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An In-situ Photocathode Loading System for the SLC Polarized Electron Gun

R. E. Kirby, G. J. Collet, K. Skarpaas
Stanford Linear Accelerator Center
Stanford, CA 94309 USA

Abstract

An ultra-high vacuum loadlock system capable of operating at high voltage has been added to the SLC Polarized Electron Gun. The unit incorporates facilities for heat cleaning, activating and measuring the quantum efficiency of photocathodes. A tray of up to four photocathodes can be exchanged without bringing the activation unit or gun up to atmosphere. Low voltage quantum efficiencies of 20% have been obtained for bulk GaAs at 633 nm and 6% for a 0.3 micron GaAs layer at 755 nm. Results for other cathodes as well as operational characteristics are discussed.

I. INTRODUCTION

Polarized laser photoemission from GaAs, or related III-V compound, photocathodes form the basis for most polarized electron sources currently in use. Extremely clean vacuum conditions are required to extend the usable lifetime of these cathodes between re-activations. In addition, sources such as the SLC Polarized Electron Gun (PEG) [1] must function under high voltage conditions (peak fields of ~10kV/mm). A high voltage discharge occurring in the gun is capable of irreversibly damaging the cathode, an event which is enhanced by the presence of Cs used to activate the photocathode to negative-electron affinity. In the past, the PEG has been baked and high voltage-processed to eliminate breakdown sites on the gun electrodes. The cathode was then installed and the gun rebaked. It has been shown [2] that baking reactivates some breakdown sites, requiring re-processing with potential for cathode damage. Also, we have observed that quantum efficiencies (QE) tend to be higher for cathodes that have not been baked in large systems for long time periods. Cathode replacement requires a lengthy and expensive reprocessing of the gun itself.

A cathode-loading system ("LoadLock") has been added to the PEG to address the concerns detailed above, but its use also adds a valuable capability to the polarized source program: As new, higher polarization cathodes become available, they may be easily introduced into the PEG operating on the accelerator. This approach has proven immediately successful with a thin GaAs strained-layer cathode structure [3].

II. OPERATIONAL REQUIREMENTS

Two identical LoadLock units were constructed: one for use at the SLC injector and the second at the Gun Test Facility which consists of a PEG, laser and duplicate electron beam line

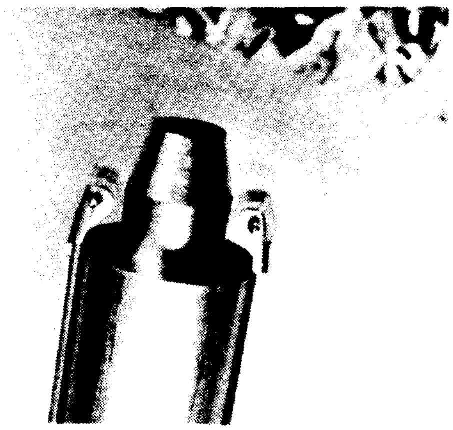

Figure 1. Cathode emitter tube. Mo leaf springs with sapphire roller bearings engage carrier tightly onto the plug end.

up to the first bend magnet. Each LoadLock and PEG incorporates an isolation valve, allowing each to remain independently under vacuum. Connection is via a low-volume short spool piece which can be evacuated and baked-out in a few hours. The functional requirements defined for LoadLock were:

- Heat clean and activate cathodes to negative-electron-affinity using Cs and NF_3.
- Measure quantum efficiency.
- Preserve ability to cool the cathode to 0°C while in the PEG.
- Vacuum environment consistent with that of the PEG.
- Require no changes to PEG electron optics.
- Be able to introduce cathodes into LoadLock for use in PEG, preferably without bringing LoadLock itself up to atmospheric pressure.

