Studies of Cs_3Sb Cathodes for the CLIC Drive Beam Photoinjector Option

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MOPFI058/SUPWA048

Introduction

- Within the CLIC (Compact Linear Collider) project feasibility study of a photoinjector option for drive beam is on-going.
- This R&D program covers both the laser and the photocathode side.
- The available laser pulse energy in ultra-violet (UV) is currently limited by the optical defects in the 4th harmonics frequency conversion crystal induced by the 0.14 ms long pulse trains.
- Potential solution of the problem: Cs_3Sb photocathodes sensitive to green light.

CLIC and the PHIN Photoinjector

- The 3rd CLIC Test Facility (CTF3) at CERN [1] is operated with a drive beam produced using a thermionic gun and a sub-harmonic bunching system.
- This baseline setup creates the required time-structure but generates also parasitic satellite bunches, which cause beam losses and radiation issues.
- In the PHIN photoinjector, with its RF gun and the phase-switching set-up installed on the laser bench, satellite-free beam production has been demonstrated [2].
- The CLIC drive beam design parameters cannot be completely achieved with PHIN.
- The main challenge is to achieve high bunch charges, long trains and high bunch repetition rates together with sufficiently long cathode lifetimes.
- With Cs_2Te cathodes using UV laser light lifetimes of up to 300 h could be achieved for nominal PHIN parameter[3] but for 140 µs long trains the UV generation is a major issue and not yet solved.

CLIC and PHIN design parameters

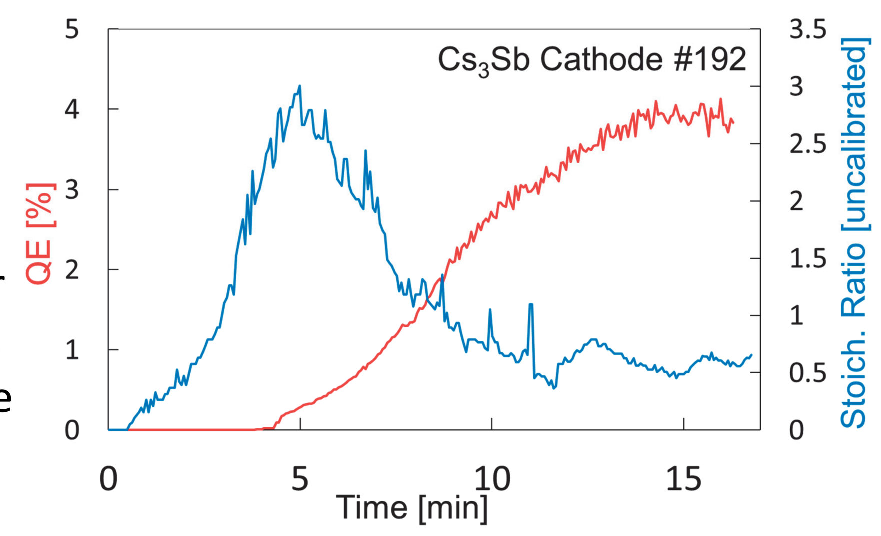
Parameter	CLIC	PHIN
Charge/bunch (nC)	8.4	2.3 (nominal) 9.2 (achieved)
Bunch length (ps)	10	10
Bunch rep. rate (GHz)	0.5	1.5
Number of bunches	70000	1800
Train length (µs)	140	1.2
Charge/train (µC)	590	4.1
Macro pulse rep. rate (Hz)	50	5
Charge stability (%)	<0.1	<0.25
Beam current/train (A)	4.2	3.4
Cathode lifetime (h) at QE>3% (Cs_2Te, UV laser), QE>0.5% (Cs_3Sb, green laser)	>150	>50

Cathode Production by Co-deposition

- The cathodes were produced and characterized at the CERN photoemission laboratory, where a dedicated preparation set-up and a 70 keV DC electron gun including a diagnostic beam line are available [4].

