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CAVITY PROCESSING AND TESTING ACTIVITIES AT JEFFERSON LAB FOR LCLS-II PRODUCTION *

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Abstract

Cryomodule production for LCLS-II is well underway at Jefferson Lab. This paper explains the process flow for production cavities, from being received at the Test Lab to being assembled onto cavity strings. Taking our facility and infrastructure into consideration, process optimization and process control are implemented to ensure high quality products.

BACKGROUND

LCLS-II as a pioneering X-ray free electron laser facility [1] aiming for unprecedented scientific opportunities [2], is an intellectual collaboration between US laboratories, university, and European research institutes. It demonstrates existing SRF technology [3, 4] as well as exploring cavity performance potential [5]. SRF cavities are provided by two vendors: Research Instruments, GmbH (Germany) and Ettor Zanon, S.p.A. (Italy) [6]. The fabrication of cryomodules (CMs) are shared between Fermi Lab and Jefferson Lab (JLAB), with each lab providing 18 CMs. Production related activities at Jefferson Lab include: qualification testing of SRF cavities, limited re-processing of cavities, cavity string assembly, CM assembly, CM testing, and eventually shipping CMs to SLAC. Jefferson Lab is currently at full production stage for the project and has been making the best use of the SRF knowledge developed over the years in the community.

CAVITY PROCESS FLOW

Helium vessel dressed cavities come from vendors under vacuum, ready to be tested. After registered into JLAB inventory system, the critical dimensions and passband frequencies of the cavities are measured. The exterior surface of the cavities is cleaned prior entering the cleanroom, where the cavities are connected to test stands and leak checked at the vertical attachment area (VAA). Once cavities pass leak check, they are moved to vertical staging area (VSA) and prepared for loading into the dewar. Depending on the background of the cavity, RF testing at 2K or multiple lower temperatures is performed at the vertical testing area (VTA). Cavities qualified for a string will be transferred back to the cleanroom, disassembled of both beam line flanges and testing fundamental power coupler (FPC), receive final high pressure rinse (HPR), and assembled onto a string. If a cavity does not meet qualification at the first vertical test due to field emission early onset, an HPR is performed as a remedy attempt. Fig. 1 shows the process flow of a cavity at JLAB after arriving from the vendors. Fig. 2 shows the path of a cavity through work centers at JLAB.

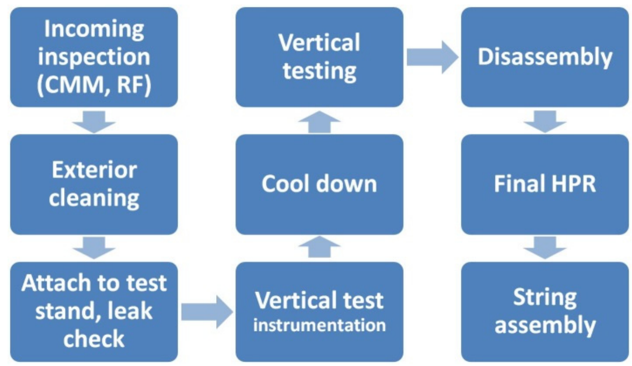

Figure 1: Process flow for LCLS-II cavities after arriving at JLAB from the vendors.

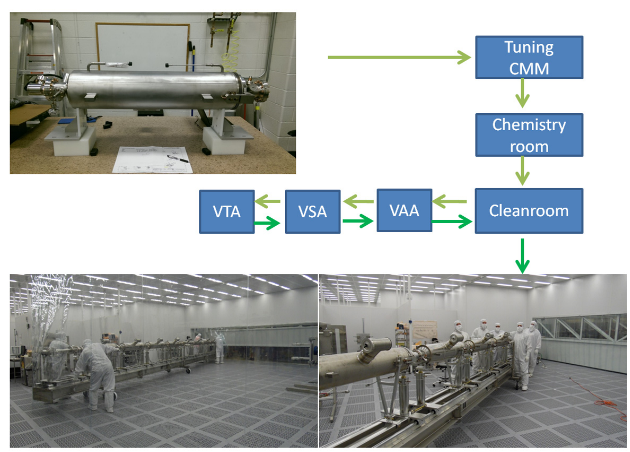

Figure 2: The path of LCLS-II cavities through JLAB work centers, from receiving inspection to an LCLS-II string.

