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EUROPEAN XFEL: ACCELERATING MODULE REPAIR AT DESY

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Abstract

The European XFEL is in operation since 2017. The design projected energy of 17.5 GeV was reached, even with the last 4 main linac accelerating modules not yet installed. 2 out of 4 not installed modules did suffer from strong cavity performance degradation, namely increased field emission, and required surface processing. The first of two modules is reassembled and tested. The module test results confirm a successful repair action. The module repair and test steps are described together with cavities performance evolution.

INTRODUCTION

The European XFEL linac is based on the TESLA SRF technology [1, 2] and is built with accelerating Cryo-Modules (CM) having 8 SRF cavities each. Currently 97 CM are installed in the machine and 4 CM will be installed later, after 2 CM are repaired. Before the CM assembly SRF cavities were tested in the Vertical Cryostat Test (VT) in the Accelerating Module Test Facility (AMTF) at DESY [3]. Each CM after the assembly at CEA (Saclay, France) was tested in AMTF on the XFEL accelerating module test bench (XATB, Fig. 1) [4, 5].

MODULE HISTORY

Module XM50 was delivered to DESY in January 2016 after the assembly at CEA (Saclay). In the Table 1 CM SRF cavities are listed. During the CM assembly following problems were identified:

- Leak at the angle valve;
- Beam line leak;
- Beam line was pumped accidentally before warm coupler parts were installed.

Module XM50 first test in February 2016 showed a degradation of the cavities' performance compared with VT results – mostly with strong gamma radiation – dark current caused by field emission (see Fig. 2, 3). Decision was taken not to install and use the module XM50 in the E-XFEL machine and re-assemble it after cavities' re-treatment [6].

After disassembly XM50 the cavities underwent a High Pressure Rinse (HPR) at DESY: 7 cavities after HPR and VT were accepted for XM50.1 assembly, CAV00207 had a cold leak during second VT and was accepted after the re-assembly of the flanges, another HPR and VT.

XM50 was re-assembled at DESY to XM50.1 and tested in AMTF (on XATB2) in April 2019. Only one cavity (#2) is degraded, without FE and with a still useful accelerating gradient.

Figure 1: Module XM50.1 on the Module Test Stand XATB2 in AMTF.

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Table 1: Module XM50 SRF Cavities

position	cavity name	company
1	CAV00207	RI
2	CAV00789	Zanon
3	CAV00253	RI
4	CAV00256	RI
5	CAV00257	RI
6	CAV00260	RI
7	CAV00265	RI
8	CAV00267	RI

MODULE TEST RESULTS

During the CM tests in AMTF, the operational gradient limit on individual cavities was in general limited by either hard quench (breakdown, BD), field emission (measured X-ray threshold of 10^{-2} mGy/min) or to 31 MV/m (administrative power limit).

Table 2: CM Test Data After First Assembly (XM50)

#	$E_{acc.max}$ [MV/m]	limit	$E_{acc.oper}$ [MV/m]	limit	X_{gun} [mGy/min]	X_{dmp} [mGy/min]
1	29.6	BD	20.0	FE	0.8	1E-2
2	24.1	BD	16.4	FE	1.2	3.0
3	29.6	BD	29.1	BD	2E-4	3E-4
4	31.0	PWR	31.0	PWR	2E-5	1E-5
5	31.0	PWR	31.0	PWR	9E-3	3E-3
6	31.0	PWR	25.6	FE	5E-3	7E-2
7	31.0	PWR	23.1	FE	0.8	1E-2
8	20.8	BD	20.3	BD	0.0	0.0

Table 3: CM Test Data After Re-Assembly (XM50.1)

#	$E_{acc.max}$ [MV/m]	limit	$E_{acc.oper}$ [MV/m]	limit	X_{gun} [mGy/min]	X_{dmp} [mGy/min]
1	31.0	PWR	31.0	PWR	0.0	0.0
2	24.9	BD	24.4	BD	0.0	0.0
3	31.0	PWR	31.0	PWR	3E-4	0.0
4	31.0	PWR	31.0	PWR	0.0	0.0
5	31.0	PWR	31.0	PWR	0.0	0.0
6	31.0	PWR	31.0	PWR	8E-5	1E-4
7	31.0	PWR	31.0	PWR	0.0	0.0
8	31.0	PWR	31.0	PWR	0.0	2E-5

Tables 2 and 3 are summarizing the XM50 and XM50.1 CM test results – accelerating gradients and gamma radiation data together with single cavities limits. Figure 2 presents XM50 gamma radiation measurements results compared with VT data. In Figure 3 the XM50 CM dark current and gamma radiation measurement is shown, this measurement is done with all 8 cavities tuned to the resonance and operated at average gradient of 21 MV/m. A very high gamma radiation level was measured (12/39 mGy/min gun/dump sides) with corresponding high dark current (~1.1 μA). Thus, operating the CM at this gradient is not possible and a lower gradient of ~10 MV/m is not effective in the machine operation. In Figure 4 the operational gradients are compared between the VT and CM tests. Figure 5 compares the BD gradients of the tested CM cavities – CM tests are limited at 31 MV/m (administrative RF power limit).

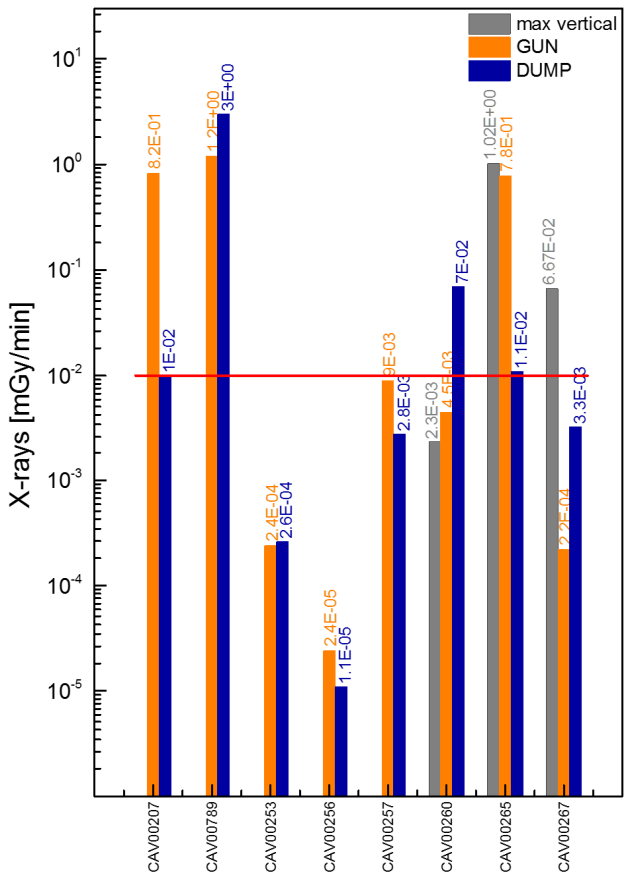

Figure 2: CM XM50 cavities X-rays measurements.

The test results show mostly FE related degradation of the XM50 after the CM assembly. CM cavities re-treatment described in details in [6] restored the cavities performance, as is seen from VT results (Fig. 4) before the XM50.1 assembly at DESY. XM50.1 CM test did show almost no gamma radiation and hence no FE related degradation after the re-assembly. Cavity 2 (CAV00789) is the only one degraded this time to lower BD gradient value compared to VT, but without FE.

Cryogenic losses based Q_0 measurements on XATB2 (see Fig. 6, two last points are taken with cavity 2 detuned) confirming the restored cavities performance in XM50.1.

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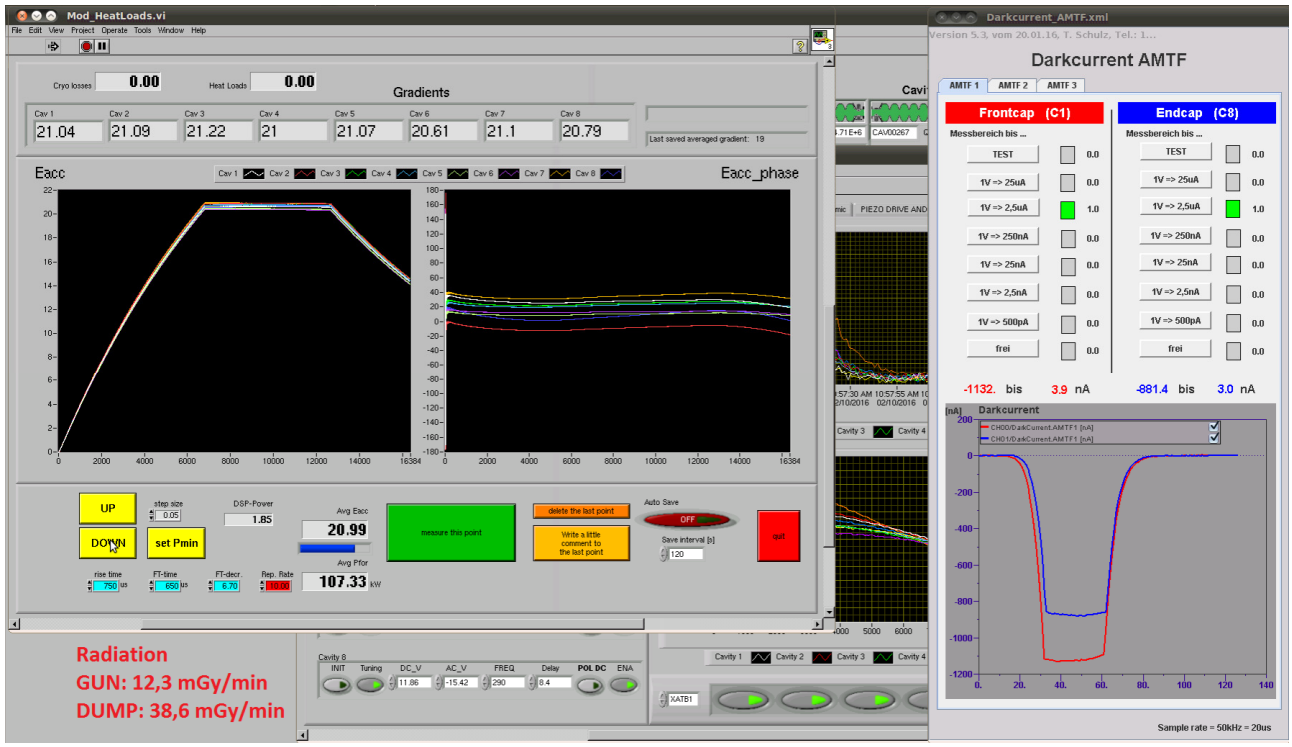

Figure 3: CM XM50 operational test with <Eacc> = 21 MV/m: corresponding gamma radiation values on the left and dark current measurement panel on the right, 1.1 µA peak value was measured.

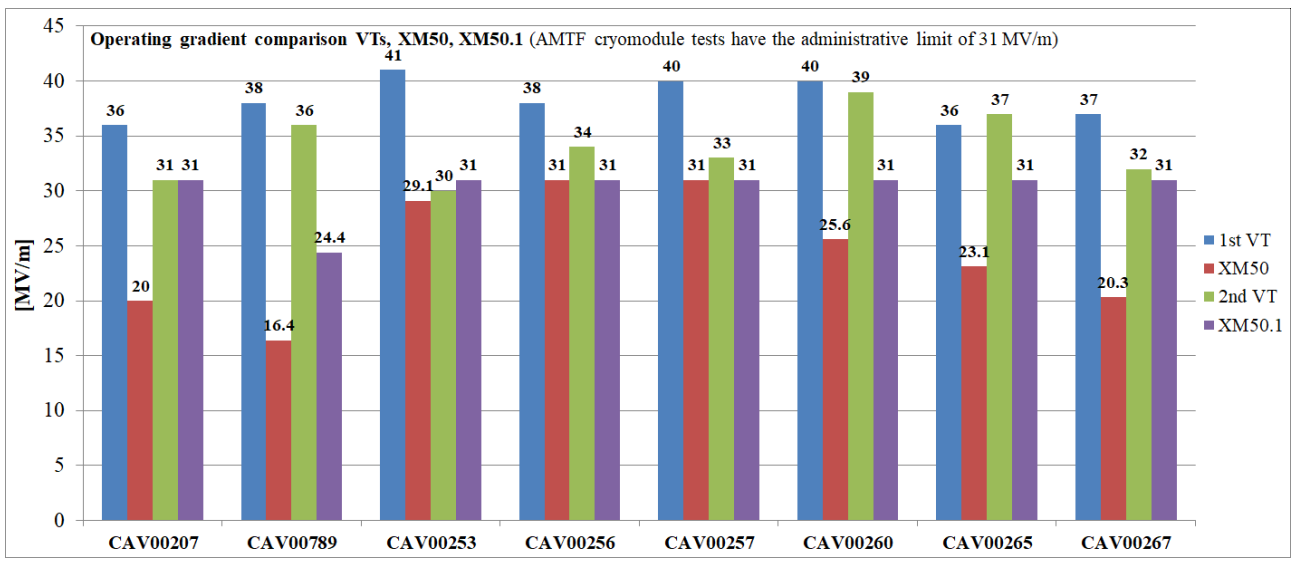

Figure 4: CM cavities vertical and module tests: operating gradient comparison.

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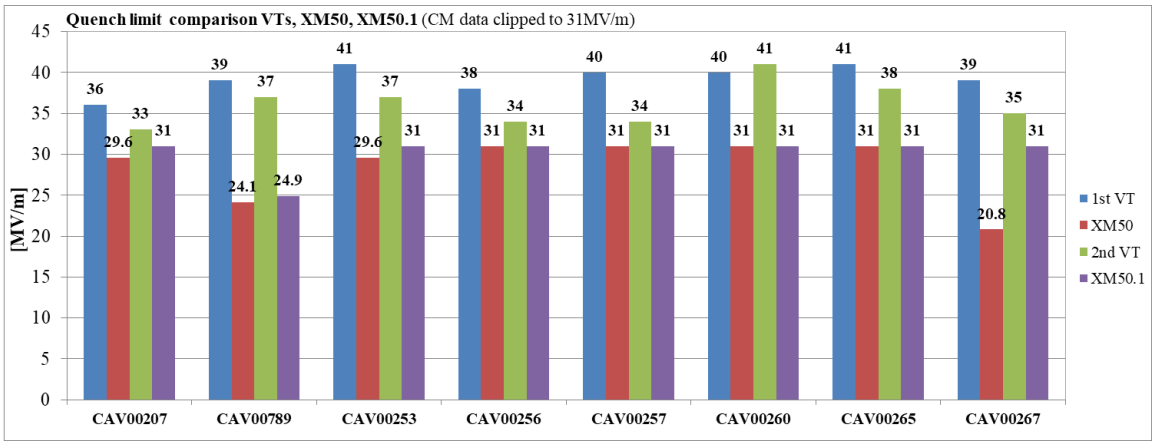

Figure 5: CM cavities BD limits comparison.

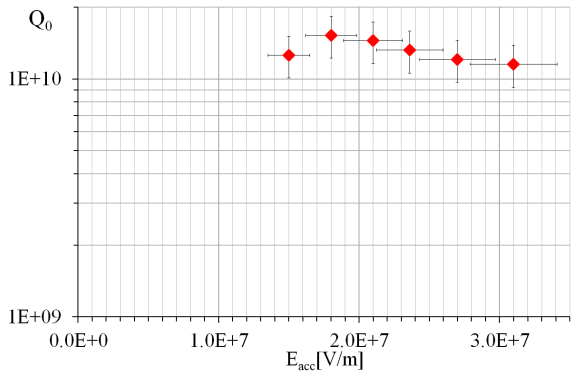

Figure 6: CM Q0 measurements (two last pt. without C2).

