Pres. FEL 2013
NY, NY, 26-28 August (2013)

BNL 101607-2013-CP

HIGH AVERAGE BRIGHTNESS PHOTOCATHODE DEVELOPMENT FOR FEL APPLICATIONS*

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August, 2013

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HIGH AVERAGE BRIGHTNESS PHOTOCATHODE DEVELOPMENT FOR FEL APPLICATIONS

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Abstract

Two load-lock chambers have been built to transport and insert multialkali cathodes in SRF guns operating at 704 MHz and 112 MHz. In this paper, we will describe the design of the load-lock chambers, transfer mechanisms, Change in QE in one of the transfer chambers and the removal of used cathode from the substrate using excimer laser.

INTRODUCTION

There has been considerable interest in generating high average current, low emittance and high brightness electron beams for a number of accelerator applications. Recent studies have shown cesium potassium antimonide to be a robust photocathode capable of producing high peak and average currents. Typically, this cathode is fabricated in a UHV system attached to the gun. However, for some applications, the fabrication site has to be physically removed from the gun location and the cathode has to be transferred between the two sites in UHV load-lock chambers. Such a detachable load-lock system should meet the constraints imposed by the fabrication chamber, gun as well as the transport system. We discuss below the constraints faced in two different SRF guns, the design of detachable load-lock systems for these guns, QE evolution in a storage chamber in one of the transport systems. In addition, in some designs, the cathode insertion section does not lend itself to cathode removal by thermal processes. An alternate mechanism, cathode removal by excimer laser is also presented

Load-Lock for 112 MHz SRF gun

112 MHz, SRF, quarter wave resonator gun was built to provide electron beams to increase the luminosity of the Relativistic Heavy Ion Beam (RHIC) at BNL by coherent electron cooling[1]. The constraints for inserting the cathode into this gun are a) particulate free insertion to preserve the Q of the SRF cavity b) breakdown-free operation in field gradients > 20 MV/m and c) thermal isolation from the cavity wall. Figure 1 shows a drawing of the insertion device. The load-lock chamber with the magazine supporting 4 cathode pucks is shown in Fig. 2. The vacuum in this chamber is maintained by a 25 l/s ion pump and a 400 l/s NEG pump. The magazine can store up to 5 cathodes reducing the down time for cathode exchange, once the load-lock is in place.

Prior to fabricating the cathode, the substrate can be heated up to 400 C by irradiating the Mo substrate puck with a 5 W CW laser operating at 532 nm. The maximum achievable temperature is dictated by the absorption coefficient of the material of the puck and the optical arrangement.

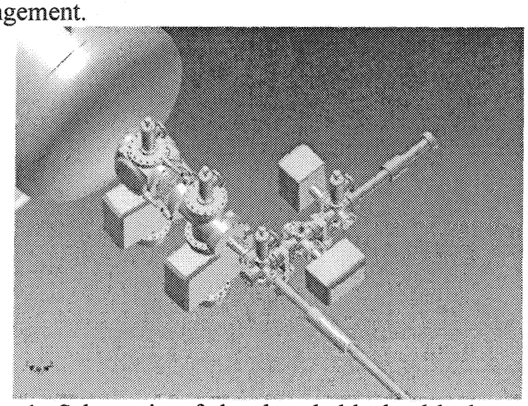

Figure 1: Schematic of the detachable load-lock system for 112 MHz SRF gun. The manipulator in the bottom right quadrant transfers the cathode from the load-lock chamber at the top right quadrant to the gun in the top left quadrant.

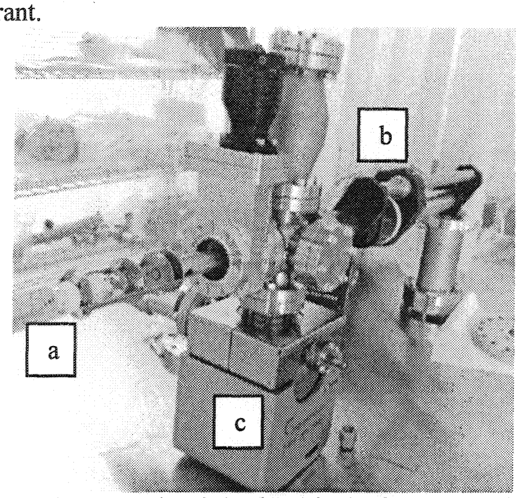

Figure 2: Photograph of the load-lock chamber with the magazine (a) in the foreground. Two sets of pucks are mounted on the magazine. (b) is manipulator and (c) is the pumping plenum

Figure 3 shows the temperature ramp-up and -down of the Mo puck. The laser heating has several advantages over the normally used resistive heating: a) only the puck is heated, b) temperature of surrounding vacuum chamber is minimally changed reducing the gas load in the system significantly, c) both heating and cooling are very fast, and d) the heat source is external to the system hence changes and modification can be made to it without altering the system. Since most photoinjector facilities already have a laser in place, the high cost associated with the laser is not a significant concern.

