Optimization of Beam Transmission of PAL-PNF Electron Linac

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1. **Introduction**

The PNF (Pohang Neutron Facility) electron Linac is providing converted neutrons and photons from electron beams to users for nuclear physics experiments and high energy gamma-ray exposures. This linac is capable of producing 100 MeV electron beams with a beam current of pulsed 100 mA. The pulse length is 2 μs and the pulse repetition rate is typically 30 Hz. This linac consists of two SLAC-type S-band accelerating columns and the thermionic RF gun. They are powered by one klystron and the matching pulse modulator. The electron beams emitted from the RF gun are bunched as they pass through the alpha magnet and are injected into the accelerating column thereafter.

In this paper, we discuss procedures and results of the beam transmission optimization with technical details of the accelerator system. We also briefly discuss the future upgrade plan to obtain short-pulse or electron beams for neutron TOF experiments by adopting a triode type thermionic DC electron gun.

2. Beam transmission optimization

2.1 Description of Linac System

As shown in Fig.1, the Linac consists of the thermionic RF-gun, QDs, STs, Alpha magnet, two S-band SLAC-type accelerating structures, PGVs, BAS, and QTs in the tunnel. And also, it consists of the timing system, 80 MW modulator, oscillator, SSA, and SLAC 5045 klystron that feeds RF powers to both the RF-gun and two accelerating structures in the klystron gallery. There are BCMs and BPRMs to detect electron beam current and monitor beam profile.

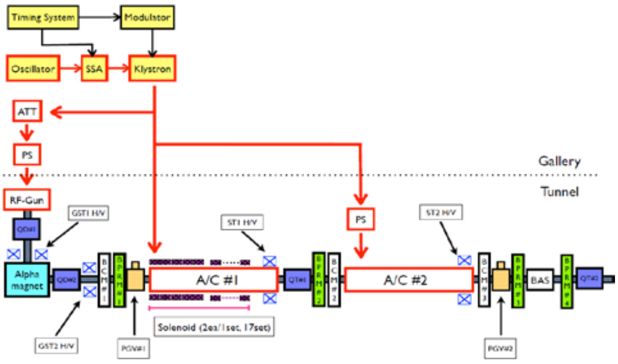

Figure 1: Electron Linac layout (QD : Quadrupole Doublet, ST : Steering Coil, QT : Quadrupole Triplet, BPRM : Beam Profile Monitor, BCM : Beam Current Monitor, SSA : Solid State Amplifier, A/C : Accelerating structure, PS : Phase shifter, ATT : Attenuator, BAS : Beam Analyzing Station).

The accelerator parameters of the linac including the RF and beam optics systems are listed in Table 1.

Table 1: The parameters of the PNF electron linac components

Beam	
Energy (MeV), *max*	100
Pulse Beam Current (mA)	100
Pulse length (μs)	2
Pulse Repetition Rate (Hz)	30
Klystron	
Output power (MW), *max*	65
Beam Vol (kV)/Current (A)	350/420
Conversion Efficiency (%)	45
Modulator	
PFN Charging Voltage (kV)	42
PFN Impedance (Ω)	2.3
Pulse transformer turn ratio	1:17
RF-gun	
Beam Energy (MeV), *max*	2.5
Beam current (mA), *max*	500
Alpha Magnet	
Pole Radius (cm)	2.5
Field Gradient, max. (T/m)	1.8
Good Field Region (cm)	14
Field Well Distortion (δG/G)	<1%
Quadrupole Doublet (2 sets)	
Pole Radius (mm)	20
Effective Length (mm)	50
Accelerating Structure (2 sets)	
Mode (π)	2/3
Frequency (MHz)	2,856
Type	*Constant grad*
Length (m)	3
Quadrupole Triplet (2 sets)	
Pole Radius (mm)	22
Effective Length (mm)	100

2.2 Beam transmission optimization of Linac

The magnetic field strengths of the QDs, QTs, STs, solenoids, and alpha magnet are adjusted in order to maximize transmission rate of the electron beam. The alpha magnet reduces the bunch length in order to improve capture efficiency by RF in the accelerating column. Since the alpha magnet requires the exact incident angle of 40.7 deg. [3], the incident angle into the alpha magnet should be controlled by the steering coil – GST1 (in Fig. 1). The electron beams are focused by a set of QDs – QD#1 and QD#2 before the accelerating column and by a series of solenoids in the accelerating column.

