HIGH POWER RF TESTS ON INPUT COUPLERS FOR 972MHZ SUPERCONDUCTING CAVITIES IN THE J-PARC PROJECT

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Abstract

Prototype coaxial input couplers with a planar rf window and a high power test stand were designed and fabricated. The high power tests with a 972MHz pulsed klystron had been successfully carried out. Input rf power of 2.2MW in a pulsed operation of 0.6msec and 25Hz (370kW in 3.0msec and 25Hz) was transferred to the input couplers without any problem.

1 INTRODUCTION

In the KEK-JAERI joint project named J-PARC (Japan Proton Accelerator Research Complex), a superconducting linac is required to boost the energy of the H^- beam from 400MeV to 600MeV. The 600MeV beam will be used for ADS (accelerator-driven system) experiments in the second phase of the J-PARC project. In the present system design of the superconducting linac [1], eleven cryomodules containing two 972MHz 9-cell niobium cavities will be installed in the linac tunnel. The accelerating gradient has been set at about 10MV/m, and the operating temperature is 2K. A prototype cryomodule with β=0.725 (424MeV) was designed last year. The construction of the prototype cryomodule has been just started for an essential R&D work. Two input couplers are needed for installation in the cryomodule. Prototype 972MHz input couplers were fabricated in order to test the high power capability and reliability. The experimental set-up, the processing procedure and the test results with high rf power are described in this paper.

2 INPUT COUPLERS

Input couplers are used for transferring rf power to superconducting cavities. Basic design of the 972MHz input coupler was carried out with referring the 508MHz input coupler for the TRISTAN superconducting cavities [2]. Similar design is also found in the KEKB and SNS superconducting cavities [3, 4]. Heat load dissipated at copper surface and a ceramic disk is considerably reduced due to a pulsed operation, in comparison with the 508 MHz coupler in a cw operation. On the other hand, heavy irradiation caused by an intense proton beam has to be taken into consideration in the design. A fundamental specification of the 972MHz input coupler is summarised in Table 1. The required input rf power is 300kW for a beam current of 30mA at the operating accelerating gradient of 10MV/m. Detailed dimensions of a 972MHz coaxial window with a choke structure and the calculated rf characteristics are shown in ref. [5]. The ceramic disk is made of Al_2O_3 with the purity of 95%, and the thickness is 7.0mm. Coating with TiN on the surface of the vacuum side was carried out. The rf window is connected with a coaxial line (ϕ80) of 50Ω. The inner conductor made of a cupper pipe is equipped with a built-in cooling channel. The projection length of the antenna tip was determined to obtain the external Q value of $5x10^5$ [5]. As shown in Figure 1, the high power test stand consists of two doorknobs connected to the WR975-waveguide system, two coaxial input couplers with a planar rf window and a pair of coupling waveguide with a pumping port.

Table 1: Specification of the 972MHz input couplers

External Q value	5×10^5	
Input rf power	300 kW,	(I_b= 30 mA)
Pulsed operation	3.0 msec, 25 Hz	

3 EXPERIMENTAL SET UP

The input couplers and the coupling waveguides were carefully rinsed with ultra-pure water. They were dried for one day and were assembled in a clean room. Then, pumping was carried out by a vacuum system composed of a turbo molecular pump of 500 l/s and a rotary pump of 16000 l/h. The input coupler system was baked out at 120°C for 24 hours prior to rf processing. The vacuum