The cathode cooling requirement has been satisfied by preserving the PEG cathode emitter tube design without modifying the gun structure. The photocathode is mounted on the vacuum side of the tube, and cooling gas is injected from the atmosphere side [4]. Cooling has been useful for extending the period between re-cesiation of cathodes. This requirement, however, means that the LoadLock unit itself is at cathode high voltage during electron beam injection.

III. LOADLOCK DESIGN

The structure of LoadLock consists of three sub units: mechanical drive, cathode activation chamber, and cathode tray. Cathode wafers are mounted onto individual Mo carriers using a Ta ring clamp. The carriers can be shuttled between the emitter tube (Fig. 1) and the cathode tray (Fig. 2) using a system of bellows-sealed linear motions.

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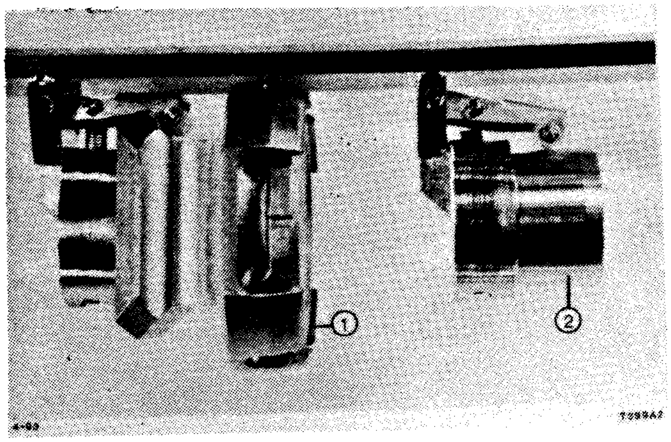

Figure 2. Photocathode carrier tray shows both a position occupied by a Mo wafer carrier (1) and an empty position (2).

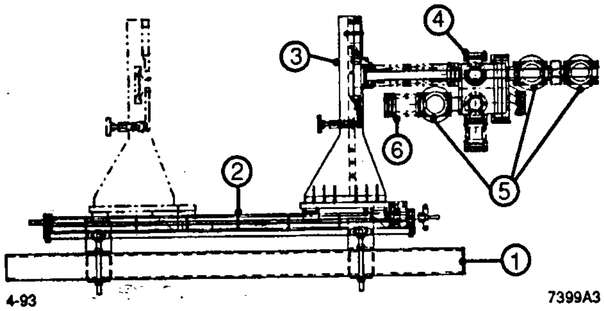

Figure 3. Mechanical drive. 1-Support beam, 2-Rail, 3-Emitter tube transfer assembly, 4-Activation chamber (services not shown), 5-Isolation valves, 6-Carrier tray, Item 3 also shown in emitter tube-retracted position for cathode activation/exchange (dashed).

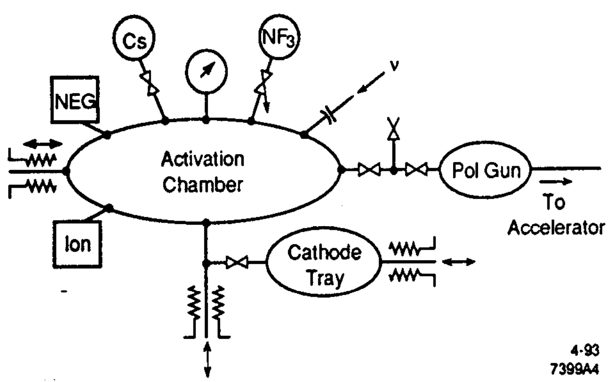

Figure 4. Schematic structure of LoadLock.

The main mechanical drive (Fig. 3) moves the emitter tube through the activation chamber and into the PEG. After insertion, the drive unit is removed and the remaining LoadLock components are enclosed by a corona shield and a high voltage insulating gas containment vessel. After several hours of dry air flow-through, the unit continually stands off a 120kV potential.