An experiment was conducted to control optics of the electron beam in the following manners. First, Beam current measured at BCM#1 was controlled by adjusting the magnets around the alpha magnet. Second, beam current measured at BCM#3 was confirmed after adjusting the magnet devices after the BCM#1. Third, the preceding process was repeated when transmission was not high enough. The BCM#1 is the measured value of beam current at the exit of the alpha magnet and BCM#3 is the measured value of beam current at the second accelerating structure.

Figure 2 shows the measured beam current at BCM#1and BCM#3 with current transformers of 2 V/A. The beam currents at BCM#1 and BCM#3 are 120 mA and 110 mA, respectively. After optimization of magnets, we obtained the transmission of about 91%.

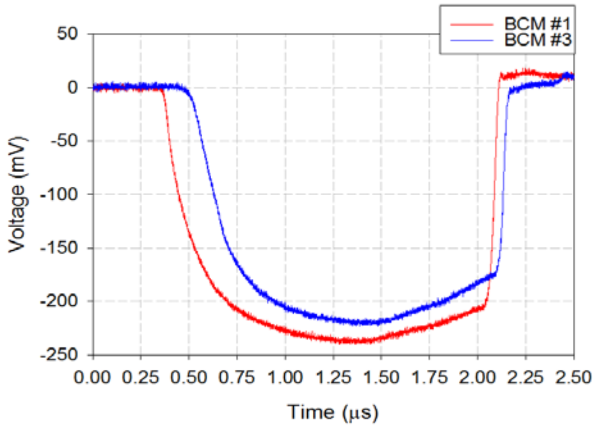

Figure 2: Beam currents at BCM#1 and BCM#3.

Figure 3 shows transverse profiles of the electron beam at BPRM#1 and BPRM#4. BPRM#1 is placed after the alpha magnet while BPRM#4 is placed close to the neutron/gamma-ray conversion target to predict the beam image on that target. As shown in Fig. 3, the transverse profile of the electron beam at BPRM#4 is out of round compared with that at BPRM#1. More study on the beam optics tuning is supposed to be required

(a)

(b)

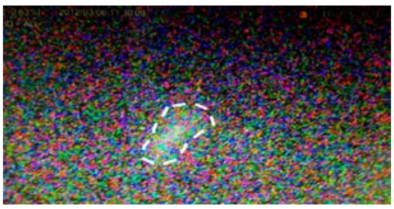

Figure 3: Transverse beam profiles at BPRM#1 (a) and BPRM#4 (b).

3. Summary and Future Plan

In the recent beam re-conditioning of PLS-PNF electron Linac, we obtained the beam transmission rate of 91% by adjusting the magnets. Nevertheless, more optimization is required for well-focusing and then a round shape of the transverse beam profile. One-to-one comparison between the simulation and measurement will be performed. The image capturing method will be improved using a frame grabber for the CCD camera. This optimization will be conducted to minimize the beam energy spreads with measurement by the bending magnet as well as to maximize the beam current transmission.

The PLS-PNF electron Linac has an upgrade plan to adopt a thermionic DC e-gun. With the triode e-gun, this linac will provide ~10-ns short pulse electron beams at ~1 A or 2-µ s long pulse beams at ~500 mA. The pre-buncher and buncher cavities are now being designed and will be fabricated at PAL.

Figure 4 : A photo of PLS-PNF electron Linac tunnel.

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