INPUT COUPLERS FOR CORNELL ERL*

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Abstract

Cornell has developed two types of coaxial input couplers for the Energy Recovery Linac (ERL) Project. Both couplers are 1.3 GHz CW coaxial couplers. The coupler for ERL injector is a 65 kW CW coupler with variable coupling (Q_{ext} = 9×10^4 to 9×10^5). The coupler for ERL main linac is a 5 kW CW coupler with fixed coupling. It can be easily modified for variable coupling operation. Couplers have been tested on test stands and in cryomodules and showed good performance.

INTRODUCTION

Cornell University wants 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. The injector consists of a DC photoemission electron gun, a buncher, and an accelerating cryomodule. The injector cryomodule houses five (twelve for full ERL injector) 2-cell superconducting cavities. Each cavity has two symmetrically placed coaxial input couplers.

Now Cornell is building a prototype cryomodule of the main linac. An ERL main linac cryomodule (MLC) is 9.8 m long and houses six 7-cell superconducting cavities [3]. Each cavity has a single coaxial RF input coupler.

INJECTOR COUPLER

Each 2-cell injector cavity is equipped with two symmetrically placed coaxial input couplers (Figure 1). That allows to reduce the RF power for each coupler and dramatically decrease the transverse kick from the coupler which is essential for the ERL injector.

The parameters of the injector coupler are summarized in Table 1. The design of the coupler is based on the TTF-III coupler design [4]. It was significantly modified to comply with the ERL injector requirements. The main challenges were strong coupling, wide range of coupling adjustment and high CW power. The design of the injector coupler [5] is shown in Figure 2.

The coupler has a large Pringles-shaped antenna tip, large diameter of cold coaxial line, large size of the cold ceramic window. For reducing overheating of bellows that are parts of the design, the bellows in outer conductors of the coaxial lines are subdivided in two sections with heat intercepts between the sections; the

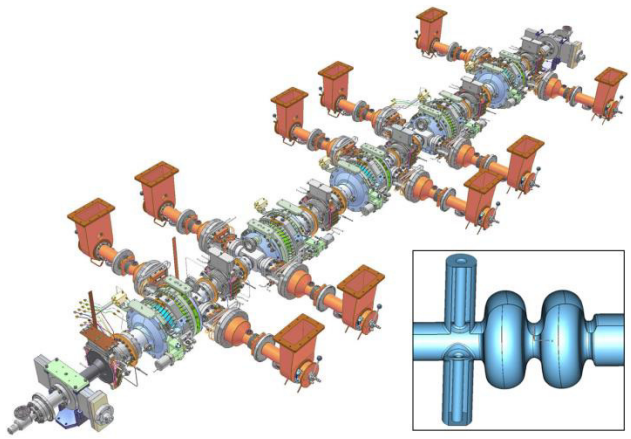

Figure 1: Injector cavities with input couplers.

Table 1: Parameters of ERL Injector Coupler

Central frequency	1300 MHz
Bandwidth	±10 MHz
Maximum CW RF power transferred to matched load	65 kW
Number of ceramic windows	2
Q_{ext} range	9×10^4 to 9×10^5
Cold coaxial line impedance	60 Ω
Warm coaxial line impedance	46 Ω
Coaxial line OD	62 mm
Antenna stroke	≥15 mm
Heat leak to 2 K	<0.2 W
Heat leak to 5 K	<3 W
Heat leak to 80 K	<75 W

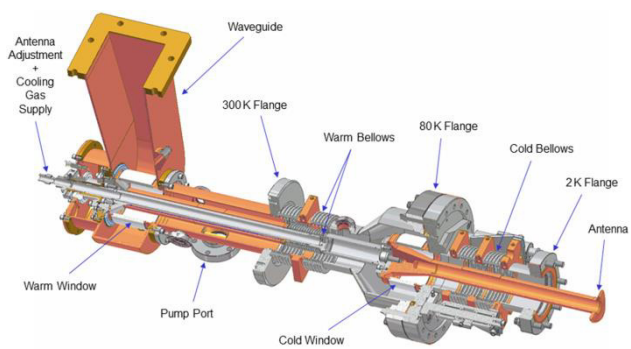

Figure 2: Injector coupler design.

