OPERATION OF THE HIGH POWER RF SYSTEM FOR PEFP RFQ

H. J. Kwon, Y. S. Cho, Y. H. Kim, M. Y. Park, K. T. Seol, C. B. Shim
PEFP, KAERI, Daejeon 305-353, KOREA

Abstract

A high power RF system for PEFP RFQ has been developed and operated. The required peak power is 535kW, and pulse width, repetition rate for initial operation are 100μs, 10Hz respectively. All of the RF components including RF window, input coupler, klystron power supply and cooling system have the capacity of operating at 535kW average power level. Therefore RF duty can be increased for higher average power operation. The TH2089F klystron was operated in pulse mode by modulating the input RF power. The RF power from the klystron was divided into two legs and delivered to RFQ. In this paper, the system description and operation results are presented.

INTRODUCTION

A 100MeV proton accelerator has been developed by PEFP (Proton Engineering Frontier Project) as a 21C Frontier Project [1]. As a front end accelerating structure, 3MeV, 350MHz RFQ has been developed. It's operating scheme is pulse mode with 120Hz repetition rate and 0.1-2ms pulse width. The required peak RF power taking into account the Q degradation of 75% is 535kW.

The high power RF system for driving the PEFP RFQ has been developed also. As stated in earlier paper, the RF system including klystron, circulator, RF window, input coupler, klystron power supply and cooling system have the capacity of operating at 535kW average power level [2]. The TH2089F klystron was operated in pulse mode by modulating the input RF power from the RF generator, therefore the RF duty (or also pulse width, repetition rate respectively) can be adjusted for test purposes.

Some RF components such as input coupler and RF dummy loads have been modified to improve their RF properties.

The initial operation parameters of the RF system considering the waveguide loss are 600kW with 100μs pulse width and 10Hz repetition rate respectively. At first, the RF system with klystron, circulator and dummy load has been tested up to 600kW power level with 100μs pulse width at 350MHz. But the RFQ tuning results showed that the cavity resonant frequency was 352.1MHz, therefore it was determined to drive the RFQ at 352.1MHz using TH2089F klystron with lower duty factor.

HIGH POWER RF SYSTEM LAYOUT

The RF power from the klystron was divided into two legs and delivered into the RFQ because of the power limitation of the RF window. The high power RF system for PEFP RFQ has already been installed as shown in Figure 1 and Figure 2 respectively. Because there is no other space for high power test of the klystron, the high power RF system for RFQ has also the role of klystron test bench. For high power test of the klystron, one piece of waveguide section which connected to the RFQ in Figure 1 was removed and the shorting plate was installed.

