STATUS OF 100-MeV PROTON LINAC DEVELOPMENT FOR PEFP*

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Abstract

The Proton Engineering Frontier Project (PEFP) at Korea Atomic Energy Research Institute (KAERI) [1] is developing a 100-MeV high-duty-factor proton linac, which consists of a 50-keV microwave ion source, a 3-MeV radio frequency quadrupole, a 100-MeV drift tube linac, a 20-MeV beam transport line, and a 100-MeV beam transport line. It will supply proton beams of 20-MeV and 100-MeV with peak current of 20 mA to users for proton beam applications. The beam duty factor will be 24% and 8% respectively. The 20-MeV front-end accelerator has been installed and operated at Daejeon site for user service, and the rest part of the accelerator has been fabricated and will be installed at the new site of Gyeongju in 2011. The detailed status of the 100-MeV proton linac will be presented.

INTRODUCTION

The 20MeV part of the PEFP 100-MeV linac is now operating at Daejeon site since 2007 [2]. Main change in the linac operation was replaced a DC power with a modulator and the development of the microwave ion source. The fabrication of the main components of the 100-MeV linac was finished and under test at the project site. The installation will begin after completing the building construction at the end of this year. The beam commissioning is scheduled in 2012. The brief report summarizes the 20-MeV linac operation, the 100-MeV linac and beam line development, the installation and commissioning plan, and the status of civil construction.

20-MeV ACCELERATOR OPERATION

The operation goals of the 20-MeV accelerator at Daejeon site are supplying beams to users, the machine study, and testing the 100-MeV machine components. The operation parameters are restricted to the average beam current of 1μA at Daejeon site due to the insufficient radiation shielding in the building.

Because of the long term operation requirement more than 100 hours, the ion source was upgraded to the microwave type. It uses a 2.45GHz magnetron as a microwave source and a combination of aluminium nitride and boron nitride as a microwave window. After the 100 hour DC beam test, the ion source was installed to drive the 20-MeV linac in 2011 [3]. The output beam emittance was measured by using the electric sweep scanner and the result was 0.35π mm mrad in normalized rms value which was higher than the design value.

Another important upgrade was adopting the modulator using the high frequency switching method by Insulated Gate Bipolar Transistor (IGBT) [4]. One modulator was simultaneously used to drive the two klystrons for the 20-MeV linac. Voltage dividing resistors were used to supply the modulating anode voltage for the triode type electron gun. The typical operation parameters of the modulator were 2.4MW peak power with 1ms pulse width and 4Hz repetition rate. The voltage droop was 1.8% which increased to 3% at full peak power. We are going to reduce the droop within 1% by controlling the IGBT switching pulse width or frequency.

The 20-MeV machine was tested in the high repetition rate up to 15 Hz and long pulse width up to 500 μs [3]. The result is given in the left of Figure 1 for the long pulse operation. Unfortunately both tests were limited by the radiation levels at Daejeon site but there were no serious problems during test. The emittance was measured by using the quadrupole scan method with a wire scanner. The result is given in the right of Figure 1. We found that the values were well agreed with the simulation result.

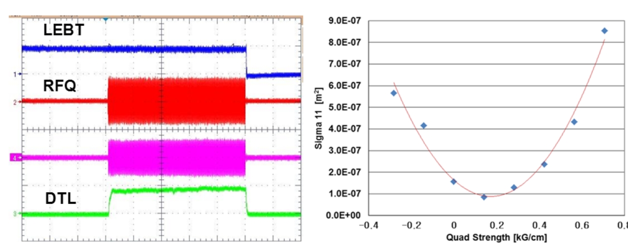

Figure 1: Long pulse signal of 500μs pulse width (left) and fitting for calculating emittance by using quad scan method (right).

100-MeV ACCELERATOR AND BEAM LINE DEVELOPMENT

It needs seven DTL tanks to accelerate proton beams from 20-MeV to 100-MeV. Three of them were aligned at Daejeon site a few years ago. The DTL tanks were transported to Gyeongju site which is located about 220km away from Daejeon. After the transportation by using vibration free vehicle, we didn't observe any appreciable effects in the field profile measurement. The other DTL tanks were delivered to Gyeongju site directly. The alignments of all the tanks were finished at December, 2010. The last 100-MeV DTL tank just after the alignment is shown in Figure 2.

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Figure 2: Last 100-MeV DTL tank after development (December 22, 2010).

The PEFP will provide ten beam lines, five for 20-MeV beams and five for 100-MeV beams[5]. All the beam line magnets were prepared: 2 AC magnets, 107 Quadrupole magnets, 11 Bending magnets[5]. All of them were fabricated and the fiducialization and field measurement were done. The strip line type BPM was developed for the beam line. The electrode was 100mm in inner diameter with 70mm long and 45 degree width. The prototype BPM was installed and tested at the 20-MeV accelerator as shown in Figure 3. In order to extract the high current and large beam with the diameter of 300 mm, we developed concave aluminium-beryllium alloy (AlBeMat) window, 0.5mm thickness and 300mm diameter [5]. We will adopt a fast closing gate valve system to protect main facilities from the accident caused by the failure of the beam window.

Almost all components for the 100-MeV linac such as klystrons, modulators, and RCCS were also prepared at Gyeongju site.

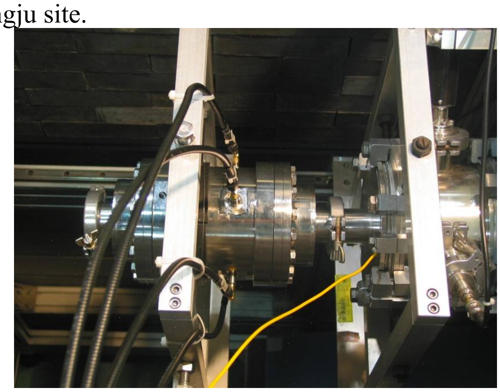

Figure 3: Strip line BPM for PEFP beam lines which was installed and tested at 20-MeV accelerator.

