THE FIRST PROCESSING OF CAPACITIVE-COUPLING COUPLER AT ROOM TEMPERATURE IN A CRYOMODULE AT STF

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Abstract

We are constructing Superconducting RF Test Facility (STF) at KEK for the R&D of ILC accelerator. In the beginning of year 2007, we installed one TESLA-like 9-cell cavity and one high-gradient Low-Loss (LL) type 9-cell cavity into cryomodules at STF. For the LL 9-cell cavity, an Capacitive-Coupling (CC) input-coupler, a ball-screw tuner and other peripherals were assembled with the cavity. The assembled cavity package was installed with thermal shields and so on into a cryomodule. After the installation, we performed the first processing of Capacitive-Coupling (CC) input-coupler in a cryomodule at the room-temperature. We achieved the power of 250 kW with the pulse-width of 1.5 msec at the repetition rate of 5 pps. This presentation describes about the assembly of a CC coupler and a high-gradient LL 9-cell cavity in a clean room and the processing of the CC coupler at the room temperature in a cryomodule.

INTRODUCTION

We are planning to construct Superconducting RF Test Facility (STF) at KEK for the R&D of ILC accelerator in the next two years [1]. In the first stage, we installed one TESLA-like 9-cell cavity and one high-gradient Low-Loss (LL) type 9-cell cavity into cryomodules. The details of the fabrication and inner-surface treatment of LL 9-cell cavities are found elsewhere [2]. The LL 9-cell cavity which has reached the gradient of 19 MV/m in a vertical test was installed into the cryomodule. In the end of the fiscal year of 2007, i.e. March 2008, we will finish the first cooling test of these two cavities at the temperature of 2 K in the cryomodules. In 2008, we are planning to install four TESLA-like 9-cell cavities and four high-gradient Low-Loss (LL) type 9-cell cavities into cryomodules as shown in Figure 1. In this article, we will describe the first assembly of a LL 9-cell cavity, a Capacitive-Coupling (CC) coupler and a ball-screw tuner in a clean room, the installation of the cavity package into a cryomodule, and the first processing of the CC-coupler at the room temperature in a cryomodule.

CAPACITIVE-COUPLING COUPLER

The specification of the CC coupler including the thermal losses is shown in Figure 2, where the input peak RF-power is 500 kW with the pulse-width of 1.3 msec at the repetition rate of 5 pps, and the averaged RF-power is 3.25 kW. The thermal losses of CC coupler in the specification at the thermal anchors of 2 K, 5 K, and 80 K are 0.25, 3.42 and 3.38 W, respectively. Details of the designing concept of CC coupler are found elsewhere [3].

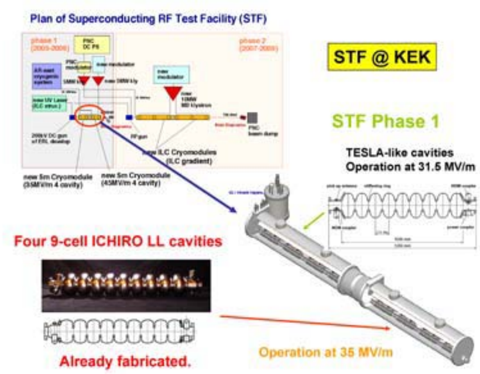

Figure 1: Superconducting RF Test Facility (STF) at KEK.

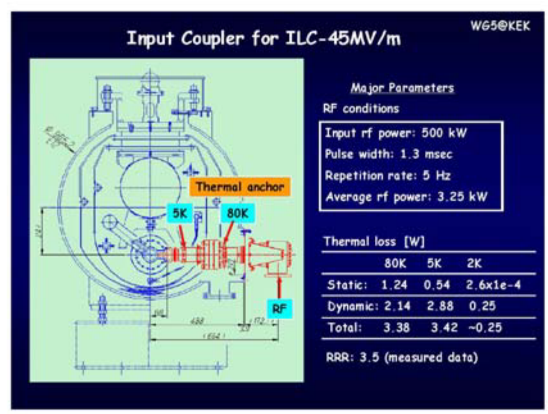

Figure 2: Specification of Capacitive-Coupling (CC) coupler.

