INPUT COUPLER FOR CORNELL ERL MAIN LINAC*

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Abstract

Each 7-cell cavity of the Cornell ERL Main Linac has a single coaxial type input coupler with fixed coupling, $Q_{ext} = 6.5\times10^7$. The input coupler will operate at RF power up to 5 kW at full reflection. The coupler design is based on the design of TTF-III input coupler with appropriate modifications and with taking into account the Cornell experience with couplers for ERL Injector. Four couplers have been fabricated by Communications & Power Industries, Beverly Microwave Division (CPI BMD) and tested at Cornell on the test stand up to 5 kW CW. No major issues were noticed during the tests. One coupler was attached to a prototype linac cavity. The cavity was successfully tested with great results achieved inside the horizontal test cryomodule. More couplers will be supplied soon. Six couplers will be installed in the Main Linac Cryomodule Prototype.

INTRODUCTION

Cornell University plans to build a hard X-ray light source driven by an Energy Recovery Linac (ERL). The proposed Cornell ERL will operate in CW at 1.3 GHz, 2 ps bunch length, 100 mA average current in each of the accelerating and decelerating beams, normalized emittance of 0.3 mm-mrad, and energy ranging from 5 GeV down to 10 MeV, at which point the spent beam is directed to a beam stop [1, 2].

Cornell has already built and commissioned a short ERL injector prototype and continues to test it and improve its performance. Now it is building a prototype cryomodule of the main linac.

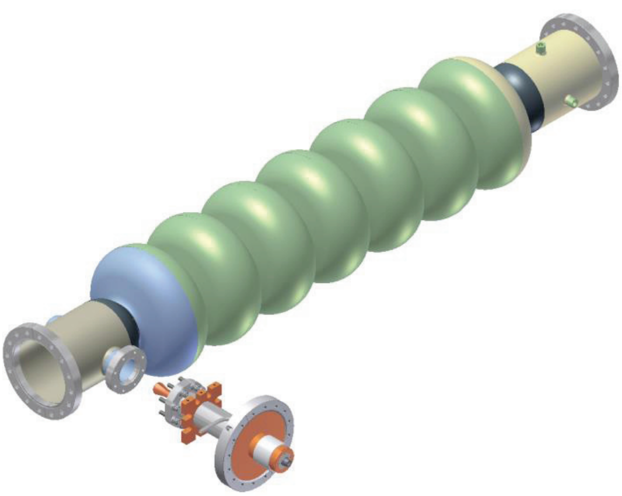

Figure 1: A 7-cell cavity with input coupler.

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An ERL main linac cryomodule (MLC) is 9.8 m long and houses six 7-cell superconducting cavities. Each cavity has a single coaxial RF input coupler which transfers power from an RF power source to the beam-loaded cavity (Fig. 1).

COUPLER DESIGN

Ideally, RF power consumption by superconducting cavities in the main linac of ERL is very low. However, we need to have an excess power for keeping cavity field level stable despite cavity detuning due to microphonics, possible beam loss, beam return time errors, etc. For the Cornell ERL, the input coupler must deliver up to 5 kW CW RF power to a main linac cavity, though under nominal conditions it will operate with 2 kW average and 5 kW peak power. Due to the nature of ERL, the couplers will almost all the time operate under conditions with full reflection.

To make the design more economical, the couplers provide fixed coupling to the cavities with the $Q_{ext} = 6.5\times10^7$. If necessary, the coupling adjustability can be achieved using three-stub tuners in input transmission lines to have a range of Q_{ext} from 2×10^7 to 1×10^8. ERL linac couplers must accommodate movement of the cavities during cool down including a lateral movement of up to 10 mm since one end of the coupler is attached to the moving cavity and the other end is attached to the fixed vacuum vessel port.

The design of the ERL main linac coupler is based on the TTF-III and Cornell ERL injector couplers, and takes into account experience gained from the ERL injector couplers [3].

A 3D CAD model of the ERL main linac coupler is shown in Fig. 2. The coupler consists of several sub-assemblies as it is shown in Fig. 3. The main assemblies are the cold coupler, the warm outer and inner coaxial sub-assemblies and the waveguide box. The coaxial lines and two ceramic windows are of the same size as those in the TTF-III coupler. The left coupler flange is to be attached to the superconducting cavity cooled to 1.8 K. The right flange is to be attached to the room temperature vacuum vessel. The middle flange, where two coupler assemblies are joined, is floating and kept at 40 K. There is a 5 K intercept between 2 K and 40 K flanges. All coaxial parts, with the exception of antenna and 5 K heat intercept, are made of stainless steel with copper plating on surfaces carrying RF currents. The antenna and heat intercept are made of copper.

