SLAC-PUB-11657
January 2006
(A)

ILC @ SLAC R&D Program for a Polarized RF Gun *

J. E. CLENDENIN, A. BRACHMANN, D. H. DOWELL, E. L. GARWIN,
K. IOAKEIMIDI, R. E. KIRBY, T. MARUYAMA, R. A. MILLER, C. Y. PRESCOTT,
J. W. WANG

Stanford Linear Accelerator Center
Menlo Park, CA 94025, USA

J. W. LEWELLEN

Argonne National Laboratory
Argonne, IL 60439, USA

R. PREPOST

Department of Physics, University of Wisconsin
Madison, WI 53706, USA

Abstract

Photocathode rf guns produce high-energy low-emittance electron beams. DC guns utilizing GaAs photocathodes have proven successful for generating polarized electron beams for accelerators, but they require rf bunching systems that significantly increase the transverse emittance of the beam. With higher extraction field and beam energy, rf guns can support higher current densities at the cathode. The source laser system can then be used to generate the high peak current, relatively low duty-factor micropulses required by the ILC without the need for post-extraction rf bunching. The net result is that the injection system for a polarized rf gun can be identical to that for an unpolarized rf gun. However, there is some uncertainty as to the survivability of an activated GaAs cathode in the environment of an operating rf gun. Consequently, before attempting to design a polarized rf gun for the ILC, SLAC plans to develop an rf test gun to demonstrate the rf operating conditions suitable for an activated GaAs cathode.

Contributed to
XIth International Workshop on Polarized Sources and Targets (PST05)
November 14-17, 2006, Tokyo, Japan

* Work supported by Department of Energy contracts DE-AC02-76SF00515 (SLAC), W-31-109-ENG-38 (ANL) and DE-AC02-76ER00881 (UW).

ILC @ SLAC R&D PROGRAM FOR A POLARIZED RF GUN*

J. E. CLENDENIN, A. BRACHMANN, D. H. DOWELL, E. L. GARWIN,
K. IOAKEIMIDI, R. E. KIRBY, T. MARUYAMA, R. A. MILLER, C. Y. PRESCOTT,
J. W. WANG

Stanford Linear Accelerator Center
Menlo Park, CA 94025, USA

J. W. LEWELLEN

Argonne National Laboratory
Argonne, IL 60439, USA

R. PREPOST

Department of Physics, University of Wisconsin
Madison, WI 53706, USA

Photocathode rf guns produce high-energy low-emittance electron beams. DC guns utilizing GaAs photocathodes have proven successful for generating polarized electron beams for accelerators, but they require rf bunching systems that significantly increase the transverse emittance of the beam. With higher extraction field and beam energy, rf guns can support higher current densities at the cathode. The source laser system can then be used to generate the high peak current, relatively low duty-factor micropulses required by the ILC without the need for post-extraction rf bunching. The net result is that the injection system for a polarized rf gun can be identical to that for an unpolarized rf gun. However, there is some uncertainty as to the survivability of an activated GaAs cathode in the environment of an operating rf gun. Consequently, before attempting to design a polarized rf gun for the ILC, SLAC plans to develop an rf test gun to demonstrate the rf operating conditions suitable for an activated GaAs cathode.

1. Introduction

The ultimate goal of the R&D program is to develop an L-band rf gun system for polarized electrons that will meet the ILC beam operational requirements. Unpolarized rf photoinjectors have already been demonstrated to meet these requirements [1], but because of the uncertainty in the viability of an activated GaAs-type photocathode in the environment of an operating rf gun, the ILC

* Work supported by Department of Energy contracts DE-AC02-76SF00515 (SLAC), W-31-109-ENG-38 (ANL) and DE-AC02-76ER00881 (UW).

baseline configuration presently specifies a dc gun for generation of polarized electrons. The advantages of an rf over a dc gun include:

- For a beam that consists of a train of closely-spaced pulses (as required by the ILC), the source laser system can be used to generate the high peak current required for each micropulse without the need for post-extraction rf chopping or bunching;
- Lower beam emittance—both transverse and longitudinal—which will improve the operational reliability and efficiency of the injector; and
- Higher quantum yield (QY) with a higher threshold for the surface charge limit.

