BEAM TESTS OF THE PEFP 20MEV ACCELERATOR *

H. J. Kwon#, Y. S. Cho, H. S. Kim, J. H. Jang, D. I. Kim, K. T. Seol,
I. S. Hong, Y. G. Song, B. S. Park, S. P. Yun
PEFP, KAERI, Daejeon 305-353, Korea

Abstract

Proton Engineering Frontier Project (PEFP) 20MeV proton accelerator has been installed and tested at KAERI (Korea Atomic Energy Research Institute) site. After the radiation license was issued, some parts were modified to increase a peak beam current above 1mA. A proton injector composed of an ion source and a LEBT (Low Energy Beam Transport) was modified for better transmission rate through the LEBT. The field profile of the RFQ was measured to check the dipole field effect. In addition, beam loss was measured along the DTL to check and adjust the operating parameters. In this paper, the modifications of the 20MeV accelerator are summarized and the recent test results are presented.

INTRODUCTION

One of the missions of the PEFP is to develop a 100MeV proton linear accelerator. As a front end of a 100MeV machine, a 20MeV accelerator has already fabricated and installed at the KAERI test stand [1][2]. The 20MeV accelerator consists of a 50keV proton injector, a 3MeV radio frequency quadrupole (RFQ) and a 20MeV drift tube linac (DTL). The 20MeV DTL is divided into four tanks to limit the heat load to within the cooling capability at a 24% duty operation. The initial test with peak current of 1mA at low duty has been completed to check on the overall performance of the machine [3]. After the radiation license was issued, the test started again. The main purpose during this test period was to increase the beam current up to the design level. For this goal, some parts were modified before test to accomplish the above mission as follows: 1) the emitter aperture of the ion source and the overall length of the LEBT were reduced, 2) geometry of the collimator was changed and electron trap was installed in LEBT, 3) the field profile of the RFQ was measured and re-tuned because the dipole mode were increased up to 10% that of quadrupole. After the modification, the beam test was conducted again. The beam current was reach up to 20mA with the tuning of the DTL operating parameters. The overall layout of the 20MeV proton accelerator including beam diagnostic devices is shown in Fig. 1.

MODIFICATION OF THE PROTON INJECTOR

The PEFP proton injector includes an ion source and a low energy beam transport (LEBT). The duoplasmatron type ion source operates in a pulse mode by switching the extraction high voltage power supply and the LEBT consists of two solenoid magnets for a beam focusing and two steering magnets for a beam position and angle adjustment. The main modifications of the proton injector were the reduction of the emitter aperture of the ion source and overall length of the LEBT system. The original emitter diameter of the ion source was 16mm and the length from the ion source to the RFQ 256cm. The beam dynamics calculation showed that the transmission rate of the proton beam through the LEBT was 58% because of the intrinsic large emittance from the ion source and the solenoid aberration. Also the transmission rate through the RFQ was estimated about 68%. To improve the beam transmission rate through the LEBT and RFQ, the emitter aperture of the ion source was reduced to 6mm in diameter and the length of the LEBT

