# INPUT COUPLER FOR MAIN LINAC OF CORNELL ERL*

V. Veshcherevich† and S. Belomestnykh
Cornell University, Ithaca, NY, U.S.A.

*Abstract*

Main linac cryomodule of the Cornell ERL consists of 7-cell cavities operating at 1300 MHz in CW mode. Each cavity has a single coaxial type input coupler with fixed coupling, $Q_{ext} = 2\times10^7$. 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. Unlike that of the TTF-III coupler, the cold assembly of the ERL main linac input coupler does not have bellows, which makes it stiff so the antenna orientation is not changing during cool down. Mechanical flexibility, necessary to accommodate large lateral movement of the cavity inside the vacuum vessel during cool down, is achieved by using two bellows insertions both in inner and outer tubes of warm coaxial line. The inner tube of the warm coaxial line is cooled with air to improve power handling capability.

## INTRODUCTION

The proposed Cornell Energy Recovery Linac (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 dump [1].

The main linac cryomodules for the ERL will be based on TTC technology, but must have several unique features dictated by the ERL beam parameters. An ERL cryomodule is 9.8 m long and incorporates 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 (Figure 1). The coupler is a coaxial coupler derived from the TTF-III design [2, 3].

The TTF-III coupler was designed for a pulsed superconducting linac application. Hence not all features of the TTF-III design are important for the ERL linac, operating in CW regime. On the other hand, there are features specific to CW applications. Therefore, the TTF-III coupler design was slightly modified to meet ERL requirements.

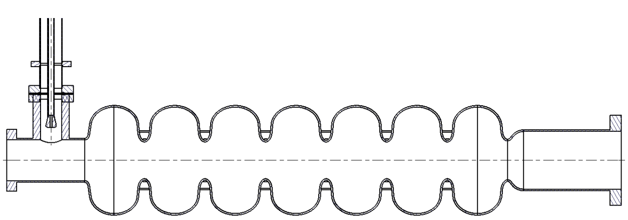

Figure 1: A 7-cell cavity with input coupler.

## REQUIREMENTS TO COUPLER

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. This excess power for Cornell Energy Recovery Linac is 5 kW.

Therefore, the input coupler has to deliver up to 5 kW CW RF power to a main linac cavity. 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 will provide fixed coupling to the cavities with the $Q_{ext} = 2\times10^7$. If necessary, the coupling adjustability will be achieved using three-stub tuners in transmission lines. Similarly to TTF-III couplers, ERL linac couplers must accommodate lateral movement of the cavities after cool down of up to 10 mm.

While many parameters of TTF-III coupler are suitable for ERL linac, its average power handling capability is not high enough. One of TTF-III couplers, provided by ACCEL Instruments, was tested in CW regime on a warm coupler test stand at Rossendorf and in the HoBiCaT cryostat at BESSY by a collaboration of ACCEL, BESSY, Cornell, DESY and Rossendorf FZK [4, 5]. Extrapolation of the test results suggests that at 5 kW with full reflection the temperature of the inner conductor will reach very high value of 300 °C. Cooling the inner conductor with compressed air (or other coolant), similar to that implemented in the input couplers of Cornell ERL Injector, is necessary to safely operate at this power level.

## COUPLER DESIGN

Designing the main linac coupler, we also took into account our experience with ERL Injector couplers [6]. The design of injector coupler was also based on TTF-III coupler design. However, it was designed to operate at much higher power, up to 50 kW CW.

