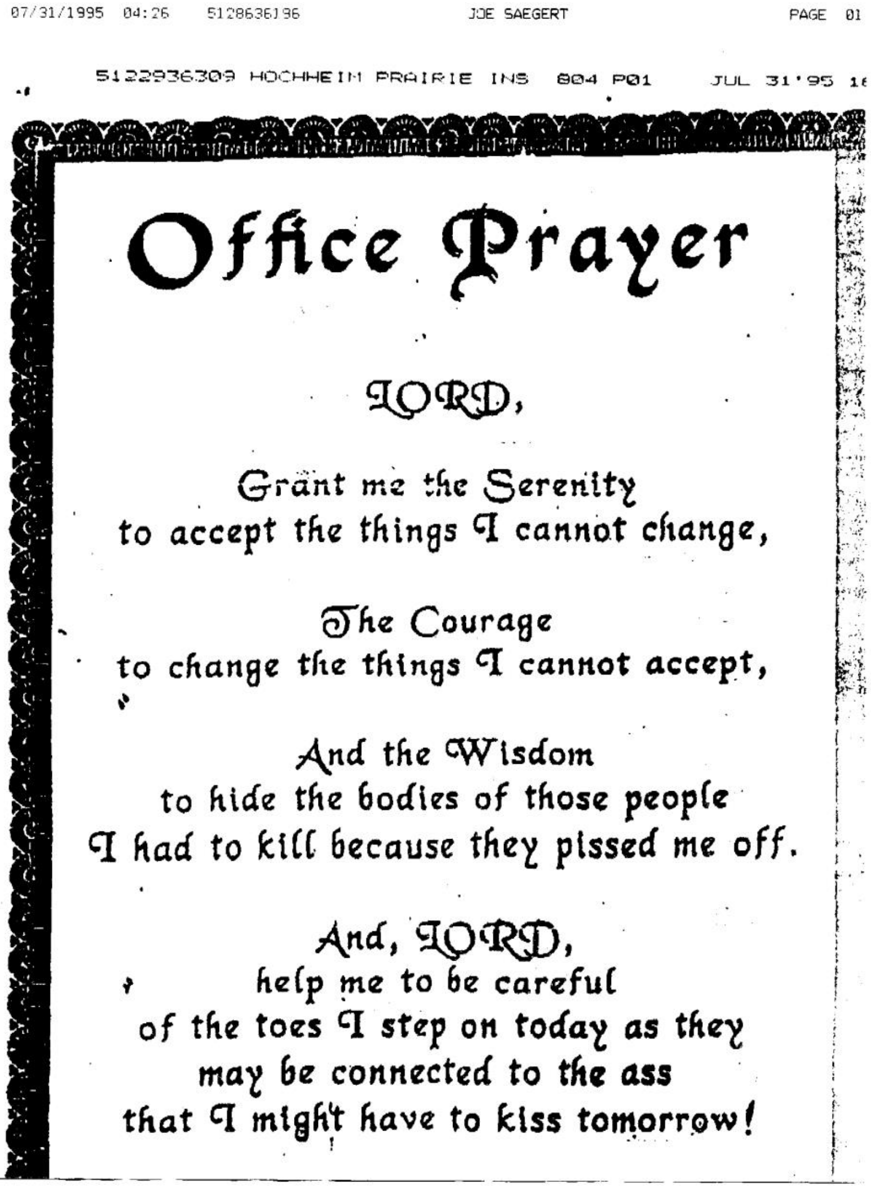
Conditions for a photocathode---

High yield cathodes require excellent vacuum 10^--14 Torr for water and oxygen

Stable composition



07/31/1995 04:26 5128636196 JOE SAEGERT PAGE 01

5122936309 HOCHHEIM PRAIRIE INS 804 P01 JUL 31'95 1

Office Prayer

LORD,

Grant me the Serenity
to accept the things I cannot change,

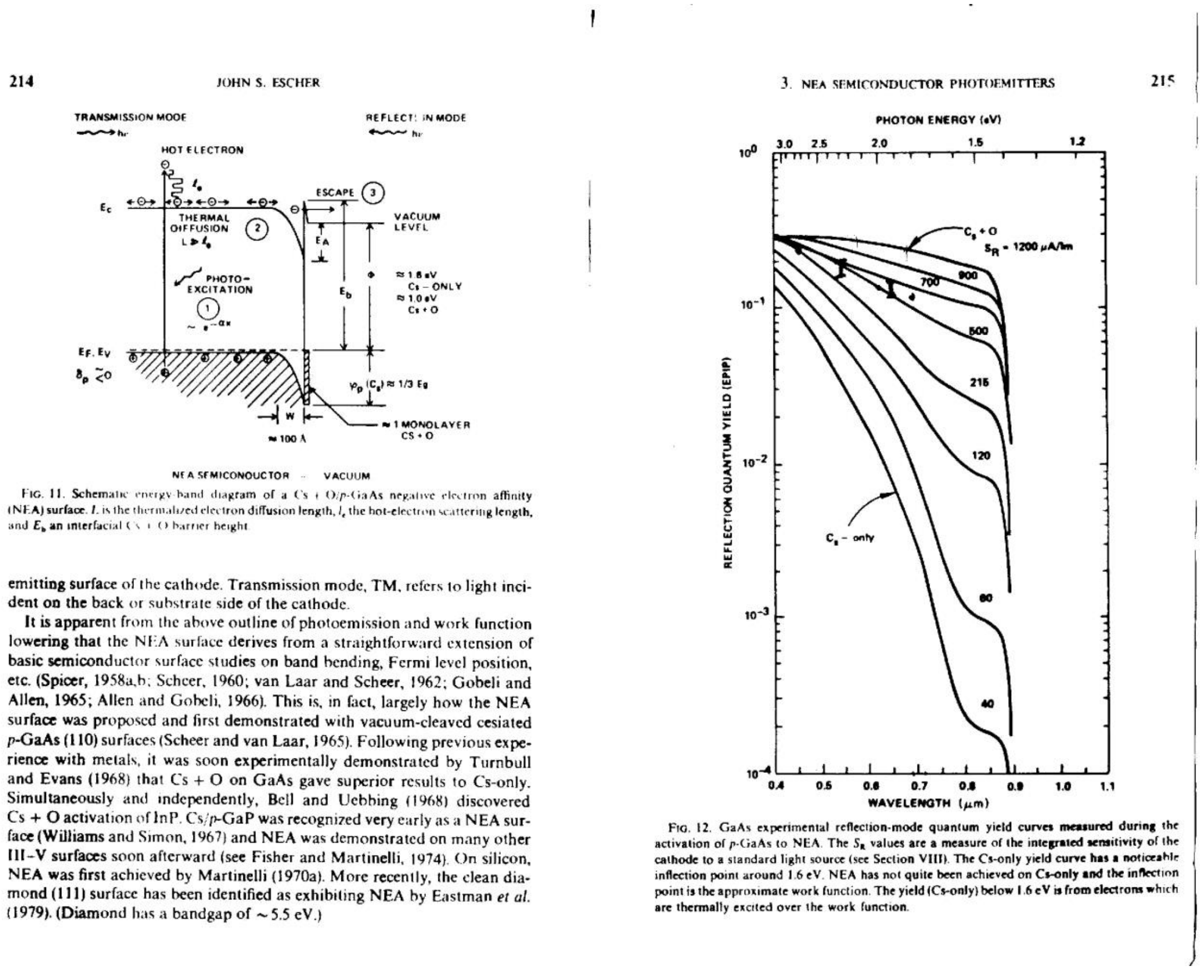
The Courage
to change the things I cannot accept,

And the Wisdom
to hide the bodies of those people
I had to kill because they pissed me off.

And, LORD,
help me to be careful
of the toes I step on today as they
may be connected to the ass
that I might have to kiss tomorrow!

Easy fabrication

Photocathode operation involves; 1 p-type material, 2 electrons pumped across the band gap from the valence band to the conduction band, 3 Transport to the surface without falling back into the valence band, 4 Transmission from the surface into the vacuum.



