# *H-Beam Cleaning of Metal Cathodes*

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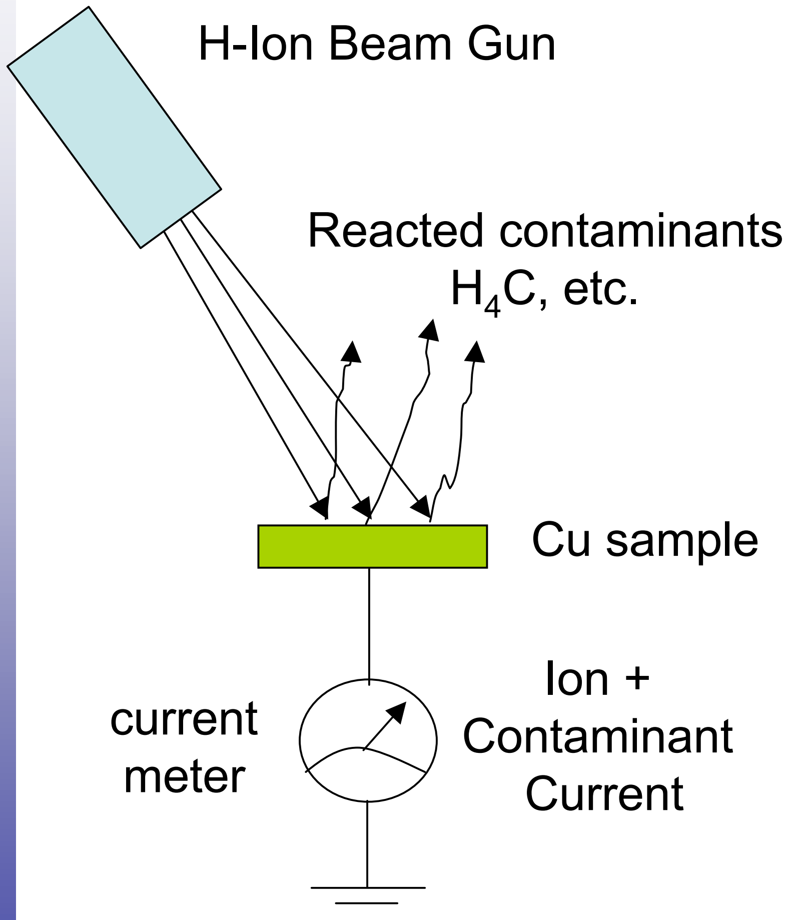
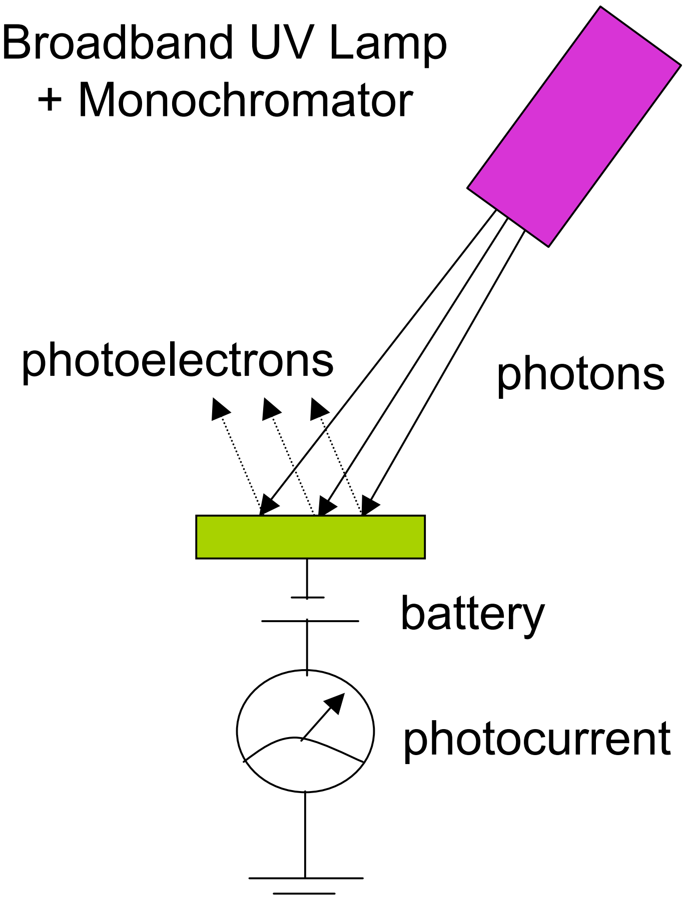
**Introduction**
**Cleaning and Measurement of Metal Cathodes**
**Extraction of Work Functions**
**Comparison with Theory**
**Implementation into cathode processing and on gun**

