RECENT RESULTS FROM SECOND SOUND, T-MAPPING AND OPTICAL INSPECTION OF 1.3 GHz CAVITIES AT DESY*

F. Schlander#, S. Aderhold, D. Reschke, K. Twarowski, DESY, 22603 Hamburg, Germany

Abstract

DESY is preparing for the delivery of 800 superconducting 9-cell cavities (Fig. 1) for the European XFEL [1]. The review of earlier data and the analysis of data obtained recently helped to define the rules for preparation of cavities and give guidance for the quality assessment of the expected cavity delivery. The experience gained from temperature mapping, the second sound technique [2] and optical inspection [3] will be compared and an overview of the results obtained so far will be given in this report.

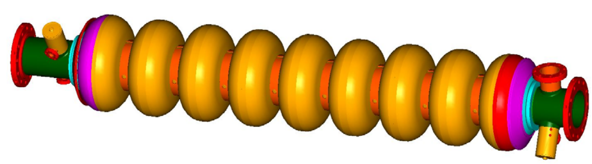

Figure 1: 3D model of a 9-cell 1.3 GHz European XFEL design cavity.

RECENT CAVITY TEST RESULTS

Since the last SRF Workshop 66 cavity tests have been carried out at DESY. Most of these tests have been done with cavities from the 6th and 8th production series. Cavities from production series 7 (3 hydroformed cavities) and 9 (4 cavities in XFEL-design, test of a new fabrication process) have not been included in this report. There were also a few tests with cavities of earlier series, but the status of these cavities including the surface treatment was unclear.

This results in a total number of 48 tests, 30 from the fine grain production series 6, and 18 of the large grain production series 8.

The results are shown in Fig. 2, which shows the maximum field obtained for the various batches. The topmost figures indicate the performance of the two production series whereas the latter three diagrams categorise the maximum field according to cavity treatment. The 6th production shows a broad field gradient distribution between 16 and 38 MV/m. The tests with the low gradients showed strong radiation indicating field emission. For the large grain cavities of the 8th production, there is a series of tests in the range from 20 to 30 MV/m. These are the tests with BCP surface including two EP tests. For the higher gradients, these are EP surfaces only [4].

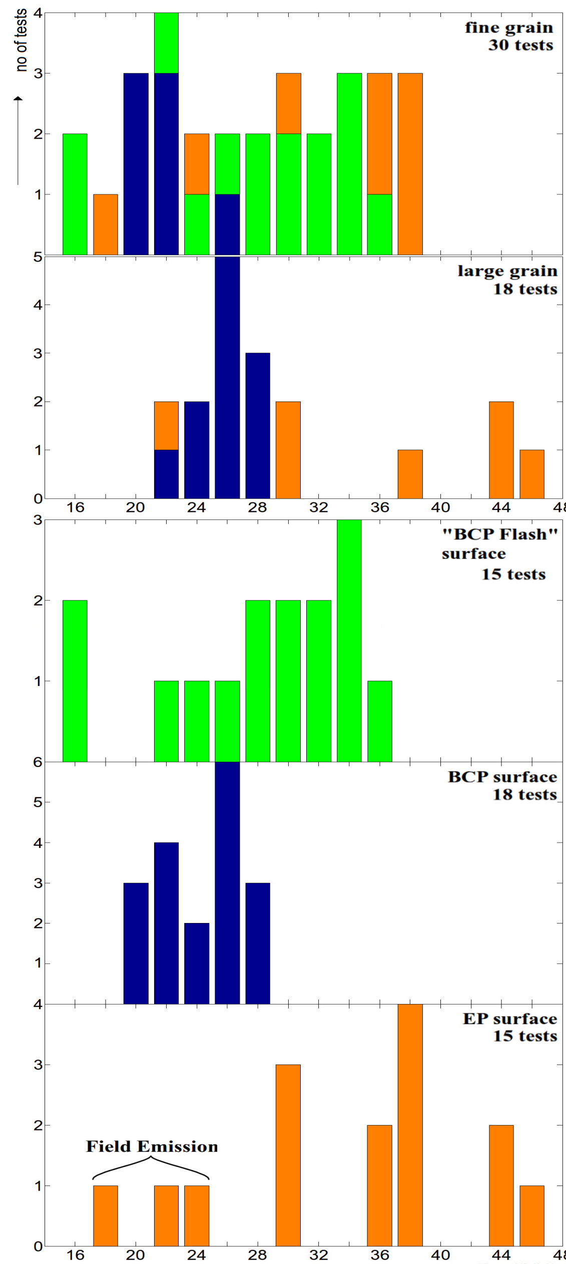

Figure 2: Gradient performance of cavities tested by material and surface treatment – the colors indicate the surface treatment.