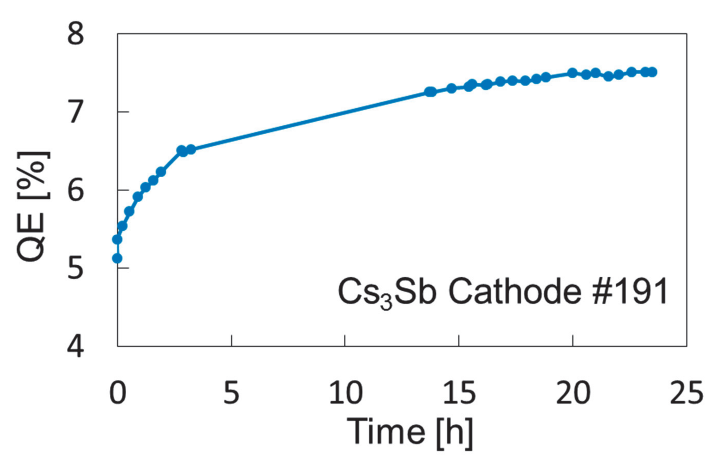
Co-deposition process

- By evaporating Cs and Sb at the same time, the metallic elements can mix together in the vapor phase and deposit as a compound onto the substrate.



- The stoichiometric ratio of the vapor mixture is controlled by two different thickness monitors.
- QE is monitored during the deposition cycle to optimize the process.

QE improvement



- The QE rise during the first hours of electron beam generation in the DC gun.
- This initial QE improvement was observed also for Cs_2Te cathodes [5].

Cs_3Sb cathodes produced by co-deposition

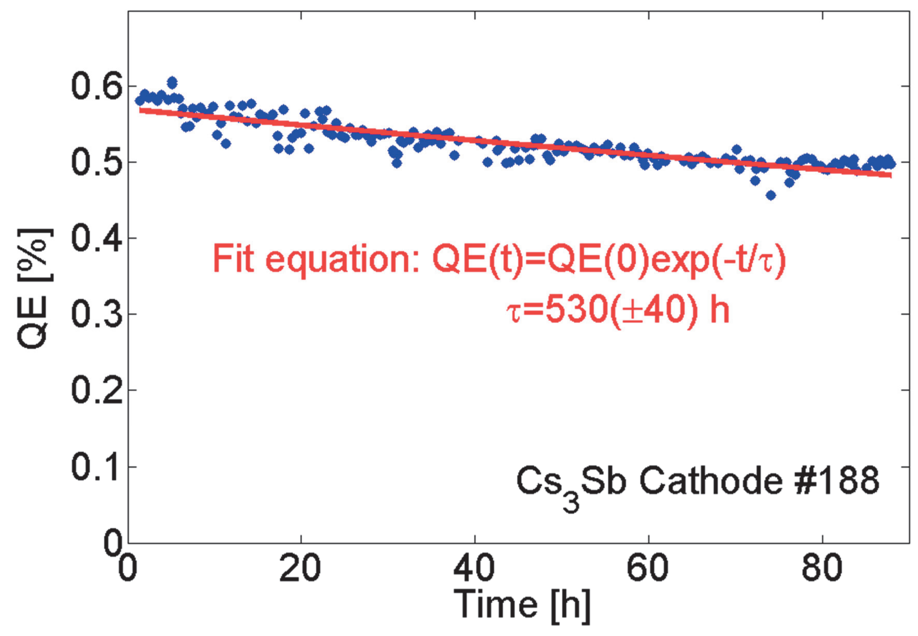
No.	Initial QE (%)	Max QE (%)	Evaporated Cs (nm)*	Evaporated Sb (nm)*	Final stoich. ratio*
178	0.3	0.5	120	18.4	2.9
179	1.4	2.3	156	24.5	1.74
180	0.6	1.0	52	14.4	0.82
187	0.3	0.4	67.6	4.7	4.9
188	1.3	2.2	152	17.8	2.3
189	2.3	4.4	64	15	1
191	5.4	7.5	156	14	1.7
192	2.0	2.7	9.7	3.5	0.66
193	4.2	5.8	10.8	7.6	0.66

- Excellent QE values of up to 7%.
- No obvious correlation between QE and the final stoichiometric ratio or the evaporated quantity.
- More production data is needed for a detailed analysis.

