A LOAD-LOCKED GUN FOR THE JEFFERSON LAB POLARIZED INJECTOR*

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Abstract

Construction is underway at Jefferson Lab on a load-locked polarized electron source. The design incorporates all of the essential features of the existing non load-locked gun and improves on the designs of existing load-locked guns operating at other labs. When complete, we expect the new load-locked gun to enhance the versatility of the JLAB polarized injector.

1 INTRODUCTION

Historically, load-locked guns have been constructed as a means of circumventing seemingly insurmountable obstacles that have prevented labs from delivering reliable polarized beam to physics end-stations. For example, at SLAC, prior to the construction of their load-locked gun, full cathode activation in the main gun chamber caused high voltage breakdowns. It is believed that the high voltage breakdowns were associated with cesium deposition on the cathode electrode during the initial activation [1]. Once this process (i.e., initial full activation of the photo cathode) was performed in the preparation chamber of their load-locked gun, the high voltage incidents ceased. At MAMI, short cathode lifetimes (~ hours) necessitated frequent cathode replacement, a situation that prevented reliable beam delivery to nuclear physics users during a typical months-long experiment [2]. The load-locked gun at MAMI now allows the accelerator staff to change photo cathodes with minimal delay (few hours) to the nuclear physics program.

At Jefferson Lab, we have demonstrated that a load-locked gun is not essential to meet the demanding requirements of the Jefferson Lab nuclear physics program. For example, unlike SLAC, we do not have any high voltage problems associated with doing cathode activation in the gun proper and, unlike MAMI, our cathode life at high current is excellent. Over the past two years, we have identified a number of mechanisms that contribute to the decay of photo cathode quantum efficiency. Understanding these decay mechanisms has allowed us to implement design changes to our non-load-locked gun that have resulted in exceptional lifetime (1/e lifetime > than 100 H at 100 μA, > 1000 H at 10 μA) [3].

With our present non-load-locked gun, 10's of Coulombs can be delivered to Users before intervention (i.e., re-cesiation or heat treatment followed by full activation) is required. Such polarized source performance means that intervention can occur during a scheduled-maintenance day, (every other week at JLAB) with no impact on the physics program.

Still, the obvious disadvantage of the present non-load-locked gun is that a bake-out is required when photo cathode replacement is necessary. We have reduced the entire replacement process (photo cathode replacement, bake-out and gun re-commissioning) down to fifty-two hours beam to beam - albeit small, but still a delay. Although we do not expect to improve the inherent performance of the non-load-locked gun, we believe a load-locked gun will greatly enhance the *versatility* of the polarized injector. With a load-locked gun, we could rapidly change photo cathodes to meet changing demands of the nuclear physics program, and during biannual facility development periods; we could change photo cathodes quickly to conduct photo cathode research using the superb diagnostics in the injector.

Before making specific design plans, we outlined the basic features of the Jefferson Lab load-locked gun. These features are based on our experiences at JLAB and the experiences of our colleagues at other Labs. They include:

- Installation of the photo cathode from air to the gun chamber must take less than six hours.
- The load-lock vacuum chamber must be at ground potential and there must be no moving parts at high voltage.
- The gun and bend magnet must produce beam in the horizontal plane; the bend magnet must not deflect the beam more than 15 degrees.
- There will be four chambers; a) main gun chamber, b) cathode preparation chamber, c) heat cleaning chamber, and d) atomic hydrogen cleaning chamber where samples are inserted into the load-lock mechanism and cleaned with atomic hydrogen
- A fifth chamber may be added for storage of photo cathodes or cleaned wafers ready for activation.
- Gun features that have proven to be essential on the non-load-locked gun (superb vacuum, electrodes designed specifically for Jefferson Lab beam current requirements, electron optics that minimize stray electrons hitting vacuum chamber walls, etc.) must be incorporated into the load-locked gun design.

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A brief description follows of the load-locked gun being assembled with specific detail on the major points of interest.

