**H-Beam Cleaning of Metal Cathodes**

David H. Dowell
SLAC & LCLS

Introduction
Cleaning and Measurement of Metal Cathodes
Extraction of Work Functions
Comparison with Theory
Implementation into cathode processing and on gun
H-Beam Cleaning

H-Ion Beam Gun

Reacted contaminants $H_4C$, etc.

Cu sample

Ion + Contaminant Current

Current meter

QE vs. Wavelength Measurement

Broadband UV Lamp + Monochromator

Photons

Photoelectrons

Battery

Photocurrent

Cu sample
QE vs. Wavelength with Increased Exposed to H-Beam

- **Initial**
- 0.63 mC
- 2.07 mC
- 3.03 mC
- 10.23 mC

Wavelength (nm)

- 180
- 200
- 220
- 240
- 260
- 280
- 300
Fowler Plots with increasing H-ion Exposure

\[ \ln \left( \frac{QE}{T^2} \right) = B + \ln \left( f \left( \frac{\hbar \omega - \phi}{kT} \right) \right) \]

\[ f(x) = e^x - \frac{e^{2x}}{4} + \frac{e^{3x}}{9} - \ldots \quad \text{for } x \leq 0 \]

\[ f(x) = \frac{\pi^2}{6} + \frac{x^2}{2} - \left( e^x - \frac{e^{2x}}{4} + \frac{e^{3x}}{9} - \ldots \right) \quad \text{for } x \geq 0 \]
Work function vs. exposure to H-beam

Theoretical Work Function:
3.9 eV: Hodges & Scott, Phys. Rev B7,73(1972)

For a truly clean surface, the measured work function is in reasonable agreement with theory (~10-15% higher than theory)
Photoemission from a simple metal

Quantum Efficiency

\[ QE = (1 - R) \frac{\int_{E_{\text{vac}}}^{E_{\text{ferm}}} dE \int_{0}^{1} d(\cos \theta) \int_{0}^{2\pi} d\phi \ DOS_{F-D}(E_{\text{ferm}}, E)}{\int_{0}^{2\pi} E_{\text{vac}} \int_{0}^{2\pi} d(\cos \theta) \int_{0}^{2\pi} d\phi \ DOS_{F-D}(E_{\text{ferm}}, E)} \]

\[ \cos \theta_{\text{max}} = \frac{E_{\text{ferm}} + \phi_{\text{work}} - \phi_{\text{schottky}}}{E + \hbar \omega} \]

Mean-Square Transverse Momentum

\[ \langle p_{\perp}^2 \rangle = \frac{\int_{E_{\text{vac}}}^{E_{\text{ferm}}} dE \int_{0}^{1} f(\theta) d(\cos \theta) \int_{0}^{2\pi} d\phi \ DOS_{F-D}(E_{\text{ferm}}, E)}{\int_{0}^{E_{\text{vac}}} dE \int_{0}^{1} d(\cos \theta) \int_{0}^{2\pi} d\phi \ DOS_{F-D}(E_{\text{ferm}}, E)} \]

\[ p_{\parallel} = p_{\text{tot}} \cos \theta \]

- QE dependents upon the reflectivity, the density of states and kinematical filtration

- Discrepancies between this simple model and observations for both QE and “thermal” emittance allow improved understanding of the emission process
Comparison of Measured and Computed QE vs, Wavelength

- **Theory, 0V/m**
- **Expt, 0V/m**
- **Theory, 50MV/m**
Possible Implementation on S-band Gun
Cathode Cleaners

**H-Ion Cleaning**
(potentially useful for quick in-situ cleaning)

- **H-Ion Beam Gun**
- Reacted contaminants: $\text{H}_2\text{C}$, etc.
- **Cu sample**
- Current meter
- Ion + Contaminant Current

+ XPS (contamination) and AFM (roughness) characterization of the surface

**H-Plasma Cleaning**
(potentially useful for cleaning entire surface area of cathode before installation)

- **Cleaner electrode**
- Plasma arc in H-gas
- **Cu sample**
- **HV Power Supply**
RF Plasma Cleaning of Gun & Cathode

- Osc
- Klystron or CW RF amplifier
- RF power, ~500 watts
- H-gas outlet
- Flowing H-gas
- H-gas pressure ~mTorr
Summary and Conclusions

H-beam and Plasma Cleaning is a promising technique for producing atomically clean surfaces

Excellent comparison with theory

Plans for implementing on the RF gun is in progress
  Cathode processing before installation
  In-situ processing