

Beam Simulator for KOMAC 100 MeV proton linac

Sung-Kyun Park^a, Young-Gi Song^a, Hyeok-Jung Kwon^a, and Yong-Sub Cho^a
^aKorea Multipurpose Accelerator Complex, Korea Atomic Energy Research Institute,
181, Mirae-ro, Geoncheon-eup, Gyeongju-si, Gyeongsang buk-do, 780-904, Korea
*Corresponding author: skpark4309@kaeri.re.kr

1. Introduction

The Korea multi-purpose accelerator complex (KOMAC) is a multi-user facility that provides a high-intensity proton beam for a variety of user programs. A main equipment of the facility is a proton linear accelerator that is comprised of a 50 keV injector, 3-MeV radio frequency quadrupole (RFQ), and 100-MeV drift tube linac (DTL). In this facility, there are periodically fresh operators, who do not have any experiences about the accelerator control system. A proton beam simulator for 100-MeV proton linear accelerator is currently under development at KOMAC in order to be used as the training program for these new operators.

The facility has very limited information about the beam dynamics inside of the accelerator during the routine operation because of the limited number of diagnostic tools. A operational goal of maintaining the high beam quality and minimal beam loss can not be achieved without the detailed knowledge of the beam distribution. In a desirable situation of the accelerator operation, the knowledge of the beam distribution along the proton linac can be available to help the beam performance and the linac operation to be optimized. After getting real-time operational parameters through the accelerator control system, the simulation will be updated quickly and then the simulator will display user-requested beam quality values at any proper location along the accelerator.

2. Code structure

The code structure of the simulator is shown in Fig.1. The proton beam simulator is based upon the beam dynamics simulator algorithms of the PARMILA code [1], but implemented in C++ GUI programming with Qt 4 [2].



Fig. 1. Top level code structure of the proton beam simulator.

On the Input side, the input monitor is identical with the one of the real accelerator operation system. Qt 4 makes the input text for the PARMILA code based on the

input information earned by the input side of Qt 4. The simulation result shown in Fig. 2 is made from the PARMILA code. Python programming language draws the beam distribution in the x and y axes. On the output side, the beam distribution graphs of x vs y made by python are displayed on the Qt 4 monitor. The beam distributions made in the several part of the proton linac are shown with beam transmission, that is, after RFQ, after DTL I (20-MeV DTL), after DTL II (100-MeV DTL), and TR103 (100-MeV Beam line).

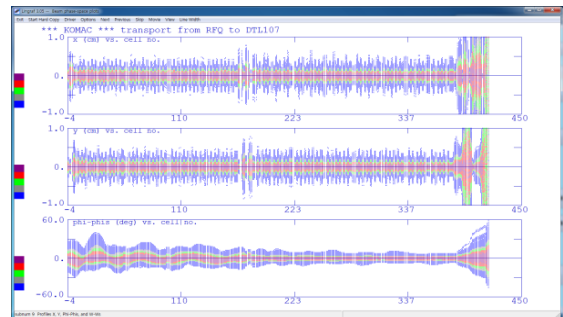


Fig. 2. The simulation results of the PARMILA code. From top to bottom are x, y, and energy coordinates versus cell number.

3. Input parameters

Three values of several parameters of the real accelerator operation system are chosen as the input values of the simulator: a quadrupole current, an amplitude and phase of low level radio frequency (LLRF), and a temperature of a resonance frequency control cooling system (RCCS).

2.1 Quadrupole current

The magnetic-quadrupole lens [3] is the most useful method to compensate the transverse RF-defocusing effects in linac. The quadrupoles installed in the proton linac of KOMAC are located within the drift tubes in DTLs. Fig. 3 shows the input monitor used to enter values of the quadrupole currents in the beam simulator.



Fig. 3. The input monitor for the quadrupole current in the beam simulator.

For a particle moving along the z direction with velocity v and with transverse coordinates (x, y) , the Lorentz force components are

$$F_x = -qvG_x, F_y = qvG_y$$

$$\text{where } G = \frac{\partial B_x}{\partial y} = \frac{\partial B_y}{\partial x} \quad (1)$$

If qG is positive, the lens focuses in the x axis and defocusing in the y axis. When the quadrupole current is increased, the transverse quadrupole gradient, G is also increased. The transverse distribution of the proton beam in the simulator is controlled by the quadrupole current.