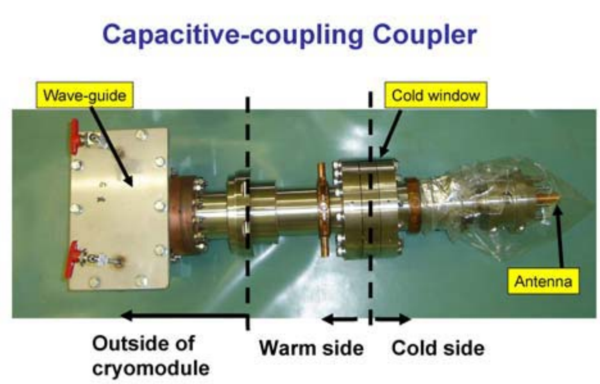

Figure 3: Picture of Capacitive-Coupling (CC) coupler.

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Four proto-type CC couplers were fabricated and three of them were already processed in test stands [4]. A picture of fabricated CC coupler is shown in Figure 3. The coupler is divided into cold and warm parts by a cold ceramic RF-window in the middle. There is a RF wave-guide at the end of warm part. The half of warm part including the wave-guide is located outside a cryomodule and the rest of part is located inside a cryomodule.

ASSEMBLY OF 9-CELL CAVITY AND INPUT-COUPLER IN A CLEAN ROOM

In order to assemble a LL 9-cell cavity and a CC coupler in a clean room, we newly designed and fabricated an assembly table as shown in Figure 4. Six wheels fixed on the assembly table support the cavity, and therefore the cavity can be rotated very easily during assembly procedure.

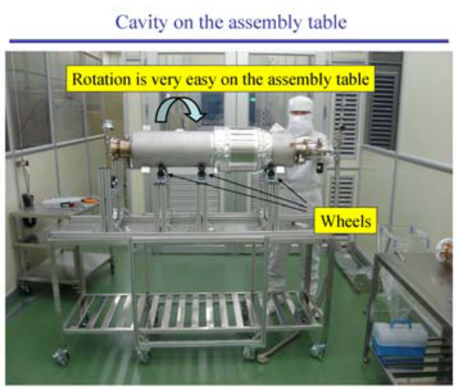

Figure 4: LL 9-cell cavity on the assembly table in a clean room.

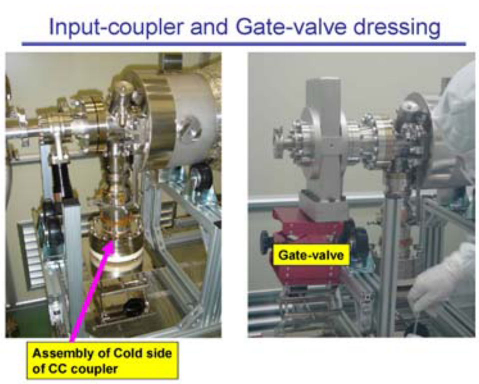

Figure 5: Assembly of a CC coupler and a gate-valve on the LL 9-cell cavity in a clean room.

After High-Pressure Rinse was performed with the LL 9-cell cavity, the cavity was moved and setup on the assembly table in a clean room. Figure 5 shows the assembly of a CC coupler and a gate-valve on the LL 9-cell cavity. During the assembly procedure, we supplied the pressurized air into the cavity. The air was introduced into the cavity from one of beam pipes through a filter. Consequently, the air constantly flows out of the cavity through all open ports and beam-pipes during the assembly procedure. This might lowered the possibility for accidental particles to move into the cavity.

In the assembly inside the clean room, only the cold part of the CC coupler is dressed on the cavity. After dressing antennas for field pickup and two HOM couplers, as well as a slow motor and a piezo actuator of a ball-screw tuner [5] on the cavity, the dressed cavity was mounted to the structure of the He return-pipe of a cryomodule. The cavity package was covered with 5-K and 80-K thermal shields and installed into a cryomodule as shown in Figure 6.

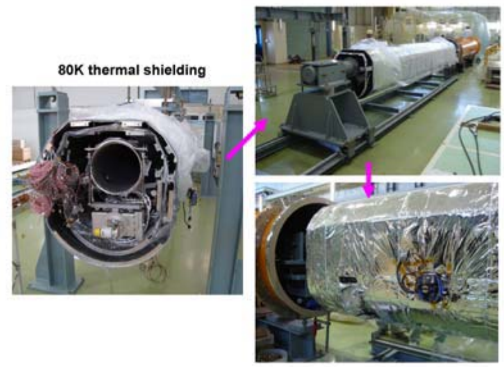

Figure 6: Installation of cavity package covered with thermal shields into a cryomodule.

