Advanced Tools for Production and Characterization of Photocathodes for use in Free Electron Laser Based Light Sources

J. Nasiatka, J Feng, H.A. Padmore

Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

Tri-Element deposition is a unique and novel method for producing K-Cs-Sb bi-alkali photocathodes. The methodology in our production technique produces very consistent, high-quality photocathodes that are reproducible independent of the skill of the person operating the coating equipment.

The deposition temperature is maintained by a PID control system. The deposition rates are fixed and started at the same time. Growth is observed within a few minutes and is very steady.

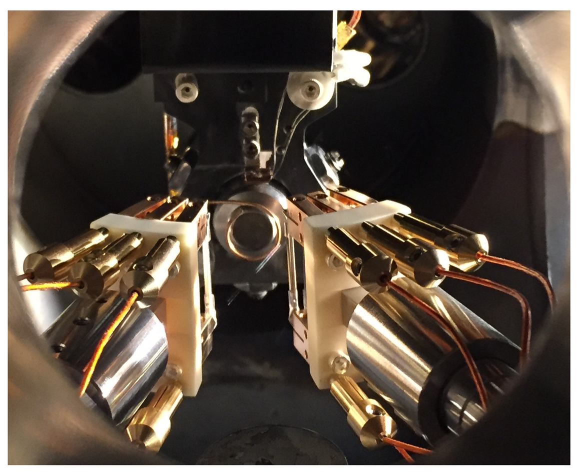
The photocurrent is measured during growth and when a maximum is reached (typically after ~4 hours) the process is stopped. If growth goes past peak, the rate of decline is very slow and appears to stabilize, so the window of opportunity is much larger and does not require constant monitoring.

The transverse momentum of electrons produced by a photocathode contributes significantly to the performance of Free Electron Laser-based light sources (FEL) as well as systems designed for ultrafast electron diffraction (UED) and dynamic transmission electron microscopy (DTEM).

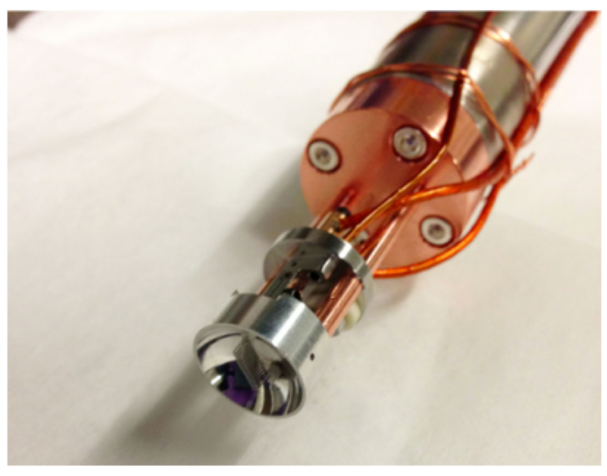
This lab-based device allows photocathodes to be evaluated in-situ, eliminating delays required to transfer a cathode to a suitable accelerator gun and allowing for a more timely screening of materials and fabrication techniques.

The design of low emittance and high quantum efficiency photocathodes is one of the key challenges for next generation FEL based light sources. In order to study these parameters, a light source that provides high photon flux and narrow bandwidth in the UV-Vis spectrum with a small spot size has been developed.

