Multi-Alkali Photocathodes Performance in a DC 300 kV Inverted Geometry Electron Gun

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Introduction

The electron beam (EB) is generated by **photoemission** (Fig.1). The quantum efficiency (QE) of the photocathode (PC) measured over time describes for how long it is possible to obtain current from the photocathode (eq. 1).

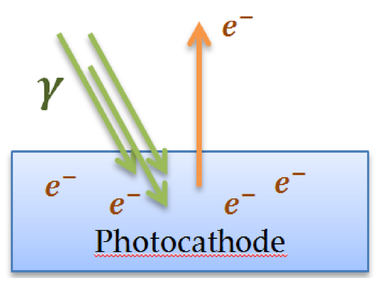

Fig. 1. Representation of photoemission.

$$QE(\%) = \frac{N_{e^-}}{N_\gamma} \times 100 = \frac{Ihc}{\lambda P e} \times 100 = \frac{124 I}{\lambda P} \quad (1)$$

Lifetime, τ, is the time by which the QE has decreased to $1/eQE_0$ (eq. 2).

$$QE(t) = QE_0 e^{-t/\tau} \quad (2)$$

Our goal is to run a stable electron beam at **5 mA**, with a **CsK_2Sb** photocathode to evaluate its **QE lifetime**.

Methods

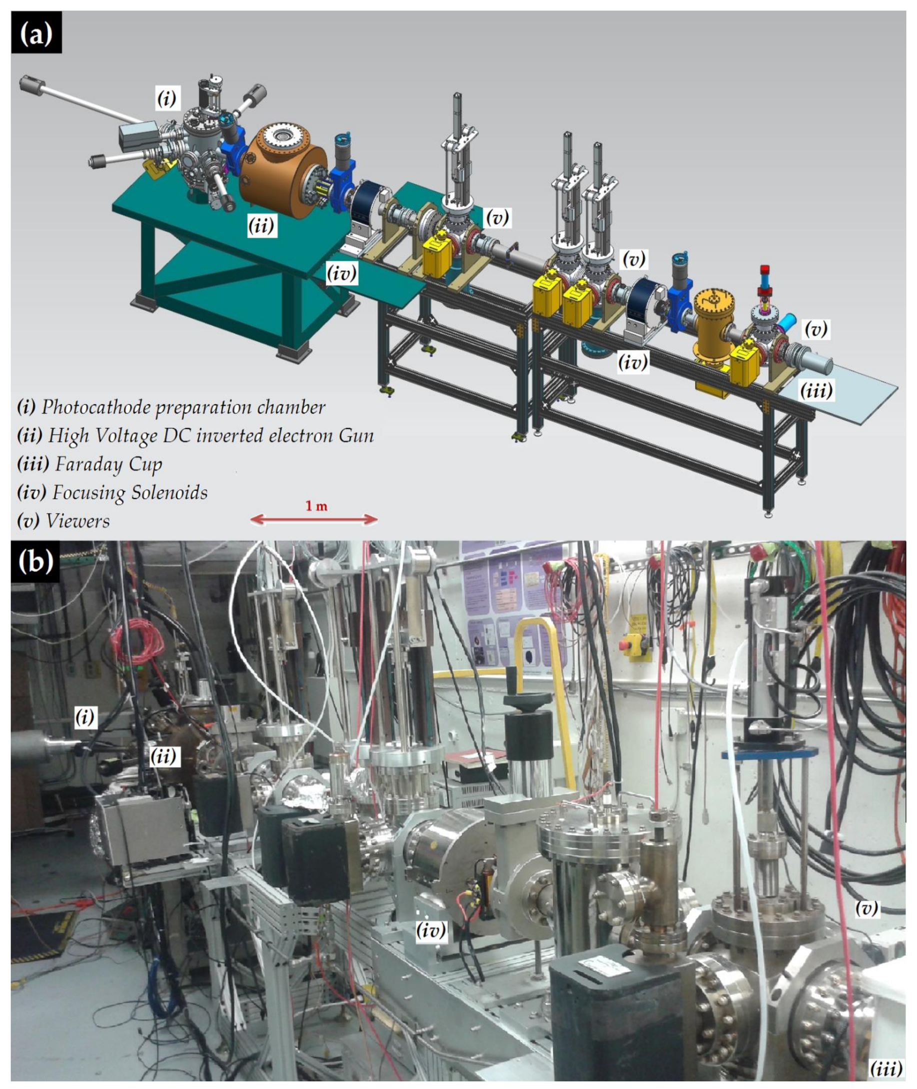

Fig. 2. (a) Beam line schematic. (b) Gun Test Stand (GTS) beam line picture. The PC is fabricated at the preparation chamber (i), then it is introduced to the HV-DC electron Gun (ii). The EB is produced by shinning green laser light on it. Then it is focused (iv) and steered with magnets to the Faraday cup (iii) at the dump of the beam line. The Faraday cup collects beam current. The beam shape can be observed through the viewers (v).

In order to produce EB, a 532 nm 10 W Verdi laser illuminates an in-house fabricated CsK_2Sb photocathode (Fig. 2. (i)). The photocathode is at 300 kV inside the electrode of the inverted electron Gun (Fig. 2. (ii)).

Current evolution in time (measured at the dump) is monitored to evaluate the QE lifetime of the photocathode (as showed in Fig. 3).

ABSTRACT

The electron-ion collider (**EIC**) proposed by Jefferson Laboratory requires **unprecedented hundreds of mA** of un-polarized electron beam at MHz repetition rates (Continuous Wave, CW) to cool down the ion beam. As a viable alternative to Cs:GaAs photocathodes (in ~100 kV DC electron guns) for generating an electron beam that meets those stringent requirements we are studying multi-alkali photocathodes in a High Voltage Direct Current (HV-DC) inverted-geometry insulator electron gun. The performance of our in-house fabricated **CsK_2Sb** photocathodes is characterized with the **1/e QE lifetime**, showing great robustness in a **300kV DC** inverted-geometry electron gun. Even severe damage at the photocathode electrostatic center caused by arcing did not affect QE in the laser-illuminated area; moreover no QE decay was detected while measuring lifetime at 0.1 and 0.5 mA sustained in each case for several hours. We present the highest electron beam current (1.0 mA DC) generated at the highest voltage (300kV) in an inverted-geometry electron gun with multi-alkali photocathodes. The next step towards higher current needed for the EIC is to run stable 5.0 mA electron beam with the same electron gun configuration.

