

TEST RESULTS OF THE PEFP 20-MEV PROTON ACCELERATOR*

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Abstract

An 20 MeV proton accelerator has been developed by Proton Engineering Frontier Project (PEFP). The accelerator consists of a 50 keV proton injector, a 3 MeV radio frequency quadrupole (RFQ) and a 20 MeV Drift Tube Linac (DTL). The initial test is being performed at KAERI (Korea Atomic Energy Research Institute) site. A pulsed proton beam is extracted from the proton injector by switching the high voltage power supply of the ion source. The beam transmission rate through the RFQ was measured with respect to the vane voltage to set the RF operating point. The 20 MeV DTL consists of four tanks and the beam transmission characteristics have been checked for various parameters. In this paper, a test stand for a 20 MeV accelerator at KAERI site is introduced and the test results are discussed.

INTRODUCTION

One of the missions of PEFP is to develop a 100 MeV proton linear accelerator. For this purpose, a 20 MeV accelerator was already fabricated and installed at KAERI test stand [1][2]. About two years later, the 20 MeV accelerator will be moved to be installed in Gyeongju city which was selected as a host city for PEFP 100 MeV accelerator. An initial test has been carried out at KAERI site to check the overall machine performance and tune the accelerator operating parameters. The test is being done at low duty, that is 50 μ s beam pulse width and 0.1 Hz repetition rates, because of the improper radiation shielding for full beam power. The installed 20 MeV accelerator at KAERI site is shown in Figure 1.



Figure 1: 20 MeV proton accelerator installed at KAERI test stand.

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20 MEV ACCELERATOR TEST STAND

The main accelerator facilities at KAERI test stand are 20 MeV accelerator itself, two sets of 1 MW, 350 MHz RF system, two sets of -100 kV, 20 A DC high voltage power supply for the klystron, two sets of 2 MW cooling system for the cavity and RF system.

The ambient condition at KAERI test stand is not stabilized. Therefore the RF cavities should be stabilized against varying ambient conditions – especially ambient temperature. For this purpose, heater and heat shield were installed around the RFQ and DTL cavities. An 1 kW heating power per RFQ and a DTL tank was used. The heater was controlled by PID mechanism of the SCR power unit. By using this method, the frequency could be stabilized within ± 1 kHz.

The design duty of the 20 MeV accelerator is 24 % and two sets of 1 MW, 350 MHz klystron are used to drive a 20 MeV accelerator, one is for RFQ and the other is for DTL. All the other ancillary facilities such as klystron power supply and cooling system were designed for 100 % duty operation. During the low duty operation at KAERI test stand, the RF system is operating such that the electron beam of the klystron is CW whereas only the input RF signal is modulated for the low duty pulse operation.

Two sets of klystron power supply are used to drive two sets of 1 MW klystron. As mentioned above, the design duty of 20 MeV accelerator is 24 %, therefore, not modulator, but DC high voltage power supply is used as a klystron power supply. During test, the klystron power supply is operating in CW mode.

Two sets of cooling system are operating, one is for RFQ, the other is for DTL. One set of the cooling system at KAERI test stand supplies cooling water both to the klystron and cavity simultaneously. With this cooling circuit configuration, the thermal load can be maintained nearly constant irrespective of the duty factor. Three-way valve is used to control the cooling water temperature during operation.

INITIAL TEST OF 20 MEV ACCELERATOR SYSTEM

The purposes of the initial test of the 20 MeV accelerator systems are to check and evaluate the overall performance of the system itself, and to tune the accelerator parameters for proper beam acceleration. Especially, during the initial test, we should check the beam transmission through the accelerator at low beam current, because the radiation shield is not enough for full beam power at KAERI test stand. Therefore, the operation

parameters for initial test are 50 μ s beam pulse width and 0.1 Hz repetition rate.

Proton Injector[2]

The injector includes a duoplasmatron proton source and a low-energy beam transport (LEBT). The beam current extracted from the source reached up to 50 mA at a voltage of 50 kV using a 150 V, 10 A arc power. The extracted beam has a normalized emittance of 0.2π mmrad from a 90 % beam current, where the proton fraction is larger than 80 %. To achieve pulsed operation, a high-voltage switch is installed in the high voltage power supply, whose rising and falling time is less than 50 ns. Figure. 2 shows the beam signal, which is measured with a Faraday cup at the exit of LEBT. With the semiconductor switch, the pulse length and the repetition rate can be easily changed.

The LEBT consists of two solenoid magnets that can filter the H_2^+ , and two steering magnets that can control the beam position at the entrance of the RFQ.

