HIGH POWER TESTS OF CW INPUT COUPLERS FOR CERL INJECTOR CRYOMODULE

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Abstract

An injector cryomodule for the compact energy-recovery linac (cERL) requires six input couplers operating in CW mode. The input couplers were designed, fabricated and tested at a high power test system with a 300 kW CW klystron. The RF conditioning of the CW input couplers was successfully carried out at the test stand. The RF conditioning procedures and results are described.

INTRODUCTION

The compact energy-recovery linac (cERL) is under construction at KEK. In the cERL injector cryomodule, electron beams of 10 mA are accelerated from the beam energy of 500 keV to 5 MeV. In the future 3-GeV ERL project at KEK, the electron beam current increases to 100 mA, and the beam acceleration to 10 MeV will be required for the injector cryomodule. A three 2-cell cavity system was chosen for the cERL injector, as shown in Figure 1, [1]. Each cavity is driven by two input couplers to reduce a required RF power handling capacity and also to compensate a coupler kick. In the cERL injector cryomodule, critical hardware components are not superconducting cavities but RF input couplers operating in CW mode. After the initial tests of two prototype input couplers, six input couplers for the installation in the cryomodule were fabricated, and three pairs of input couplers were carefully conditioned. Construction of the cERL injector cryomodule is in progress now, [2].

DESIGN OF CW INPUT COUPLER

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 [3], as shown in Figure 2. The impedance of the coaxial line was changed from 41.5 Ω of a prototype coupler to 66 Ω in order to reduce RF losses on a Cu-plating surface. The diameter of the outer conductor is 82 mm, and the diameter of the inner conductor was reduced from 41 mm to 27 mm. Thermal intercepts at 5 K by liquid-He and 80 K by liquid-N_2 are attached at the outer conductor of the input coupler. The inner conductor and RF window are cooled by water. Main specification of the cERL injector cryomodule is shown in Table 1. Accelerating voltage (V_c), accelerating gradient (E_{acc}), loaded Q value (Q_L) and required RF input power (P_{RF}) in three cavities are listed in case of the beam parameters of 10 mA and 5 MeV. The values of Q_L and P_{RF} are indicated by per coupler. Although the required RF power is 10 kW for the cERL injector, the final target is 170 kW for the future 3-GeV ERL project.

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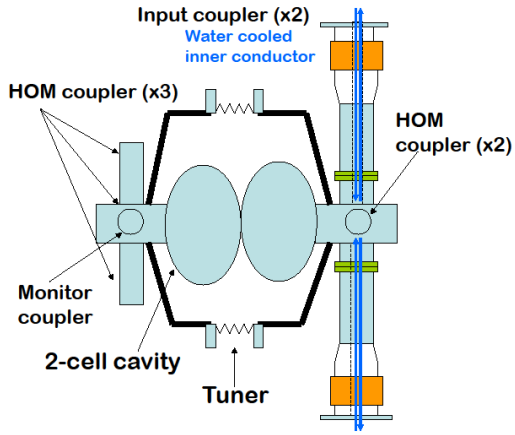

Figure 1: Conceptual structure of 2-cell cavity with 2 input couplers and 5 HOM couplers for cERL injector.

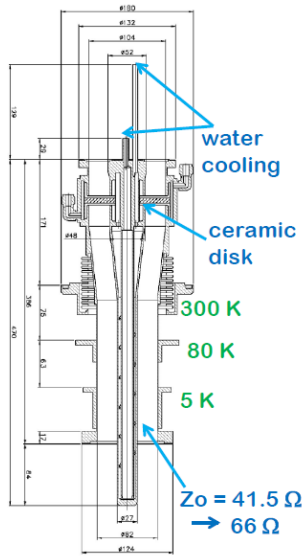

Figure 2: Schematic drawing of CW input coupler with coaxial ceramic RF window.

Table 1: Main specification of cERL injector cryomodule.

	Cavity-I	Cavity-II	Cavity-III
V_c	1.5 MV	1.8 MV	1.8 MV
E_{acc}	6.5 MV/m	7.5 MV/m	7.5 MV/m
Q_L	1.0×10^6	4.0×10^5	4.0×10^5
P_{RF}	7.5 kW	10 kW	10 kW

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CONDITIONING OF PRTOTOTYPE INPUT COUPLERS

A pair of prototype input couplers are shown in Figure 3 and an assembled high power test stand is shown in Figure 4. High power test of the input couplers were performed by using a newly developed 300 kW CW klystron. The input couplers were conditioned up to 100 kW for 2 hours in a pulsed operation with a duty of 10 % (200 kW in case of less than 1 %), and 30 kW for 1.5 hours and 50 kW for 0.5 hours in a CW operation, as shown in Figure 5. The total conditioning time was about 36 hours for 7 days. After the conditioning finished, the high power test system was disassembled to check. The dark black surface by excessive heating around the bellows of two inner conductors locating between a RF window and a doorknob-type transition was found, as shown in Figure 6. It was understood that sufficient cooling at the coaxial lines was indispensable to increase the required input RF power.