ASSEMBLY OF INPUT-COUPLER IN A CRYOMODULE

After moving the cryomodule into a RF-test tunnel, the warm part of CC coupler was installed and connected onto the cold part of CC coupler in the cryomodule. The installation procedure was performed inside a temporal clean-room tent to keep clean environment during the assembly. Figure 7 shows the steps of the assembly, where the inner and outer conductors of warm part were firstly installed on the cold RF window of the CC coupler inside the cryomodule. The warm part of the coupler was fixed with bolts around the coupler-port flange of the cryomodule, and finally the RF wave-guide was assembled with the warm part of the coupler outside the cryomodule.

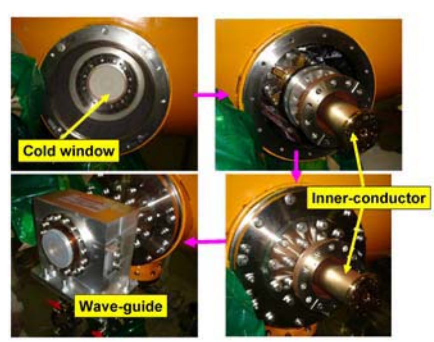

Figure 7: Installation of the warm part of the CC coupler on the cold part of CC coupler in the cryomodule.

The RF wave-guide of the CC coupler was connected to the wave-guide-to-coaxial-cable converter in order to measure the resonant frequencies of the cavity with a network analyzer. The π-mode resonant frequency of the cavity was measured to be 1.297823 GHz. Replacing the wave-guide-to-coaxial-cable converter with bellows, the CC coupler was connected to the RF wave-guide from a klystron as shown in Figure 8. The warm side of CC coupler and the inside of the cavity as well as the cold side of the CC coupler were pumped with two ion pumps separately. Two Nude Ion Guage (NIG) sensors were used to monitor the pressures of the cavity and the warm side of the CC coupler. The two NIG sensors and the arc-sensor which monitors the arc of the warm side of the CC coupler were used to setup an interlock system for the processing of the CC coupler in the cryomodule.

After the whole assembly procedure finished, we found a small leak at the connection of cold and warm parts of CC coupler where the leak point was located inside the cryomodule. The leak rate was about 1E-9 Pa m^3 / sec with helium gas. Because of the limitation of time, we left the leak as it is and pumped down inside the cryomodule, i.e. outside the coupler. What we have learned from this leak was that we did not expect or consider well about this kind of leaking trouble and our assembly procedure did not include the leak-check process in each step of assembly. To resolve this problem, we should have designed and fabricated some tools for a quick leak-check in each step of assembly. These tools are now under design and might be used in next assembly.

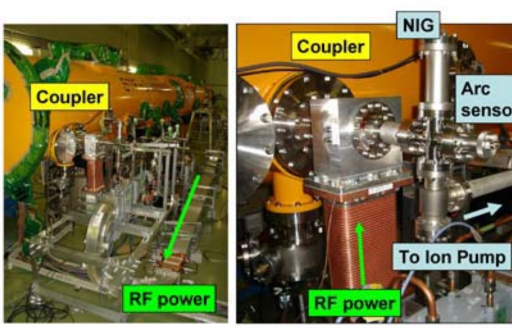

Figure 8: RF wave-guide and vacuum pumping system were connected to the CC coupler in the cryomodule.