Figure 4 is a schematic of the services available in the cathode activation chamber. The activation chamber is pumped

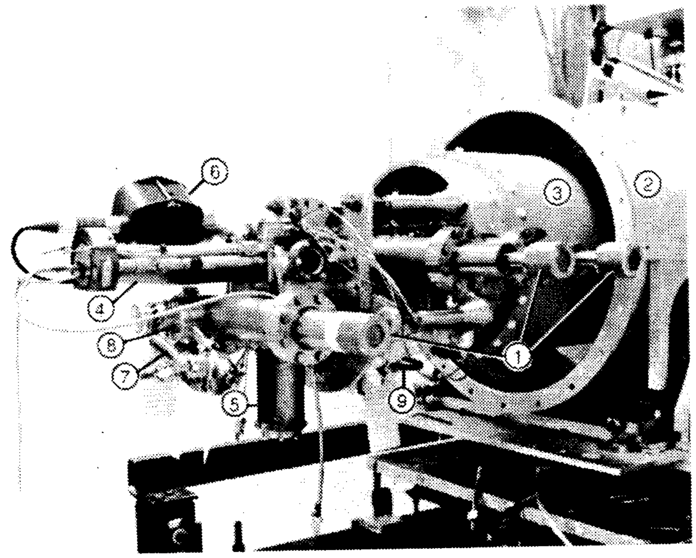

Figure 5. LoadLock attached to the PEG. 1-Isolation valves, 2-Part of HV gas container, 3-G10 support cylinder, 4-Emitter tube and bellows, 5-Cathode exchange linear motion, 6-Ion pump, 7-NEG pump, 8-Cathode tray, corona shield and high voltage container not shown.

by a combination of an 8 l/s diode ion pump (powered by a fiber-optic-isolated supply) and by a room temperature ST707 non-evaporable-getter pump [5]. The residual gas composition is >99.9% H_2 at a pressure of $<1\times10^{-10}$ torr. A gas heater unit inserted into the emitter tube allows heating of SLC 15 mm diameter cathodes to ~600°C. During heating, the evolved gas (>99%) is H_2, which has been shown [6] to be beneficial for removing oxides and hydrocarbons from GaAs surfaces. A completed LoadLock unit connected to a PEG at the Gun Test Facility is shown in Fig. 5.

The cathode tray is separated from the activation chamber by an isolation valve so that a total of four carriers may be used in LoadLock. A laser alignment screen in a carrier is occasionally used for system alignment and then removed from PEG for cathode replacement. The tray stays connected to, and is pumped by, LoadLock during operation.

IV. PERFORMANCE

LoadLock units were tested in two stages: initially by connection to a simple vacuum chamber containing a cathode-anode electrode structure, photo-electron current collector and light window, and finally, by connection to a PEG at the Gun Test Facility. Bulk GaAs(100) was used in the first system. QE's and life times were measured down to 0°C. QE's as high as 20% at 633 nm and 9% at 755 nm were achieved with life times at 0°C, identical to previous PEG performance [4].

Measurements at the Gun Test Facility concentrated on thin GaAs (300 nm) and 300 nm GaAs strained-layers. The latter were used on the accelerator when the first LoadLock/PEG combination was moved into operation. The thin GaAs QE at 120kV was 6% at 755 nm, measured at the Gun Test Facility. Full details of SLC cathode performance are reported elsewhere [3], but the current LoadLocked SLC strained-layer cathode on the linear accelerator produces 80% polarization and ~1% QE at 830 nm, 120kV.

V. CONCLUSION

The addition of LoadLock to the SLC electron source has resulted in a marked improvement in source capability and reliability. Large amounts of Cs, associated with high voltage breakdown, have been excluded from the gun. A small channel cesiatior has replaced the effusion cell on the gun proper. This allows remote additions of Cs to the cathode during the running cycle when a full re-activation is not required. LoadLock has also allowed a rapid upgrade of source polarization from the 28% of the 1992 SLC/SLD experimental program toward 80% in 1993.

VI. REFERENCES

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