ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI032

FIRST CRYOMODULE TEST AT AMTF HALL FOR THE EUROPEAN X-RAY FREE ELECTRON LASER (XFEL)

K. Kasprzak, B. Dzieza, W. Gaj, D. Karolczyk, L. Kolwicz-Chodak, A. Kotarba, A. Krawczyk, K. Krzysik, W. Maciocha, A. Marendziak, K. Myalski, Sz. Myalski, T. Ostrowicz, B. Prochal, M. Sienkiewicz, M. Skiba, J. Swierblewski, M. Wiencek, J. Zbroja, P. Ziolkowski, A. Zwozniak
The Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Krakow, Poland

Abstract

The Accelerator Module Test Facility (AMTF) at DESY in Hamburg is dedicated to the tests of RF cavities and accelerating cryomodules for the European X-ray Free Electron Laser (XFEL). The AMTF hall is equipped with two vertical cryostats, which are used for RF cavities testing and three test benches that will be used for tests of the accelerating cryomodules. Recently, the first cryomodule teststand (XATB3) was commissioned and the first XFEL cryomodule (XM-2) was tested by team of physicists, engineers and technicians from The Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences in Krakow, Poland, as a part of Polish in-kind contribution to XFEL.

This paper describes the preparation for the cryomodule test, differences with the old teststands CryoModule Test Bench (CMTB), the cryomodule test and the test procedure updates done at the AMTF test bench. The first test of the accelerating cryomodule on the AMTF was successfully performed and the preliminary test results are presented.

INTRODUCTION

The test [1,2] of pre-series accelerating cryomodule XM-2 for the European X-ray Free Electron Laser (XFEL) was performed with use of the recently commissioned Test Bench (XATB3) in the Accelerator Module Test Facility (AMTF) at DESY in Hamburg. This teststand was developed to simplify and to speed up the time needed for full test procedure, namely: preparation, cool down, measurement, and warm up of each of serial-production XFEL accelerating cryomodules. The test procedures used in the old teststand (CMTB) were updated for the XATB3 and a comparison study with the old teststand results was done.

In this paper the work and conclusions are summarized in four sections corresponding to four test domains: mechanical, vacuum, cryogenic and RF.

MECHANICAL

The difference in construction of the teststands CMTB and AMTF cause several significant differences in the method of preparing the cryomodules for the test. In case of the CMTB, each cryomodule was installed into the test bench, after prior removal of a substantial part of the concrete ceiling. Whereas in the AMTF, a dedicated movable support was designed in order to simplify and speed up of the cryomodule installation. Assembling any cryomodule onto the movable support is much easier, because it takes place outside of the teststand. Furthermore the waveguides construction has changed, allowing reducing amount of components necessary for dismantling, which simplify the procedure of connecting the waveguides to the cryomodule (waveguide connection is shown in Fig. 1). Besides there is no need to disassemble flexible connectors for all pipe connections and there is a possibility to use the sets of MLI insulation, consisting of ten layers each instead of wrapping each layer individually.

Considering the XATB design, the preparation of the accelerating cryomodule for the measurement is simplified and less time consuming than in the CMTB.

Figure 1: The accelerating cryomodule in the XATB3.

VACUUM

Vacuum systems necessary to perform the test of the cryomodule at the AMTF hall has been presented on diagram at Fig. 2. Significant improvement compare to the CMTB has been made by permanent installation of pump station with mass spectrometer (TB3.UP_XATB_1) at Feed-cap side. This pump station is needed during problems with vacuum pressure inside the beamline, which may occur any time during cool down or warm up process. Two sets (HERA/D65) of pump stations have been foreseen to pump down insulation vacuum (ISO-VAC) in the XATB3. It has been also foreseen to connect/disconnect additional unit of HERA pump station. This time those two sets of pump stations have been connected directly to Feed-cap and End-cap device but not to Sliding Muff like at the CMTB. This solution allows now to open Sliding Muff without additional disconnection and leak check of connection those two pumps station from/to Feed-cap and End-cap device. The procedure of pumping down of ISO-VAC for the newly arrived cryomodules has been also changed compared to the CMTB. Due to significantly increased speed of

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI032

dehumidification of the vessel, process of pumping down of ISO-VAC up to 1mbar and venting up to 1bar should be repeated three times.

