# DESIGN OF ELECTRON GUN SYSTEM FOR THE PLS-II LINEAR ACCELERATOR*

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*Abstract*

The PLS-II, the major upgrade program of the PLS (Pohang Light Source, a 2.5-GeV 3rd generation light source), is planned at the Pohang Accelerator Laboratory. The PLS 2.5-GeV linear accelerator, being the full-energy injector for the PLS storage ring, should be upgraded to provide the beam energy of 3 GeV. For the PLS-II linac, we are going to establish a dual electron gun system in which two guns will be on the accelerator beam-line with a bending magnet enabling immediate switching of guns. The dual gun system is expected to achieve high reliability for the top-up injection to the PLS-II storage ring. Also the gun will be upgraded to provide the beam energy of 200 keV and a pulse high-voltage modulator will be constructed. Fifteen-section PFNs will be connected in series to make final impedance of approximately 17.3 ohm. A new modulator applying the inverter technology will be used to charge the PFN and obtain more stable charging performances. In this article the authours would like to report on the design status of the accelerator beamline and inverter modulator for the dual gun system.

## INTRODUCTION

The PLS-II project aims to upgrade the brightness and quality of synchrotron radiation emitted from the storage ring by increasing the beam energy 3 GeV from 2.5 GeV, reducing the beam emittance and higher stability in the storage ring. In order to achieve this, it is required to modify the injector linear accelerator and the storage ring. In especially, in order to keep the stored beam current of the storage ring, the injected beam from the linear accelerator is increasing beam energy of 3 GeV with top-up operation. Moreover, it is important in the top-up operation that linear accelerator increase reliability and stabilization of the injected beam. The single bunch beam from the linear accelerator is required in the top-up operation. The gun system is planning to prepare the 0.2 ns pulse width beam by using a Kentech pulser. As the influence exerted by the timing jitter of the gun trigger signal is reduction, we consider the increasing of voltage for gun system. In addition, the dual gun system is consider for the improvement of the reliability. The particles tracking simulation in these cases are done by using PARMELA in order to confirm the beam reasmission, bunch length and energy spread at end of pre-injector which is consist of the thermionic gun, re-entrant type pre-buncher, 4cells buncher and two accelerating structures with some focusing magnets.

The buncher has a traveling-wave structure with only four cavities, including the input and output couplers.[1] It is operated in the 2π/3 mode with a phase velocity of 0.7c. Therefore, it has a length of one free-space wavelength (104.96 mm). The input RF power is about 1 MW and the peak field is about 3.5 MV/m. The specifications of the buncher are presented in Table 1.

Table 1: Bunch Parameters of PLS-II

| | |
|---|---|
| Frequency(MHz) | 2,856 |
| Operating mode | 2π/3 |
| No load Q | 10,000 |
| Shunt impedance (MΩ/m) | 36.1 |
| Attenuation (NP/m) | 0.228 |
| Phase velocity | 0.75C |
| Group velocity | 0.0117C |
| Band width(MHz) at VSWR 1.2 | 4 |
| Disk aperture diameter, 2a (mm) | 22.614 |
| Cavity diameter, 2b (mm) | 83.292 |
| Period length (mm) | 26.249 |
| Disk thickness (mm) | 5.844 |
| Operating temperature (℃) | 45±0.2 |

## BEAM DYNAMICS DESIGN

For the PLS-II, we are going to achieve a fast replacement of the gun on gun failures by inserting a gate valve and a pumping tee between the gun and existing accelerating beam line. This will move the gun position upstream by an amount of about 200 mm (Fig. 1) and there will be more beam blow-up driven by the space-charge forces. PARMELA simulations for this modified beam line configuration showed that with proper adjustment of the solenoid lens field, the beam can be matched to the downstream optics without significant beam losses.

As an alternative scheme for PLS-II, we have designed a dual-gun system in which another gun is added to the perpendicular direction to the existing accelerator beam line. A bending magnet is installed at the junction of those two guns for an on-line switching between the guns. PARMELA simulations were done for designing the beam line and the results are shown in Fig. 2.

