PRELIMINARY RF TEST IN PLS 2.5 GEV LINAC FOR PAL-XFEL*

W. H. Hwang†, H. G. Kim, W. W. Lee, Y. J. Han, J. Y. Huang, J. H. Choi
Pohang Accelerator Laboratory, POSTECH, Pohang, Korea

Abstract

In PAL-XFEL, the specification of the beam energy spread and rf phase is tighter than PLS Linac. We examined the rf performance in the present 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 according to the variation of environmental condition and cooling temperature. We reduced the beam energy drift and the rf phase drift in long-term by improvement of cooling and air conditioning control system. Also, rf phase compensation system is needed for stable beam quality. This paper describes rf system including the rf phase measurement and phase compensation system for the PAL-XFEL.

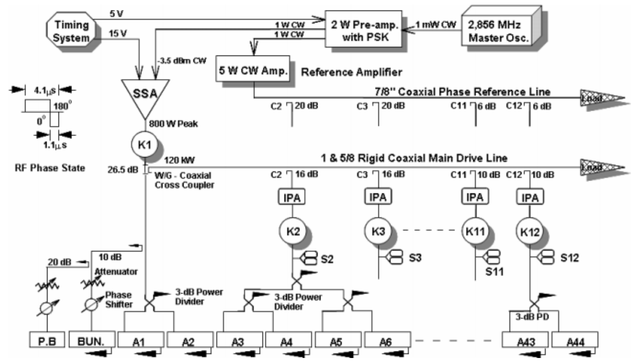
INTRODUCTION

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 designed energy spread of the linac is 0.6%. The beam voltage of a modulator is stabilized within the design specification of ± 0.5% in two stages [3]. The design tolerance of the drive system's phase stability is less than ± 3.5^0 during 72 hours for the entire 145-m long drive system [4]. 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. 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 how environment temperatures change the beam energy and phase measurement results.

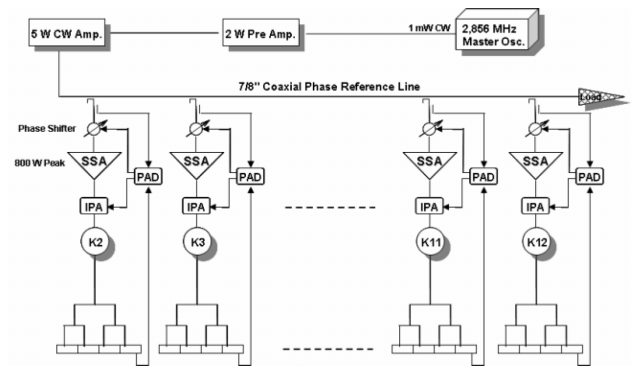
The rf design parameters for XFEL as shown Table 1 is tighter than for present PLS Linac.

Table 1: Design Parameters for PAL-XFEL

Parameters	PLS Linac	PAL-XFEL
Beam Energy	2.5 GeV	3.7 GeV
Energy Spread	0.6%	0.03% (rms)
Phase Stability	±3.5^o	0.1^o (rms)
Amplitude Stability	±0.5%	0.1% (rms)



(a) Present PLS 2.5GeV Linac



(b) Upgrade Linac for XFEL

Figure 1: Schematic diagram of linac rf system.

BEAM ENERGY DRIFT

Energy spectrum width depends on the rf phase, and the energy spread for small angular spread α is [5]

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

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

$$\Delta\theta = 2 \bullet \tau \bullet Q \bullet \upsilon \bullet \Delta T \tag{2}$$

where, Δθ is the phase difference between rf and beam, 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 ^{0}C and then calculated energy spread is about 0.5%. The energy spread by cooling temperature variation of accelerating

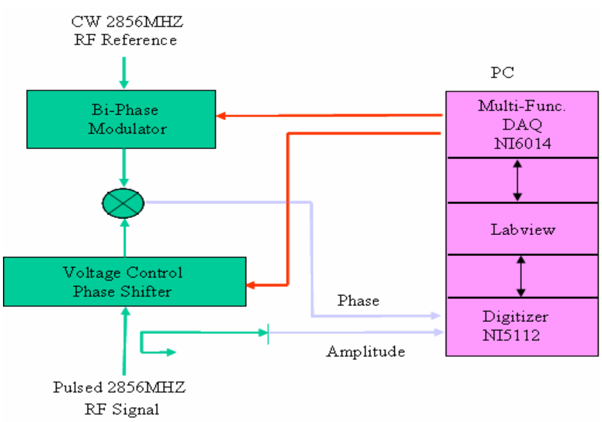
*Supported by MOST
†hohwang@postech.ac.kr

column is about 0.9% in the variation of 0.52 ^{0}C during 3 hours and it is more than 0.6% of designed value [6].