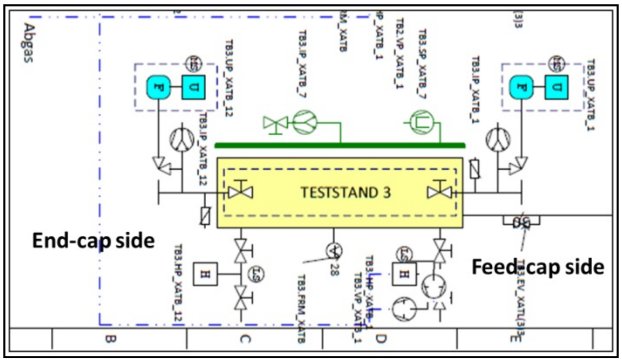

Figure 2: Test setup chart.

In case of the beamline connections at Feed-cap and End-cap side, two new clean rooms (Fig. 3a) have been foreseen and also additional pump station with mass spectrometer (TB3.UP_XATB_12) at End-cap side. Those improvements have allowed performing a process of the beamline connection simultaneously for both sides of the cryomodule, which is very efficient from time point of view. From the other hand, solution to use only gloves (Fig. 3b) instead of clean room suit (Fig. 3c - CMTB) turned out to be more economical. New solution has been also implemented regarding dismounting of vacuum monitoring system (VMS) or beamline angle valve (BAV) for newly arrived cryomodules.

At the AMTF test benches process of venting those devices now is performed directly through beamline of Feed-cap and End-cap devices. At the CMTB additional pump station with mass spectrometer and Dewar with liquid nitrogen has been required to perform this step. It is worth to mention that at the AMTF hall Dewar with liquid nitrogen for venting of UHV components has been replaced by flooding device. This flooding device uses nitrogen provided directly from line, manovacuometer and sets of filters. New software solution has been also implemented to control of the vacuum systems at the AMTF hall. Now control panels can be made directly by the user, which is more convenient and efficient in case of necessity of quick access to vacuum control systems.

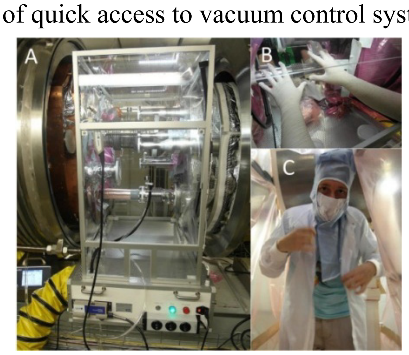

Figure 3: New clean for beamline connection at the AMTF hall.

CRYOGENICS

This paragraph summarizes tests performed on the cryomodule XM-2 at the XATB3 from cryogenic point of view. Results of heat load measurements of XM-2 (XATB3), XM-3 (at CMTB) and XRC are shown in the Table 1. XRC is the required XFEL Refrigerator Capacity (XRC) [3].

The numerical calculations of the heat loads were done for the whole assembly. Obtained values during measurements of static heat load and with magnets supplied with 50A are higher than expected from the numerical simulations. However results from heat loads tests for XM-2 and XM-3 are in a good agreement.

Table 1: Heat Loads at 2 K Line

Module	Static Heat loads [W]	Dynamic Heat loads[W]	
		Magnet (3*50A)	With average gradient 23.5 MV/m
XM-2(XATB3)*	5.4	1.3	2.8
XM-3(CMTB)	6.4	2.2	3.0
XRC [3]	7.2	12.9	
Calculated [3]	2	0.1	8.5

* one cavity detuned

Results of the XM-2 module dynamic heat loads measurements, tests of the level sensor and determination of the work region are presented below.

Dynamic Heat Loads

Measurements of dynamic heat loads with cavities supplied with RF power were also done. To perform the measurements at 2K, the assumption was made that the pressure in the 2K circuit is stable and equal 30.6mbar, which corresponds to 2K temperature. Results of dynamic heat loads at 2K line with RF power for the modules mounted at the CMTB and the XATB3 are quite different. At the CMTB it was possible to obtain few clearly visible, stable steps with different RF power levels, from the measurements, what was impossible to reach at the XATB3 in the cryomodule single-shot operation (without re-supply of helium).

