Operation Status of KOMAC

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1. Introduction

The development of the KOMAC (Korea Multi-purpose Accelerator Complex) accelerator facility was completed early in 2013 and started user service from July 22, 2013. The main accelerator is a 100-MeV proton linac which consists of a 50-keV ion source, a 3-MeV RFQ (radio-frequency quadrupole), and a 100-MeV DTL (drift tube linac). For the user service, it is equipped with the beam lines including target rooms. The linac and beam lines were developed through PEFP (Proton Engineering Frontier Project), the first phase of KOMAC, from 2002 to 2012 [1]. Currently, the accelerator is commissioned with the average proton beam power of about 10 kW. The beam power will be increased gradually up to 96 kW for 20 MeV beam and 160 kW for 100 MeV beam. Two beam lines are operational at present for user service and the number of available beam lines will be augmented to ten, five of which will be dedicated to 20-MeV beam lines and the others to 100 MeV proton beam. Reflecting the increasing demands of radioisotopes for the medical and industrial applications, we are constructing a beam lines for RI production. The status of KOMAC accelerator and beam lines will be presented in this work.

2. KOMAC 100-MeV Linac and Beam Lines

The KOMAC facility is three-story building. The first floor hosts the linac and beam lines. The second floor is a klystron gallery where the high power RF system, RCCS (resonance control cooling system) and various magnet power supplies are located. The third floor is dedicated for modulator room which has four modulators to drive 9 klystrons. The layout of the accelerator building is shown in Fig. 1.

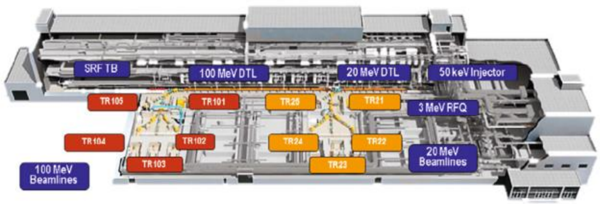

Fig. 1. Layout of the KOMAC accelerator building

The main parameters of the KOMAC linac are summarized in Table 1. The injector of the linac is composed of a microwave ion source with the extraction voltage of 50 kV and a low energy beam transport (LEBT) with two solenoids for matching the proton beam into the RFQ [2]. The peak beam current from the ion source is 20 mA and the beam pulse length can be varied by using a solid state high voltage switch in an oil tank.

Table 1. Main parameters of KOMAC linac.

Parameter	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)

The 20-MeV part of the linac consists of a 3-MeV RFQ and a 20-MeV DTL [3]. The peak beam current and the maximum beam duty are 20 mA and 24%, respectively. The RFQ is a four vane type with the resonant coupling and dipole rods for field stabilization. It is fabricated through vacuum brazing with OFHC (oxgen-free high conductivity) copper. The total length of the RFQ is about 3.2 m. The 20 MeV DTL includes four tanks which are driven by single klystron. The FFDD lattice was adopted for the 20 MeV DTL with pool-type electro-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 DTL tanks are driven by its own klystron to make it easy to control the amplitude and phase of the accelerating field inside the DTL tank. The required RF amplitude and phase stability are 1 % and 1 degree, respectively and achieved by low level RF control system with digital feedback control. The focusing lattice is also FFDD with electro-quadrupole magnets, the integrated field of which is 1.75 T. The 100 MeV linac installed inside the tunnel is shown in Fig. 2 [2-5].

The KOMAC accelerator facility can provide 20-MeV and 100-MeV proton beams to users [6]. In order to fit a 45-degree bending magnets for 20-MeV beam extraction and to match the output beam from 20-MeV section into next 100-DTL section, we installed a medium energy beam transport (MEBT) after the 20-MeV DTL. The beam irradiation specimen is located at a target station in the air. The accelerated proton beam is extracted through beam window made by AlBeMat with 300 mm in diameter, installed at the end of the beam line as shown in Fig. 3

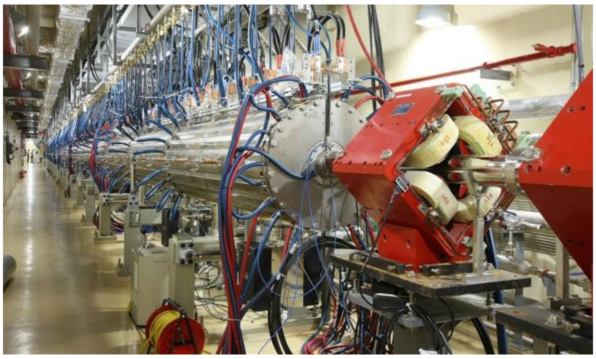

Fig. 2. KOMAC 100-MeV DTL.