RF SYSTEM

Total 11 sets of RF systems are required for the 100MeV Linac. The RF system layout for the 100MeV Linac was fixed as shown in Figure 4.

One of the important interfaces with the building construction was the imbedded waveguide section into the tunnel [6]. The waveguide penetration sections have the bending structure for radiation shielding. They were fabricated into a piece of waveguide of WR2300 half height to prevent the moisture and any foreign debris inside concrete block of 2.5m. Leakage was inspected with the pressure of 0.25 psig, and VSWR was also measured within 1.2. The penetration sections have been installed within the sleeve of the building construction structure as shown in Figure 5.

The low level RF (LLRF) system adopted a digital technology with EPICS operator interface (OPI) [6]. The IF / LO frequencies were 50MHz, 300MHz. A commercial multi-channel, high-speed data converter (PENTEK 7142) was used. The main characteristic of the LLRF system was its capability to produce the synchronized phase IF signal directly which could eliminate the external IQ modulator. 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 test results of the LLRF system by using 20-MeV linac showed that the amplitude and phase of the cavity could be controlled within 0.18% and 0.09 degree respectively in standard deviation.

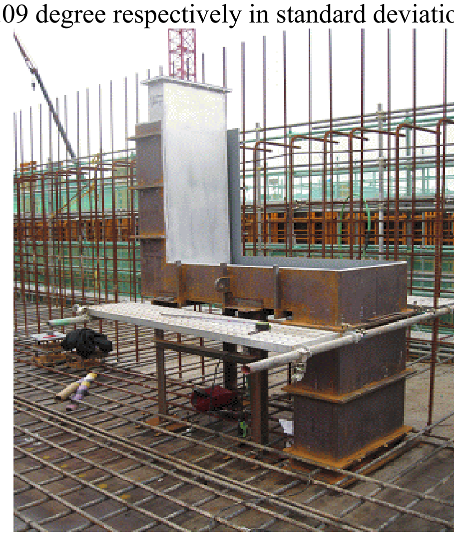

Figure 5: Installation of waveguide penetration section.

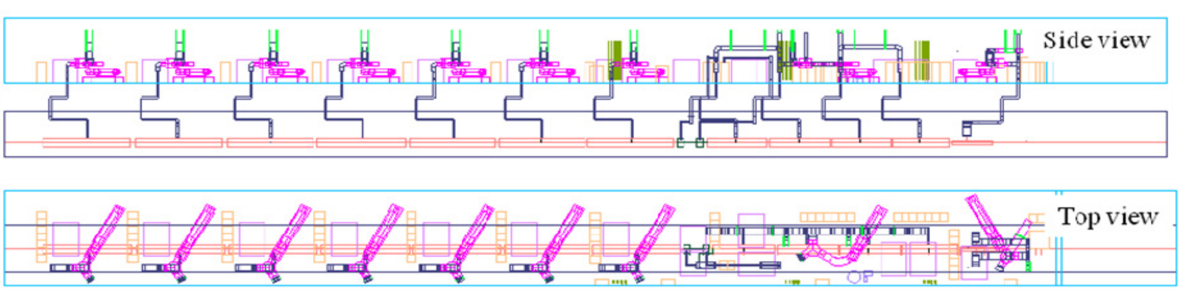

Figure 4: RF system and waveguide layout for the 100MeV Linac.

INSTALLATION AND COMMISSIONING PLAN

Assembly and test of the components will be performed in the assembly building because the crane is placed only in the assembly building. All of them will be moved into the tunnel and experimental hall for installation Before the installation, DTL tanks, MEBT tanks and magnets were fiducialized with its frame as a reference. And we will build the network points in the tunnel, the klystron gallery, experimental halls and target rooms to align the components. The alignment network will be linked by 5 see-through holes between floors. All of the alignment work will be done using two LEICA laser trackers. In tunnel, the alignment tolerance is within ±50μm. And the magnets will be aligned within ±100μm in beam transport lines.

The goal of the beam commissioning is the beam power of 100W at the end of the linac where the pulse width and repetition rate are 50μsec and 1Hz with the beam energy of 100 MeV and the peak beam current of 20 mA [7]. The commissioning process consists of two stages. One is for a 20MeV linac and a MEBT by using a beam stop which will be installed in MEBT. The other is for 100MeV beams by using a 1-kW beam dump installed at the end of the linac.

CIVIL CONSTRUCTION

Gyeongju city which is located in the south-eastern part of Korea hosted the project in January 2006. The building construction started in September 2009. The accelerator tunnel will be prepared in November 2011. The construction of the other building will be finished in August 2012 including the accelerator building, the experimental hall, and the conventional facilities. Figure 6 shows the bird's eye view of the construction site. The construction status of the accelerator building is given in Figure 7.

Figure 6: Bird's eye view of the construction site (July 29, 2011).

Figure 7: Construction of the accelerator building (July 31, 2011).

CONCLUSION

One of the goals of PEFP launched by the Korean government in July 2002 is developing a 100-MeV proton linac. The 20-MeV part of the linac has been successfully developed and tested at the Daejeon site. The fabrication of main components of the 100-MeV linac was finished and the preliminary tests are under progress. The linac installation starts from November 2011 after finishing the accelerator tunnel construction. The beam commissioning is scheduled in 2012.

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