the cavity fundamental frequency and field profile distribution is found even when accelerations of 6 g and more impacted the cavity. Cavity AC138 installed into a transport box did not show changes in cavity performance during transport studies.

REFERENCES

[1] J. Schaffran, „Transport Simulation on XFEL cavity design", ILC-HiGrade-Report-2010-006.

[2] B. v. d. Horst at al., "Experiences on Improved Cavity Preparation Cycles with a Vision on Industrialization of the XFEL Cavity Preparation", SRF2009, Berlin, Germany TUPO072.

[3] S. Barry, CEA Saclay, France, private communication

[#1] Institute for BFSV - Consultancy, Research, System planning and Packaging; www.bfsv.de

[#2] ® Amptown cases; www.amptown-cases.co.uk