GaAs Photocathode Activities at Daresbury Laboratory

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GaAs photocathodes

- High QE over the entire spectrum of visible light once it is activated to the negative electron affinity (NEA) state.

Some issues
- Lifetime
- Response time

$E_{\text{VAC}}$ $E_{\text{CBM}}$ $E_{\text{g}}$ $E_{\text{F}}$ $E_{\text{VB}}$ Vacuum

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ALICE Gun

- Current ALICE cathode:
  - VGF Bulk GaAs cathode, Zn doped, 31 mm diameter and 625 μm thick
  - Consistently achieving 3% QE @ 532 nm
- No cathode change possible.
Photocathode preparation facility (PPF)

- Provide a rapid and reliable way to exchange the photocathode.
- Prepare the photocathodes in a controllable and reproducible way.
- Remove the activation process from the gun.
Photocathode preparation facility (PPF)
Photocathodes

- New epitaxial grown GaAs cathodes – 10 mm diameter:
  - Reflection mode (RM) bound to molybdenum substrate
  - Transmission mode (TM) bound to glass or sapphire substrate
- Different thickness’ of active layer to enable a fast measurement of time response.
Cathode preparation

- Chemically cleaned with HCl/IPA solution in N\textsubscript{2} purged glove box.
- Transported to the loading chamber without exposure to the air.
- Heat cleaned and activated in the preparation chamber.
- Degraded photocathodes are heat cleaned and re-activated.
- When it is not possible to fully recover the QE, it is cleaned by atomic hydrogen cleaning.
Achieved QE and lifetime

- Consistently achieving 14 - 19% QE.
- Lifetime in the order of 1000 hours.

A typical activation curve with \( \text{O}_2 \)

\[ \frac{1}{e} \text{ lifetime} = \frac{1}{0.001} \text{ hrs} = 1000 \text{ hrs} \]

\[ \text{QE} = e^{-t/688.81} \]

\[ R^2 = 0.95 \]

Dark lifetime in the preparation chamber (9 \( \text{10}^{-12} \) mbar)
Cathode preparation

- QE vs the number of activations with O\textsubscript{2} and NF\textsubscript{3}

- Repeated heat cycles and activations with O\textsubscript{2} lead to a degradation in achieved QE. Cathode needs to be removed for chemical cleaning in order to achieve high QE again.

- NF\textsubscript{3} provides a more stable QE after repeated activations.
Gas exposures after activation with \( \text{O}_2 \) and \( \text{NF}_3 \)

- \( \text{O}_2 \) activation
- Compared with \( \text{NF}_3 \) activation
Future work - Cold cathode energy distribution measurements

- Future experiments are to use existing systems to measure the 3D energy distribution of a low energy (10-20V) electron beam. The GaAs cathode will be at liquid nitrogen temperatures.

- Use existing PPF for cathode preparation.
Future work - Cold cathode energy distribution measurements

- Energy distribution measured as a function of QE decay.
Future work - 160 KV photoinjector for time response and emittance measurements (cold cathode)

- Experiment will make use of GaAs cathodes with different thicknesses of active layer for time response measurements.

  - Diagnostic line will be used for emittance measurements.

  - The aim is to measure both parameters as a function of QE decay at LN₂ temperatures.
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