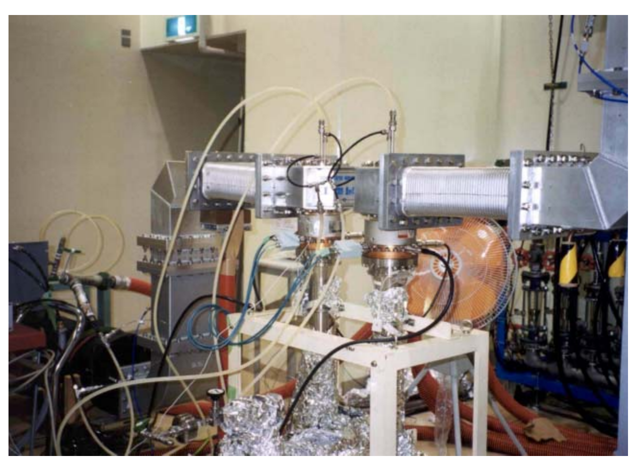

Figure 1: High power test stand

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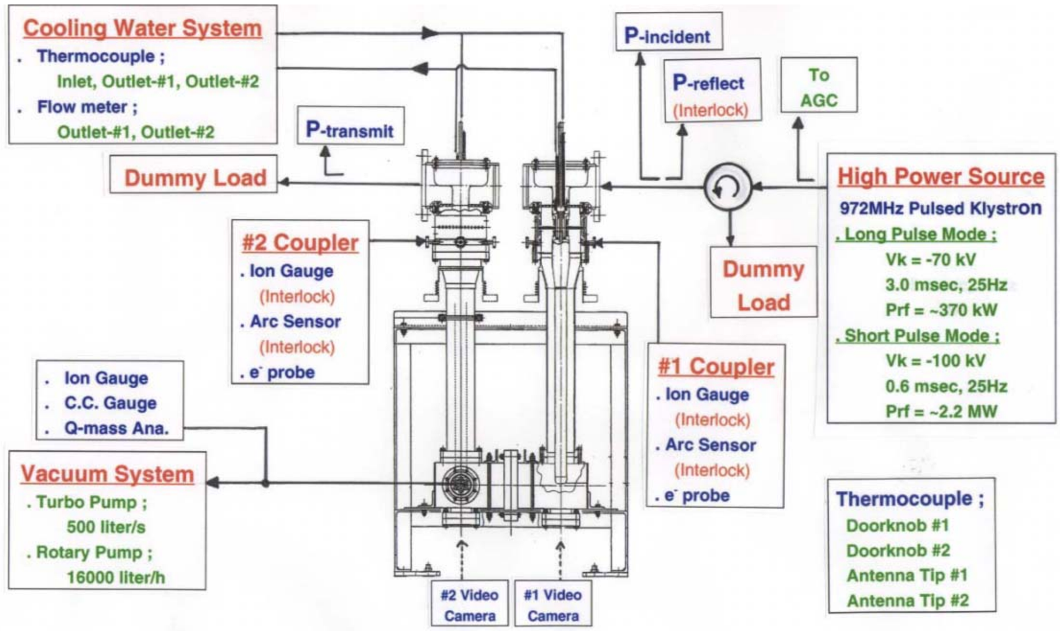

Figure 2: Experimental instrumentation for high power tests

pressure at room temperature has reached to about 1×10^{-6} Pa. An experimental instrumentation for high power tests is shown in Figure 2. An ionization gauge, a cold cathode gauge and a residual gas analyser are installed in the vacuum system. An ionization gauge, an arc detector and an electron pick-up probe are attached at three small ports close to the rf window of each input coupler. These monitoring instruments are very important to prevent a fatal sparking discharge around the rf window. Two video cameras locating at the bottom of the coupling waveguide can observe visible lights like a glow discharge by multipacting. A water-cooling system for the inner conductors is equipped with thermocouples and flow meters, which are used for a calorimetric measurement of the rf loss. A 972MHz pulsed klystron is a prototype for normal conducting cavities aiming at performances of 0.6msec, 50Hz and the maximum power of 3.0MW [6]. A longer pulsed operation is required for superconducting cavities. Therefore, modification in the rf control system and adjustment of the DC power supply system were carried out. In the present operated condition, the maximum available rf power is 370kW in the long pulse mode of 3.0msec and 2.2MW in the short pulse mode of 0.6msec.

4 HIGH POWER TESTS

Up to the present, high power tests had been carried out four times, as summarised in Table 2. The initial rf processing was started with a low duty factor of 0.1msec and 10Hz. The interlock level of vacuum pressure at the rf window was set to 5×10^{-4} Pa. The first deterioration of the vacuum pressure was observed at 30kW. As seen in Figure 3, the input rf power had been carefully increased, and the processing time up to 300kW was 22 hours. With gradual increment of the duty factor, the maximum rf power of 350kW in the long pulse mode of 2.45msec was transferred. There was no work of interlocks due to vacuum burst or arc detection during the processing. The maximum average rf power was 21kW. The temperature rise to about 100°C was observed at the antenna tip in the initial test without cooling water. Therefore, the necessity of forced cooling in the inner conductor was concluded, and the water-cooling was started in the successive processing. Rf loss at the rf window and the inner conductor was measured in various power levels by a calorimetric method. The rf loss was about 0.2% of the average input rf power [7]. In the third test, finally, 2.2MW in the short pulse mode of 0.6msec was fed to the input couplers without any trouble. However, degradation of the vacuum pressure had been still observed between 400kW and 800kW even after processed up to 2.2MW, as shown in Figure 4. The vacuum degradation in this power range was simultaneously accompanied with detection of electrons by the pick-up probe and observation of lights

Table 2: Procedure of rf processing

Test	Pulsed operation	Max. rf power	
1. Initial Tests:			
	0.1msec, 10Hz	300kW	(Fig. 3)
	2.45msec, 25Hz	350kW	
2. Exposure to N_2 gas:			
	0.1msec, 10Hz	300kW	(Fig. 5)
	2.45msec, 25Hz	350kW	
	0.6msec, 25Hz	1100kW	
3. Kept for one month without pumping:			
	0.1msec, 25Hz	1700kW	(Fig. 5)
	0.6msec, 25Hz	2200kW	(Fig. 4)
	Standing Wave	650-800kW	(Fig. 6)
4. Exposure to air:			
	0.1msec, 25Hz	360kW	(Fig. 5)
	3.0msec, 25Hz	370kW	(Fig. 4)
	Standing Wave	370kW	

by the video camera. The cause must be due to multipacting at the rf window or coaxial line. Main residual gas components desorbed by multipacting were H_2 and N_2+CO [7]. In order to investigate memories of the rf processing effect, the input couplers were exposed to N_2 gas and air for a few days, (and residual gases in vacuum without pumping for one month). Baking at 120°C for 24 hours was always carried out after the exposure. As seen in Figure 5, the processing time up to 300kW was less than two hours in any case. Therefore, no major influence due to the exposure was observed.

