BEAM COMMISSIONING OF THE 100 MeV KOMAC LINAC*

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Abstract

The operation of the 100 MeV proton linear accelerator for multipurpose application started in July, 2013 at Korea Multipurpose Accelerator Complex (KOMAC), Korea Atomic Energy Research Institute (KAERI). Also, the operation of the two beam lines, one for 20 MeV beam and the other for 100 MeV beam, started in order to supply proton beams to users. The accumulated operation time was 2,290 hours and the proton beam was supplied to 937 samples in 2013.

INTRODUCTION

After the successful commissioning and getting the operation license of the facility, KOMAC started its 100 MeV proton beam service at July, 2013 [1]. The facility consists of a 100 MeV proton linac including a 50 keV injector, a 3 MeV radio frequency quadrupole (RFQ), and a 100 MeV Drift Tube Linac (DTL), and 20 MeV and 100 MeV beam lines. 100 MeV linac and beam lines are installed in the first floor of the accelerator building, high power RF components including klystrons, circulators and cooling systems are installed in the second floor and the modulators for the klystrons are installed in the third floor. The KOMAC site is shown in Figure 1. As shown in the Figure, ion beam application building and roads are under construction.

Figure 1: KOMAC site

KOMAC 100 MEV PROTON LINAC

The main parameters of the linac are summarized in Table 1. The injector of the KOMAC accelerator consists of a microwave ion source with the extraction voltage of 50kV, and a low energy beam transport (LEBT) for matching proton beams into the RFQ. The LEBT consists of 2 solenoids and 2 steering magnets. The ion source can work in cw (continuous wave) and pulsed modes. The peak beam current is 20 mA.

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The 20-MeV part of the linac consists of a 3-MeV RFQ and a 20-MeV DTL. The peak beam current and the maximum beam duty are respectively 20 mA and 24%. The RFQ is a four vane type with the resonant coupling and dipole rods for field stabilization. The total length of the RFQ is about 3.2 m. The 20 MeV DTL includes four tanks which are driven by a klystron. The FFDD lattice was adopted for the 20-MeV DTL with pool-type quadrupole magnets.

The 100-MeV part of the linac consists of 7 DTL tanks. The maximum beam duty is 8% and the peak beam current is 20 mA. In this part, each klystron drives a DTL tank. The focusing lattice is also FFDD with quadrupole magnets whose integrated field is 1.75 T. The 100 MeV linac installed inside the tunnel is shown in Figure 2 [2][3][4].

Table 1: Parameters of KOMAC Linac

Parameters	Value
Frequency	350 MHz
Beam Energy	100 MeV
Operation Mode	Pulsed
Max. Peak Current	20 mA
Pulse Width	<1.33 ms (< 2.0 ms for 20 MeV)
Max. Beam Duty	8% (24% for 20 MeV)
Max. Beam Power	160 kW (96 kW for 20 MeV)

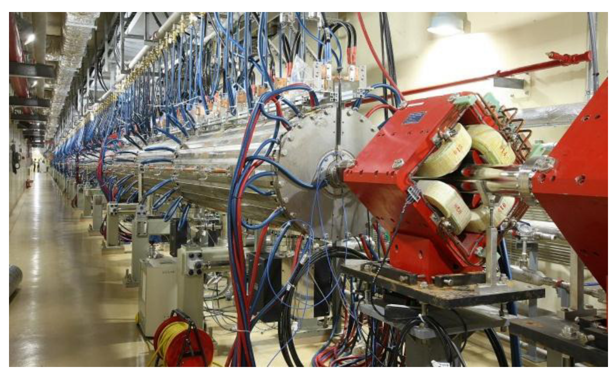

Figure 2: 100 MeV proton linear accelerator

The KOMAC accelerator facility can provide 20 MeV and 100 MeV proton beams to users. The 100 MeV beam line starts from the end of the linac. The 20 MeV beam line extracts proton beams in the middle of the linac. In order to install a 45 degree bending magnets for 20 MeV beam extraction and a beam matching system into the next DTL tank, we installed a medium energy beam transport (MEBT) system after the 20 MeV DTL. Among the 10 beam lines originally designed, KOMAC now opens two beam lines, one for 20 MeV beam (TR23) and the other for 100 MeV beam (TR103). In future, we will

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open the other beam lines step by step. The 100 MeV beam line seen from the accelerator tunnel is shown in Figure 3. The straight beam line corresponds to the TR103 beam line. The inside view of the TR103 target room is shown in Figure 4. External beam is supplied to the sample in TR103 target room. A beam pipe from the beam line comes from the right bottom side of the Figure 4. Beam window made by AlBeMat with 300 mm in diameter is installed at the end of the beam line to extract the proton beam to air. The sample holders and lead shield are also shown in the Figure.

Figure 3: 100 MeV beam line seen from accelerator tunnel to TR103 target room

Figure 4: 100 MeV target room (TR103)

There are 9 klystrons used for driving 100 MeV linac. The specifications of the klystron are such that the peak power is 1.6 MW with 9 % duty factor at 350 MHz.

