SLAC–PUB–6074
March 1993
(A)

Performance of the SLC Polarized Electron Source and Injector with the SLAC 3 km Linac Configured for Fixed Target Experiments*

A. D. YEREMIAN, R. K. ALLEY, J. E. CLENDENIN, J. C. FRISCH, C. L. GARDEN, L. A. KLAISNER, A.V. KULIKOV, R. H. MILLER, C. Y. PRESCOTT, P. J. SAEZ, D. C. SCHULTZ, H. TANG, J. L. TURNER, M. B. WOODS
M. ZOLOTOREV
Stanford Linear Accelerator Center
Stanford, CA 94309

Abstract

The SLC polarized electron source (PES) can be modified to produce μsec-long pulses for injection into the unSLEDed SLAC 3 km linac, with a duty factor considerably higher than for SLC. Such beams are desirable for fixed target experiments at SLAC requiring polarized electron beams of up to 50 mA within an energy spread of 0.5%, at energies of up to 26 GeV. During the fall of 1992, the SLAC linac was operated continuously for two months unSLEDed with the PES dye laser (715 nm) modified to produce a 1 μec pulse at 120 Hz. An AlGaAs photocathode was installed in the electron gun to achieve 40% polarization, and a prebuncher was added to the SLC injector to improve capture for long pulse beams. We discuss the performance of the polarized electron beam for long pulse operation.

I. INTRODUCTION

A fixed target experiment (E-142) was conducted at SLAC for which a 1–2 μsec electron pulse of 10–20 mA at the target at a repetition rate of 120 Hz and with at least 40% polarization was required. To accommodate these requirements, the Candela dye laser at the SLC Polarized Electron Source (PES) was modified to produce a low intensity laser pulse >1 μsec. To improve the electron capture by the injector, an S-band pre-buncher was installed upstream of the S-band buncher and capture section. The layout of the polarized gun and the first few meters of the beam line are shown in Fig. 1.

The PES was operated at 60 kV to produce a 1 μsec, 30 mA electron pulse at 120 Hz from the source.

II. LASER

The Candela flash lamp-pumped dye laser used for the SLC 1992 run was modified to produce a pulse width >1 μsec (Ref. 1). This was accomplished by decreasing the laser cavity losses by making two changes: 1) the dye concentration was reduced from 3 to 2×10^{-4} mol/*l*; and 2) the reflectivity of the output coupler was increased from 55% to 80%. The laser output

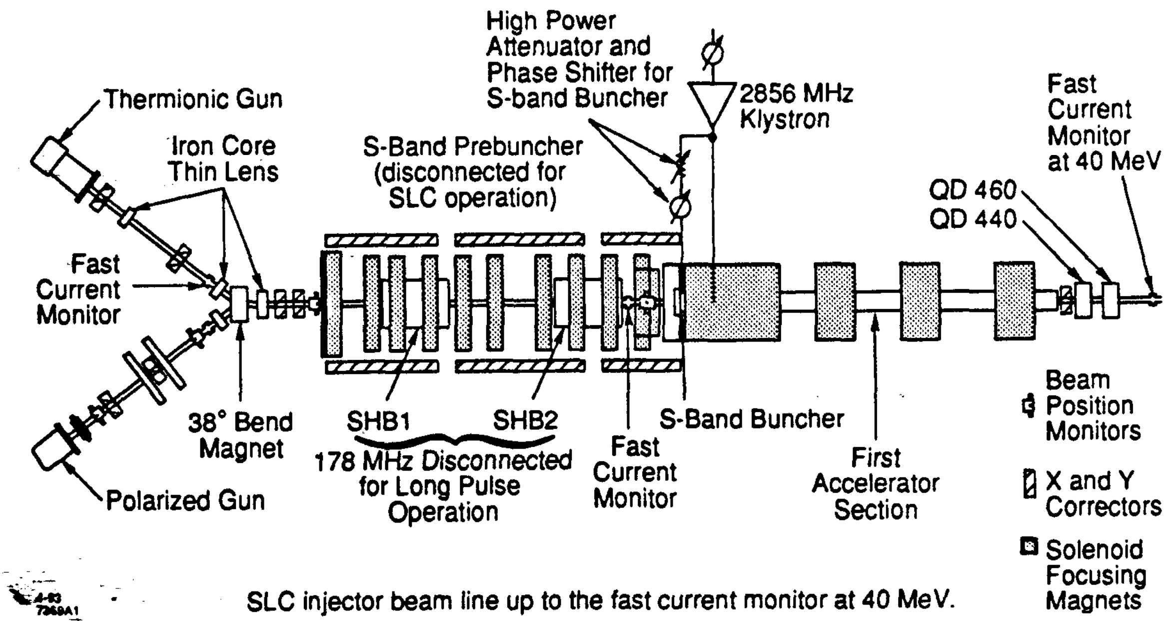

Figure 1. SLC injector beam line up to the fast current monitor at 40 MeV.

