SUPERCONDUCTING RF CRYOMODULE PRODUCTION & TESTING AT FERMILAB

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Abstract

Fermilab has produced two cryomodules for superconducting RF (SRF) applications to date. The first of these is an ILC prototype containing eight 1.3 GHz Tesla-type cavities and a superconducting quadrupole. This cryomodule is of the Type 3+ design developed by the TESLA collaboration. The assembly of this cryomodule was accomplished at Fermilab with much assistance from DESY and INFN-Milano. The cryomodule will be tested at Fermilab in the fall of 2010. The second cryomodule produced at Fermilab contains four 3.9 GHz nine-cell cavities. The cavities and cryomodule were designed at Fermilab; the design concepts are quite similar to the 1.3 GHz Type 3+ cryomodule. This cryomodule was shipped to DESY, tested, and is now operating as part of a third-harmonic system in the FLASH facility. Fermilab plans to build five more 1.3 GHz cryomodules over the next several years for a total of six, which will be installed and operated in the New Muon Lab beam test facility at Fermilab.

CRYOMODULE PRODUCTION AT FERMILAB

Cryomodule Assembly Facility (CAF) is the main infrastructure at Fermilab for the assembly of the SRF Cryomodules. The infrastructure consists of two buildings: CAF-MP9 is where the assembly of the qualified dressed cavities into a cold string is done in a Class 10 cleanroom and the cold mass is partially assembled. CAF-ICB is where the partially assembled cold mass is transported for alignment and final assembly.

We have assembled two cryomodules at CAF. First one is a 1.3GHz TTF type 3+ cryomodule (CM1) assembled with the assistance of DESY and INFN-Milano colleagues; this module components were sent from DESY as a kit for assembly. CM1 is currently installed at the NML beam test facility (Fig. 1) at Fermilab and is being prepared for high power cold testing. The second one is a 3.9GHz module, fully designed and assembled at Fermilab. This module was tested at CMTB/DESY. It is currently fully operational at FLASH/DESY as a part of the third-harmonic system. [1]

FNAL plans to assemble 5 more (one Type 3+, four Type 4) 1.3GHz cryomodules within the next couple of years to populate the NML beam test facility with modules. The objective is to achieve the S1 (module with 31.5 average operating gradient) and S2 (demonstration of an RF unit with 3 modules) goals for the ILC R&D.

Cryomodule 1 (CM1)

After the decision that SRF technology will be used for the future linear collider, FNAL decided to build SRF infrastructure and gain the know-how for the technology to conduct R&D and become a world leader in this field. As a part of the infrastructure, CAF was designed and built at FNAL. CAF is an upgraded version of Hall 3 module assembly infrastructure at DESY. CAF group observed a module assembly at DESY and transferred the know-how for module assembly to FNAL. The first module CM1 was assembled at FNAL using a module kit that DESY provided. DESY and INFN-Milano personnel assisted the assembly at CAF. Successful assembly of CM1 at CAF proved the CAF infrastructure is adequate for module assembly and the CAF group has gained the know-how to work on SRF components.

Figure 1:CM1 from the kit to an installed module at the NML beam test line.

CM1 is currently installed at the NML beam test facility. The module beamline was interconnected with the feed, end can and ion pumps. The module cryogenic pipe welding to interconnect the feed can and end can is completed. The high power conditioning of the power couplers is underway. Our first goal is to understand the

performance of cavities in CM1 compared to HTS tests at DESY. We want to verify our assembly techniques in CAF. Note that the dressed cavities provided by DESY for CM1 are not 35 MV/M cavities. We do not expect to meet the S1 goal of 31.5 MV/M. Average of horizontal tests is 23.5 MV/M for the cavities. If we can achieve a gradient close to this value, this will be a good proof for the successful assembly of CM1 at CAF.

3.9GHz Module

Fermilab has constructed a cryomodule containing four superconducting radio frequency (SRF) cavities operating at 3.9 GHz for the Free electron LASer in Hamburg (FLASH) facility at the DESY laboratory (Fig. 2). This cryomodule, known as ACC39, was proposed to linearize the energy distribution along a bunch upstream of the bunch compressor. The components for this module including the cavities were fabricated in USA. The assembly was done at CAF by the CAF technicians, DESY experts observed the assembly. Great care went into design and fabrication of a carrier fixture and techniques to minimize shock and vibration to components within the vacuum vessel (couplers and cavities mostly) to ship the 3.9GHz module from Fermilab to DESY. [2]

The module was tested at CMTB/DESY prior to installation in their beamline (FLASH). The test of the module showed that the average gradient of the cavities is same as achieved during horizontal test of individual cavities. [3]

This effort has proven to be far more than merely a scaled version of a 1.3GHz TESLA module. With this work successfully complete, Fermilab has gained valuable experience in designing, fabricating and assembling SRF devices as well as building up the necessary expertise and infrastructure. From the assembly stand point of view, the successful assembly and operation of this module proved that CAF infrastructure and CAF group technical competence is up to the par to conduct R&D on SRF components.