The cold subassembly does not have bellows. Two sets of bellows are placed in the warm portion of the coupler, in both the inner and outer conductors. In this way, high flexibility is achieved while keeping the cold antenna fixed relative to the cavity coupler port (see Fig. 4).

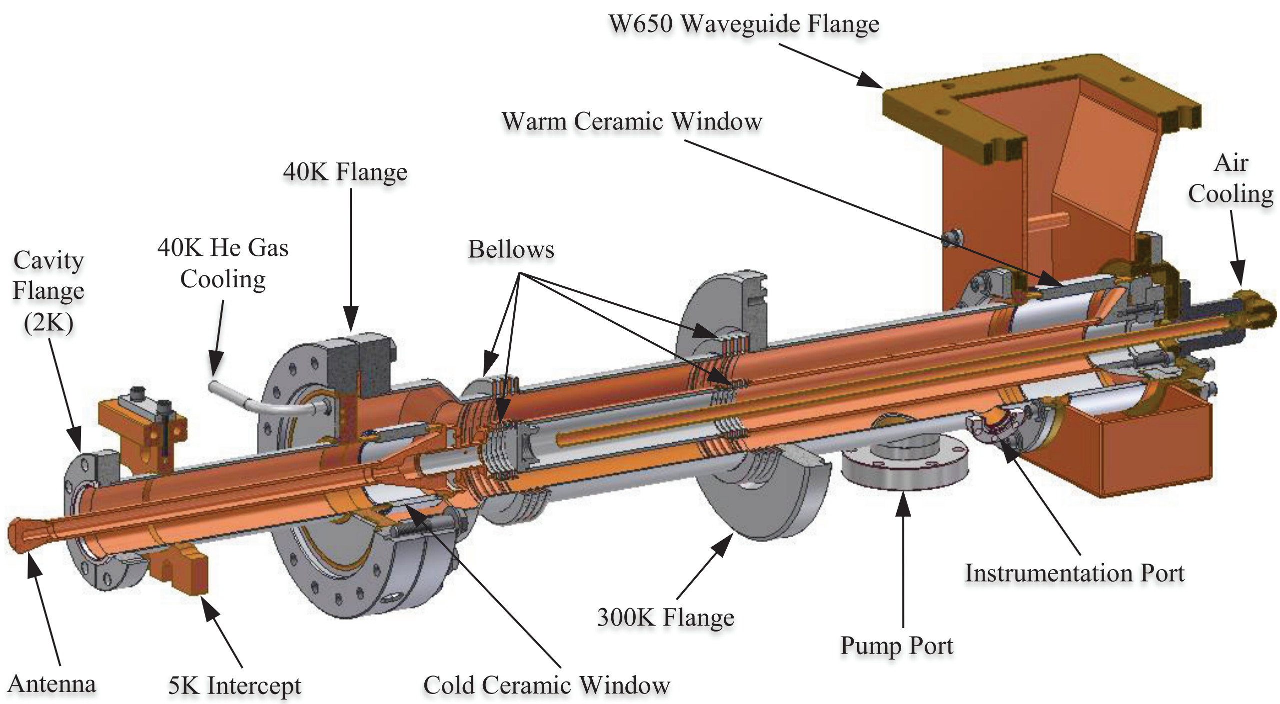

Figure 2: 3D CAD model of input coupler.

The center tube of the warm coaxial portion of the coupler is cooled by compressed air. The 5 K intercept and 40 K flange of the cold coupler are cooled by helium gas with temperatures 5 K and 40 K respectively.

Parameters of the coupler are summarized in Table 1. Static and dynamic heat loads of the coupler on the cryogenics are shown in Table 2.

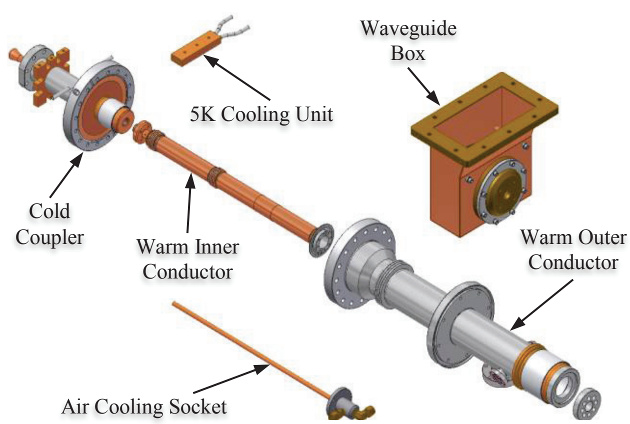

Figure 3: Exploded view of the coupler.

