XFEL AMTF operation completed: results and lessons learned

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In order to produce short pulsed electron beam of 17.5 GeV energy, the XFEL linear accelerator is being built at DESY in Hamburg. Before being installed in the accelerator tunnel, 103 accelerator modules have to be tested in Accelerator Module Test Facility (AMTF). Cavities and cryomodules are tested at two vertical cryostats and three horizontal test benches. Two valve boxes and a liquid helium (LHe) storage tank are installed to enable cryogenic operation of AMTF. This paper describes our experience of three years cryogenic operation of AMTF. All 800 cavities and almost all cryomodules have been tested. The test results and lessons learned are also summarized.

1. Introduction

The European X-ray Free Electron Laser (XFEL), which will serve as research facility for multiple users, is under construction at DESY, Hamburg. The main linac will consist of 100 cryomodule with 8 cavities and one superconducting magnet package in each module. The cryomodule of ca. 12 m length has the cold mass, the 5-8K as well as 40-80K shields, see Figure 1. The cavity and magnet package are mounted on the 300 mm tube, which serves as a backbone for the whole cold mass at 2K temperature level. More details on cryomodule development history and present cryomodule design could be found in references [1-3].

In order to test XFEL cryomodules, Accelerator Module Test Facility was built, see Figure 2 for schematic overview and reference [4] for details of construction.

The present paper gives updated performance experience on the cryogenic infrastructure operation.
over the last three years after testing of all cavities and ca. 85 cryomodules [5]. In the first part, a short overview of cryomodule and cavity testing rate is given. Comparison to testing rates design values is also considered here. In the second part, experience based on three year’s operation is given and in the last one lessons learned are discussed.

2. Testing rate of superconducting cavities and cryomodules

Figure 3 shows the testing rate of cryomodule over past three years at three test benches (XATB). All tested cryomodules including prototypes, pre-series and re-testing of XM3, XM23, XM60 and XM61 are counted. Modules, which were cooled down but not tested for some reasons, e.g. due to cold leaks or coupler repairing actions, are not included.

The ramping-up of cryomodule testing rate was done in 2014 year, when typical challenges occurred, e.g. commissioning of other XATBs, cross-check of changings in assembly procedures, first optimization of test procedure, etc., for more details please see [5]. A bit slower testing rate at the beginning of 2015 was caused by two reasons, i) occupation of XATB1 due to testing of 3.9 GHz module and ii) some leaks into the coupler or cryostat isolation vacuums [5]. Due to gained experience with cryogenic module testing and cryomodule performance, the simplified testing procedure was implemented in the May 2015, e.g. dynamic heat loads on 5-8K and 40-80K shields were skipped, High Order Mode (HOM) coupler spectrum as well, etc. This allowed to increase the testing rate in June-July 2015 and to test some cryomodule stored before or ones after minor repairs, e.g. repairing the couplers or small vacuum leaks into coupler vacuum. Starting from August 2015, the testing rate is limited by supply rate of cryomodules from CEA, France, and has typical fluctuations, e.g. due to summer/winter holidays or maintenance weeks for cryomodule assembling infrastructure. A bit slower testing rate at the end of 2015 and beginning of 2016 was caused by the cryomodule delivery, which in turn was somehow delayed by coupler manufacturing as repairing actions on set-up for coupler conditioning.
For the time being, all XFEL cavities have been tested. Cryogenic testing of cavities at vertical cryostats XATC1 and 2 went smoothly without any challenges. If cryogenic activities at XATB were low, it was possible to use free cooling capacities for XATC and testing rate could reach ca. 9, sometimes up to 10 cavities per week, which is significantly larger than the design value of 6 cavities per week. After optimization of the testing procedures, it was decided to keep the testing rate of 8 cavities per week, and to increase for the case if free cryogenic capacities as well as operating personal from Institute of Nuclear Physics of Polish Academy of Science (IFJ-PAN) team are available.

The present operational experience, which is gained over several years, could be summarized as the following:

- Cryogenic operation of XATC1 and 2 is performed as expected and no deviation from standard procedures was observed, see [5] for detailed discussion on testing cycles and some challenges and figure 4 for the cavity testing rate.
- Cryogenic testing at XATBs was also very successful, though some challenges particular during the commissioning phase were time and man-power consuming [5].
- Maintenance periods, which required the warm-up and cool-down of whole infrastructure, could be reduced to one week per year. Some smaller repairs, e.g. changing of a warm valve or cone of cryogenic valves, could be conducted in parallel to the operation and did not affect the test schedule.
- Besides typical challenges mentioned in the previous paper [5], operation of several cryogenic valves should be also noted. These valves were installed in several boxes or test benches and showed typical challenges, e.g. leaks over valve seat, abnormal value of Cv, clamping. Several attempts were taken for the repairing, however without significant success. It is still difficult to attribute this challenging valve behavior to some specific reason (e.g. it could be also wrong mounting after welding inside the box), however in our opinion most probably the know-how transfer within the company manufacturing the valves was not very successful.
3. Cooperation between different institutions/universities

XFEL is an international project with substantial part of “in-kind” contribution from different institutions and universities. The IFJ-PAN (Poland) team was in charge for the AMTF test operation. The cooperation between all involved DESY groups and IFJ-PAN experts was smooth and extremely successful. As short notes for the future projects, it is worth to mention the following:

- In advance of the serial production of cavities and cryomodules, test of prototypes at the existing TESLA Test Facility could be conducted for about 2 years to develop the test procedures for the AMTF.
- During the prototype testing also the team could be built up. Similar to CERN case [6], it took a couple of years to train the corresponding operational team.
- In comparison to CERN case [6], the rotation of operation team after two years operation was not done, which positively influenced the AMTF operation.

4. Summary and final remarks

Presently, all cryogenic facilities at AMTF operate at design parameters. All superconducting cavities for XFEL project have been tested, though some minor testing of cavities devoted to the further performance improvement or after repairing actions is ongoing. Up to now, tests of cryomodules is at the end phase (ca. 85 modules are or being tested) and with expected last serial cryomodule leaving the AMTF at June-July 2016.

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References
[1] The European X-Ray Free-Electron Laser, Technical Design Report (TDR), Hamburg, DESY 2006-096, July 2007
[2] Bozhko Y, Lierl H, Petersen B, Sellmann D, Zolotov A, Requirements for the cryogenic supply of the European XFEL project at DESY, Advances in Cryogenic Engineering (2005), 51B 1620-1627
[3] Pagani C at al. Further improvements of the TESLA test facility (TTF) cryostat in view of the TESLA collider, Advances in Cryogenic Engineering (1999) 45A, 939-946
[4] Bozhko Y, Petersen B, Sellmann D, Wang X, Zhirnov A, Zolotov A, Anashin V, Belova L, Kholopov M, Konstantinov V, Pivovarov S and Pyata E Test stands for testing serial XFEL accelerator modules 2011 Advances in Cryogenic Engineering 57B 1110-1107
[5] Anashin V, et al. Experience with cryogenic operation of Accelerator Module Test Facility during testing of on third of XFEL cryomodules, Advances in Cryogenic Engineering, Material Science and Engineering 101 (2015) 012139
[6] Chohan V Operation for LHC cryomagnet tests: concerins, challenges and successful collaboration, 2007, Proceedings of APAC or LHC Project Report 984