Results

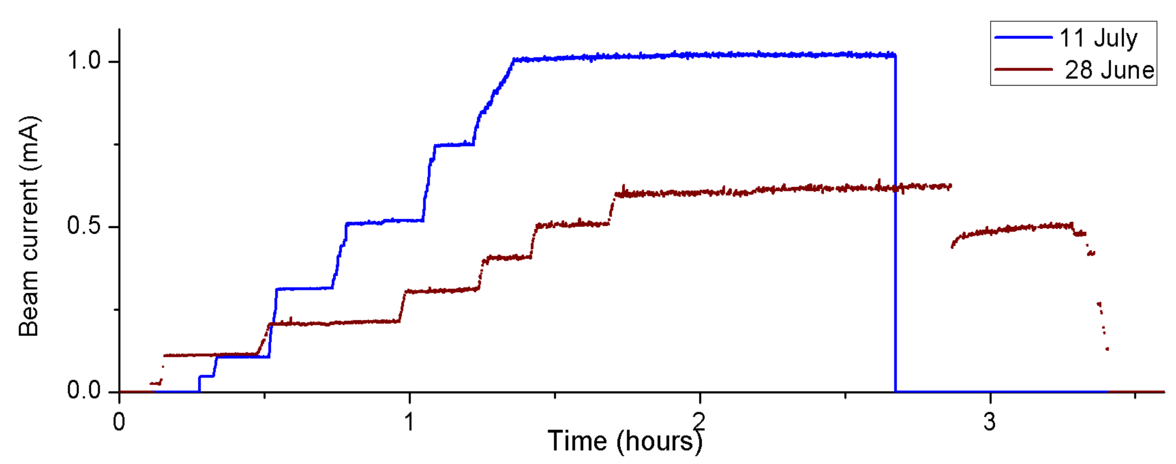

Fig. 3. EB run at 0.6 mA and 1 mA for more than 1 hr. The runs were stopped due to HV-Power Supply (PS) trips. There is no observable QE decay with time. The QE decay for the 0.6 mA run was caused by an arcing event.

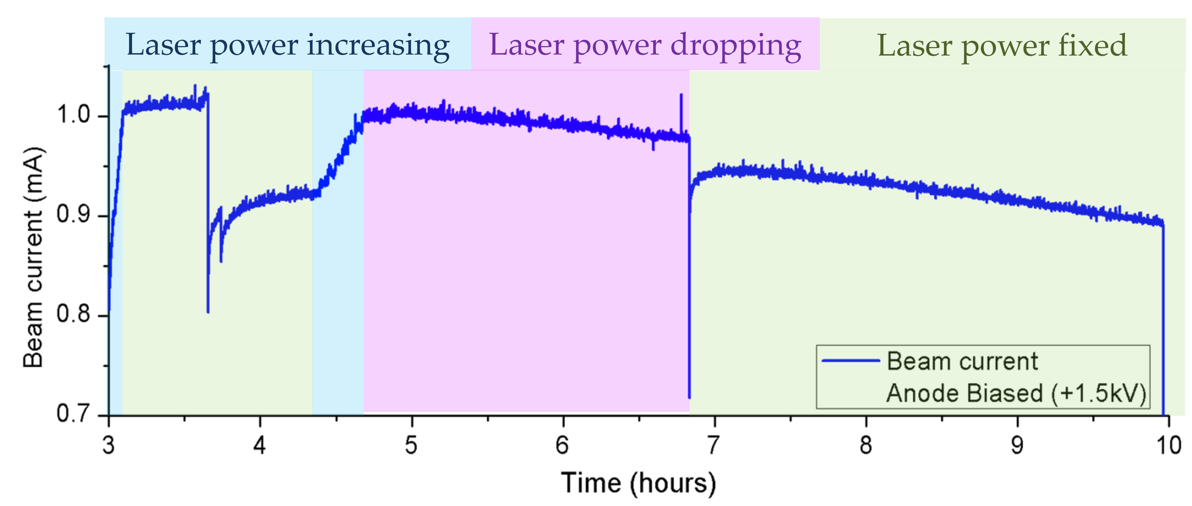

Fig. 4. EB run at 1 mA for ~ 6 hours. Each current drop was caused by an arcing event. Background colors indicate the laser power status: blue– laser power (LP) increase; green – LP fixed; purple– LP drop.

- We have not observed QE decay up to 1 mA when running beam without any arcing event (Fig. 3).
- We have not been able to increase to 5 mA (maximum of the HV Power Supply) because ion back bombardment induces arcing events (AE) in the PC, decreasing slightly the QE (Figs.4-5).
- QE of the damaged PC is around 2-3% when the laser spot is located at a non-damaged (blue) area (Fig.6).