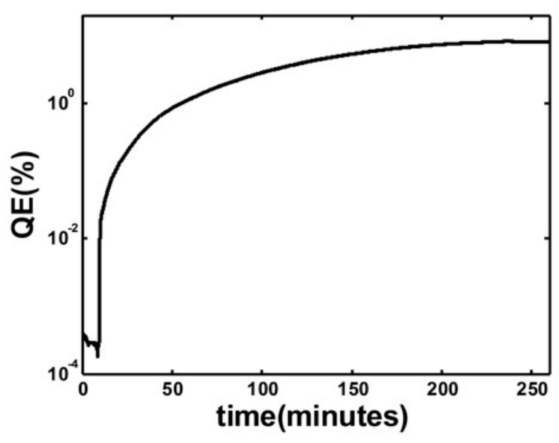
Triple-Element Deposition System



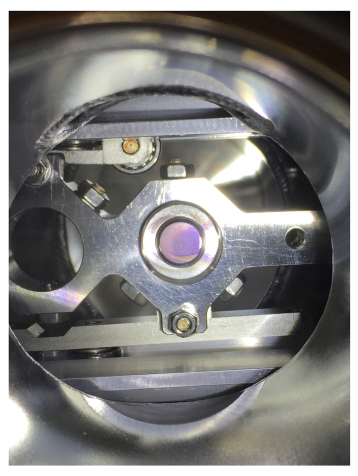
Deposition System



IR Heating System



Photocurrent vs Time



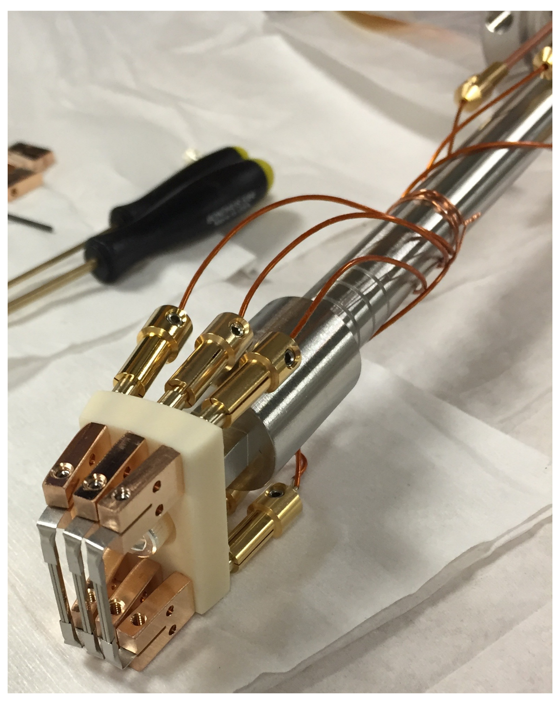
Completed Photocathode

Yo-Yo Deposition

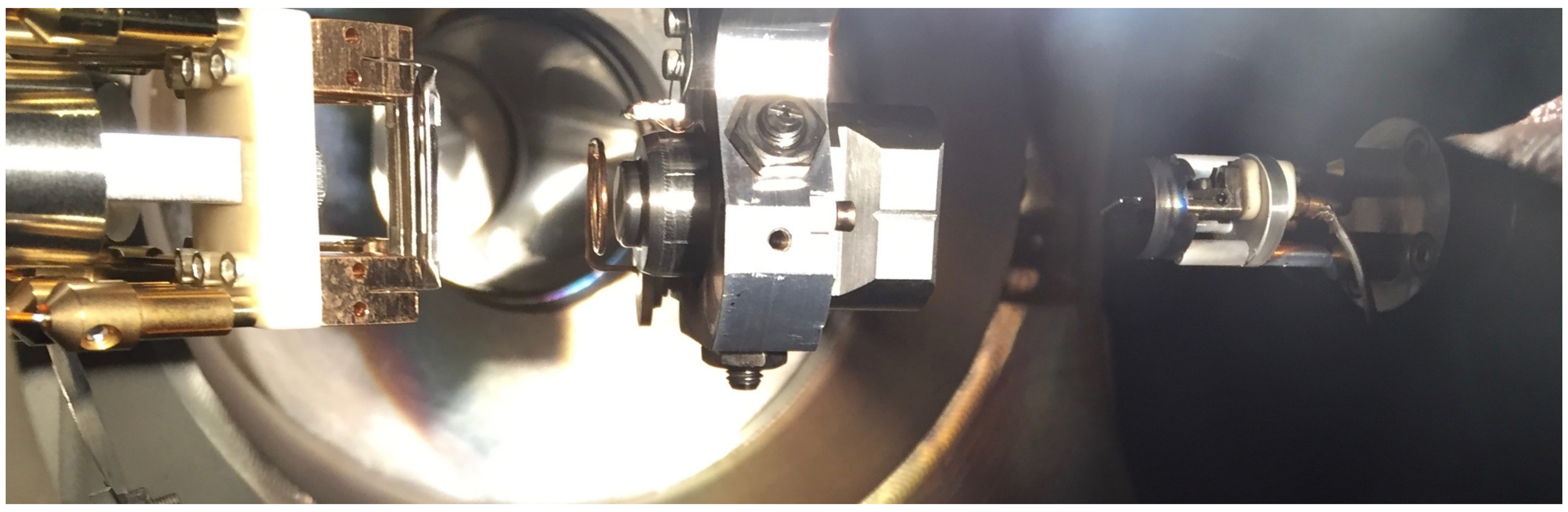
Typically bi-alkali photocathodes have been produced using the 'Yo-Yo' method using different combinations of sequential deposition starting with Sb. The second layer containing the alkali then reacts with the Sb to form a mono-alkali photocathode (K_3Sb) When the third layer is deposited it reacts with the mono-alkali to form the bi-alkali cathode (K_2CsSb.)