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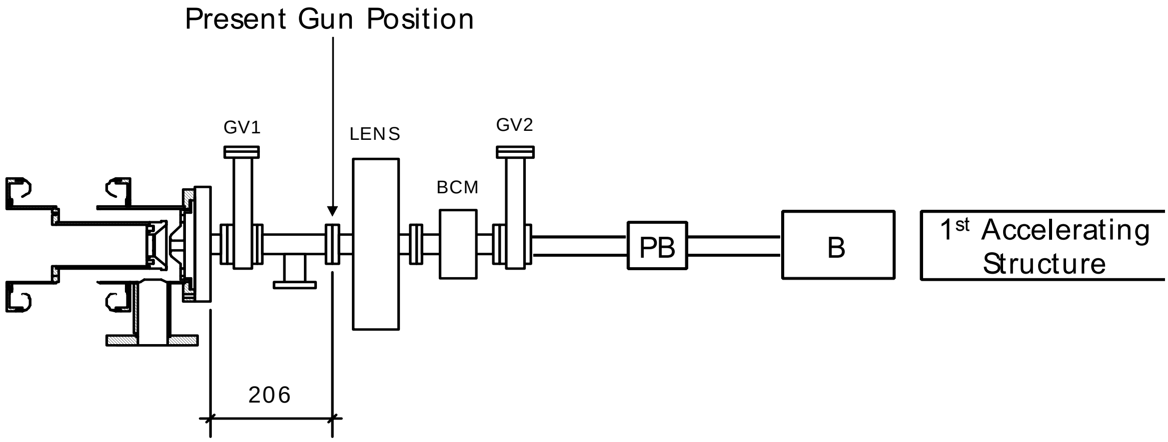
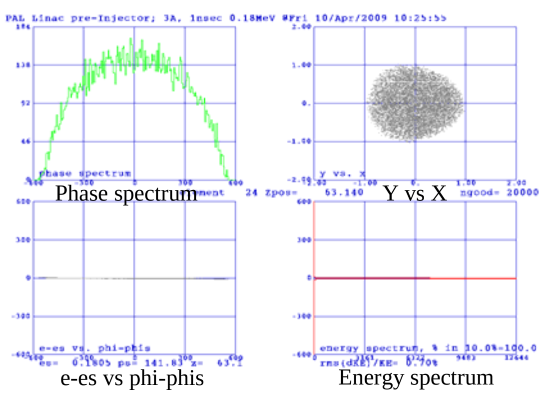
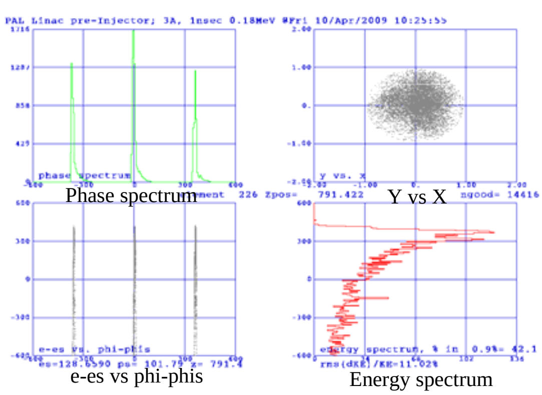



Figure 1: Layout of the PLS-II Electron Gun. For fast replacement of the gun on gun failure, a spare gun with a gate valve attached is prepared at fully operational condition, moved to the accelerator tunnel with the gate valve attached to it, and installed to beam line.




(a)




(b)

Figure 2: PARMELA simulation results for the dual-gun system. (a); Phase-space plots after the bending magnet, (b); at the end of the 2nd accelerating structure.

## ELECTRON GUN PARAMETER

The designed electron bunches for the pre-injector are formed by the electron gun operating at the stable mode of 200kV, 2A current amplitude and 10 Hz repetition rate [1]. The dispenser cathode-grid unit diameter 16 mm (Y-824, Eimac) is used as electrons emitter. This cathode does not provide a required current and also is not durable enough. To provide the complex project parameters an electron gun with parameters listed below was designed.

Electron energy: 200 keV
Bunch current amplitude: 1 A
Pulse duration: 1-1.5 ns
Pulse repetition rate: 10 Hz
Calculated Beam emittanc: 10 π mm mrad
The cathode life-time more than $10^4$ hours

The electron beam is emitted by thermal cathode assembly, and extracted by 200 kV high voltage. On the 1 nsec mode, this gun generated 25 A peak currents. The electrons were transported to the pre-buncher along the magnetic field, about 600 Gauss, by eight Helmholtz coils. The bunching efficiency was obtained to be 64-65 % and the energy spread was obtained