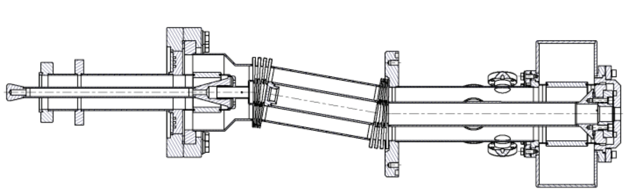

Figure 4: Mechanical flexibility of the coupler.

Table 1: Parameters of ERL Main Linac Coupler.

Operating frequency	1300 MHz
Maximum power (CW)	5 kW
Q_{ext} (fixed)	6.5×10^7
Cold coaxial line impedance	70 Ohm
Warm coaxial line impedance	46 Ohm
Cold coax line outer diameter	40 mm
Warm coax line outer diameter	62 mm

Table 2: Heat Loads of the Input Coupler with RF off and on at Full Power.

	Static Heat Load	Dynamic Heat Load	Full Heat Load
To 2 K	0.05 W	0.06 W	0.11 W
To 5 K	0.64 W	0.32 W	0.96 W
To 40 K	3.78 W	5.94 W	9.72 W

After finishing the design, fabrication of couplers was ordered from Communications & Power Industries, Beverly Microwave Division (CPI BMD).

COUPLER TESTS

A test stand was built for coupler tests. During the linac operation, there is almost no beam loading due to energy recovery: the accelerating beam takes the power but the decelerating beam gives it back. Due to that, the coupler always operates in standing wave mode, with almost full reflection. Therefore, we decided to test couplers in similar operation conditions. We built a copper cavity with a coupler port. The coupler under test is attached to the cavity. The cavity is overcoupled ($\beta = 17$). Overcoupling is not as strong as for the

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accelerating cavity (β = 300), however it is a good model of real operation. Figure 5 shows the coupler assembled with the cavity and the waveguide on the test stand. A 5 kW solid state simplifier was used for tests.

We have tested four couplers so far: two prototype couplers and two production couplers. All the tests were smooth. We had no major issues with couplers. One coupler developed mild vacuum actions that were processed in a few hours. For two other couplers we saw only a few vacuum spikes in the beginning of tests. One coupler showed no vacuum actions at all.

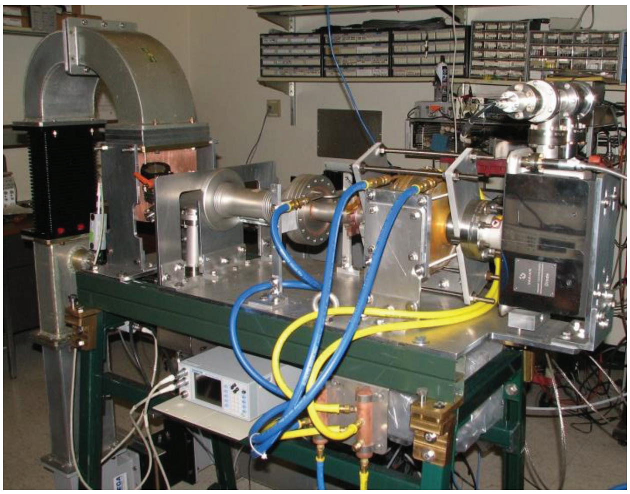

Figure 5: Coupler on the test stand.

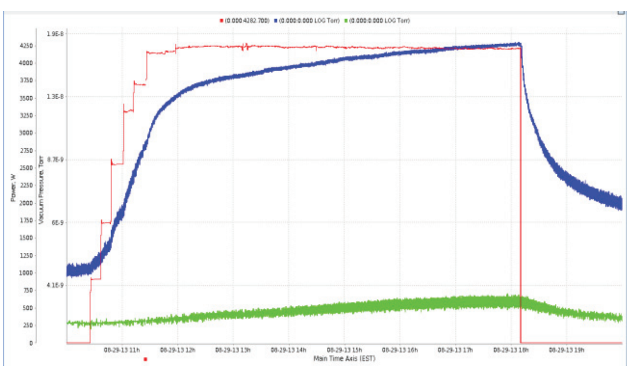

Figure 6: Plots of RF power (red) and vacuum pressure in cold (green) and warm (blue) parts of the coupler during the test.

