SLC POLARIZED BEAM SOURCE ELECTRON OPTICS DESIGN*

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This paper describes the design of the beam-line from the polarized electron gun to the linac injector in the Stanford Linear Collider (SLC). The polarized electron source[1] is a GaAs photocathode, requiring 10^{-11}-Torr-range pressure for adequate quantum efficiency and longevity. The photocathode is illuminated by 3-nsec-long laser pulses. The quality of the optics for the 160-kV beam is crucial since electron-stimulated gas desorption from beam loss in excess of 0.1% of the 20-nC pulses may poison the photocathode. Our design for the transport line consists of a differential pumping region isolated by a pair of valves. Focusing is provided by a pair of Helmholtz coils and by several iron-encased solenoidal lenses. Our optics design is based on beam transport simulations using $2\frac{1}{2}$-D particle-in-cell codes to model the gun and to solve the fully-relativistic time-dependent equations of motion in three dimensions for electrons in the presence of azimuthally symmetric electromagnetic fields.

The design of the polarized beam source transport system is nearly complete. We are beginning to fabricate two identical systems. One system is to be installed in the SLC this summer for operation this autumn. A copy is to be installated in a polarized gun test laboratory this summer, in order to test the SLC polarized source prior to operating the source in the SLC, and for future tests of new photocathode guns.

In the present configuration, shown in Figure 1, two guns can be mounted on the SLC injector. One gun has a GaAs photocathode suitable for producing a polarized electron beam. The other gun, which has a thermionic cathode, has produced the unpolarized beams used in previous SLC operations. Both of these guns aim into a "Y"-shaped vacuum chamber inside a DC bend magnet that can bend the beam from either gun into the SLC injector.

Isolation of the photocathode gun vacuum from the "Y" region is necessary for two reasons: (1) It will be necessary occasionally to remove the photocathode gun from the accelerator and to replace it with a spare. When swapping guns, it is desirable to maintain vacuum in the guns and in the "Y" chamber. (2) The photocathode demands pressure below 10^{-10} torr for adequate quantum efficiency and lifetime. The best pressure attained in the "Y" chamber is of order 10^{-9} torr.

The vacuum system design is described elsewhere in these proceedings[2] The goal of photocathode vacuum isolation is met by a pair of all-metal straight-through valves with low magnetic permeability[3] The valves have 2.9-cm-diameter aperture and are 18-cm long. One valve seals-off the gun. The other valve seals-off the "Y" chamber.

The valves pose a challenge for the optics design because they lengthen the beam transport line and constrict its aperture. A potential source of gas load comes from beam loss. The total charge in the 3-nsec pulse is 20 nC. In order to maintain electron-stimulated gas desorption at an acceptable level, we estimate that beam losses must be less than 0.1% before the bend, and less than 1% after the bend.

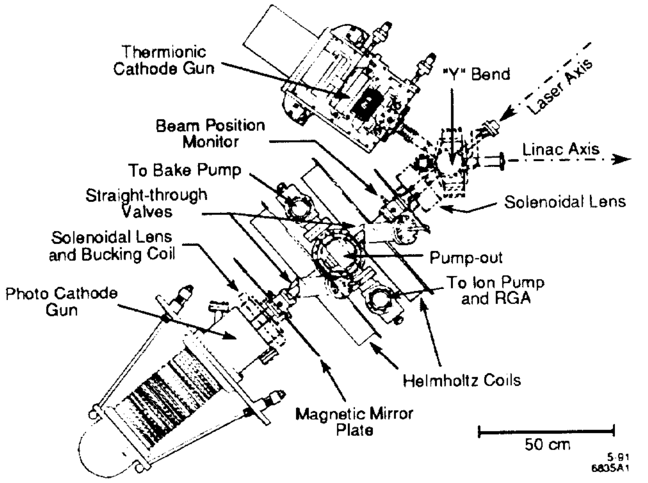

Figure 1: Plan view of the SLC gun region. The polarized electron beam emerges from the photocathode gun (at lower left), passes through a pair of straight-through valves and Helmholtz coils, and is bent through the "Y" chamber into the linac injector. The upper beam-line is the (unpolarized) thermionic gun.