## LINAC E-GUN MODULATOR DESIGN

The cathode high voltage pulser is a thyratron switched line type modulator as show in Fig. 3. The pulser consists of a high voltage inverter power supply with an protection circuit. The 12 section PFN is inverter charged via the charging resistor $R_1$ voltage reversal resistor $R_2$ and holding diode $CR_1$. The width of the pulse is adjustable from 4 us downward by using corresponding fewer of the 12 PFN section. The switch tube, $S_1$, is CX 1599(E2V) hydrogen thyratron which discharge the PFN into the primary of the 1 : 24 step up pulse transformer $T_1$. The primary of the pulse transformer is also provided with an inverse voltage clipper module diode type of CKE(RHP 30). The clipper is required to provide additional load for the transformer backswing. The pulse transformer has a flux reset bias winding which is driven by a DC power supply thru a pulse isolation inductor $L_b$. The use of flux reset or bias allows the transformer is smaller and less expensive than a unit without core bias. The secondary of the transformer is bifilar and is used to provide heater power to the e-gun. 220 volt power is fed up the bifilar winding to a filament step down transformer at the hot end. The filament transformer is in the same oil filled case with the pulse transformer tank. The filament and pulse power both fed to the e-gun thru a bifilar high voltage output bushing[2][3]. A dummy resistor $R_L$ loads secondary of pulse transformer in parallel with e-gun. In the event of a load arc the reflected power is sensed in the inverse voltage protection diode $D_1$ and reversal protection resistor $R_2$ via the current transformer $CT_1$ and a trigger blanking circuit is activated. A 11 kΩ resistor is used which provides a net impedance variation to modulator of 11 kilo-ohm to 100 kilo-ohm as the e-gun current varies form zero to 20 A peak. This is obviously an electrically in-efficient solution but laboratory use is more practical and economical than charging PFN impedances to match each 20 % change in e-gun impedance.

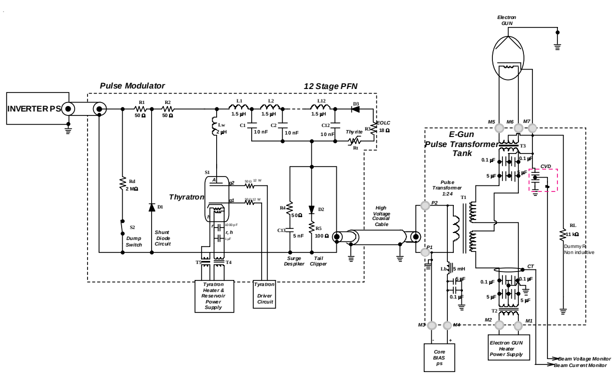



Figure 3: Line type pulse modulator schematic diagram.

## SIMULATION OF GUN MODULATOR

In order to predict performance of a new 3.4 µs PFN, computer simulations have been performed using PSim. Figure 4 shows the thyratron is modelled as a byderctinal used with a turn on time of 30 µs and a constant switch drop of 20 V. Stray capacity and wire inductance have been added. The pulse transformer is modelled using the simple three element component. This has been shown to be valid for predicting rise time and flat top performance for step-up pulse transformer having turns ratios greater than 1. The electron gun is modelled using a voltage-controlled –current source whose output is controlled by V, I ordered pairs in look up table.

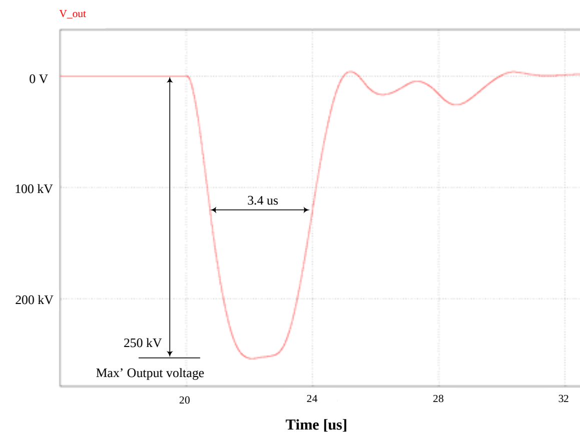



Figure 4: Output voltage waveform.

## CONCLUSION

Design studies for the electron gun are in progress. Given the glaring lack of normative data regarding the PLS-II the major upgrade, this study can be seen as the first in a needed stream of research investigating selection by dual gun and dc electron gun. If designed dual type gun, this is distance from electron gun to long beam-line to raise beam voltage more than 200 kV. DC type electron gun confirmed that voltage are used by 80 kV but they are difficult to use like dual type gun. We hope to complete the design of the pre-injector linac.

## ACKNOWLEDGMENTS

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