Abstract

A new pulser developed for the SLC thermionic gun has been operational since September 1984. It consists of two planar triode amplifiers with a common output triode driving the gun cathode to produce two independent pulses of up to 9 A with a 3 nsec FWHM pulse width. Three long-pulse amplifiers are also connected to the cathode to produce pulses with widths controllable between 100 nsec and 1.6 nsec. Each amplifier has independent timing and amplitude control through a fiber optic link to the high voltage plane of the gun cathode-grid structure. The pulser and its operating characteristics are described.

Introduction

The basic components of the SLC injector were installed in the spring of 1981. Since then the injector has been continuously improved. Although a laser gun capable of producing polarised electrons is still planned, the original thermionic gun* remains in place. This gun uses the EIMAC Y-796 cathode-grid assembly. With a drive of 200 V the gun is capable of producing up to 20 A peak current with a rise and fall time of less than 200 psec.

The SLC requires two electron bunches per accelerating RF pulse of the linac. (The second bunch will be accelerated to a positron target.) The required charge of 8 nC for each electron bunch must be contained in a small fraction of a cycle of the accelerating S-band RF. Space charge forces make it difficult to deliver the required charges to the bunching system in a pulse width of much less than 1 nsec. Consequently two sub-harmonic RF cavities (SHB) are used in addition to the normal S-band buncher to compress gun pulses of up to about 3 nsec width into a single S-band cycle.

The transverse emittance of the injector electron beam is dominated by the bunching process. To avoid the disruption to the beam caused by wakefields generated by the beam passing through the linac accelerating sections, the transverse emittance of the beam is reduced by about an order of magnitude during one inter-pulse period in a 1.2 GeV damping ring. The damping ring parameters require the two electron bunches to be 62.6 nsec (11 SHB cycles) apart.

The original gun pulser consisted of four, 3-transistor avalanche pulser driving 30 ft coaxial inversion transformers that produced a gun pulse of 8 to 7 A in a 5 nsec pulse. While this resulted in a single-bunch beam of adequate charge and emittance, the recovery time of the avalanche transistor circuit (several psec) precluded the possibility of providing the second bunch required by the SLC. Consequently a new pulser has been developed that is capable of producing two pulses of the required charge of any (including zero) interval. Additional independent amplifiers also are provided that can drive the gun cathode to produce electron pulses of 100 nsec to 1.5 nsec width for non-SLC experiments.

Fast Pulsers

The new SLC pulser uses a planar triode to provide the repetitive high current pulses required of the gun. Planar triodes are small rugged microwave tubes designed to operate up to 3 GHz. The output tube requires a large drive pulse which would normally be provided by an avalanche transistor circuit. However, because of the repetitive pulse limitations of such a circuit, it was decided to use two independent drive circuits with their outputs summed together. The two drive circuits allow independent control of the pulse separation and pulse amplitudes.

The pulser schematic is shown in Fig. 1. Two small planar triodes, type 875S, produce two independent drive pulses to an output amplifier triode, type 8940. The impedance matching between stages is accomplished with a coaxially-wound RF transformer, T3, although there are other methods that would be equally adequate. The output triode, V3, is operated in a common-cathode configuration, which provides a significant current gain. The plate of V3 directly drives the gun cathode, and since the tube is working into a very small load impedance, there is very little rise time degradation due to Miller-effect feedback capacitance between the pulse and grid.

Fig. 1. Schematic diagram of the fast double pulser.
avalanche pulser discharges the energy stored in two 68 pf capacitors to form a drive pulse whose width is determined by a 14-inch clip line at the cathode. For convenience the control bias for the tube is supplied through this same clip line.

Each of the fast pulsers will produce a 200 V pulse into a 30 Ω resistive load.

