HIGH POWER INPUT COUPLER FOR KEKB SC CAVITY AND NEW 1MW TEST BENCH

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Abstract

KEKB superconducting cavities have been driving the design current of 1.1 A from spring of 2003. To increase luminosity of KEKB, the current will be increased as high as possible. For higher current operation of superconducting cavities more than 1.1 A for KEKB, one of key component is a high power input coupler. To increase operation power of 300 kW to 500 kW, the 1 MW coupler test bench have been constructed. The new couplers already tested up to 500kW with doorknob transitions enforced air cooling at the new 1 MW coupler test bench.

DEDICATED 1 MW KLYSTRON SYSTEM FOR COUPLER TEST BENCH

To test the high power couplers for KEKB, new 1 MW klystron power supply and klystron system have been constructed at D10 area, all four existing klystron are use for KEKB operation.

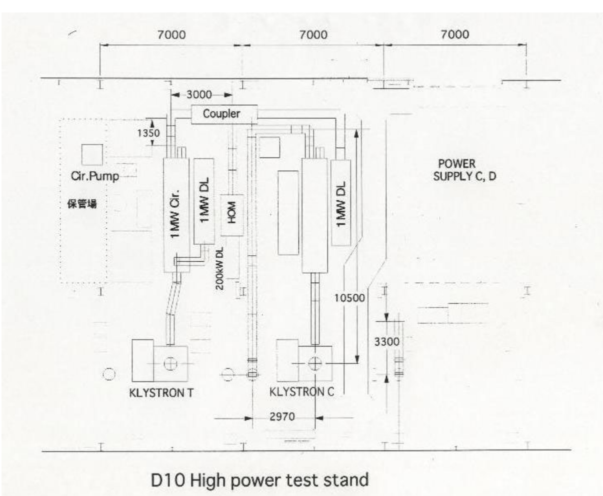

Figure 1: Coupler test bench at D10 area between operating klystron for KEKB.

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KEKB INPUT COUPLER

The input coupler for KEKB superconducting cavity is almost same design as that used for TRISTAN superconducting cavities.(1) The gap of 3 mm of choke structure was changed to 4 mm to reduce the field strength at ceramic disk. One of authors pointed out for TRISTAN coupler using water cooling of inner conductor. The calculated heat transfer by radiation is 0.6 W for the electro-polished Cu inner conductor(2). This heat transfer is small and is expected almost no effect to cavity performance in case of high field of more than 10 MV/m for KEKB. The water cooling has enough cooling capacity up to 1 MW. The window of the coupler is almost same as 1MW klystrons used at TRISTAN, which have long lifetime of more than 50000 hours. So the TRISTAN coupler can be operated 1 MW principally but used up to 200 kW at TRISTAN time. So for higher power operation, the KEKB couplers need more diagnostics for precise RF processing and interlock
system for operating at bad vacuum condition compared to klystrons. Three monitoring ports were set near the ceramic window to monitor vacuum pressure, electron and discharge light (arc sensor) for protection and diagnosis.
The KEKB couplers tested up to 800 kW[3] by the traveling wave and 300 kW totally reflected standing wave, changing phase up to half wave (in short time 500 kW which equivalently corresponding 2 MW traveling wave). In the second beam test, frequent discharge around the coupler occurred and temperature changed by cool gas flow rate affect to this trip rate. So condensed gas affects the surface condition and multipacting of the coupler occurred. Before the third test we prepared a biased type doorknob transition which can supply a bias voltage to the inner conductor of the coaxial input coupler. The biased type doorknob transition was tested at the test bench up to 300 kW standing wave changing phase half wave length and traveling wave. Between the inner conductor and the doorknob, a capacitance of 1300 pF was inserted. The insulating material was two layer of polyimide (like as Kapton) films of 0.125 mm thick.(4)

The bias-type door-knob transitions were tested 450 kW transmission condition and 300 kW full reflection condition without air duct cooling.

