PLS-II LINAC UPGRADE

Byung-Joon Lee, Soung Soo Park, Sang Hee Kim, Youngdo Joo, Changbum Kim, Mungyung Kim, Jea-Young Choi, Ilmoon Hwang, Sung-Ju Park, Taekyun Ha, Yoon-Gyu Son, S. Chunjarean, Sei Jin Kwan, Seunghwan Shin, Jung Yun Huang, and Sang Hoon Nam
Pohang Accelerator Laboratory, Pohang, Kyungbuk 790-784, KOREA

Abstract

We report on the recent status of the Pohang Light Source (PLS-II) linac at Pohang Accelerator Laboratory (PAL). From 2009, the linac upgrade has been started increasing its energy from 2.5 GeV to 3 GeV aiming stable top-up operation. Top-up operation requires high energy stability from the linac beam energy and machine reliability of the linac modulator systems. Especially, thus we present machine stability including RF and modulators as well as beam energy stability using diagnostic system. Finally, we will discuss the beam stability optimization.

PLS-II LINAC

The pre-injector system in PLS-II consists of the electron gun, the bunching system (a pre-buncher and a buncher) and two accelerating columns reaching electron beam energy of about 100 MeV as shown in Fig. 1.

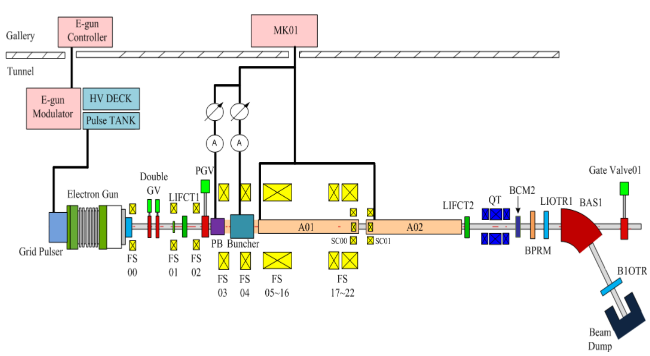

Figure 1: PLS-II pre-injector layout with position of beam diagnostic station.

The electron gun for the PLS-II is the same one used in PLS. It is the triode type with a < 1 ns (or 250 ps) grid pulser to generate short pulse to fit into storage ring rf buckets (~0.8 ns with 4 rf cavities at present). In PLS-II, to replace the electron gun system quickly for the emergency case, dual vacuum valves system was inserted in between the electron gun and the pre-buncher. Also one more focusing solenoid was placed adjacent to the electron gun to minimize the beam spread due to increasing drift length by dual vacuum valves system. To measure the absolute value of the beam current and the beam charge from the electron gun and those from just after through the bunching system (pre-buncher and buncher), two fast current transformers (FCT, Bergoz) were installed. The beam current from the electron gun with the < 1ns grid pulser is shown in Fig. 2. The peak current and the charge (i.e. the area of the current waveform) were 1A and 1.26 nC respectively. The duration of the electron beam was about 2 ns at base. The electron beam jitter with respect to the reference signal for the gun grid pulser was 60 ps in peak to peak.

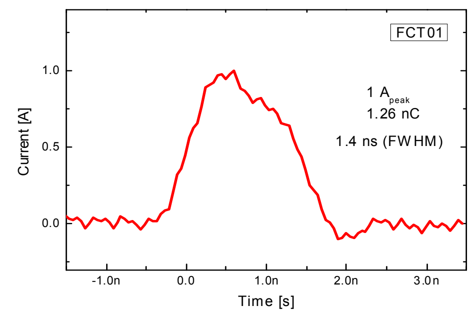

Figure 2: Electron beam profile from electron gun in PLS-II

Bunching system including a standing wave pre-buncher in 2856 MHz, a 4-cell travelling wave bucher (0.5c to 0.75c) and two accelerating columns generates 100 MeV electron beams. This electron beam has 5 micro-bunches with their peak to peak deviation of 350 ps. Micro-bunch length of less than 10 ps is expected with proper operation.

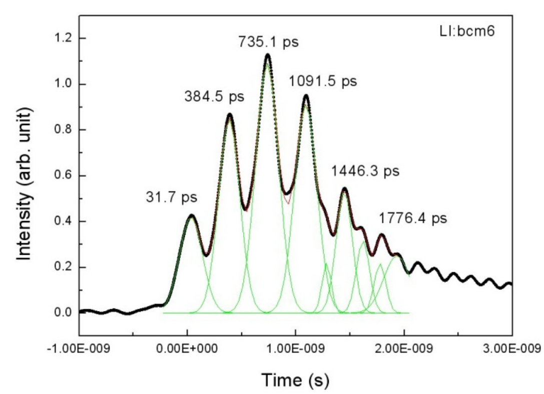

Figure 3: Bunching pattern from BPM6 in the Linac.

