

SRF SYSTEMS FOR ASTA AT FERMILAB*

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Abstract

The Advanced Superconducting Test Accelerator (ASTA) at Fermilab, now being commissioned, is comprised of a number of superconducting RF systems including single-cavity cryomodules and a TESLA/ILC style 8-cavity cryomodule. Two of them, 'Capture Cavity 2' and 'Cryomodule 2', have been cooled to 2 Kelvin and brought into operation. We provide an overview of the unique characteristics of each of the systems, commissioning experience, and latest results including their respective operating characteristics.

INTRODUCTION

ASTA, now being constructed and commissioned at Fermilab, is planned to be an advanced accelerator R&D (AARD) facility providing a high brightness, high intensity electron beam. It has been extensively described [1, 2]. ASTA consists of a normal conducting photoinjector, two 'booster' SRF cavities, a TESLA style 8-cavity cryomodule, beam transport lines including space for experimental facilities, and beam dumps. In the coming months, it is planned to initiate an experimental program with electrons at a peak energy of 55 MeV. In parallel the 8-cavity cryomodule will be brought into full operation. Future plans call for electrons to be accelerated through the single cryomodule to a peak energy of order 300 MeV. Long-term plans call for injection into a small storage ring, the Integrable Optics Test Accelerator (IOTA). Figure 4 shows these SRF components in their respective locations in ASTA.

CAPTURE CAVITIES

ASTA operation with accelerated electrons is planned to begin as early as summer 2014. The peak beam energy will be achieved by acceleration through two 'booster' cavities, Capture Cavities 1 and 2.

Capture Cavity 1

Capture Cavity 1 (CC1), a single cavity TESLA style 1.3 GHz 9-cell device was the workhorse of the A0 Photoinjector operated at Fermilab until October 2011 [3]. It provided an accelerating field of approximately 14 MeV. Since its decommissioning at A0 it has been undergoing an extensive upgrade [4]. The main thrust is installation of a new cavity which has been tested to a peak gradient of 29 MV/m at Fermilab's Horizontal Test

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Facility. At the time of this writing the upgrade is in its final stages and installation of CC1 at ASTA is planned for the summer of 2014.

In anticipation of its arrival at ASTA, the 300 kW klystron previously used to drive it at A0 has been relocated to ASTA and is in early stages of re-commissioning there.

Capture Cavity 2

Capture Cavity 2 (CC2) has been in operation at ASTA since 2010 [5]. Since its installation (see Fig. 1) it has operated at gradients as high as 24.5 MV/m although in recent operational periods it has been limited to 21 MV/m by vacuum and cryogenic perturbations. These instabilities appear to be sourced in the cavity itself rather than in the coupler. Like CC1 it is driven by its own 300 kW klystron capable of 1.6 millisecond RF pulse lengths for normal operation at a repetition rate of 5 Hz. As conditions permit it is planned to repeat on-resonance conditioning to a higher power, up to 1MW, at narrow pulse widths, with an alternate klystron.

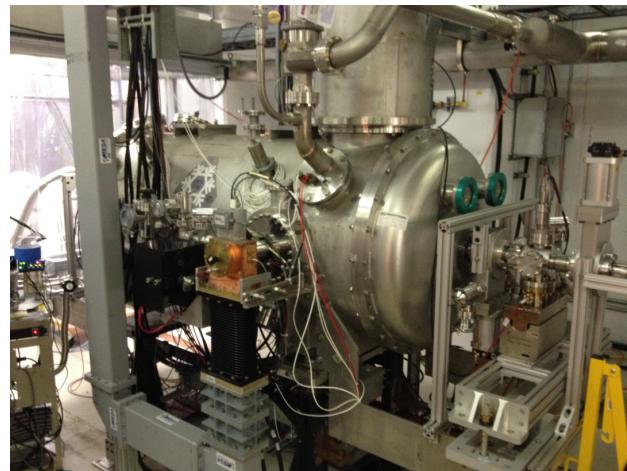


Figure 1: Capture Cavity 2 installed in ASTA.