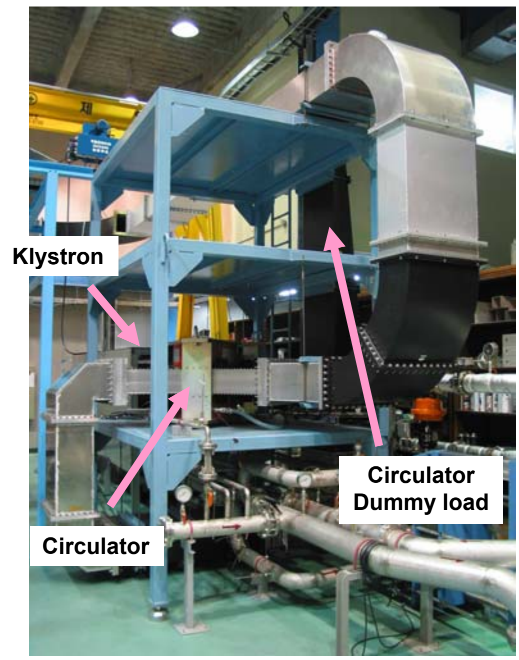

Figure 1: Klystron, circulator, dummy load

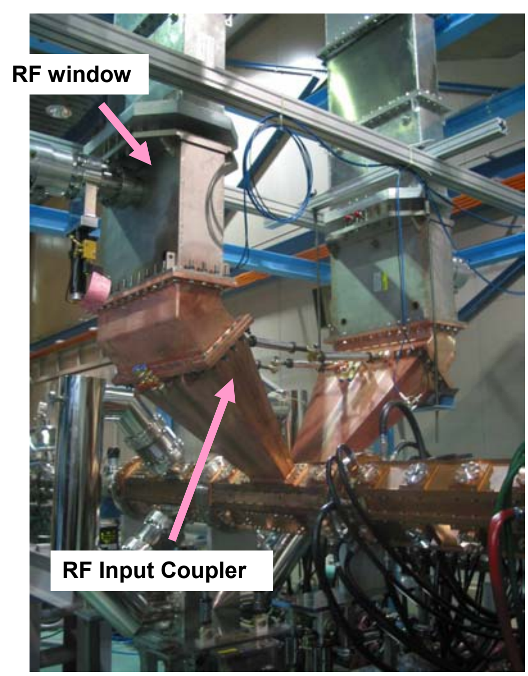

Figure 2: RF window, RF input coupler

IMPROVEMENT OF THE HIGH POWER RF COMPONENTS

RF Input Coupler

The RF input coupler for the PEFP RFQ is the ridge loaded waveguide type with iris coupling. At first, the ridge width was the half of the waveguide width along the coupler downstream for insensitivity of the cutoff frequency with dimensional error. But that structure has more sensitivity to the multipacting. Therefore the ridge structure has been changed into the one that has constant ridge width that was not only insensitive to the dimensional error but also multipacting. And in addition to the constant ridge width, the length of the coupler has been changed into shorter one for better matching. The RF input coupler with constant ridge width was fabricated with two pieces of steel, welded together and then copper plated. The one pieces of the coupler before welding and plating is shown in Figure 3. The coupling beta can be adjusted by controlling the hole at the end of the coupling slot. Two couplers are now installed in the PEFP RFQ as shown in Figure 2.

Figure 3: One piece of the RF input coupler

RF Dummy Load

A RF dummy load for circulator was re-tuned at the lower coolant temperature range than original one with MEG and water mixture as coolant. The original one was 48°C~60°C with MEG (50%) and water (50%) mixture. But there were tuning problems with the above coolant, which showed somewhat higher VSWR. Therefore the load should be re-tuned. Moreover the coolant temperature range of 48°C~60°C was somewhat higher for our cooling system. Therefore the load was re-tuned using matching posts in the coolant temperature range of 37°C~43°C which was a moderate valve for our cooling system in klystron operation. The measured VSWR was lower than 1.25 : 1 within the operating temperature range.

A RF dummy load for magic tee was designed, fabricated and low power tested. The power rating is 100kW at 350MHz. It used MEG and water mixture as a coolant and the operating temperature range was also 37°C~43°C. The fabricated load was tuned using three matching posts. The measured VSWR was lower than 1.2 : 1 within the operating temperature range. The load is now installed at the one arm of the magic tee.

OPERATION OF THE HIGH POWER RF SYSTEM

High Power Test of the Klystron

As stated earlier, one piece of the waveguide into the RFQ was removed and a shorting plate was installed to carry out the high power test of the klystron. In fact, this test included the high power tests for circulator and dummy load too. The signal from the RF generator was modulated to provide proper pulse parameters. The klystron was tested up to 600kW peak power with 100µs pulse width at 350MHz. The pulse shape at 600kW is shown in Figure 4. The relatively long tail of the reflected power pulse came from the crystal detector characteristics. The operating parameters of the klystron at 600kW peak power level are summarized in Table 1. Among those parameters, the gun perveance is somewhat higher than that obtained at Factory Acceptance Test, that is 1.67µperv. in this tests with respective to 1.41µperv. at FAT. And recently, the reasons for higher gun perveance are being investigated.