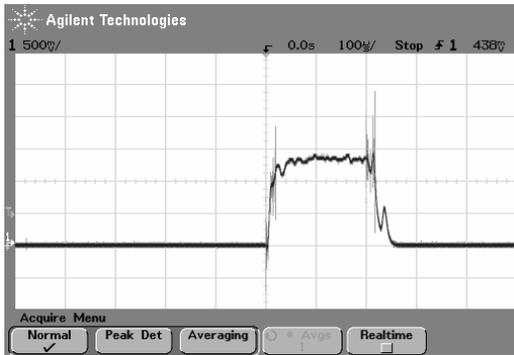


Figure 2: Beam signal at the LEBT exit (1mA/div. 200us pulse).

RFQ [3]

The output beam current from the RFQ was measured with respect to the LEBT magnet parameters and RFQ vane voltage.

A current transformer developed by Bergoz was installed at the exit of the RFQ to measure the beam current. The current transformer is tuned to the fundamental beam frequency, which is 350 MHz and can catch the bunched beam signal component of 350 MHz. The sensitivity of the current transformer is 2.5 V/A. Because the peak beam current would range from a few tens μ A to a few mA during initial beam test, it is difficult to directly measure the signal from the current transformer. Therefore two stage RF amplifiers were installed.

The measured output beam currents of the RFQ depending on the solenoid magnet current and steering magnet current are shown in Figure 3 and Figure 4 respectively. For the solenoid magnet, the solenoid #1 is located in the ion source side and its function is to parallelize the diverging beam from the ion source, whereas the function of the solenoid #2, which is located

in the RFQ side, is to focus the parallel beam into the RFQ. The measured results showed that the beam current dependency is more sensitive to the solenoid #2 which mainly determines the input beam parameters of the RFQ. For the steering magnet, the steering magnet for y-direction is nearly optimum at “zero” current state, but the steering magnet for the x-direction effectively increased the output current. As shown later, this result is related with the DTL tank steering.

The output current through the RFQ was measured to set the RF operating point. The peak beam current during test was about 1 mA. The measured beam current and PARMTEQ simulation result are shown in Figure 5. During the test, the current transformer tuned to 350 MHz acted like a filter which could pick up the bunched beam signal, therefore the current transformer picked up the accelerated beam signal. From the test results, the operating point of the RF amplitude could be determined, which was about 10 % higher than the design value.

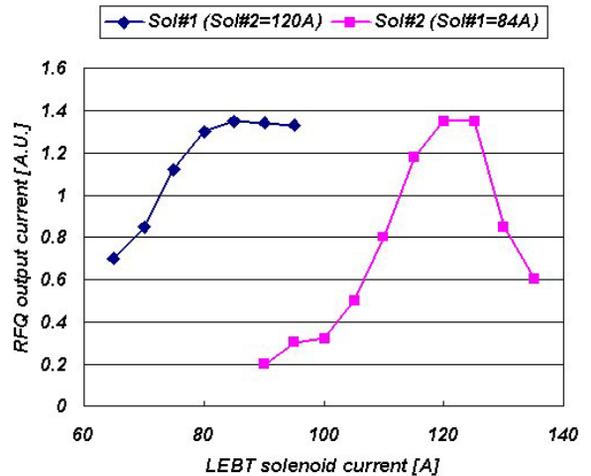


Figure 3: RFQ output beam current depending on LEBT solenoid current.