214 JOHN S. ESCHER

FIG. 11. Schematic energy-band diagram of a Cs + O/*p*-GaAs negative electron affinity (NEA) surface. *L* is the thermalized electron diffusion length, l_e the hot-electron scattering length, and E_b an interfacial Cs + O barrier height.

emitting surface of the cathode. Transmission mode, TM, refers to light incident on the back or substrate side of the cathode.

It is apparent from the above outline of photoemission and work function lowering that the NEA surface derives from a straightforward extension of basic semiconductor surface studies on band bending, Fermi level position, etc. (Spicer, 1958a,b; Scheer, 1960; van Laar and Scheer, 1962; Gobeli and Allen, 1965; Allen and Gobeli, 1966). This is, in fact, largely how the NEA surface was proposed and first demonstrated with vacuum-cleaved cesiated *p*-GaAs (110) surfaces (Scheer and van Laar, 1965). Following previous experience with metals, it was soon experimentally demonstrated by Turnbull and Evans (1968) that Cs + O on GaAs gave superior results to Cs-only. Simultaneously and independently, Bell and Uebbing (1968) discovered Cs + O activation of InP. Cs/*p*-GaP was recognized very early as a NEA surface (Williams and Simon, 1967) and NEA was demonstrated on many other III–V surfaces soon afterward (see Fisher and Martinelli, 1974). On silicon, NEA was first achieved by Martinelli (1970a). More recently, the clean diamond (111) surface has been identified as exhibiting NEA by Eastman *et al.* (1979). (Diamond has a bandgap of ~5.5 eV.)

3. NEA SEMICONDUCTOR PHOTOEMITTERS 215

FIG. 12. GaAs experimental reflection-mode quantum yield curves measured during the activation of *p*-GaAs to NEA. The S_R values are a measure of the integrated sensitivity of the cathode to a standard light source (see Section VIII). The Cs-only yield curve has a noticeable inflection point around 1.6 eV. NEA has not quite been achieved on Cs-only and the inflection point is the approximate work function. The yield (Cs-only) below 1.6 eV is from electrons which are thermally excited over the work function.

First attempts with GaAs were very difficult. Tried to follow in Charlie Sinclair’s footsteps. Only mild success. I remember him saying that ion gauges were little chemical factories and had to be parked far away from the cathode. If sputtered clean, they had to be annealed to get rid of near surface damage. The recombination rate at the surface would be so high that even though the work function was low enough, there would be little or no emission. (problems with obtaining low defect density p type GaAs)

Low measurement 8 orders of magnitude low!!

Moved to cesium antimonide. A lot of time was expended trying to make cesium antimonide that kept a good quantum efficiency. In a small demountable system, many cathodes would be made before a stable cathode could be made. One of the limitations was the use of the Saes getters that were purchased. They were limited to a few fabrications because of the physical size. They were also packaged in cans that were pumped out and refiled with Ar and soldered shut.

antimony source, the cesium source and the oxygen source.

Process had three knobs. The Cesium antimonide is not thermodynamically stable at the optimium operating point. It must have a slightly positive cesium over pressure to replace the evaporation losses.

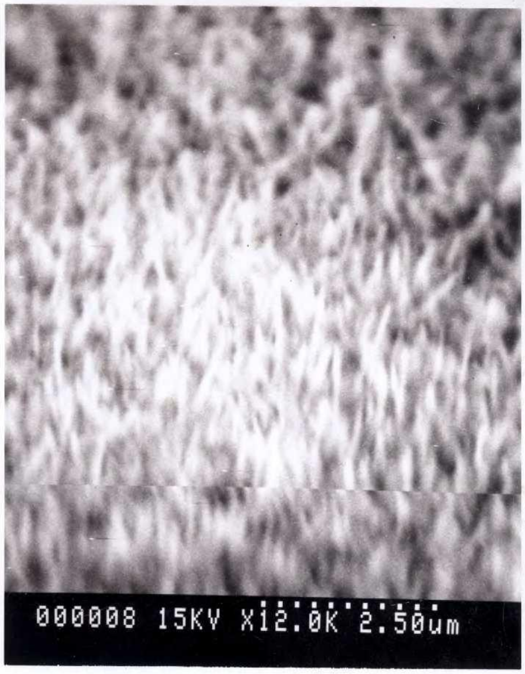
Finally moved to the potassium cesium antimonide cathode. First 7% cathode was made in a demountable system and was stable for a month, until the vacuum was broken. It happened by mistake. Out of frustration, I left for lunch with the equipment on and when I returned it was done. I realized that the cathode could not be made quickly. The thought was that it took time to diffuse the alkalis into the antimony until the proper composition was reached.

Made own sources. Water discovery!

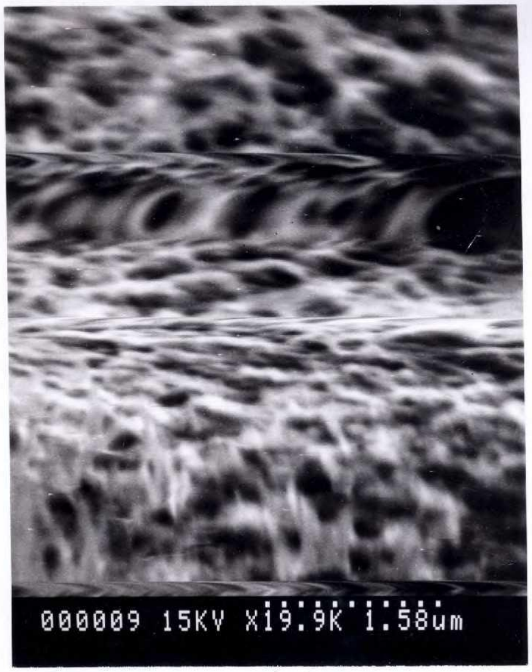
During this time, I built a photocathode fabrication chamber for Boeing. It included a cylindrical mirror analyzer, which I also built, to assist with cathode fab and cathode failure. There wasn't much time to work with this system. The one thing that I did learn was that the Auger spectrum showed only cesium and potassium on the surface. None of the antimony peaks could be seen. This made me believe that the cesium-potassium formed a capping layer that was stable.

Tried making Ag-Bi-O cathodes. Easiest cathodes I ever made. Put Bi on a piece of stainless foil, put on a hot plate until it turned canary yellow. Put in chamber, heat and add Cs. Guaranteed 4% QE every time.! Lifetime to 1/e was about 40 minutes. It could be revived with a new dose of Cs. Another 40 min, and it was down. I could do this all day, recover and die, repeat. So this cathode exhibited a need for a higher partial pressure than CsSb!

Next I threatened to quit unless they left me alone to do some research. I added a cathode fabrication chamber on the rapid introduction chamber of a home brew analytical system. Only two photos remain of that work. This is when the scales fell off my eyes. First photo shows what looks like grass. That is when I realized that they were whiskers. Whiskers grow from a liquid and push up from the substrate.



Room Temp 9/6/89 former active area.



Heated to 160C 9/6/89

1a

Aluminum on Mica

1b

Antimony on Aluminum/Mica

1c

1%-2% at 543.5 nM

1d

After heating to 250 C for about 2 hours.

1e

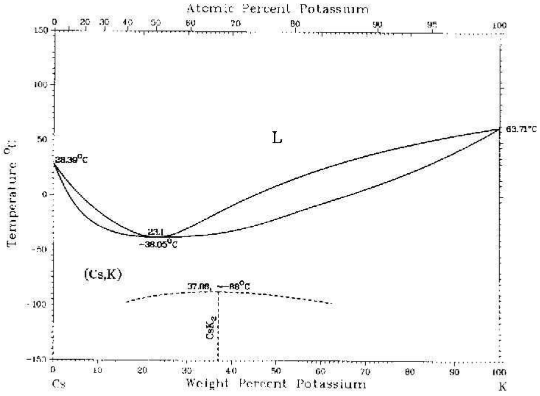
5%-6% QE fabricated on material

1f

6%-7% QE fabricated on material

Show phase diagram for cesium-potassium. Other alkali mixtures as well.

