BEAM CURRENT AND ENERGY MEASUREMENT OF THE PEFP 20MEV ACCELERATOR*

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

Abstract

The beam test of the Proton Engineering Frontier Project (PEFP) 20MeV proton linear accelerator started again, after the upgrade of the RF control system. One of the important goals during this test period is to increase the beam current to the design level. Various current transformers were installed along the linac to measure the beam current itself and possible beam loss along the accelerator. Also two sets of beam position and phase monitors (BPPM) were installed at the end of the 20MeV accelerator to measure not only the beam position and phase but also the beam energy. In this paper, the overall test results including beam current and energy measurement are presented.

INTRODUCTION

One of the missions of the PEFP is to develop a 100MeV proton linear accelerator. As a front end of 100MeV machine, a 20MeV accelerator was already fabricated and installed at KAERI test stand [1][2]. The 20MeV accelerator consists of 50keV proton injector, 3MeV radio frequency quadrupole (RFQ) and 20MeV drift tube linac (DTL). The 20MeV DTL is divided into four tanks to limit the heat load within cooling capability at 24% duty operation. The initial test with peak current of 1mA at low duty has been done to check the overall machine performance [3]. After the upgrade of the low level RF control system, the test started again [4]. The main purpose during this test period is to increase the beam current up to the design level. For this goal, various current transformers were installed along the linac. An AC current transformer (ACCT) was installed in front of the RFQ, a fast current transformer (FCT) and a Faraday cup were installed at the exit of the 20MeV DTL and tuned current transformers (Tuned CTs) were installed between DTL tanks. Two BPPMs were installed at the exit of 20MeV DTL to measure not only the beam position and phase but also the time of flight for the beam energy measurement. The overall layout of the beam diagnostics device along the 20MeV linac is shown in Figure 1.

BEAM CURRENT MEASUREMENT

The PEFP proton injector includes ion source and low energy beam transport (LEBT). The duoplasmatron type ion source operates in pulse mode by switching the extraction high voltage power supply and the LEBT consists of two solenoid magnets for beam focusing and two steering magnets for the beam position and angle adjustment. To measure the beam current from the proton injector, an ACCT was installed in front of the RFQ. The Bergoz ACCT consists of in-vacuum ACCT sensor with 55mm inner diameter and associated electronics. The electronics has 1V output when 20mA current pass through the ACCT. Therefore it can be used directly for the measurement of the low peak current value during initial test stages. The ACCT was shielded from the magnetic field of the LEBT solenoid below 20Gauss by using the steel housing.

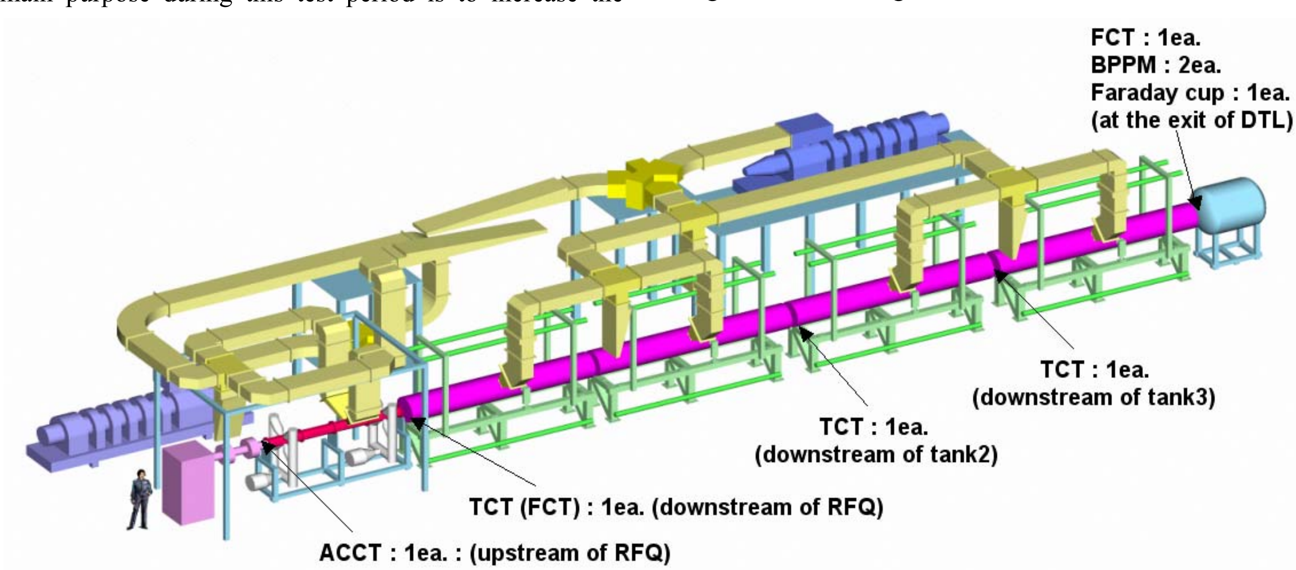

Figure 1: Beam diagnostics layout.

