100MEV PROTON ACCELERATOR COMPONENT TESTS BY USING 20MEV LINAC*

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Abstract

A 100MeV proton accelerator is being developed by the Proton Engineering Frontier Project (PEFP). As a front part, a 20MeV linac has been installed and operated at Korea Atomic Energy Research Institute (KAERI) site. Among the components for the 100MeV accelerator, some parts were installed and tested by using 20MeV linac. One modulator for a 100MeV linac was installed to drive two klystrons simultaneously which were used for a 20MeV linac. Various operating parameters such as a long term voltage fluctuation are checked during operation. Also a LLRF system for 100MeV linac, which was modified from the 20MeV system, was installed and tested. In this paper, the operation characteristics of the 20MeV linac are presented especially from the viewpoint of the newly installed components such as a modulator and LLRF system.

INTRODUCTION

A 100MeV, 20mA proton accelerator is developed by PEFP. It will be installed at Gyeong-Ju site at 2012 [1][2]. As a front end part of the 100MeV accelerator, a 20MeV linac has been installed and operating at KAERI site. The operation goals of the 20MeV linac at KAERI site are as follows.

- It supply beam to users
- It is used for the machine study
- It is used for the test bench of the 100MeV machine components

Many components of the 100MeV accelerator were completed and stored at Gyeong-Ju office, which include DTL tanks, klystrons, modulators, RCCS (resonant frequency control cooling system) and beam line magnets as shown in Fig. 1. Some components such as a modulator and LLRF system were installed and tested at 20MeV linac at KAERI to check their performances before they would be fully installed and commissioned in Gyeong-Ju site at 2012. Also the beam test was conducted by using these newly installed components.

MODULATOR TEST

The modulator for the 100MeV accelerator was installed to drive the 20MeV linac. The purpose of the operation was to test the modulator in the real system in advance before it would be installed for the 100MeV accelerator at Gyeong-Ju site.

The specifications of the modulator are summarized in Table 1.

Figure 1: DTL stored at Gyeong-Ju office.

Table 1: Specifications of the Modulator

Parameters	Value
Input voltage	3300Vac
Output voltage	-105kV
Output current	50A
Output peak power	5.8MW
Output average power	520kW @ 9% duty
Efficiency	> 92%
Pulse width / repetition rate	1.5ms / 60Hz
Flat top voltage regulation / droop	1% / 1%
Arc energy	< 20J

The modulator used high frequency switching method by using Insulated Gate Bipolar Transistor (IGBT), which topology was used for the SNS modulator [3]. There were two klystrons in the 20MeV linac and one modulator was used to drive the two klystrons simultaneously. The klystron (TH2089F, THALES) for 20MeV linac has a triode type electron gun. Therefore, modulating anode voltage should be supplied. Voltage dividing resistors were used to supply the modulating anode voltage. In addition, capacitors were installed in parallel with the resistors to reduce the voltage rising time. The operation parameters of the modulator were 2.4MW peak power with 1ms pulse width and 4Hz repetition rate. The initial test results such as voltage and current profile of the modulator and the long term voltage stability are shown in Fig. 2, Fig. 3 respectively. The difference of the current profile of the two klystrons (Ch3, Ch4 in Fig. 3) was mainly due to the difference of the high voltage line inductance. The voltage droop was 1.8%. In fact, the voltage droop at full peak power was 3%. We are going to reduce the droop within 1% by controlling the IGBT switching frequency. The voltage decreased about 0.8% and the fluctuation was less than 0.2% in standard deviation during 8 hours operation as shown in Fig. 3. The low average power was considered to be the reason of the voltage decrease of the long term operation. The average power would be increased after the modulating anode voltage dividing system was modified and the overall control system was upgraded.