This process is highly variable and producing a viable photocathode is very difficult, even when using the same deposition system with the same settings, a cathode produced today is most likely going to be different from a cathode made the day before.

Small variances in substrate temperature, deposition rates/thickness and timing of starting/stopping the coating can yield wildly different cathodes. The initial growth of the mono-alkali is very slow to start and can take several hours before any growth is observed and is highly variable. This is further complicated because when the maximum photocurrent is reached, there is a very short time window to stop the coating of that layer before a rapid decrease happens and the cathode is ruined. This requires a very skilled operator who can pay very close attention to the process during the 6-12 hours of coating waiting for just the right moment.



K and Cs Deposition Mount



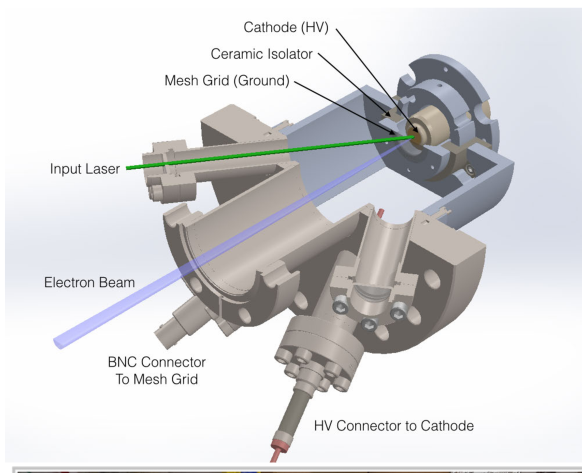
Deposition System with IR Heater

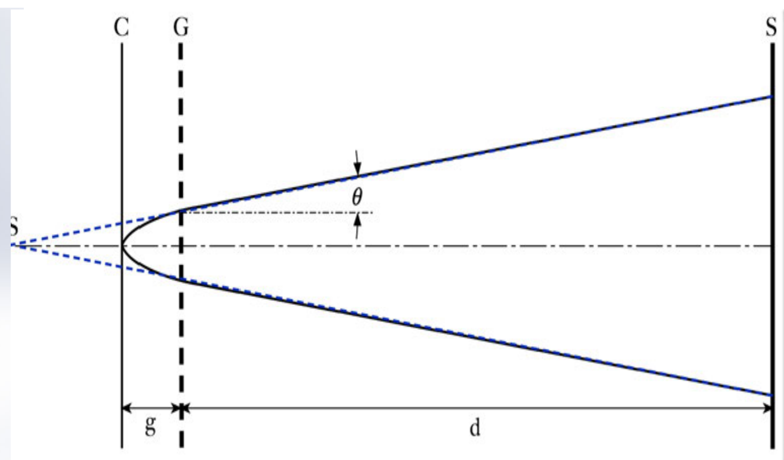
Momentatron

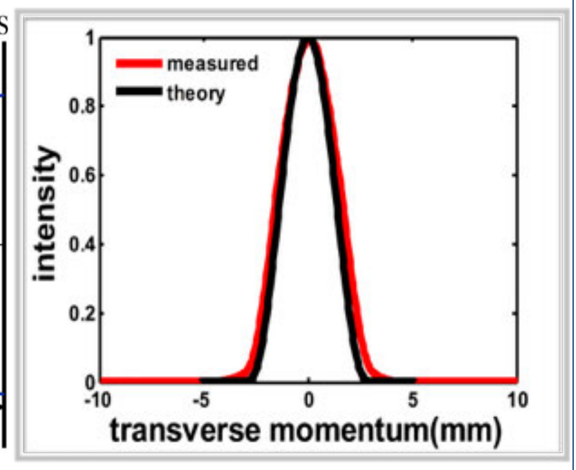
