S-BAND LOW LEVEL RF SYSTEM FOR 10 GEV PAL XFEL*

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Abstract

In PAL, we are constructing a 10 GeV PxFEL machine. The output power of the klystron is 80MW at pulse width of 4us and the repetition rate of 120 Hz. And the specifications of rf phase and amplitude stability are 0.05 degrees (rms) and 0.05% (rms) respectively. We achieved the stability of 0.03 degrees (p-p) at low power rf output using a phase and amplitude detection system (PAD) and phase amplitude control system (PAC). This paper describes the microwave system and the PAD and PAC system for PxFEL.

INTRODUCTION

Pohang Accelerator Laboratory, PAL, constructed the PLSII machine with 3.0GeV injector linac in 2011. We start user service in this year. Also, we are constructing 10GeV FEL machine. The PxFEL requires rf stability of 0.05 % rms and 0.05 degrees rms respectively as specifications. This value is 10 times tighter than PLSII linac as shown Table 1. The high precision phase amplitude detection system (PAD) and phase amplitude control (PAC) system is also needed to meet specifications of the rf stability [1, 2]. We need a test facility to perform the LLRF system and high power components for FEL. We will construct two test facilities in this year. One is ATF (Accelerator Test Facility) to test the performance of an accelerator structure. The other is GTF (Gun Test Facility) to test rf gun and injector for FEL. We developed a LLRF System and 1kW pulsed SSA (Solid State Amplifier) for ATF.

Table 1: Design Parameters for PxFEL

Parameters	PLS II Linac	PxFEL
Beam Energy	3.0 GeV	10.0 GeV
RF Phase Stability	0.5°	0.05° (rms)
RF Amplitude Stability	0.5%	0.05% (rms)

The LLRF system of the XFEL consists of solid-state amplifier (SSA), phase and amplitude detector (PAD), and phase and amplitude control (PAC) units as shown in Figure 1. The function of PAC is to control the phase and amplitude of klystron drive rf, to provide pulsed rf signal, to provide PSK (180 degrees phase shifter). The rf pulse width and PSK trigger time are 4 μs and 3.17 μs respectively.

The electron beam is accelerated with 4 μs pulsed rf of 2856MHz. 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 long-term rf phase drift is related largely to cooling water temperatures and air temperature. Also the rf phase variation by temperature variations affected to beam energy. The long-term drift can be corrected by rf phase feedback system. Pulse to pulse short-term variations cannot be corrected by feedback system. A stable high voltage modulator can correct the short-term variations.

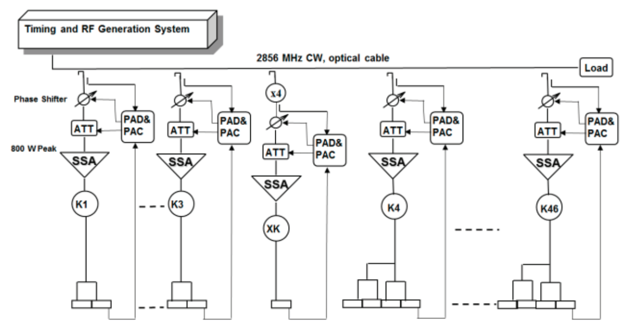

Figure 1: Microwave system for PxFEL

LLRF SYSTEM

The low-level signal conditioning unit consists of a preamplifier, CW rf amplifier, isolator, rf pulse modulator, and PSK. The switching time of PSK is shorter than 50 ns. The AB-class SSA amplifies an rf signal by using the multi-cascade method. The input pulse width of the SSA is adjustable from 0.2 μs to 7 μs by PAC system. The output power of the SSA is adjustable from 0.1kW to 1kW. The rising and falling times are about 0.1 μs and 0.1 μs, respectively. We developed the 1kW amplifier, PAD, PAC, and signal conditioning units.