*Supported by Department of Energy contract DE-AC03-76SF00515.

Presented at the Particle Accelerator Conference (PAC '93), Washington, D.C., May 17–20, 1993

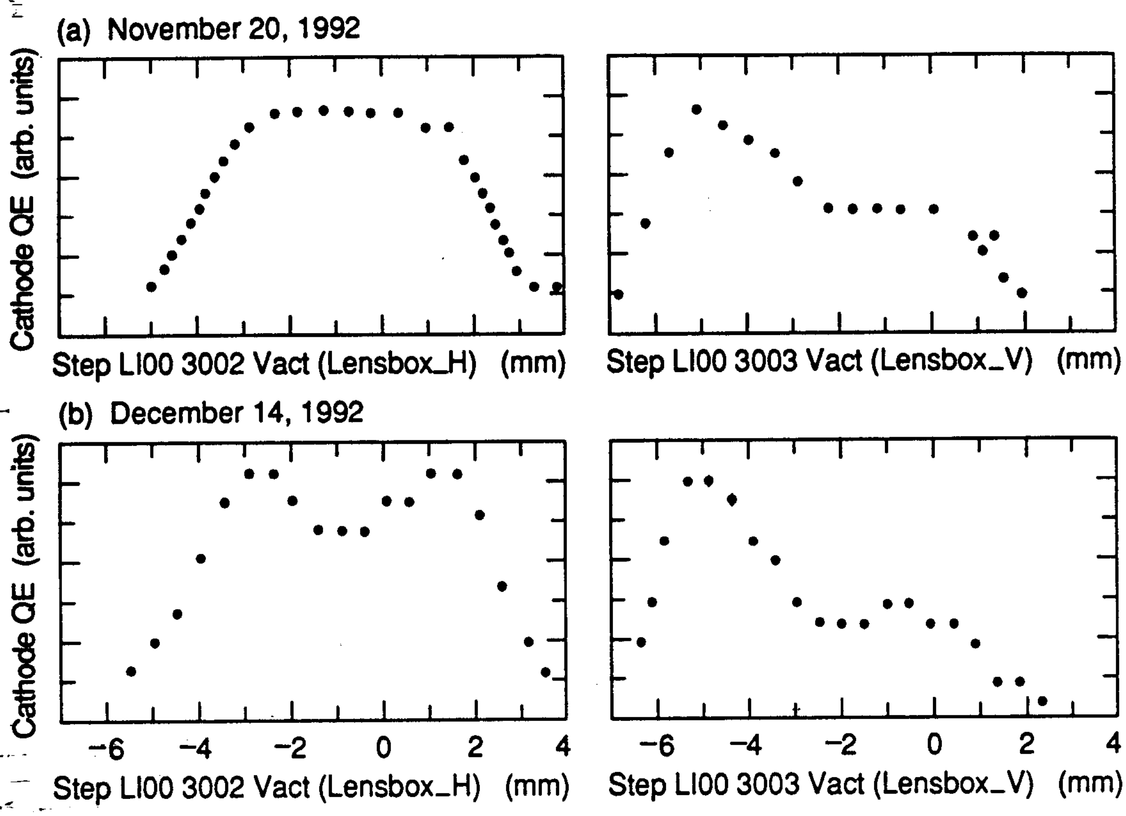

Figure 2. Horizontal (LENSBOX H) and Vertical (LENSBOX V) QE scans of the cathode.

pulse was chopped and flat-topped with a pulsed-Pockels cell and crossed-polarizer system, TOPS (Top Hat Pulse Shaper), to produce the desired light pulse. Although the system was capable of producing a 2 μec long pulse under optimum conditions, during the E-142 run, the laser was operated in the 1.0–1.3 μsec range. A fast pulser, LPC (Laser Pulse Chopper), upstream of TOPS, could produce a narrow SLC-type pulse that was detectable by the SLC linac beam position monitors. Normally the short pulse was run at 1 Hz with the production pulse operating at 119 Hz. To optimize laser power and dye lifetime, the Candela was operated at 715 nm with Oxazine 720.

III. CATHODE

The active layer of the photocathode was 0.3 mm of $Al_{0.12}Ga_{0.88}As$, Be doped to 6×10^{18} cm^{-3}. At final activation of the cathode by heat cleaning and cesiation the initial quantum efficiency (QE) was 1.5% at 750 nm (at low V), rapidly dropping to 0.8% (at 60 kV). The cathode temperature throughout the run was maintained at 0°C, which in the SLC gun is thought to increase the lifetime of the cathode. The gun for this run was Diode Gun 1.

