DESIGN AND FABRICATION OF THE CORNELL ERL INJECTOR CRYOMODULE*

E. Chojnacki#, S. Belomestnykh, Z. Conway, J. Kaufman, M. Liepe, V. Medjidzade, D. Meidlinger, H. Padamsee, P. Quigley, J. Sears, V. Shemelin, and V. Veshcherevich,
CLASSE, Cornell University, Ithaca, NY 14853, U.S.A.

INTRODUCTION

The Energy Recovery Linac (ERL) development effort at Cornell will first produce an ERL beam source [1]. A portion of the source is an SRF Injector cryomodule to accelerate a cw beam with 2 ps bunch length and 100 mA average current from an input energy of 0.3 MeV to an output energy of 5-15 MeV while preserving an emittance of 1 mm-mrad. The Injector cryomodule is based on TTF III technology with modifications for cw operation. In this technology, the cavity helium vessels are pumped to 1.8K (12 Torr) through a common 10″ Helium Gas Return Pipe (HGRP) from which the beamline is suspended. All of the 1.8K cryomodule components are surrounded by 5K intercepts to minimize heat leak to 1.8K, and the 5K intercepts are likewise surrounded by 80K intercepts. To deliver the 0.5 MWCW average power to the beam, the Injector cryomodule contains five 1.3 GHz SRF 2-cell cavities, each cavity having two 50 kWCW coax couplers to deliver power from five 100 kWCW klystrons. Cold beamline HOM loads are placed between each cavity and outboard of the first and last cavities.

The description of the ERL Injector cryomodule will begin with the SRF cavities and progress outward to the vacuum vessel. Insight gained from the fabrication process that will benefit the future ERL Linac cryomodule design will be highlighted.

BEAMLINE STRING

SRF Cavity

The SRF cavities in the Injector cryomodule are a 2-cell design with two coax RF couplers per cavity [2]. There are no stiffening rings between the cavity cells, so several repetitions of corrective cavity tuning were required due to deformations from handling and pumping when performing vertical tests. A few mild multipactor barriers exist for this cavity in the iris transition to the large beam pipe, but they were easily processed away in about 1 minute in vertical tests and did not appear at all after baking and installation in the Injector. A sampling of Q_o vs. E curves from vertical tests for unbaked cavities is shown in Fig. 1. There was a firm limit of $Q_o=1.3\times10^{10}$ in these vertical tests, despite an unbaked BCS and 3 mOe residual magnetic field theoretical limit of $Q_o=4.6\times10^{10}$. It is likely that the vertical test apparatus has unintended RF losses or unidentified sources of magnetic field.

After vertical tests, each of the five cavities had their helium vessels welded on and precision reference surfaces machined onto the helium vessel flanges for accurate mounting to the HGRP. The cavities then received a light BCP etch, high pressure rinse (HPR), and were stored in a clean room for up to 2 months as other beamline components were fabricated. Just prior to string assembly, each cavity received another HPR, was vacuum baked in pairs at 120C for 48 hrs, then vented with filtered dry N_2 and promptly mounted on the growing beamline string.

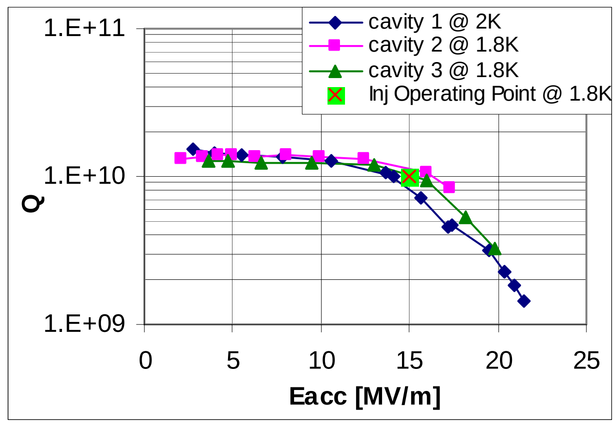

Figure 1: A sampling of Q_o vs. E curves from vertical tests for unbaked cavities.