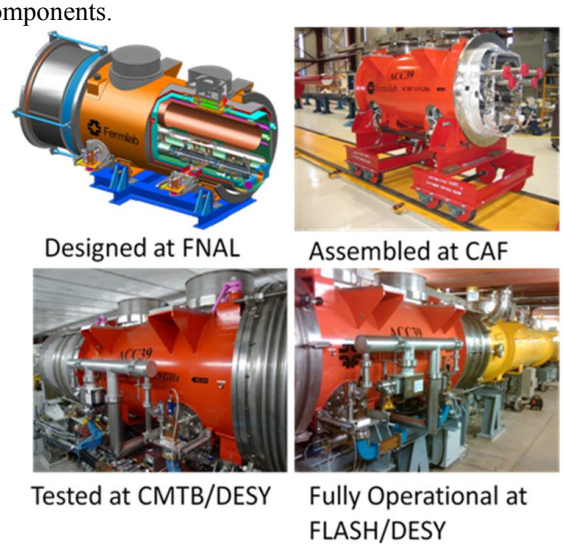

Figure 2: 3.9GHz cryomodule from design to successful operation at FLASH.

CM2 and Beyond

Fermilab is currently working to qualify eight dressed cavities to start the assembly of the second 1.3GHz cryomodule (CM2). CM2 cold mass components were delivered from INFN-Milano as a kit. Fermilab is providing eight dressed cavities processed, tested and qualified fully at USA laboratories. The cavities for CM2 will be a mixture of cavities built at Research Instruments (formerly ACCEL) in Germany and Advanced Energy Systems (AES) in USA. The cavities are currently being processed either at Jefferson Laboratory and/or at Fermilab Surface Processing Facility located at Argonne National Laboratory. The cavities are vertically tested at either Jefferson Laboratory and/or at IB1 Vertical Test Facility at Fermilab. [4] The cavities are welded to their helium vessel at CAF (Fig. 3). The dressing of the cavities is done at CAF facility and the last qualification test is done at Fermilab Horizontal Test Facility. So far, we have accumulated three cavities. Eight cavities are needed to start the cavity string assembly of CM2. We plan to start the assembly of CM2 in late CY2010. CM2 will be a Type 3+ 1.3GHz cryomodule. The objective to assemble this module is to re-test the gained experience of assembling modules at CAF. CM2 will be installed and tested at NML beam test facility as the second cryomodule.

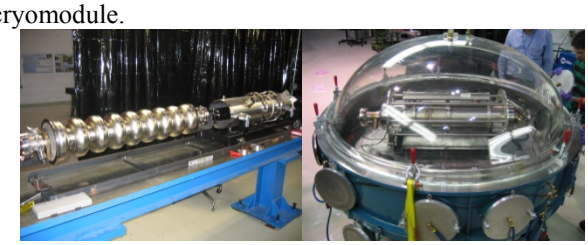

Figure 3: Cavity to Helium Vessel Assembly & Welding Infrastructure at CAF.

Fermilab plans to produce four more cryomodules after CM2. The design of these four modules will be Type 4. Several design optimizations were done from Type 3+ to Type 4. The magnet will be located in the middle of the module for CM3. Also to support the R&D for Project X at Fermilab, Type 4 design gas return helium pipe structure has the capability to support magnet/s at position 2, 5 and 7 as needed. The cavity and the magnet support schemes are the same in the Type 4 design; therefore this allows us to either install a cavity or magnet at the above specified locations. A CAD model of Type 4 design 1.3GHz module can be seen in Fig. 4.

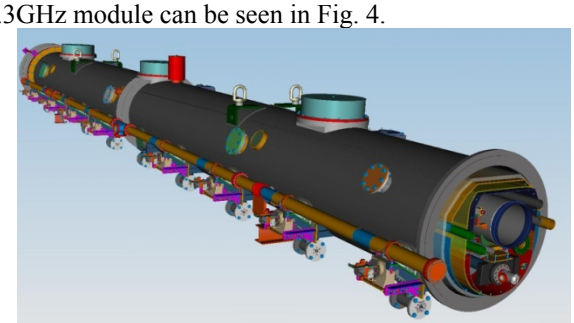

Figure 4: Type 4 Cryomodule.

