

## STATUS OF THE XFEL TESTCAVITY PROGRAM\*

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### Abstract

In preparation of the European XFEL-project a test cavity program of about 25 1.3GHz niobium single-cell cavities was launched at DESY in the beginning of 2005 in parallel to the accelerator nine-cell structure activities. After a successful start-up of the DESY in-house fabrication main topics of the program are the optimisation of cavity electron beam welding preparation, the performance of large grain niobium and the qualification of further niobium vendors for cavity production. So far reproducibly all cavities (TESLA cell shape) exceed gradients of 28 MV/m at high Q-values. An electropolished mono-cell fabricated of large grain material reached 41 MV/m at  $Q_0 = 1.4 \cdot 10^{10}$ .

### INTRODUCTION

The European X-Ray Free Electron Laser XFEL [1] will be based on app. 1000 superconducting 1.3 GHz nine-cell cavities of the existing TTF/FLASH type. In preparation of the large-scale cavity fabrication a program based on single-cell test cavities was initiated to investigate four major fields:

- Qualification of modified fabrication parameters. In particular a modified procedure of electron beam (EB) welding of the cavity cells can improve the workflow of a large scale production.
- Qualification of alternative niobium vendors. New vendors for high quality niobium came into the market in the last years.
- Capability of large grain niobium for series nine-cell production. The superconducting rf-properties of all cavities tested at DESY so far are discussed. More details about material properties and cavity production can be found in [2].
- Development of dry-ice cleaning as additional cleaning process. This topic will not be discussed within this paper. Latest results can be found in [3].

Further activities related to the test cavity program are the analysis and optimisation of the “120C bake” process, comparison of electropolishing (EP) and etching (BCP) preparation process and the superconducting photo-cathode gun cavity with 0,6 cells [4].

### TEST CAVITY FABRICATION

#### Test cavity

The DESY standard single-cell test cavity is based on two “long” end-halfcells of the TESLA shape (Fig. 1). The need for compatibility resulted in the standard test

cavity design with no mechanical differences between various industry and in-house productions.

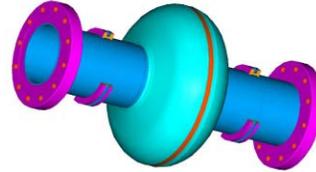


Figure 1: 3-D model of the DESY standard single-cell test cavity

Within the last year 18 cavities were completed at DESY. All machining, EB welding and mechanical / optical checks take place at DESY. Deep drawing of the cups and electropolishing (EP) of cavities is done in industry. Etching (BCP) of components and cavities is split between DESY and industry.

Furthermore, 6 cavities of large grain and mono-crystal niobium were fabricated at Accel Instruments GmbH. The final mechanical and optical checking was done at DESY.

In general all BCP and EP processes can be done in-house, but due to overloading of the facilities at DESY and in order to initiate industrialisation of the EP process a close cooperation with industry was preferred. EP of the cavities is done at Henkel Lohnpoliertchnik GmbH. Components are etched by Poligrat GmbH. Accel etches most of the cavities. Firing under vacuum conditions as well as final cavity preparation like cleanroom assembly and high pressure rinsing is done at DESY for all cavities.

#### Qualification of DESY in-house fabrication

The DESY in-house fabrication was qualified by 3 single-cell cavities of well-known niobium quality (fine grain niobium with RRR 300 by W.C. Heraeus GmbH). After fabrication the cavities were electropolished and high pressure rinsed as final treatment. They were tested before and after the vacuum bake-out at app. 130°C (“bake”). The tests before bake are limited by the typical Q-slope without field emission. After bake all cavities show high Q-values above  $10^{10}$  and exceed gradients of 28 MV/m shown in Fig.2. The cavity 1DE1 is limited by a local thermal breakdown (“quench”) at 34 MV/m far off the equator, what indicates, that the material or – less probable – the final treatment is responsible for the limitation. The cavities 1DE2 and 1DE3 are limited by quenches in the equator area, which may indicate a limitation caused by the weld. These cavity performances successfully qualify the DESY in-house fabrication, but there are options for further improvement.

\*We acknowledge the support of the European Community-Research Infrastructure activity under FP6 “Structuring the European Research Area” program (CARE , contract number RII3-CT\_2003-506395)

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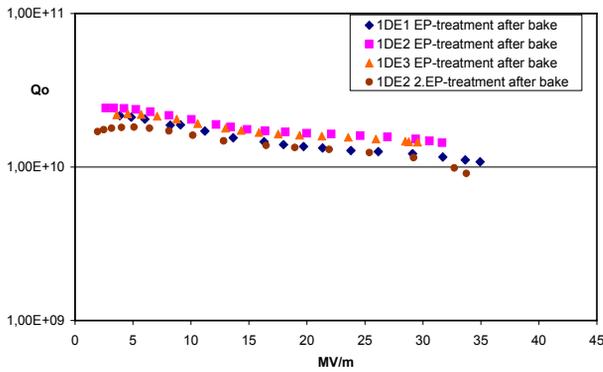