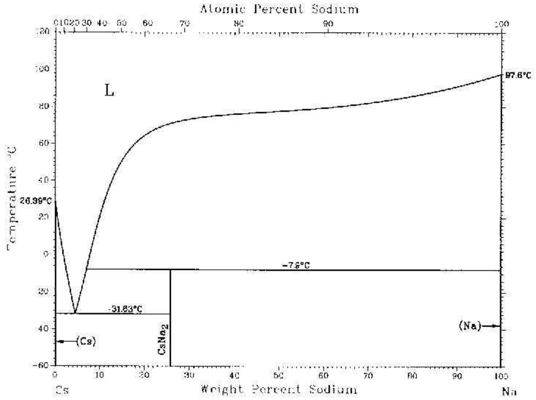
Cs-K



C.W. Bale and A.D. Pelton, 1983

Phase	Composition, wt% K	Pearson symbol	Space group
(Cs,K)	0 to 100	*cI*2	*Im*$\bar{3}$*m*
CsK_2	37.0	*hP*2?	...
Other reported phase			
Cs_6K_7	?	...	...

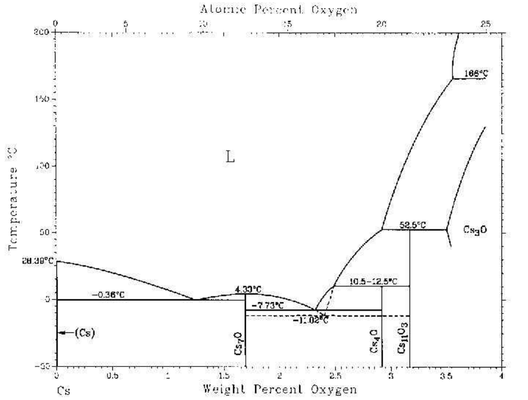
Cs-Na



C.W. Bale, 1982

Phase	Composition, wt% Na	Pearson symbol	Space group
(Cs)	0	*cI*2	*Im*$\bar{3}$*m*
$CsNa_2$	25.7	...	...
(Na)	100	*cI*2	*Im*$\bar{3}$*m*

Cs-O



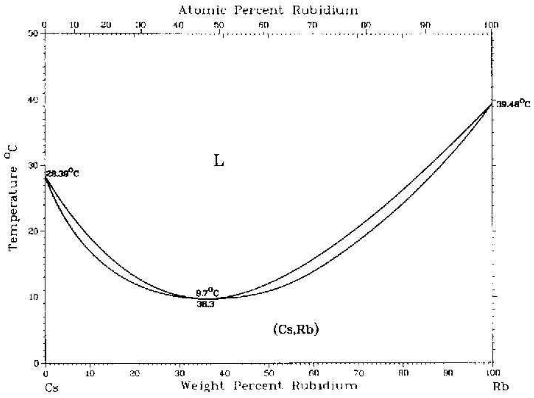
P.R. Subramanian, 1990

Phase	Composition, wt% O	Pearson symbol	Space group
(Cs)	~0	*cI*2	*Im*$\bar{3}$*m*
Cs_7O	~1.7	*hP*24	*P*$\bar{6}$*m*2
Cs_4O	3	...	...
$Cs_{11}O_3$(a)	~3.2	*mP*56	*P*2$_1$/*c*
Cs_3O	~4	...	...
Cs_2O	~5.7	*hR*3	*R*3*m*
CsO	~10.7	*oI*8	*Immm*
Cs_2O_3	~15	*cI*28	*I*$\bar{4}$3*d*
CsO_2(LT)	~19.4	*tI*6	*I*4/*mmm*
CsO_2(HT)(b)	~19.4	*cF*8	*Fm*$\bar{3}$*m*

(a) Also reported as Cs_7O_2. (b) Above ~200 °C

SEM of cathode showing crystals. Showing liquid that is crystallizing.

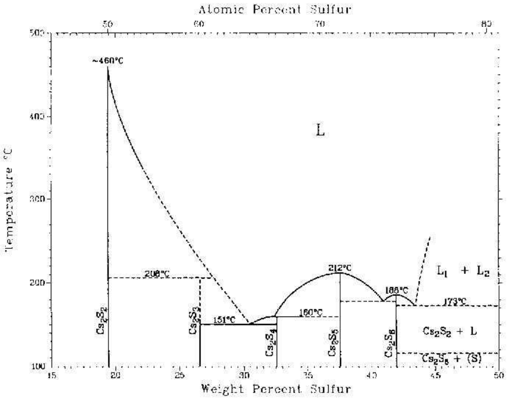
Cs-Rb



C.W. Bale and A.D. Pelton, 1983

Phase	Composition, wt% Rb	Pearson symbol	Space group
(Cs,Rb)	0 to 100	*cI*2	*Im*$\bar{3}$*m*

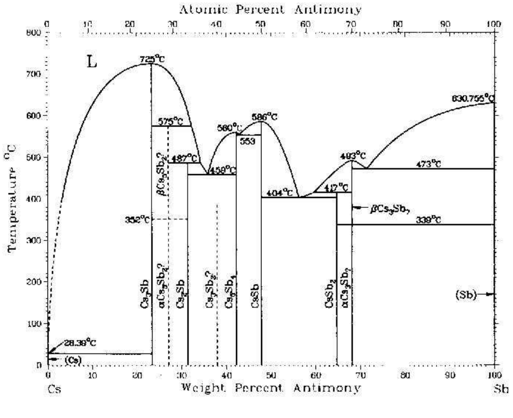
Cs-S



From [Smithells]

Phase	Composition, wt% S	Pearson symbol	Space group
Cs_2S_2	19.4	*oI*8	...
Cs_2S_3	27	*oC*20	*Cmc*2_1
Cs_2S_4	~34.7	...	...
Cs_2S_5	~40.0	..	...
Cs_2S_6	~42.5	...	...

Cs-Sb

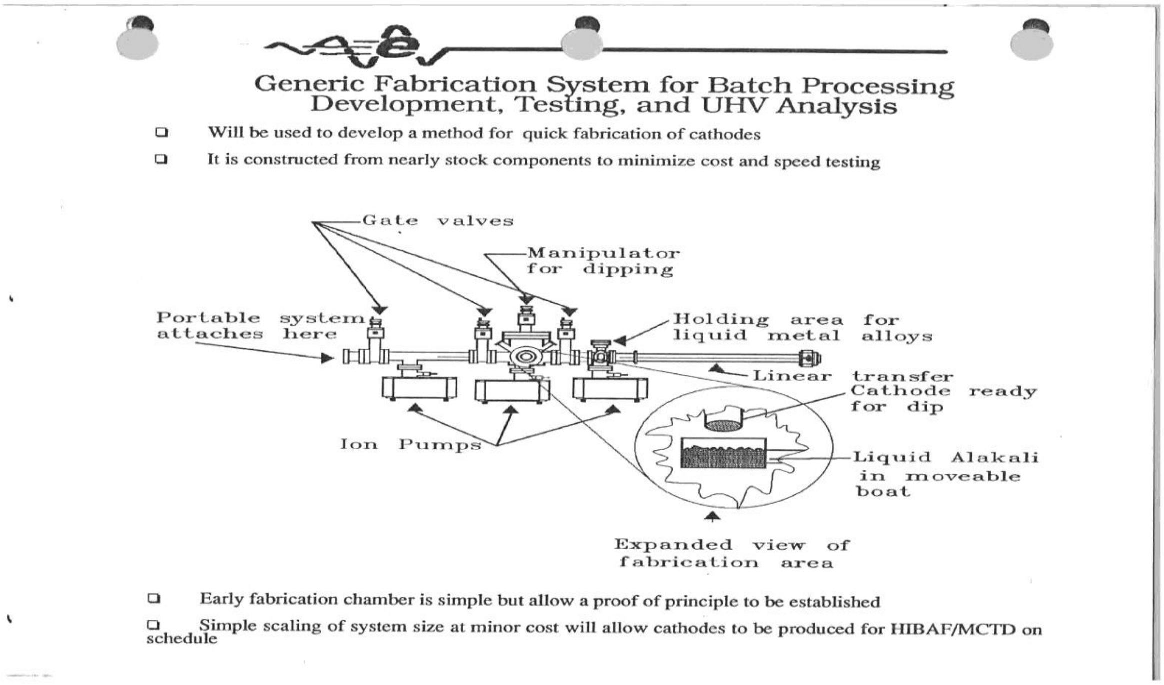


F.W. Dorn and W. Klemm, 1961

Phase	Composition, wt% Sb	Pearson symbol	Space group
(Cs)	0	*cI*2	*Im*$\bar{3}$*m*
Cs_3Sb	23	*cF*16	*Fd*3*m*
αCs_5Sb_2	26.8	...	..
βCs_5Sb_2	26.8	...	...
Cs_2Sb	31	...	...
Cs_3Sb_2	38	...	...
Cs_5Sb_4	42.2	...	...
CsSb	47.8	*oP*16	$P2_12_12_1$
$CsSb_2$	64.7	...	...
αCs_3Sb_7	68	...	...
βCs_3Sb_7	68	...	...
(Sb)	100	*hR*2	*R*$\bar{3}$*m*

