Status of Jefferson Lab's Load Locked Polarized Electron Gun

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Abstract. A new 100 kV load locked polarized electron gun has been built at Jefferson Lab. The gun is installed in a test stand on a beam line that resembles the first few meters of the CEBAF nuclear physics photoinjector. With this gun, a GaAs photocathode can be loaded from atmosphere, hydrogen cleaned, activated and taken to high voltage in less than 8 hours. The gun is a three chamber design, with all of the moving parts remaining at ground potential during gun operation. Studies of gun performance, photocathode life times, transverse emittance at high bunch charge, helicity correlated effects and beam polarizations from new photocathode samples will all be greatly facilitated by the use of this load locked gun.

INTRODUCTION

The JLab photoinjector must be extremely reliable to meet the demands of the three hall nuclear physics program. The present two-gun design[1], one production gun and one spare, was chosen as an alternative to load lock gun-based designs used at labs such as SLAC[2], MAMI[3], ELSA[4], and NIKHEF[5]. The two-gun design has been successful because each gun provides exceptional photocathode lifetime. Lifetimes, measured in Coulombs extracted before the QE becomes unacceptably low, are approximately 300 C when operating at high current (250μA from gun) and 600 C at low current (65μA from gun). A gun can typically provide uninterrupted beam for two to three weeks at high current (250 μA) before the laser spot must be moved to a higher quantum efficiency (QE) location on the photocathode. The laser spot is 0.5 mm in diameter and a 5 mm active area is defined on the photocathode by anodization[6]. There are approximately five locations that can provide beam before the cathode must be heated and reactivated. A cathode can often be used for three months at typical production currents before it needs to be heated and re-activated. Cathode replacement and gun swaps have been occurring approximately yearly.

Despite the good performance of ~~our~~ the dual horizontal guns, there are drawbacks to a non-load-locked polarized electron gun. Field emission begins to develops after about the fourth successive activation, as suggested by our limited data. Severe field emission may require time consuming repolishing of the cathode electrode.

Installing a new photocathode within a gun necessitates venting the gun to atmospheric pressure and a subsequent gun bake to 250 C, which takes 3 days to complete. If extensive vacuum work is necessary, such as opening the gun to repolish the electrode, a sacrificial bulk GaAs has to be installed to check the quality of the

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work before a more expensive strained layer GaAs photocathode is installed. This prolongs the effective downtime of the gun.

LOAD-LOCK GUN DESIGN

A load-lock polarized electron gun has been designed at Jefferson Lab to improve the performance of the Jlab photoinjector[7]. The load-lock has been designed to enable replacement of the GaAs photocathode within an eight hour time period. In addition, the gun design incorporates the best features of the existing photoguns including extreme high vacuum, excellent pumping conductance, and electrostatic optic elements without short focal lengths. Finally, to keep the system as simple as possible, the entire loading assembly is kept at ground potential and no moving parts are taken to high voltage.