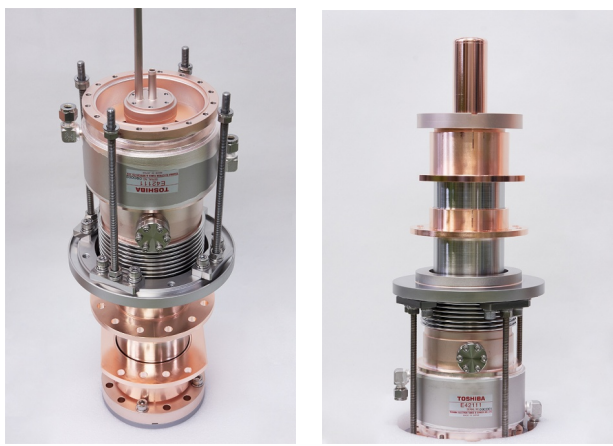

Figure 3: Two prototype input couplers, (#1 and #2).

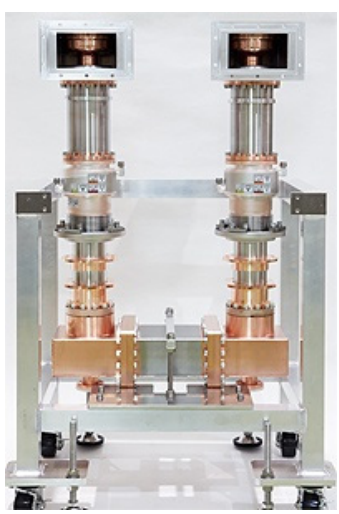

Figure 4: High power RF test system consisting of two input couplers, coupling waveguides as a vacuum chamber, coaxial lines and doorknob-type transitions.

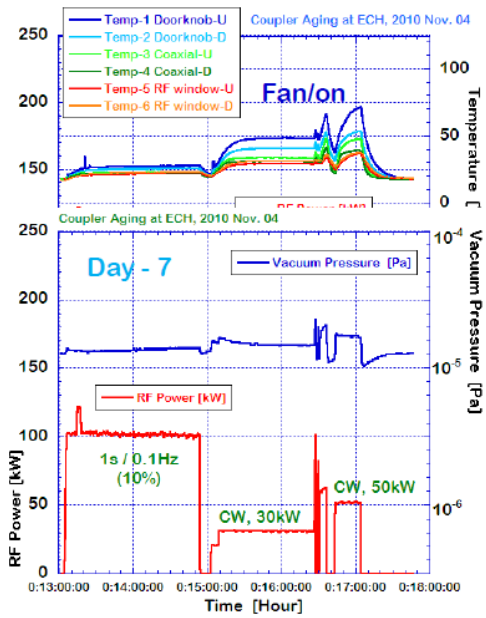

Figure 5: RF conditioning results of #1 and #2 prototype input couplers: temperature rises (top), vacuum pressure (middle) and input RF power (bottom).

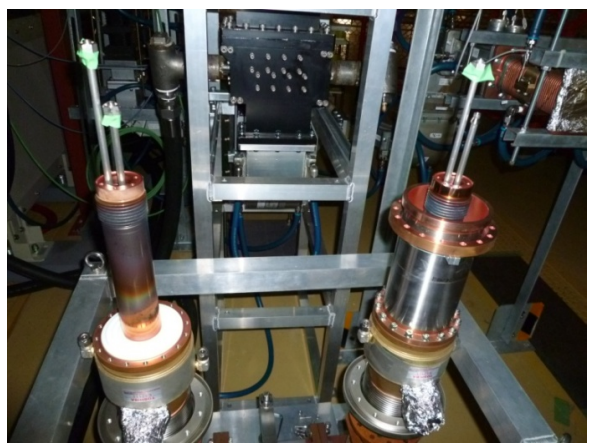

Figure 6: Surface colour change by excessive heat-up around bellows of inner conductors in #1 and #2 prototype input couplers after conditioning at CW 50 kW for 30 minutes.

