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SUMMARY OF THE SUPERCONDUCTING RF MEASUREMENTS IN AMTF HALL AT DESY

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Abstract

The AMTF (Accelerator Module Test Facility) at DESY was built for the tests of all superconducting cavities and cryomodules for the EuXFEL linac. After successful commissioning of the EuXFEL, the AMTF has been adapted in order to perform SRF (super conducting radio frequency) measurements of cavities and accelerating modules for different projects. Several SRF cavities related projects are still ongoing, while others were just finished. Some of those projects are dedicated to test components for the infrastructure of accelerators which are under construction, while other ones are devoted to new R&D paths aiming for cavities and modules with high performance which are under investigation at DESY. This paper describes present activities performed at AMTF with special emphasis on performing SRF measurements for the ongoing cavity productions. Most of the presented data is related to vertical cryostat cavity testing. However, some data about cryomodules and a new coupler test stand will be shown as well. Detailed statistics about the number of vertical tests performed within the last two years are also presented.

INTRODUCTION

After successful commissioning of EuXFEL, several modifications of the AMTF test stands and inserts were introduced. Currently, AMTF consists of the following test benches (cf. Fig .1):

- Vertical test stand with possibility of changing the operating frequencies (424 MHz, 704 MHz, 852 MHz, 1.3 GHz)
- Vertical test stand for 1.3 GHz elliptical cavity tests
- Horizontal test stand for tests of 3.9 GHz cryomodules
- Horizontal test stand for tests of 1.3 GHz cryomodules
- Coupler test stand

Six vertical cryostats inserts are available in AMTF preparation area. For the EuXFEL purposes all of them could house up to four 1.3 GHz cavities. Nowadays, after rebuilding, following insert configurations are available:

- 2 x R&D inserts with different instrumentation, both for a single 1.3 GHz cavity (single or nine cell)
- 2 x 704 MHz inserts for two ESS cavities at once (shown in Fig 2)
- 1insert for up to four 1.3 GHz cavities
- 1insert for up to three 1.3 GHz cavities and one QPR (quadrupole resonator) cavity (cf. Fig 3)

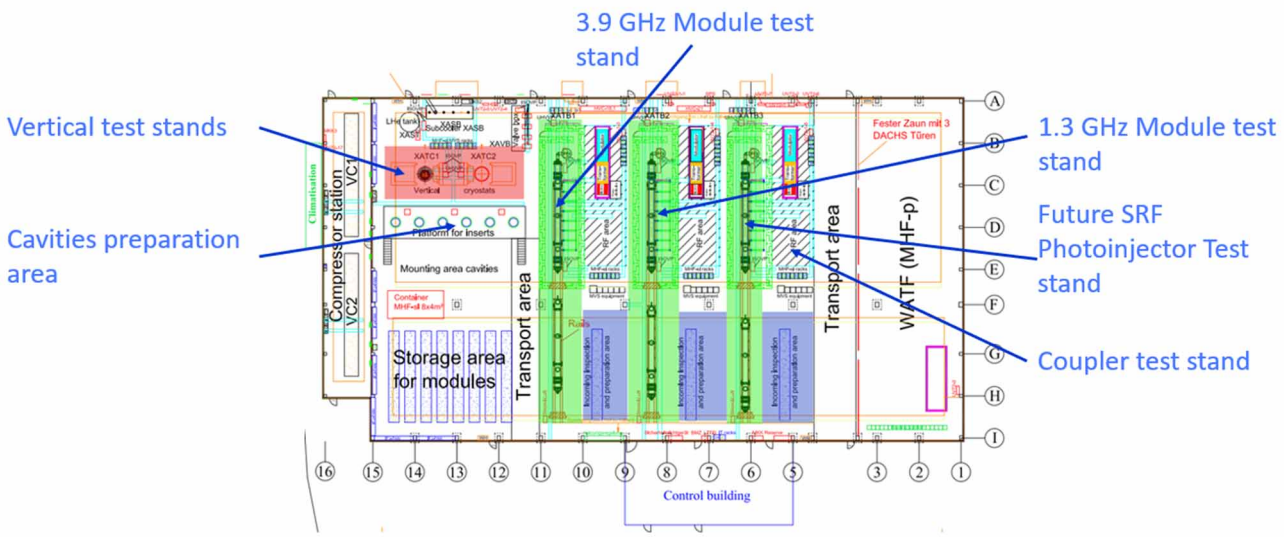

Figure 1: Diagram of the AMTF.