It occurred to me that I could coat the surface with Sb, dip it into the liquid alkali mix, pull it out, shake it off and voila, I would have a cathode. Great idea! Problem was that when I dipped the cathode into the mix, the antimony wen into the solution and the stainless steel substrate came out clean!

How to make this great idea work. I called it the modified dip process. A name to puzzle any competitors. Deposit Sb, head cathode, put a loop into the alkali mix, pull out and evaporate to the cathode face. Add a few Langmuir's of water, sit back and watch the numbers come up on the ammeter. When finished, carefully add some oxygen to further lower the workfunction.



Generic Fabrication System for Batch Processing Development, Testing, and UHV Analysis

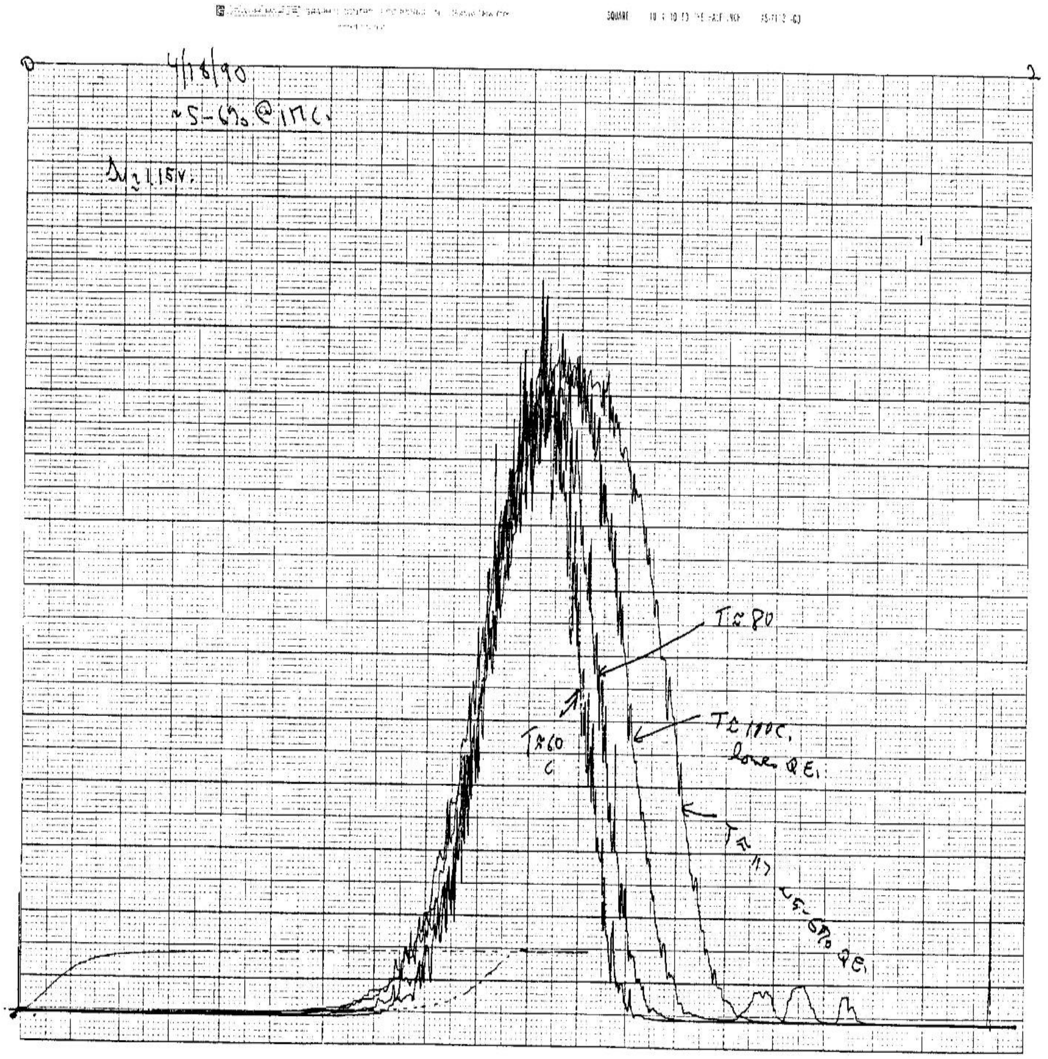
- Will be used to develop a method for quick fabrication of cathodes
- It is constructed from nearly stock components to minimize cost and speed testing

- Early fabrication chamber is simple but allow a proof of principle to be established
- Simple scaling of system size at minor cost will allow cathodes to be produced for HIBAF/MCTD on schedule

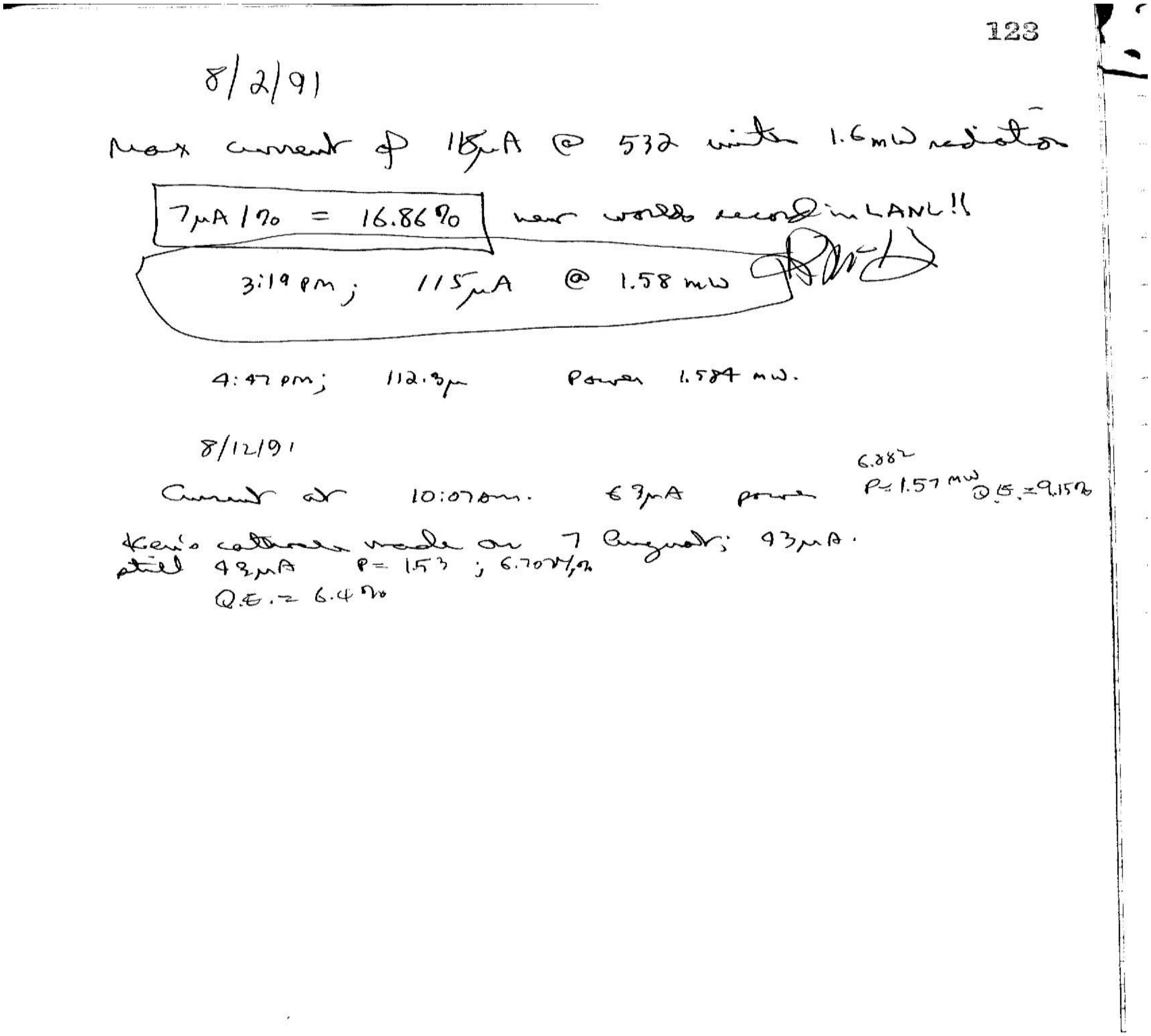
Problem never solved was the "gritty" cathode formed. Since it made good crystals on the surface, there was some bare areas. They saw the effect in the photoinjector. Laser spot to measure the QE was too big to see the granularity. Cathodes were extremely uniform across the active area.