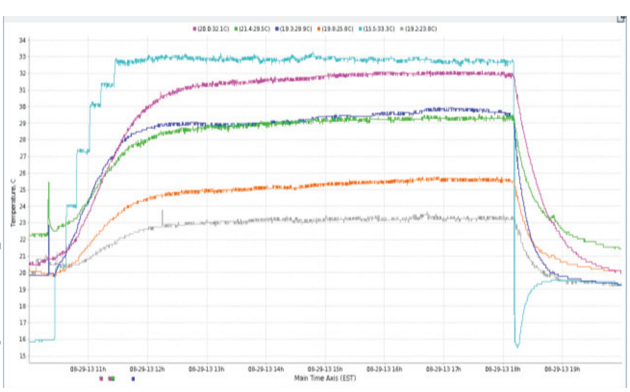

Figure 7: Plots of temperatures in different points of coupler (red, blue, and green), waveguide box (magenta), cavity (cyan) and cooling air outlet (grey).

Figures 6 and 7 show plots of RF power, vacuum pressure in the coupler and temperatures during one of the tests. A slow increase of vacuum pressure and coupler temperature is explained by creeping up the room temperature during the test.

More couplers will be supplied and tested soon.

One of the tested couplers was attached to the first prototype 7-cell cavity for the Cornell ERL main linac (Fig. 8). This cavity was assembled in a small horizontal test cryomodule and tested. The test showed great performance of the cavity including record *Q* performance [4].

Now Cornell is building a full scale prototype of the main linac cryomodule (MLC) [5]. Six cavities with six couplers will be installed in this MLC prototype. The completion of the assembly and start of tests of the MLC prototype are scheduled for 2014.

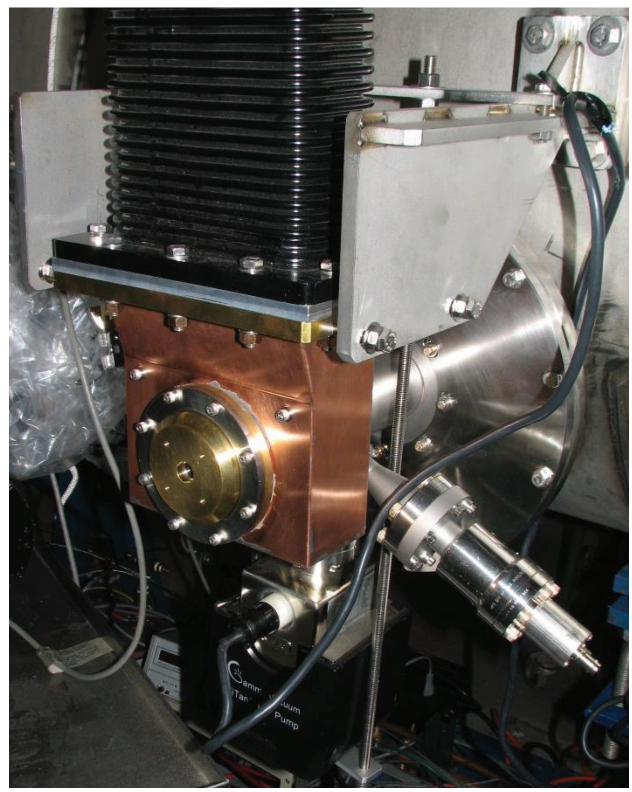

Figure 8: Coupler installed in the horizontal test cryomodule.

SUMMARY

The input coupler for the main linac cavities of Cornell ERL is designed. First couplers have been fabricated and tested. Couplers showed good performance during the tests on the test stand and on the test cryomodule with a main linac cavity. The building of the prototype of the ERL main linac cryomodule with six cavities equipped with couplers is under way.

REFERENCES

[1] G. H. Hoffstaetter, S. Gruner, and M. Tigner, eds., "Cornell Energy Recovery Linac: Project Definition Design Report," erl.chess.cornell.edu/PDDR.

[2] C. E. Mayes, *et al.*, "Cornell ERL Research and Development," Proceedings of the 2011 Particle Accelerator Conference, New York, NY, March–April 2011, p. 729.

[3] V. Veshcherevich and S. Belomestnykh, "Input Coupler for Main Linac of Cornell ERL," Proceedings of SRF2009, Berlin, September 2009, p. 543.

[4] N. R. A. Valles *et al.*, "Record Quality Factor Performance of the Prototype Cornell ERL Main Linac Cavity in the Horizontal Test Cryomodule," these proceedings.

[5] R. Eichhorn, *et al.*, "Design and Construction of the Main Linac Cryomodule for the Energy Recovery Linac Project at Cornell," these proceedings.

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