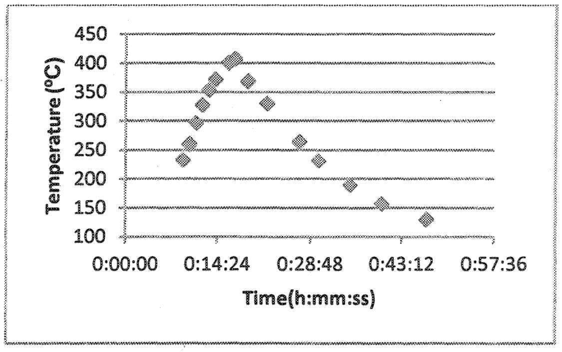

Figure 3: Temperature of molybdenum puck irradiated with 5 W, 532 nm CW laser. The laser is turned off at 0:17:00.

Figure 4 is a photograph of the load-lock storage chamber attached to a transfer arm (transfer arm1) and fabrication chamber consisting of another transfer arm (transfer arm 2) and deposition chamber. The base pressure of the fabrication chamber is in the range of 1.5-$3x10^{-11}$ Torr.

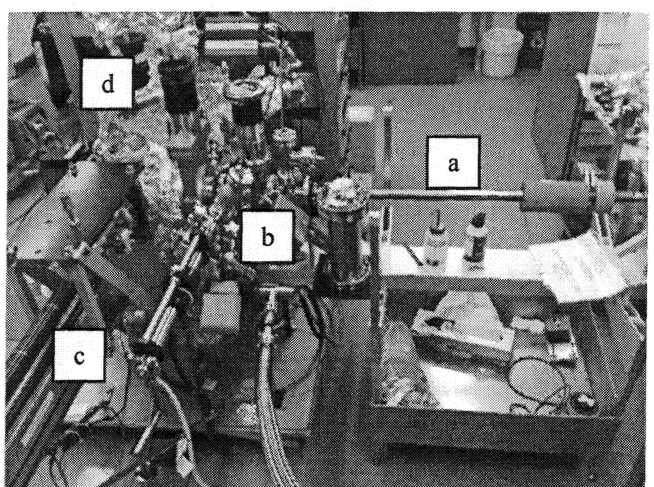

Figure 4: K_2CsSb cathode fabrication system. a) Transfer arm 1; b) Storage chamber; c) Transfer arm 2; d) Deposition chamber.

For subsequent measurements, molybdenum or tantalum substrate is attached to a dummy copper puck and inserted into this magazine. The system was then pumped and baked to achieve a base pressure of $7x10^{-11}$ torr. In order to check the performance of the cathode after storage, a K_2CsSb cathode was fabricated on a Ta substrate using the conventional evaporation scheme: 100 Å of Sb at a substrate temperature of 80 ˚C, 200 Å of K at a substrate temperature of 140 ˚C and Cs thickness for maximum electron yield at a substrate temperature in the range of 125-135 ˚C. The cathode is then transferred to the storage chamber. The dark life of the cathode over a period of time was established by measuring the QE of the cathode during this period. The change in the QE as a function of time is shown in Figure 5. Even this reduced QE is sufficient to support the coherent electron cooling experiment for which this scheme was developed.

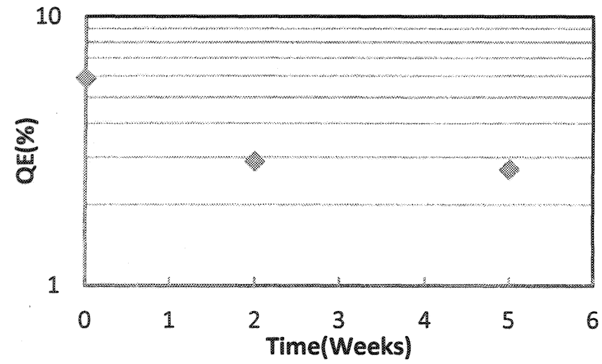

Figure 5 The cathode dark lifetime in the 112MHz load-lock chamber. The maximum QE is 9% immediately after fabrication

One of the cathodes fabricated using the above recipe was exposed to different energy densities and repetition rates of an excimer laser operating at 248 nm. Figure 6 shows clearly the regions exposed to the laser. Subsequent QE and EDX measurements indicate that the K_2CsSb has been removed completely from the substrate. Based on prior experience, the authors believe that this process may be insensitive to either the UV wavelength or the pulse duration of the laser. Hence the irradiation with a UV laser beam provides a novel, non-thermal alternative for the removal of alkali cathodes.