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Figure 2: Two 704 MHz cavities installed to one of the dediacted inserts in the AMTF preparation area.

Figure 3: QPR cavity installed to the dedicated insert, which is able to house in addition three single cell cavities.

This relatively big amount of test stands and inserts allows to perform plenty of different measurements. Within last two calendar years (2021, 2022) a total number of 206 vertical test were performed.

VERTICAL TEST STATISCICS

In the AMTF vertical cryostats two main types of measurements are conducted:

1. Vertical tests (VT) as acceptance tests for accelerator cavities. Usually only Q_0vsE_{acc}-curves for π-mode at 2 K (including radiation processing if needed) measurements are performed and fundamental mode spectra are taken. HOM spectra are measured for some types of cavities. Sometimes for diagnostics purposes also other modes are measured in addition. It barely happens that cavities are measured at different temperatures (1.8 K, 1.5 K) in these acceptance tests. Usually only few hours (3-5 h) are needed to test one cavity at 2 K. An exemplary result of this type of measurement are shown in Fig. 4.

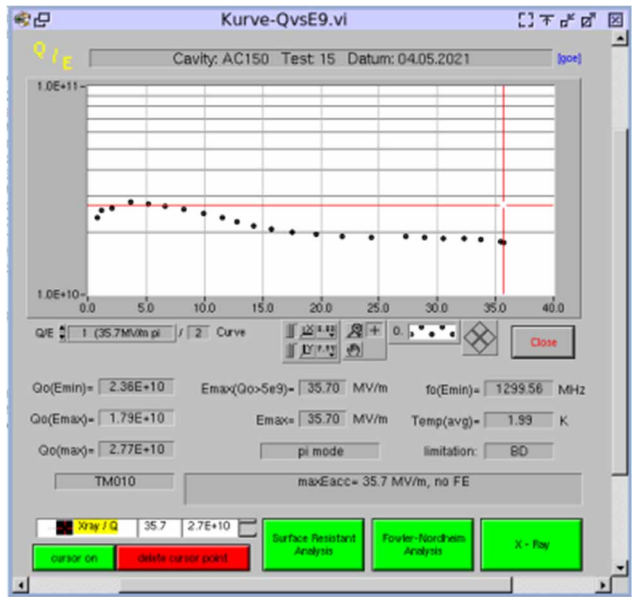

Figure 4: Example of an acceptance test result for an accelerator cavity type. Shown is a screenshot of the measurement program.

2. VT for R&D cavities (single cells, 9 cells and SRF guns). These measurements at cryogenic state (defined as below T_c = 9.2 K) mostly consists of:
   - Q(E_{acc}) at 2 K
   - Q(E_{acc}) at 1.8 K
   - Quench spot detection via second sound measurements at 1.8 K, if cavity quench limit can be reached
   - Q(E_{acc}) at 1.5 K
   - Q(T) from 3.5 K to 1.4 K

In most of the cases at least two working days are needed in order to perform the full measurement program for R&D cavities. Cool down and warm up of the cryostats in semi –automatic mode lasts about 12 hours each. An example for the results of a R&D cavity measurement is shown in Fig. 5.

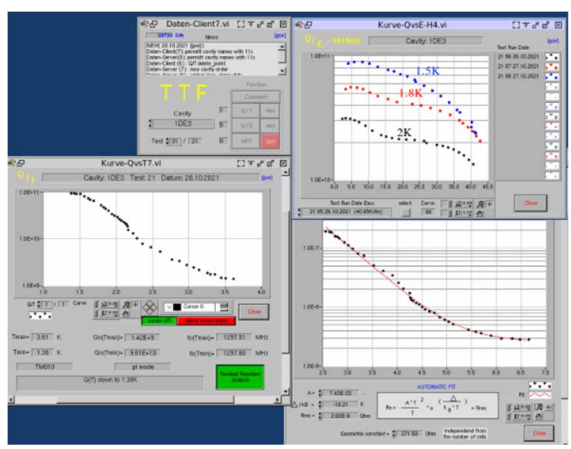

Figure 5: Example of results for an R&D cavity. Shown are several Q(E) curves and a Q(T) curve with its fit for determination of the residual resistance.