The proposed main linac coupler is shown in Figures 2 and 3. Like TTF-III and ERL injector couplers, this coupler consists of three sub-assemblies: cold and warm coaxial sub-assemblies and waveguide. The coaxial lines and two ceramic windows are of the same size as those in the TTF-III. The left coupler flange is to be attached to the superconducting cavity cooled to 2 K. The right flange, the closest to the bellows, is to be attached to room temperature vacuum vessel. The middle flange, where two coupler assemblies are joined, is floating and

* Work supported by NSF Award PHY-0131508, the Empire State Development Corporation (ESDC) Energy Recovery Linac Project # U316, and Cornell University.
† vgv1@cornell.edu

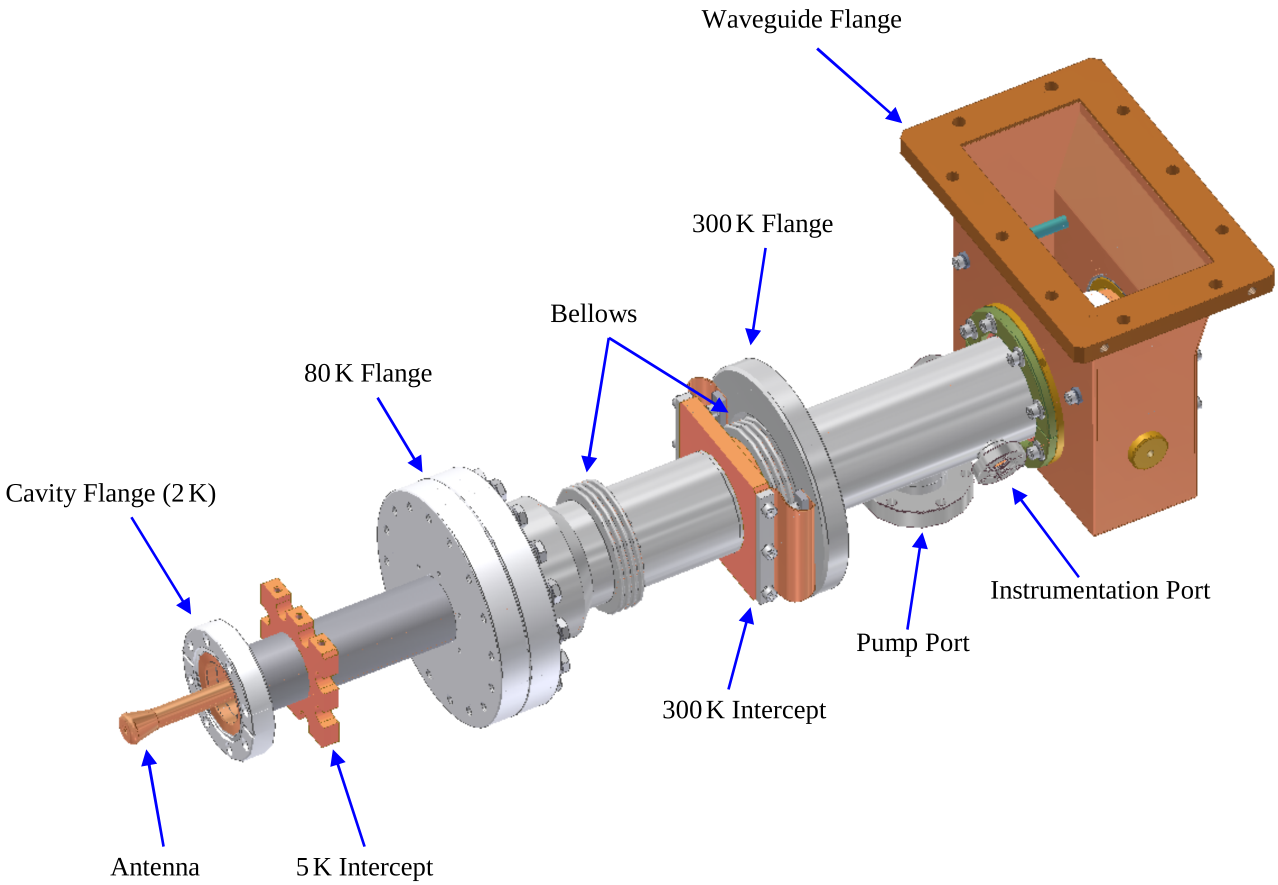


Figure 2: 3D CAD model of input coupler.