PAD and PAC

The function of PAD is to measure the phase and amplitude of klystron output. The function of PAC is to control the phase and amplitude of the klystron drive rf power. As shown in Figure 2, the PAD clock is running at 238MHz which is 8 times the IF frequency 29.75MHz. The 238MHz for the clock input and the 29.75MHz as a signal input to the 4 channel ADC board were used. S-band PAD chassis have an EPICS on RTEMS Coldfire IOC which reads 4 FIFOs from the 16 bit 238MHz ADCs. The rf is down mixed with the 2826.75MHz LO reference

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to 29.75MHz IF, which is digitized at 238MHz. The IOC does the down conversion to base band, averages over a specified number of points, up to 512, and the set the EPICS I and Q records.

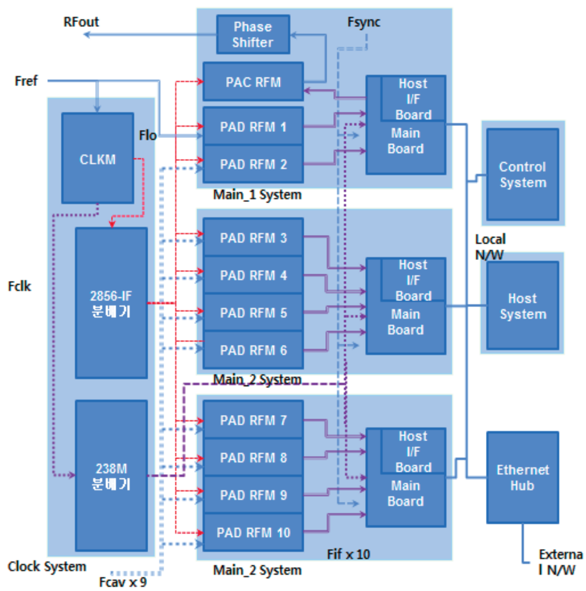

Figure 2: Block diagram of LLRF system

LLRF controller consists of ADC, DSP, and DAC as shown in Figure 3. ADC digitize the analogue rf of the PAD with sampling frequency of 238MHz. DSP measure the phase and amplitude of PAD module using I_D and Q_D from ADC. Also DSP calculate the phase and amplitude of PAC module. DAC converse the digital to analogue and send to the PAC module. The stability of PAC output is 0.017% of amplitude and 0.026 degrees of phase as shown in Figure 4. The stability of klystron output in PLSII MK11A module is 0.17% of amplitude and 0.13 degrees of phase as shown in Figure 5.