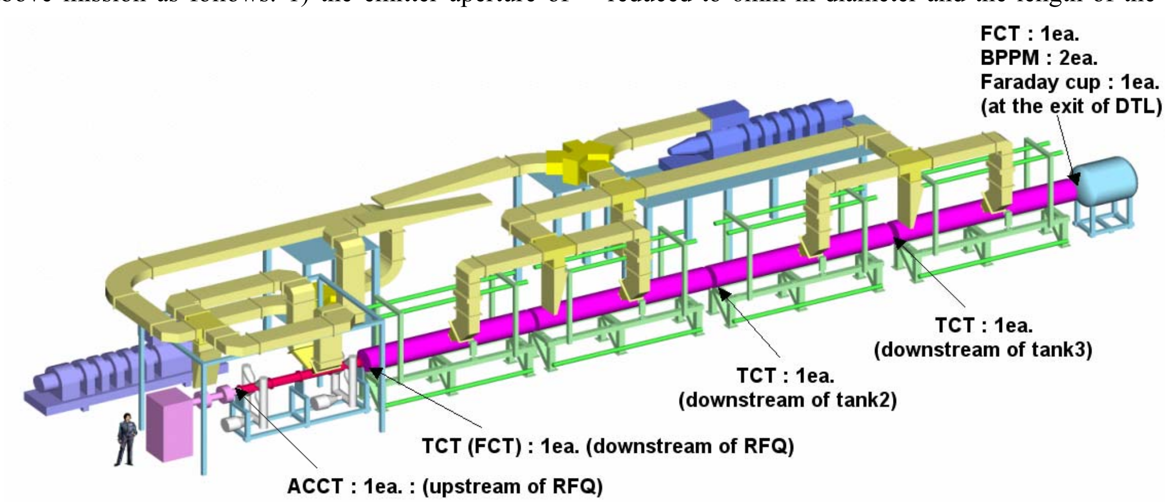

Figure 1: PEFP 20MeV accelerator and its beam diagnostics layout at KAERI site.

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was reduced to 201cm. The transmission rates through the LEBT and RFQ were calculated as 95% and 92% respectively [4]. In addition to those, the collimator geometry changed. The purpose of the collimator was to protect the ACCT from the proton beam which was installed at the downstream of the LEBT as shown in Fig. 1. In the original design, the ACCT was installed such that it could measure the back streaming electron currents. Therefore the measured beam current was so high with unstable signal profile. To circumvent this problem, the collimator with deep nose was installed to protect the ACCT from measuring the electron current. Another modification was to install the electron trap in front of the RFQ to avoid the electrons from entering the RFQ. With the help of the new collimator with nose and electron trap, the ACCT current signal showed relatively stable manner with less noise. The modified proton injector is shown in Fig. 2.

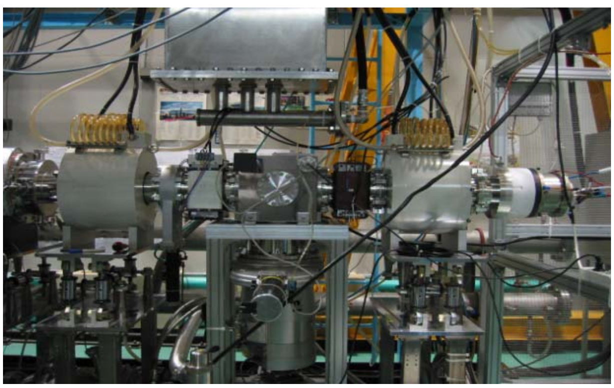
Figure 2: Modified proton injector (Left side : ion source, right side : RFQ)

RE-TUNE OF THE RFQ CAVITY

The high current operation of the RFQ showed some problems. Those were the transmission curve depending on the RF power decreased after it reached the maximum points. Also it seemed that the maximum achievable beam current was limited by some factors. To investigate the cause of these problems, the field profile of the RFQ was measured. The measured profile showed that the quadrupole field itself did not change, but the D1 and D2 dipole field profile increased up to 10% that of quadrupole field. The dipole field was less than 3% at original tuning period.

The cause of the increase of the dipole field was not known, but it was evident that large dipole field could limit the achievable beam current. The RFQ was re-tuned to reduce those dipole field components. The dipole field profile of the original tuning period, 10% (measured) field profile and the re-tuned cases were shown in Fig. 2 and Fig. 3 respectively. The dipole field profile was reduced to 5% that of the quadrupole field after re-tuning the cavity.