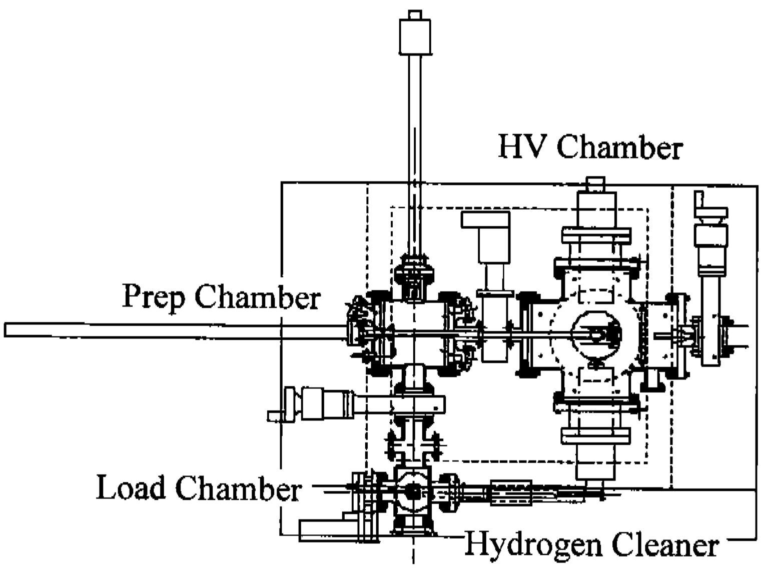

FIGURE 1. Overhead view of Load-Lock Gun. Load, hydrogen clean and heat chamber is shown at the bottom, preparation chamber with manipulators attached is at the top left, and the high voltage chamber is on the right.

Load, Hydrogen and Heating Chamber

The first chamber in the load-lock gun is the load, hydrogen clean and heat chamber. It is a small chamber which is initially baked but then vented with a dry nitrogen purge and only opened into a glove bag over pressurized with nitrogen to minimize water vapor contamination. The system is pumped down with a combination of a 60 l/s turbo pump and an 11 l/s ion pump. The cathode is mounted on a machined molybdenum puck and secured with indium solder and a tantalum cup. The puck is loaded in this chamber on stainless steel fingers attached to a 4.5 inch flange. The back of the puck is hollow, and a ceramic heater can be inserted into the hollow in the puck for heating. The temperature of the puck is measured by a thermocouple that can be moved in against the side of the puck on a bellows. Cross calibration of the temperature read by the thermocouple to the actual temperature of the cathode has been made by using both an optical pyrometer and by heating the wafer until the non-congruent evaporation of As from the surface leaves the surface frosted at ~620°C. A hydrogen cleaner mounted to this chamber allows the surface of the GaAs to be cleaned by RF dissociated hydrogen or deuterium. The puck and cathode can be cooled more quickly by the insertion of a copper cooling finger, which is on a second bellows coincident in the port with the thermocouple. This chamber also has a convectron gauge to measure the pressure of the hydrogen during cleaning and a Residual Gas Analyzer (RGA) to detect leaks and to determine the contaminant species in the chamber. Base pressure in this chamber is ~1e-8 Torr.

Preparation Chamber

The second chamber in this load-lock gun is the preparation chamber. The puck is moved from the loading to the preparation chamber on the transverse manipulator, which is a Surface Interface (now Transfer Engineering) magnetic manipulator. This manipulator has translational motion only, and grabs the puck with fingers spaced somewhat wider than the dock fingers in the load chamber and holds the puck with springs. The puck is then transferred to the longitudinal manipulator, which has both rotational and translational mobility. This longitudinal manipulator fits into the hollow back of the puck and can hold the puck firmly with ears that fit into internal grooves in the recess of the puck.

Bias for activation in the preparation chamber is applied by means of a ring anode biased positively just in front of the puck. Cesium (Cs) is deposited using of two SAES[8] alkali metal dispensers on a bellows and the oxidant used is NF_3 which is introduced through a Balzers dosing valve. The preparation chamber has 5 optical ports for either white light or laser activation and to assist in the handoff between the two manipulators. Pumping in this chamber is accomplished through a combination of a 60 l/s ion pump and a GP100 NEG cartridge pump, with a pumping speed of 600 l/s for H2 and 300 l/s for CO. Base pressure in this chamber is ~1e-10 Torr.

High Voltage Chamber

The high voltage chamber has been designed to have excellent pumping conductance and minimal material at high voltage. The HV chamber is a 6 way, 10 inch cross, made of electropolished 316L stainless steel. The system is pumped by 3 GP500 SAES NEG pumps, with a pumping speed of 1900 l/s for H2 and 650 l/s for CO. Base pressure as measured by an extractor gauge is 9e-12 Torr. Only the top of the ceramic, the cathode support, the cathode electrode and the puck with the photocathode are taken to high voltage. The puck snaps into place in the cathode support by means of sapphire rollers mounted on stainless steel springs which fit against the beveled back edge of the puck, holding the puck and cathode securely in place. The longitudinal manipulator can then be retracted, leaving no moving parts at high voltage. The cathode electrode is made out of titanium, which should provide less secondary electron emission.

