SLAC-PUB-7947
September 1998

Reflections on the SLAC Polarized Electron Source*

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Presented at the
Low Energy Polarized Electron Workshop
St. Petersburg, Russia
September 2-5, 1998

*Work supported by Department of Energy contract DE-AC03-76SF00515

REFLECTIONS ON THE SLAC POLARIZED ELECTRON SOURCE*

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Since its inauguration in 1992, the SLAC polarized electron source[1] has provided beam for numerous experiments with a high degree of reliability. The success of the source is due to processes used in the assembly and operation of its component systems. Improvements in the source configuration over this period have included the addition of a photocathode loadlock system, use of high polarization photocathodes and incorporation of solid state laser systems as photon sources. Stability of the delivered beam is primarily due to choice of critical subcomponents, reliance on computer controlled feedbacks and in some cases, operation of the photocathode near its saturation point.

The SLAC injector is a dual gun system with a thermionic gun on one leg of a Y-shaped selector bend and a polarized electron gun (Pgun) on the second. The Pgun is a standard Pierce diode electrode type as shown in figure 1.

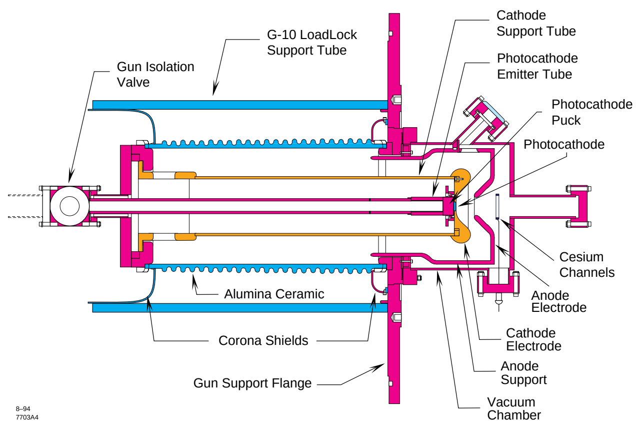

Figure 1. Polarized electron gun cross section. The loadlock attaches to the gun isolation valve.

The loadlock, which was added in 1993, serves several purposes. First, it enables the introduction of new photocathodes from atmosphere without venting either the main loadlock volume or the polarized electron gun. Second, it functions as an activation chamber which inhibits the introduction of oxidizing gas into the gun, a feature contributing to the many thousand hours *e*-fold cathode lifetimes in the Pgun. Third, it allows the

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selection from among several candidate cathodes of the best material for a particular experimental run. Base pressure in the Pgun is typically < $3x10^{-11}$ Torr, with all partial pressures other than hydrogen contributing less than $5x10^{-12}$ Torr.

The Pgun is operated at 120 kV with an output beam repetition rate of 120 Hz. In the collider mode, a pair of 2 ns pulses are generated with a spacing of 62 ns. The leading pulse is polarized and used at the interaction point, while the trailing pulse is used for positron generation. Peak currents are 5 A in this mode. For fixed target experiments, pulse lengths ranging from 100's of ns to microsecond time scales are used. So that the intense beam monitoring instrumentation can function, one pulse out of 120 is replaced with a short, high intensity pulse.

The current laser system consists of a set of two YAG-pumped Ti:sapphire lasers for short pulse production and one flashlamp-pumped Ti:sapphire laser for long pulse operations. The YAG lasers are limited to 60 Hz operation, so two are necessary to generate the 120 Hz beams. The lasers are intensity and time stabilized via feedbacks. The laser light is circularly polarized by a Pockels cell and delivered to the photocathode via an evacuated transport line and polarization preserving mirror box. Circular polarization in excess of 99% is routinely achieved. A diagram of the system in long pulse operation is shown below in figure 2.

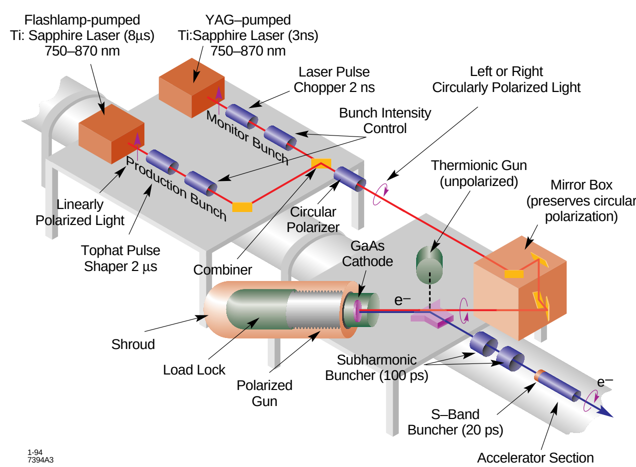

Figure 2. Injector layout for long pulse operation using the Flash-Ti:sapphire at 119 Hz and one cavity of the YAG-Ti:sapphire short pulse laser for the 1 Hz witness beam.

