RF POWER COUPLER FOR PROTOTYPE CRYOMODULE AT JAERI

M. Matsuoka#, N. Akaoka, H. Asano, E. Chishiro, N. Ouchi, H. Suzuki, O. Takeda, H. Yoshikawa,
JAERI, Japan Atomic Energy Research Institute, Tokai-mura, Ibaraki-ken, 319-1195, Japan,
E. Kako, S. Noguchi
KEK, High Energy Accelerator Research Organization, Tsukuba city, Ibaraki-ken, 305-0801, Japan
H. Hattori, K. Okubo, K. Sennyu,
MHI, Mitsubishi Heavy Industries, Ltd., Yokohama city, Kanagawa-ken, 220-8401, Japan

Abstract

Two RF power couplers for the prototype cryomodule (600MHz, β=0.604) were fabricated and their high power tests performed. The maximum peak power of 35kW, which is required for the horizontal tests, was achieved in the test stand for both couplers. Those couplers were installed in the cryomodule and the horizontal tests were carried out. This paper describes the design and the test results of these couplers.

1 INTRODUCTION

The basic specification of the power coupler is listed in Table 1. The frequency of 600MHz was chosen for the original JAERI project, high intensity proton accelerators. Maximum RF power of 35kW and the external Q value of 1.7*10E6 are required for obtaining the electrical field of 16MV/m in the horizontal test. The coupler is based on the type of TRISTAN. HFSS code is used for designing all parts of the input coupler.

2 DESIGN AND FABRICATION

2.1 RF window

The RF window is a coaxial disk type and was designed with HFSS code. The dimensions of those are shown in Figure 1. The shape of the window is based on the coupler of the normal conducting cavity for KEKB. The lower VSWR can be obtained for tuning the inner and outer diameter of the window. The calculation results of RF property are shown in Figure 2. The VSWR value of the window is low enough at 600 MHz.

The ceramic window is made of Al_2O_3 (purity of 95%) as same as that of TRISTAN coupler [1]. The thickness is 8mm and the vacuum side is coated with TiN to reduce the secondary emission ratio. The window is blazed with the coaxial conductor made of OFHC copper. The window can be cooled by water through the inner and outer conductor.

Table 1: Specification of RF power coupler

Frequency	600 MHz
Power	35 kW (@pulse)
	20 kW (@CW)
Q_{in}	1.7*E6
RF window	
Type	Disk
Material	Al_2O_3 (95%)
Temperature	300K
VSWR	< 1.1
Waveguide/coaxial line. transition	
Type	Doorknob
Bias	No (can be applied)
VSWR	< 1.2
Inner conductor	
Material	OFC
Outer diameter	52.1 mm
Cooling	Water
Outer conductor	
Material	Cu on SUS316L
Inner diameter	120 mm
Cooling	Thermal intercept

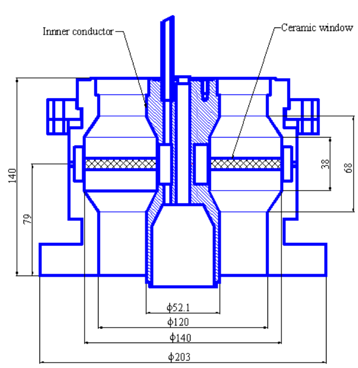

Figure 1: Cross section view of RF window

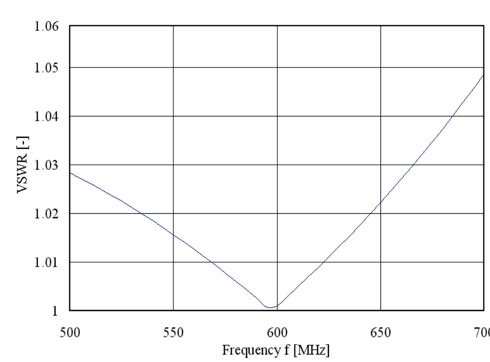

Figure 2: VSWR of RF window vs. frequency (calculated by HFSS)

On leave from Mitsubishi Heavy Industries, Ltd.
E-mail ; matsuoka@linac.tokai.jaeri.go.jp

2.2 Transition from waveguide to coaxial line

The transition from waveguide to coaxial line is a doorknob type. The shape of the doorknob is based on the type of TRISTAN[1] and scaled according to the frequency. The dimensions were shown in figure 3. DC bias between the inner conductor and the outer conductor can be applied. The characteristics of the RF transmission are calculated as shown in figure 4.