The electrostatic optics in this HV chamber are identical to those in the production gun, with a 25 degree angle between the surface of the cathode and the cathode electrode. A bias of –100 kV is applied to the cathode, and the anode is 6 cm away, giving a maximum field of 4MΩ/m at the highest part of the cathode electrode and ~1MΩ/m at the surface of the cathode.

The 2.5 inch beamline leading away from this HV chamber is coated with a NEG material to maintain the lowest possible vacuum in the HV chamber. This same NEG coated beamline is used in the production nuclear physics machine.

INSTRUMENTED BEAMLINE

The beamline connected to the load-lock polarized electron gun in the Injector Test Stand consists of an 5 meter long beamline similar to the production beamline. Downstream of the gun is a NEG coated beamline which is then followed by a 15° bend and a Y chamber lined with additional NEG pumps to limit conductance from the beamline back into the gun. The beamline has 5 viewer screens, 1 harp scanner and 2 Beam position monitors (BPM). When the incident laser light has RF structure, the 100 kV beam can be seen with the BPMs and real time information about the current and position of the beam can be obtained. This will allow remote monitoring of beam during lifetime studies and allow us to monitor changes in beam intensity or position with changing helicity which is of critical importance for parity violation experiments.

At the moment, the beamline has no Wien filter or Mott polarimeter, though spaces have been designated for these pieces of equipment. These polarimetry devices will be installed in the near future.

EXPERIMENTAL RESULTS

Initial tests of this load-lock gun have been done by loading bulk GaAs[9] from air, hydrogen cleaning, heating to liberate the hydrogen and activating with Cs/NF_3. Following this loading, cleaning and activation, the QE of the photocathode was measured at two diode laser wavelengths. QE at 770 nm was measured to be 9.2% and QE at 860 nm was measured at 6.6%. These values are close to the best QE measurements that we have made in a baked, NEG pumped test chamber. Whether heating in the unbaked loading chamber is detrimental to the cathode performance will be verified in the near future.

The HV chamber has been taken to -110kV for processing then returned to -100kV with minimal leakage current. A current of 100 nA can be measured at the power supply, but these losses are primarily explained by losses in the cables and the corona. A test of the dark current in this gun will be performed and reported on at a later date.

COMMISSIONING EXPERIMENTS

The initial experiments planned for this load-lock gun are a series of lifetime measurements. Jefferson Lab has been anodizing all but the central portion of the GaAs cathodes to limit the emission of unwanted electrons from the edges of the cathode. A systematic study of the active area size, the anodization technique and the radial position of the anodized area will be made. In addition, the effect of different wavelengths and contaminant species on cathode lifetime will be studied. Due to the quick loading time, this gun is an ideal platform for studying different photocathode materials. Following the lifetime studies, a series of experiments will be made to gain an understanding of the helicity correlated effects caused by cathode anisotropy along with beam based and laser based feedback systems that can be used to control these effects for parity violation experiments.

If the performance of this load-lock gun proves superior to those in the production machine, the design is such that it can replace one of the conventional guns with minimal reconfiguration.

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[7] Schneider, W.J., *et al.* "A Load-Locked Gun for the Jefferson Lab Polarized Injector" *Contributed to IEEE Particle Accelerator Conference (PAC99), New York, 29 Mar - 2 Apr 1999.*

[8] SAES Getters USA Inc., 1122 East Cheyenne Mountain Blvd., Colorado Springs, CO; GP100 and GP500 pumps, and Cs alkali metal dispensers.

[9] American Xtal Technology, 4311 Solar Way, Fremont, CA; Zn doped GaAs at 1.5e19, (100) surface, Etch Pit Density <5000/cm^2, 600±25 um thick.