ILC-HIGRADE CAVITIES AS A TOOL OF QUALITY CONTROL FOR EUROPEAN XFEL

A. Navitski[1], E. Elsen[1], B. Foster[1, 2], J. Iversen[1], R. Laasch[2], A. Matheisen[1], D. Reschke[1], J. Schaffran[1], X. Singer[1], W. Singer[1], L. Steder[1], Y. Tamashevich[2], M. Wenskat[1]
[1]DESY, Hamburg, Germany, [2]University of Hamburg, Hamburg, Germany

Abstract

Part of the quality control (QC) and quality assurance (QA) scheme to achieve the designed parameters of the European XFEL cavities is presented. Results of the first tests of QC cavities from the "ILC-HiGrade program" as well as examples of feedback to the cavity fabrication during the ramping-up phase is presented.

INTRODUCTION

In order to ensure that the design goals of the European XFEL (EXFEL) [1] cavities are met, an extensive quality control (QC) and quality assurance (QA) scheme has been devised. An additional quality control tool is given within the "ILC-HiGrade program" [2]. .

EUROPEAN ILC-HIGRADE PROGRAM

The EXFEL cavity order includes an additional 24 cavities as part of the European ILC-HiGrade programme. Initially, these cavities serve as quality-control (QC) samples extracted from the serial production of EXFEL cavities on average once per month.

An overview flow scheme of the so-called "QC cavity" preparation is given in Fig. 1.

The first few cavities have already been delivered and passed the first cold RF tests. After this standard acceptance test, the cavities are taken out of the production flow and released for further R&D. The QC and QA have to include all processing steps of the EXFEL cavities.

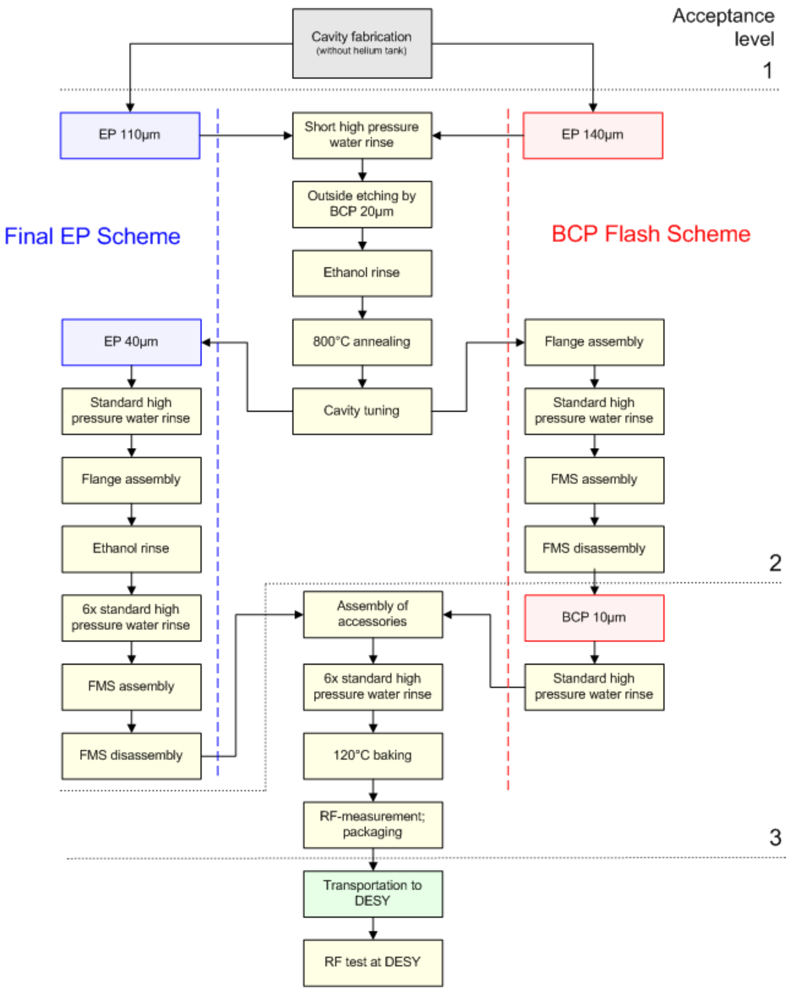

Figure 1: Flow scheme for the "ILC-HiGrade" cavity quality assurance.

