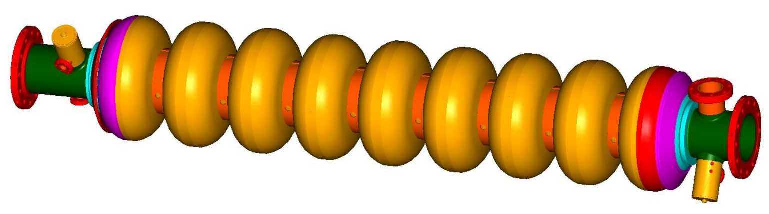
Recent Results from Second Sound, T-Mapping and Optical Inspection of 1.3 GHz Cavities at DESY

Felix Schlander, Sebastian Aderhold, Detlef Reschke, Krzysztof Twarowski
Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

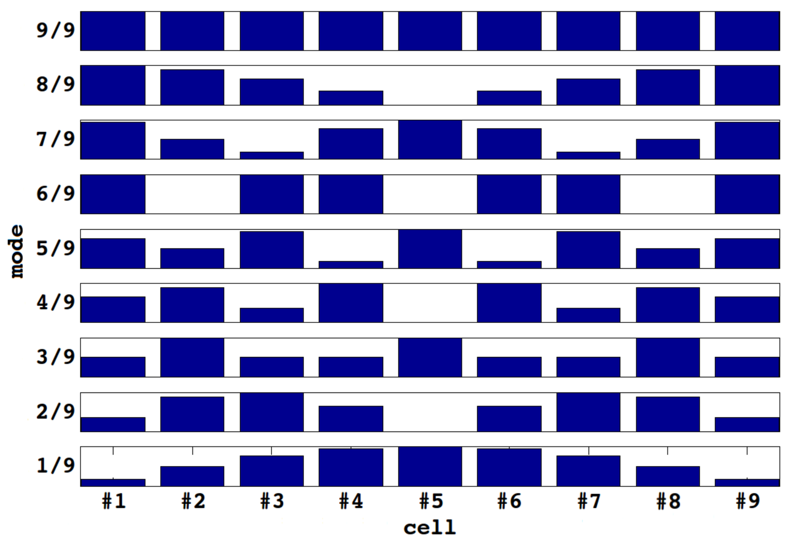
Abstract

DESY is preparing for the delivery of 800 superconducting 9-cell cavities for the European XFEL. 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 and optical inspection will be compared and an overview of the results obtained so far will be given in this report.



3D model of a 9-cell 1.3 GHz European XFEL design cavity

Fundamental field modes in a 9-cell cavity



Field distribution in a 9-cell cavity for all modes, normalized to the max. field achieved. In the accelerating mode (π-mode) the field is distributed uniformly in all cells, for all other modes it varies from cell to cell. The mode measurements can be used to excite selected cells and hence reduce the cell ambiguity in locating quenches amongst various cells.