CAVITY PROCESS TRACKING

Cavity process tracking is achieved by Pansophy system [7]. Each process has a traveler, which is a list of actions extracted from the procedure designated to the specific task. Travelers allow users to input critical information of the processes. The data entered could be searched within the network and used for statistics.

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CAVITY QUALIFICATION

VTA testing is performed on cavities in as-received condition, as long as the cavities pass the leak check.

The specification of a cavity that passes the qualification test is:

At 2 K,

- $Q_0 \geq 2.5\times10^{10}$ at E_{acc} = 16 MV/m (Equivalent to Q_0 of 2.7×10^{10} in CM)
- Field emission onset at $E_{acc} \geq 17.5$ MV/m
- Maximum $E_{acc} \geq 19$ MV/m

For cavities failing qualification, limited re-processing is performed at JLAB. The protocol for first round re-processing is: removing FPC-end beamline flange, HPR, assembly beamline flange, and vertical test. Fig. 3 shows the vertical test results of a production cavity, as-received and after one cycle of re-processing. The as-received cavity failed because of a field emission onset of 10.5 MV/m. After re-work (HPR), the cavity did not show field emission up to 24 MV/m and was qualified for the string.

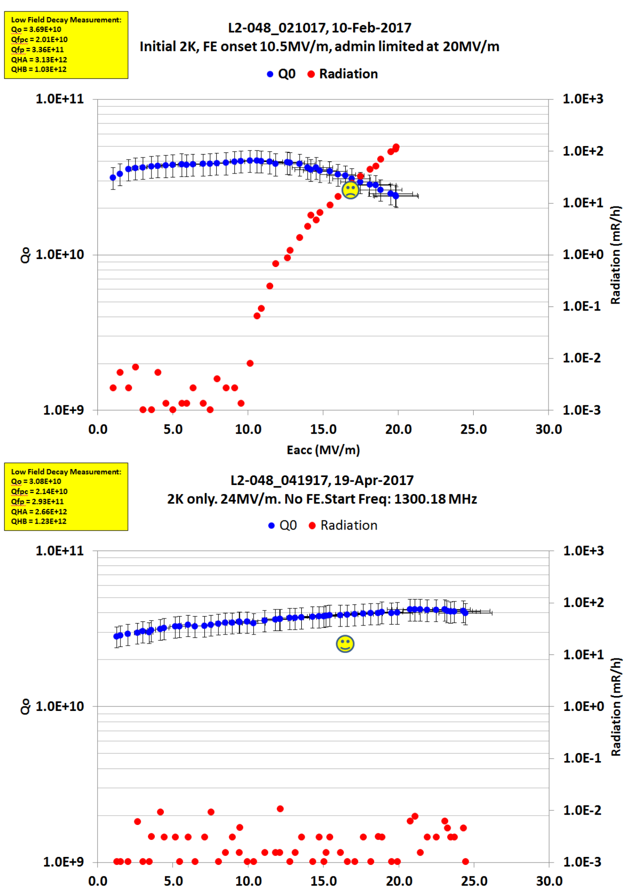

Figure 3: Vertical testing results of a production LCLS-II cavity, as-received (upper plot) and after HPR re-work (lower plot), Q_0-E_{acc} curve in blue and radiation measurements in red.

STRING PROCESS FLOW

During string preparation stage, all parts needed on the string are collected and cleaned for entering the cleanroom. The magnetic fields of hardware and tools are surveyed based on the magnetic hygiene specification. Demagnetization is performed as necessary. Rail and tooling are cleaned, passed into the cleanroom and set up.

Upon completion of string preparation, selected string cavities are slowly vented to atmosphere with filtered nitrogen. The two beamline flanges and the testing FPC are disassembled in a clean manner. Before disconnecting the flanges, the bolt holes are cleaned with isopropanol alcohol soaked wipes and deionized nitrogen to remove loose particulates. After disconnecting the flanges, the sealing surfaces on the cavity flanges are cleaned with wipes. The cavity is then ready for the final HPR. After HPR and drying overnight, the cavity and an inter-cavity bellows are assembled vertically before the cavity-bellow subassembly is set onto the rail to connect to the upstream end of the string. The FPCs are attached after the cavities are assembled and aligned onto the rail. With two cavities per day, the string assembly takes about a week to complete.