One of most important beam parameters to identify the beam quality is a transverse emittance of electron bunches. During the commissioning (June 2011), the

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beam emittance and twiss functions at 100 MeV are measured in order to match the beam optics to beam transport line and go through it to the storage ring. To get the transverse emittance measurement, well-known technique, quadrupole scan, is used at the pre-injector (see Fig. 1). In PLS, its measurement was done several times but not presented well. In PLS-II we measured beam emittance in horizontal only because we found that the strength of the quadrupole magnet was not strong enough resulting in poor focusing the beam in vertical direction. The horizontal beam parameters at the entrance of the quadrupole were ε_x[mm-mrad] =0.5911, β_x[m] = 6.691, α_x=-0.1692 and γ_x=0.1537.

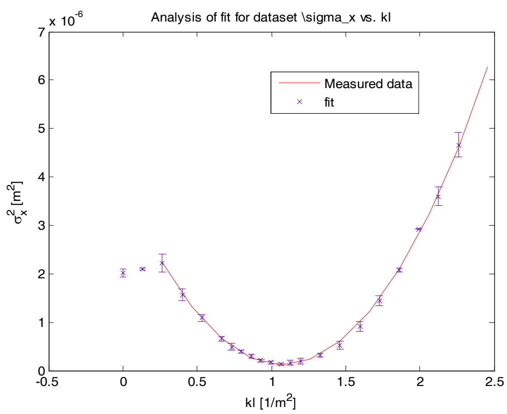

Figure 4: Focusing quadrupole scan for rms nomalized emittance in horizontal plane.

Other pivot parameters for the PLS-II linac will be the energy spread which should be less than 0.2% rms and energy jitter (< 0.2%) for the top-up operation. Table 1 shows the summary of the parameters for the PLS-II linac.

Table 1: PLS-II Linac parameters.

Beam Energy	3 GeV
Transverse Emittance	<70 nm mrad
Energy Spread	< 0.2 % in rms
Energy Stability	< 0.2 % in rms
Machine length	~160 m
# of Accelerating column	46
# of Klystrons	16
SLED Energy Gain	~1.5

End April 2012, we developed real time energy monitoring system using OTR target after HB1 which is placed at the starting point of the BTL. The OTR target (580 nm aluminium coating on the 50 microns polyimide film) is thin enough to pass the electron beam minimizing the influence on the beam characteristics. That is why, we are able to monitor the beam energy spread and stability in real time during the beam operation. Fig. 5 shows the real time monitoring window in the operating room. The electron beam on the OTR target is taken by CCD camera and is plotted in Gaussian fitting to compute the energy spread and stability.

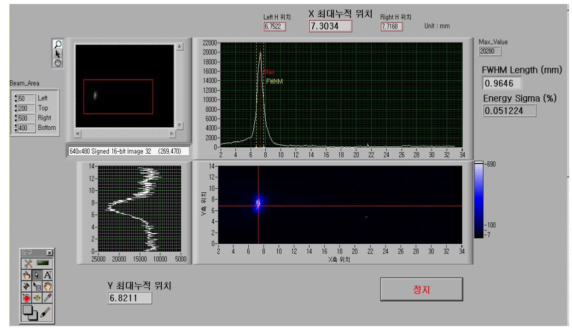

Figure 5. Real time monitoring for energy spread and jitter

During the top-up operation test, the energy spread σ_E=Δp/p was obtained about 20 seconds per every 3 minutes resulting in ~0.2% in rms. As seen in Table 1 our target for energy spread is < 0.2%. To obtain the low energy spread could be by both operating at the crest phase and reducing micro-bunch length determined by the velocity and the phase of particles at the entrance of and field gradient of the first accelerator column [2]. Our case to get energy margin for the beam injection, the last klystron (MK16) phase is at the out of phase now. In PLS-II, to ensure the low energy spread, we installed a slit at the dispersive section just after horizontal bending magnet (HB1) at the early of BTL. The energy stability was 0.2% for 10 hrs measurement. This value satisfies the PLS-II Linac parameters but in fact we could see the shot by shot drift during the beam injection. This might be strongly decoupled with energy stability. To further increase the energy stability, stabilities in the modulator, in the klystron amplitude and phase, and in the SLED amplitude and phase must be improved.

