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THE SLC POLARIZED ELECTRON SOURCE*

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Abstract

A polarized electron source consisting of a 3-electrode photocathode gun and a flashlamp-pumped dye laser has been designed and built for the SLC and is currently undergoing commissioning. The source is described, and the operating configuration is discussed. The present status of the source and future plans are briefly indicated.

1. Introduction

The use of GaAs as a photocathode in an electron gun for producing a polarized beam for injection into a high energy electron accelerator was pioneered at SLAC.[1] The original GaAs source, which is still being used at SLAC to study methods of achieving higher polarization, was designed to produce peak currents exceeding 100 mA in a 1.6 μsec pulse at repetition rates of up to 180 Hz. The gun had a two electrode structure with the cathode biased at 60 to 70 kV. The basic configuration of this electron gun has been repeated in many other accelerator centers now producing or planning to produce polarized electron beams.

The SLC requires a single S-band bunch[2] of 5×10^{10} e^- per pulse at the interaction region to collide with a similar positron bunch at rates of up to 120 Hz. The injector utilizes subharmonic bunching to compress a 2 ns pulse into a fraction of an S-band cycle. The subharmonic buncher operates at the sixteenth subharmonic of the 2856 MHz accelerating RF of the linac. Given the efficiency of the buncher and the remaining sections of the SLC, the gun itself is required to produce up to 2×10^{11} e^- per bunch which is equivalent to a peak current of about 16 A. The transverse emittance of the initially accelerated beam is dominated by an emittance growth in the buncher of about a factor of 10.

The SLC positron beam originates with an electron beam from the same gun gen-

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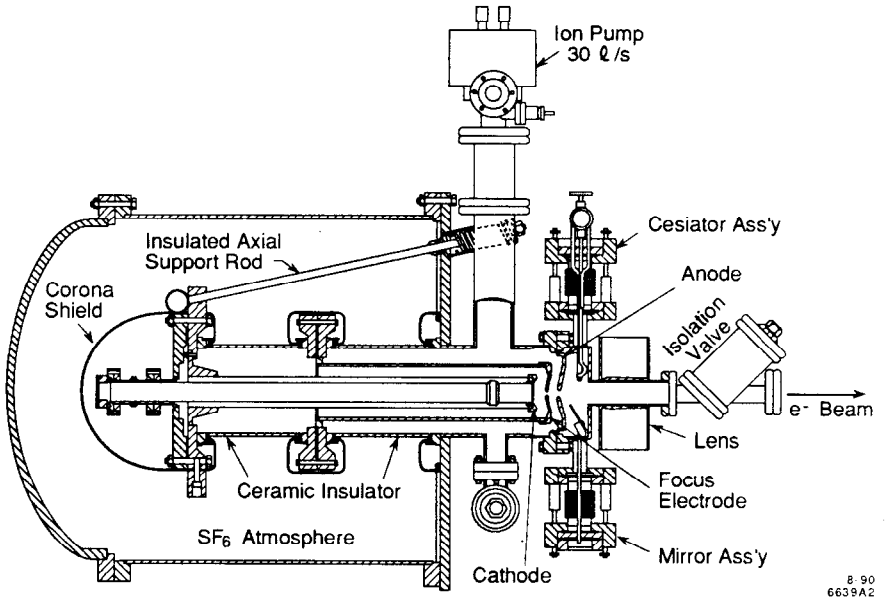

Figure 1: The SLC Polarized Electron Gun. The GaAs cathode sits in the middle of a larger stainless steel cathode structure and can be separately retracted for heat treatment. The cesiator and mirrors are on linear manipulators. For cesiating the cathode, they are positioned along the beamline. The cesium beam passes through a hole in the mirror. During the cesiation process, the cathode is biased to about 50 VDC. The photoemission is monitored with an electrometer. Typically an ordinary incadescent lamp is used to illuminate the cathode. The light from the side-mounted lamp is bounced from the mirror to the anode, back to the mirror, and finally to the cathode.

erating the colliding electron beam. At 120 Hz, the two gun pulses must be accelerated by the same linac RF pulse. Since the overall positron production efficiency is about unity, these two gun pulses also must be approximately equal in intensity.

2. Description of the Source

To meet SLC requirements, a new GaAs photocathode gun was designed to operate at up to 200 kV to minimize longitudinal space charge effects at high intensities.[3] A focusing electrode was placed between the cathode and anode to allow the transverse emittance to be adjusted. The focusing electrode also limits the electric field at the cathode to < 3 MV/m at the full 200 kV bias, although fields as high as 12 MV/m are present on other portions of the electrode surfaces that are exposed to Cs. The gun is shown in Fig. 1. A schematic of the SLC injector is shown in Fig. 2. The source specifications are given in Table 1.