* Work is supported by NSF Grants NSF DMR-0807731 and NSF PHY-1002467.
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ISBN 978-3-95450-142-7

bellows in the inner conductor is cooled by compressed air. Air cooling of the warm ceramic window is also used.

Twelve couplers (two prototypes and ten production couplers) have been fabricated by Communications & Power Industries, Beverly Microwave Division (CPI BMD). Ten production couplers have been installed in the ERL injector cryomodule in 2008. Two of ten couplers were tested on the test stand up to 61 kW CW [6]. In the cryomodule, couplers were processed in pulse and CW modes without beam; then processing continued during high current beam operation. Beam current up to 75 mA was accelerated in the ERL injector [7]. RF power up to 40 kW CW per coupler was applied during beam operation. Figure 3 shows the couplers installed on one side of the cryomodule (the remaining five are installed on the other side of the cryomodule).

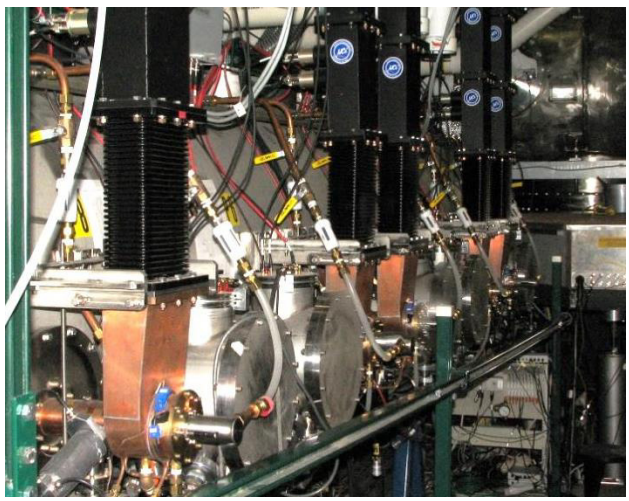

Figure 3: Injector cryomodule

MAIN LINAC COUPLER

Each 7-cell cavity of the ERL main linac has a single, 5 kW coaxial input coupler (Figure 4). The parameters of a coupler are summarized in Table 2. The design of the ERL main linac coupler is also based on the design of TTF-III coupler and takes into account experience gained from the ERL injector couplers [8]. A 3D CAD model of the ERL main linac coupler is shown in Fig. 5.

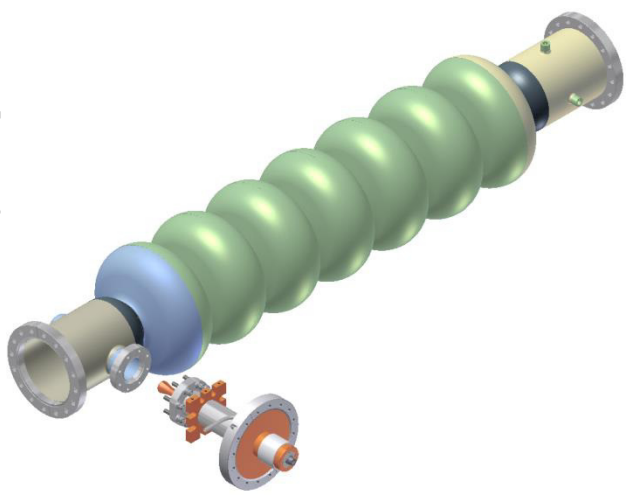

Figure 4: A 7-cell cavity with input coupler.

Table 2: Parameters of ERL Main Linac Coupler.

