BEAM COMMISSIONING OF KOMAC LINAC*

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Abstract

The KOMAC (Korea multi-purpose accelerator complex), whose first phase is the proton engineering frontier project, developed a 100-MeV proton linac which consists of a 50 keV injector, a 3-MeV radio frequency quadrupole (RFQ) and a 100-MeV drift tube linac (DTL). The installation of the linac was finished and in commissioning stage. The goal of the beam commissioning in June 2013 is accelerating 100-MeV proton beams with the beam power of 1 kW to the beam dump which is located downstream of the linac. This work summarized the present status and plan of the beam commissioning of the linac.

INTRODUCTION

The KOMAC accelerator facility consists of a 100-MeV proton linac and 20-MeV and 100-MeV beam lines[1, 2]. The linear accelerator consists of a 50keV proton injector, a 3-MeV RFQ, and a 100-MeV DTL. The DTL is separated into two parts, one for 20-MeV proton beams with 4 DTL tanks and the other for 100-MeV with 7 DTL tanks. There is a medium energy beam transport (MEBT) between two parts of DTL for extracting 20-MeV proton beam by a 45-degree bending magnet, and matching beams into the next DTL tank with 8 quadrupole magnets and 2 rf cavities. The matching part is realized by 2 small DTL-type tanks with 3 cells [3].

The operation frequency of the linac is 350MHz and the peak beam current is 20 mA. The maximum beam duty is 24% for 20-MeV part of the linac and 8% of 100-MeV proton beams. Hence the beam power becomes 160kW at the end of the linac. Figure 1 shows the linac in the accelerator tunnel. The specification of KOMAC100-MeV linac is given in Table 1.

Figure 1: 100-MeV proton linac installed in the accelerator tunnel.

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Table 1: Specification of KOMAC 100-MeV Linac

Parameters	Low energy	High energy
Output Energy	20 MeV	100 MeV
Peak beam Current	20 mA	20 mA
Beam Duty	24%	8%
Pulse Width	2 ms	1.33 ms
Repetition Rate	120 Hz	60 Hz
Average Beam Current	4.8 mA	1.6 mA
Average Beam Power	96 kW	160 kW

20 MeV COMMISSIONING PLAN

The beam commissioning of the KOMAC 100-MaV linac is separated into 2 steps, one for 20-MeV proton beam with a beam stop located in MEBT, and the other for 100-MeV beams with a beam dump located at the end of the linac.

The 20-MeV part consists of the ion source, RFQ, and 4 tanks of DTL [4]. The injector consists of a microwave ion source with the extraction energy of 50 keV for the proton beams with the peak beam current of 20 mA, and the low energy beam transport (LEBT) with two solenoids and two steering magnets for matching proton beams into RFQ. The design value of the beam emittance is 0.2 π mm-mrad in the normalized rms unit. The RFQ can accelerate proton beam beams up to 3 MeV. It is four vane type and uses the resonant coupling scheme and dipole stabilizing rods. The operation point of the RFQ is determined by comparing the measured beam transmission through the RFQ with the PARMTEQ result. The simulation result is given in Figure 2. The 20-MeV part of DTL includes 4 tanks which are driven by a 1-MW klystron. In the first step, the relative rf phases between DTL tanks are carefully adjusted to zero. Then four DTL tanks can be treated as a cavity and the operating point can be determined by the usual phase scan method. Table 2 shows the output energy of each 20-MeV DTL tank.

Table 2: Input and Output Energies of 20-MeV DTL Tanks

	Input Energy (MeV)	Output Energy (MeV)
DTL21	3.0	7.2
DTL22	7.2	11.5
DTL23	11.5	15.8
DTL24	15.8	20.0

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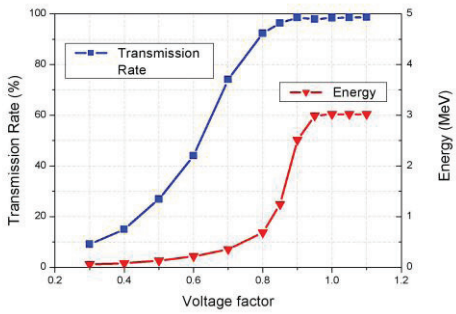

Figure 2: PARMTEQ result of the beam transmission in the KOMAC RFQ.