To maximize the data from these QC cavities, a surface-mapping technique (“Second Sound” [3] and temperature mapping (T-mapping)) is applied in a second cold RF test. Therefore the cavities are delivered with the normal full treatment of the inner surface but without a helium tank. All other fabrication steps, specifically the mounting of the field-profile measurement system into the cavity, including the measurement itself, and its removal from the cavity is carried out. This will allow a check of whether possible contamination via handling in these steps poses a problem to cavity performance. The QC cavities are also equipped with HOM antennas to resemble the XFEL cavities as much as possible. A full documentation of the production steps is provided by fabricating companies except some deviations due to the missing helium tank.

To ensure that the cavity can be subsequently welded into a helium tank in the framework of the ILC-HiGrade programme, leak tests at the conical disks are indispensable. To facilitate the handling of the QC cavities in the process steps after the omitted helium tank welding procedure, an appropriate handling fixture is foreseen.

Because of the omitted tank welding, the ILC-HiGrade cavities arrive roughly two weeks in advance of the main production stream. This allows better monitoring of the production processes and detection of any fabrication difficulties.

Several further R&D steps are foreseen with these cavities within the ILC-HiGrade and CRISP [4] programmes as a feasibility study for the ILC. They are carried out in close collaboration with the experts engaged in the EXFEL production. The aim is to improve the understanding of defects and further exploration of new cavity preparation and repair techniques that can achieve high accelerating fields with high fabrication yield. The details of this programme can be found elsewhere [5].

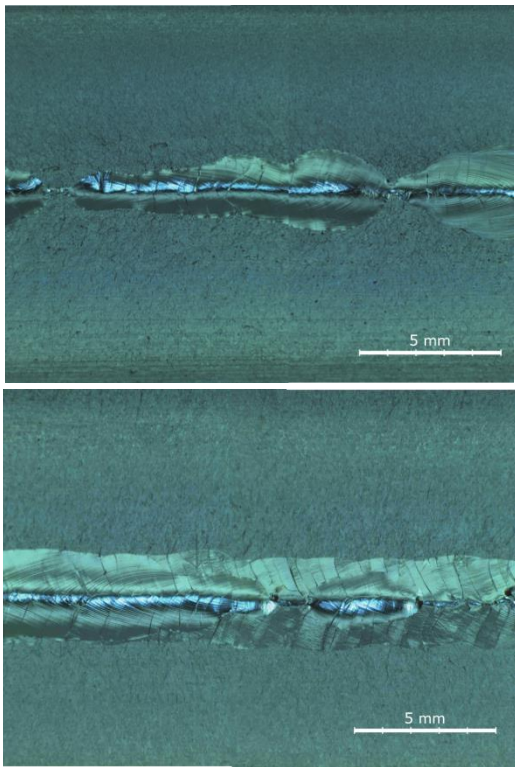

Figure 2: An example of the welding optimization process showing initial, not optimized (upper) and optimized (lower) equator welding seams.

FEEDBACK TO THE EXFEL FABRICATION

Optimisation of the Electron-Beam Welding

One of the difficulties that occurred during the ramp-up phase of the EXFEL cavity production was incomplete penetration of the welding seams and strong variation of the seam-width. Optical inspections with conventional endoscopes at companies gave some indications of the problem. Detailed analysis of the defects, however, was only possible using the optical inspection system OBACHT [6]. The system provides much better resolution and image quality and can allow better tracing of surface modifications through the production steps by detailed recording and very good positioning repeatability as compared to conventional endoscopes. Figure 2 shows an example of the initial, unoptimised status with a welding seam that does not completely penetrate the material and strong variation of the seam-width; the right-hand image was taken after optimisation and shows a homogeneous welding seam with full penetration*.