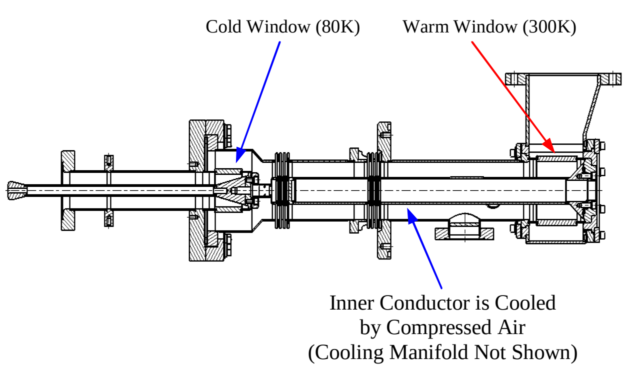


Figure 3: Section view of the coupler.

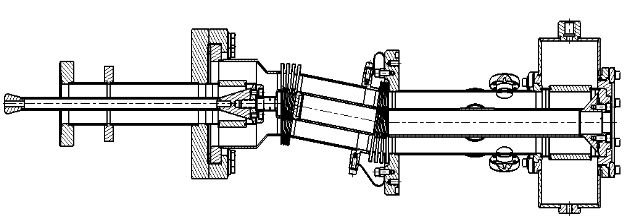

Figure 4: Mechanical flexibility of the coupler.

kept at 80 K. There is a 5 K intercept between 2 K and 80 K flanges. All coaxial components, with the exception of heat intercepts, are made of stainless steel with copper plating on surfaces carrying RF currents. The heat intercepts are made of copper.

The cold subassembly does not have bellows, which makes it stiff so the antenna orientation is not changing during cool down. Elimination of bellows increases the static heat leak to 5 K cooling circuit, but not enough to worry about as it is comparable to the heat load due to RF power dissipation in CW mode of operation. Heat loads of the coupler on the cryogenics with RF power off and with full RF power are summarized in Table 1. Figures 5 and 6 show calculated temperature distributions along inner and outer conductor of the coaxial portion of the coupler.

As we mentioned above, according to numerical simulations and RF tests, the inner conductor in the warm portion of the TTF III coupler shows an excessive heating at higher power operation and needs cooling. In our design the inner tube in the warm coaxial portion of the coupler is cooled by compressed air similarly to the ERL injector coupler.

After cooling down the cryomodule, linac cavities shrink inside the warm vacuum vessel. As the coupler is attached to the cavity and to the vacuum vessel, the cold end of the coupler moves relatively to the warm end. This movement might be significant, up to 10 mm in a horizontal direction. Therefore the warm portion of the coupler has to have mechanical flexibility to accommodate this movement. High flexibility is achieved by using two bellows insertions both in inner and outer tubes of warm coaxial line as it shown in Figure 4.

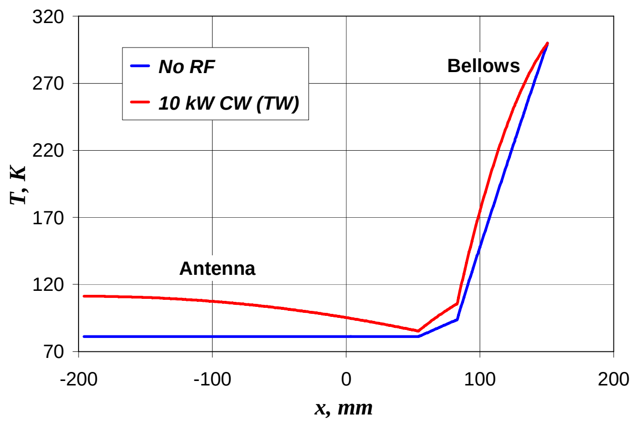


Figure 5: Temperature distribution along inner conductor.