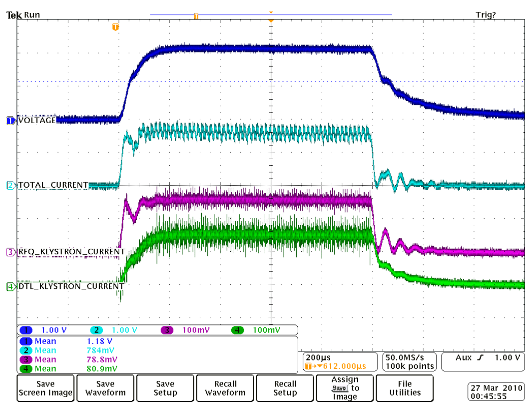

Figure 2: Modulator voltage and current pulse profile.

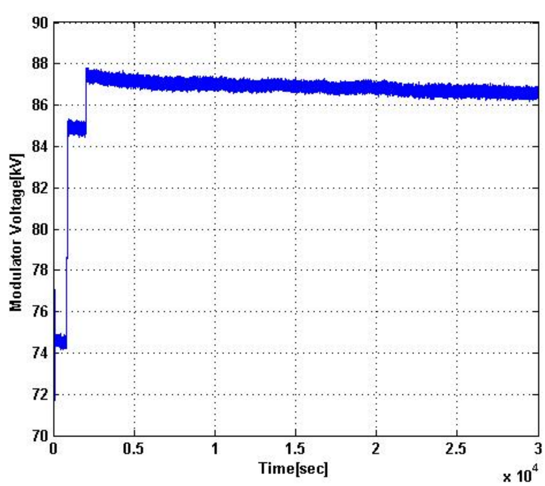

Figure 3: Voltage stability during initial operation.

LLRF SYSTEM TEST

The low level RF system of the 20MeV linac was modified. It adopted new control board and new EPICS operator interface (OPI).

A commercial multi-channel, high-speed data converter (Pentek 7142) was adopted as a new control board for the digital LLRF system. The specifications of the board are as follows.

- ADC: 125MHz, 14bits, 4Ch.
- DAC: 320MHz, 16bits, 1Ch.
- FPGA: Xilinx Virtex4 XC4VSX55
- Memory: DDR2 SDRAM (64M×32)
- Clock: External (1to 300MHz), internal (125MHz)
- Gate: Internal or external

The main characteristic of the new board was its capability to produce the synchronized phase IF signal at every trigger. Therefore, the IQ modulator installed at the analogue box and other auxiliary components for the IQ modulator could be eliminated. The block diagram of the modified LLRF system is shown in Fig. 4. We are going to use a LO (300MHz) as a reference signal and down convert the RF signal from the cavity or up convert signal from the board using the same reference signal. The analogue system was also modified to accommodate the IF signal directly from the control board. An EPICS control system based on the VME was newly developed and described more precisely elsewhere [4].

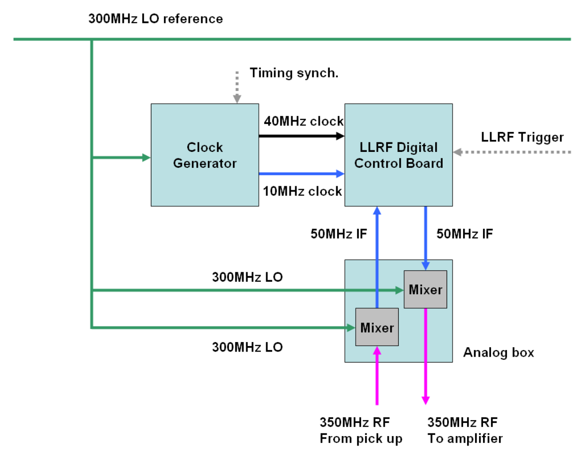

Figure 4: Block diagram of the modified LLRF system.

The control system adopted general PI control algorithm using I/Q signal. The FPGA board clock was 10MHz and the latency of the control system was 1μs. The preliminary test results of the LLRF system by using 20MeV linac are shown in Fig. 5 and Fig. 6 respectively. The amplitude and phase of the cavity could be controlled within 1% and 1 degree respectively as shown in the Figure.

