Studies of Cs₃Sb Cathodes for the CLIC Drive Beam Photoinjector Option

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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 ultraviolet (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: Cs₃Sb photocathodes sensitive to green light.

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].
- 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 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.

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).
- 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.
- Similar lifetimes at PHIN for pressure ~4* 10⁻⁹ 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].
- The 1/e cathode lifetime is 530 hours (3 times higher than the lifetime previously measured at PHIN photoinjector [6]).

CLIC and PHIN design parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CLIC</th>
<th>PHIN</th>
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</thead>
<tbody>
<tr>
<td>Charge/bunch (nC)</td>
<td>8.4</td>
<td>2.3 (nominal)</td>
</tr>
<tr>
<td>Bunch length (ps)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Bunch rep. rate (Giga)</td>
<td>0.5</td>
<td>1.5</td>
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<tr>
<td>Number of bunches</td>
<td>70000</td>
<td>1800</td>
</tr>
<tr>
<td>Train length (μs)</td>
<td>140</td>
<td>1.2</td>
</tr>
<tr>
<td>Charge/train (μC)</td>
<td>590</td>
<td>4.1</td>
</tr>
<tr>
<td>Macro pulse rep. rate (Hz)</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>Charge stability (%)</td>
<td>&lt;0.1</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>Beam current/train (A)</td>
<td>4.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Cathode lifetime (h)</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>QE&gt;0.5% (Cs3Sb, green laser)</td>
<td>Cathode lifetime is 530 hours (3 times higher than the lifetime previously measured at PHIN photoinjector [6]).</td>
<td></td>
</tr>
</tbody>
</table>

Cathode Lifetime Measurements

- Cathode production by co-deposition
- The cathode lifetime is ~19 h.
- Pressure in the gun < 8*10⁻¹¹ mbar.
- Similar lifetimes at PHIN for pressure ~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 gun [8].
- The 1/e cathode lifetime is 530 hours (3 times higher than the lifetime previously measured at PHIN photoinjector [6]).

Cathode Lifetime Measurements

- 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 Cs₂Te cathodes [5].
- QE maps of cathode #192

Conclusions/Outlook

- High quality Cs₃Sb 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.

References: