FIRST RF MEASUREMENT RESULTS FOR THE EUROPEAN XFEL SC CAVITY PRODUCTION

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Abstract

The first reference cavities (RCV) for the European XFEL Project are being tested within the collaboration of Research Instruments (RI), E. ZANON, IFJ-PAN and DESY:

- production and warm RF measurements of cavities and their components at RI and ZANON;
- surface preparation at DESY;
- cold RF tests at DESY by IFJ-PAN.

Purpose of the RCV is to establish a stable cavity fabrication and qualification of the surface preparation infrastructure at industry.

All necessary RF measurements were done, starting with mechanical fabrication in 2011, till the tuning and cold cavity RF tests in 2012.

We present the first results of RF measurements within RCV production for the European XFEL.

INTRODUCTION

For the first time the superconducting (SC) cavities for the XFEL are not only fabricated by industry, but also the full preparation "ready for cold RF test".

Before starting the (pre-)serial production each supplier of XFEL SC cavities (RI and ZANON) has produced 4 dummy (DCV) and 4 reference (RCV) cavities to qualify the new equipment and check the sequence of the fabrication process.

The main aspects of the RF measurements procedure for the European XFEL were described in [1].

These measurements allow checking the RF quality of the cavity (tuning, cold RF tests) and help to predict the mechanical parameters (length after tuning or deformation during transportation).

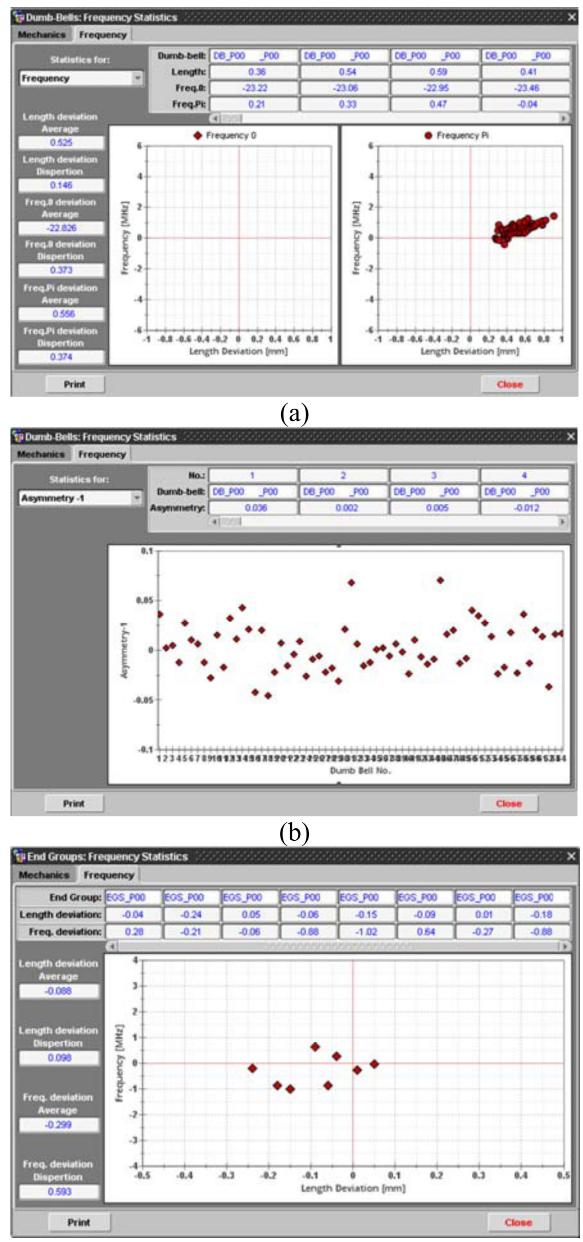
PRODUCTION OF PARTS

The main ideas of cavity parts (dumb-bells (DB) and end-groups (EG)) control are quick tests of their shapes before final cutting and checking the correspondence of the pi-mode frequency to part's length after trimming.

Only extensive 3D shape measurements can give the final results of the cell shape status, but RF measurements can give a prognosis for a series of 32 DB in one hour. The necessary field distribution for the fundamental mode can be obtained relatively easy by cavity tuning even for a wrong shape, but the behaviour of the higher order modes (HOM) spectrum is not predictable in this case. So a wrong shape is more critical and dangerous for HOM and beam dynamics.

The results of final RF measurements, when the parts are ready to be welded together in a cavity, are collected in the XFEL database [2].

Some examples of statistical values are shown in figure 1: the correspondence of pi-mode frequency to the length for DB (a) and EG (c). As a DB consists of two half-cells the symmetry of their volumes is additionally checked (b). These values are limited by ±0.1. In case a DB is out of tolerance, it has to be checked mechanically and additionally compensated or reshaped.



(a)

(b)

(c)

Figure 1: Statistical data for dumb-bells (a, b) and end-groups (c) are in tolerance.

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CAVITY FABRICATION

To guarantee that the cavity length after tuning will be in tolerance of ± 3 mm, we make a prediction of this value twice: before and after cavity welding.

This prediction is based on the known length, pi-mode frequency of cavity parts, the amount of chemical treatment before and after welding, shrinkage of welding seams and other mechanical factors.

To compare these predictions with real values the data were collected in table 1. One can see the good accordance of predicted length deviation (first two columns). Only for cavities CAV00503 and CAV00506 the differences are a little higher and reach about 1 mm. It can be explained by the reduction of real shrinkage during cavity welding of about 0.08 mm per weld.

The difference between predicted and real values could partly be due to the different amount of chemical treatment before tuning: about 130 µm for cavities CAV00001-004, and about 180 µm for others. The influence of other factors is being analyzed.

Table 1: Length deviation relative to planned value

Cavity	dL, mm		
	predicted before welding	predicted after welding	real value
001	1.64	1.65	0.93
002	1.08	0.41	-0.45
003	3.18	3.20	2.60
004	3.03	3.07	2.18
500	0.00	0.11	2.43
502	0.02	0.16	1.09
503	0.50	1.45	3.41
506	0.49	1.12	3.10

After the cavity welding the results of all warm (at room temperature) RF measurements are collected in the XFEL database [3] as presented in figure 2. These data are accessible to the public.

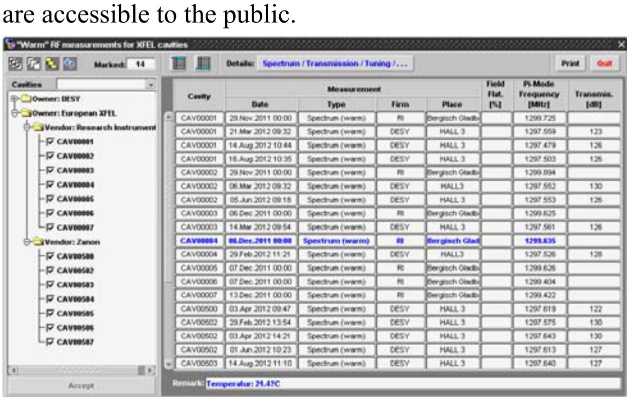


Figure 2: Presentation of warm RF measurements in XFEL database.

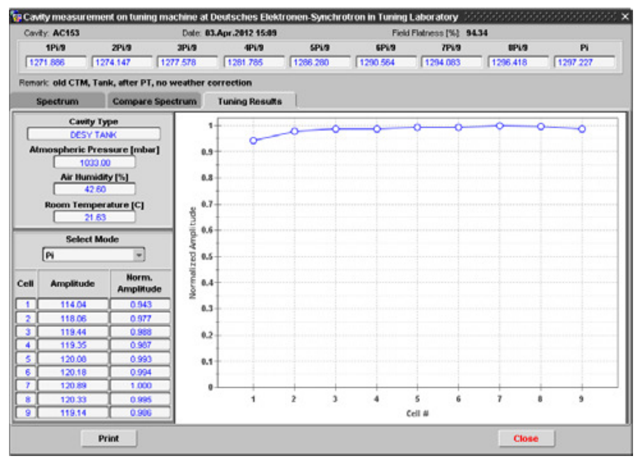
TUNING

The reference cavities were tuned once before the cold RF test. Results of these tuning procedures are summarised in table 2. The pi-mode frequencies for cavities CAV00001-004 are higher (about 1297.60 MHz) than for others (about 1297.44 MHz) because of the difference in planned additional chemical treatment: 40 µm and 10 µm correspondingly.

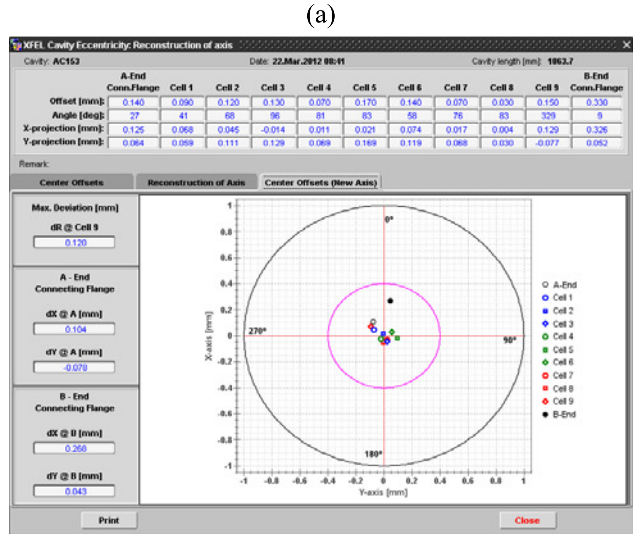
Table 2: Parameters after tuning

Cavity	Length, mm	Pi-mode frequency, MHz	Field flatness, %
001	1282.34	1297.623	99
002	1280.95	1297.644	97
003	1284.00	1297.585	98
004	1283.58	1297.545	99
500	1283.83	1297.411	99
502	1282.49	1297.419	98
503	1284.81	1297.458	97
506	1284.50	1297.459	98

As all tuning procedures for the reference cavities were done at DESY, no data transfer to the XFEL database was foreseen. An example of results' presentation is shown in figure 3 for cavity AC153. This cavity should be mounted into XFEL Module XM-3.



(a)



(b)

Figure 3: Tuning results: (a) - RF measurements, (b) - eccentricity

TRANSPORTATION

Each cavity has a long way from the manufacturers (RI or ZANON) to DESY for the cold RF test, then to CEA (Saclay, France) to be assembled inside the accelerating module and finally back to DESY for the module RF test and installation into the XFEL tunnel.

Comparison of cavity's spectra before and after transportation helps to control the absence of cavity deformation. Results and analysis of spectra comparison can be done automatically in the XFEL cavity database by choosing two spectra for a cavity. The Root mean-square error for the relative spectrum (RS) (1) multiplied by the operational frequency 1.3 GHz (MSE) helps us to estimate a possible deformation (cell's detuning) of a cavity.

$$RS = \{R_i\} = \{F_i/f_i - F_N/f_N\}, \quad (1)$$

where i = 1…9, $\{F_i\}$ and $\{f_i\}$ – two spectra.

As an example for cavity CAV00002, the value of MSE is only 4 kHz. The exceeding of the 10 kHz limit for MSE means that the cavity's field flatness could be lower than the critical 90%. In this case additional measurements and investigation of transportation errors have to be done.

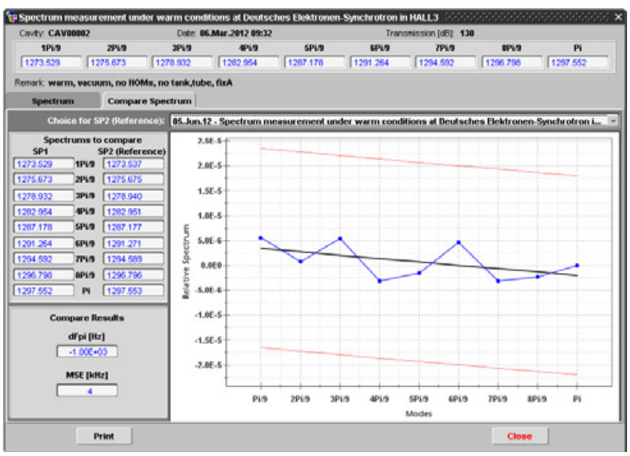
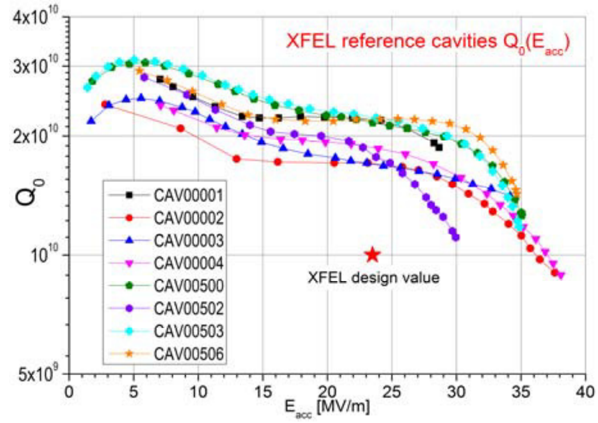


Figure 4: Comparison of two spectra (two columns at the left panel) for CAV00002. RS – blue broken line.

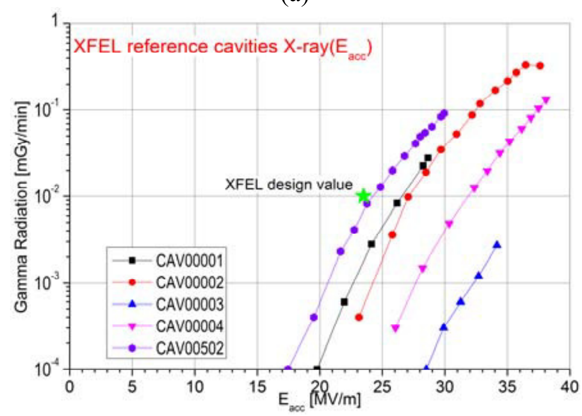
COLD RF TESTS

As a final quality check of the cavity a CW RF cold test is done after all preparation steps are finished. RCV were tested in LHe at 2K without cavity tank and HOM couplers feedthroughs in order to get a first performance evaluation. Later, during XFEL cavity production, cavities will be tested with all auxiliaries.

Results of the first cold RF tests (see figure 5) after the cavities' tuning and final chemical treatment at DESY of all reference cavities show the correspondence with the XFEL operation specification ($E_{acc} \geq 23.6$ MV/m with a Q-value $Q_0 \geq 10^{10}$ and radiation X-ray < 10^{-2} mGy/min).



(a)



(b)

Figure 5: Cold RF test results: after surface preparation at DESY: (a) – $Q_0(E_{acc})$, (b) – X-ray(E_{acc}).

SUMMARY

The fabrication of 8 reference cavities by RI and ZANON allows us not only a test of the quality of the companies' infrastructure, but also of the communication between the members of the European XFEL Project.

The results of all measurements reflect the high quality of the so far produced cavities, which have reached accelerating gradients from 28 to 38 MV/m.

This presentation also shows the diversity of XFEL database abilities, such as collecting of all data, their presentation and automatic calculations.

ACKNOWLEDGMENTS

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REFERENCES

[1] A. Sulimov et al., "Description and First Experience with the RF Measurement Procedure for the European XFEL SC Cavity Production", 2nd IPAC'11, San Sebastian, Spain, 2011, pp. 277-279.
[2] http://xfel.desy.de/cavity_database/
[3] http://xfel.desy.de/cavity_database/rf_measurements/

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