* This work is supported by MOST of the Korean government
#hjkwon@kaeri.re.kr

1-4244-0917-9/07/$25.00 ©2007 IEEE

The low droop FCT was installed at the exit 20MeV DTL. The FCT was also purchased from Bergoz. The droop is less than 1%/us and the minimum L/R time constant is 100us. The measured L/R time constant was about 115us. The turn ratio of the FCT is 20 : 1 and the measured sensitivity is 1.25V/A. The upper cutoff frequency of the FCT is 850MHz. Therefore it can measure the beam bunch signal. Because the signal level from the FCT is low and the signal to noise ratio is low for the application to the low peak current value during initial test, the signal was processed using amplifier to measure the current properly. Also a 10 MHz low pass filter was used to reject the high frequency components of the beam signal.

The tuned CT is a narrow bandwidth current transformer tuned to fundamental beam bunch frequency. It was developed by Bergoz with the cooperation of the Pohang Accelerator Laboratory (PAL) [5]. It measured 350MHz beam bunch signal. Because the tuned CT measured the fundamental component of the beam bunch signal, it has no droop in the beam current signal which is a troublesome in FCT. Three tuned CTs were installed after the RFQ, DTL tank2 and tank3 to measure the relative beam transmission through the tanks. Because the limited space between DTL tanks, the installed tuned CT is very compact with 20mm thickness.

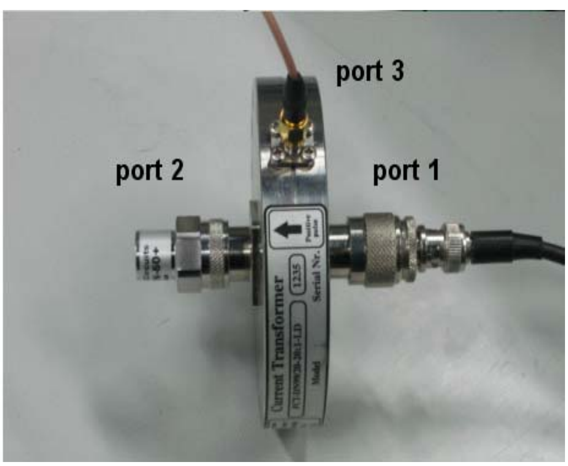

Figure 2: Tuned current transformer.

To measure the sensitivity of the turned CT at 350MHz beam fundamental frequency, we used Network analyzer. The measured tuned CT is shown in Figure 3. To be sure the matching of the inner conductor, the S11 and S21 parameter was measured between port 1 and port 2 with a matched load at port 3. The measured S11 and S21 values at 350 MHz were –27.2dB and –0.15dB respectively which showed good matching. Then, the coupling between port 1 and port 3 was measured. The S31 parameter was –29.8dB at 350 MHz. From this measurement, the sensitivity of the tuned current transformer was 3.24V/A. Here the voltage is amplitude of the 350MHz signal, current is a DC component of the beam current. Because the output signal from the tuned CT is low at low peak current test, a RF amplifier is installed between tuned CT and oscilloscope to increase the output signal level. Recently, the tuned CT installed at the exit of the RFQ was replaced with the FCT to measure the input and output beam current of the DTL consistently using the same device.

A Faraday cup is installed at the end of the 20 MeV DTL to cross check the beam current value measured by FCT. The Faraday cup was made by Graphite and can be removed from the beam path. The beam signal from the Faraday cup is processed by the low noise current preamplifier (SR570, SRS) which can be used up to 5mA peak current. After the cross check between FCT and Faraday cup, we are going to use the FCT as a standard beam measurement device.

The measured beam current during the test is shown in Figure 3. The peak beam current at the Faraday cup is 2mA.

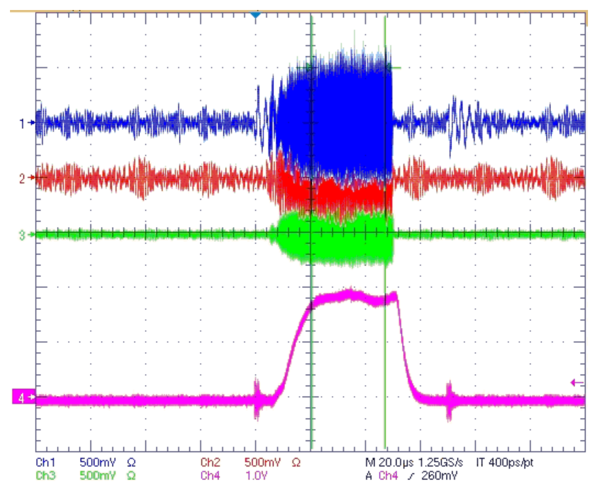

Figure 3: Measured beam current - 2mA peak (Ch 1 : RFQ output current, Ch2 : tank2 output current, Ch 3 : tank3 output current, Ch4 : 20 MeV DTL output current)