For the SLC 1992 run, a thick GaAs cathode was used, for which the bandgap at 0° C is about 1.44 eV (860 nm) (Ref. 2). At 715 nm, the polarization at the source was ~27%. For E-142 the expected polarization at the source was increased by using a cathode with a larger bandgap. Adding 12% Al to the active layer increases the bandgap at 0°C to about 1.63 eV (760 nm). By using a 0.3 mm thick $Al_{0.12}Ga_{0.88}As$ cathode operated at 0° C, the source polarization at 715 nm was expected to be ~40% (Ref. 3). The typical electron polarization measured by MØller in End Station A (ESA) was 41% .

During the entire run the QE did not change significantly. The QE profile across the cathode surface started with a large peak on the "+" vertical side. Near the end of the run, a dip in the middle of the horizontal scan was observed (see Fig. 2).The horizontal (LENSBOX_H) and vertical (LENSBOX_V) scans of the cathode were made with a HeNe laser (spot diameter ~2 mm) on November 20th and December 14th. The abscissa indicates motion of the lens box in mm.

The average QE as measured at 60 kV with a modulated diode laser operating at 750 nm varied over a period of many days between 0.7% and 0.9%. These variations may have been entirely instrumental.

It is not known why the QE held constant. Certainly the lower voltage helped. The dark current at HV (laser blocked) was typically about 10 nA, a factor of 5 to 10 lower than during SLC 1992 run (for which the voltage was 120 kV with a different gun). The gun vacuum was also extremely low: the mass 4 (28) peak was about 6 (1) x 10^{-12} Torr, unchanged with HV on or off. The low peak currents (compared to SLC 1992) may have helped reduce electron stimulated molecular desorption from the vacuum components near the source cathode. All the vacuum components except the cathode were at about 35°C, the temperature of the accelerator housing.

V. ELECTRON BEAM INTENSITY

The laser beam intensity at the cathode was kept constant by a hardware feedback system integral to TOPS. To compensate for changes in the QE, provision was made for a software feedback system which monitored the electron beam intensity at the first BPM (Beam Position Monitor) and could adjust the attenuation of the laser beam using the BIC (Bunch Intensity Control) located just downstream of TOPS. Since the QE was essentially constant, the software feedback was not activated, the BIC being adjusted only occasionally and in manual mode in response to changed beam requirements or sometimes, near the end of a lamp/dye cycle, when TOPS could no longer provide the desired laser intensity.

Since E-142 was the first fixed target experiment with the full SLC linac, it is perhaps not surprising that although the instrumentation for tuning the beam was adequate, it was not optimal. Midway into the run, the transmission of the beam from the polarized gun cathode to the beam switchyard through the 0.7% energy defining slits was increased from 25% to 55%. This was accomplished by adjusting the injector bunching and steering using the entire linac as a monitor.

For most of the experiment, the Candela beam diameter on the cathode was maintained at about 6 mm. (The active area of the cathode has a diameter of 14 mm.) Thus the maximum current density drawn from the cathode was about 0.2 A cm^{-2}.

The Candela is a multimode laser with an intensity jitter of 3 to 4%. TOPS reduced this jitter by about a factor of ~2. The electron beam intensity jitter as measured on the linac toroids at 40 and 200 MeV was typically the same as the laser jitter at the TOPS output.

V. SUMMARY

There were about 1062 total hours in the E142 run. The PES was available to provide full intensity beams to the linac for 96% of that time. The downtime attributed to the PES totaled only 41 h, of which 32 h were associated with scheduled lamp and dye changes followed by restoration of the injector beams.

The timing of the lamp and dye changes was driven by downtimes scheduled as part of the turn on for the SLC 1993 run, and thus was not optimum for PES efficiency. Nonetheless, the average interval between these changes was about 200 h (8.4 days).

Other than for maintenance tasks such as lamp and dye changes, the PES was operated entirely from the SLC Main Control Center by the SLC operators.

REFERENCES

1. "Polarized Light Sources for Photocathode Electron Guns at SLAC," M. woods, J. Frisch, K. Witte, M. Zolotorev, Dec. 1992, SLAC PUB 5965, submitted to the 10-th Int. Symp. on H.E. Spin Physics, Nagoya, Japan (1992).
2. "Polarized Source Performance in 1992 for SLC-SLD," D. Schultz, R. Alley, J. Clendenin, J. Frisch, C. Garden, E. Hoyt, L. Klaisner, A. Kulikov, C. Prescott, P. Saez, H. Tang, J. Turner, M. Wicks, M. Woods, D. Yeremian, M. Zolotorev, February 1993, SLAC-PUB-6060, submitted to the 10-th Int. Symp. on H.E. Spin Physics, Nagoya, Japan (1992).
3. "Electron Spin Polarization in Photoemission From the Thin AlxGA1-xAs," T. Maruyama, E. L. Garwin, R. A. Main, R. Prepost, J. S. Smith, J. D. Walker, SLAC–PUB–5367, 1992, to be published in Journal of Applied Physics.