2 MAIN GUN CHAMBER

The gun design (figure 1) is a novel one as it makes use of the better electron optics of a horizontal configuration, has no moving parts at HV and has all adjacent chambers at ground potential. Low base pressure (with and without beam extraction) and wise choice of materials is thought to be the most important ingredient for long photo cathode lifetimes. The main gun chamber is manufactured from a standard six-way stainless steel cross. It has one 220 l/s ion pump and three GP 500 MK 2, SORB-AC SAES cartridge pumps symmetrically located around the photo cathode. The non evaporable getter (NEG) pumps are well suited for pumping CO, CO_2 and greatly enhance the pumping speed (~ 4000 l/s) for hydrogen, the dominant gas species in the vicinity of the photo cathode. Pressure in the gun chamber is further reduced, because all cathode preparation is done in a separate chamber. We have achieved pressures below $1x10^{-12}$ Torr with a similar gun [4] pumped by a massive NEG array. That was measured by an extractor gauge with a measurement limit claimed to be $1x10^{-12}$ by the manufacturer.

A stainless steel tee supports the cathode electrode which has a shape designed for high current operation and is made of titanium alloy (Ti-6Al-4V). The titanium exhibits better high voltage performance (ie conditioning, low field emission current at full gun fields, etc.)[5]. The ceramic, to isolate the 100 kV (120 kV peak) high potential, is located vertically so that photo cathode preparation is performed at ground potential. A molybdenum puck, which carries the cathode wafer, is similar in concept to the SLAC design. The puck is held in place inside the tee supporting the cathode with a stem spring holder and sapphire rollers. The electrode holder, triple point protectors and internal surfaces of the six-way cross are electropolished while the electrodes are metallographically polished with diamond paste. The anode, also manufactured of titanium alloy, is mounted on a stainless steel spider with a large open area to increase vacuum conductance from the gun proper through a 2.5-inch beam line. A channel cesiator is provided behind the anode for in situ "touch-up". Alignment of the electrodes relative to the beam axis was accomplished to better than a ½ mm.

A Surface Interface (SI) manipulator [6], on the beam axis which can both translate and rotate, is used to move the puck between the preparation chamber and the gun (figure 2). A silver plated stainless steel adapter, mounted on the manipulator engages a set of transfer ears inside the puck to allow attachment and release of the puck. Movement of the puck into and out of the gun has worked smoothly although we have not yet baked out the entire apparatus. Isolation between the gun and the cathode preparation chamber is accomplished through a 1.5-inch ultra high vacuum metal sealed VAT valve [7].

3 CATHODE PREPARATION CHAMBER

The cathode preparation chamber contains all of the components to produce negative electron affinity (NEA) photocathodes: a stainless steel chamber with eight ports placed around the circumference. Two ports are used for the SI manipulators, the others ports are for a 40 l/s sputter ion pump, a GP 100 SAES NEG, a channel cesiator, a NF3 oxidizer, an optical window with a mirror for light and a ring anode. In addition, a SRA [8] residual gas analyzer (RGA) and an extractor gauge have been added for vacuum diagnostics. On beam axis of the chamber is the SI manipulator, previously mentioned, that transfers the puck into the gun. The puck is transferred from the on axis to the transverse manipulator via an aluminum clamp that attaches to the molybdenum puck. This transfer from gun manipulator to load lock manipulator has also worked smoothly; again we have not baked. Pressure in the cathode preparation chamber is maintained at better than $1E^{-9}$ Torr. At some point, we may add a storage area to the preparation chamber that will allow us to activate a number of wafers during an accelerator maintenance day and store them for future use. Separating the cathode preparation chamber from the next chamber - heat-cleaning chamber is a 2.5-inch VAT ultra high vacuum metal sealed valve.

4 HEAT CLEANING CHAMBER

Heating the photocathode samples is accomplished in a separate chamber in a manner that differs from techniques used at other labs. The heat-cleaning chamber is fabricated from two six-way stainless steel crosses and one water-jacketed spool piece where the heating takes place. A SI manipulator allows transfer of the puck between the load-locked or the cathode preparation chambers into the heat-cleaning chamber. A Research Inc. model 4085 infrared spot heater, powered by a Chromolox Port –12221 control system is used to heat the wafer to ~ 600 C at a ramp rate up and down of 1 degree C per second. The chamber is also equipped with active cooling. The heater is capable of 750 W although we have found that 375 W appears to be sufficient and have limited the power supply. A thermocouple in the IR beam is presently used for control of the heater. We are in the process of developing the parameters (rates of heating, thermocouple location, pressure rise, etc.) for the heat-cleaning chamber. Separating the cathode preparation chamber from the heat-cleaning chamber is a 2.5-inch VAT ultra high vacuum metal sealed valve. We hope to maintain ultra high vacuum using a combination of a 40 l/s ion pump and a GP100 SAES NEG to minimize the pressure rise during the heating cycle and to remove the hydrogen which is desorbed from the wafer due to the hydrogen cleaning process. A similar 2.5-inch

VAT ultra high vacuum metal sealed valve separates the heat cleaning chamber from the atomic hydrogen cleaning chamber.