BEAM ENERGY MEASUREMENT

Two sets of BPPMs are installed after the 20 MeV DTL to measure not only the beam position and phase but also the beam energy by the time of flight method. The distance between two BPPMs is 250mm, which corresponds to 4.10ns time difference between signals from two BPPMs. Actually, the BPPM electronics includes the beam phase measurement function, but the transient response time is about 200us when the beam turns on. Therefore it is difficult to measure the beam phase during initial beam test with 50us beam pulse width. To solve the problem, we used digital oscilloscope to measure the phase difference. The signal from the oscilloscope is shown in Figure 4. Because the sampling rate of the oscilloscope (Tektronix, TDS3054B) is 5 GS/s, the measured signal should be processed to get proper information on the beam energy. The measured signal was fitted with up to 3rd order harmonics of the beam fundamental frequency and then the zero crossing points were compared to get the time difference between two signals. The measured data points and the fitting curves

1-4244-0917-9/07/$25.00 ©2007 IEEE

are shown in Figure 5. The results showed that the beam energy was 20.0MeV with a maximum deviation of ±2 % in one macropulse.

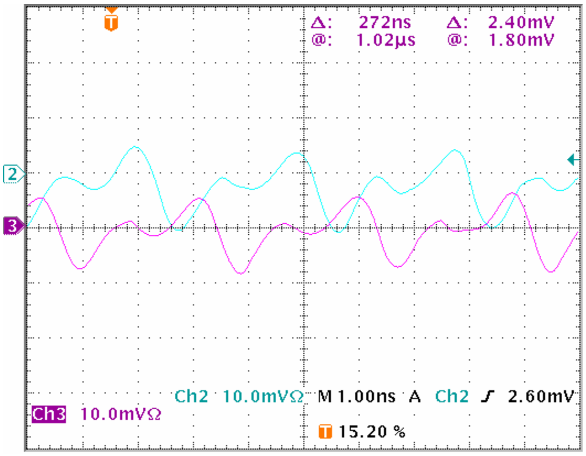

Figure 4: Measured BPPM signal (Ch 1 : upstream side - BPPM1, Ch 2 : downstream side – BPPM2)

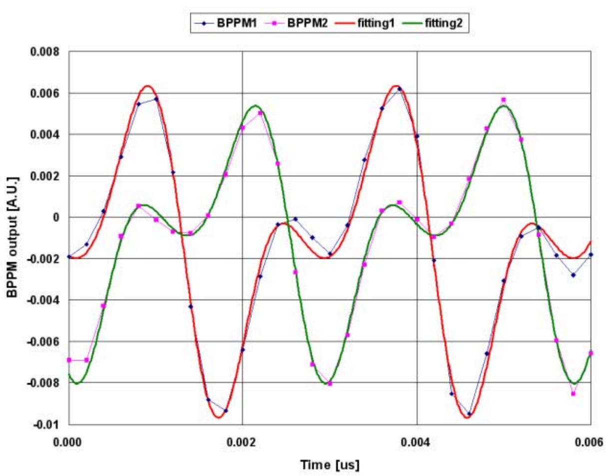

Figure 5: Measured data points and fitting curve

CONCLUSION AND DISCUSSION

Various sets of current transformers are used for the initial test of the PEFP 20MeV proton accelerator. The main devices to measure the beam transmission at initial test are ACCT at RFQ upstream, FCT at RFQ downstream and FCT at DTL downstream. To measure and process the current signal properly, a data acquisition system is being developed using fast ADC. During the initial test, the characteristics of the tuned CT are going to be checked continuously.

The beam energy was measured using time of flight method. The initial measurement results showed the beam energy was 20.0MeV with a maximum ±2 % deviation in one macropulse. The relatively large deviation is not supposed to be real one. There are several sources that may contribute to this large deviation, such as low signal to noise ratio of the original signal, beam stability itself and the transient characteristics of the BPPM itself and so on. Among those, the fitting errors from low signal to noise ratio may be significant factor that contribute to the large scattered value. To complement the measurement result, we are going to measure the energy with energy degrader.

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] H. S. Kim, et al., “Development of the Digital RF Control System for the PEFP Proton Accelerator”, Proc. Of APAC 2007, India, January, 2007.

[5] S. J. Park, et al., “Status of Beam Diagnostic Systems for the PEFP”, Proc. Of PAC 2005, Knoxville, August, 2005.

1-4244-0917-9/07/$25.00 ©2007 IEEE