MEASUREMENT OF BEAM ENERGY DRIFT IN PLS 2.5 GEV LINAC*

W. H. Hwang[†], H. G. Kim, W. W. Lee, S. J. Park, Y. J. Han,
Pohang Accelerator Laboratory, POSTECH, Pohang, Korea

Abstract

In the PLS 2.5GeV Linac, the beam energy is changed by cooling temperature, air condition, and modulator high voltage jitter. The main factor to change the beam energy is the rf phase drift by environmental conditions. We measured rf phase drift of SLED output and the beam energy according to the variation of cooling temperature. This paper describes how environment factors change the beam energy drift.

INTRODUCTION

The PLS 2.5 GeV linac is operated as a full energy injector to the PLS storage ring, a third generation synchrotron light source. The schematic diagram of the linac rf system is showed in Fig. 1[1, 2]. The PAD units shown in the figure is not yet installed. The designed energy spread of the linac is 0.6 %. The electron beam is accelerated with pulsed rf of 2856 MHz. The rf frequency, phase, and power are very important factors in linac operations. The change of these factors gives influences on the electron beam energy and the energy spread. The magnitude of change of these factors depends on various factors such as the drive signal of klystrons, modulator beam voltage, and environmental conditions. The beam voltage of a modulator is stabilized within the design specification of ± 0.5 % in two stages [3]. The temperature of accelerating sections is routinely controlled within 45 ± 0.2 ˚C. The design tolerance of the drive system's phase stability is less than ± 3.5˚ during 72 hours for the entire 145-m long drive system[4].

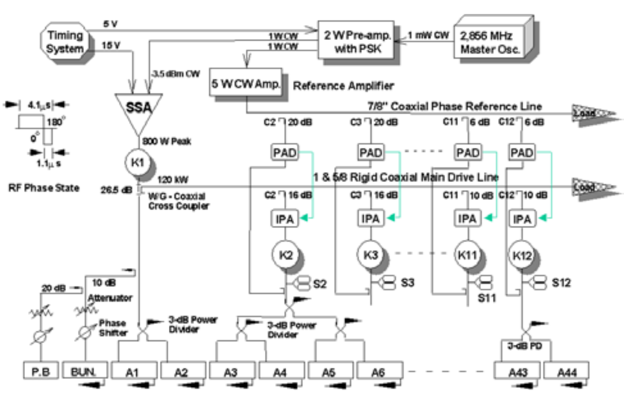

Figure 1: Schematic diagram of PLS linac rf sysem.

Beam injection into the storage ring has been done two times per day. Until the last year, the linac beam energy was changing by > several tens MeV in injection time and sometimes up to 200 MeV, as shown in Fig. 2. We measured beam energy variation and investigated its causes. We found it is related largely to cooling water temperatures. Also the rf phase variation by temperature variations affected to beam energy. This paper describes measurement results of beam energy and how environment temperatures change the beam energy.

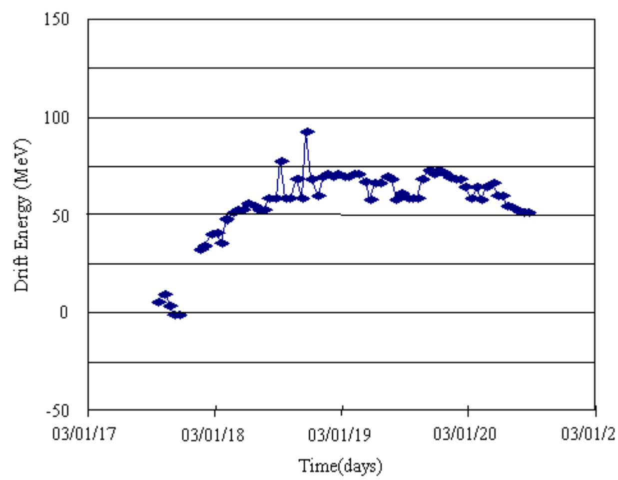

Figure 2: Beam energy drift in PLS Linac.

BEAM ENERGY DRIFT

Energy spectrum width depends on the rf phase, and the energy spread for small angular spread α is

$$\frac{\Delta E}{E} \approx \frac{1}{2}\left[\frac{\alpha}{2} + \frac{\sum \theta_n}{N}\right]^2 \qquad (1)$$

where N is the number of sections and θ is individual rf phase error. The phase variation of accelerating column caused by the cooling temperature variation, ΔT is

$$\Delta\theta = 2 \bullet \tau \bullet Q \bullet \upsilon \bullet \Delta T \qquad (2)$$

where, Δθ is the phase difference between rf and beam, energy spread, Q is unloaded Q value of accelerating column(13,000), τ is attenuation coefficient(0.57) and υ is linear coefficient of thermal expansion(1.65E-5). Normal cooling condition of accelerating column is controlled within ± 0.2 ˚C and then calculated energy spread is about 0.5%.

Fig.3 is shown the beam energy variation affected by cooling temperature of accelerating column. The measurement is performed during 3 hours. The energy spread is about 0.9 % in the variation of 0.52 ˚C and it is more than 0.6 % of designed value.