The required values of the quadrupole magnetic field and cavity field for beam matching in MEBT were determined by a TRACE3D simulation [5] as shown in Figure 3. We performed the beam dynamics simulation by using the PAMILA code [6] under the condition determined by TRACE3D in order to check beam loss in MEBT. The PARMILA simulation result is given in Figure 4 through whole DTL tanks from 20 MeV to 100 MeV. The beam diagnostic elements in MEBT system are a Faraday cup and two current transformers for beam current measurement, and two beam position monitors. It also includes 2 steering magnets to adjust the beam trajectory injected into the next DTL tank.

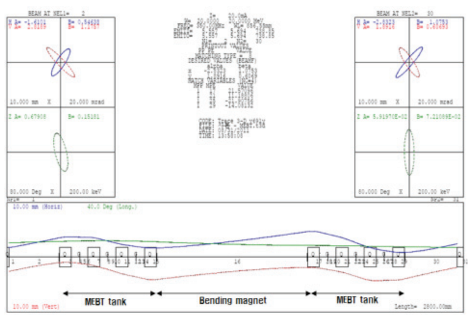

Figure 3: Determination of the beam matching condition in the MEBT system (TRACE3D calculation).

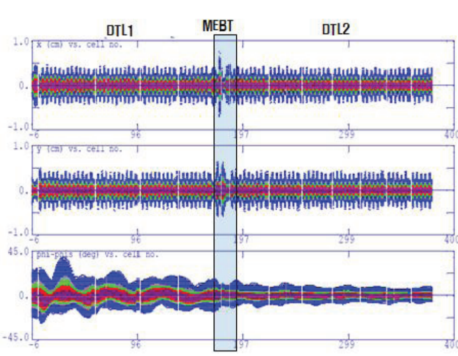

Figure 4: PARMILA result of beam simulation.

INITIAL TEST RESUT OF 20 MeV PART

The 20-MeV part of the linac had been operated at Daejeon site of KAERI until 2011. Hence the 20-MeV linac commissioning is a retesting process of the linac operation condition at Daejeon. After conditioning the 20-MeV linac cavities for few days in April 2013, rf powers reached to 400 kW in RFQ and about 130kW for each DTL tanks. The rf signal of RFQ and DTL is given in Figure 5 and Figure 6, respectively. In Figure 5, the red, blue, and green lines are the forward power, reflected power, and cavity power going into RFQ, respectively. The four lines in Figure 6 represent the signals of the cavity powers in the 20-MeV DTL tanks.

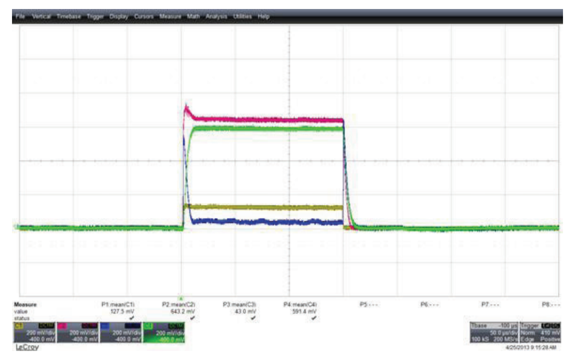

Figure 5: The rf signal for the 3-MeV RFQ.

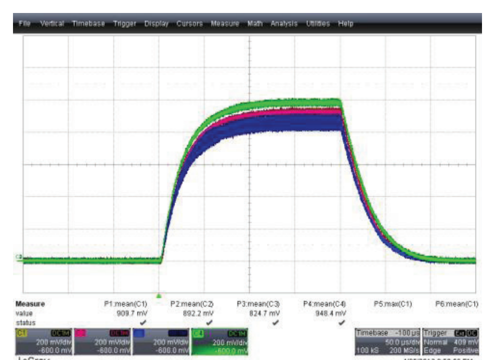

Figure 6: The rf signal of forward power in each DTL tank of KOMAC 20-MeV linac.