Fig. 3. 100-MeV target room. Beam goes from left to right.

3. Commissioning and User Service

The beam commissioning goal in 2013 was 1 kW beam at the 100 MeV target room (TR103) [7, 8]. Most valuable tools during the commissioning were the beam position monitors (BPM) and the beam loss monitors (BLM). In addition to the BLMs, radiation monitors are installed inside tunnel, beam line halls and the target rooms. 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 measured with BPM. We achieved 1-kW beam at TR103 successfully in July, 2013 and got an operation license of the facility, then we started the beam user service. The goal of the beam commissioning in 2014 was 10-kW beam at TR103. For this goal, we increased the operation duty of the RF system up to 10 Hz with 550 us pulse length. The beam current signal measured by beam current monitor during the commissioning is shown in Fig. 4

The operation time was 2,290 hours in 2013, 2,863 hours in 2014 and 1,368 hours in first half of this year. In 2014, 25 weeks were spent for beam service, 9 weeks for the machine study and 19 weeks for maintenance and upgrade. There were several trips during the accelerator operation and the availability in 2014 was 86.3 %. Total downtime was 111 hours in 2014.

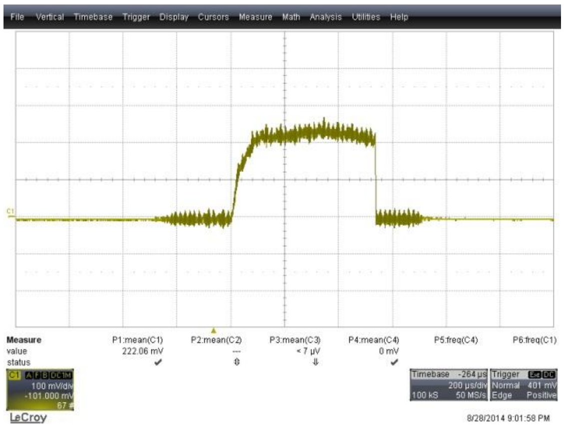

Fig. 4. Beam current signal (550 us)

The downtimes of each component in 2014 are shown in Fig. 5 and Fig. 6. Downtime due to ion source problem amounts to 40% of total downtime. Main issues were the magnetron faults and the high voltage switch failures. Downtime related with the utility reached 20%, which includes shielding door problem and the target holder failure at the target room. For the DTL, we experienced the vacuum trouble caused by the RF arcing at the slug tuners in the DTL tanks. We solved the problem by augmenting the RF seal at the slug tuners. The malfunction of the three-way valve is main source of the trips in the RCCS. There was also a downtime related with the modulator. The major problems of the modulator were the IGBT blasting in the switching plate and the malfunction of the controller. It took about 5 hours to replace the failure IGBT with new ones, including test.

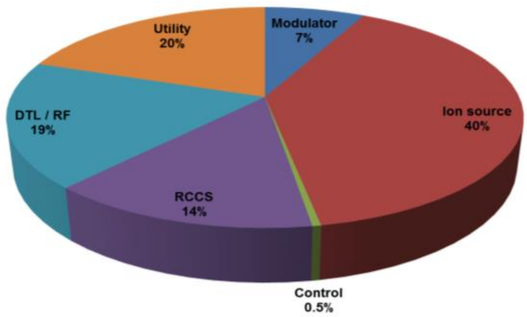

Fig. 5. Downtime statistics in 2014.

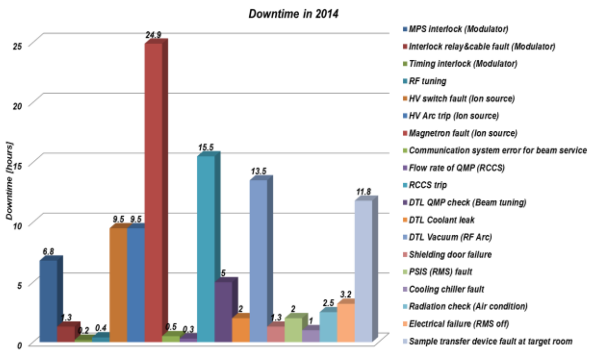

Fig. 6. Downtime of each component in 2014.

The users, who have a plan to use the proton beams, apply through Korea Proton Beam User Association (KOPUA). KOPUA selects the applications and decides beam service schedule. There were 25 weeks beam service periods in 2014 and 27 weeks planned in 2015.

The operation is based on the weekly plan and the beam service starts on Monday and finishes on Friday. Total 2,150 samples from various R&D fields, as shown in Fig. 7, such as biomedical science, nuclear data, neutron science and semiconductor applications were treated in 2014. About half of the samples come from the research institutes and the samples from industry amount to 7 % as shown in Fig. 8.