Beamline HOM Loads

Beamline HOM loads are required for the Injector to provide sufficient bandwidth and damping for the high average current and short bunch length [3]. The loads must operate cold, with an 80K heat sink for RF and 5K intercepts between the loads and the cavity beam tubes, as shown in Fig. 2. Three types of RF absorbers were used to damp in a band from 1 GHz to over 40 GHz. The absorbing tiles were matched as closely as possible for thermal contraction from the soldering temperature of 523K to the operational temperature of 80K to different types of backing plates, as indicated in Fig. 3. Offline cold tests of the HOM assemblies showed that the TT2 ferrite-10W3 Elkonite combination led to tile fractures and particulate that could contaminate the cavity. Thus, all of the TT2 tile/plate combinations were extracted from the large diameter loads and replaced with the Co2Z-3W3 Elkonite combination. From the expansion characteristics in Fig. 3, mating the TT2 to 3W3 may have been a better choice to avoid transitions from tension to compression around 250K. This and other modifications to the HOM loads for ERL Linac use are being investigated. All of the HOM loads were vacuum baked at 120C for 48 hrs prior to the TT2 replacement operation, but due to concern of

* Work supported by NSF, New York State, and Cornell University
# epc1@cornell.edu

particulate contamination, all loads were rigorously flushed with filtered methanol just prior to mounting on the beamline string. The HOM loads have a mounting surface that is precision machined to provide automatic alignment when attached to the HGRP by thermal transition supports, which are also precision machined.

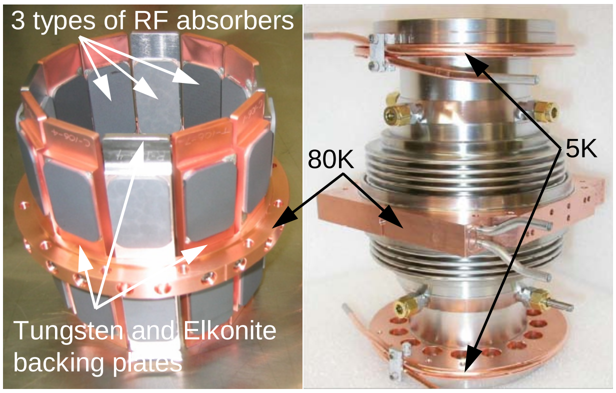

Figure 2: Cornell ERL Injector beamline HOM load.

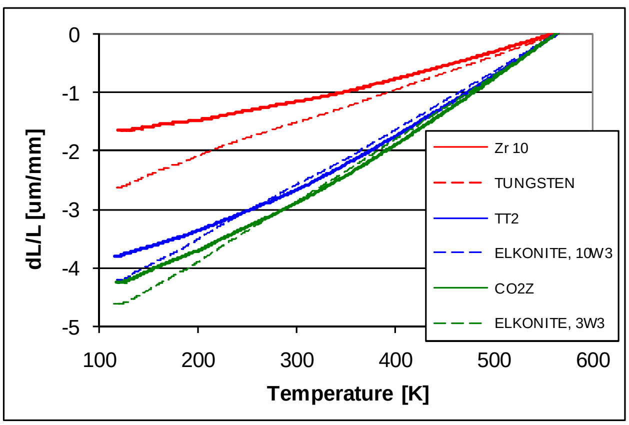

Figure 3: Thermal expansions of materials used in the beamline HOM loads.

RF Couplers

The first two of ten production ERL Injector couplers were processed up to 61 kWCW in a cold test cryostat [4]. In the interest of time, it was decided to not perform offline processing of the remaining production couplers. The cold parts of the ten couplers were vacuum baked at 150C for 48 hrs, then vented with filtered dry N_2 and promptly mounted to the cavities of the beamline string. A protective cap was placed over the cylindrical cold window with an SMA fitting connected to the center conductor through a spring contact. The SMA fitting allowed monitoring of the cavity frequency during later mounting of the tuner without exposing the cold window to a non-clean room environment. The warm parts of the couplers were stored in a clean room, then flushed with filtered water and methanol just prior to mounting to the cold parts through vacuum vessel RF ports.