A cathode plug is loaded into the head from the rear and locked in position via three spring loaded balls.

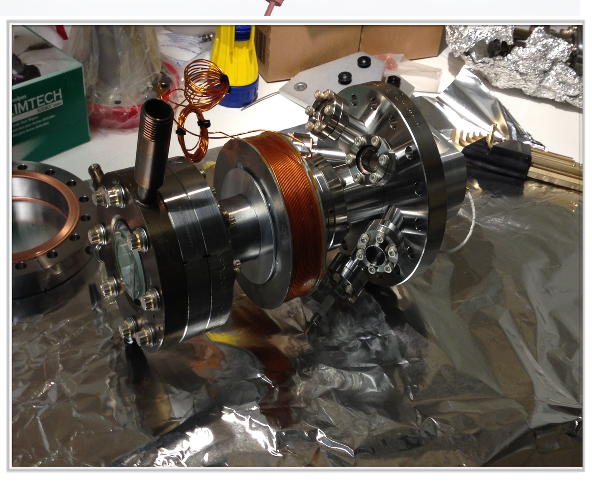
The Cathode is held at High Voltage (6-10kV) and the Anode mesh is grounded.

Transverse momentum is extracted from the beam intensity distribution recorded on a microchannel plate with a phosphor screen coupled to a CCD detector.



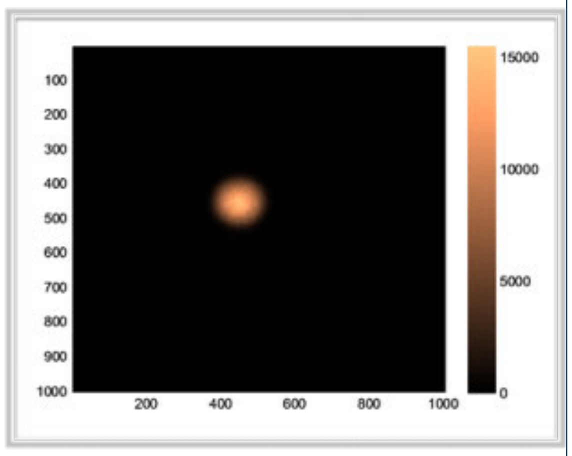






Assembled Momentatron

- Electrons produced at the photocathode plane C are accelerated in a high gradient field.
- They pass through a grounded mesh grid plane G into a drift region.
- And are then recorded by a detector at plane S.



UV Monochromator

The optical layout consists of laser driven plasma light source, four 200mm fl paraboloid mirrors, a 150um dia. entrance pinhole, a 1200l/mm plane grating, and a 100um core delivery fiber.

To minimize any Ozone generation, the optics are all enclosed in a vacuum chamber that is pumped to 10^{-3} Torr.

The spectral resolution is 1.5nm and the overall flux is between $6x10^{-11}$ and $4x10^{-12}$ ph/sec