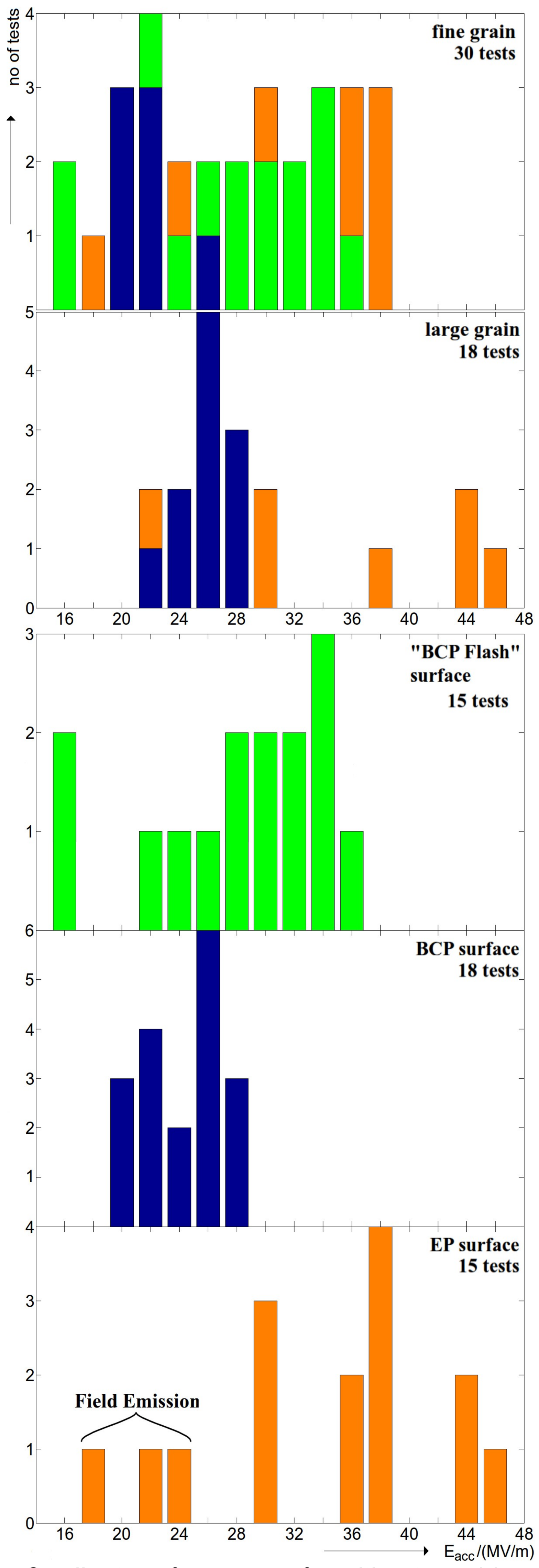
Cavity tests

Data used

Form Nov 2009 to June 2011 a total number of 66 cavity tests have been done at DESY. A few cavities do not show a clear cavity history including the current surface, and cavity production series 7 (3 hydroformed cavities) and 9 (4 cavities in XFEL-design, test of a new fabrication process) are not included in this report. So the dataset contains test of the cavity production series 6 and 8 with fine grain and large grain niobium respectively for which the number of tests amount to 30 and 18, i.e. in total 48 tests.

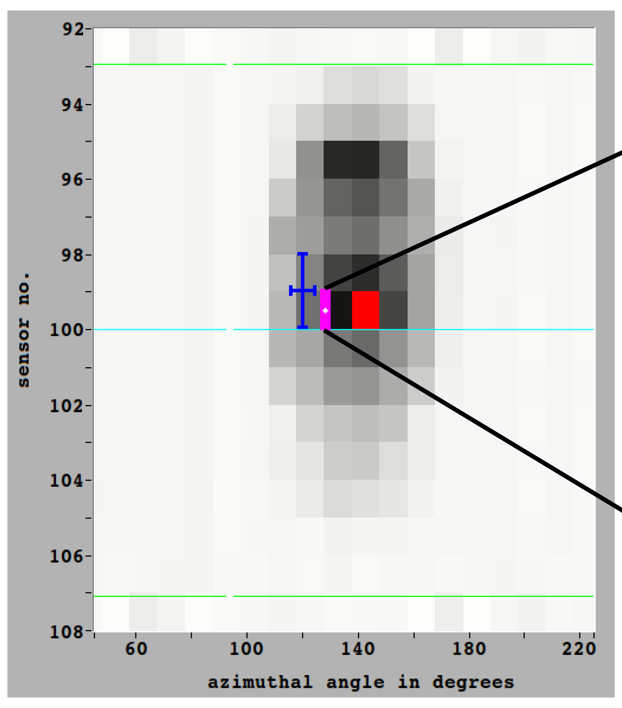
- For the EP cavities there are only 3 (20%) tests with gradients below 30 MV/m with strong radiation observed, leading to the assumption of field emission
- For the different cavity series there are two „groups" in the diagram representing the BCP and the EP surface
- 36 tests (76%) reach the XFEL specification of 23.6 MV/m in this test sample
- The BCP cavities reach gradients up to 30 MV/m

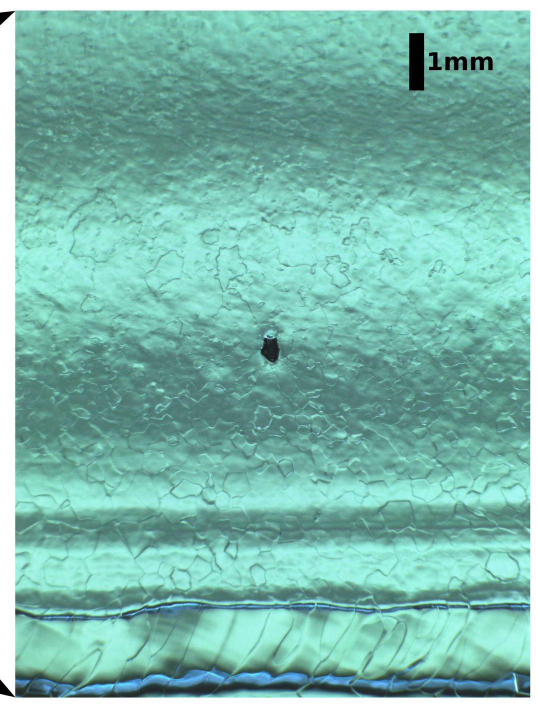
Test results



Gradient performance of cavities tested by material and surface treatment – the colors indicate the surface treatment

Example of correlation between mode measurements, quench localisation and optical inspection