The light source is a Candela flashlamp-pumped dye laser that can be operated at up to 120 Hz with a maximum power output of 70 kW in a 600 ns pulse. For the SLC, 2 ns pulses are selected from the laser beam using a Pockels cell and two crossed

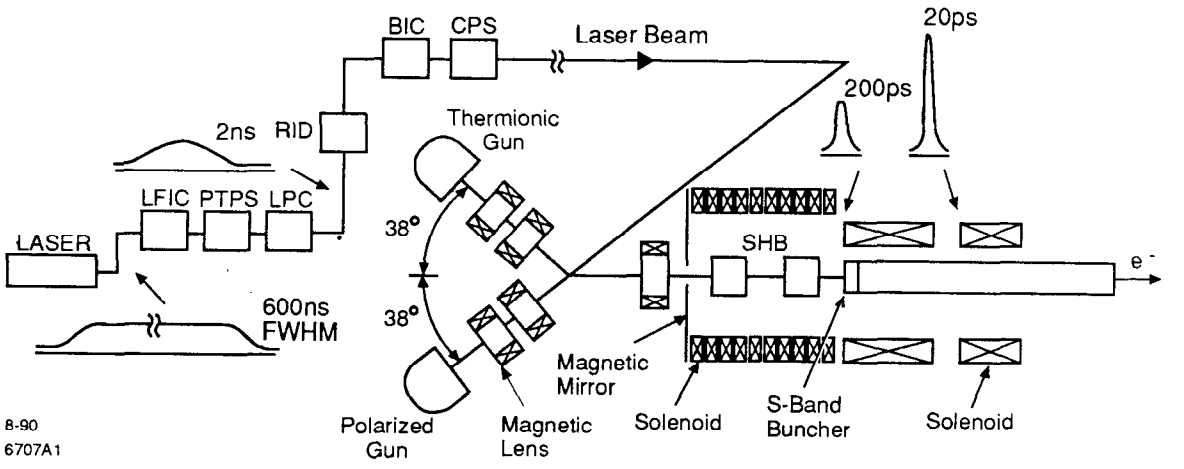

Figure 2: Schematic of the SLC injector. There are two gun ports, to one of which the SLC thermonic gun is presently connected and operating. The 600 ns laser pulse traverses the following electro-optic devices: LFIC (laser feedback intensity control), PTPS (pulse-to-pulse stabilizer), and LPC (laser pulse chopper), at which point the laser pulse is 2 ns as shown. Next is the RID (ratio of intensity driver), BIC (bunch intensity control), and CPS (circular polarization sign), after which the laser beam is directed to the gun cathode. The temporal structure of the polarized gun electron pulse follows the laser pulse and thus is also ~2 ns FWHM. The phase space of the photocathode electron beam is designed to be similar to that of the thermionic gun. Two stages of electron bunch compression are shown: at ~200 ps after the SHB (subharmonic buncher), and at ~20 ps in the accelerator section where the beam is fully relativistic. There is no significant depolarization during the bunching process.

Table 1. SLC requirements for the polarized source.

Item	Requirements	Present Status	Units
Laser repetition rate	120	120	Hz
Maximum gun current	2×10^{11}	(a)	e^-/bunch
Pulse-to-pulse intensity jitter (σ)	< 0.5	~ 3	%
Pulse-to-pulse timing jitter (σ)	< 15	< 30	ps
Pulse duration (FWHM)	2	< 3	ns
Pre- and post-bunch charge in accelerated beam	$< 5 \times 10^8$	(b)	e^-/bunch
Pre- and post-bunch charge after Damping Ring	$< 1 \times 10^8$	(c)	e^-/bunch
Bunch separation (nominal at 120 Hz)	61.625	(d)	ns

(a) Present laser intensity sufficient if Q.E. > 0.5%.

(b) Present laser optics sufficient if charge is integrated over 600 ns.

(c) Present laser optics sufficient if charge integrated over 30 ns.

(d) Temporal pulse separation with present laser optical system completely controllable through the SLC timing system.