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In Fig. 6 statistics for those two types of measurements are shown. It is easily visible, that after commissioning of the EuXFEL, SRF measurements at DESY concentrated more and more to R&D related measurements.

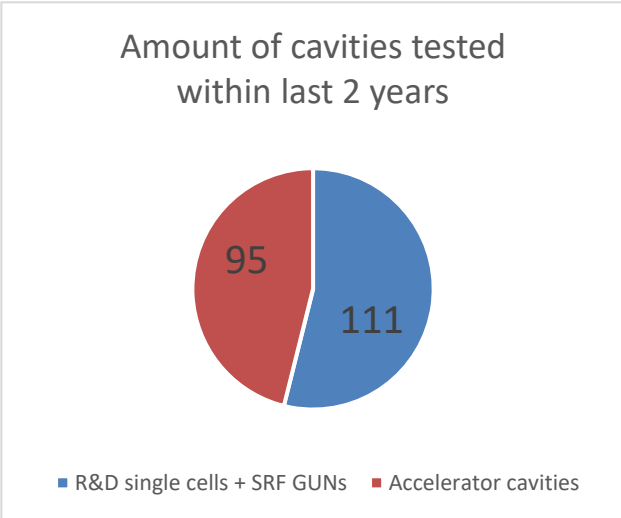

Figure 6: Cavities tested within the last two calendar years, R&D projects and cavities for accelerator qualification.

DESY also provides services for external companies and institutes wrt. vertical cavity testing. During the last two calendar years 76 Vertical tests were performed for sub – contractors.

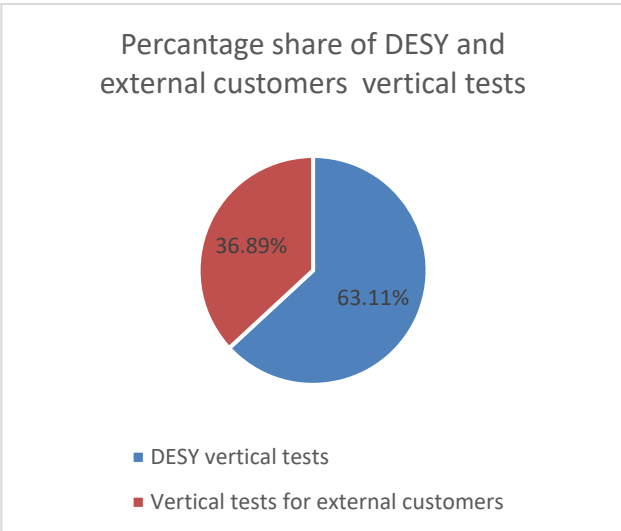

Figure 7: Percentage share of DESY and external customers vertical tests.

As it can be seen in Fig. 7, in despite of the fact that DESY performs vertical tests for few different external projects, still almost 2/3 of the total amount of the SRF measurements within the last two years is dedicated to DESY internal projects (both R&D and cavities for accelerators).

In Table 1 more detailed information about cavities shapes tested for R&D projects is given. Most of the R&D paths are devoted to different cavity surface and especially heat treatments [1, 2]. For these purposes, single cell cavities are used in almost all cases. However, the other important R&D path is the development of SRF guns [3].

Table 1: Number of R&D Vertical Tests by Shape

Cavity shape	Number of vertical tests	Percentage
Single cell	93	83.8%
SRF Gun	18	16.2%

Due to the fact, that several of the RF components used for cavity measurements are frequency dependent, every change of the cavity frequency type requires some test bench adaptations. Figure 8 presents the current setup of two different power amplifiers for two different types of frequencies installed at the AMTF vertical test bench number 1.

Figure 8: Power amplifiers for 704 MHz and 1.3 GHz vertical tests.

In Table 2 the amount of vertical test for the different cavity frequencies within last two calendar years are presented.

