

CONSTRUCTION OF INJECTOR CRYOMODULE FOR CERL AT KEK

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Abstract

The compact energy-recovery linac (cERL) is under construction at KEK. In the injector cryomodule, electron beams of 10 mA are accelerated from the beam energy of 500 keV to 5 MeV. The injector cryomodule consists of three 2-cell cavity systems, and each cavity is driven by two input couplers. The design features, component test results and assembly status of the injector cryomodule for the cERL are described in this paper.

INTRODUCTION

Construction of Compact ERL (cERL) light-source is now in progress at KEK [1, 2], in order to demonstrate excellent ERL performances for the future project. An injector for the cERL is required to accelerate CW electron beams of 10 mA from the beam energy of 500 keV to 5 MeV. The operating accelerating gradient of superconducting cavities is 6.5~7.5 MV/m, and the required input RF power in each cavity is about 20 kW in CW operation. In the cERL injector cryomodule, critical hardware components are not superconducting cavities but RF input couplers and higher order-mode (HOM) dampers. Research and development of the cERL injector cryomodule was started in 2007, [3, 4]. Construction of the injector cryomodule is just under way and will be completed in July of 2012.

INJECTOR CRYOMODULE

An injector cryomodule containing three 2-cell cavities was designed, as shown in Figure 1. Each cavity is driven by two input couplers to reduce a required RF power handling capacity and also to compensate a coupler kick. The 2-cell cavities are dressed with a He jacket made of titanium, and magnetic shields are put inside of the 2K-He jacket. A HOM coupler scheme was chosen for HOM damping, and five loop-type HOM couplers are attached on both beam pipes of each cavity. Efficient cooling of RF feedthroughs for HOM pick-up antennas is one of the important issues. A slide-jack tuner with a pair of piezo elements is attached at the thick titanium base-plates for a frequency tuning system. An RF input coupler is a most critical component in a high power application of superconducting cavities. A coaxial coupler with a single disk-type ceramic window is used for the CW input couplers, [5]. Since the input couplers are assembled with cavities in a clean room before installation in the cryomodule, it should be short as possible. Therefore, it is critical to take the dynamic and static heat loads of the input couplers and HOM power extraction cables. They are anchored to the 5K He-reservoir panels put on both sides of the 2-cell cavities, which act as thermal shields as well.

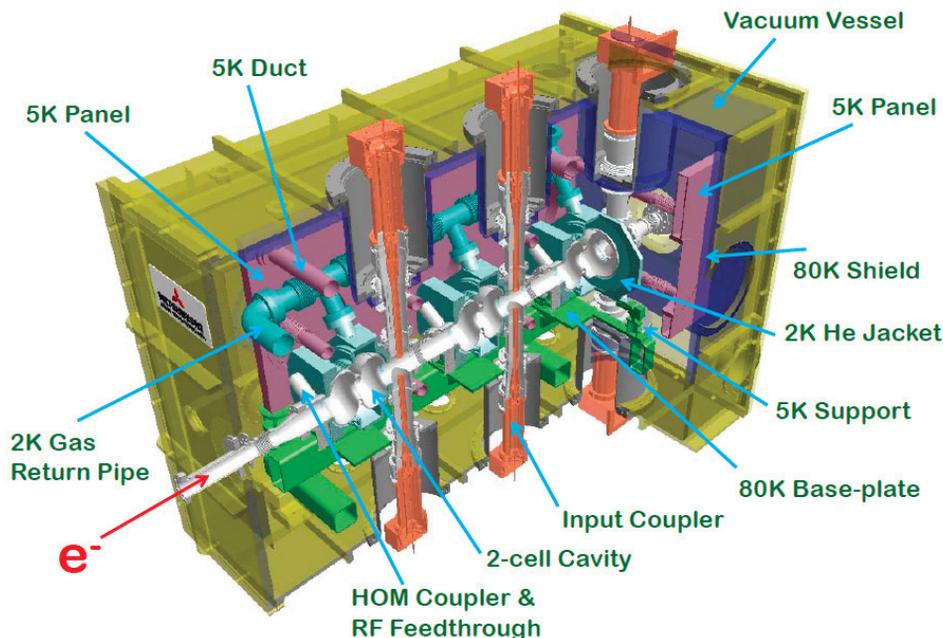


Figure 1: Injector cryomodule for cERL.

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KEY COMPONENTS

There are four kinds of key components for the cERL injector cryomodule. They are 2-cell cavities, HOM couplers, RF feedthroughs and input couplers. Completed three 2-cell cavities for the injector cryomodule are shown in Figure 2. They have a TESLA-like cell-shape and a large beam pipe aperture of 88 mm. A new loop-type HOM coupler was developed for 2-cell cavities, as shown in Figure 3, [6]. Five HOM couplers were welded by electron beams in both beam pipes of a 2-cell cavity. Completed six input couplers for the injector cryomodule are shown in Figure 4. The impedance of the coaxial line was changed from 41Ω of a prototype coupler to 69Ω in order to reduce RF losses on a Cu-plating surface, and the diameter of the outer conductor is 82 mm. Thermal intercepts at 5 K by liquid-He and 80 K by liquid-N₂ are attached in the outer conductor of the input couplers.

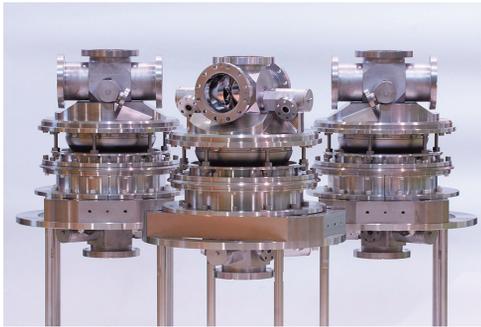


Figure 2: Three 2-cell cavities.