*Supported by MOST
†hohwang@postech.ac.kr

In the measurement period of 1 year, the energy variation had been more serious (> 100MeV). The variation in outside temperature caused cooling water temperature changes, and we upgraded the cooling control system to preserve the LCW temperature, as shown in Fig. 4. First, we inserted reservoir to preserve the amount of flowing water to the load. Secondly, We replaced 2-way valve to 3-way valve to control the amount of flowing water of tower and bypass. After these, the energy drift is decreased within 50 MeV regardless of big variations in outside temperature.

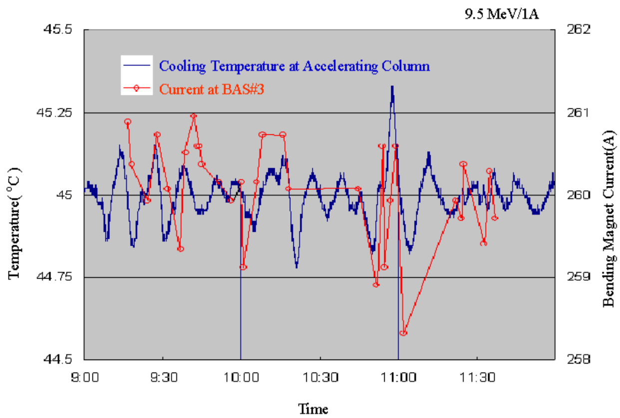

Figure 3: Beam energy drift caused by cooling temperature of accelerating column.

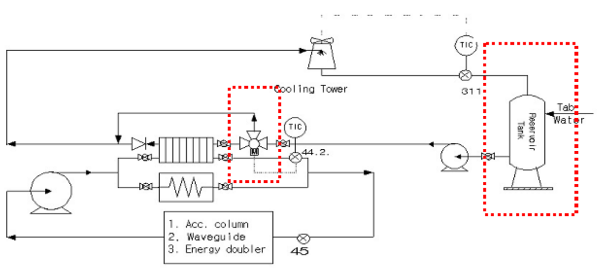

Figure 4: Schematic diagram of 3-way control valve for precision temperature controller.

PHASE MEASUREMENT

The beam energy spread is related to the rf phase by Eq. (1). So phase measurement system is constructed to measure rf phase of the SLED output referring the SLAC phasing system [5]. We assigned the one point in the period of interaction between beam and rf of 4 μsec of rf pulse and measured the amplitude and phase at the point. In this measurement as shown in Fig. 5, rf amplitude coupled by 10dB coupler and phase information from mixer output send to oscilloscope. The temperature of cooling, room and outer is recorded by PC through a GPIB. Also the oscilloscope and power supply are controlled by PC through a GPIB.

The phase detector system consists of a bi-phase modulator, a double balanced mixer, a voltage controlled phase shifter and an amplitude detector. Amplitude-independent phase measurement is achieved by an in-situ compensation process that was done by the controller based on the LABVIEW program. The mixer output and detector output are given by the following relations,

$$V_{mix} = \alpha\left|\vec{S}\right|\cos(\phi_s - \phi_r \pm \pi/2) + V_{offset} \qquad (3)$$

and

$$V_{amp} = \beta\left|\vec{S}\right| \qquad (4)$$

For $\phi_s - \phi_r < 10^\circ$, the signal phase can be calculated as

$$\phi_s = \pm\frac{\beta}{\alpha}\times\frac{V_{mix} - V_{offset}}{V_{amp}} + \phi_r \qquad (5)$$

And each pulse phase jitter is

$$jitter = \left|\phi_s - <\phi_s>\right| \qquad (6)$$

where, $<\phi_s>$ is the average phase. In this system, the phase was recorded by averaging 30 successive data. By high voltage modulator, maximum phase jitter of each pulse was about ± 3 degrees during 10 minutes.

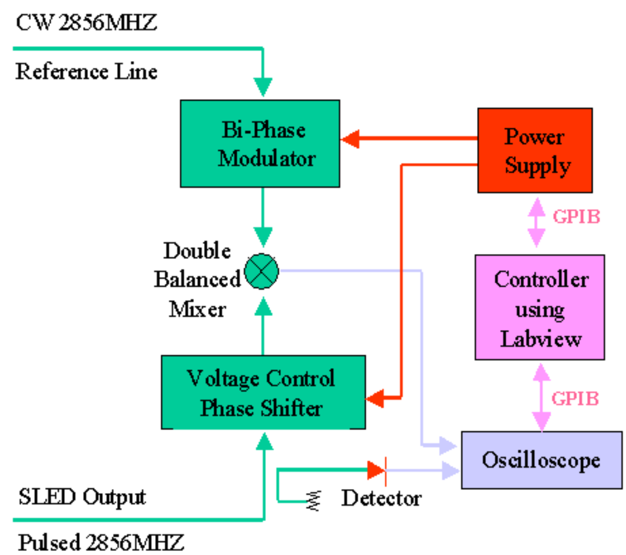

Figure 5: Phase measurement system.