CRYOMODULES 1 & 2

To date two 8-cavity TESLA style cryomodules have been cooled down to 2 Kelvin and powered at ASTA.

Cryomodule 1

CM-1 was installed in 2010 and was operated in the cold from December 2010 through March 2012 when it was removed. Its performance has been previously documented [6]. Table 1 summarizes each cavity's performance and source of limitation. Operation of CM-1

was a valuable experience in anticipation of installation and operation of the subsequent cryomodule, CM-2/RFCA002.

Table 1: CM-1 Cavity Gradient Limitations

Cavity	Peak E_{acc} (MV/m)	Estimated maximum Q_0 (E09)	Limitation
1/Z89	20.2	11	'Soft' quench
2/AC75	22.5	12	Quench
3/AC73	23.2	0.43	'Soft' quench
4/Z106	24*	2.3	*RF limited
5/Z107	28.2	39	Quench
6/Z98	24.5	5.1	Quench
7/Z91	22.3	4.7	'Soft' quench
8/S33	25	18	Tuner motor malfunction

Cryomodule 2

CM-2/RFCA002 has been installed at ASTA since April 2013 as seen in Fig. 2. In the intervening months all cavities and couplers have been conditioned in the warm (off-resonance), cooled down to 2 Kelvin, and then each cavity individually powered and characterized. Figure 3 compares the gradients achieved at ASTA to those from bare cavity vertical tests at Jefferson Lab as well as from dressed cavity tests at Fermilab's Horizontal Test Stand.



Figure 2: Cryomodule 2 installed in ASTA.

All but one cavity achieved the administrative upper gradient limit of 31.5 MV/m set for this initial stage of cryomodule testing. These gradients were achieved with each cavity pulsing at 5 Hz and with adaptive Lorentz Force Detuning Compensation active. A companion paper at this conference provides more detail as to cavity performances [7].

With this phase of testing complete powering of the entire cryomodule is planned to begin in the summer of 2014.

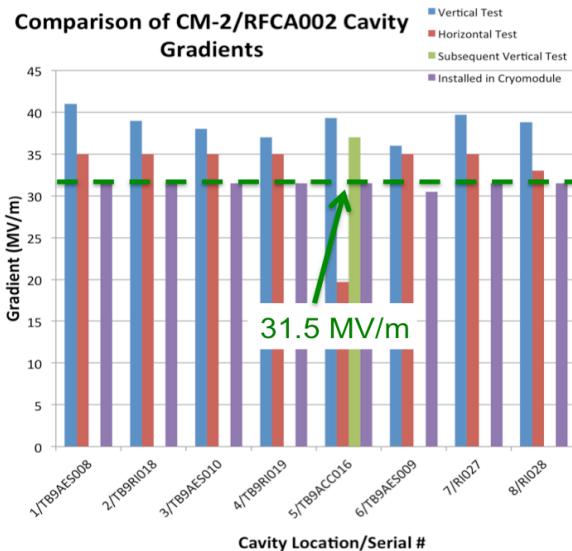


Figure 3: Comparison of CM-2/RFCA002 cavity gradients: vertical test (blue), horizontal (red), and in CM-2 (purple). An administrative limit of 31.5 MV/m was set for CM-2 testing.

INFRASTRUCTURE

As much as possible standardized interlocks, system protection, and controls schemes have been implemented for these SRF systems. Both capture cavities are driven by identical 300 kW klystrons while a 5 MW one powers the cryomodule. The Low Level RF systems of the capture cavities is of a common architecture. Lorentz Force Detuning Compensation is integrated into all three SRF systems. A common cryogenics system provides of order 110 Watts of cooling at superfluid temperatures [8].

CONCLUSION

Three SRF systems make up the primary accelerating components for ASTA. Two of them are now in operation with the third, CC-1, expected to be installed in the very near future. In sum they will provide a total acceleration of order 300 MeV.