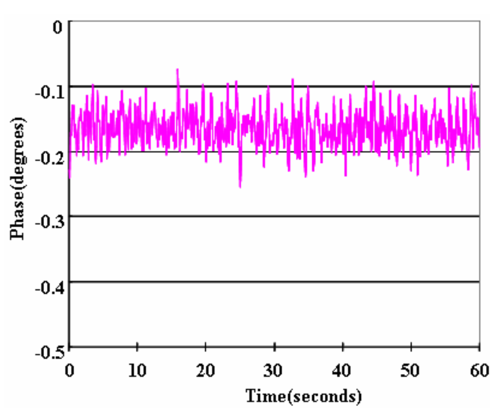
PHASE AND AMPLITUDE MEASUREMENT SYSTEM

Analogue Measurement System

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 [7]. We assigned the one point in the period of interaction between beam and rf pulse of 4 μsec and measured the amplitude and phase at the point. In this measurement as shown in Fig. 2, the rf amplitude coupled by 10dB coupler and the phase information from mixer output send to oscilloscope. The temperature of cooling, room, and outer are recorded by PC through a GPIB. Also the oscilloscope and power supply are controlled by PC through a GPIB.



(a) schematic diagram



(b) phase accuracy

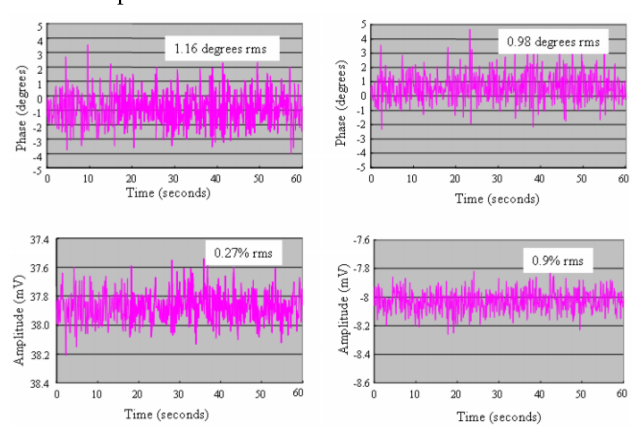
Figure 2: Analogue pulse to pulse phase and amplitude measurement system.

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 phase accuracy of pulse to pulse phase measurement is 0.1^{o} (peak-peak) and 0.03^{o} (rms), and the accuracy of amplitude is 0.3%.

The rf phase of the SLED output in MK10 module was found to be changed by the room temperature variations in the MK1 module [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^{o} with 1^{0}C change in the room temperature. The room temperature of klystron gallery was controlled to within 23 ± 2^{0}C, currently it is controlled within 0.5^{0}C in normal operation.

The rf phase variation of SLED output with its cooling temperature is about 10 degrees per 1^{0}C variation of the cooling water temperature. In normal operation, the temperature of the SLED is controlled to within 45 ± 0.2^{0}C. The rf phase is changed by about 1 degrees per 1^{0}C variation of the cooling water temperature for klystron tubes. The temperature of klystron tube is controlled within 32 ± 1^{0}C in normal operation.

A pulse-pulse phase and amplitude measurement for each klystron and modulator module is important to design the PAL_XFEL. The measurement is conducted in K5 module of PLS linac. As shown in Fig.3, the phase and amplitude variation is 1.16^{o} and 0.27% rms value at klystron output. And it is 0.98^{o} and 0.9% rms value at SLED output.