OUTLOOK

CM XM50.1 will be provided with the waveguide RF power distribution [7] and should be later installed in the European XFEL linac. Currently CM is moved to the Cryo Module Test Bench (CMTB) at DESY to perform the CW test in a frame of CM CW operation R&D program at DESY [8, 9].

SUMMARY

- The European XFEL superconducting accelerator is still missing one RF-station, 4 CM – one CM has 8 SRF cavities. 2 CM out of 4 did suffer from the cavities' performance degradation after the 1st CM assembly and must be re-assembled and re-tested at DESY.
- First CM, XM50, was re-assembled after 8 cavities HPR re-treatment and VT at DESY. VT results did show a restored cavity performance after the HPR.
- CM test after the re-assembly showed a good performance: only one cavity out of 8 did degrade after the CM assembly, but without FE and with a still usable gradient.
- Successful CM repair means a feasibility of such action to restore the CM performance.

ACKNOWLEDGEMENTS

We want to express our gratitude to all colleagues from DESY contributing to and supporting the cryo module assembly and testing.

REFERENCES

[1] The European X-Ray Free Electron Laser Technical Design Report, http://xfel.desy.de

[2] H. Weise, "Status of the European XFEL", in *Proc. 28th Linear Accelerator Conf. (LINAC'16)*, East Lansing, MI, USA, Sep. 2016, pp. 7-11. doi:10.18429/JACoW-LINAC2016-MO1A02

[3] D. Reschke, V. Gubarev, J. Schaffran, L. Steder, N. Walker, M. Wenskat, and L. Monaco, „Performance in the Vertical Test of the 832 nine-cell 1.3 GHz Cavities for the European X-ray Free Electron Laser", *Phys. Rev. Accel. Beams*, vol. 20, p. 042004. Apr. 2017.

[4] M. Wiencek, K. Kasprzak, A. Zwozniak, D. Kostin, D. Reschke, and N. Walker, "Update and Status of Test Results of the XFEL Series Accelerator Modules", in *Proc. 17th Int. Conf. RF Superconductivity (SRF'15)*, Whistler, Canada, Sep. 2015, paper MOPB080, pp. 319-323.

[5] K. Kasprzak, M. Wiencek, A. Zwozniak, D. Kostin, D. Reschke, and N. Walker, "Test Results of the European XFEL Serial-production Accelerator Modules", in *Proc. 18th Int. Conf. RF Superconductivity (SRF'17)*, Lanzhou, China, Jul. 2017, pp. 312-316. doi:10.18429/JACoW-SRF2017-MOPB106

[6] S. Sievers *et al.*, "Retreatment of European XFEL Series Cavities at DESY as Part of the Repair of European XFEL Accelerating Modules", in *Proc. 29th Linear Accelerator Conf. (LINAC'18)*, Beijing, China, Sep. 2018, pp. 384-387. doi:10.18429/JACoW-LINAC2018-TUPO028

[7] S. Choroba, V. V. Katalev, and E. M. Apostolov, "Series Production of the RF Power Distribution for the European XFEL", in *Proc. 28th Linear Accelerator Conf. (LINAC'16)*, East Lansing, MI, USA, Sep. 2016, pp. 1008-1010. doi:10.18429/JACoW-LINAC2016-THPLR067

[8] J. Branlard *et al.*, "Highlights of the XM-3 Cryomodule Tests at DESY", in *Proc. 29th Linear Accelerator Conf. (LINAC'18)*, Beijing, China, Sep. 2018, pp. 388-390. doi:10.18429/JACoW-LINAC2018-TUPO029

[9] D. Kostin, J. Sekutowicz, "Progress towards Continuous Wave Operation of the SRF Linac at DESY", Proc. SPIE 11054, Superconductivity and Particle Accelerators 2018, 1105406 (14 May 2019); doi: 10.1117/12.2524952.