PROCESSING OF COUPLER AT THE ROOM TEMPERATURE

In the RF-test tunnel, the CC coupler which was installed in the cryomodule was processed at the room temperature with high-power RF input from a klystron. From Figure 9 to Figure 12 show the processing history of the CC coupler in terms of the RF-power and pulse width as the function of processing time. In the normal processing procedure of CC coupler at a test-stand, we start from a low RF-power with the pulse-width of 100 ns. However, because of the limitation of instrumentation, we started this processing from the pulse-width of 30 us. During this processing with the pulse-width of 30 us at the repetition rate of 5 pps, a severe breakdown occurred within one hour as shown in Figure 9. After following five-hour processing, the pulse-with was decreased to 10 us which was the minimum possible setting-value of the pulse-width of the instrumentation. After additional processing for eleven hours with the pulse-width of 10 us at the repetition rate of 5 pps, the RF power reached 140 kW as shown in Figure 10 and 11. The RF power was increased until 250 kW, and once the power reached 250 kW, the pulse-width was increased step by step to 1.5 ms at the repetition rate of 5 pps as shown in Figure 12. The total processing time to reach the power of 250 kW was about 28 hours. The interlock levels of the pressure for warm and cold sides of CC coupler started from 5.0 E-6 Pa and 5.0E-6 Pa, respectively. At the end of the processing, both the levels were 5.0 E-5 Pa and 1.0E-5 Pa, respectively.

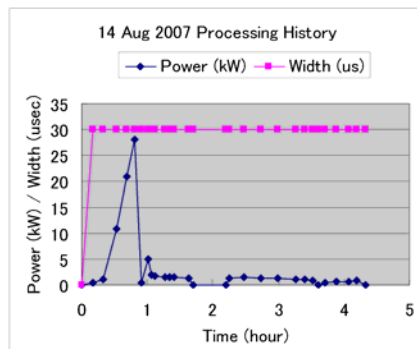

Figure 9: Processing history of CC coupler on 14th August 2007. The interlock levels of the pressure for warm and cold sides of CC coupler were 5.0 E-6 Pa and 5.0E-6 Pa, respectively.

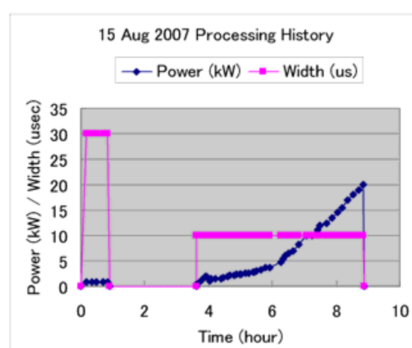

Figure 10: Processing history of CC coupler on 15th August 2007. The interlock levels of the pressure for warm and cold sides of CC coupler were 1.0 E-5 Pa and 5.0E-6 Pa, respectively.

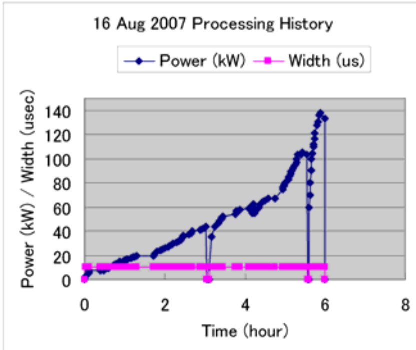

Figure 11: Processing history of CC coupler on 16th August 2007. The interlock levels of the pressure for warm and cold sides of CC coupler were 5.0 E-5 Pa and 1.0E-5 Pa, respectively.

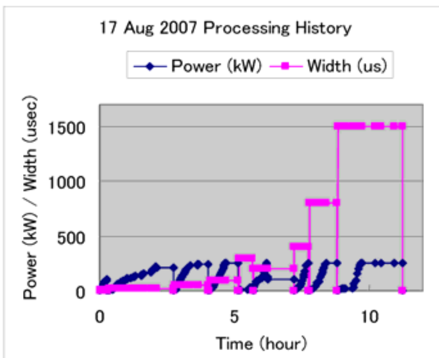

Figure 12: Processing history of CC coupler on 17th August 2007. The interlock levels of the pressure for warm and cold sides of CC coupler were 5.0 E-5 Pa and 1.0E-5 Pa, respectively.

The formula which describes the klystron power of *Pg* to keep a constant accelerating field for a beam is given as formula (1), where *Pb*(design) is the beam power in design, *Pb*(real) is the beam power in a real accelerator, ω is 2π times resonant frequency, Δω is shift or detuning from ω, and Q_L is the loaded Q of cavity.

$$P_g \sim \frac{Pb(design)}{4} \times \{1 + (\frac{Pb(real)}{Pb(design)})^2 + 4 \times (\frac{\Delta\omega}{\omega/Q_L})^2\} \quad (1)$$

In the first cooling test at STF, there is no beam and *Pb*(real) = 0. Then we can simplify formula (1) as follows.