Including some more tests from the 6th production, the tests with cavities having a BCP surface achieve up to 28 MV/m. For the EP surfaces there have been gradients achieved up to 46 MV/m and only three tests show gradients below 30 MV/m due to strong field emission. High gradients are thus best achieved with EP treated

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#felix.schlander@desy.de

cavities. For the specified gradient of 23.6 MV/m for European XFEL cavities, the observed yield of 76% is promising.

FIELD DISTRIBUTION IN DIFFERENT MODES IN A 9-CELL CAVITY

For a 9-cell cavity, there are nine fundamental modes with different frequencies which can be excited separately. This leads to different electromagnetic field distributions and maximum fields in varying cells, as shown in Fig. 3. The mode measurements can be used to confine the origin of quench locations (or reduce the uncertainty in finding origins of quench locations).

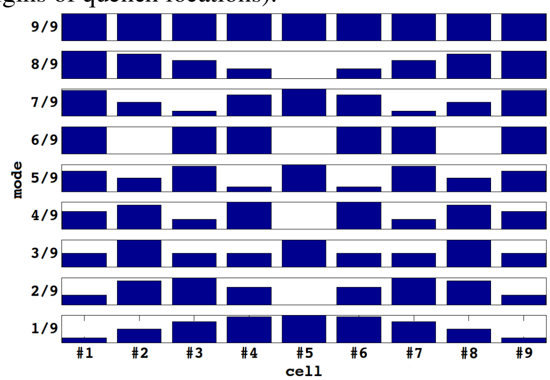

Figure 3: Field distribution in a 9-vell cavity for all fundamental modes, normalised to the max. field in each mode.

CORRELATION EXAMPLES

Mode measurements and quench localisation

An example for the correlation between quench locations and mode measurements is the second test of AC155 [4]. The quenching cells and locations and the corresponding fields in latter cells are shown in Table 1.

Table 1: Mode measurements and quench locations of AC155 test 2. The quenching cells are marked in red

Mode	**Quench location (dz=±10mm, dφ=±5°)**	**Cells (#) with highest field [MV/m]**	
π-mode	Iris area between #2/#3 @ 200°	#1 - #9:	44.5
8/9 π-mode	21 mm below equator #1 @ 133°	#1, #9:	45
7/9 π-mode	Iris area between #1/#2 @ 230°	#5: #1, #9:	49 46
6/9 π-mode	Iris area between #1/#2 @ 230°	#1, #3, #4, #6, #7, #9:	43
5/9 π-mode	10 mm above equator #5 @ 186°	#5: #3, #7:	47 44
4/9 π-mode	7 mm above equator #4 @ 274°	#4, #6: #2, #8:	50 44
3/9 π-mode	Iris area between #2/#3 @ 200°	#2, #5, #8:	45
2/9 π-mode	16 mm above equator #3 @ 278°	#3, #7: #2, #8:	45 40
1/9 π-mode	10 mm above equator #5 @ 186°	#5: #4, #6:	48 45

For all modes the mode measurements fully agree with the quench location detected by second sound. For several modes there was radiation indicating field emission, even these modes fit with the quench positions.

Quench localisation and optical inspection

A new example showing coincidence between the location of the quench and optical inspection is cavity Z161. This cavity achieved a gradient of 13.6 MV/m in π-mode and quenched in cell 2 as shown in Figure 4. This cavity is not in the examined data set since it is a cavity from the 9th production series.

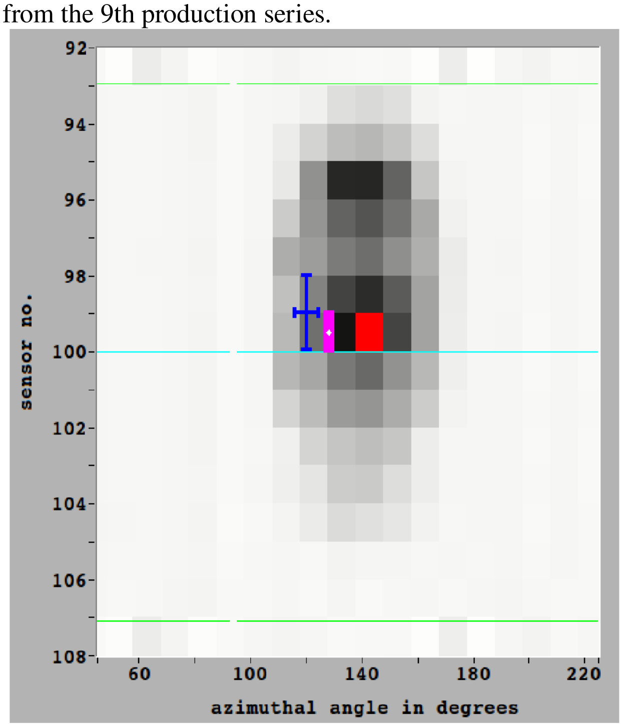

Figure 4: Section of the temperature map of Z161 in π-mode. Cell 2 is visible in an angular range from 45° to 225°. The turquoise line shows the position of the equator.