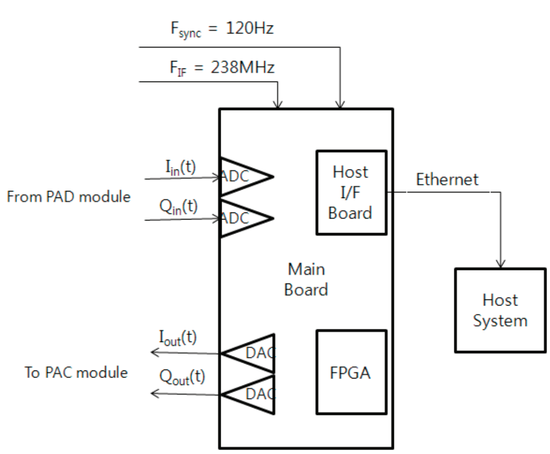

Figure 3: Block diagram of LLRF controller

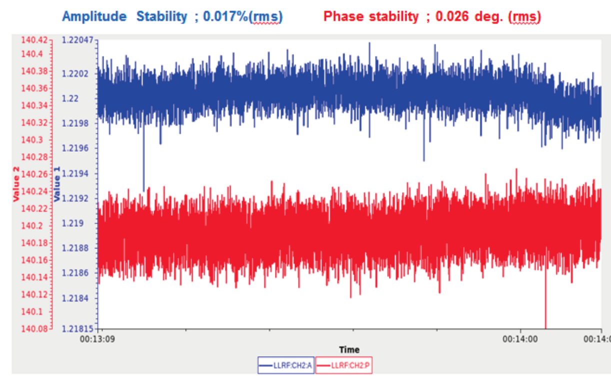

Figure 4: RF stability of PAC output

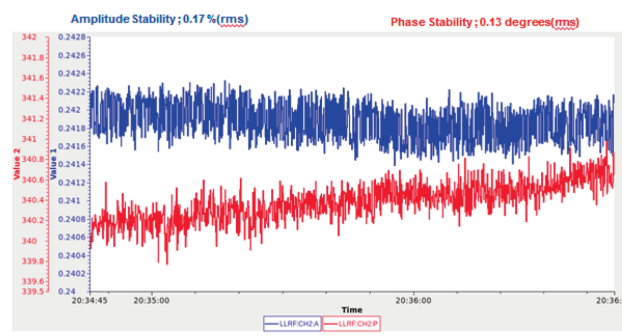

Figure 5: RF stability of klystron in MK11A

SSA (Solid State Amplifier)

The AB-class SSA amplifies 1mW input power to 1kW by using the multi-cascade method as shown in Figure 6. The input pulse width of the SSA is adjustable from 0.2 μs to 7 μs by PAC system. The rising and falling times is less than 0.1 μs. The test results of SSA for ATF show in Table 2. The short-term phase and amplitude variation is 0.075° and 0.115% rms value at SSA Output. Phase flatness is 5 degrees maximum. The rising and falling time is 30ns. PSK switching time is 40ns as shown in Figure 7.

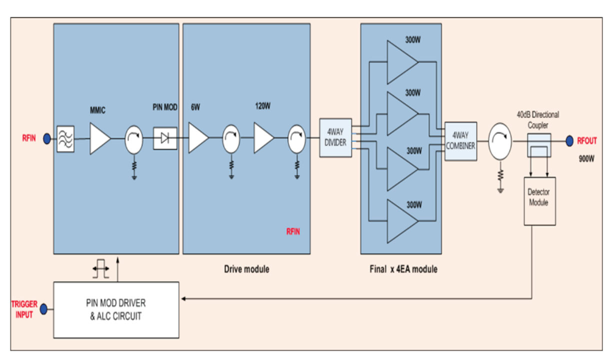

Figure 6: Block diagram of SSA

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Table 2: Test Results of SSA for ATF

Parameters	Results
Operating Frequency(MHz)	2856+/- 1
Input Power(dBm)	-15~0
Output Power (kW)	0.01~ 1
Power Gain(dB)	60
IN/OUT vswr	1.2/1.3
RF Pulse Width(microseconds)	0.5~6
Pulse Repetition Rate(Hz)	1~120
Rising/Falling Time(nanoseconds)	30
Phase Stability(degrees, rms)	0.075
Amplitude Stability(%, rms)	0.115
Harmonics@ P0.5dB(dBc)	-67

Figure 7: Test results of SSA for ATF

SUMMARY

There are two systems to obtain the beam stability. One is the phase feedback system for long-term stability. The other is the invert-type power supply to keep modulator beam voltage stable less than 0.01 % rms for short-term stability. Development of PAD & PAC for FEL is undergoing. Preliminary, we developed the LLRF system for ATF. The phase and amplitude variation of PAC output is 0.026 degrees and 0.017% respectively. We measured the phase and amplitude variation from K11A klystron in the PAL linac. The phase and amplitude variation of 0.13 degrees (rms) and 0.17% (rms) at klystron output is far larger than the design value of 0.05 degrees (rms) and 0.05% (rms) for PAL_XFEL. Also, we developed the 1kW SSA, the output stability is 0.08 degrees of phase and 0.1% of amplitude. Improvement of output stability for SSA is needed for FEL. The development of precision high voltage power supply for modulator is needed to meet FEL specification for rf short-term stability. Also the precision PAC and temperature system is needed to meet FEL specification for long-term stability.

REFERENCES

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[2] H. Hanaki, T. Asaka, H. Ego, H. Kimura, T. Kobayashi, S. Suzuki, Proceedings of Linear Accelerator Conference, TUP014(2010).