Why water and not oxygen. Cathodes made with a little water had good yields at room temp. Cathodes made with oxygen had good yields at temp, but fell off as they approached room temp.

I built a 127 degree analyzer on a small fabricator. I could measure the electron energy distribution while the temperature was changing. If the workfuction was dropping I would have expected the peak to remain stationary and the cutoff to move up in energy. However, the cut off remained the same but the peak shifted downwards and narrowed up. This could only mean that the Fermi level was changing. I attributed this to a small energy difference in the acceptor levels from OH and O. Pure speculation, I ave no measurement to prove this except the movement of the photopeak.



Getting ready to make a photocathode transfer system, I made a boat that could hold Na, K, Cs and Rb. When baking out the system, the window cracked. Chamber came up to air. Put another window on, pumped out and continued. Made a cathode that was a record 16.8 % QE with all the alkalis. Seemed to be stable and harder to poison. I had my program manager and Charlie Sinclair make their own xathodes where I only told them what to do. They all made cathodes in the 15% QE region.



123

8/2/91

Max current of 115µA @ 532 with 1.6mW radiation

7µA / % = 16.86% new worlds record in LANL!!

3:19 pm; 115µA @ 1.58 mW

4:47 pm; 112.3µ Power 1.584 mW.

8/12/91

Current at 10:07am. 63µA power P≈1.57 mW Q.E.=9.15% 6.882

Ken's cathode made on 7 August; 43µA.
still 43µA P= 1.53 ; 6.707µ/%
Q.E.= 6.4%

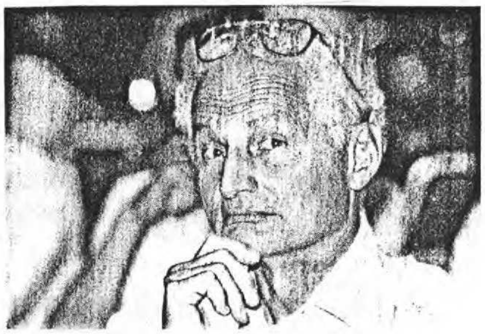
Sad note. Went on vacation and tech tried to help by cleaning up the system, so I never knew the composition of the boat!

Made cathode transfer system. It worked well. Couldn't get the FEL guys to use two valves with pumps in between.

Cathodes-R-Us

Low milage cathodes!
Only been to Santa Fe and Back!!
CHEAP!
No Warranty!

R.W."Honest Bob" Springer, President



A "typical" customer

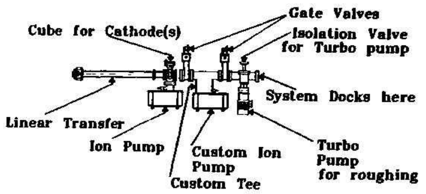


Fig. 1. This is a schematic layout of the transfer system. The photocathodes are made in a system (not shown) that docks adjacent to the turbo pump, used for roughing. The two ion pumps are used to provide a "guard vacuum" against accidental gas leakage across the valve seats. The PAM (not shown) is normally located on the top of the cube. Once the cathodes are moved into the cube, they are illuminated with laser light through a glass viewport, and the emission current is collected and measured from a biased copper ring.

When the wire is hot, and has a work function that exceeds the ionization potential of the alkali, the atoms that strike the wire will leave ionized. The ionization probability is nearly unity, according to the Saha–Langmuir equation [3]. The ions are then collected on the collector wire of the tube. The biases used in the tube are the same as for a normal ionization gauge. The sensitivity is then calculated using the thermodynamic equation for the number of molecules/cm^2 s, the area of the collector wire, and the relationship between the current on the ion gauge controller and the pressure read. For the systems used, the conversion factor was ~ 570 (see Appendix A for details). Thus, for a pressure read at 4×10^{-7} Torr, the partial pressure of cesium was about 7×10^{-10} Torr. This is the pressure at the detector, but the actual pressure at the cathode surface is unknown. It is suspected to be much lower. This is because the only volume that needs to become saturated is in the tee itself. Further investigation is needed to determine if it is a true reflection of the partial pressure of cesium over the cathode face. However, the literature suggests that the partial pressure of alkali metals exists in photocathode tubes [4,5]. The presence of a slight excess alkali might enhance cathode lifetime, or represent the partial pressure over the cathode surface. If there is benefit from an excess alkali, it may be due to three effects: (1) the partial pressure of cesium compensates for the evaporation at the cathode surface; (2) the partial pressure of cesium is consumed by the excess water vapor present in the vacuum system, thus acting as a getter pump; (3) both mechanisms are at work. Until further measurements are made, this and other measurements concerning the over pressure of cesium with the multialkali cathodes could simply reflect a slight excess of cesium from final processing, and the complete lack of water to react and bind it to the walls.