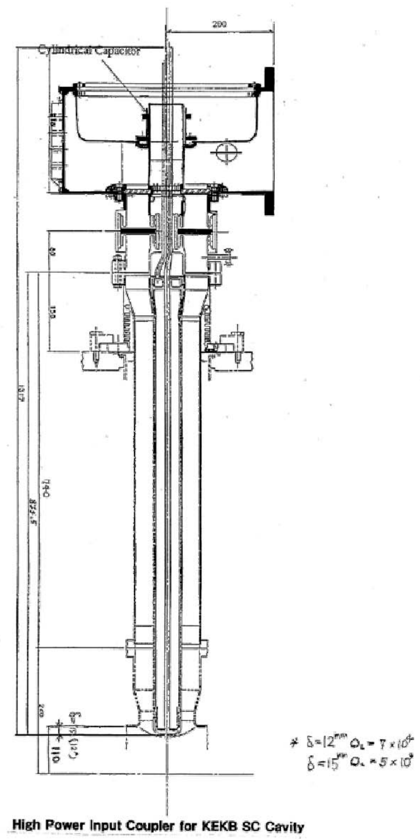

Figure 2: High power input coupler for KEKB.

One of the limitation of the KEKB coupler for high power operation is heating at capacitor for bias voltage. An air duct is added near this capacitor to increase cooling power.

COUPLER PREPARATION

The coupler is shown in Fig. 2. The inner conductors were prepared some rinsing before RF processing. The rinsing process were followings.

1. Acetone rinsing after electron beam welding a electro polished inner conductor and a window.
2. ultra-pure water rinsing
3. ozonized water rinsing
4. ultra-pure water rinsing
5. dried by N_2 gas
6. evacuated at test stand

The outer conductors were electro plaited by Cu using piro-phosphoric acid. And rinsed with pure water and sieled with N_2 gas. And

1. ultra pure water rinsing
2. ozonized water rinsing
3. ultra pure water rinsing
4. dried by N_2 gas
5. evacuated at test stand.

The inner conductor and the outer conductor tested at test bench up to 450 kW. The tested couplers were set at the cryostat using clean hut with small moving mechanism.

COUPLER PROCESSING AND BIAS AGING

For high power operation, the capacitor at door knob was heated higher temperature than the other, so an air duct attaching to increase cooling power. Using this doorknob coupler with air duct, two new couplers have been tested up to 500 kW. Fig. 3 shows history of the coupler processing.

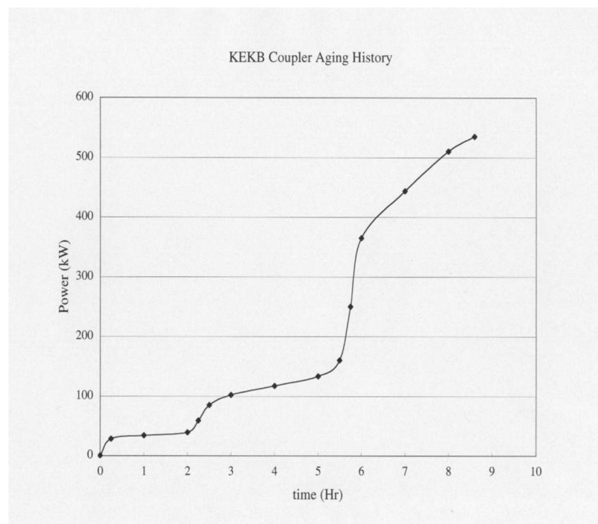

Figure 3: KEKB coupler processing history. The two couplers reached more than 500 kW less than 10 hours.