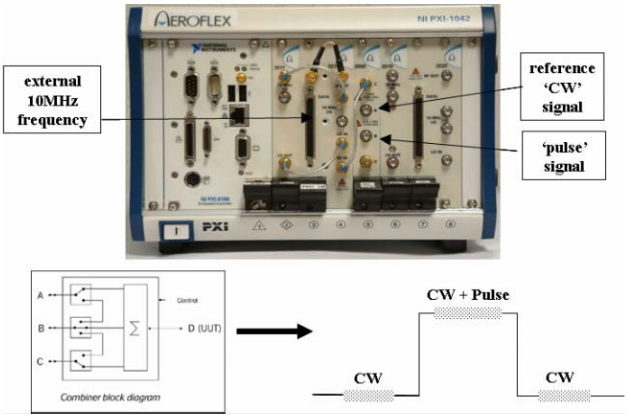


(a) Klystron (b) SLED

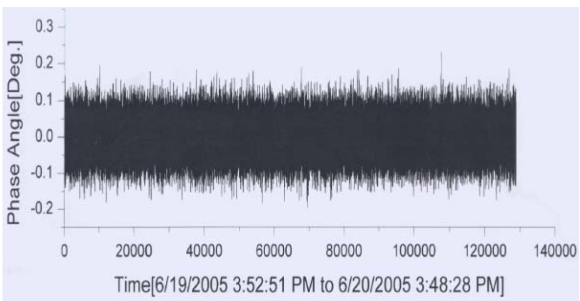
Figure 3: Pulse to pulse phase and amplitude variation during 60seconds in K5 module.

Digital Measurement System

The digital detector system as shown in Fig. 4 consists of a local oscillator, power combiner and rf digitizer PXI module made by Aeroflex Co. [8]. The reference cw 2856 MHz signal and pulsed signal is added in combiner. The phase of the pulsed 2856MHz signal is obtained by comparison cw signal with cw+pulse signal. The phase measurement is achieved by the controller based on the LABVIEW program. The phase accuracy of pulse to pulse phase measurement is 0.2^{o} (peak-peak).



(a) schematic diagram



(b) phase accuracy

Figure 4: Digital pulse to pulse phase measurement system.

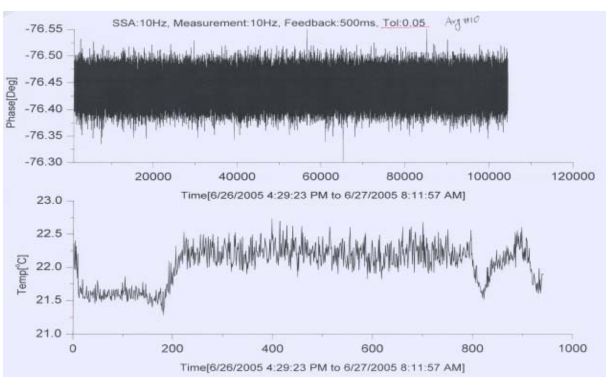


Figure 5: Phase compensation results of pulsed 2856 MHz SSA by digital phase measurement system

The phase feedback is achieved by using digital measurement system and analogue phase shifter. The phase of 600watts SSA (Solid State Amplifier) with pulsed 2856 MHz is compared with cw 2856MHz reference signal. The phase change by the temperature variation is compensated by analogue phase shifter controlled by Labview program. The phase of SSA output is controlled within 0.1^o (peak-peak) after averaging of 10 as shown in Fig. 5.

SUMMARY

The beam energy is changed by cooling temperature, air condition, and modulator high voltage jitter. We measured beam energy and phase variation by environmental condition. The SLED output phase was found to be changed by 3^0 per 1^{0}C room temperature, by 10^0 per 1^{0}C SLED cooling temperature, and 1^0 per 1^{0}C klystron tube cooling temperature. The pulse-to-pulse phase jitter was about ± 3^0. We designed the analogue and digital phase measurement system. The performance of digital system with phase accuracy of 0.2^o (rms) is similar to analogue system of 0.1^o (peak-peak). The diversity of digital system is better than the analogue system.

The phase and amplitude variation of 1^o (rms) and 0.3% (rms) at klystron output is larger than the design value of 0.02^o (rms) and 0.01% (rms) for PAL_XFEL. But, the phase by long-term condition can be controlled within 0.1^o (peak-peak) by the phase compensation system. And the phase by short-term condition can be stable by improvement of high voltage modulator stability.

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] The Stanford Two-Mile Accelerator, SLAC, 1968

[6] W. H. Hwang, et. Al, "Influences of Environmental Temperature Changes on RF Phase and Beam-Energy Drift in the PLS 2.5 GeV Linac," in *Beam Instrumentation Workshop-2004*, AIP Conference Proceedings 732, Knoxville, 2004, pp310-316

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

[8] www.aeroflex.com