CONDITIONING OF INPUT COUPLERS FOR CRYOMODULE

Six input couplers for the injector cryomodule were fabricated, as shown in Figure 7. The impedance of the coaxial line is 66 Ω, and the loaded Q value (Q_L) per coupler is 1.0×10^6 for the No.1 cavity and 4.0×10^5 for the No.2 and No.3 cavities. High power RF test stand for conditioning a pair of input couplers is shown in Figure 8. Prior to the RF conditioning, baking at 120 °C for 50 hours was carried out. 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-

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type transition was cooled by nitrogen gas flow. The inside of the bellows, which is a highest heating-up spot, was also cooled by nitrogen gas flow. Whole outer surface of the test stand was cooled by air wind from two electric fans. An interlock level of vacuum pressure was set at 1.0×10^{-4} Pa. An arc detector was installed to avoid a fatal discharge at a vacuum side of an RF window in each coupler. Total 14 temperature sensors were attached at the inside of the inner conductors, the outside of the outer conductors and the doorknobs. Conditioning of these input couplers was carefully carried out, as shown in Figure 9 and 10. The RF condition was initially started in a short pulsed operation of 10 μsec and 5 Hz. Input RF power was gradually increased up to 200 kW, and the pulse width was extended to 30 μsec, 100 μsec, 0.5 msec and 2 msec with 5 Hz, step by step. After the duty cycle was increase to 5 %, 10 % and 20 % at 60~80 kW, the conditioning was finally carried out up to 30~40 kW in a CW operation. When the monitored temperature rise reached to around 100 °C, the conditioning was stopped for safety. There was no colour change around the bellows after the disassembly in each coupler test.

Figure 7: Six input couplers for injector cryomodule; #3 and #4 couplers for No.1 cavity, #5 and #6 couplers for No.2 cavity, #7 and #8 couplers for No.3 cavity.

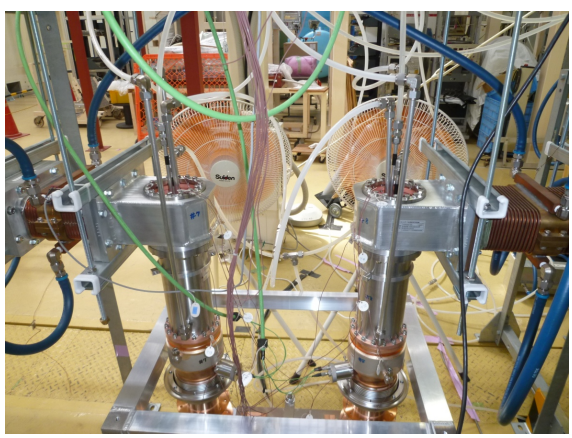

Figure 8: High power test stand for RF conditioning with improved cooling by nitrogen gas flow in a pair of #7 and #8 input couplers.

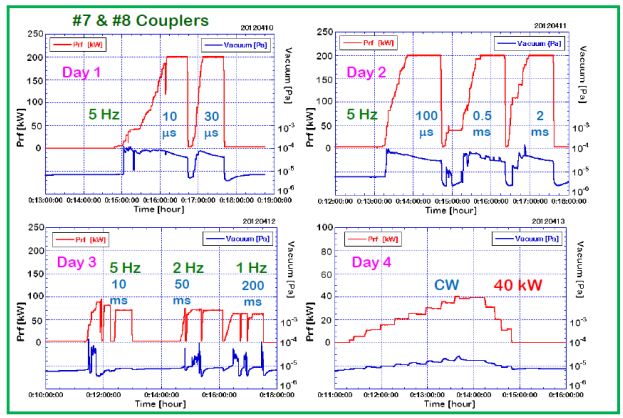

Figure 9: RF conditioning procedure of #7 and #8 input couplers for four days (maximum CW 40 kW): input RF power (red line) and vacuum pressure (blue line).

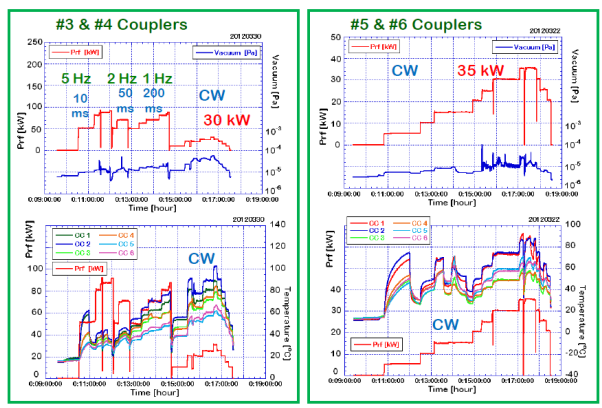

Figure 10: Temperature rises during conditioning in #3 and #4 input couplers (maximum CW 30 kW) and #5 and #6 input couplers (maximum CW 35 kW).

SUMMARY

- The conditioning of the prototype input couplers was limited by excessive heating at the bellows of two inner conductors locating between an RF window and a doorknob-type transition.
- After improved cooling by nitrogen gas flow at the coaxial line, six input couplers for the cERL injector cryomodule were carefully conditioned up to an RF power level of 30~40 kW in a CW operation.

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