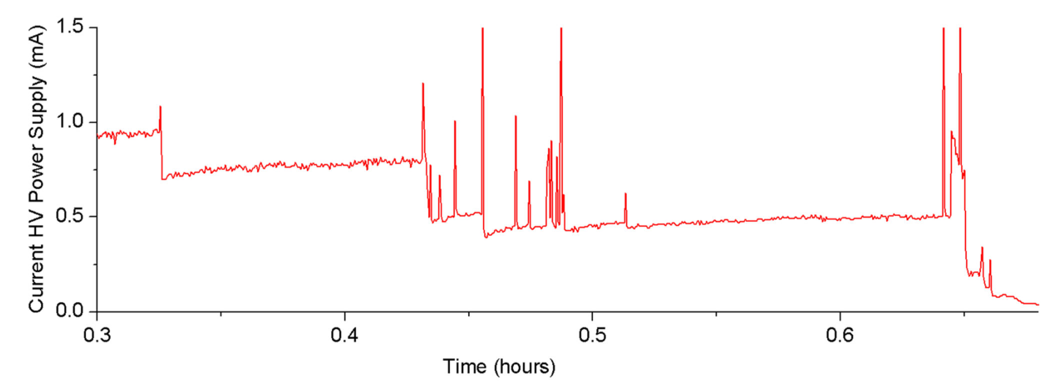

Fig. 5. (a) Current at the HV-PS during a series of arcing events. Each spike represents an arcing event. Even after several AE the photocathode still provides beam current.

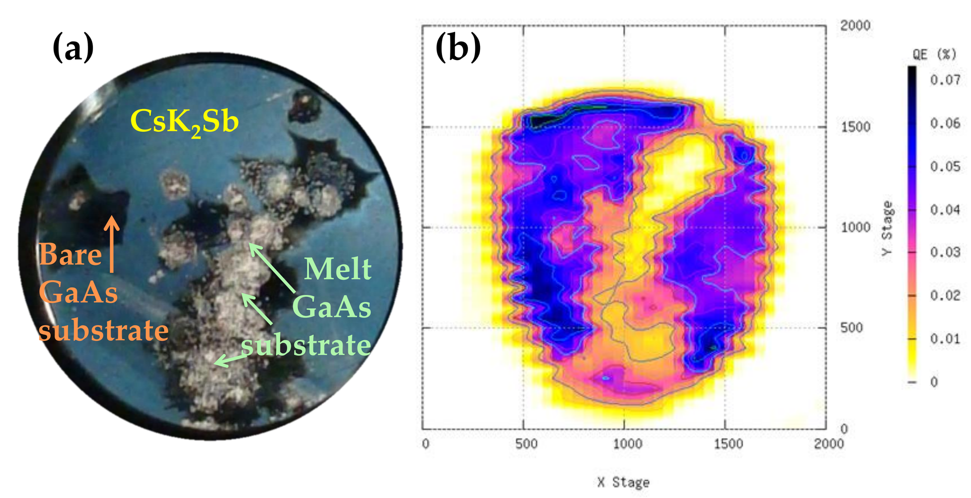

Fig. 6. (a) Damage at the electrostatic center of the PC caused by a series of arcing events. With anode biased from 0 to +1500 V

(b) QE map of the PC shown in (a).