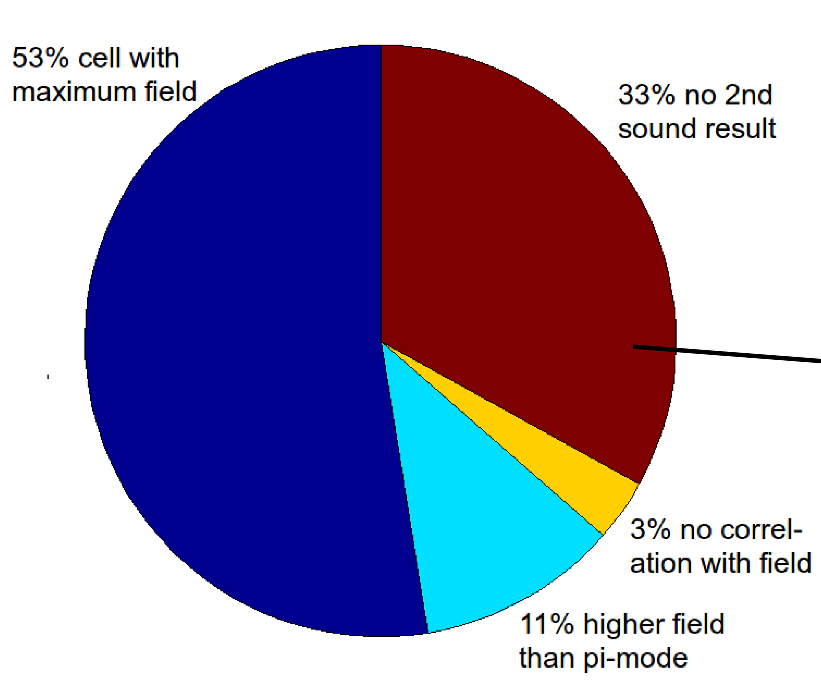
Left: Temperature map of Z161, cell #2 in π-mode measurement. The cavity achieved a gradient of 13.6 MV/m. The red dot is the hot spot determined by T-map, the blue mark is the calculated quench location by second sound. The purple spot shows the position of a defect observed by optical inspection.
Right: Picture of the inner surface of Z161 at the quench location.

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

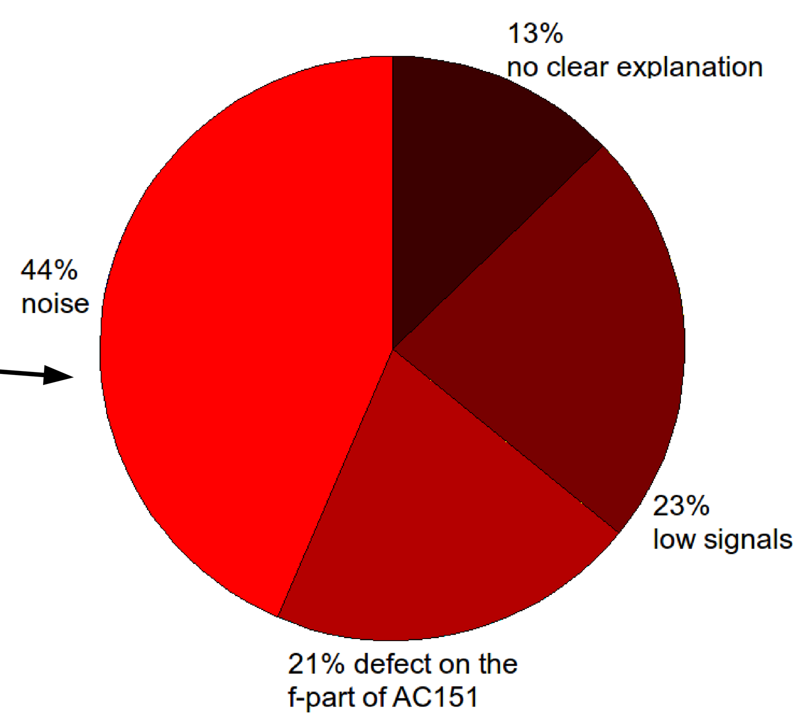
The table shows the quench locations obtained with second sound of AC155 and the results of the mode measurements showing the cells with the highest fields.

Very good agreement between all diagnostic tools

Comparison of mode measurements with second sound data



Observation from 118 mode measurements and simultaneously running second sound measurement (13 cavities + 1 cavity with HOM feedthroughs).



Categories for failing second sound location.

Results:

- When measuring successfully there is good agreement between the location derived from second sound and the peak field excited in mode measurements in a given cell
- Few datasets show quenches in cells with higher fields than in π-mode, but not in cells with highest field gradient
- For very few datasets there is no obvious correlation between field and quench location
- Almost half of „bad" second sound measure-ments are due to noise and low signals
- AC151 had a damaged HOM coupler antenna (f-part) leading to Q-switches (local heating at the latter HOM coupler) and no proper measurements
- Some second sound measurement fail when the stored energy in the cavity is too low

Summary

- From November 2009 to June 2011 there were 66 tests in total of 9-cell cavities in the vertical test stands at DESY.
- The cavities experiencing BCP treatment do not exceed an accelerating field of 30 MV/m thus confirming earlier observations
- EP cavities reach higher accelerating gradients. However, some cavities fail at small gradients due to strong field emission.
- Second sound and temperature mapping were used on some 10 cavities and the results show good agreement between the mode measurements and quench locations

Acknowledgements

Special thanks to the staff working in the cavity test area (hall 3)