The BPM subassembly is pre-assembled and leak checked before the cavity assembly process starts. Slow pump down and leak check of the entire string are done once all components are assembled and tightened. Fig. 4 shows the LCLS-II string assembly snapshots and work flow.

OPTIMIZED PROCESSES TO REDUCE FIELD EMISSION

Knowledge and experience from all these years SRF technology development has been adopted in cavity processing at JLAB to ensure clean assembly of LCLS-II string. Slow evacuating and slow venting are applied to reduce possible particulate transfer by turbulent air flow [8, 9]. The slow evacuating process is achieved by using a metering valve regulating the fore line pressure. The slow venting process is controlled at a rate of 250 sccm with a mass flow controller. A clean flange disassembly procedure, adapted from the particle free flange assembly (PFFA) practice, is implemented in the disassembly of cavities and strings. Careful cleaning of bolt holes and sealing surface is performed to reduce the chance of particulate contamination [10, 11]. Dedicated covers and clamps are used during the assembly of cavities and strings [12]. In consideration of string assembly sequence, vertical assembly and horizontal assembly are combined efficiently to maximize existing vertical assembly expertise; minimum amount of disassembly and valve operation cycles are involved to reduce particulate generation. Fig. 5 captures some of these efforts in the cleanroom during an LCLS-II cavity string assembly.

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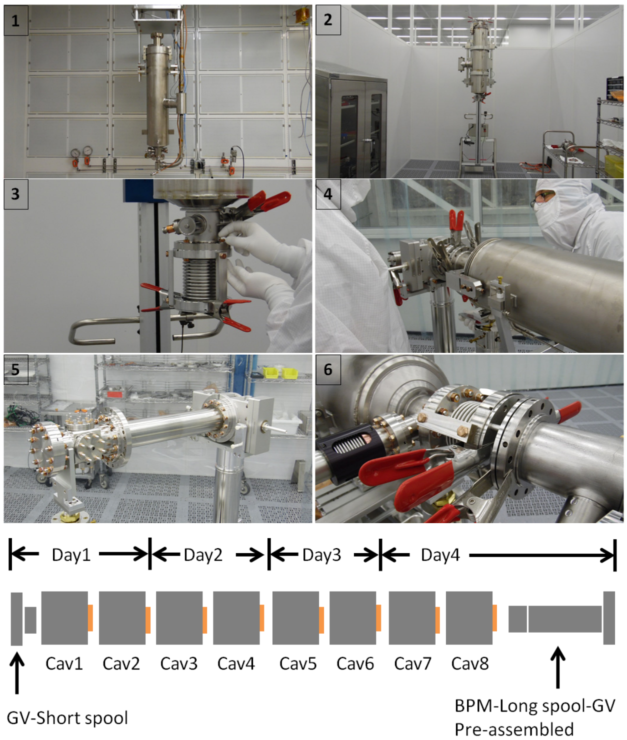

Figure 4: LCLS-II string assembly activities and work flow (lower cartoon). Upper images: 1) A cavity on a test stand at VAA. 2) A cavity received HPR and drying in the assembly cubicle. 3) Vertical assembly of a bellows to a cavity. 4) Horizontal assembly of a cavity beamline flange to the short spool. 5) BMP subassembly. 6) Horizontally connecting of two cavity-bellow subassemblies.