Figure 2:  $Q_0(E_{acc})$ -performance of the cavities for qualification of the DESY in-house fabrication

### MODIFIED PREPARATION OF EB WELDING

The present specification of cavity fabrication gives a limit of maximum 8h between the final cleaning (etching) of the weld area and the EB welding (“8h-rule”). Obviously this is a restriction of the cavity fabrication workflow. In a test series of 5 cavities fabricated of well-known niobium quality (fine grain niobium with RRR 300 by Heraeus) storage of the cleaned components before EB welding under defined conditions was investigated. Fabrication of one reference cavity was performed according to the present specification with the described “8h-rule”. Components (cups) of two cavities each were stored for one week under vacuum and pure nitrogen atmosphere before welding the equator weld.

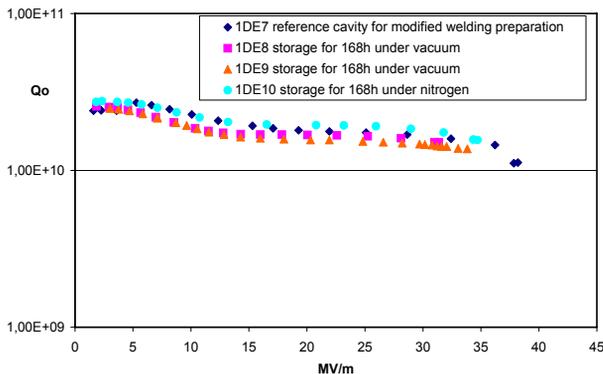


Figure 3:  $Q_0(E_{acc})$ -performance of the cavities with modified preparation before EB welding

Up to now four cavities with a good performance are tested with gradients between 31 MV/m and 38 MV/m (Fig.3). The missing test of 1DE11 stored under nitrogen is coming soon. The modified welding preparation is preliminary accepted and will be applied to the next cavity production.

### ALTERNATIVE VENDORS OF NIOBIUM

In addition to the established vendors for high purity sheet niobium additional companies came into the market within the last years. Of special importance is Plansee, which uses the well-proven Nb ingots of Heraeus and

establishes a sheet production. A summary of material properties is given in Table 1.

#### Plansee Niobium

Using Nb ingots of Heraeus, Plansee produced sheets with RRR of 300. Three cavities have been successfully completed by DESY in-house fabrication. The cavities are under preparation for the first rf test.

#### ITEP Giredmet Niobium

Three cavities have been fabricated in-house of Russian ITEP-Giredmet Nb with very high RRR > 600. Eddy current scanning of the first test sheets showed one spot with an iron and copper contamination (Fig.4), which indicates a lack of cleanliness during sheet rolling. RRR of the EB weld region is up to 1000 (Fig.4).

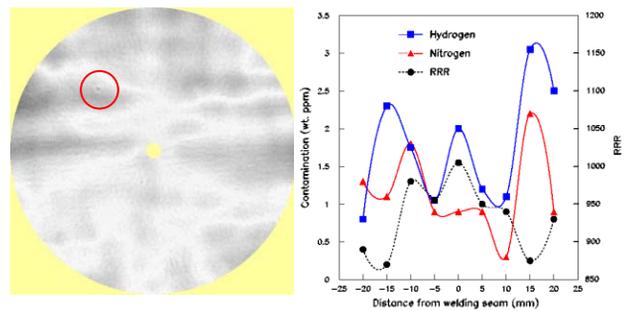


Figure 4: Left: Eddy current scan of Giredmet Nb sheet. The suspicious spot is marked. Right: Nitrogen + hydrogen content in wt.ppm and RRR across the EB weld region

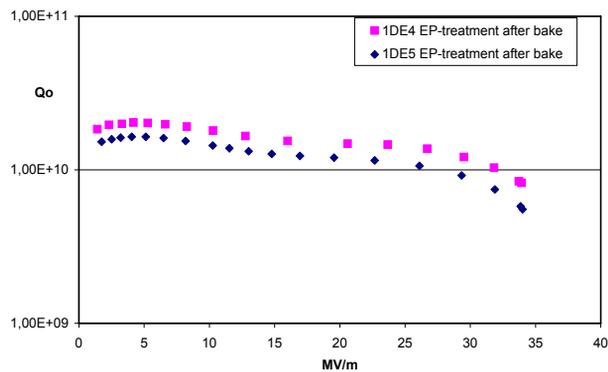


Figure 5:  $Q_0(E_{acc})$ -curves of the ITEP-Giredmet cavities

After bake both tested cavities achieved gradients of 34 MV/m limited by quench (Fig.5), but especially cavity 1DE4 showed significant field emission loading in several tests despite of repeated, thorough cleaning. More investigations are required to prove or disprove a possible relation of this effect to the material properties.