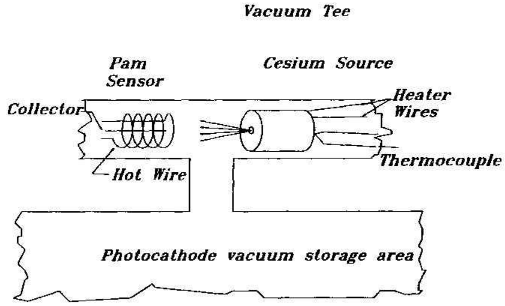
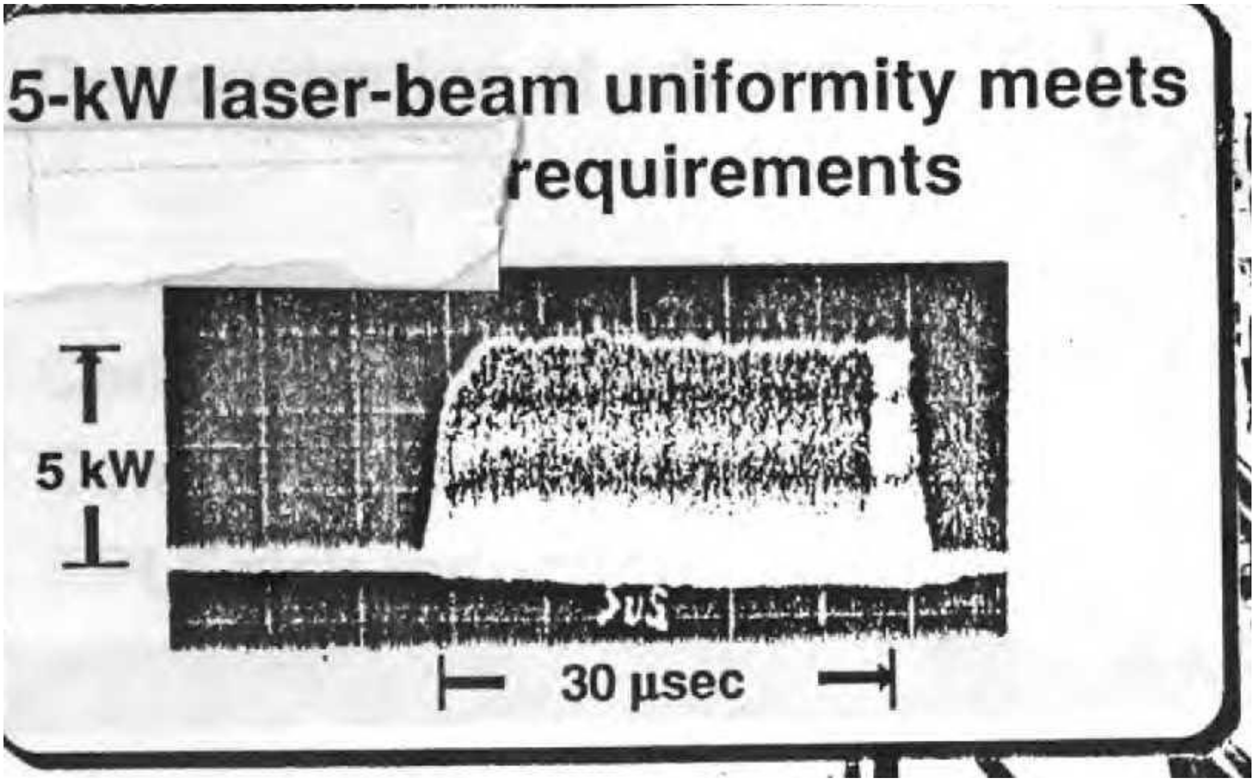


Fig. 2. The Pressure Alkali Monitor (PAM) is placed in a vacuum tee that is mounted on the top of the cube. The cesium source is temperature controlled and alkali pressure controlled through an "or" circuit. If the pressure of the alkali is too low, the source may be heated until a maximum temperature is reached, to prevent an alkali spill. When the desired pressure is reached, the temperature is lowered to just maintain this pressure. If there is any significant water present, the cesium will be react with it at the walls of the chamber, thus lowering the partial pressure of cesium, and causing the circuit to call for more cesium. No more cesium is used than is necessary to maintain a partial pressure at the detector.

3. Results and discussion

The methodology of the experiment was to find the minimum requirements and processing necessary to move and preserve a photocathode. The very first transfer attempts were done with the minimal treatment to the storage cube. The base pressure was just what was obtained without a bakeout of the pumps and system. According to the pump controllers, the base pressure was in the mid 10^{-7} Torr range. The first cathodes had only tens of minutes to an hour for lifetimes.

After the first attempt, an alkali monitor feedback system was adopted. The system was again pumped, but no bakeout effected. The cesium generator feedback system was allowed to equilibrate by coming to a temperature and cycling. The equilibrium of temperature cycling occurs when the temperature to produce a given value at the monitor is well below the previous reaction temperatures on source start up. The cesium sources were often operated at temperatures as high as 595°C to begin to obtain a partial pressure in the 10^{-10} Torr range. Once this pressure was obtained, the temperature of the source would drop with time. In a well baked system, this temperature can be as low as 200°C, or oscillate about 400°C with 30 s to 1 min. periods. Fig. 3 shows the cathode lifetime using only the feedback system and no bake. Again, the cathode lifetime is improved, but is unsatisfactory.



5-kW laser-beam uniformity meets requirements

Started looking for a vacuum hearty cathode. Amorphous SiH films were p type and had a good band gap. So I started to make composition tailored SiC to SiH materials with a decreasing band gap. Amorphous materials are called non-direct and have an adsorption constant that is not a weak as indirect, but not as sharp as a direct band gap material. I wanted to make p type material doped with Al. I wanted a material that I could assess before putting together a dispenser photocathode. Since the silicon material is a type I photoconductor, the carrier production and lifetime could be measured before the cathode was made. I had the cs generator that would produce cs at temperatures below 300C. 300C was the temperature where the hydrogen would desorb from the SiH material. So, it might be possible to operate the cathode at a temperature hot enough to allow water to come down to the surface, either decompose into H and OH or not react at all. For the dissociation, you could give up and electron as long as it did not remain or react.

We were moving along on a success track, and SDI was cancelled and the work with it.

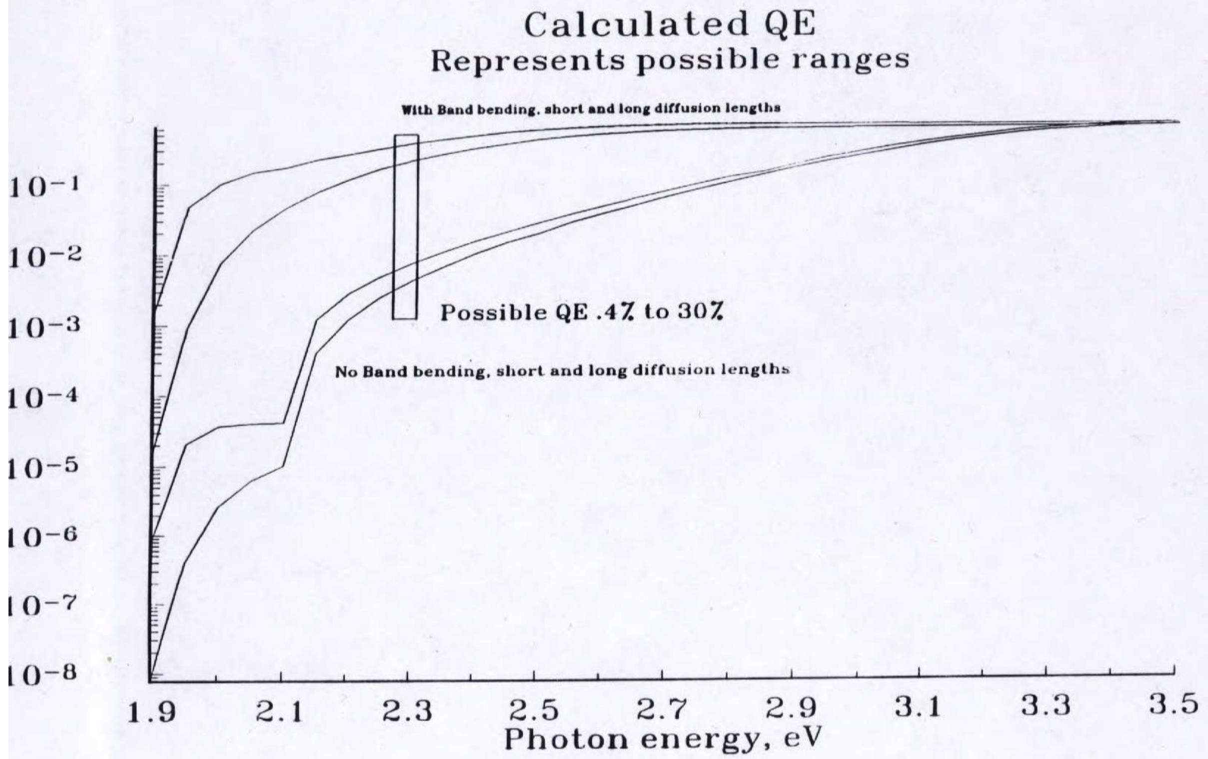


Figure 5

FIN

Nuclear Instruments and Methods in Physics Research A318 (1992) 396–400
North-Holland

NUCLEAR
INSTRUMENTS
& METHODS
IN PHYSICS
RESEARCH
Section A

Photocathode transfer and storage techniques using alkali vapor feedback control

R.W. Springer and B.J. Cameron

MS E-549, MST-7, Box 1663, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Photocathodes of quantum efficiency (QE) above 1% at the doubled YAG frequency of 532 nm are very sensitive to the local vacuum environment. These cathodes must have a band gap of less than 2.3 eV, and a work function that is also on the order of ~ 2 V or less. As such, these surfaces are very reactive because they provide many surface states for the residual gases that have positive electron affinities such as oxygen and water. In addition to this problem it is found that the optimal operating point for some of these cesium based cathodes is unstable. Three of the cesium series were tried, the Cs–Ag–Bi–O, the Cs_3Sb and the K_2CsSb. The most stable material found is the K_2CsSb. The required vacuum conditions can be met by a variety of pumping schemes such as using sputter ion diode pumps and baking at 250°C or less for whatever time is required to reduce the pump currents to below 1 μA at room temperature. To obtain the required partial pressure of cesium, a simple, very sensitive, diagnostic gauge has been developed that can discriminate between free alkali atoms and other gases. This Pressure Alkali Monitor (PAM) can be used with cesium sources to provide a low partial pressure using standard feedback techniques. Photocathodes of arbitrary composition have been transferred to a separate vacuum system and preserved for over 10 days with less than a 25% loss to the QE at 543.5 nm.

