Field Profile Adjustment and Beam Acceleration Test of PEFP 3 MeV RFQ

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1. Introduction

As a front end part of the 100-MeV proton linac of Proton Engineering Frontier Project (PEFP), a 20-MeV proton accelerator has been installed and tested at Korea Atomic Energy Research Institute (KAERI) site. The 20-MeV accelerator consists of a 50-keV proton injector, a 3-MeV Radio frequency quadrupole (RFQ) and a 20-MeV Drift Tube Linac (DTL) [1]. After the permission of the accelerator operation at April 2007 from KINS, efforts were focused on the stabilization and increase of the proton beam current, especially from the 3-MeV RFQ. Several modifications were applied to both the proton injector and RFQ such as an reduction of the extraction hole diameter of the ion source, reduction of the whole length of the Low Energy Beam Transport (LEBT), an installation of the electron trap in front of the RFQ, re-align of the accelerator components [2]. Finally, we measured and re-tuned the RFQ cavity field profile and could obtain the 20mA peak current from the RFQ. In this paper, we discuss about the re-tuning of the RFQ field profile and its effect on the beam current increase.

2. Field Measurements and Tuning

Before we measured the field profile of the RFQ, it was difficult to increase the RFQ output beam current above the 10 mA peak value with stable manner. In addition, we could observe that the beam current decreased as RF power increased just after it reached the peak value, which was hardly possible in RFQ accelerator. Therefore, it was determined to measure the RFQ field profile.

2.1 Measurement Setup

The field profile of the RFQ was measured based on the Slater's perturbation theorem [3]. We used aluminum hollow ball bead whose diameter was 9.4 mm as a perturbator. And the perturbed resonance frequency was measured using network analyzer (Agilent, 8753ES). The temperature of the RFQ was stabilized using the 1 kW heater installed at the RFQ wall. During the measurement, we measured the phase shift of S21 parameter, which was proportional to the frequency shift at the measurement range, of which typical values were about 1 degree. Then the field profile was obtained from the square root of the phase shift.

2.2 Measurement Results and Its Effect on the Beam Current

The measured profile revealed that the quadrupole field itself did not change, but the D1, D2 dipole field profile increased up to 10 % from less that 3% at original tuning as shown in Fig. 1 and Fig 2. To investigate the dipole field effect on the beam, we developed single particle tracking program under asymmetric field profile such as dipole field. It contains two term potential field which describe the quadrupole field, and the dipole field is described by the scaling of the SUPERFISH code results. The result showed that the maximum deviation of the beam center from the RFQ axis was about 2mm in vertical direction which was large value corresponding to the minimum aperture size of the RFQ [4]. From this result, it could be a source for unstable beam current and was determined to re-tune the RFQ cavity.

2.3 Cavity Re-tuning

The RFQ cavity was re-tuned. 20 tuners were used for correct the dipole field among total 50 tuners, which located at the end of each segment and just beneath of the RF coupler. The most effective tuners which affected the dipole field were the 2 set of tuners located at the beneath of the RF coupler. The final field profiles after the tuning are shown in Fig. 1 and Fig. 2, too. The estimated beam center deviation with these field profiles was less than 0.3 mm.

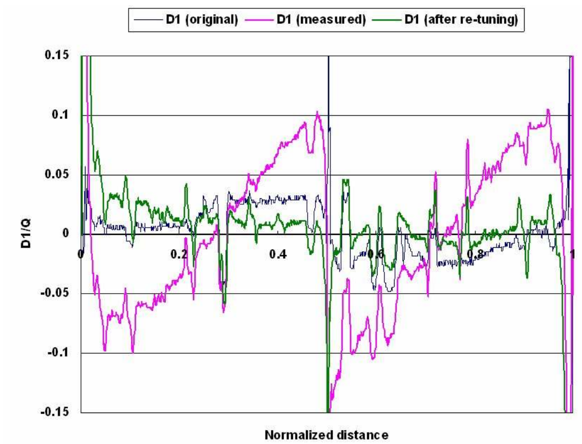

Figure 1: D1 field profile along the RFQ
(Original: blue, measured: pink,
after re-tuning: green)

