TEST RESULTS OF THE PEFP 3MeV RFQ UPGRADE*

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Abstract

A 3MeV RFQ for 100MeV proton accelerator has been developed at PEFP (Proton Engineering Frontier Project). The tuning results of the cavity showed that both the frequency and field profile were beyond the tuner limit. To check the cavity characteristics, RF test including proton beam acceleration has been done. To solve the problems in existing RFQ, new RFQ so called RFQ Upgrade has been fabricated. Because the main problem of the existing one is improper tuning of the cavity, the important step for development of RFQ Upgrade is to adjust the vanes before brazing. In this paper, the test results of the existing PEFP RFQ and the pre-brazing tuning are presented.

INTRODUCTION

The PEFP RFQ has been designed and constructed to accelerate proton beam from 50keV to 3MeV [1]. The RFQ is a 324cm–long, 4-vane type and composed of 4sections with 36 slug tuners, 8 vacuum pump ports. A coupling plate is used between two segments to stabilize the longitudinal field. The transverse field stabilization is accomplished by dipole stabilization rods. The operation mode of the RFQ is pulse whose maximum pulse width and repetition rate are 2ms, 120Hz respectively. The peak RF power which considers the beam loading and 75% Q degradation is 535kW. The tuning results showed that the resonant frequency of the cavity is somewhat higher than design frequency. Therefore other methods in addition to slug tuners should be used to tune the cavity correctly. To check the overall system including high power RF system, vacuum system, cooling system in addition to cavity characteristics, high power RF test has been done. In order to meet the resonant condition, the RF system was operated in FM mode. The PEFP RFQ is shown in Figure 1 and parameters of RFQ are given in table 1. To solve the problems in existing RFQ such as sharp edge, reverse curvature radius at radial matching section, inadequate RF seal in addition to the tuning problem, new RFQ so called RFQ Upgrade has been designed and fabricated [2]. It consists of four sections with almost same physical dimensions compared with existing one. In order to solve the problem related to the improper cavity tuning, pre-brazing tunings of each section to translate minor vanes were carried out. Recently, pre-brazing tunings of all sections of RFQ Upgrade were completed. The brazing of the two sections were carried out and remaining two sections are waiting for brazing.

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Figure 1: PEFP 3MeV RFQ.

Table 1: Existing PEFP 3MeV RFQ Parameters

Particle	Proton
Frequency	350.0 MHz
Input / Output Energy	50 keV / 3.0 MeV
Max. Peak beam current	20.0 mA
Input / Output Emittance	0.2 πmm.mrad
Transmission	95.4 %
Repetition rate	120 Hz
Pulse Width	0.1 – 2 ms
Max. Beam Duty Factor	24 %
Max. Average Beam Current	4.8 mA
Peak Surface field	1.8 Kilpatrick
Length	3.24 m
Peak RF Power	535 kW (75% Q. Calculated)
Field Stabilization	Resonant Coupling Dipole Stabilizer Rods

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INITIAL RF POWER TEST

The vacuum system for RFQ consisted of two cryopump for cavity, a TMP for each window and beam dump side. The vacuum inside the cavity and window was maintained less than 2E-7 torr before the test.

The high power RF system for RFQ consists of klystron, circulator, waveguide components, RF window and power coupler and is designed to have the capacity of operating at high duty level. The RF power from the klystron was divided into two legs by magic tee and delivered to RFQ. The TH2089F klystron can be operated up to high duty, and for the test, only the low level input signal to the klystron was pulse modulated without electron beam modulation, that is to keep the constant electron beam power. The circulator can deliver RF power up to 1.3MW in forward direction and permit up to 1.3MW reverse power at any phase. The RF window is a planar type and can deliver 900kW into the load with VSWR less than 1.1.

The power coupler is a ridge loaded waveguide type with iris coupling. . The 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 2. The holes at the end of the coupling slot were used to match the impedance. In PEFP RFQ, the diameter of the coupling hole was determined as 6mm for critical coupling.

During the RF power test, the resonant frequency changes according to the temperature of the cavity. In PEFP RFQ, the change rate is about –10kHz/C. Because the temperature control system of cooling water depends only on the external cooling fan in existing cooling system of PEFP RFQ, it is difficult to regulate the coolant temperature precisely. Therefore it was determined to control the driving frequency against the resonant frequency change according to the temperature of the cavity cooling water, that is to operate the RF system in FM mode. During the test, the resonant frequency was selected when the field inside the RFQ cavity was maximum, and the frequency range was 352.2MHz ~ 352.3MHz according to the coolant inlet temperature range of 30C~36C.

For the initial RF power test, the RFQ was driven from low power level at 352.1MHz, 50μs, 0.1Hz. The RF parameters such as the forward power, cavity power, reflected power from RFQ, power toward klystron were monitored. The RF tests were carried out repeatedly to check the overall system performances. Until now, the RF power with above pulse parameters was delivered into the RFQ stably up to 250kW. The RF signal at this power level was shown in Figure 3. In Figure 3, the upper part is the forward power to the klystron, and the lower part RFQ pick up signal. At this power level in Figure 3, continuous proton beam was injected into the RFQ from the ion source whose energy was 50kV. To avoid the damage of the RFQ resulted from the focused proton beam, the beam matching or focusing using LEBT was not used but the beam was rather spread into large area. The pulsed beam current from the Faraday cup at the location of 70cm downstream from the RFQ exit was shown in Figure 4. The beam current was about 2 μA. From the calculation, the voltage factor at the operating RF power level was about 73% and the estimated transmission rate was above 90%.