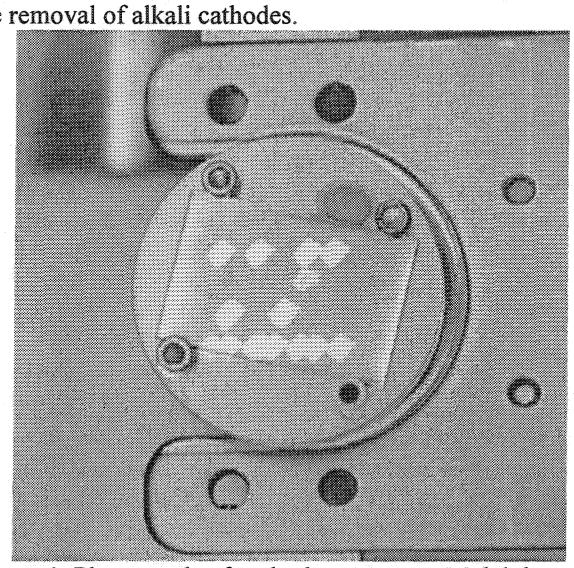

Figure 6: Photograph of cathode grown on Molybdenum substrate. The rectangular regions were exposed to excimer laser

Load-Lock chamber for 704 MHz injector

The 704 MHz injector is built to test the concept of energy recovery LINAC for high average currents and can support currents up to 0.5 A. The cathode of choice is K_2CsSb that is an integral part of a quarter wave choke joint. Figure 7 shows drawing of the SRF gun and Fig. 8, the grooved choke joint that supports the cathode [2].

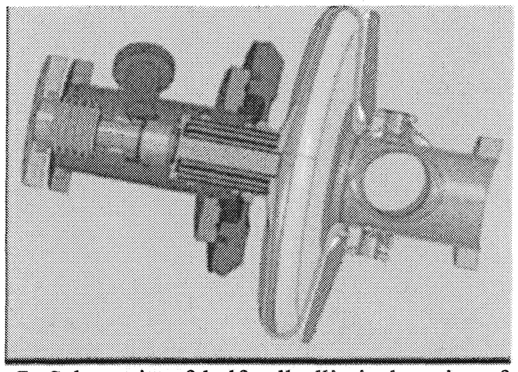

Figure 7: Schematic of half-cell elliptical cavity of 704 MHz SRF gun with the choke joint on the left and electron beam tube on the right.

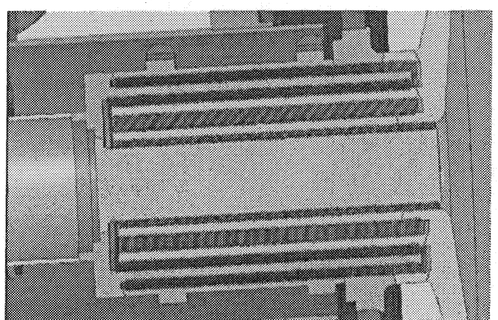

Figure 8: Schematic of grooved, double choke joint supporting the cathode. Back wall of the gun is seen at the right edge of the drawing.

Photograph of the cathode stalk mounted to the transport cart and the transport cart are shown in Figs. 9 and 10 respectively. The vacuum plenum of the transport cart is made up of 2 ion pumps, one with the pumping speed of 400 l/s and the second with 40 l/s and a TSP. A cold-shield near the isolating valve protects the cathode from the gas load released during the baking of the mating section of the load-lock. At present the cathode stalk with copper cathode has been inserted into the gun and RF testing will be starting very shortly.

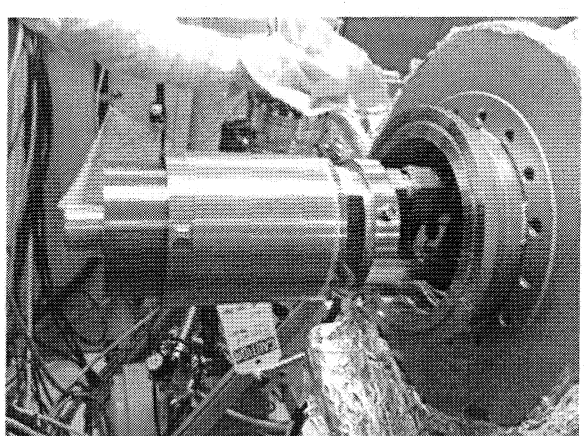

Figure 9: Photograph of the cathode stalk with copper cathode mounted on the transport cart.

Figure 10: Photograph of the transport cart, before attaching to the gun.

ACKNOWLEDGMENT

The load-lock chamber for the 704 MHz SRF gun was developed in collaboration with the Advanced Energy Systems. This research has been supported by the United States Department of Energy through Contract numbers DE-AC02-98CH10886. The Unites States Government retains, and the publisher, by accepting the article for publication, acknowledges, a world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for the Unites States Government purposes.

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