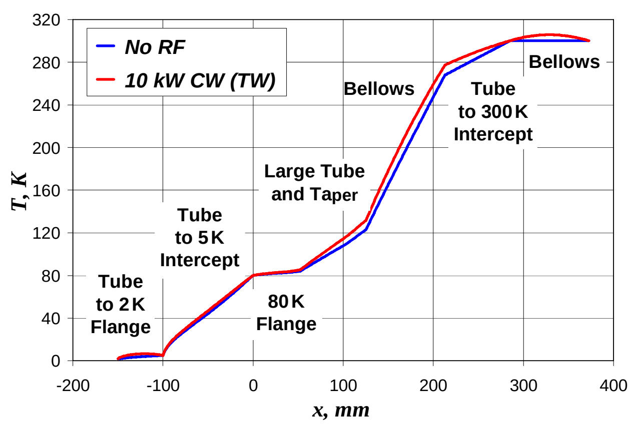


Figure 6: Temperature distribution along outer conductor.

Table 1: Heat Loads of the Input Coupler with RF Off and On at Full Power

| | Static Heat Load | Heat Load at Full RF Power |
|---|---|---|
| To 2 K | 0.03 W | 0.15 W |
| To 5 K | 1.55 W | 1.94 W |
| To 80 K | 2.26 W | 9.33 W |

Coupling to the cavity depends on the antenna length as it is shown in Figure 7. The length is chosen to ensure the $Q_{ext} = 2\times10^7$. The coupling also depends on the distance from the cavity to coupler port in the beam pipe.

Computer simulations performed with Mutipac2.1 code [7] showed no evidence of mutipacting in the coupler.

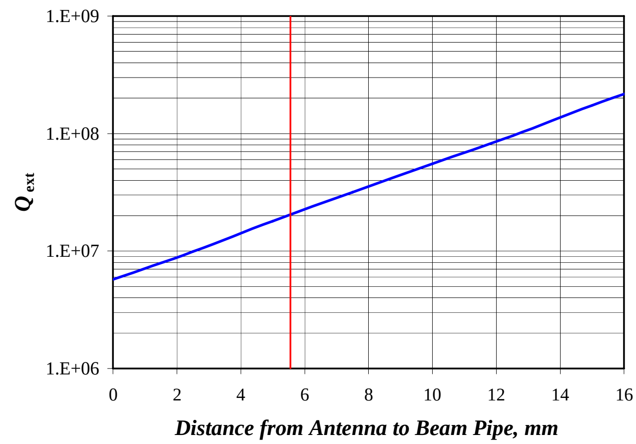


Figure 7: Dependence of $Q_{ext}$ on the coupler antenna length.

## SUMMARY

The preliminary design of input coupler for the main linac cavities of Cornell ERL machine has been made, including electrical parameters, thermal analysis, multipacting simulation and mechanical features. After finishing the engineering design, two prototype couplers will be ordered for tests.

## REFERENCES

[1] J. A. Crittenden, *et al.*, "Developments for Cornell's X-Ray ERL," Presented to PAC'09, Vancouver, May 2009.

[2] W.-D. Moeller for the TESLA Collaboration, "High Power Coupler for the TESLA Test Facility," Proceedings of the 9th Workshop on RF Superconductivity, Santa Fe, NM, 1999, Vol. 2, p. 577.

[3] B. Dwersteg, *et al.*, "TESLA RF Power Couplers Development at DESY," Proceedings of the 10th Workshop on RF Superconductivity, Tsukuba, Japan, September 2001, KEK Proceedings 2003-2, p. 447.

[4] S. Bauer, et al., "CW test of the TTF-III input coupler at Rossendorf," Cornell LEPP Report ERL 04-10 (2004).

[5] J. Knobloch, *et al.*, "CW Operation of the TTF-III Coupler," Proceedings of the 2005 Particle Accelerator Conference, Knoxville, TN, May 2005, p. 3292.

[6] V. Veshcherevich, *et al.*, "High Power Tests of Input Couplers for Cornell ERL Injector," Proceedings of the 13th Workshop on RF Superconductivity, Beijing, October 2007, p. 517.

[7] P. Yla-Oijala *et al.*, "Electron multipacting in TESLA Cavities and Input Couplers," Part. Accel. 63 (1999) 105.