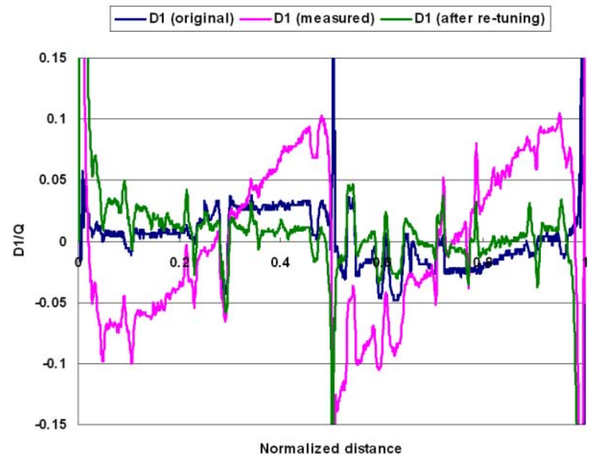

Figure 3: D1 dipole field profile (Original : blue, measured : purple, re-tuning :green)

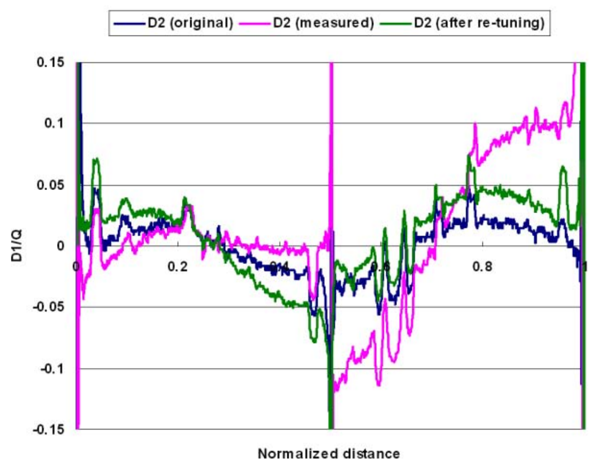

Figure 4: D2 dipole field profile (Original : blue, measured : purple, re-tuning :green)

BEAM TESTS OF THE RFQ

The RFQ beam test was done after the completion of the field re-tuning. The RFQ output beam current was measured and compared with that before 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. The RFQ output current was increased up to about twice with the same RF power level. The beam transmission rate through the RFQ was also measured as shown in Fig. 5. The beam transmission rate before re-tuning the cavity showed the current decrease after the maximum value. But the current droop was eliminated after the re-tuning, which followed that PARMTEQ simulation results. After the adjustment of the operating parameters such as LEBT steering magnet current, solenoid magnet current, RFQ RF power, we could get 20mA peak current from the RFQ.

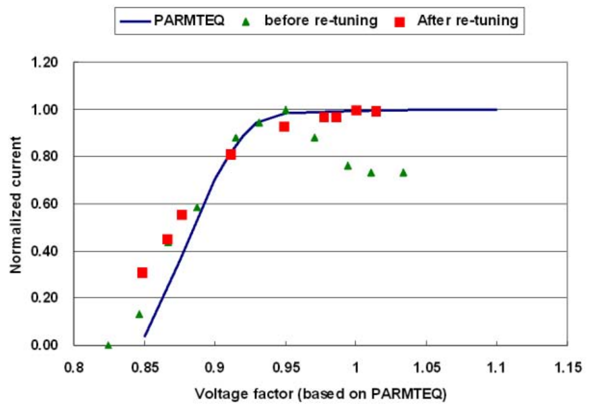

Figure 5: RFQ transmission rate (Red rectangle: data after re-tuning)