#### Cabot Niobium

The available sheets of Cabot niobium with RRR of about 230 do not meet the specified RRR-value of 300. Nevertheless two cavities were fabricated and rf tests are under preparation.

Table 1: Material properties of investigated vendors

Cavity	Nb Vendor	No. of Sheets	RRR	Tensile strength [N/mm <sup>2</sup> ]	Yield strength	Elongation %	Hardness	Grain Size ASTM
1DE4 – 1DE6	ITEP - Giredmet	8	640 – 980	154	95	36 – 42	41	3,5 - 5
1DE12 – 1DE13	Cabot	30	234 – 320	165 – 176	62 – 64	60 – 64	54	8
1DE14 – 1DE16	Plansee (Heraeus)	18	307 – 317	125 – 149	45 – 50	35 – 48	47 ± 5	5 - 6
1DE17 – 1DE19	Ningxia	7	333 – 344	157 – 166	108 – 121	56 – 60	58 – 60	6,0 – 6,5

### Ningxia Niobium

For the first time fine crystal Nb sheets with RRR of 300 by the Chinese vendor Ningxia were available. Three cavities are in fabrication and will be completed soon.

## LARGE GRAIN NIOBIUM

Five cavities of large grain niobium supplied by Heraeus have been fabricated at Accel. A RRR of about 500 indicates excellent thermal properties of this material. Details about the material properties and cavity production can be found in [2]. Three cavities were tested after electropolishing as final surface treatment. The cavities 1AC3 + 1AC4 with deep-drawn cups achieve excellent gradients of 41 MV/m and 37 MV/m, respectively limited by quench (Fig.6). The cavity 1AC5 with forming of the cups by spinning is limited at 29 MV/m. The single-cell 1AC7 as well as the nine-cell cavity AC114 are produced of a different Nb ingot and finally processed by BCP. Unfortunately the first test of AC114 was affected by strong field emission starting at 18 MV/m. Nevertheless the cavity achieved 29 MV/m. With a quench at 25 MV/m 1AC7 stays well below the electropolished cavities and results achieved on etched cavities at JLab [5, 6].

This discrepancy as well as the wide scatter of gradients suggested a detailed comparison of the performance after EP- and BCP processing for all large grain cavities. As a first result the cavity 1AC3 lost 12 MV/m after 50µm etching and is now limited by a quench at 29 MV/m.

After EP treatment of large grain Nb no “Q-disease” caused by hydrogen absorption was found up to now.

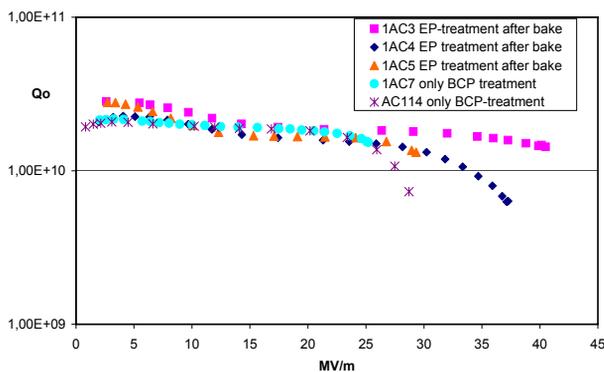


Figure 6: Best  $Q_0(E_{acc})$ -performances all tested cavities of large grain niobium

One cavity fabricated of two mono crystal sheets was tested after a BCP treatment and limited by a quench at disappointing 19 MV/m. A further test after electropolishing is under preparation.

## SUMMARY + OUTLOOK

In Fig. 7 the best gradients of all cavities tested up to now are summarized with their final preparation. In the next months a full comparison of the performance of large grain cavities after final BCP- vs. EP-processing will be completed. In addition to the above described cavities of alternative niobium vendors, the first large grain cavities fabricated in-house at DESY are under preparation.

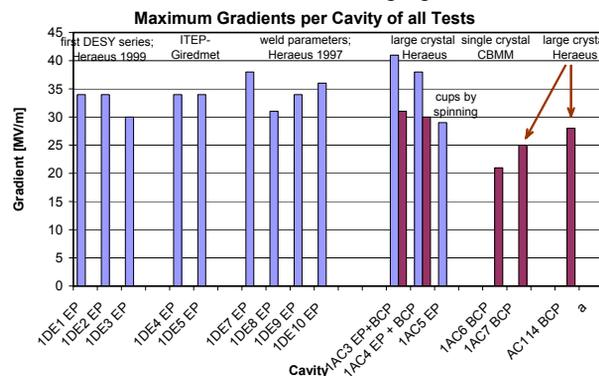


Figure 7: Summary of the best gradients of DESY in-house fabrication and large grain cavities

## ACKNOWLEDGEMENT

We acknowledge the support of all involved DESY colleagues as well as the good cooperation with Accel, Henkel, Heraeus and Poligrat realizing this program.

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