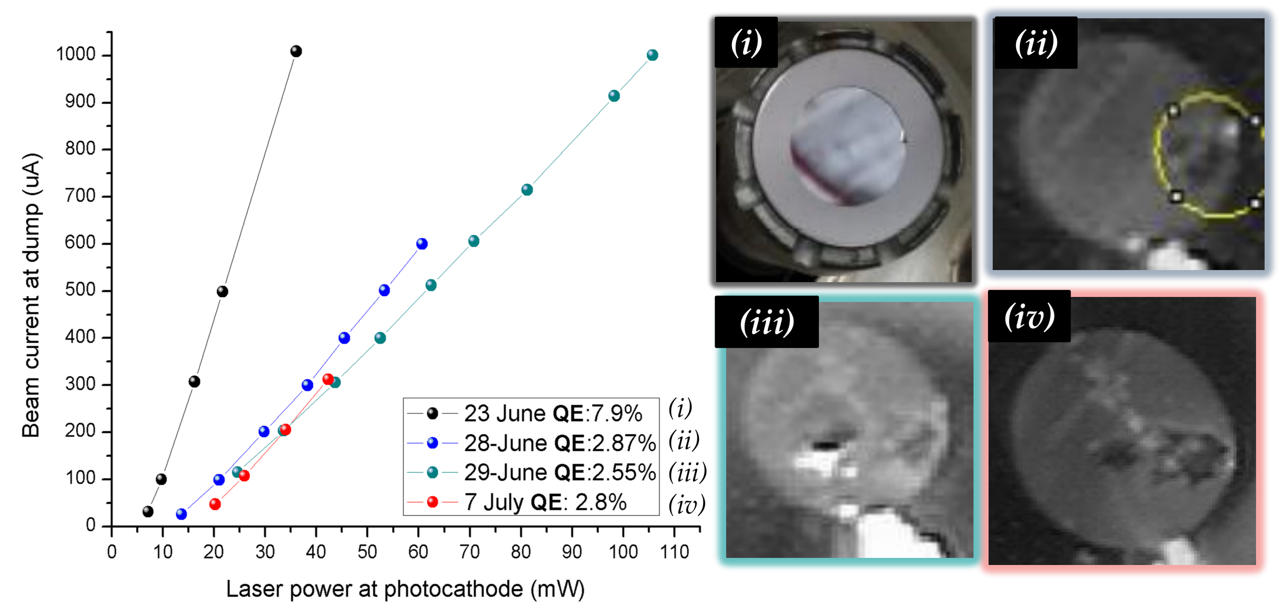

Fig. 7. QE curves for different EB runs (left). Laser spot was located at a non-damaged area to obtain the curves. Each QE curve is related to a PC image where the different damages are visible (right). QE barely changes after arcing damage at non-damaged spots.

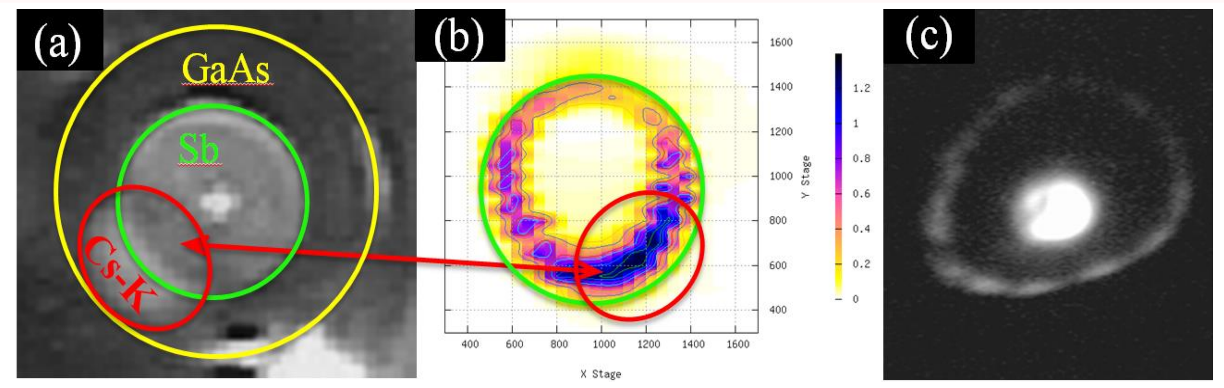

Fig. 7. (a) Picture of a masked photocathode fabricated to reduce EB halo by limiting the active area. The bright point in the center is the laser beam. (b) QE scan of the masked photocathode. (c) Picture of the EB generated by locating the laser spot at the geometrical center of the masked photocathode.

Conclusion and future work

Project concllusions are the following:

- ✓ CsK_2Sb is a very robust photocathode.
- ✓ Up to 1 mA, there was no observable QE decay.
- ✓ Biasing the anode did not reduce arcing events.
- ✓ We have achieved 1 mA DC at 300 kV in an inverted electron gun (highest current at the highest voltage with this type of gun).

In order to go to 5 mA (the limit of the HV power supply), to evaluate QE lifetime, it is necessary to:

- Make better masked photocathodes
- Install DC clearing electrodes at the end of the beam line
- Place beam dump at an angle with respect to the beam line
- Improve beam focusing and transport

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