2.3 Inner conductor

The inner conductor shown in Figure 5 is made of OFHC and has a cooling pass inside. The outer diameter is 52.1 mm as same as 120D coaxial line. The length is determined by coupling to 5-cell cavity (β=0.604). The smoothness of the surface is obtained by the electro-polishing. Then inner conductor was welded with the RF window by EBW (Electron Beam Welding). Just before assembling with the outer conductor, the inner conductors and the RF windows were rinsed by ultra pure water in a clean room (Class 100).

2.4 Outer conductor

The outer conductor is made of stainless steel (SUS316L), and coated with copper inside. The thermal intercepts are on the outside to cool and reduce the heat load into the cryostat. Ultra pure rinsing was carried out as same as the inner conductor.

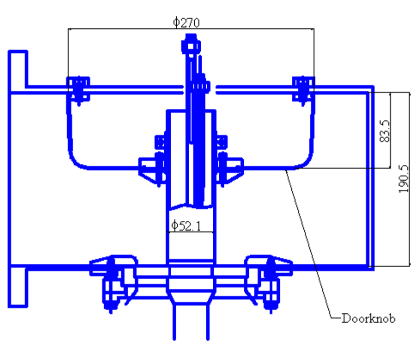

Figure 3: Cross section view of doorknob

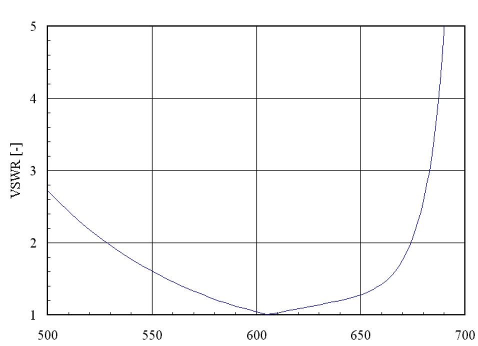

Figure 4: VSWR of doorknob vs. frequency (Calculated by HFSS)

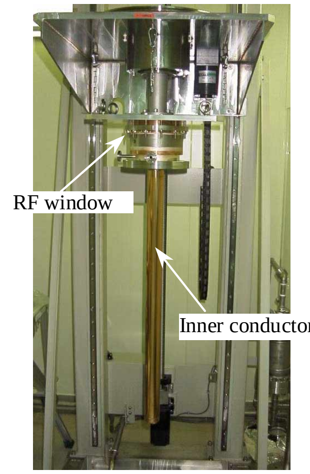

Figure 5: Inner conductor and RF window

2.5 Coupling cavity

The coupling cavity is fabricated for the high power test of the input coupler. The cavity is a rectangular type made of stainless steel (SUS304) and is coated with copper inside. The length of the cavity and the position of the inner conductor is determined by calculation with HFSS.

3 LOW POWER TEST

3.1 RF window

RF transmission performances of the windows were measured with a network analyser. The result is shown in Table 2. VSWR values of the windows are under 1.1. The characteristics are deferent from the calculation results because the electrical connection between the RF window and the coaxial line was not enough.

3.2 Doorknob

RF transmission performances of the doorknob were measured with a network analyser as same as the RF window. The result is shown in Table 2. VSWR values of the windows are under 1.2.

3.3 Input coupler with coupling cavity

VSWR is not enough good as shown in Table 2. This is the reason why there is a different dimension between the basic design and the fabrication. The calculation results of the actual fabricated model are consistent with the measurement results.

Table 2: Summary of low power test

	No.1	No.2
RF window		
VSWR	1.1	1.1
Doorknob		
VSWR	1.2	1.2
Test stand		
VSWR (without doorknob)	1.2	
VSWR (with doorknob)	1.4	
Set up for horizontal test		
Q_{in}	1.2E6	1.1E6

4 HIGH POWER TEST

IOT (Inductive Output Tube) was adapted for an RF power source. To obtain the stable RF pulse, PLL and ALC system, which is for RF control of TRISTAN's superconducting cavity, were prepared. The vacuum system consists of a turbo molecular pump and a rotary pump. A vacuum sensor and an arc sensor are located the side of each window. One can observe the partial pressure using by the mass spectrum analyser. Figure 6 is a photograph of the high power test stand.