1. Introduction

Photocathodes used in photoinjectors can produce very high current densities, i.e. $> 1000\ A/cm^2$. These cathodes can be made from a variety of materials. However, if a CW injector is to be fabricated, it is found that the limiting technology is the power of mode-locked laser light in the 2.3 eV range and above. At this point in time, obtaining a mode-locked, crystal doubled, CW laser at 30 watts is a major development effort. In order to obtain ~ 8–10 nC/micropulse a cathode of about 3% quantum efficiency (QE) at 2.3 eV is required. The cathodes in this class are of the multi-alkali antimonide [1] or gallium arsenide [2] type. Aside from the difficulty in cathode fabrication, the cathode lifetime in the injector is a problem. The chief difficulty is contamination from residual gases. The major effort to improve the vacuum has been to remove the residual water from the system. A number of experiments have been carried out to verify that cathode transfer and storage can be accomplished. The goal for the hardware is to produce a $1/e$ storage lifetime of 240 h (10 d). With these results, it becomes feasible to produce a cassette of cathodes for use on photoinjectors. This development then provides improved operating conditions because the fabrication of photocathodes can be separated from the accelerator, and the cathodes can be stockpiled for later use.

A ten-day storage time meeting these requirements has been demonstrated on two separate pieces of hardware. Both were brought on line *new*, which means that the vacuum components had not been previously used in ultrahigh vacuum. We found that the cathodes could be preserved if the vacuum system was baked 2 to 3 times at a temperature not exceeding 250°C for 24 h each bake. The criteria for a successful bake was the establishment of a stable, low Cs alkali pressure, i.e. low to mid 10^{-10} Torr region, and a residual ion pump current less than 1 μA when room temperature was reached ($P_{(est)} = 2\text{–}3 \times 10^{-9}$ Torr). An alkali monitor was used, and temperature cycling on the cesium source was observed to determine that the partial pressure of cesium in the unit had reached an equilibrium value. The estimate of the partial pressure of cesium in the chamber, based on a calculation for the detector sensitivity, is a few times 10^{-10} Torr.

2. Experiment

Experiments have been carried out using the equipment schematically shown in fig. 1. One of the 20 l/s pumps has been modified into a pump pipe, and the other simply bolted onto the storage cube. An alkali monitor/feedback system has been added to the top of the cube. Fig. 2 shows the schematic arrangement of this device. The detector probe, similar to a Bayard–Alpert gauge tube, is mounted on one end and a typical cesium source is mounted on the other end of the vacuum tee. The detector works by heating the grid wire to incandescence using a transformer. A standard ion gauge controller was used in the degas mode.

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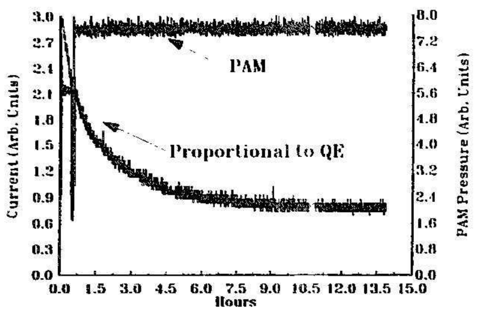

Fig. 3. Cathode lifetime, system 1, 4-5-'91. System was allowed to pump and benefit from the PAM. The lifetime had improved over the system with no bakeout, but the lifetime is still too short.

After several bakeouts on the vacuum system, a lifetime and cesium profile was found as in fig. 4. The cathode after fabrication had a QE only slightly greater than 3%, but it rose to nearly 5%. The QE then began a gradual decline through the first 100 h. At this time, the cesium partial pressure was increased by about 20%. The QE then rose to nearly 5% again, and then began a gradual decline. At about 250 h, the heater on the cesium source was turned off, and just the cesium pressure monitored. As can be seen, the cathode QE rose again slightly, and then began to drop until the experiment was terminated at 330 h or nearly 14 d.

A final test for system 1 was carried out by monitoring the cathode life, while beginning the test on system 2. Fig. 5 shows how the QE varied for 130 hours for the last test run on system 1. There is no significant drop in the QE.

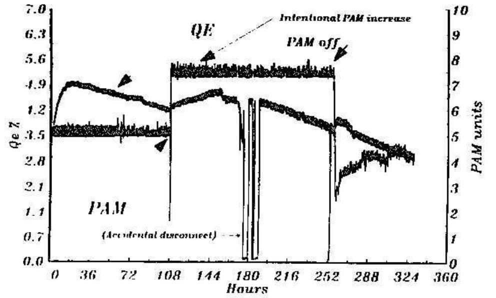

Fig. 4. Proof-of-principle transfer chamber lifetime test with PAM on (7-5-'91). This was the first successful extended storage. A trace amount of water present probably accounts for the initial increase in the QE. However, the continued absorption of water would cause the lifetime to decrease. The effect of changing the partial pressure of cesium in the tee was very small during this run.

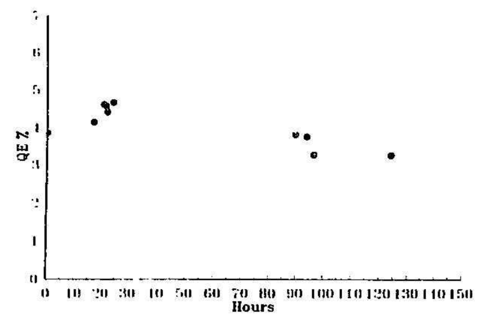

Fig. 5. The next test on this system (5-17-'91) indicates that the cathode lifetime is getting better with time. The specific reasons for this improvement are still under investigation, but likely involve the absence of water and low partial pressure of cesium.

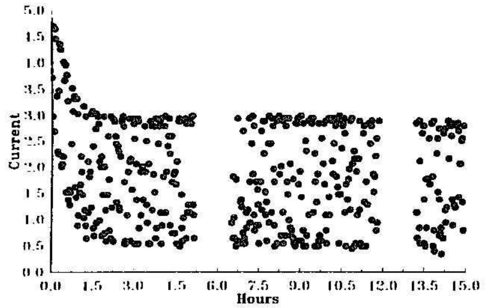

Fig. 6. The first test in the second system (5-29-'91) shows a lifetime of about 3 hours. The scatter in the data was due to a noisy laser near the end of its life. In spite of the scatter, it is clear that there is still too much water present in this system.

System 2 begins with a large scatter plot as shown in fig. 6. The laser seems to have had a lot of noise in it during this test. From the view of the "envelope" of the data, it is clear that the cathode life was very poor

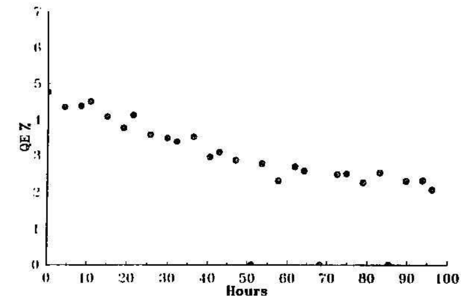

Fig. 7. Test on 6-13-'91: the lifetime has improved after a second bakeout. The 1/e time is about 130 h.