The optics design is further complicated by the fact that the photocurrent is not space-charge limited at the head, tail, and outer radial edges of the beam pulse. This situation arises because the chopped 3-nsec-long laser pulse has finite rise- and fall-times, and because the spatial distribution of the laser spot on the photocathode has edges of diminishing intensity. The temporal distribution used in the simulations is shown in Figure 2.

The basic optics design was calculated using Herrmannsfeldt's electron optics and gun design code[4] to model the gun electrode structure, and the CONDOR electromagnetic simulation code to model the transport line.[5, 6]

The magnetic field configuration for the optics design is shown in Figures 3 and 4, which were calculated by the POISSON computer program. The focusing field necessary to transport the beam efficiently through the pair of low-permeability straight-through valves[3] is provided by a pair of air-core Helmholtz coils. The coils, which are

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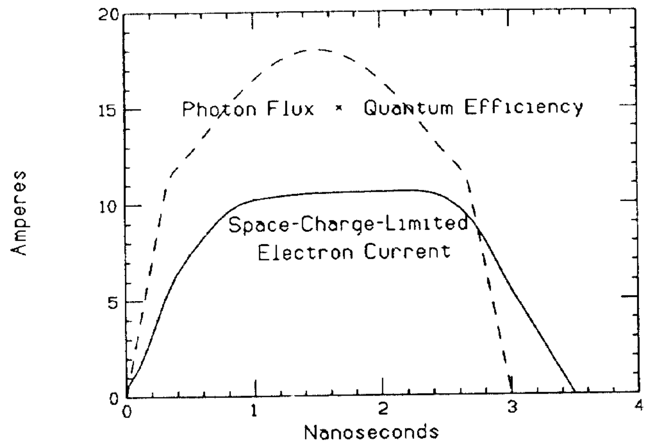

Figure 2: Temporal profile of the laser pulse and the resulting photoemission pulse.

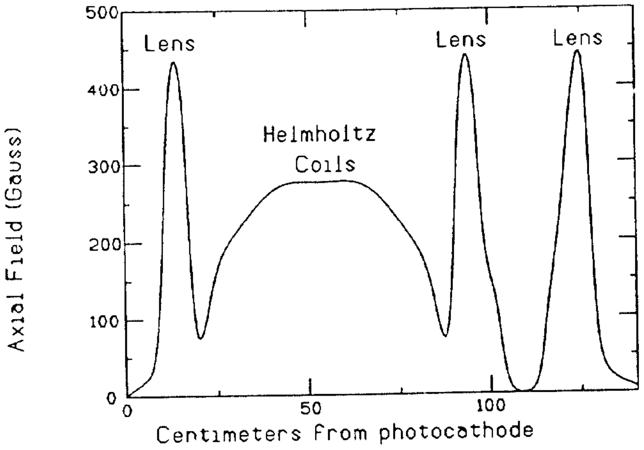

Figure 3: Axial focusing field profile from the photocathode to beyond the "Y" bend chamber, computed by POISSON.

wound from hollow water-cooled conductor, are to be run at half of their 19000-amp-turn peak capability. The coils, which encircle the valves, have 40-cm inner-diameter, 63-cm outer-diameter, and are separated by 26 cm.

Additional focusing is provided by 2500-amp-turn iron-encased solenoidal magnetic lenses. Lenses are located 40 cm on either side of the center of the Helmholtz pair. One of these lenses is mounted on the gun. Another is mounted on the entrance to the "Y" chamber. A third lens is mounted on the exit of the "Y" chamber. The lenses are bakeable to 250°C.