The results of the high power test are listed in Table 4. Under all the conditions, the sufficient results were obtained. The feature of the reflected power depending on the input power is shown in Figure 7. The ratio between reflection and input power is about 3% in this system. The RF loss measured by the temperature rise of cooling water is about 130W for two windows and inner conductors at the transmitted power of 35kW. Figure 8 shows the typical time chart in the RF processing. The pressure rising began at the transmitted power of about 12kW and hydrogen gas was observed during the RF processing as shown in figure 9.

5 CONCLUSIONS

The input couplers for the 600MHz cryomodule achieved the maximum input power of 35kW. These couplers were installed in the cryomodule and the horizontal test was carried out [3].

Table 4: Summary of high power test results

RF terminal condition And operational mode	RF power	Conditioning time
Dummy load		
CW	35 kW	3.8 H
Pulse	35 kW	7.3 H
Perfect reflection		
CW	20 kW	0.8 H
Pulse	35 kW	1.4 H
Perfect reflection + waveguide (λ/4)		
CW	20 kW	0.5 H
Pulse	35 kW	2.8 H
In cryomodule		
CW	20 kW	0.5 H (#1),0.5 H (#2)
Pulse	35 kW	4.0 H (#1),2.0 H (#2)

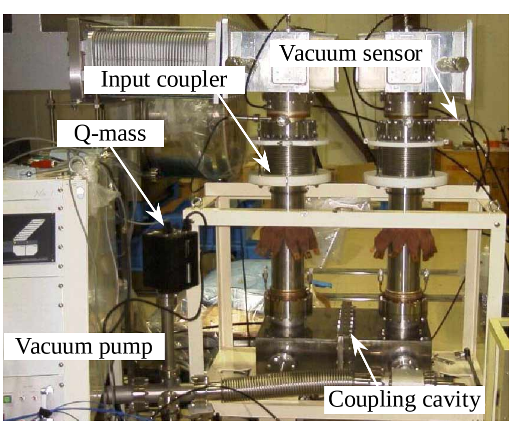

Figure 6: High power test stand

REFFERENCES

[1] S. Noguchi, et al., "COUPLERS-EXPERIENCE AT KEK-", Proc. of the 4th Workshop on RF Superconductivity, 1989, pp.397-412.

[2] E. Chishiro et al., "Evaluation of Operating Characteristics of IOT RF Source", 24th Linear accelerator meeting in Japan, 1999,

[3] N. Ouchi, et al., "600MHz PROTOTYOE CRYOMODULE FOR HIGH INTENSITY PROTON LINAC AT JAERI ", in this meeting.

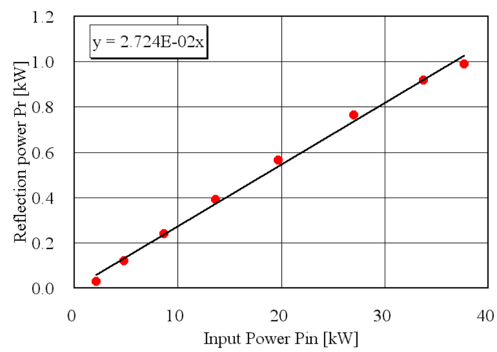

Figure 7 Reflection power vs. input power

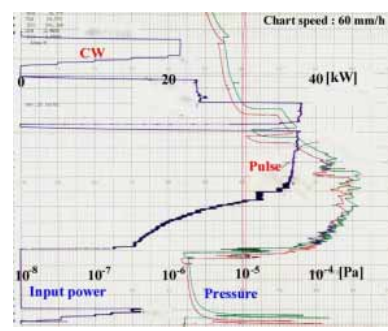

Figure 8 Time chart of RF processing

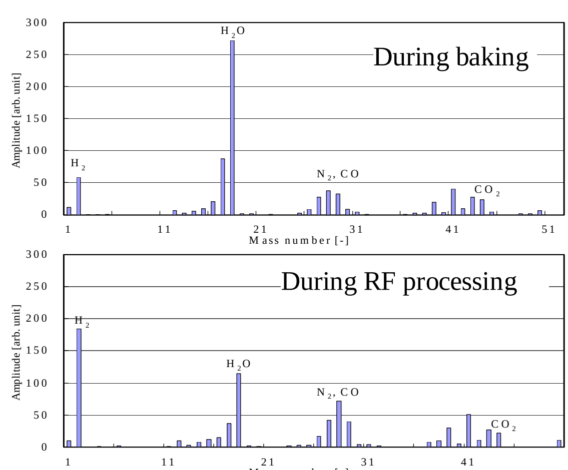

Figure 9: Mass spectrum at high power test stand