The rf phase of the SLED output in MK10 module was found to be changed by the room temperature variations in the MK1 module, as shown in Fig. 6. As the temperature change, the phase of SLED #10 is affected by the phase of klystron #1, the thermal expansion of MDL (Main Drive Line) and reference line and master oscillator parts etc.. In this case, the rf phase is changed by 3 degrees with 1˚C change in the room temperature. The room temperature of klystron gallery is controlled to within 23 ± 2 ˚C in normal operation.

The rf phase variation of SLED output with its cooling temperature is shown in Fig. 7. The rf phase is changed by about 10 degrees per 1˚C variation of the cooling water temperature. In normal operation, the temperature of the SLED is controlled to within 45 ± 0.2˚C.

The rf phase change of SLED output and beam energy drift, with the cooling temperature changes in klystron tubes is shown in Fig. 8. The rf phase is changed by about 1 degrees per 1˚C variation of the cooling water temperature for klystron tubes. The temperature of klystron tube is controlled within 32 ± 1˚C in normal operation.

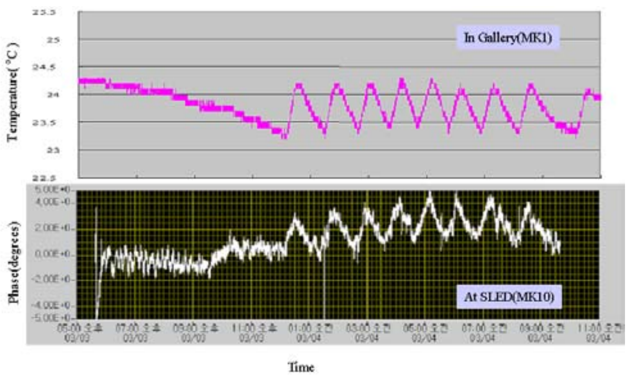

Figure 6: rf phase drift caused by room temperature.

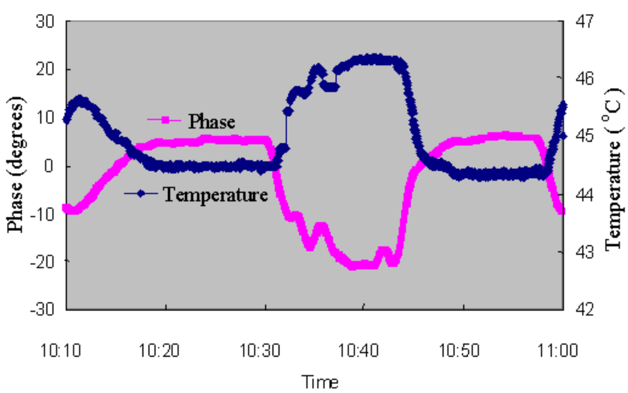

Figure 7: rf phase drift caused by cooling temperature of SLED.

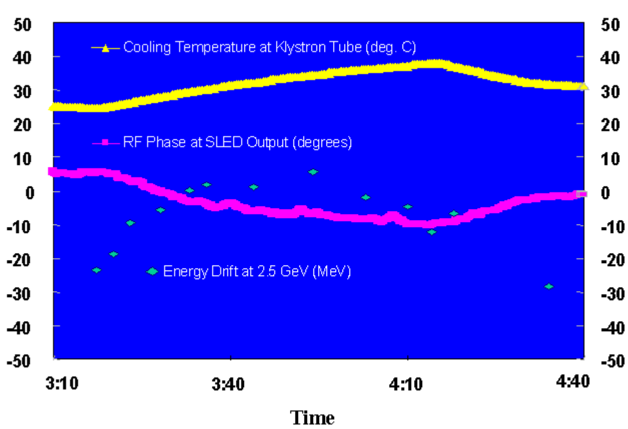

Figure 8: rf phase drift caused by cooling temperature of klystron tube.

SUMMARY

In the PLS 2.5GeV Linac, the beam energy is changed by cooling temperature, air condition, and modulator high voltage jitter. We found out that the rf phase variations that cause beam energy drifts, were caused by environmental conditions. The SLED output phase was found to be changed by 3˚ per 1˚C room temperature, by 10˚ per 1˚C SLED cooling temperature, 1˚ per 1˚C klystron cooling temperature variations. The pulse-to-pulse phase jitter was about ± 3˚. Work to suppress these phase variations are under way.

REFERENCES

[1] Design Report of Pohang Light Source (revised ed.), Pohang Accelerator Lab., 1992

[2] W. Namkung, "PLS 2-GeV Linac," Proc. International Linac Conf., Japan, 1994

[3] M. H. Cho, et al., "High Power Microwave System for PLS 2-GeV Linac," Proc. International Linac Conf., Japan, 1994

[4] H. S. Lee, et al., "Microwave System of PLS 2-GeV Linac," Particle Accelerator Conference, Dallas. Texas, 1995

[5] J. D. Fox and H. D. Schwarz, "Phase and amplitude detection system for the Stanford linear accelerator," SLAC-PUB-3071, March 1983