S-BAND RF SYSTEM FOR 0.1 nm SASE FEL AT PAL*

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Abstract

Pohang Accelerator Laboratory, PAL, has been proposing a 0.1 nm SASE FEL. This machine will be designed with an S-band rf linear accelerator to produce a 10.053 GeV electron beam. The output power of a klystron is 80 MW with a pulse width of 4μs and a repetition rate of 30 Hz. The beam energy spread and rf phase stability are 0.037% (rms) and 0.1° (rms), respectively. The SASE FEL needs a modulator stability of 0.1% (rms). We have developed a modulator DeQing system for the existing modulator systems that are "line type modulator system". We are also considering an inverter power supply to meet the required specification of the FEL machine. We are developing a phase amplitude detection system (PAD) and a phase amplitude control (PAC) system to obtain the required rf stability. This paper describes the rf system for the PAL XFEL (PxFEL).

INTRODUCTION

The PxFEL is a 4th generation light source to produce a coherent X-ray free electron laser. This machine is designed with an S-band rf linear accelerator to obtain a 10.053 GeV electron beam. The rf stability is a key issue to get stable beam for the PxFEL. As shown in Table 1, the rf design parameters for the XFEL need to have much better than those of present PLS Linac. In the PxFEL, the specifications of the beam energy spread and rf phase are 0.1 % (rms) and 0.1° (rms) respectively [1]. The rf system and klystron-modulator have to provide stable beam operation. The rf frequency, phase, and power are very important factors in the linac operation. A change in these factors influences the electron beam energy and the energy spread. The long-term drift caused by environmental condition can be corrected by the rf phase feedback system. The phase amplitude detection system (PAD) and phase amplitude control (PAC) system also improve the rf stability. Also, the beam voltage stability of the klystron is directly related to a PFN (pulse forming network) charging voltage of the modulator. Therefore, a good regulation of the PFN charging voltage is essential in the modulator. The short-term variations can be corrected by a stable modulator system. We have developed a deQing system to keep the modulator beam voltage stable by less than 0.01 % (rms). In addition, we have also developed a modulator with a constant current source using inverter power supply. This paper describes the microwave system and new modulator system considering the improvement of the rf stability for the PxFEL.

*Work supported by MOST and POSCO
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Table 1: Design Parameters for the PxFEL

Parameters	PLS Linac	PxFEL
Beam Energy	2.5 GeV	10.053 GeV
Energy Spread	0.6%	0.037% (rms)
Phase Stability	±3.5°	0.1° (rms)
Amplitude Stability	±0.5%	0.1% (rms)

MICROWAVE SYSTEM FOR PXFEL

The S-band microwave system of PxFEL is divided into two parts as shown in Figure 1 and Figure 2. One is a drive system and the other is a waveguide system. The drive system consists of an RF signal source (2856MHz), MDL (main drive line), SSA (solid-state amplifier), PAD (phase and amplitude detector), and PAC (phase and amplitude control) units. The waveguide system in one module consists of a s-band klystron, a SLED, and two constant gradient accelerating sections. A short x-band rf section, operating at 11.424GHz, requires a modest power source to operate at 37 MV/m over a length of 0.6m to generate the needed 22 MV of the x-band rf [2].

