HIGH POWER TEST OF PEFP RFQ

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Abstract

In the PEFP (Proton Engineering Frontier Project), a 350MHz, 3MeV RFQ (Radio Frequency Quadrupole) has been developed and tested. It is 3.2m long four vane type RFQ which consists of two segments coupled by coupling plate. The tuning results showed that the resonant frequency is somewhat higher than 350MHz and other methods in addition to slug tuners should be used to tune the cavity correctly. To check the cavity characteristics, high power RF test has been done. The required peak RF power is 535kW and pulse width, repetition rate for initial test are 50μs, 0.1Hz respectively. Because the temperature regulation of the cooling system was poor, frequency modulation was used to drive the RF power into the cavity. In this paper, the status and test results of the PEFP RFQ are presented.

INTRODUCTION

The PEFP RFQ has been designed and constructed to accelerate proton beam from 50keV to 3MeV. 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 PEFP RFQ is shown in Figure 1 and parameters of RFQ are given in table 1.

Figure 1: PEFP 3MeV RFQ

Table 1: 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

RFQ TUNING

The tuning of the RFQ cavity includes resonant frequency tuning, quadrupole field profile adjustment along the cavity and field stabilization against the external perturbations. The designed vane gap voltage of the PEFP RFQ increases from 75kV up to 100kV, and this voltage profile should be adjusted by using 36ea. slug tuners.

End Region Tuning

End region tuning is composed of two parameter tuning: undercuts on the vane and shape of the end plates. The undercut in the end region is essential to make the RFQ work properly on the designed frequency. Currently, the undercut of PEFP RFQ has the shape of rectangle with dimension of 48.3mm x 30mm with R6 in the inner corner edges.

Stabilizer Rod

When the dipole mode frequencies near the operating mode are too close to the operation mode, the cavity will be very sensitive to the perturbations. Using the dipole stabilizer rods, which are mounted on the end plates and coupling plate, the dipole mode frequency can be adjusted. There are four stabilizer rods in the middle of each quadrant and they will lower the dipole mode frequencies. By adjusting the rod lengths, the differences between the operation mode frequency and nearest dipole mode frequencies can be approximately equalized. In PEFP RFQ, stabilizer rods are 10mm in diameter and 135mm long.

Field Profile Measurement and Tuning

Bead perturbation method using metallic bead which has a cylindrical shape with 10mm in diameter and 10mm long respectively was used to measure the H-field profile along the RFQ. These beads are attached on four nylon wires running through the bisectors of each quadrants and 75mm from the centre of the cavity (approximately 21mm from the walls). The setup for RFQ tuning is shown in Figure 2. The tuning results showed that the cavity frequency was 352.1MHz because of the limitation of the tuner perturbation against the cavity field profile. And it was determined to design and fabricate a new RFQ because of some other problems such as sharp edge and reverse curvature radius at radial matching section in addition to the tuning problem [1]. Also it was determined to drive the RFQ with 352.1MHz until the new RFQ replaces the old one.

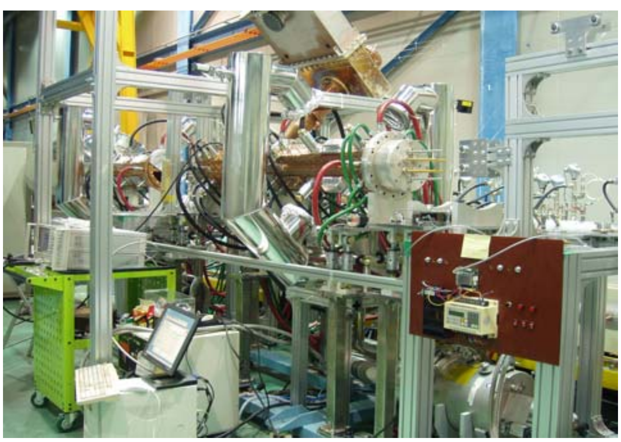

Figure 2: Test setup for RFQ tuning

TEST SETUP

As stated earlier, it was determined to drive the RFQ with 352.1MHz because of the tuning problem.

During the high 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. During the test, the resonant frequency was selected when the field inside the RFQ cavity was maximum, and the frequency range was 351.3MHz ~ 352.2MHz according to the coolant inlet temperature range of 30C~36C [2].

The high power RF system 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 [3].

The security box was used to protect the high power RF component and RFQ from RF related problems. All RF related fault signals such as klystron window arc, circulator arc, RF window arc and high reflected power from the RFQ were the input signals of the security box and the output signal from the box was used to interrupt the low level RF signal.

INITIAL HIGH POWER TEST

For the initial high power test, the RFQ was driven from low power level at 352.1MHz, 50μs, 0.1Hz. The first multipacting like phenomena was occurred at 2.5kW power level and stabilized at 7kW. After that, the power was increased and maintained to wait the field stabilization inside the cavity repeatedly. Recently, the klystron forward power was increased up to the 320kW at 352.1MHz as shown in Figure 3. In Figure 3, the upper part is the klystron forward power, and the lower part RFQ pick up signal. Both the pulse width and repetition rate were maintained to be fixed value during the initial test. After the initial test, the pulse width and repetition rate are going to be increased. 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.

CONCLUSION

An initial high power 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. And also it was determined to design and fabricate a new RFQ not only due to tuning problem but also some other problems.

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 high power test is supposed to be the valuable experience for us and give a baseline for design and fabrication of new RFQ.

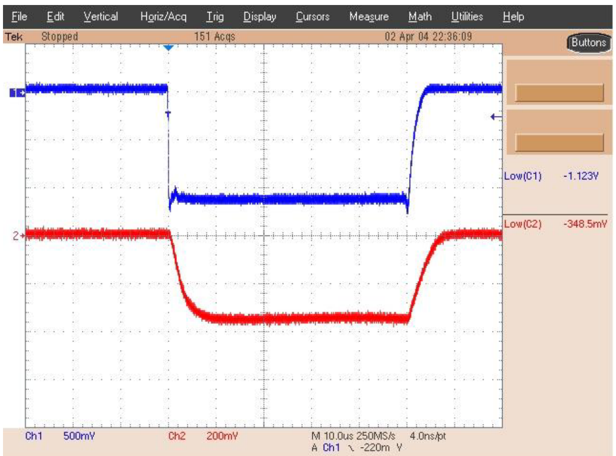

Figure 3: RF signal (10µs/div.)

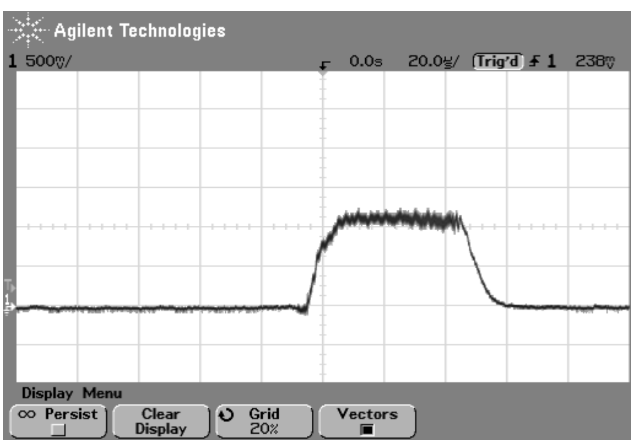

Figure 4: Pulsed beam signal from Faraday cup (10µs/div., 1µA/div.)

ACKNOWLEDGMENT

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