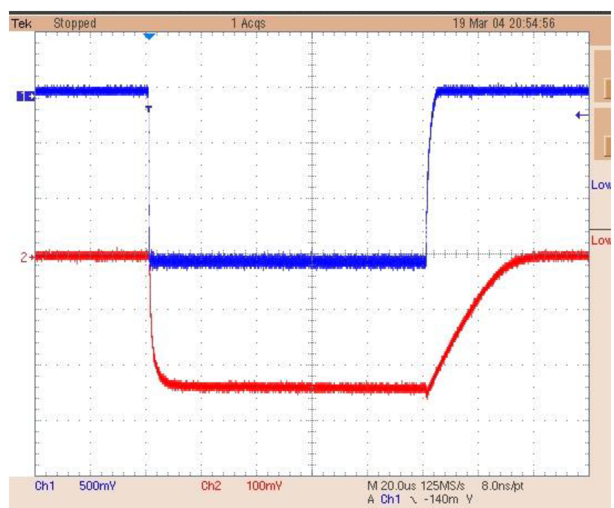

Figure 4: Pulse shape of the klystron at 350MHz

Table 1: Operating parameters

Parameters	**Values at test**	**Values at FAT**
Beam voltage	75kV	73.2kV
Cathode current	14.8A	14.6A
Anode voltage	43.2kV	47.2kV
Driving frequency	350MHz	350MHz
Peak RF power	600kW	600kW
Pulse width	100µs	∞

Driving the RFQ

The tuning results of the PEFP RFQ showed that its resonant frequency was 352.1MHz [3]. Therefore it was determined to drive the RFQ at 352.1MHz in advance and then new RFQ was re-built [4]. The pulse shape of the klystron at 352.1MHz is shown in Figure 5. At first, the pulse width and repetition rate were reduced to 50μs, 0.1Hz respectively during conditioning. The relatively long tail of the pickup pulse also came from the crystal detector characteristics. Until now, the klystron delivered RF power up to 260kW at 352.1MHz and did not show any abnormal phenomena. The saturated RF power was about 60% of that at 350MHz with the same beam power.

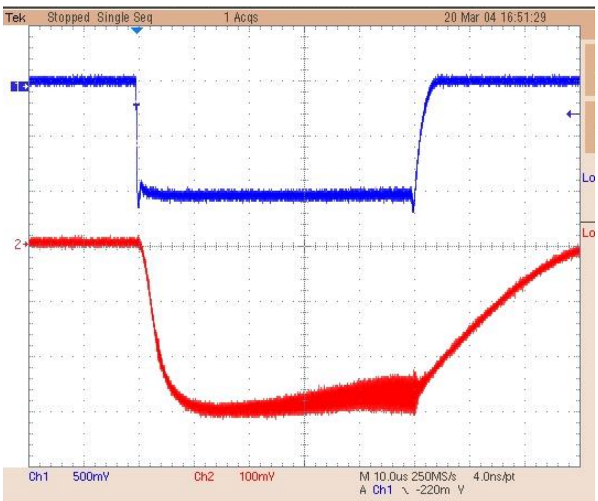

Figure 5: Pulse shape of the klystron at 352.1MHz

CONCLUSIONS

The high power RF system for PEFP RFQ was revised and operated.

The RF dummy load for the circulator was re-tuned for better VSWR and system operation. The results showed that the VSWR was less than 1.25 : 1 within coolant temperature range of 37°C~43°C with MEG (50%) and water (50%) mixture as a coolant. Also the dummy load for magic tee was designed, fabricated and tested at low power level. The measured VSWR was less than 1.20 : 1 within the operating temperature range. But this load should be high power tested up to design value.

The klystron was tested in pulse mode up to 600kW at 350MHz. The measured gun perveance was higher than the value at FAT. The reasons for this difference are being investigated. The klystron was operated in pulse mode to drive the PEFP RFQ. Because of the tuning problem of the RFQ, the operating frequency was 352.1MHz. Until now, the klystron was operated up to 260kW at 352.1MHz and did not show any abnormal phenomena. But the saturated RF power was about 60% of that at 350MHz with the same beam power, which showed lower efficiency than the value at 350MHz. The klystron is going to be operated up to 600kW at 352.1MHz to drive the PEFP RFQ until new RFQ replaces the old one.

REFERENCES

[1] B. H. Choi, "Proton Linear Accelerator Development and Its Utilization Program in PEFP", in these conference.

[2] H. J. Kwon, et al., "RF System for PEFP RFQ", Proc. of LINAC 2002, Gyeongju, Korea, 2002.

[3] C. B. Shim, et al., "High power test of PEFP RFQ", in these conference.

[4] Y. S. Cho, et al., "Upgrade Design of PEFP 3MeV RFQ", in these conference.