Study and Repair of Welding Spatters

Endoscope and OBACHT inspections showed the occasional occurrence of ~mm-sized “spatters” on the surface after welding (see Fig. 3). The reason for this is as

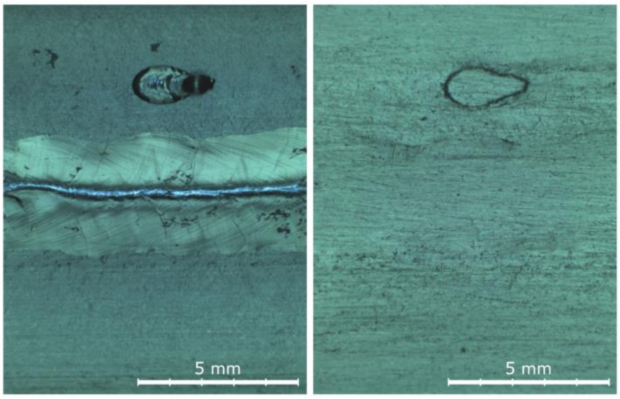

Figure 3: Spatter before (left) and after (right) local mechanical polishing.

yet unclear and is the subject of further investigation. As a consequence, additional local repair of the cavities is required to remove these defects, which are essentially unaffected by the standard polishing techniques. An

* Note that for technical reasons, two different cavities are shown.

optimum repair procedure is currently under study. An example of local mechanical polishing, which was carried out manually, is shown in Fig. 3. However, some difficulties occurred due to the absence of simultaneous optical control of the grinding procedure to determine the amount of material to remove.

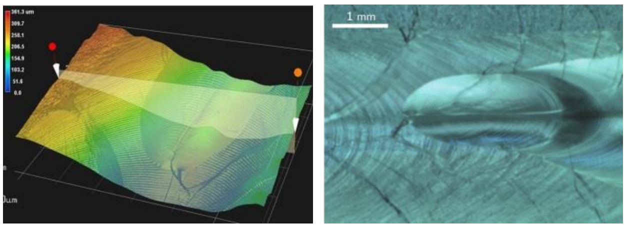

Figure 4: Comparison of 3D profilometry images with 2D optical image from OBACHT.

Replica Study of Some Conspicuous Welding Seams

Some areas of the cavity inner surface and especially the welding seams show occasionally some conspicuous features that cannot be unambiguously interpreted by the OBACHT analysis due to the absence of detailed height information. In order to analyse the geometry of such areas, a "replica" technique in which the inner surface of the cavity is replicated by pressing hardened rubber onto the surface [5] is applied and the resulting profilometry data are compared with the OBACHT results. An example of such a comparison is shown in Fig. 4, which

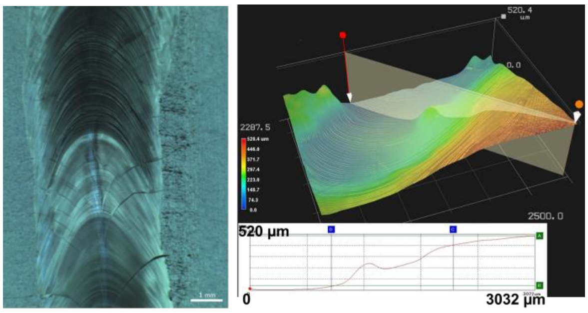

Figure 5: Optical image and profile of the welding seam.

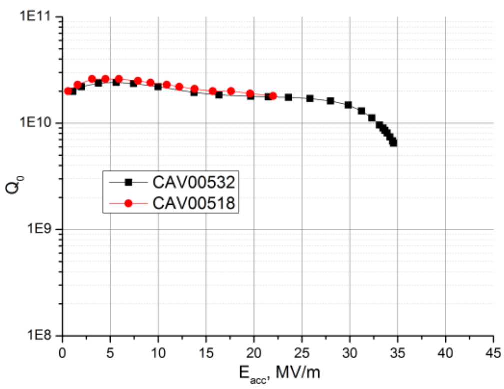

Figure 6: Cold test results of the cavity CAV00532 with no radiation, rf input power limited at 200 W and of the CAV00518 with no radiation and quench at 22 MV/m.

established that a feature known as a "snake head" at the electron-beam welding entry/exit was in fact not standing proud of the surface as had been thought from the OBACHT images. The cavity could therefore follow the usual cavity-polishing procedure.