2. Elements of the R&D Program

2.1. *Improved Vacuum*

Operating pressures at the cathode of 10^{-11} Torr or better are essential. To achieve this level, the conductance between the cathode and pump must be significantly improved and the outgassing rate of the structure must be decreased. The conductance for pumping on any rf structure can be improved by using z slots [2] or multiple small holes (sieve) [3] in the outer cylinder. In addition, the conductance within the rf structure itself depends on the design. Two interesting possibilities are the plane-wave-transformer (PWT) and the higher-order-mode (HOM) designs. The HOM design [4] is particularly inviting because it contains no internal structures, which not only optimizes conductance, but also minimizes internal joints and simplifies cooling. By choosing an appropriately tapered radius for the HOM structure, it's electric field on axis, $E_z(z,r=0)$, can be made equivalent to that of the standard BNL-type design. A tapered 0.75-wavelength L-band HOM cavity is compared to a standard 0.715-wavelength structure in Figure

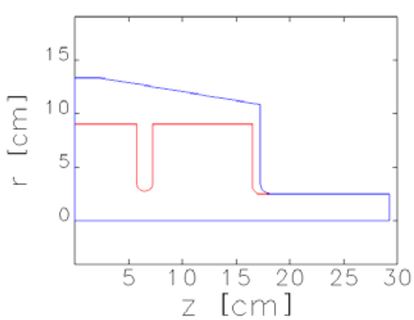

Figure 1. Cross section of a tapered L-band HOM TM011 rf gun structure (larger radius) superimposed over a standard BNL-type TM010 gun structure.

1. An HOM gun with slots or sieve would have an overall conductance about 20 times higher than a standard gun.

The typical gas load of an operating rf gun corresponds to an outgassing rate of 10^{-11} Torr-l/s cm^{-2}, which includes the effect of virtual leaks from grain boundaries and structural joints. A reduction in this rate of at least an order of magnitude is required. The type of material used may be important. Various types of Class 1 OFE Cu and related alloys will be examined. Assembly and cleaning techniques will also be evaluated.

Improved conductance and a lower outgassing rate, combined with sufficient pumping speed—provided at these low pressures by NEG pumps—should result in the desired pressure at the cathode.

2.2. *Reduction of Field Emitted Electrons*

When a GaAs cathode activated to negative electron affinity (NEA) was tested in a ½-cell S-band rf gun at BINP, the QY lifetime of the cathode was measured in terms of only a few rf pulses [5]. This rapid deterioration was attributed to back bombardment of the cathode by electrons, which of course does not occur for a dc gun. Since all the photoelectrons are expected to exit the gun, the principal problem will be with field emitted electrons. Field emission is most likely to originate at the cathode plug, the iris, and the rf input coupler. The coupler source can be mitigated by using z-coupling or eliminated entirely using axial coupling. The iris source can be reduced by elliptical shaping. Field emission from the cathode plug is a problem that will require special study. Of course the peak rf fields for all these components will be lower for L-band than for S-band. In addition, the gun can be operated at the peak field value that minimizes damage to the cathode from back accelerated electrons. As with a dc gun, ions can also damage the cathode. However simulation studies indicate that few if any of the ions will actually hit the cathode [6]. Any reduction in field emission will also reduce the number of ions present.

To understand better the potential mechanisms for cathode damage, simulations will be used to track electrons field emitted from critical areas under a variety of conditions (peak rf field and phase). For the optimum operating conditions, the energy distribution of the electrons hitting the cathode will be determined. Although the number distribution cannot similarly be specified, the energy information will be useful to guide very controlled cathode damage studies using SLAC's surface analysis apparatus [7].

Simulations will also be used to determine the operating peak rf field and phase that will minimize cathode surface damage.

3. Testing

Once the elements of the program described in section 2 above have matured, a test gun will be constructed paying particular attention to the elements that affect the cathode performance, but to save time and cost, minimizing efforts on issues that are already understood. A high quality cathode preparation chamber and load-lock will be integrated into the gun design.

The test gun will be rf processed with a dummy cathode in place. The L-band rf station now under construction at SLAC will provide the required rf power. Following successful processing, the QY lifetime of an activated cathode placed in the gun will be measured without rf. Lifetimes comparable to those achieved with dc guns should be demonstrated. This same system will be studied with rf on to determine what the limits are on the QY lifetime of the activated cathode relative to no rf and what the sources are of any deteriorated performance.

4. Conclusion

The R&D program at SLAC for a polarized rf gun is designed to demonstrate the viability of such a gun system for the ILC injector. The major known problems will each be studied and optimum solutions incorporated into the design of a test gun. A demonstration of reasonable QY lifetime with rf on will provide the technical justification for the construction of a polarized rf gun that will meet all the operational requirements—in addition to polarization—of the ILC.

References

1. J. Baehr *et al*., *TESLA Note 2003-33* (2003).
2. R. Sheffield *et al*., *PAC93*, p. 2970.
3. D. Yu *et al*., *PAC2003*, p. 2129.
4. J. W. Lewellen, *Phys. Rev. ST-AB* **4**, 040101 (2001); J. W. Lewellen, *LINAC2002*, p. 671.
5. A. Aleksandrov *et al.*, *EPAC98*, p. 1450.
6. J. W. Lewellen, *Phys. Rev. ST-AB* **5**, 020101 (2002); R. P. Fliller III *et al*., *PAC2005*, p. 2708.
7. D. T. Palmer, R. E. Kirby, F. K. King, *SLAC-PUB-11355* (2005).