Cathode Lifetime Measurements

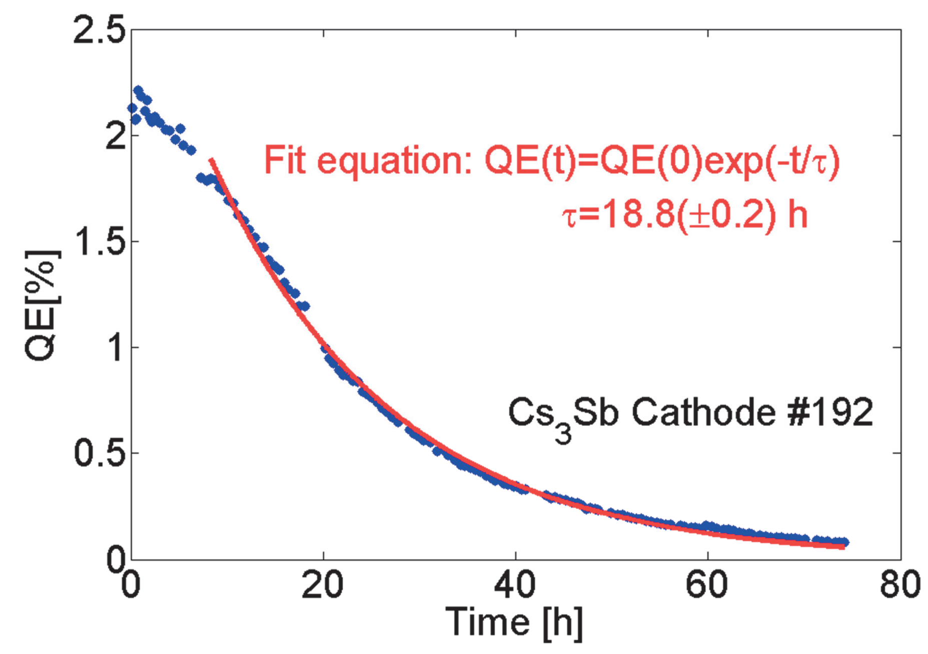
- The lifetime was measured in the DC gun setup at the photoemission laboratory probing them with green laser beam at high repetition rate (up to 2 kHz).

Low average current measurement



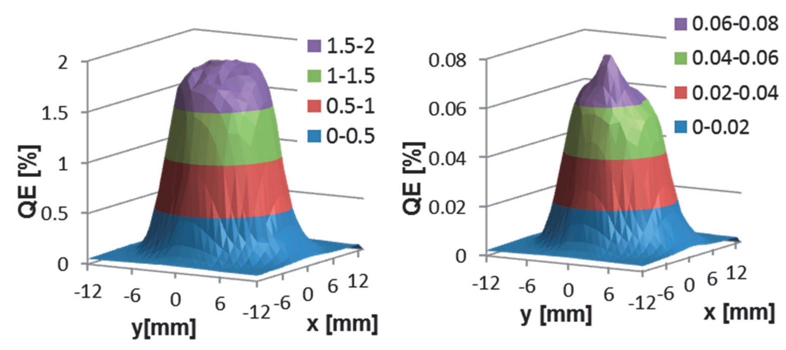
- Cathode #188 (previously used) generated 321 mC over almost 4 days (average current: 1 µA).
- Pressure in the gun below the detection limit ($<10^{-11}$ mbar).
- The 1/e cathode lifetime is 530 hours (3 times higher than the lifetime previously measured at PHIN photoinjector [6]).

High average current measurement



- Cathode #192 generated 33 C over 3 days (average current: 120 µA). The 1/e cathode lifetime is ~19 h.
- Pressure in the gun $< 8*10^{-11}$ mbar.
- The lifetime is lower due to the chemical poisoning of the cathode surface: the higher the beam current the higher the desorption induced by beam losses [7].
- Similar lifetimes at PHIN for pressure $\sim 4* 10^{-9}$ mbar, but lower average beam current. Possible explanation: ion back bombardment (a beam dependant degradation process) which is stronger in DC than RF guns[8].

QE maps of cathode #192



- The initial flat top QE map (left) experienced an overall QE reduction (right). The peak in the center, where the laser hits the cathode, might be due to a laser cleaning process already observed with Cs_2Te cathodes[5].

Conclusions/Outlook

- High quality Cs_3Sb cathodes sensitive to green laser beam were produced by co-deposition.
- Further investigations of the photoemissive layer with XPS analysis are planned .
- The lifetime measurements at low average beam current have shown very promising results. The quick degradation for Cathode #192 under high average beam current might be related to its thin photoemissive layer and studies of cathodes with thicker layers will be considered.
- The recently produced cathodes will be tested in the PHIN RF photoinjector with beam parameters beyond the nominal PHIN values .

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[2] M. Csatari et al., Nucl. Instr, And Meth. A 659 (2011) p.1.
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[6] C. Hessler et al., to be published.
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[8] R.P. Fliller III et al., Proc. PAC'05, Knoxville (2005).

LA³NET is funded by the European Commission under Grant Agreement Number GA-ITN-2011-289191