Another example of such a comparison is shown in Fig. 5, where a large protrusion of the whole welding seam has been confirmed by the profilometry measurements on the replica. Its height was more than 500 µm, while the tolerance is 300 µm. The repair of this cavity involved as a first step the reduction in the height of the welding seam and the checking of the welding parameters.

Cold RF Tests and Surface Inspection of the First QC Cavities

The first few QC cavities have been already delivered and passed first cold RF tests and detailed investigation of the inner cavity surface by means of the high-

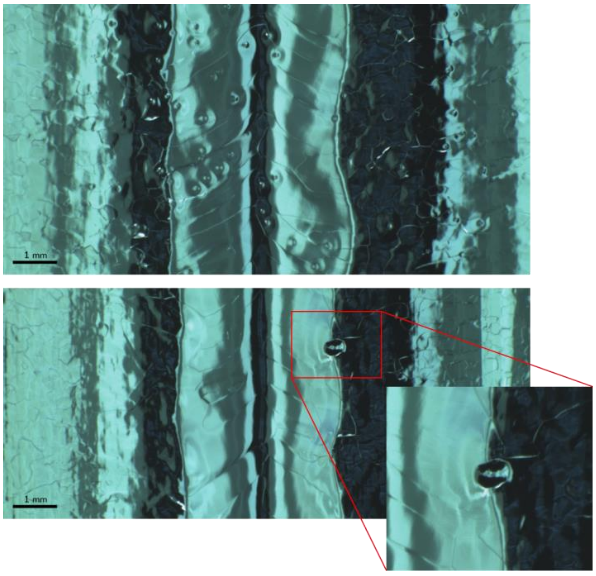

Figure 7: Optical images of some "pits" (upper) and "cat-eyes" (lower) on cavity CAV00532.

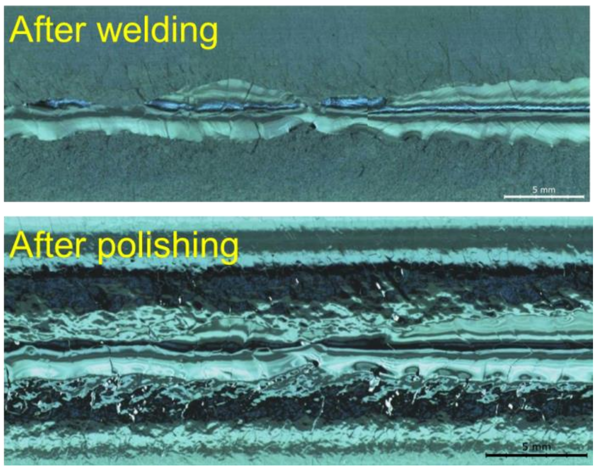

Figure 8: Optical images of the equator welding seam of the cavity CAV00518.

resolution optical system OBACHT. The first cavity (CAV00532) showed a successful cold rf result with almost 35 MV/m (Fig. 6) maximum accelerating gradient with no X-ray radiation; the test was limited at 200 W due to the maximum available input rf power. The cavity showed these excellent results despite the observation of some tiny "pits" and "cat-eyes" on the surface (Fig. 7).

The second cavity (CAV00518) showed an unsuccessful cold rf result with only 22 MV/m maximum accelerating gradient with no radiation but limited by the quench. The OBACHT inspection indicates a defective equator welding seam with strong seam-width variation and probably not fully welded areas as a possible reason for the quench (see Fig. 8). Further detailed studies with "Second Sound" and T-mapping will be applied to localise the quench and to clarify the limiting factor for this and other defective cavities.

CONCLUSIONS

An extensive QA and QC scheme geared to achieve the design parameters of the European XFEL cavities has been implemented. Twenty-four ILC-HiGrade cavities will be used to identified limitations in industrial production and serve as a tool for QC for the EXFEL

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