Gate Valves

All-metal pneumatic gate valves custom made for the Cornell ERL Injector were attached at each end of the beamline string inside the clean room. The valves engage RF contacts around the aperture when open to minimize beam wakefields and heating. The custom aspect of the valve is that the actuator is demountable at mid-body to provide a short length for insertion of the beamline into the vacuum vessel. Attachment of the pneumatic portion then occurs through a side port adapter on the vacuum vessel, allowing external actuation.

String Assembly

A photograph of the completed beamline string in the clean room is shown in Fig. 4. All of the vacuum flanges between components are conflat with copper gaskets. After pumping out the string in the clean room at a slow rate of 1 Torr/min to minimize particulate migration, the gate-valves were closed to seal off the beamline throughout the remainder of cryomodule assembly.

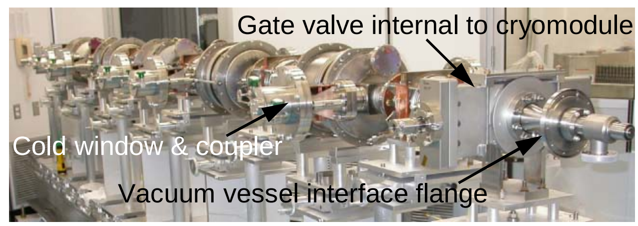

Figure 4: Completed beamline string in the clean room.

COLD MASS ASSEMBLY

In parallel to beamline string assembly, a cold mass assembly fixture was erected in a nearby high bay area. Three 1.6 m long Ti HGRP sections and six composite support posts had precision reference surfaces machined onto them to maintain precise alignment in going from reference surfaces on the composite posts outside of the vacuum vessel down to the beamline axis. The three HGRP sections were mounted on the assembly frame with two composite posts each, aligned to each other with a welding fixture, and welded together with intervening Ti bellows. Next, the 2-phase pipe was welded to the HGRP and the 5K supply and return manifolds mounted with G10 supports. The beamline string was then rolled out of the clean room to underneath of the HGRPs, raised, and bolted to the HGRPs using precision supports attached to the cavity helium vessels and HOM loads. The beamline attachment operation had an elapsed time of about 60 minutes. Flexible 1.8″ ID tubes from the 2-phase pipe were attached to the helium vessels with conflat flanges. Cryoperm magnetic shields were then attached to the cavity helium vessels followed by the cavity blade tuners with piezos. Attachment of the blade tuners and piezos proved more difficult and time consuming than desired, as well as making the magnetic shield more complicated. Though the blade tuner functions satisfactorily, the design will be re-visited for simplification or replacement with another design for the ERL Linac. The top potion of the grade 1100 aluminum 80K shields were mounted to the composite posts and the 80K supply and return manifolds mounted to the interior of the shield. A second layer of cryoperm magnetic shield was mounted around the tuner, and individual shields wrapped around the tuner stepping motors. Approximately ninety ¼″ stainless steel jumper tubes of various shapes were then orbital welded between the 5K and 80K manifolds to the HOM loads and RF couplers. A photograph of this stage of cold mass assembly is shown in Fig. 5.

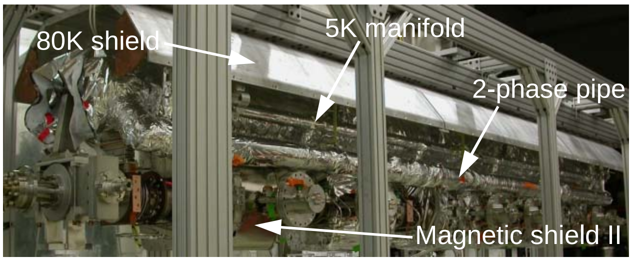

Figure 5: Cold mass assembly in a high-bay area.