2.2 Amplitude and phase of LLRF

A single mode of an accelerating cavity is described as a parallel resonant circuit driven by a current generator with frequency ω . The axial voltage in the cavity, $V(t)$ is

$$V(t) = \frac{RI_0}{\sqrt{1 + \gamma^2}} \cos(\omega t + \varphi + \varphi_\gamma + \delta) \quad (2)$$

where R is a circuit shunt resistance and φ is the phase of the resonator voltage relative to the driving current. δ is a synchronous phase. The amplitude of LLRF is defined as RI_0 in the equation (2) and the phase of LLRF is φ . Fig. 4 shows the input monitor used to enter values of LLRF in the beam simulator.

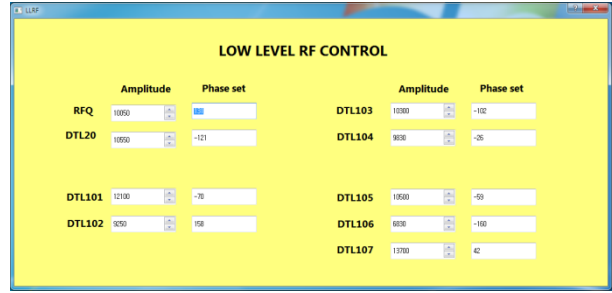


Fig. 4. The input monitor for Low Level RF in the beam simulator.

2.3 Temperature of RCCS

RCCS, the thermal tuning system of the DTL, compensates for the temperature variation of the accelerator's inner room [4]. That is, this system removes the dissipated heat from the copper RF structure of each DTL and maintains the resonance frequency through the active temperature control. The resonance frequency drops under 4 kHz with every 1 °C of temperature rise.

In the equation (2), φ_γ is the phase happened by the detuning factor, γ and defined as $\varphi_\gamma = -\tan^{-1} \gamma$. The detuning factor, γ in the case of the loaded quality factor $Q \gg 1$ is given as

$$\gamma = 2Q \frac{\omega - \omega_0}{\omega_0} \quad (3)$$

where ω_0 is the resonant frequency. Fig. 5 shows the input monitor used to enter values of temperatures of RCCS in the beam simulator. The variation of these temperatures make ω_0 changed and the amplitude and phase of the axial voltage will be also modified.



Fig. 5. The input monitor for temperatures of RCCS in the beam simulator.

4. Output beam distributions

Beam distributions and beam transmissions made as a result of the simulator are shown in Fig. 6. Since result plots are changed according to these input parameters, the propriety of input parameters can be decided from the result of the output monitor.

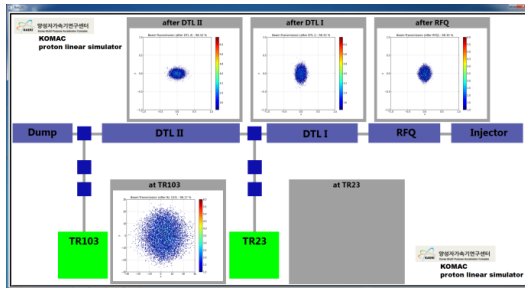


Fig. 6. The output monitor of the beam simulator.

3. Conclusions

In this work, the beam simulator for KOMAC 100 MeV proton linac is not only developed as the training programs for the new operator, but will be also used to optimize the beam quality inside of the accelerator during the beam operation.

ACKNOWLEDGMENTS

This work was supported by Ministry of Science, ICT & Future Planing.

REFERENCES

- [1] H. Tadedo, J. Billen, PARMILA, LANL publication, LA-UR-984478, 2005.
- [2] J. Blanchette, M. Summerfield, C++ GUI Programming with Qt 4, Second Edition, 2008
- [3] J.P. Blewett, Radial Focusing in the Linear Accelerator, Physical Review, Vol.88, p.1197, 1952
- [4] H. Kwon, Resonance frequency control characteristics of the 100-MeV drift tube linac, Proceeding of IPA2013, THPWO068, 2013