5 ATOMIC HYDROGEN CLEANING AND LOAD LOCK CHAMBER

The primary function of this chamber is to introduce a number of different wafers on pucks and store them for eventual processing. Processing that takes place in the load lock is atomic hydrogen cleaning which is now the only cleaning method used to prepare photo cathodes at JLAB [9]. To maximize quantum efficiency we have incorporated an in situ atomic hydrogen cleaner. The highest quantum efficiencies achieved at JLAB have been wafers that were cleaned in situ in a low voltage test chamber. Similar efficiencies have been achieved when samples obtained in a portable cleaning chamber were transferred through air and installed in a gun. A Balzer model TMU-071 turbo-pump is used during atomic hydrogen cleaning where typical values for temperature and pressure near the sample are 350 C and $1x10^{-5}$ Torr respectively. The load lock makes use of the identical infrared heater presently used in the heat-cleaning chamber to raise sample temperature for atomic hydrogen cleaning. It is anticipated that in situ atomic hydrogen cleaning will provide a means to clean exotic photo cathode materials for which wet chemistry techniques are incapable; for example, chalcopyrites that contain silicon.

6 CONCLUSIONS

In summary, we have discussed the design of the polarized electron gun and its associated processing chambers. We have developed a 100 kV photoemission electron source, which currently supports the delivery of highly, polarized, high average current CW electron beams with long cathode operational lifetime. The new load-locked source incorporates the capability of exchanging, cleaning (both atomic hydrogen and heat) and activating (co-deposition of cesium and NF_3) the photo cathodes without breaking the necessary ultra high vacuum. The gun chamber proper is separated from the preparation, heating and cleaning load lock chambers so that it is capable of reaching the extreme high vacuum regime to obtain long cathode lifetimes.

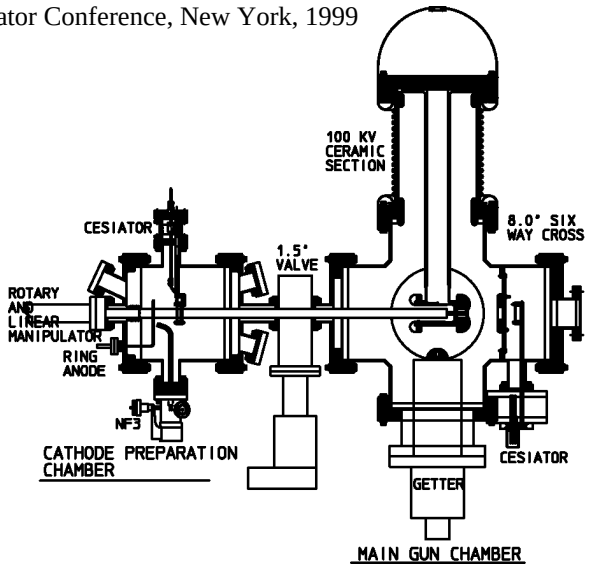

Fig. 1

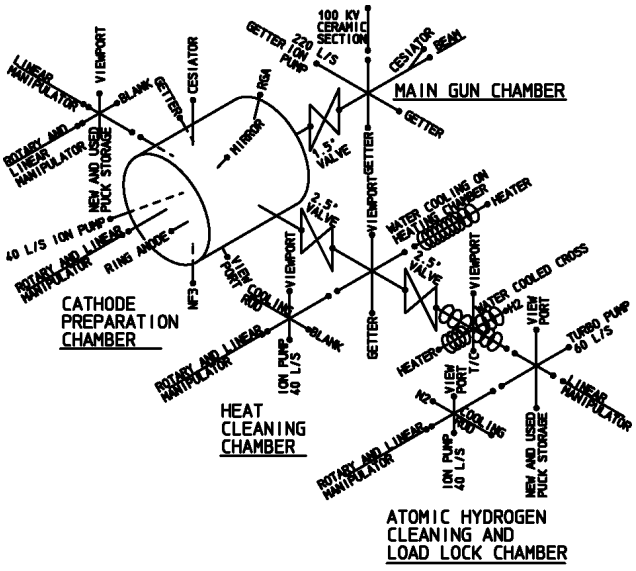

Fig. 2

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