9 sets of digital low level RF systems are also installed to control the RF amplitude and phase within 1 % and 1° respectively. One of the characteristics of the LLRF system is that one klystron drives four independent DTL tank (which corresponds to 20 MeV DTL) [5].

In order to control the resonant frequency of the DTL, a cooling water systems called a resonant control cooling system (RCCS) are used. There are 11 RCCSs to control the resonant frequency of 11 DTL tanks. The operation range of the temperature is between 21 and 33 °C and it can control the temperature within ±0.1 °C.

There are 4 modulators for a 100 MeV linac. Each modulator drives 2 or 3 klystrons simultaneously. The peak output power is 5.8 MW and the average power is 520 kW with a duty of 9%. The pulse width and the repetition rate are 1.5 ms and 60 Hz, respectively. The modulator used the insulated gate bipolar transistor (IGBT) as the high frequency switching method.

All systems, not only accelerator itself but also utilities, Personnel Safety Interlock System (PSIS) and Radiation Monitoring System (RMS) are controlled in the accelerator control room. Accelerator control system is based on EPICS. During the beam service, the beam line operators communicate with the accelerator operators by using wireless communication. They requests beam conditions and beam starts and so on with double check algorithm.

COMMISSIONING AND ACCELERATOR OPERATION

We used several methods during beam commissioning. There are 16 beam loss monitors (BLMs) installed along the DTL. In addition to the BLMs, radiation monitors are installed inside tunnel, beam line halls and target room. Also beam phase monitors are installed at the downstream of every DTL tanks. We set the RF parameters of each DTL tank roughly by using the BLM and radiation monitor and compared the results with the phase scan method by using the beam phase measurement. The ion chamber was used as a BLM for the DTL. The beam current signal is shown in Figure 5. The upper signal is the output current from the RFQ measured by the FCT, middle signal is the output current from the 20 MeV DTL measured by the ACCT and the lower signal is the current at the end of the 100 MeV DTL. The beam profile was measured at the target room by using the flat panel detector and the result is shown in Figure 6. The rms beam size is 3 mm in diameter with the normal quadrupole magnet current value in the beam line.

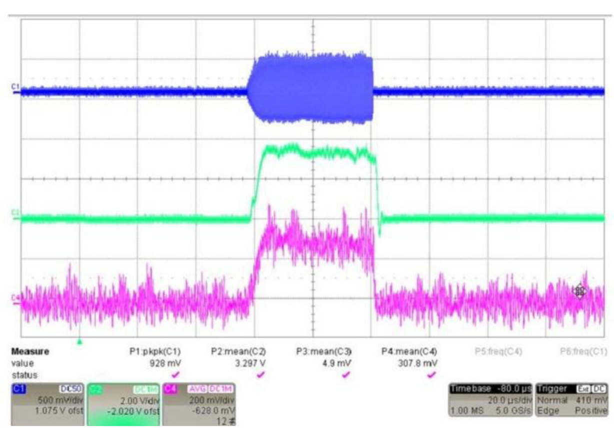

Figure 5: Beam current signal

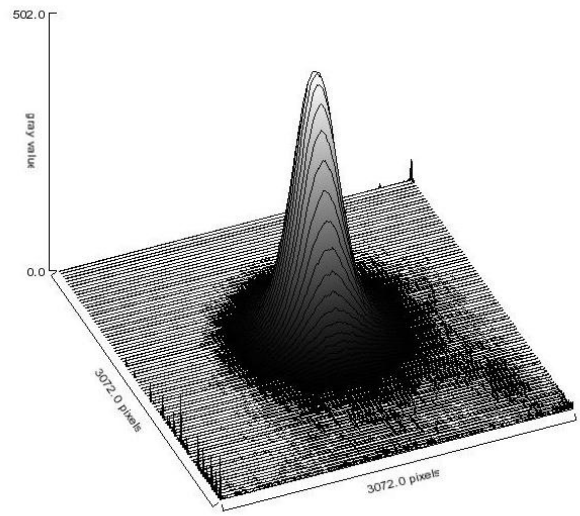

Figure 6: Beam profile at the target room

The operation time was 2,290 hours in 2013 and 1,482 hours in the first half period of 2014. In 2013, 15 weeks were used for beam service, 9 weeks for machine study and 6 weeks for maintenance and upgrade after the start of the beam service in July whereas 25 weeks are planned for beam services, 9 weeks for machine study and 19 weeks for maintenance and upgrade in 2014. There were several trips in the facility and the availability in 2013 was 82.0 %. The downtime of each component in 2013 is shown in Figure 7 and Figure 8 respectively. 40% of the downtime comes from the arcing of the DTL RF power coupler. The down time from the utility reached 28%, which includes shut down of the cooling pumps caused by the momentary electrical power failure, stop of the RF and vacuum related systems caused by the water leak from the fire protection system at the klystron gallery and the vacuum system shut down caused by the mal function of the electrical power contactor. There was also a down time caused by the modulator. The major problems of the modulator were the IGBT blasting in the switching plate and the mal function of the controller.