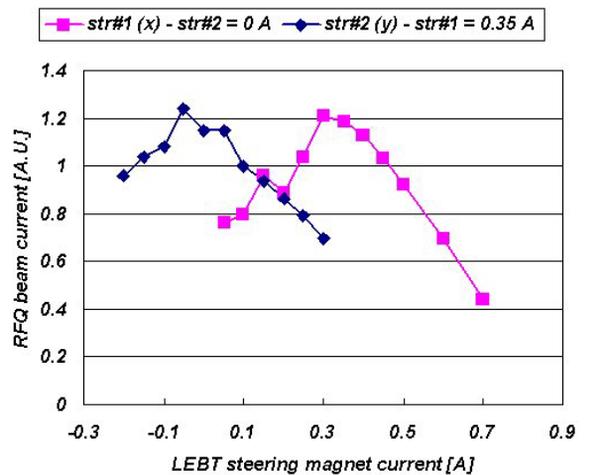


Figure 4: RFQ output beam current depending on LEBT steering magnet current

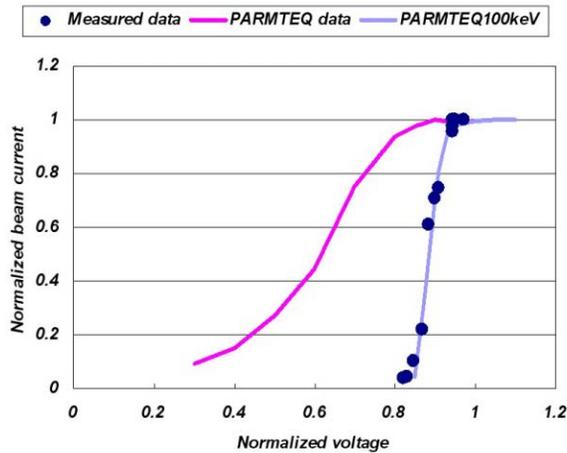


Figure 5: RFQ output current depending on RF field, (Red line: total beam current, Blue line: accelerated beam current, Dot : measured beam current).

DTL

The unique characteristic of PEFP 20 MeV DTL is that one klystron drives four DTL tanks simultaneously. Also the cavity cooling circuits for four tanks are connected in parallel from one cooling system. For this multi-cavity driving concept, the tank wall temperature control mechanism with heater is installed, and mechanical phase shifters are also installed in each waveguide leg to the tank. By doing this, we can consider four independent tanks as one cavity. Therefore the resonant frequencies of each DTL tank were adjusted by controlling the wall temperature of each tank. During the test, the global operating condition was adjusted by controlling the coolant temperature.

The current transformers were installed at the entrance of tank 1 and at the exit of tank 2, tank 3. Also a Faraday cup was installed at the exit of tank 4. During the test, the beam transmission through the DTL tanks was measured depending on the operating parameters using these beam diagnostic devices.

The LEPT parameters above mentioned and mechanical phase shifters were adjusted in advance. After that, beam steering was performed. The beam position monitor is not working yet at low current level, we determine the proper beam steering by measuring the beam transmission. Because the PEFP DTL has no steering magnet in the drift tubes, we move the tank itself for the beam steering. The minimum resolution that we can steer the tank was 30 μm . During the test, the position that the low energy side of the tank 1 was moved 1 mm in the $-x$ direction, high energy side of the tank 1 and all sides of tank 2 were moved 0.5 mm in $-x$ direction, and all the other tanks were not moved, is the best position for the 100 % beam transmission through the DTL. The DTL input beam current and output beam current profiles are shown in Figure 6. During the test, the beam current was fluctuating because of the uncontrolled low level RF

system and also the beam signals from the current transformer was decayed at some instance because of the improper cooling of the RF amplifier.

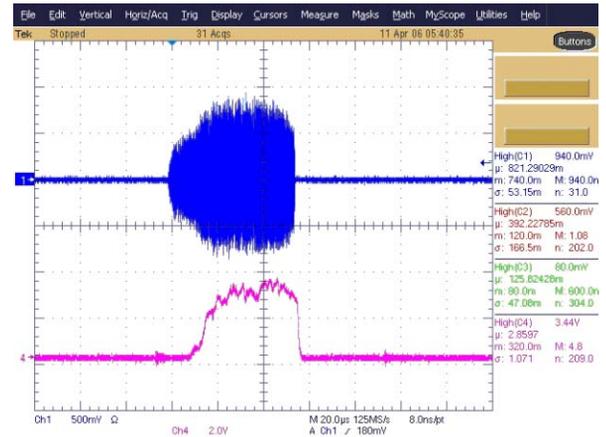


Figure 6: Beam Signals of the 20 MeV DTL, (CH1: ~1mA at RFQ exit, CH2: ~1mA at DTL exit).

CONCLUSION

The initial beam test of the PEFP 20 MeV proton accelerator was carried out. The purposes of the initial test were 1) to check the overall machine performance, 2) to tune the machine parameters for proper beam acceleration.

During the test, the performance of the 20 MeV accelerator itself, two sets of 1 MW, 350 MHz RF system including klystron, HPRF components, DC high voltage klystron power supply and also cooling system were checked, maintained and improved.

Some operating parameters such as LEPT solenoid and steering magnet currents, mechanical phase shifters, wall temperatures of each DTL tanks and steering of the DTL tanks were adjusted for 100 % beam transmission through the DTL.

To understand more about the PEFP 20 MeV accelerator performance, the RF stabilization mechanism should be implemented in the LLRF system and more stable beam diagnostic systems should be installed.

REFERENCES

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