BEAM TESTS OF THE DTL

After the test of the RFQ, the beam test of the DTL started. The beam transmission through the DTL was about 80%. During test, the beam loss pattern was measured using pocket dosimeter (ALOKA, PDM-192) in every 20cm along the DTL. The result was such that a few numbers of noticeable localized peaks were measured as shown in Fig. 6. A beam dynamics study using PARMILA was done to investigate the cause of the localized beam loss pattern. The results showed that the cause of the first peak was estimated from the polarity reversal of the 30th electromagnet of the 2nd DTL tank. The beam loss pattern after the polarity reversal of the above quadrupole magnet is shown in Fig. 6. It could be seen that the first peak disappeared. In this case, the transmission rate through the DTL was nearly 100%. The second and third peak could not be explained from the polarity reversal of the electromagnet. And the peak could be greatly reduced by the stabilization of the tank resonance conditions. A 20mA peak proton beam could be accelerator up to 20MeV with the above conditions and the typical beam signal is shown in Fig. 7. The beam currents from the proton injector, RFQ and DTL were measured by ACCT, Tuned-CT and FCT respectively. The operating conditions were such that the RF pulse width was 50μs and the repetition rate was 1Hz.

CONCLUSION AND DISCUSSION

After the operation license was issued from the Government for higher beam current, a few modifications have been done including proton injector and RFQ. The emitter aperture of the ion source and the overall length of the LEBT were reduced to increase the beam transmission rate through the LEBT. The field profile of the RFQ was measured and re-tuned to increase the peak beam current through the RFQ. The beam loss pattern along the DTL was measured and used to tune the DTL. After all, we could get 20mA peak beam current at the end of the 20MeV DTL.

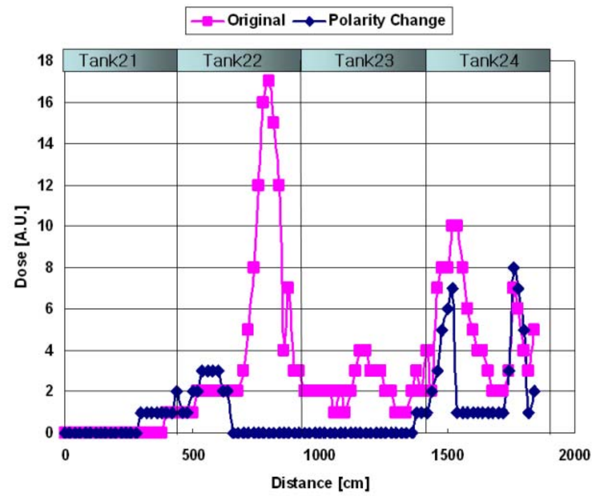

Figure 6: Beam loss distribution along the DTL (Original : purple, after polarity change : blue)

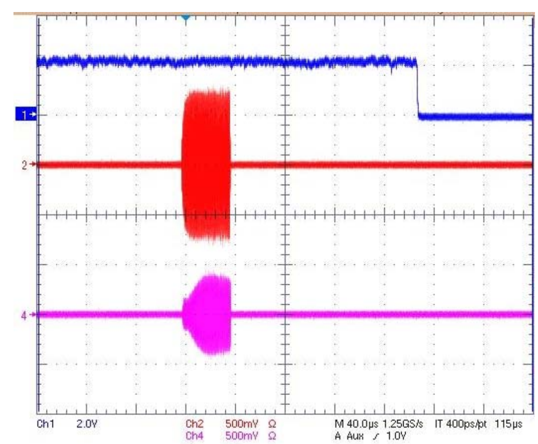

Figure 7: Beam signal of PEFP 20MeV linac (Ch 1: proton injector, Ch2 : RFQ, Ch 4 : DTL)

REFERENCES

[1] B. H. Choi, et al., “High Power Proton Accelerator Project in Korea”, Proc. Of APAC 2007, India, January, 2007.

[2] Y. S. Cho, et al., “100 MeV High-Duty-Factor Proton Linac Development at KAERI”, Proc. Of LINAC 2006, Knoxville, August, 2006.

[3] H. J. Kwon, et al., “Test Results of the PEFP 20MeV Proton Accelerator”, Proc. Of LINAC 2006, Knoxville, August, 2006.

[4] L. Young, “Simulations of the Proton Engineering Frontier Project ion source, LEBT and RFQ”, The 11th International Workshop on Accelerator and Beam Utilization, Korea, September, 2007.