The red square shows the hot spot determined by the temperature mapping system [5], while the second sound system located a spot close to this position, marked in blue. The optical inspection showed an irregularity (shown in Fig. 5) which is marked violet in the temperature map. After the optical inspection this cavity was dissected to do further investigation of several spots found in the cavity [6].

In summary these diagnostic tools show consistent results and the second sound method showed good agreement with all temperature maps done up to now.

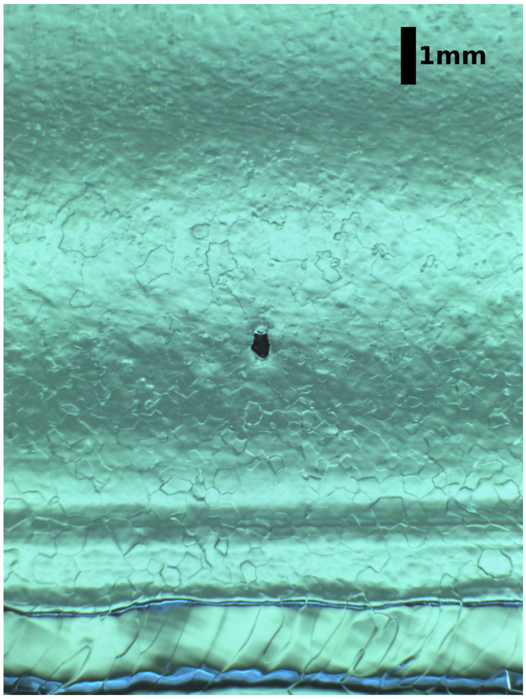

Figure 5: Inner cavity surface of the spot marked in Fig. 4. At the bottom of the picture the welding seam of the equator can be seen.

COMPARISON OF MODE MEASUREMENTS WITH SECOND SOUND DATA

Second sound data has been recorded in 118 quenches from 14 cavities (Fig. 6, 13 cavities in all 9 fundamental modes and 1 cavity with HOM feedthroughs, so only the pi-mode had been measured). From these 118 modes, for 53% the quench was located in the cell with the maximum field, while 11% quenched in cells with fields exceeding the π-mode field. Few modes do not show correlation with the field distribution in the cavities and for 33% of the modes no quench location was obtainable by second sound.

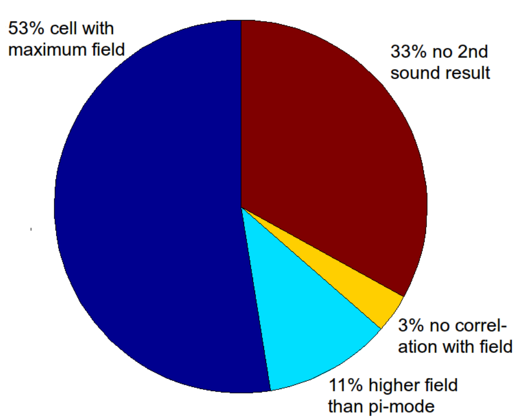

Figure 6: Observation from 118 mode measurements and simultaneously running second sound measurement

For 5 of these 39 modes without second sound result, the data taken does not provide any reasonable quench location. For the remaining measurements there is a clear explanation, as shown in Fig. 7. Almost half of the irregular measurements are due to noise. One cavity, AC151, had a damaged f-part (part of the antenna at HOM coupler) causing Q-switches, the other data faced the trouble of low signals because of very low energy stored in the cavity in the lower modes.

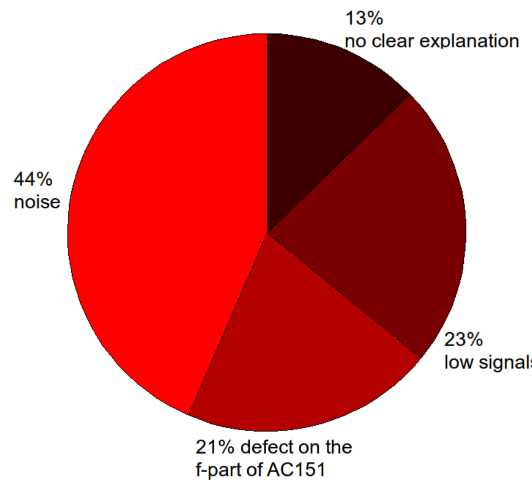

Figure 7: Categories for failing second sound quench location measurement.

SUMMARY

From November 2009 to June 2011 there were 66 tests in total of 9-cell cavities at the vertical test stands at DESY. These tests confirm the former DESY experience with BCP surfaced cavities not exceeding a field gradient of 30 MV/m. Tests with electropolished cavities hold the promise of satisfying the needs of the International Linear Collider [7] with gradients up to 46 MV/m.

The quench localisation tools second sound and temperature mapping were used on some 10 cavities and the results obtained showed a very good agreement between the mode measurements and quench locations.

ACKNOWLEDGEMENTS

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