$$P_g \sim Pb(design) \times \{0.25 + (\frac{\Delta\omega}{\omega/Q_L})^2\} \quad (2)$$

In the ILC, the RF frequency is 1.3 GHz and then ω = 2π times 1.3E9. The loaded Q of the LL cavity and CC coupler is given as Q_L = 2.6E6 where the strong coupling of CC coupler to the cavity is dominated. Δω depends on the accelerating filed. If we assume the accelerating field of 15 MV/m, Δω = 2π times 0.32 kHz. Inputting these values into formula (2) and we obtain followings.

$$\begin{aligned} P_g &\sim Pb(design) \times \{0.25 + 0.42\} \\ &= 0.67 \times Pb(design) \end{aligned} \quad (3)$$

The pulse-shapes of forward and backward RF voltages during this processing are shown in Figure 13. Because these pulse-shapes are measured through directional couplers, diodes and an oscilloscope, we assume that the pulse-shapes roughly represent the voltages. Because the coupling-constant of the CC coupler to the cavity is matched to the beam-loaded situation, most of forward RF-power is reflected backward. Assuming no beam in the first cooling test of the cavity in the cryomodule, the pulse-height of input RF voltage was decreased by 23 % after the rising time of 500 us and the pulse-height was kept at 77 % of the full height for 1 ms in a pulse. Because the square of voltage is proportional to the power, the measured voltage of 77% pulse-height for 1 ms is equivalent to 60% power for 1 ms after 100% power during the rising time of 500 us. This 60% is near the 67% in formula (3). Actually, this pulse-shape used in the processing is optimized for the TESLA-like cavity to make a flat field inside the cavity for 1 ms when the cavity is cooled down at the temperature of 2 K without beam. In addition to this pulse-shape, we are going to prepare various templates of pulse-shape for klystron RF-power depending on the detuning of LL cavity at various accelerating fields.

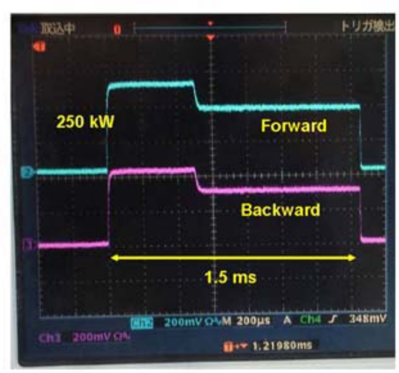

Figure 13: The pulse-shapes of the forward and backward RF voltages just before the RF wave-guide of the CC coupler. The peak RF-power of 250 kW was achieved with the pulse-width of 1.5 ms at the repetition rate of 5 pps.

PLAN

Unfortunately, a leak was found around the He-jacket of the LL cavity or He-supplying pipes in the cryomodule. We already dismantled the cryomodule of the LL cavity and tried to find out the exact leak point. However, the leak point has not been found yet around the LL cavity and still the leak hunting is ongoing. On the other hand, during the leak hunting of the LL cavity, the TESLA-like cavity alone was cooled down in another cryomodule to the temperature of 2 K, and high-power test was done. In the next step, after dismantling the cryomodule of the TESLA-like cavity, we will install the LL cavity into a cryomodule again and try to cool down the LL cavity for high-power test by the end of March 2008. In parallel to the cooling test of the LL cavity, four TESLA-like cavities will be installed into a cryomodule and will be ready for the next cooling test by the end of March 2008.

SUMMARY

In the beginning of year 2007, we installed one high-gradient Low-Loss (LL) type 9-cell cavity into a cryomodule at STF. A Capacitive-Coupling (CC) input-coupler, a ball-screw tuner and other peripherals were assembled with the cavity in a clean room successfully. The assembled cavity package was installed with thermal shields and so on into a cryomodule. After the installation, we performed the first processing of Capacitive-Coupling (CC) input-coupler in the cryomodule at the room temperature. We achieved the peak RF-power of 250 kW with the pulse-width of 1.5 msec at the repetition rate of 5 pps. Unfortunately, a leak was found around the He-jacket of the LL cavity or He-supplying pipes in the cryomodule, and the leak hunting is still ongoing. The plan is that we might fix the leak and install the LL cavity into a cryomodule again, and try to cool down the LL cavity for high-power test and finish the test by the end of March 2008.

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