Before cooling down the cavities, we conditioned the input coupler up to 300 kW with full reflection condition, and up to 300 kW with DC bias voltage applied to the inner conductor up to $\pm$ 2kV. This conditioning decreased the secondary electron emission coefficients of the inner and outer conductors and the ceramic window to less than or nearly equal to one. During this room temperature conditioning, the disrobed gas was evacuated to the vacuum ion-pumps. The multipactor around the input coupler, which is known to induce break down of the superconducting cavity during high power beam operation, was strongly reduced. By doing this the cavity could be operated at high power without beam processing of the input coupler. When we applied DC bias voltages to the inner conductor up to $\pm$ 2 kV, on the starting at a bias voltage of +100 V, we observed light emission near the window on the test stand.

COUPLER OPERATION WITH BEAM

After the liquid helium vessel is filled to about 90 %, we try to raise the coupler power to 300 kW in an off-resonance condition, and raise the cavity voltage , Vc, up to 3 MV which corresponds to 12 MV/m or till breakdown(quench) occurs. Then we shift the phase of cavity up to $\pm$ 30° so that the field profile in the coupler changes in order to check and condition the less-conditioned parts of the coupler. Usually, no or slight out gassing is observed during this phase change conditioning. Conditioning at low temperature might be a source of gas condensation at the input coupler and superconducting cavity, so for the stable operation of coupler, the room-temperature bias conditioning is important. A more detailed study for this problem is being done.

The couplers handled RF power up to 380 kW to the beam with a beam current of 0.5 A. This is the highest power record for continuous operation in the world to date. Figure 4 shows the power transferred to the beam and the beam current. The maximum total power transferred to the beam was 1.4 MW by the 4 superconducting cavities.

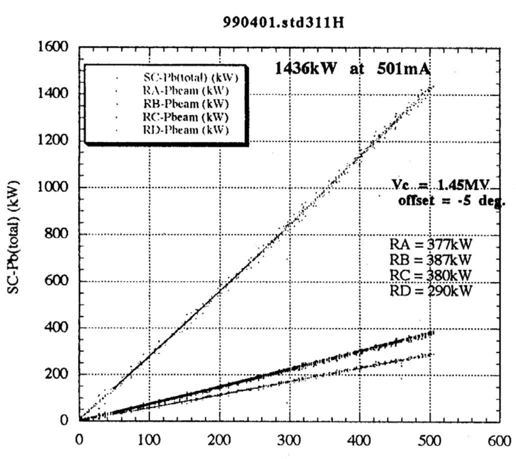

Figure 4: Power transferred to the beam and beam current.

KEKB operating more than 1.1 A beam. Resent coupler power is shown Fig. 5.

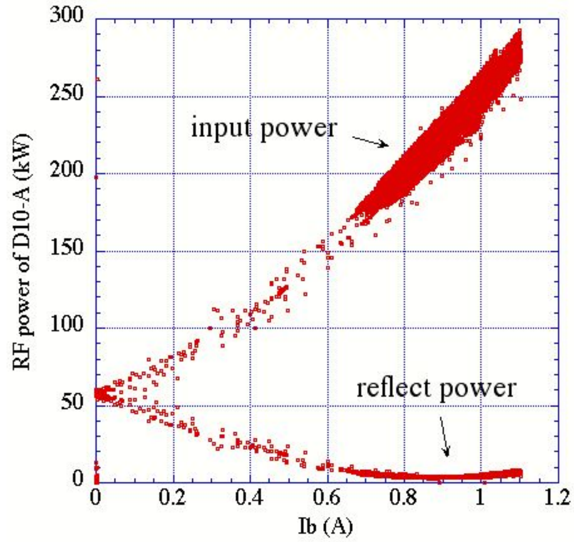

Figure 5: Coupler input power and reflecting power during KEKB beam operation.

SUMMARY

Dedicated klystron system for testing high power coupler for KEKB superconducting cavities have been constructed.

The couplers have been tested 500 kW with doorknob transformer enforced air cooling.

This system will be used for high power test of HOM load of KEKB superconducting cavities.

The high power input couplers for KEKB have been operated stably with high current beam.

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