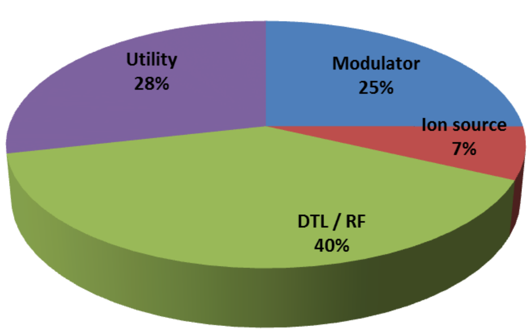

Figure 7: Down time statistics

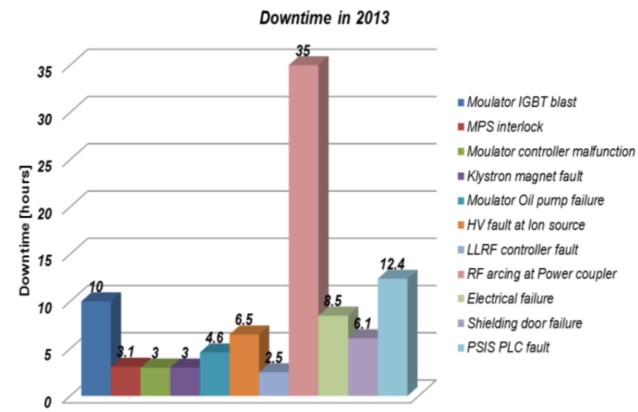

Figure 8: Down time of each component

USER SERVICE

The users, who want to use the proton beams, apply through Korea Proton Beam User Association (KOPUA). KOPUA selects the applications and decides beam service schedule. There were 15 weeks beam service periods in 2013 and 25 weeks planned in 2014.

The operation is based on the weekly plan. And the beam service starts on Monday and finishes on Friday. Before the beam service, the user discusses irradiation conditions with the beam line operator and the beam service is mainly conducted by the beam line operator.

In 2013, total 937 samples were serviced. 83 % of them used 100 MeV beam line as shown in Figure 9. 44 % of the users come from the university and 44% of the users come from the research institute whereas users belong to industry reach 12 % as shown in Figure 10 which tells us that most of the application of the proton beam was the research purpose in this first year user service. Also 56% of the users use the proton beam in the field of basic science and bio & medical science as shown in Figure 11.

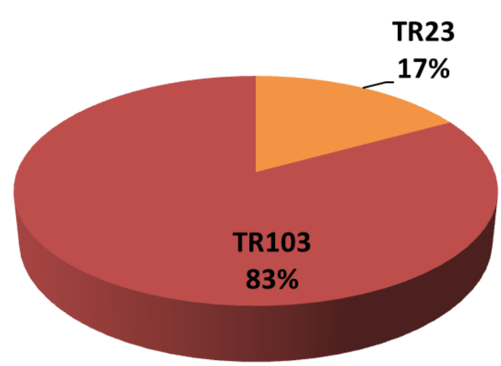

Figure 9: 20 MeV / 100 MeV user ratio

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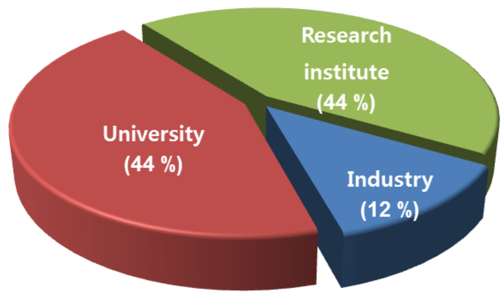

Figure 10: User distribution

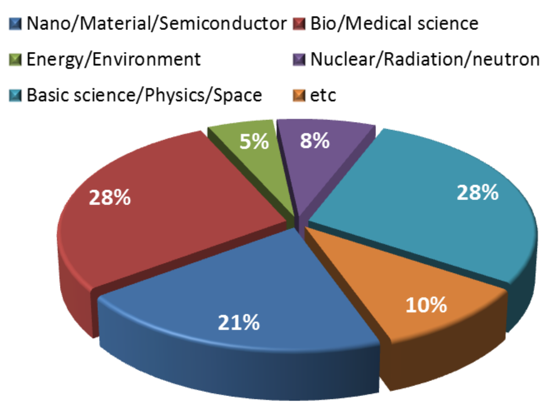

Figure 11: User application field

CONCLUSION

The beam commissioning of the proton linac up to higher beam power is still continuing in parallel with the beam service. The accelerator operation time reaches 3,773 hours from July, 2013 to July, 2014. There was total 129 hours down time during beam service period. Total 1,641 samples were irradiated for one year user beam service period. As a short term plan, we are going to install a RI production beam line by using 100 MeV beam.

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