Figure 3: Fifteen HOM couplers.



Figure 4: Six CW input couplers.

CAVITY PERFORMANCE

The limitation on cavity performance in the 2-cell cavities was not only thermal quenching at defects on the RF surface in the cells, but also the drop in Q_0 values due to heating-up at the Nb-antenna tip of the HOM pick-up probe. New RF feedthroughs with more efficient cooling property were developed, as shown in Figure 5. An Nb-antenna was joined with a center conductor made of Kovar by a screw in the original RF feedthrough, (Type-0). In Type-I feedthroughs, the Nb antenna was joined by brazing, and the material of the center conductor was changed to Mo to increase the thermal conduction. Furthermore, the material of the outer conductor was changed from Kovar to copper to improve the cooling efficiency by liquid-He, (Type-II). Finally, a male pin for connection of a center conductor was applied in Type-II'm feedthroughs. These new RF feedthroughs were tested in the vertical tests of the 2-cell cavities. The final vertical test results in each cavity are shown in Figure 6. In the No.4 cavity test with five Type-I feedthroughs, the obtained maximum accelerating gradient (E_{acc}) was limited by drop of Q_0 values due to heating-up of the Nb-antenna tip. On the other hand, the limitation in No.3 and No.5 cavities with Type-II feedthroughs was a thermal quench at the cell without heating at the Nb-antenna. All cavities achieved the E_{acc} higher than 20 MV/m, which exceeds an operating gradient in the cERL injector.

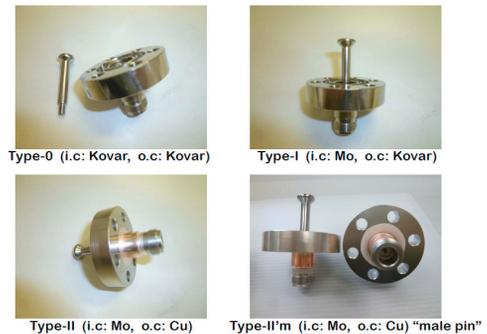


Figure 5: Four types of RF feedthroughs with HOM pick-up antenna made of niobium; material of inner conductor (i.c) and outer conductor (o.c).

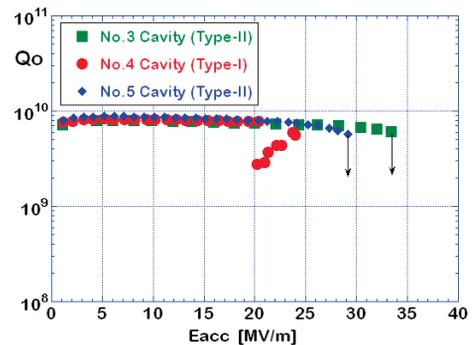


Figure 6: Final vertical test results of three 2-cell cavities with five HOM feedthroughs.

CONDITIONING OF INPUT COUPLERS

Conditioning of six input couplers for the injector cryomodule were carried out by using a newly developed 300 kW CW klystron. High power RF test stand for conditioning a pair of input couplers is shown in Figure 7. A water cooling channel was inserted inside of an inner conductor of the input couplers. The coaxial line between an RF window and a doorknob-type transition was cooled by nitrogen gas flow. Outer surface of the test stand was cooled by air wind from two electric fans. Conditioning of these input couplers was carefully carried out up to 200 kW in a short pulsed operation with a duty of less than 1 % and 30~40 kW in a CW operation, [7].

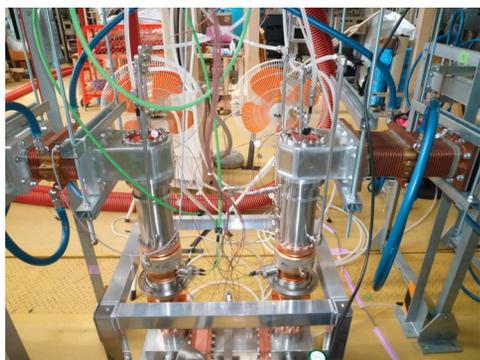


Figure 7: High power RF test stand for conditioning of input couplers.

ASSEMBLY OF CRYOMODULE

All components like input couplers, beam tubes, RF feedthroughs and vacuum parts were carefully rinsed, and they were dried in a class-10 clean room. Every RF feedthroughs for HOM couplers were replaced with new type-II'm feedthroughs, as shown in Figure 6. Six input couplers were mounted in the upper and lower ports of three 2-cell cavities. Three cavities were strung with two interconnected bellows, and two beam tubes were attached in the both end. The completed cavity string assembly is shown in Figure 8. After this, attachment of a tuner system and alignment of three cavities were carried out.



Figure 8: String assembly of three 2-cell cavities with six input couplers in a class-10 clean room.

After the cold mass assembly like a cooling pipeline of 2K-He, two reservoir panels of 5K-He and thermal shields of 80K-N₂, the string cavities are inserted into the vacuum vessel, as shown in Figure 9. The whole assembly of the injector cryomodule will be completed in July of 2012. Then, the injector cryomodule is installed in the beam line and is connected with a cold valve box. The first cool-down test is scheduled in autumn of 2012.



Figure 9: Vacuum vessel for cERL injector cryomodule.

SUMMARY

- Three 2-cell cavities with five HOM couplers, six CW input couplers and fifteen RF feedthroughs for a HOM pick-up antenna were developed for the cERL injector cryomodule. The component tests to confirm their performance were successfully carried out.
- Assembly of the cERL injector cryomodule is just progressing. After installation in the beam line, the first cool-down will be started in September of 2012.

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