Under this rf condition, we could accelerate proton beams up to 20-MeV with the peak beam current of 1 mA. Figure 7 is the initial beam signal of the RFQ and 20-MeV DTL. They are measured by a current transformer located between RFQ and the first tank of 20-MeV DTL, and a Faraday cup in MEBT. In this experiment, we checked the performance of rf system, the resonant control cooling system, the control system, and the beam diagnostics. We plan to perform the optimization of the operating condition of the linac in the 100-MeV beam commissioning process in May 2013.

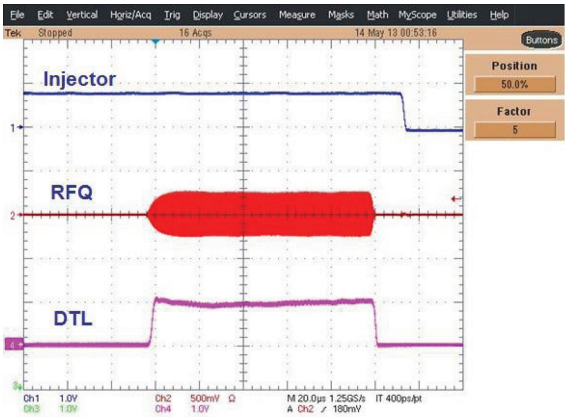

Figure 7: Initial beam signal of the 3-MeVRFQ and 20-MeV DTL.

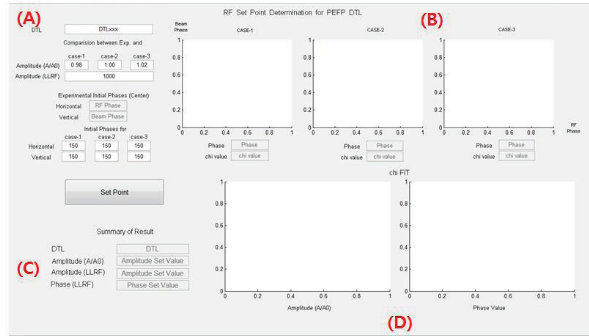

Figure 8: Screen for beam commissioning program.

100 MeV BEAM COMMISSIONING PLAN

The 100-MeV DTL consists of 7 tanks [1]. Each tank is driven by a 1.6-MW klystron. We adopted FFDD lattice in DTL tanks with the integrated field of 1.7 T for quadrupole magnets in drift tubes. The design input and output energies are summarized in Table 2. We will determine an rf set point of each DTL tank [7, 8] by using a conventional phase scan method [9]. The beam phase of each tank will be measured by a beam position monitor installed in the drift space between tanks.

Table 2: Input and Output Energies of the KOMAC 100-MeV DTL Tanks

	Input Energy (MeV)	Output Energy (MeV)
DTL101	20.0	33.1
DTL102	33.1	45.3
DTL103	45.3	57.3
DTL104	57.3	69.1
DTL105	69.1	80.4
DTL106	80.4	92.0
DTL107	92.0	102.6

The beam phases are measured as a function of rf phase for a fixed value of the rf amplitude. The measured beam phases are compared with PARMILA simulation results with different values of the rf amplitude to calculate χ^2 for each amplitude. The minimization condition in quadratic fitting of χ^2 values can determine the optimized rf set point of the amplitude and phase. Figure 9 shows a screen of a MATLAB-based program to determine the rf set-point, (a) input parameters, (b) χ^2 calculation by comparing an experimental result with simulation results, (c) rf amplitude and phase determined by quadratic fittings in (d). The detail of rf set point determination can be found in Ref [8].

CONCLUSION

The KOMAC 100-MeV linac is in beam commissioning stage. The initial test of 20-MeV part of the linac was successfully performed in April 2013. The 100-MeV beam commissioning starts in May 2013 and will be finished until June 2013. The linac facility will be in operation period to supply proton beams to users from July 2013..

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