Work Region Measurement

The measurement time on 2K line is limited and defined by the range of 2 phase pipe. The working points were found by empting and refilling the helium vessel in the feed-cap and two phase line. Due to the construction there is a change of the surface of LHe in the working region. Lower point was found by observing the change of the speed of the level drop. When the bottom of 2 phase line was reached during empting with constant load from heater, level started to fall faster. The top of two phase line was found during filling up the helium vessel with constant opening of JT valve and heaters off. The high level operating point was defined by pressure and level behavior. The safe values for measurement were estimated to 40% - 48%. Due to the specification 1% is about 2mm of length of level gauge. The results of the measurement have shown that the active and safe region is 8%. Using these two values once can be calculated that the 8% of level corresponds to ~ 16mm, which does not correspond to the 2 phase line diameter.

RF MEASUREMENTS

From RF point of view, during the XM-2 cryomodule measurement at the XATB3, several improvements were noticed comparing with the CMTB. Firstly the preparation area in front of the teststand gives opportunity to do the measurements with the Vector Network Analyzer (VNA) before the cryomodule is assembled into the teststand. This raises the efficiency during incoming inspection by avoiding waiting time for vacuum and mechanical activities at the beginning of the test.

Second significant improvement was observed by adding a possibility to change power distribution in waveguide system. Even though 5MW klystron is used instead of ~10MW (CMTB) it is possible to change power distribution to have much more or less power for each cavity pair. This will give opportunity to test especially dynamic heat loads with maximum possible gradient and also with waveguides tuned the same like they will be in the XFEL tunnel.

Thirdly LabVIEW software improvements were made. The parameter *kt* used to calculate accelerating gradient from power transmitted instead of power forwarded is calculated as average value from given number of measurements – not only from single measurement. Also dedicated software is used for the heat load measurement.

Furthermore the cryomodule performance test was done without any problems. Only the small range of helium level operation did not provide to do heat load measurements for several cavities average gradients, which was described previously (see: CRYOGENICS).

On the other hand test results are favourable (see Fig. 4). Even though that the measurement error is 10% [4], the obtained quench limits between cryomodule and vertical tests are in the error range. This is very promising for serial cryomodules production, testing and assembling. The XM-2 was also tested in the XATB1 as a part of teststand commissioning.

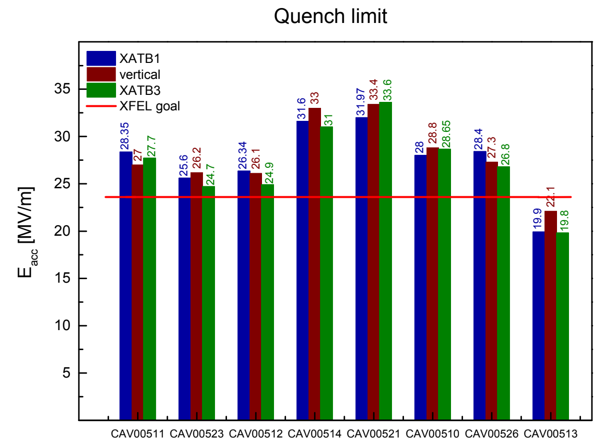

Figure 4: Comparison of quench limits between vertical, XATB1 and XATB3 test results for cavities in the XM-2.

ACNOWLEDGMENT

This work is funded by the Ministry of Science and Higher Education in Poland (MNiSzW) as a part of Polish contribution to the construction of the European XFEL

We would like to thank all the colleagues from the IFJ PAN Krakow and DESY who help and support our work at the XFEL project.

CONCLUSIONS

- Significant improvements were done to simplify and speed up testing of the serial-production cryomodule.
- Two pre-series and two serial-production cryomodules were positively tested, up to now. RF test results of the modules confirm the results obtained during cavity tests in the vertical cryostats, which is promising for the production process of serial cryomodules.
- IFJ PAN team gathered important experience with handling, preparation and testing of the cryomodules in the AMTF.

REFERENCES

[1] A. Kotarba et al., ”Proc. SPIE”, vol 9803, 8903-97 (2013).

[2] M. Wiencek et al., “Tests of The Accelerating Cryomodules For The European X-Ray Free Electron Laser”, Proceedings of SRF2013, MOP054.

[3] S. Barbanotti, “CRYO-LOSSES MEASUREMENTS OF THE XFEL PROTOTYPE AND PRE-SERIES CRYOMODULES.”

[4] D. Kostin., “Cavity accelerating gradient measurement error on the module test stand”, 03.2014; internal communication.