Figure 2: Power coupler under fabrication.

Figure 3: RF signal (10μs/div.).

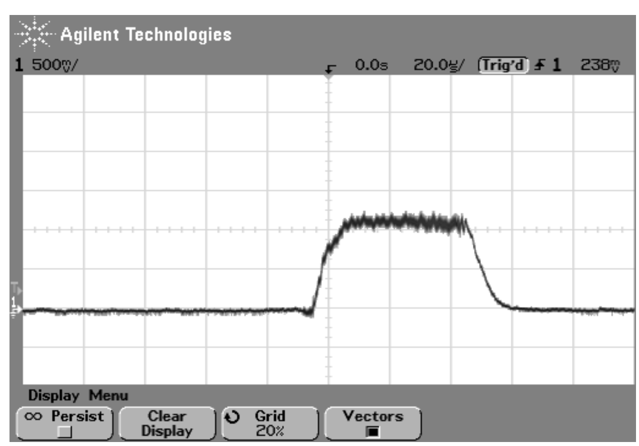

Figure 4: Pulsed beam signal from Faraday cup.

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PRE-BRAZING TUNING OF RFQ UPGRADE

A RFQ Upgrade has been designed and fabricated. As is stated earlier, the most serious problem in existing RFQ is improper tuning – that is higher resonant frequency and higher field profile error – which could not be covered with tuners. The RFQ Upgrade has two main features to solve the problem. The first is to maintain constant voltage profile compared with ramped one of the existing RFQ. The second is to modify the brazing surface from step geometry into flat one to admit the pre-brazing tuning. With those brazing surface geometry, the minor vanes can be translated to adjust the resonant frequency, quadrupole and dipole field profile.

The setup for pre-brazing tuning is shown in Figure 5. It consists of the RFQ body, dummy undercut and endplate. A dummy undercut was used to properly terminate the end region of the RFQ. Phase shift was measured using network analyser (Agilent 8753ES) with 0.25 inch diameter aluminium bead.

Figure 5: Field measurement setup for pre-brazing tuning.

The measurement for initial assembly without any translation of the minor vanes showed that the resonant frequencies of each section were about 3 ~ 4 MHz higher than designed one, the quadrupole field profile were within 5% of the designed one, and the dipole were less than 30 % of the quadrupole field. The preliminary results showed that the main issue was the frequency error. These constant and reproducible frequency errors seem to be come from constant offset error in machining. To translate the two minor vanes to decrease the frequency, the frequency sensitivity of the vane translation was calculated using SUPERFISH code. The results showed that the sensitivity were 6MHz/mm ~ 8MHz/mm for one minor vane translation. With this condition, two minor vanes were inserted into the cavity about 300um to compensate the frequency for all of the 4 sections. The field profile of the quadrupole and dipole of the 4th section after the vane adjustment was shown in Figure 6. The dipole field has same sign, which is difficult to be adjusted with only minor vanes. But those values can be controlled with about 2mm tuner displacement. The field measurement of one section was carried out after brazing to check the brazing effect. The results showed that the frequency changes of the D1, D2 and Q were within ± 200kHz, respectively.

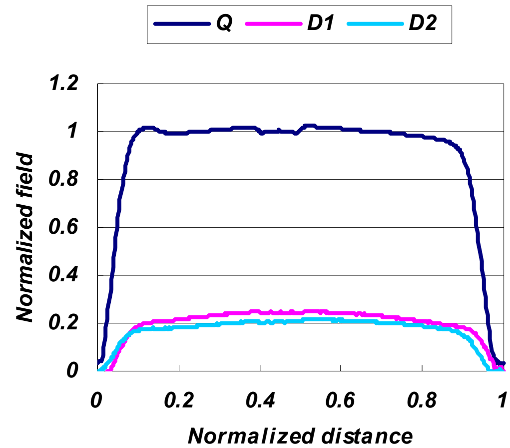

Figure 6: Field profile of section 4 after vane adjustment.

CONCLUSION

Preliminary RF test of PEPF 3MeV RFQ was carried out. The tuning results showed that the cavity frequency was 352.1MHz because of the limitation of the tuner perturbations against the cavity field profile. Therefore it was determined to drive the RFQ with 352.1MHz. The klystron forward power was increased up to the 320kW at 352.1MHz. And pulsed beam profile could be obtained from Faraday cup. The power test up to design value is going to be carried out until the new RFQ replaces the old one. The RFQ Upgrade has been designed and fabricated. To compensate the error of frequency and field profile, minor vane adjustments were carried out before brazing. Nowadays, the brazing of the two sections were completed and remaining two sections are waiting for brazing.

REFERENCES

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[2] H. J. Kwon, "Fabrication of the PEFP 3MeV RFQ Upgrade", in these proceedings.