To increase the energy for the PLS-II linac, we added two more accelerating columns to the PLS linac as shown in Fig. 6. Last four accelerating columns are made by Mitsubish, Japan and other 42 accelerating columns are provided by IHEP, China. Totally 46 accelerating columns are used. The estimated maximum average accelerating energy gradient is 30 MV/m for Mitsubish one and 25 MV/m for IHEP one respectively. In order to achieve electron beam energy from 2.5 GeV to 3 GeV, four units of the modulator systems were added. Thus totally, 16 high power klystron and modulator units labelled MK01~MK08 (Line type modulator) and MK09~MK16 (Inverter type modulator) are used. Four accelerating columns are connected to a klystron for MK02~MK08 (MK01 has two accelerating columns). From MK09~MK16, two accelerating columns are connected to a klystron [3]. This indicates four accelerating columns for one klystron were split into 2 two accelerating columns for two klystrons feeding by inverter type modulator. In addition, 14 SLED cavities having the energy gain of 1.5 are used. No SLED is on MK01. SLED for MK09A is not installed at present due to the conditioning trouble. This will be installed during the maintenance period in this summer. The present status of the modulator and RF system for PLS-II Linac refers to [3, 4].

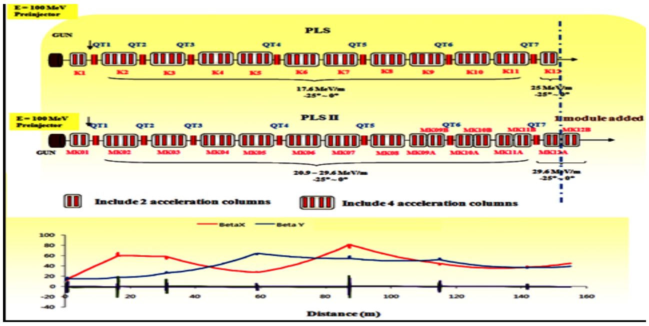

Figure 6. Lattice layouts of PLS and PLS-II Linacs.

Table 2: Average stability of MK in PLS-II.

		Average stability
Modulator	HV	0.084
Klystron	Amp.(%)	0.32
	Phase(deg.)	0.31
SLED	Amp.(%)	0.59
	Phase(deg.)	0.32
Energy	measured	0.20

Table 2 shows the average stabilities of the modulator, klystron's amplitude and phase, and SLED's amplitude and phase. The stability of the SLED's peak power amplitude is difficult to measure because small timing jitter gives large deviation with its non-linear waveform shape. This leads to almost double values of the stability of the klystron's peak power amplitude. Some modulator and klystron units have somewhat in difficulties (not seen in Table 2) to understand because modulator's stability is far from 2.5 times RF power stability (estimated from the equation below). The stability for those units must be checked modulator side and RF side at the same time again. Nevertheless, from above measurement we try to get simple estimation for the one of possible reason for a beam energy variation during the beam injection as mentioned above. This is again very important to operate PLS-II linac in stable top-up mode. Out beam energy stability was about 0.2% but it is still showing some shot by shot drift during the injection. This leads to the need of further reduction in energy instability, thus modulator's instability. To provide 0.1% of a beam energy variation, required klystron output power stability is 0.2 %. According to the following relations;

$$\frac{\Delta E_b}{E_b} = \frac{1}{2}\frac{\Delta P_{rf}}{P_{rf}} = \frac{5}{4}\frac{\Delta V_k}{V_k}$$

where $\Delta E_b/E_b$ is the beam energy stability, $\Delta P_{rf}/P_{rf}$ is a rf peak power stability and $\Delta V_k/V_k$ is a klystron cathode voltage. Finally, we could calculate the necessary PFN voltage stability of 0.080% (800 ppm). This requirement could be achieved when the deQing system is applied to the all line type modulator. At present, only two modulators (MK01 and MK02) are working with deQing system showing a half of other line type modulators' instability (MK03~MK08). After achieving energy margin by SLED installation in MK10 and conditioning other rf components, the deQing system will be applied in all other line type modualators (MK03~MK08). ,

SUMMARY

We achieved energy spread of 0.2 % and energy jitter of 0.2 %. Under this condition we have performed top-up test several times successfully. However still we found some shot by shot instability during the injection. During this summer we will further optimize the electron beam stability in PLS-II linac. We are also considering linac energy upgrading for the stable top-up operation to obtain sufficient energy margin.

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