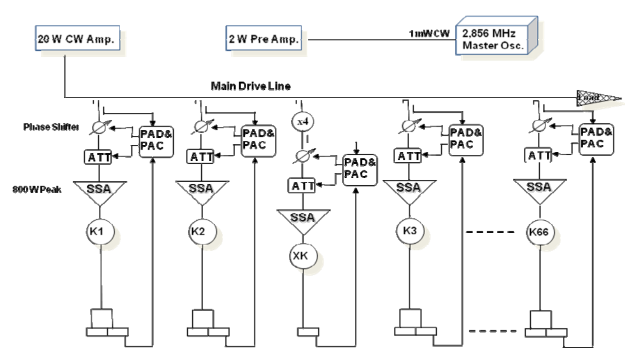

Figure 1: Microwave system for the PxFEL

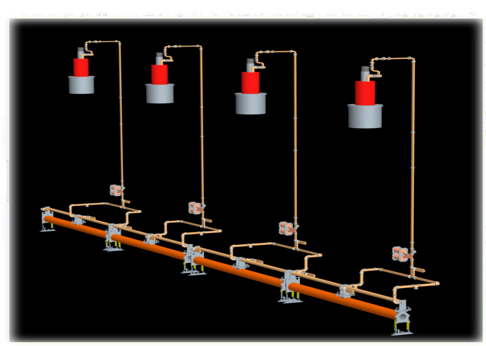

Figure 2: High power microwave system for the PxFEL

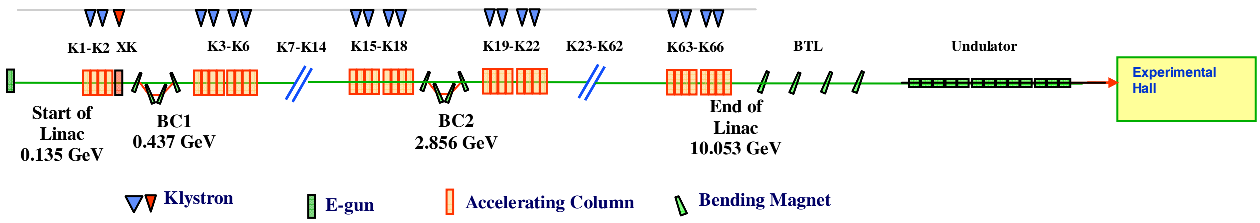

Figure 3: Layout of the PxFEL

Figure 3 shows the layout of the PxFEL. The rf system consists of 66 klystron-modulator modules and two bunch compressor chicane.

PAD

The function of the PAD is to measure the phase and amplitude of the klystron. The function of the PAC is to control the phase and amplitude of the klystron drive rf power. We have developed a digital PAD system with a resolution of 0.02^0 [3]. Our motive is to develop the PAD and PAC systems based on the SLAC LLRF system [4]. Preliminary, we have developed the PAD as shown in Figure 4. The measured phase and amplitude of the K2 klystron in the present linac are shown in Figure 5. The short-term phase and amplitude variation is 0.7^o (rms) and 0.17% (rms), respectively at the klystron output. The measured values do not meet the parameters for the XFEL. Therefore, we need to upgrade the PAD system.

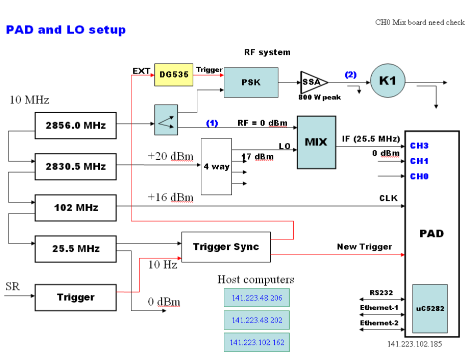

Figure 4: PAD system configuration

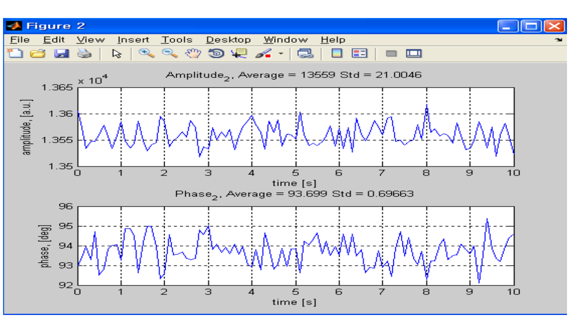

Figure 5: Pulse to pulse phase and amplitude variations during 1 minute at MK2 klystron output

Modulator Using DeQing System

The charging stability is directly affected by the DC voltage stability. The charging voltage regulation of the PFN is done by a de-Qing system to the secondary side of a charging choke as shown in Figure 6[5]. The comparator in the de-Qing controller generates an output pulse to trigger the SCR when the desired PFN voltage reaches the target voltage. The energy left in the charging chock at that time is finally dissipated in the secondary load resistors. The target level is normally adjusted to a few percent less than the maximum voltage without de-Qing control [6].