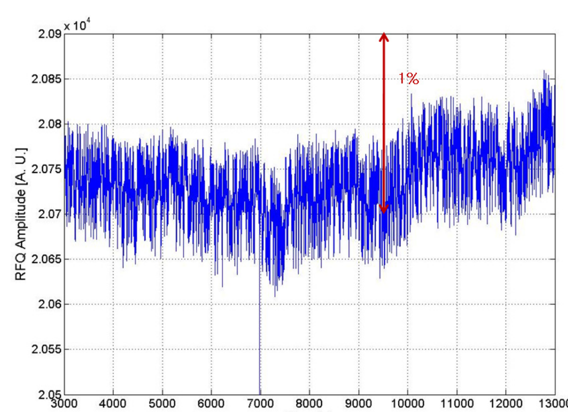

Figure 5: RF amplitude during 20MeV linac operation.

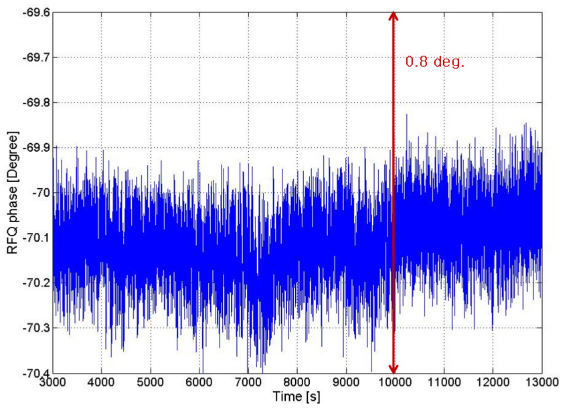

Figure 6: RF phase during 20MeV linac operation.

BEAM TEST WITH NEWLY INSTALLED COMPONENTS

The long term and long pulse behaviours of the 20MeV linac were tested by using newly installed components including modulator and LLRF system. The long term operation was restricted for four hours due to the regulation at KAERI site. The modulator and klystrons were operated at 4Hz repetition and the beam itself was operated at 1Hz with 50us pulse width. During 4 hour operation, there were 81 pulse failures among 14,400 pulses, 2 pulse failures were due to the spark from the ion source and the last came from the RFQ spark. For the long pulse operation, the beam pulse width was increased from 50us to 500us. During the test, there was no problem driven by the modulator and LLRF control system. The 500us beam pulse driven by the modulator and LLRF system is shown in Fig. 7.

CONCLUSION

The components such as a modulator and LLRF control system developed for the 100MeV proton accelerator were installed and tested at 20MeV accelerator test stand installed at KAERI. The test results of the long term and long pulse operation were such that modulator and LLRF system works well in the real operating conditions. We are going to check their other characteristics until we move to Gyeong-Ju site.

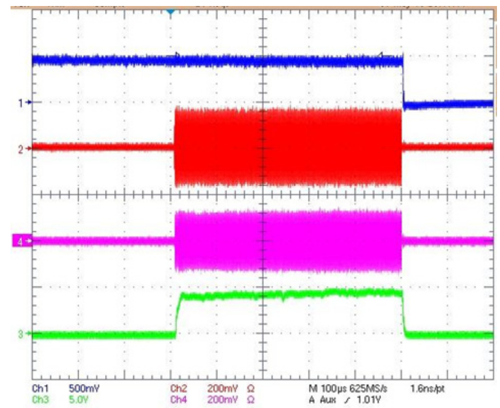

Figure 7: LEBT, RFQ and DTL output beam pulse for 500us operation. (Ch 1: LEBT current, Ch 2: RFQ current, Ch 3: DTL current, Ch 4: DTL current (Faraday cup)).

ACKNOWLEDGEMENT

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