A 1100-amp-turn bucking coil is wound around the first lens. The coil is made of solid wire, is bakeable to 250°C, and has an external cooling water circuit. The purpose of the bucking coil is to zero the DC magnetic flux through the cathode, which is important for producing a low-emittance beam. The normalized beam emittance due to axial field B_c through the cathode is $(e/2mc)R^2B_c$, where R is the beam radius at the cathode.

The beam envelope, displayed as a superposition of CONDOR's step-by-step snapshots, is displayed in Figure 5.

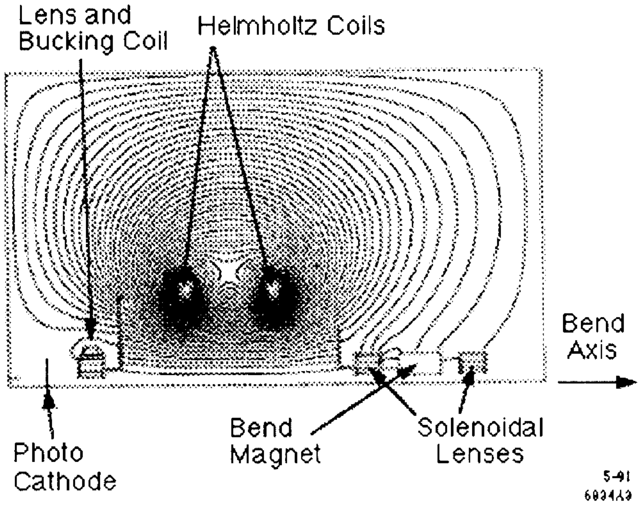

Figure 4: Magnetic flux plot from the photocathode to beyond the "Y" bend chamber, computed by POISSON.

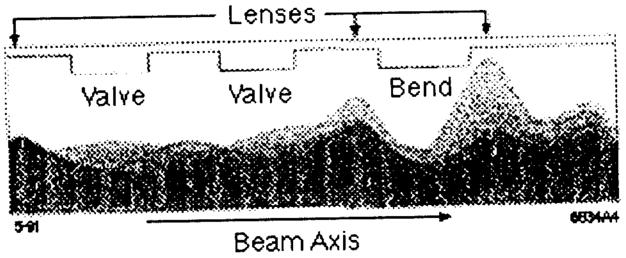

Figure 5: The beam envelope from the photocathode to beyond the bend chamber, computed by CONDOR.

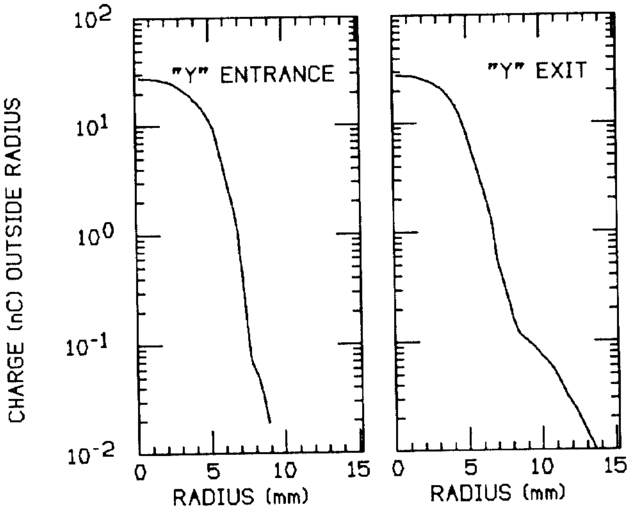

Figure 6: The beam profile before and after the bend, computed by CONDOR. *The horizontal axis in both plots extends to the beam pipe wall. The plot indicates that the desired limits on interception (0.02 nC before the bend and 0.2 nC after the bend) have been met.*

Not all dots in this figure represent the same amount of charge. A quantitatively precise plot of the beam profile in the CONDOR simulation is shown in Figure 6, both before and after the bend.

We are extending our beam dynamics simulation studies through the buncher region of the SLC injector in order to study effect of beam-size and scalloping on capture and bunching, and on depolarization induced by the intense beam's self-fields.

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References

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