Operating frequency	1300 MHz
Maximum power (CW, SW)	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
Allowable cold to warm flanges lateral offset	10 mm
Heat leak to 2 K	0.1 W
Heat leak to 5 K	< 1 W
Heat leak to 40 K	< 10 W

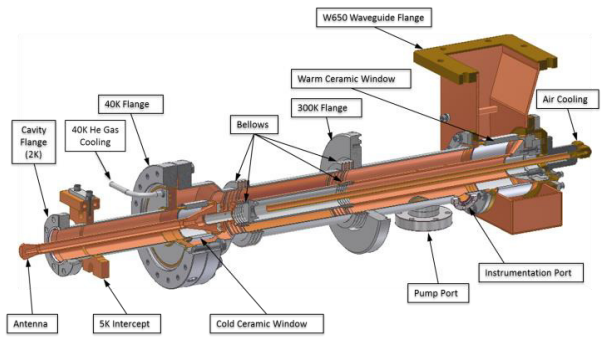

Figure 5: Main linac coupler design.

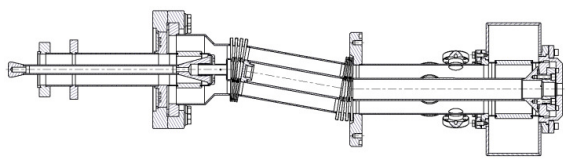

Figure 6: Great mechanical flexibility of coupler.

Due to fixed coupling, the coupler has no bellows in its cold portion. The design of the warm portion provides great lateral flexibility (see Figure 6) required to account for the cold mass shrinkage. The warm inner conductor is cooled by compressed air. All coaxial parts are made of stainless steel with copper plating on surfaces carrying RF currents with the exception of antenna and 5 K heat intercept, that are made of pure copper.

Seven couplers have been fabricated by CPI BMD. All of them were tested on a test stand up to 5 kW CW with high reflection. That is equivalent to almost 10 kW in the traveling wave mode. The results of the tests were very good [9]. Only one coupler required short processing, some couplers did not show even a single vacuum pressure spike during the test.

One coupler was attached to a prototype linac cavity that was successfully tested in the horizontal test cryomodule (HTC) with great results achieved [10]. Now the assembling of the full scale prototype of the ERL main linac cryomodule is under way (see Figure 7). The assembly should be completed before the end of 2014.

ISBN 978-3-95450-142-7

Figure 7: Cold couplers mounted on the linac cavities during cold mass assembling of main linac cryomodule.

MLC COUPLER UPGRADE

The couplers for ERL main linac sowed great performance. They were designed for fixed coupling operation; however, the coupler can be easily adapted for applications where a variable coupling is required. Coupling can be adjusted with a 3-stub tuner placed in the transmission line between the RF power source and the coupler. Also, the design of the coupler can be easily modified for achieving variable coupling.

To this end, a bellows should be added to the cold coupler outer tube for providing coupling adjustment by moving the coupler antenna. A TTF type bellows bracket can be used if a large cold mass movement is expected during cool-down of the cryomodule. As another option, a Cornell injector type linear guide can be used if only a small cold mass movement is expected. In the warm inner and outer conductors, one long bellows instead of two short bellows should be used. A tuning mechanism should be used instead of a simple air cooling socket. It will be used for air cooling also.

Figure 8 shows a 3D CAD model of the adjustable coupler with the TTF type bellows bracket.

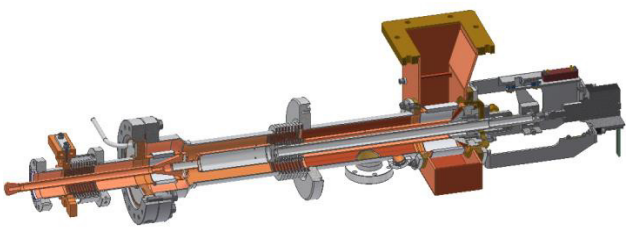

Figure 8: Modified MLC coupler with adjustable coupling.

SUMMARY

Cornell designed two types of input couplers for the proposed Cornell Energy Recovery Linac: a 65 kW coupler for the ERL injector and a 5 (design would allow 10) kW coupler for the ERL main linac. Both couplers have been successfully tested on test stands and in prototype horizontal cryomodules with superconducting cavities. Couplers showed good performance during these tests. They may be used in the Cornell ERL machine as well as in other similar applications.

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ISBN 978-3-95450-142-7