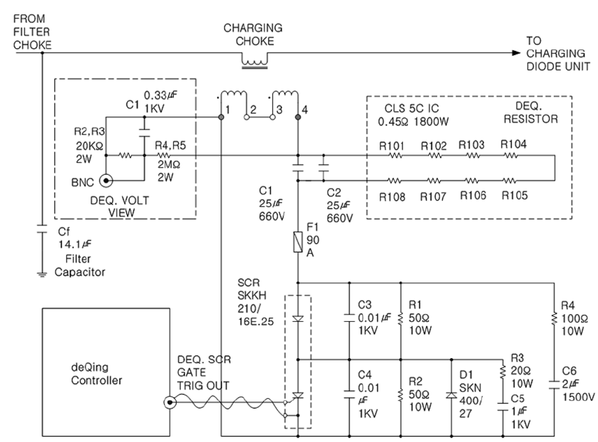

Figure 6: Circuit diagram of the deQing

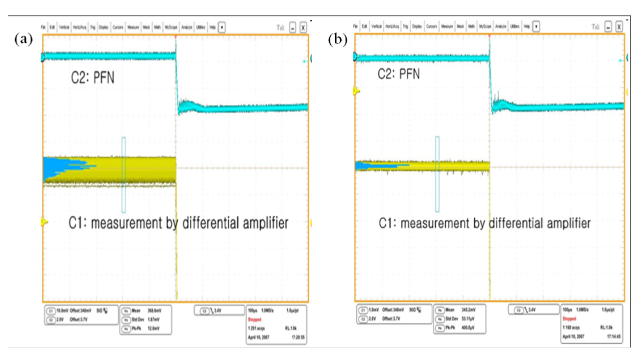

Figure 7: Stability of the PFN charging voltage: horizontal = 100 us/div, C1 = Expanded view of the PFN voltage, C2 = PFN voltage(20 kV/div), (a) de-Qing Off (C1 = 1 kV/div), (b) de-Qing On (C1 = 100 V/div).

The PFN voltage waveforms measured by a 10,000 : 1 divider are shown in Figure 7. The stability is measured by accumulating the charging waveform for 10 minutes at the repetition rate of 30 Hz. When the de-Qing controller is not activated, the stability is about RMS 5,067 PPM(Figure 7(a), mean value = 36.9 kV, standard deviation = 187 V). With the aid of the de-Qing, the variation reduces to RMS 154 PPM (Figure 3(b), mean value = 34.5 kV, standard deviation = 5.31 V).

Modulator Using Inverter Power Supply

The modulators of the PxFEL are intended to adopt a charging scheme that uses a constant current source such as an inverter power supply because it provides high reliability, compactness and stability [7]. Figure 8 shows the schematic diagram of the klystron-modulator including coarse inverters, a fine inverter, a klystron, a thyratron switch of the modulator, a precision inverter controller.

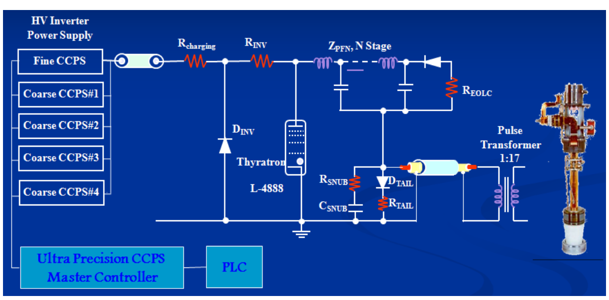

Figure 8: Circuit diagram of the modulator adopting the inverter power as the PFN charging power supply.

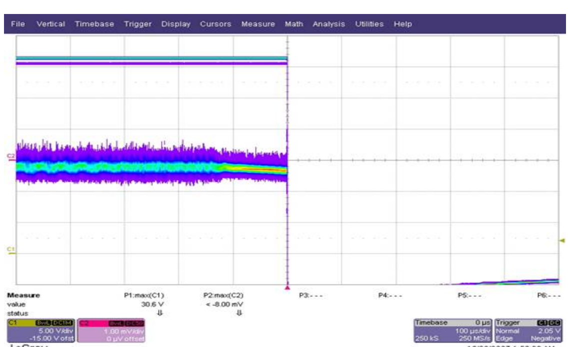

Figure 9: Stability of the PFN charging voltage: horizontal = 100 us/div, C1 = PFN voltage (5 kV/div), C2 = Expanded view of the PFN voltage PFN(2 V/div)

All the charging inverters are connected in parallel to the PFN. The coarse inverters charge the PFN up to 99 % of the target charging level. The fine inverter will charge to the target voltage and then regulates the charged level. After the PFN voltage reaches the target level, the charging level is regulated by smaller step with PWM(pulse width modulation) mode and PRM(pulse repetition modulation) mode. The PFN voltage waveforms measured by a 10,000 : 1 divider are shown in Figure 9. The stability is about 97 PPM(peak-to-peak=3.4 V) at the charging level of 35 kV.

SUMMARY

The newly proposed 0.1 nm SASE FEL at the PAL are employed in conjunction with the S-band rf linear accelerator to produce the 10.053 GeV electron beam. There are two rf systems needed to obtain the beam stability. One is the rf phase feedback system for the long-term stability. The development of PAD & PAC is undergoing. The variation of phase and amplitude 0.7° (rms) and 0.17% (rms), respectively at the klystron output is larger than the desired value of 0.1° (rms) and 0.1% (rms), respectively for the PAL_XFEL. We are expecting to meet the desired value of the new modulator to be adopted to the rf system. The other is the De-Q'ing system stability of 0.015% (rms) or the inverter power supply stability of 0.01% (rms) to keep the modulator beam voltage stable by less than 0.1 % (rms) for the short-term stability. The long-term phase variation can be controlled within 0.1° (rms) by the PAC. The short-term phase variation can be stabilized by the new modulator systems.

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