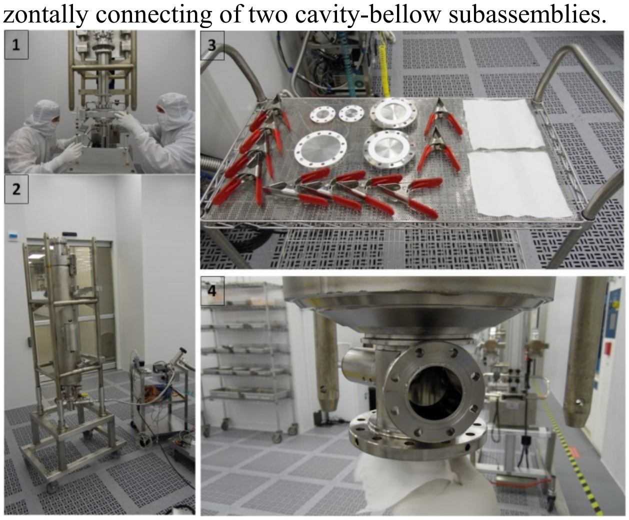

Figure 5: Efforts during LCLS-II string assembly to reduce the chance of particulate contamination: 1) Vertical assembly of a BPM subassembly. 2) Slow venting system, backfill of the cavity to atmosphere pressure with filtered nitrogen. 3) Dedicated covers and clamps used during string assembly. 4) Cleaning the sealing surface after removing the bottom flange, getting ready for the final HPR.

SUMMARY

As of 06/12/2017, 67 production cavities and 8 prototype cavities are in house at Jefferson Lab. Among them, 50 production cavities and 8 prototype cavities are tested at Jefferson Lab or DESY. Among them, 36 production cavities and 8 prototype cavities are qualified for strings. 5 strings are built. 1 CM is tested. Fig. 6 is a summary of the final vertical test performance of the 36 qualified production cavities. Fig. 7 is a comparison between VTA final performance of each prototype cavity and the prototype CM performance from the cryomodule testing facility (CMTF). The cleanliness of the cavity is preserved from the final VTA test to the prototype CM, which is a positive feedback to our current protocols for cavity processing and string assembly.

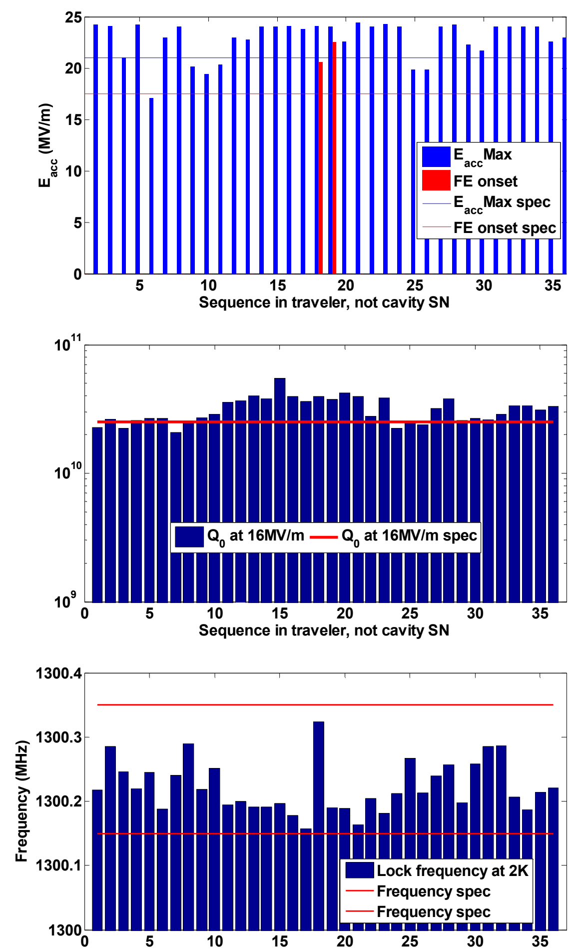

Figure 6: Final vertical test performance of 36 LCLS-II production cavities for string#2 to string #5, as of 06/12/2017.

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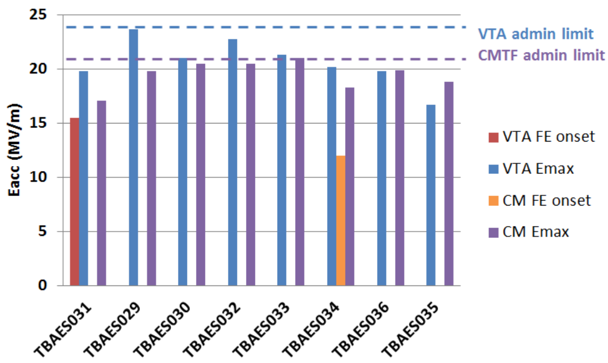

Figure 7: Performance comparison of prototype cavities during VTA final test and prototype CM test.

ACKNOWLEDGMENT

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