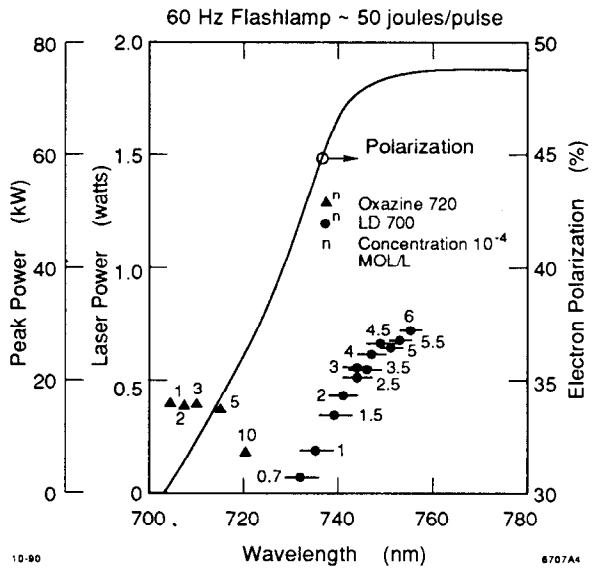

Figure 3: Laser output power and polarization of thin GaAs as a function of wavelength for two dyes of several molecular concentrations. The polarization curve shown here is taken from the "within 5 h after activation" curve shown in Fig. 2 of Ref. 4.

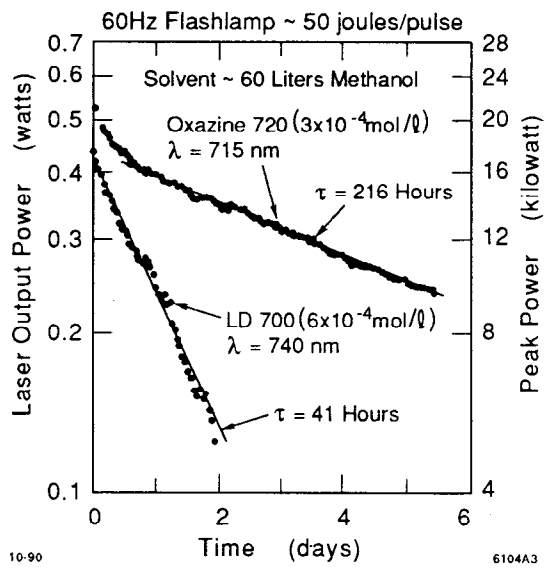

Figure 4: Measured laser outputpower as a function of time for two different dyes at optimum concentrations.

polarizers. The Pockels cell is driven by a planar triode amplifier. The fast pulse is achieved by use of a ferrite-loaded pulse compression line and pulse forming network. Additional electro-optical systems are utilized to provide intensity stabilization and to allow remote control and monitoring of intensity and timing. Timing control with low jitter is provided by the SLC timing system. The entire laser operation is designed to be monitored and controlled remotely.

The predicted maximum electron polarization from a GaAs photocathode is 50%. By utilizing GaAs crystal layers less than 0.4 mm thick, this polarization can actually be achieved even at room temperature.[4] However, a laser operating at or slightly above 760 nm is required. To date, the most promising dye for the laser is Oxazine 720. Utilizing this dye, a high-power light beam can be produced while the dye retains a long lifetime. However, the laser output power peaks at about 715 nm, a wavelength for which the polarization from a thin GaAs cathode is less than 35%. Figure 3 shows as a function of wavelength the electron polarization for thin GaAs on the righthand ordinate, and the laser intensity for two dyes at various concentrations on the lefthand ordinate. Figure 4 shows the laser intensity vs. time for both dyes at optimal concentrations.[5] By adding about 10% Al to the GaAs, the roll-off in the polarization curve can be shifted downward[6] to about 720 nm. The net result is that a polarization of about 40% is expected for the SLC source operating with the present dye laser and an AlGaAs cathode. (Depolarization effects during the acceleration and transport of the beam to the interaction region are expected to be relatively small.[7])

3. Present Status and Future Plans

The SLC polarized gun was installed alongside the SLC thermionic gun at the linac injector in the spring of 1986. The dye laser and the HV power supplies for the gun were not installed at the injector until the fall of 1989. Initial testing of the source in this configuration indicated excessive field emission at high voltage that, in turn, resulted in contamination of the cathode. The gun has been removed from the linac injector and is presently in the laboratory undergoing modification and additional testing.

Research with new cathodes to increase the polarization of the electron beam continues at SLAC. In addition, a new, tunable, solid-state laser, which is expected to be purchased during the coming year, will permit use of thin GaAs cathodes and correspondingly higher polarization. SLAC is also building a second polarized gun for the SLC. A system to rapidly exchange the two guns will be incorporated into the design in order to increase the efficiency of the polarized beam system.

Acknowledgements

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