The fast pulser circuitry is contained on a PC card with an integral plug that mates directly to the socket at the rear of the gun cathode-grid assembly as shown in Fig. 2. The pulser card is readily inserted or removed by means of the handle shown in the figure. The fast pulser drivers and bias controls as well as the filament supply and the long-pulse pulser cards are housed in a high voltage deck, As indicated in Fig. 3, the HV deck is located immediately behind the gun. The deck as well as the ground plane of the fast pulser card is electrically connected to the gun grid. A 55 CFM blower located on the HV deck provides the necessary air flow through the 3-inch manifold shown in Fig. 3 to cool the gun socket. The HV deck is suspended from the ceiling by several acrylic rods and by the 500 V isolation transformer that supplies ac power to the HV deck. Both the deck and the gun are in an air atmosphere with no surrounding cage. The deck and the high voltage end of the gun insulator are equipped with polished aluminum corona shields to keep the

The link for the fast pulser triggers utilizes a fast LED driver, a 10 μs graded-index cable, and an avalanche photodiode at the receiver card. The receiver card contains the pulse amplifiers which produce the triggers for the fast pulsers.

The analog signals for filament and bias voltages are transmitted using voltage to frequency conversion. The resulting pulse train is transmitted through a standard Hewlett-Packard fiber optic link and converted back to analog levels at the receiver.

The gun modulator interface circuitry shown in Fig. 3 allows local control of the bias and filament levels or remote control by the SLC computer control program through CAMAC modules. Additionally the SLC personnel protection system (PPS) and beam containment (B/C) system are connected to the gun control system through the modulator interface.

Performance

The pulser system described above has been used at SLAC since September, 1984, for the generation of all SLAC beams with the exception of low-energy e⁻ beams, which are now generally obtained from the newly commissioned Nuclear Physics Injector. PEP and SPEAR beams are produced by the fast pulsers operating at moderate intensity and without pulsing the SH8RF. The long-pulse pulsers, which produce beams for fixed-target experiments, are connected directly to the gun cathode and possibly degrade the performance of the fast pulsers slightly but otherwise perform nicely. They produce electron pulses of up to 3 A peak current. With the linac SLEDed, these beams are limited to a width of ≤ 200 nsec. Beams of up to 1.6 μsec width have been injected into the linac during two short unscedded periods, but these wide pulse beams have not yet been adequately transported to the high-energy physics experimental areas.

Although the gun was designed to operate at up to 200 kV, the voltage was initially limited to 150 kV due to arcing which occurred in spite of the SF₆ atmosphere which was maintained around the gun. The original avalanche pulser was particularly susceptible to damage by this HV arcing. The arcing took place primarily along the cooling manifold (the blower was then mounted at ground potential), and sometimes along the trigger-transformer or HV supply cables. With the implementation of the HV deck and fiber optic link described above, the arcing problem has been eliminated at least up to the 200 kV limit of the power supply. The gun is now operated typically at 150 to 160 kV.

Two double fast pulsers have been built for the SLC gun (one is a spare). They perform in similar fashion. The maximum output of the gun operating at 150 kV when driven hard by one of the fast pulsers is about 9 A peak. The pulser have been adjusted to produce a pulse width of 3 nsec under these conditions. Up to 60% of the charge in the
The intensity jitter in the beam adversely affects the dynamic beam loading in the line after damping. The intensity jitter at the gun has a \( \sigma \) of \( \approx 0.5\% \).

**Conclusion**

The new pulser for the SLC thermionic gun produces on an interlaced basis all the types of gun pulses needed for the SLC lines. The pulser has performed well during almost a year of continuous operation. The potential for significant improvements in the intensity, stability, and versatility of control for the fast pulsers is high.

**References**

4. When operated with a filament voltage in the range of 7 to 8 V, the dispenser cathode lifetime exceeds one year of continuous operation. The gun vacuum varies between 2 and \( 5 \times 10^{-9} \) Torr. The vacuum is roughed with cryopumps and maintained with ion pumps. The anode-electrode material is copper.
5. The SBB operates at the 16th sub-harmonic of the 2856 MHz accelerating RF of the linac.
7. The HBFR-0500 series snap-together fiber optic link is used.
9. If the need for a long-pulse pulser were eliminated, a digit line could be added at the gun cathode.
11. The maximum net drive at the gun cathode with minimum gun bias (50 V) is measured with a cathode probe (no high voltage) to be 150 V. As shown in Ref. 5, this is more than enough voltage to drive the gun into the temperature limited region. With a filament voltage of 7.75 V, the maximum current expected at 150 kV is 8 A.
13. The HBFR-0500 series fiber optic link is used. It is about two times faster than the link in Ref. 7. The driver is located in a Canmac module and the cable runs directly to the receiver on the HV deck.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.