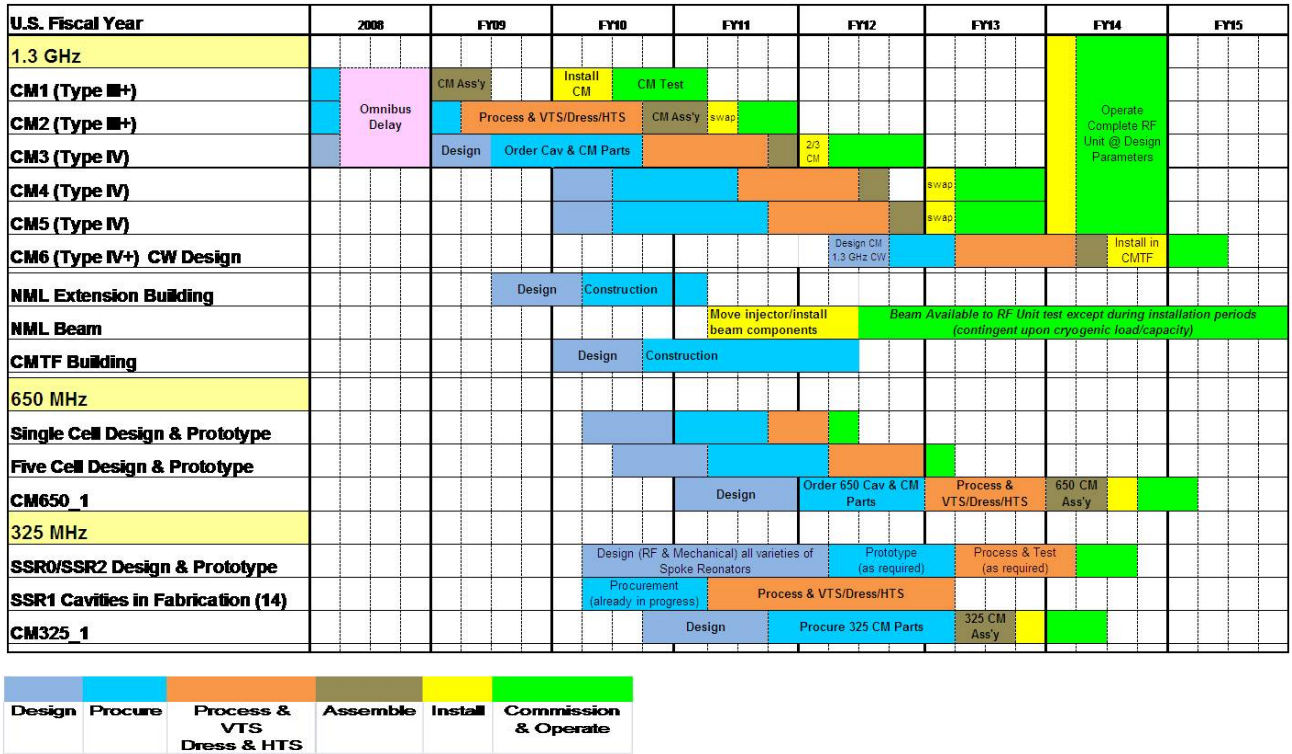

Figure 5: Cryomodule Assembly & Testing Plans at Fermilab.

The planned schedule to assemble and test cryomodules at Fermilab is summarized in Fig. 5.

SUMMARY

Fermilab has successfully assembled two cryomodules at Cryomodule Assembly Facility (CAF). With the experiences accumulated with the assembly of CM1 and 3.9GHz modules at CAF, CAF group is now ready to assemble CM2 as soon as eight dressed cavities are qualified. CAF infrastructure and the assembly group are ready to start the assembly as soon as the cavities are qualified.

Some upgrades, modifications need to be done at CAF in order to assembled Type 4 cryomodules. The required upgrades are mostly tooling/fixtures related and it will be done timely so that CAF infrastructure is ready for CM3 assembly as scheduled.

REFERENCES

[1] Elvin Harms et al., "3.9GHz cryomodule", LINAC'2010, Paper and Poster MO304, TUP013.

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[3] Elmar Vogel et al., "Test and Commissioning of Third Harmonic System at FLASH", IPAC'2010, Paper THPD003.

[4] Camille Ginsburg et al, "Superconducting RF Cavity Production, Processing and Testing at Fermilab", LINAC'2010, Poster THP026.