The photocathode is operated in somewhat different modes, as well, for long and short pulse applications. It is well known that the electrons photoemitted from GaAs have a polarization distribution which is more highly valued toward zero loss energy[2]. By allowing the negative electron affinity (NEA) state of the photocathode to decay, it is possible to cut off the tail containing the less polarized electrons. In this fashion, very high polarization for the long pulse operation is produced. Short, very intense pulse generation, on the other hand, tends to counter the NEA state by the generation of a surface photovoltage[3]. It is necessary in this case to operate the cathode with near-optimal NEA, so the polarization in that mode is not quite as high as for long pulse operation.

During the time that the SLAC polarized electron source has been in operation significant advances in photocathode design have been made. The strained GaAs photoemitter, pioneered at SLAC[4], enabled a threefold increase in source polarization beginning in 1993. Another increase was had upon decreasing the emitting layer thickness in 1994 from 300 to 100 nm. The thinner layer has two advantages. First, the overall strain relaxation is reduced simply since the layer is thinner and therefore exceeds the critical thickness by a smaller amount. Second, depolarization of the electrons during transport to the surface is inhibited by the diminished diffusion times, again only due to the decrease in thickness of the active layer. The polarization history is given below in figure 3.

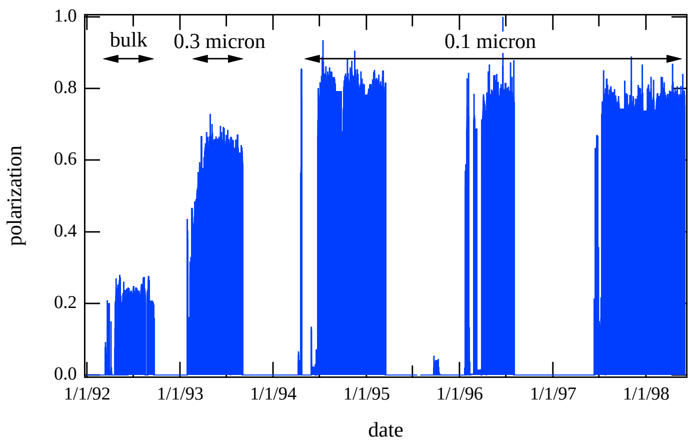

Figure 3. Polarization over a six year period as measured by the Compton polarimeter at the electron-positron interaction point.

A necessary condition for successful source operation is the delivery of beam for those times when the experiments require it. While it is possible to undertake machine physics studies when the experimental setup is unavailable, the converse is not true for the injector. In this light, the injector may be regarded as the single most critical component in the accelerator. In figure 4, below, are shown the source availability figures for experimental runs covering the last six years. The lowest values are 95%, but some runs exhibited 99% availability. While these numbers are quite good, they must be significantly improved for next generation machines, most likely through the implementation of dual injectors.

From the experiences in operating the SLAC polarized electron source, many additional lessons for next generation machines have been learned. First, for efficient choice of photocathode material, a low voltage polarization and quantum yield measurement apparatus is desirable so that new cathode material can be qualified and the best selected. Even among nominally identical wafers, enough variation is found to justify this expenditure. Second, a separate test facility for photocathode guns is useful so that the guns can be high voltage processed prior to installation and so that photocathode material can be tested for peak charge output. Third, the advantages of using a loadlock greatly outweigh the additional complexity added to the gun system through its inclusion. An additional use of the loadlock and gun test facility is the qualification and subsequent installation on the operational

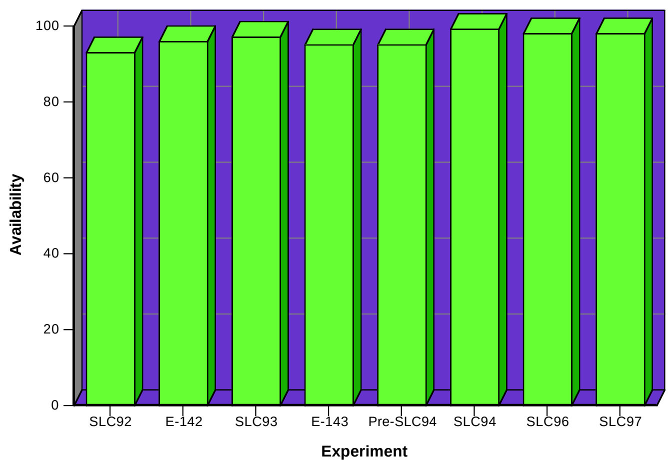

Figure 4. Availability of the source during operations over a six year period.

injector of prime photocathodes. Fourth is that automation, such as through the use of remotely controlled channel cesium sources, greatly aids the potential for maintenance of the injector system by machine operators in place of full time physicists.

Negative lessons have also been enforced by operational experiences. The placement of the SLAC loadlock at the high voltage end of the gun greatly complicates the changing of photocathodes and makes the high voltage shielding bulky and unwieldy. It also would be very advantageous to have a polarimeter on the injector beam line so that the spin transport through the accelerator could be precisely studied. Lastly, it has been determined that attempts at extrapolation of material parameters should be considered in full detail lest manufactured weaknesses be incorporated into the system. These lessons are part of the splendid success enjoyed by the SLAC polarized electron source for the past six years.

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[3] M. Woods, et al., J.Appl.Phys.73 (1993) 8531.

[4] T. Maruyama, et al., Phys. Rev. Lett. 66 (1991) 2376.