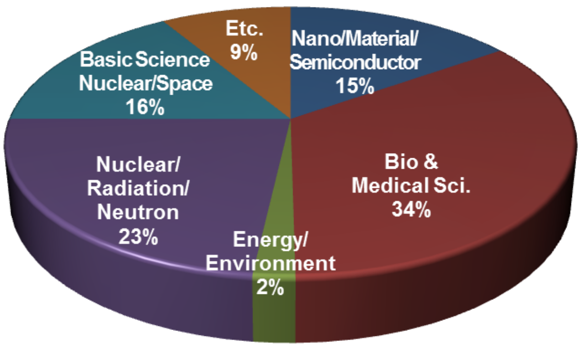

Fig. 7. Treated samples distribution according to R&D fields.

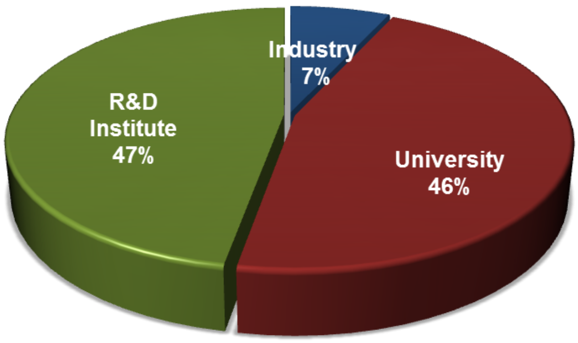

Fig. 8. Treated samples distribution according to affiliations.

4. Conclusion and Future Plan

The original design of the KOMAC facility includes ten beam lines and just two of them are currently operational. We are going to increase the number of the available beam lines step by step. As a short-term plan, a beam line for RI production is under construction. High-power proton accelerator like KOMAC can be used for new medical radio-isotope production, such as Sr-82, Cu-67, Ge-68 and Na-22. For Sr-82, it has been commercialized already because of rising demands in the market and the successful development of radiopharmaceuticals. The layout of the RI beam line and dedicated target room (TR101) is shown in Fig. 9. For that beam line, new bending magnets and beam pipes are already installed as shown in Fig. 10 and new beam window based on AlBeMet is under fabrication. In addition, the production target system and RI handling system including hot cell are being prepared.

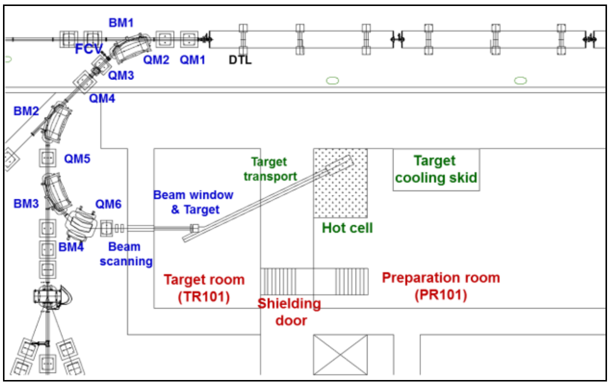

Fig. 9. Layout of RI production beam line and target room.

Fig. 10. Newly installed 45 degree bending magnets.

The beam commissioning of the proton linac up to higher beam power is still continuing in parallel with the beam service. The average beam power along with augmentation of the beam line will be increased based on the schedule shown in Fig. 11. In addition, an upgrade plan of the 100-MeV linac to a 1-GeV, 2-MW linac with pulsed spallation neutron sources is included in the National Facility Roadmap. When all of these plans are realized, the KOMAC will be a unique research complex at which high quality beams of proton, neutron and possibly other particles are available for the exploration of the frontiers of science and technology.

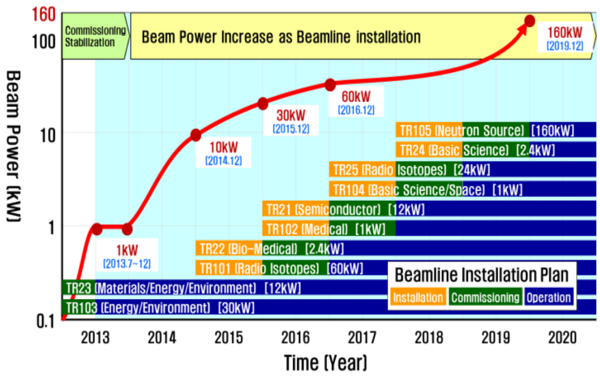

Fig. 11. Beam power and beam lines upgrade plan.

Acknowledgements

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