A plethora of instrumentation signals, including RF in semi-rigid coax, temperature sensors, cavity “wire position monitors”, resistive heaters, accelerometers, and tuner controls were routed with low thermal conductivity wire to the 80K shield port locations. The remainder of the 80K shield was then mounted around the cold mass. A third layer of magnetic shield was attached to the 80K shield, but at 80K this Co-Netic mu-metal has a shielding factor that is only 20% of its 300K value, so it is likely not providing much shielding. It would have been better to locate this shield as a lining on the 300K vacuum vessel. After wrapping the 80K shield with multi-layer insulation, the cold mass was inserted into the vacuum vessel by way of rollers on the composite support posts and rails that mated from the assembly fixture to the interior of the vacuum vessel, as shown in Fig. 6. The support for the gate valves was then transferred from brackets on the ends of HGRPs to adjustment stages on the bottom of the vacuum vessel. The cold mass was then aligned using screws attached to the composite support posts at vacuum vessel top ports to adjust gaps between precision reference surfaces on the vacuum vessel and on the composite posts. The previously described precision reference surfaces on the HGRPs, helium vessels, and HOM loads then provided known alignment of the beamline axis, as confirmed by independent laser survey.

Two portable clean rooms were positioned on the sides of the vacuum vessel and the warm parts of the RF couplers attached to the cold parts through the 10 coupler ports, as shown in Fig. 7. This operation required 10 working days as the clean rooms and coupler assembly fixtures were stepped along the length of the vacuum vessel. The vacuum vessel end plates were attached and the vessel leak tested, including He gas pressurization of the 5K and 80K cryogenic plumbing to 250 psi and the 2K plumbing to 30 psi. The completed ERL Injector cryomodule weighing 12,000 lbs and 198″ long was craned onto a truck, transported from Newman Lab to Wilson Lab as shown in Fig. 8, installed in the new Cornell ERL Injector LO area, and is presently being commissioned [5].

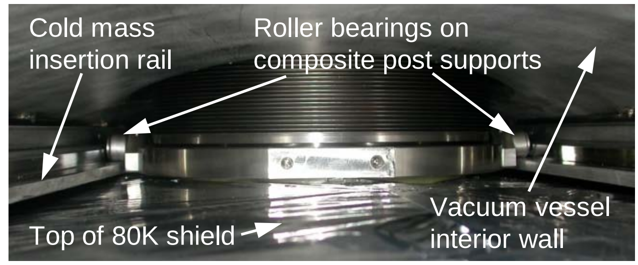

Figure 6: Cold mass insertion rails as seen from inside the vacuum vessel.

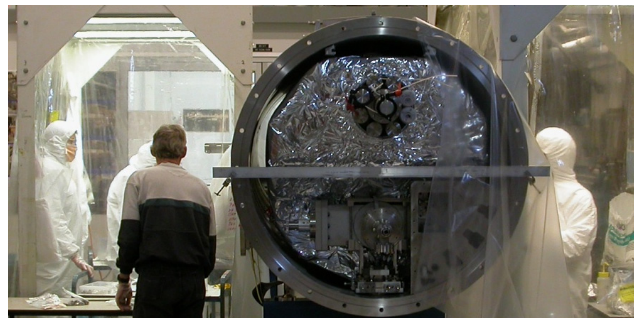

Figure 7: Portable clean rooms positioned on the sides of the vacuum vessel during warm coupler installation.

Figure 8: The completed ERL Injector cryomodule being transported from Newman Lab to Wilson Lab.

REFERENCES

[1] G. Hoffstaetter, *et al.*, “Challenges for Beams in an ERL Extension to CESR,” these EPAC’08 proceedings, Genoa (2008).
[2] R.L. Geng, *et al.*, “Fabrication and Performance of Superconducting RF Cavities for the Cornell ERL Injector,” PAC’07, Albuquerque, p. 2340.
[3] V. Shemelin, *et al.*, “Status of HOM Load for the Cornell ERL Injector,” EPAC’06, Edinburgh, p. 478.
[4] S. Belomestnykh, *et al.*, “High Power Tests of First Input Couplers for Cornell ERL Injector Cavities,” PAC’07, Albuquerque, p. 2355.
[5] M. Liepe, *et al.*, “First Test Results from the Cornell ERL Injector Cryomodule,” these EPAC’08 proceedings, Genoa (2008).