Table 2: Number of Vertical Tests by Cavities Resonant Frequency

Cavity frequency	Number of vertical tests	Percentage
1.3 GHz	159	77,2%
704 MHz	47	22,8%

BEYOND STANDARD VERTICAL TESTS

In the AMTF several other projects are realized using the vertical cryostats. Some of them, like Niobium Thermal Conductance Instrument (NTCI) [4] are almost or completely parasitic to standard measurements, while other ones, like the test of a new B-Mapping system requires very extended measurement times [5]. For some R&D cavities also f(T) measurement are performed [6]. The QPR project [7] also presents many new challenges for the measurement crew. However, all of this effort is taken in order to find a new path towards the development of better cavities. Performing second sound measurements in order to calculate quench spots became a routine measurement for R&D cavities. In Fig. 9 an example of a calculation of the quench spot for a 1.6 cell SRF Gun is shown.

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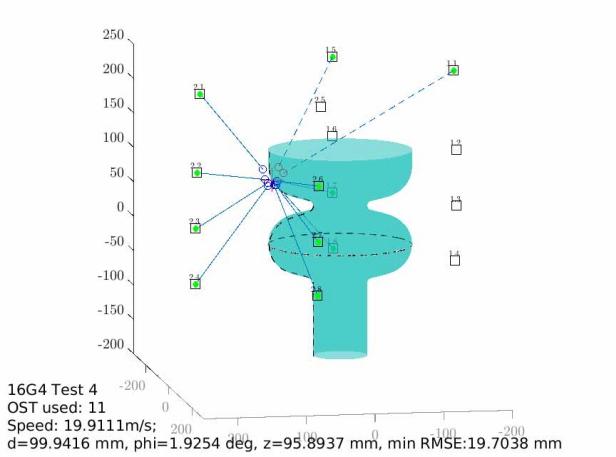

Figure 9: Trilateration of the 1.6 cell SRF Gun quench spot.

HORIZONTAL TEST BENCHES

During the EuXFEL production phase [8] 107 cryomodules tests were performed to qualify them for the tunnel installation. After this challenging period, there was no more necessity to provide three test benches for 1.3 GHz cryomodules.

It was decided to change one of the test benches to a 3.9 GHz cromodule test enviornment. One test of the spare 3.9 GHz cryomodule was taken in the year 2018. Another test is ongoing now, including new operation principles (e.g. continuous wave instead of pulse operation). The 3.9 GHz cryomodule connected to the test stand is shown in Fig. 10.

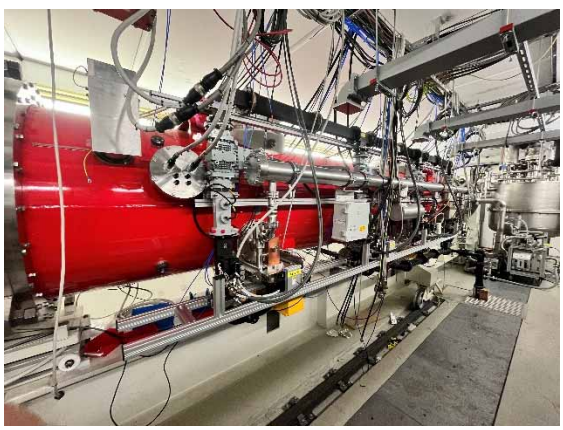

Figure 10: 3.9 GHz cryomodule (X3M2) installed in the dedicated test bench.

The second test bench is still used to test 1.3 GHz Eu-XFEL style cryomodules. However, some adaptations for the possible future EuXFEL upgrade is currently ongoing. During the last years this test stand was used to qualify two new cryomodules for the FLASH upgrade [9].

The last cryomodule test bench was completely dismounted. Part of it is already used as a coupler test stand [10]. In the bunker of this test bench the new test stand for SRF guns is in preparation [11] as well.

SUMMARY

Acceleartor Module Test Facility at DESY has undergone many changes and adaptations after succesfull measuremnts campaign for EuXFEL.

More than 200 vertical tests were performed at AMTF during the last two calendar years. Around 1/3 of them were accomplished to help different projects under development around the world. Most of the vertical tests, however, were dedicated to several differerent R&D paths which are realized in order to push cavity limits to new encouraging results.

As a part of the preparation for a possible future EuXFEL upgrade, horizontal test benches are adapted to fulfill their new purposes.

ACKNOWLEDGEMENTS

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