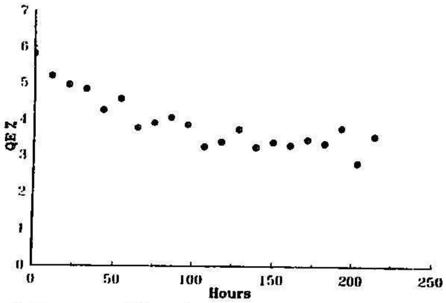

Fig. 8. Test on 6-17-'91: further bakeout of the system has improved the cathode life to a level comparable with the first vacuum system. The $1/e$ time is in excess of 800 h.

and tended to decay over about 3 h. Fig. 7 shows about another bakeout and attempt at the storage lifetime. We have improved the cathode life by about an order of magnitude, but have still not done as well as the first system. Fig. 8 shows another test where the data appears to be as good as system 1. Fig. 9 shows one last run obtained on system 2. The data had significant fluctuation due to the changing power of the test laser.

Fig. 10 shows a calculated lifetime [6] for photocathodes based on the change in work function versus exposure to H_2O. It was assumed that the change in work function increased the height of the surface barrier to the vacuum, and thus reduced the surface escape probability. This chart is likely to be accurate to a factor of 2 or 3. The curve represents the working time to $1/e$ change in QE. This calculation was used to estimate the base water pressure in the system.

A summary of the data is shown in table 1. The system number, test start date, estimate $1/e$ times, and

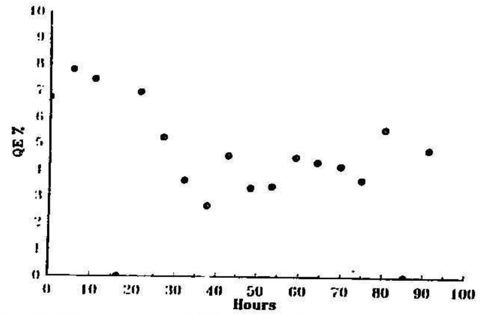

Fig. 9. The last test (6-27-'91) on this system provided a lifetime ~800 h.

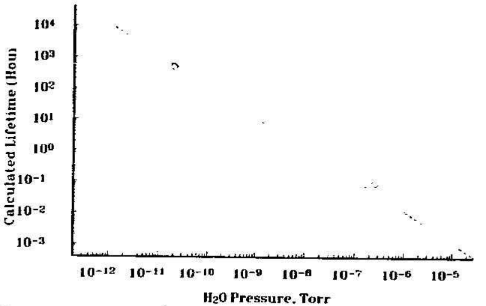

Fig. 10. Lifetime vs partial pressure of H_2O. The cathode lifetime has been calculated by knowing the change in the work function versus water exposure. With this measurement, a surface escape probability can be computed, and a time to $1/e$ determined. This graph was used to estimate the water partial pressure. Two points indicate the scant data obtained to date. Further detailed measurements are the subject of future work.

Table 1
Estimated H_2O pressure

System	Date of test	Estimated hours to $1/e$	Estimated H_2O pressure from fig. 10 in Torr
1	4/5/91	3.4	2×10^{-9}
1	4/19/91	547	8×10^{-12}
1	5/1/91	392×800	2×10^{-11}–7×10^{-12}
2	5/20/91	3.3	2×10^{-9}
2	6/13/91	130	4×10^{-11}
2	6/17/91	865	7×10^{-12}
2	6/27/91	312×1000	2×10^{-11}–6×10^{-12}

Table 2
Conditions for cathode transfer and storage

Pump size	VacIon, 20 l/s
Pump current	$I < 1$ μA
Estimated pressure	$P < 10^{-9}$ Torr
Estimated PAM pressure	$P \sim 7\times10^{-10}$ Torr
PAM control temperature cycling period	> 60 s

estimated partial pressure of water obtained from figure 10 are given.

4. Conclusions

The preliminary conditions, shown in table 2, for the cathode transfer and storage have been established. The vacuum pressure in the two pumps on the storage system must be reading less than 1 μA of current. On our experiment, the current was in excess of 20 μA due to internal leakage. While we were able to succeed in making this system work, there was always the nagging doubt that the currents may have been across a ceramic insulator, thus providing a constant source of oxygen which would shorten the photocathode life. We have not yet produced and moved multiple cathodes. We do not know the composition of the cathodes produced. Both of these questions will be the subject of the next phase of our investigation.

Appendix

The Pressure of Alkali Monitor (PAM) sensitivity was calculated as follows. The equation for the length of the wire of the ionizer is shown in eq. (1).

$$l = n1\ \pi\sqrt{r^2 + a^2}\ \text{cm}. \qquad (1)$$

Eq. (2) represents the flux of molecules per cm^2 s as derived from thermodynamics.

$$f = 3.5 \times 10^{22} \frac{p}{\sqrt{mT}} \quad \text{molecules/cm}^2\ \text{s}. \qquad (2)$$

If the particles are charged, the current then becomes the area of the wire (eq. 4) times the electron charge times the flux shown in eq. (3).

$$I = feA \quad \text{or current in amperes}, \qquad (3)$$

$$A = l\ \pi D\ \text{cm}^2 \quad \text{(area of wire)}. \qquad (4)$$

The ion gauge sensitivity is 0.1. A/Torr; thus, the conversion between the partial pressure of the cesium and the ion gauge can be readily determined as in eq. 5,

$$\text{Torr}_{\text{Cs}} = \frac{\text{Torr}_{\text{m}}}{10}\left(\frac{\sqrt{mT}}{3.5 \times 10^{22} eA}\right)\frac{\text{Torr}_{\text{m}}}{572}, \qquad (5)$$

where the variables are defined as follows: e = electron charge, A = area of wire, f = molecular flux, I = current, Torr_{m} = measured pressure from ion gauge controller, Torr_{Cs} = actual partial pressure of cesium, m = atomic mass, T = temperature in K, D = wire diameter, 0.0254 cm, l = wire length, n = number of turns, a = pitch per 2π change in Azimuth, r = radius of coil.

Thus, the maximum sensitivity of this device as configured is about 1.75×10^{-12} Torr_{Cs}, which corresponds to 1×10^{-9} Torr_{m} on the ion gauge controller.

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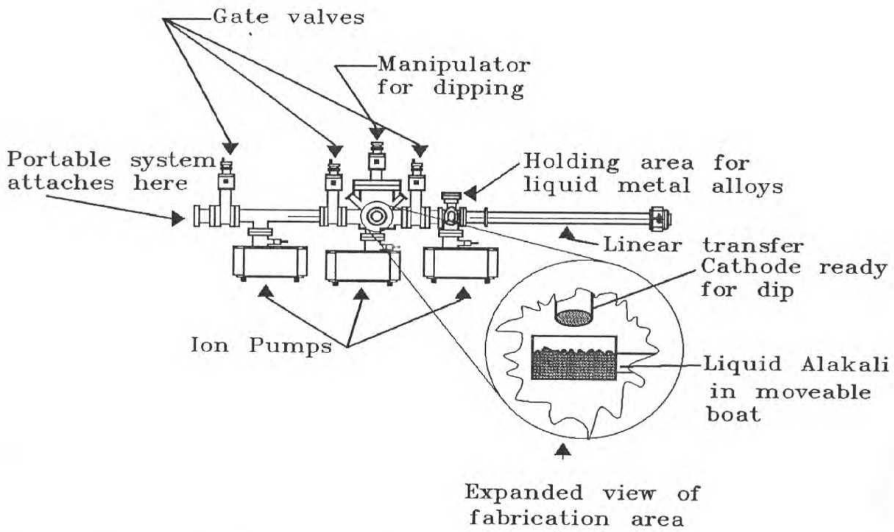
[6] To be published.

Generic Fabrication System for Batch Processing Development, Testing, and UHV Analysis

- Will be used to develop a method for quick fabrication of cathodes
- It is constructed from nearly stock components to minimize cost and speed testing



- Early fabrication chamber is simple but allow a proof of principle to be established
- Simple scaling of system size at minor cost will allow cathodes to be produced for HIBAF/MCTD on schedule