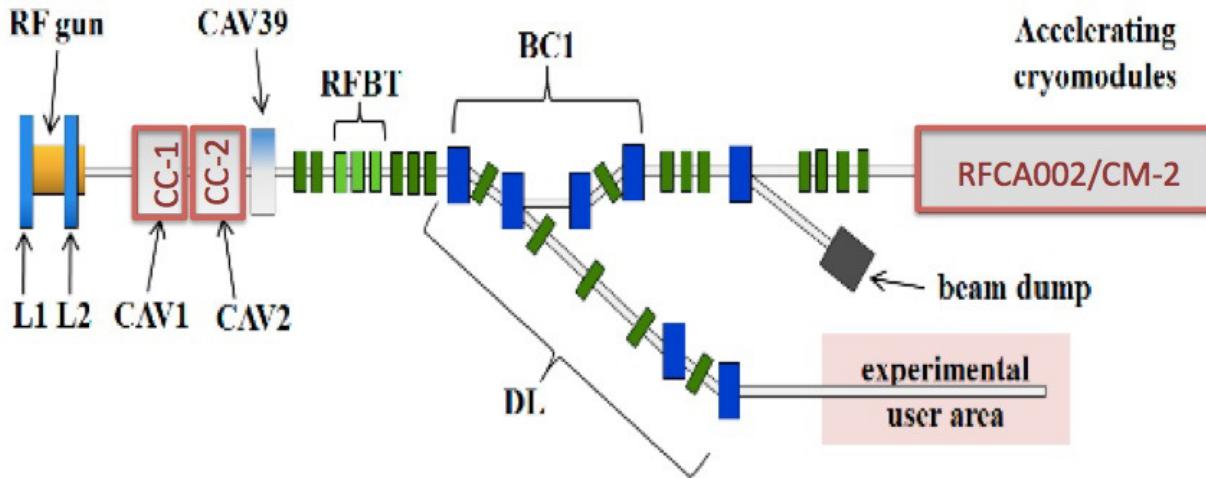


Figure 4: Layout of the ASTA Injector. SRF systems are outlined in red – CC1, CC2, and CM-2. One accelerating cryomodule is installed. Electron operation up to 50 MeV to the beam dump in parallel with CM-2 testing is the first stage of operation. Beam travels from left to right.

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REFERENCES

- [1] J. Leibfritz et al., "Status and Plans for a Superconducting RF Accelerator Test Facility at Fermilab," Proc. IPAC2012, New Orleans, USA, pp. 58-60, (2012), <http://jacow.org>
- [2] P. Garbincius, ed. et al., "Proposal for an Accelerator R&D User Facility at Fermilab's Advanced Superconducting Test Accelerator (ASTA)," Fermilab-TM-2568, 2013.
- [3] W. Hartung et al., "Beam Test of a Superconducting Cavity for the Fermilab High-Brightness Electron Photo-Injector," Proc. PAC1999, New York, pp. 992-994, (1999), <http://jacow.org>
- [4] E. Harms et al., "Rebuild of Capture Cavity 1 at Fermilab," THP012, SRF'13, to be published.
- [5] E. Harms et al., "Operating Experience with CC2 at Fermilab's SRF Beam Test Facility," Proc. LINAC'10, Tsukuba, Japan, pp. 818-820 (2010). <http://jacow.org>
- [6] E. Harms, et al., "Test Results of TESLA-Style Cryomodules at Fermilab," Proc. LINAC12, Tel Aviv, Israel, pp. 297-299, (2012), <http://jacow.org>
- [7] A. Hocker et al., "Results from RF Tests of the First US-built High-gradient Superconducting RF Cryomodule," WEPRI051, IPAC 14, Germany 2014.

- [8] A. Martinez et al., "Fermilab SRF Cryomodule Operational Experience," FERMILAB-CONF-11-258-AD.