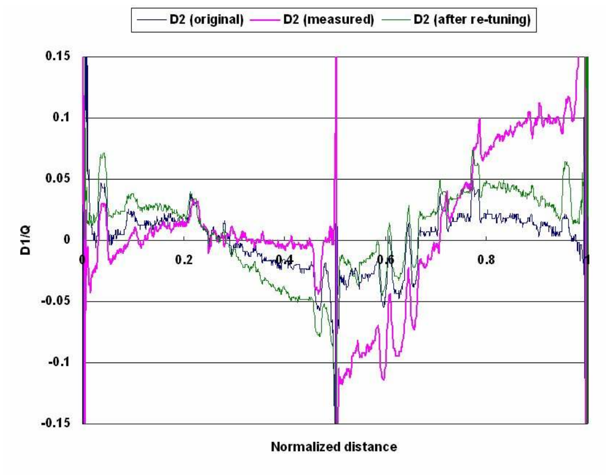

Figure 2: D2 field profile along the RFQ (Original: blue, measured: pink, after re-tuning: green)

3. Beam Test

The RFQ beam test was done after the field re-tuning. The RFQ output current was measured and compared with one before the field tuning. The LEBT parameters such as solenoid current and steering magnet current were same for two cases in order to compare the re-tuning effect and shown in Table 1. As shown in the Fig. 3, the RFQ output current was increased up to about twice with same RF power level. After the adjustment of the operating parameters such as LEBT steering magnet current, RF power of the RFQ, ion source arc current, we could get 20-mA peak current from the RFQ. The beam signals from the tuned CT at downstream of the RFQ is shown in Fig. 4.

Table 1: LEBT parameters for comparison

Parameters	Current
Solenoid 1	129 A
Solenoid 2	130 A
All steering magnet	0 A

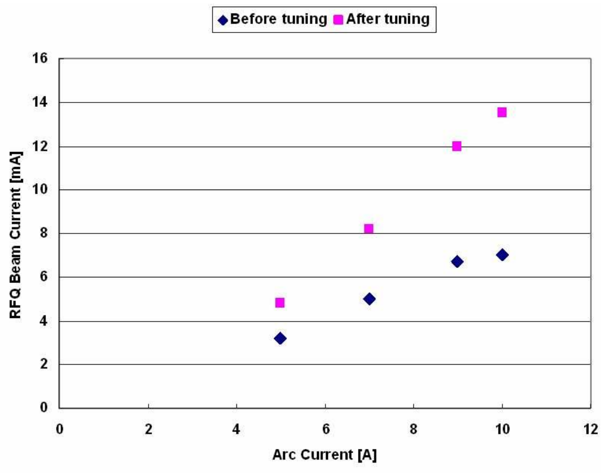

Figure 3: Comparison of RFQ beam current before and after re-tuning with LEBT parameters shown in Table 1

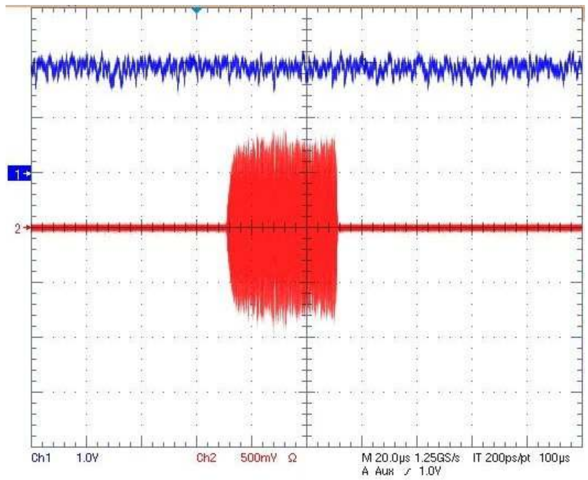

Figure 4: RFQ output beam current with 20mA peak current (red signal, horizontal: 20μs/div.)

4. Conclusions

PEFP 3-MeV RFQ was tested up to 20-mA full peak beam current. Several modifications of the proton injector were done to increase the RFQ beam current up to 10-mA. Beyond this, a field re-tuning which reduced the dipole field components of the RFQ was effective. After the field re-tuning, we could get the 20-mA peak beam current from the RFQ output.

Acknowledgement

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