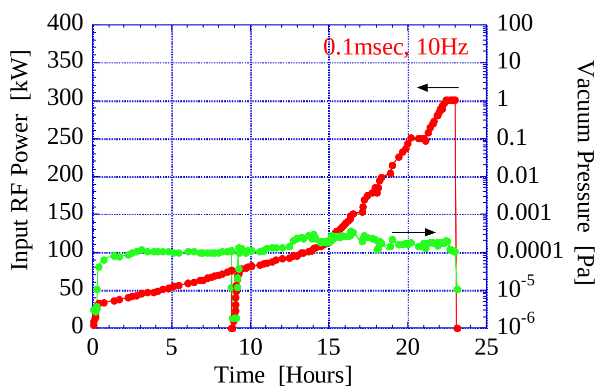

Figure 3: Rf processing logs in the initial test

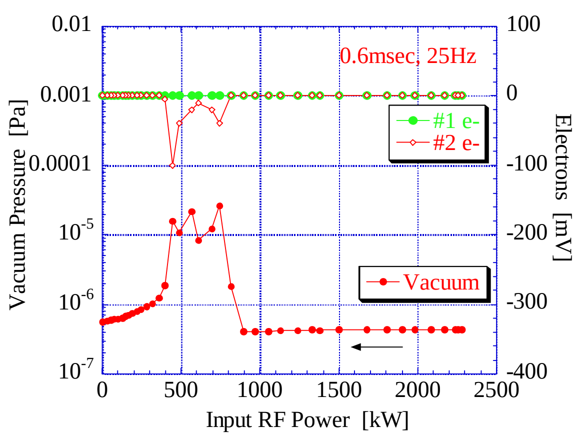

Figure 4: Vacuum pressure and electron activities after processed up to 2.2 MW

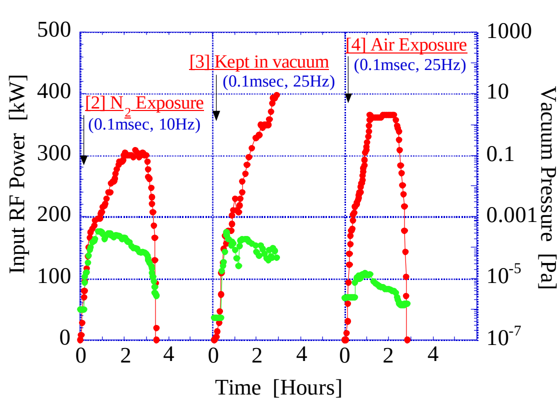

Figure 5: Effect after exposure to N_2 gas and air

RF processing in the standing wave was carried out, just after processed at 2.2MW in the travelling wave. Figure 6 shows the results in various phase conditions performed by successively changing the short-end position by 1/8 λg. Since the distribution of electromagnetic fields along the coaxial line of the couplers changes with the phase, the resonant condition of multipacting has shifted in each phase. The observation of the vacuum deterioration above 50kW suggests careful rf processing is needed in couplers installed in the actual cavities, even if processed up to 2.2MW in the test stand.

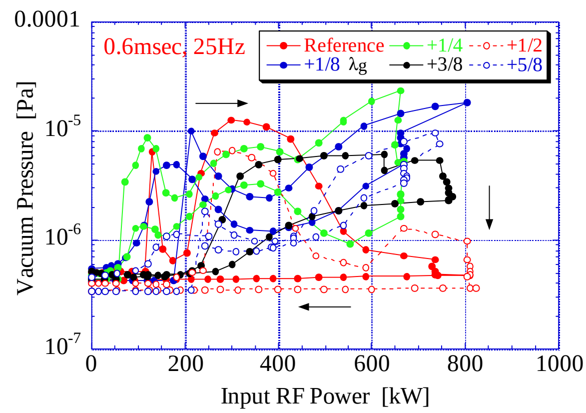

Figure 6: Rf processing in the standing wave

5 SUMMARY

Input rf power of 2.2MW in a pulsed operation of 0.6msec and 25Hz (370kW in 3.0msec and 25Hz) was transferred to the input couplers. Multipacting level was observed between 400kW and 800kW. There was no influence in the processing time due to exposure to N_2 gas and air.

6 REFERENCES

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