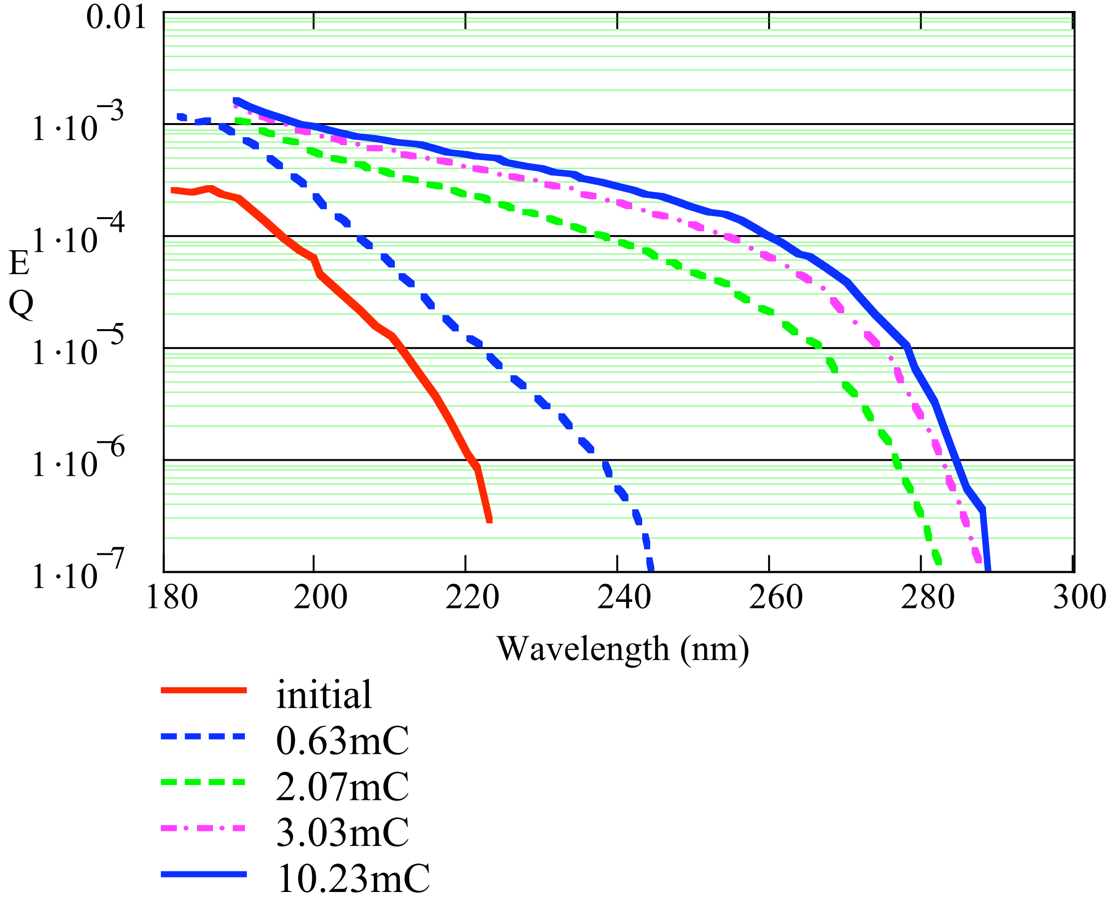
## H-Beam Cleaning




## QE vs. Wavelength Measurement



# QE vs. Wavelength with Increased Exposed to H-Beam

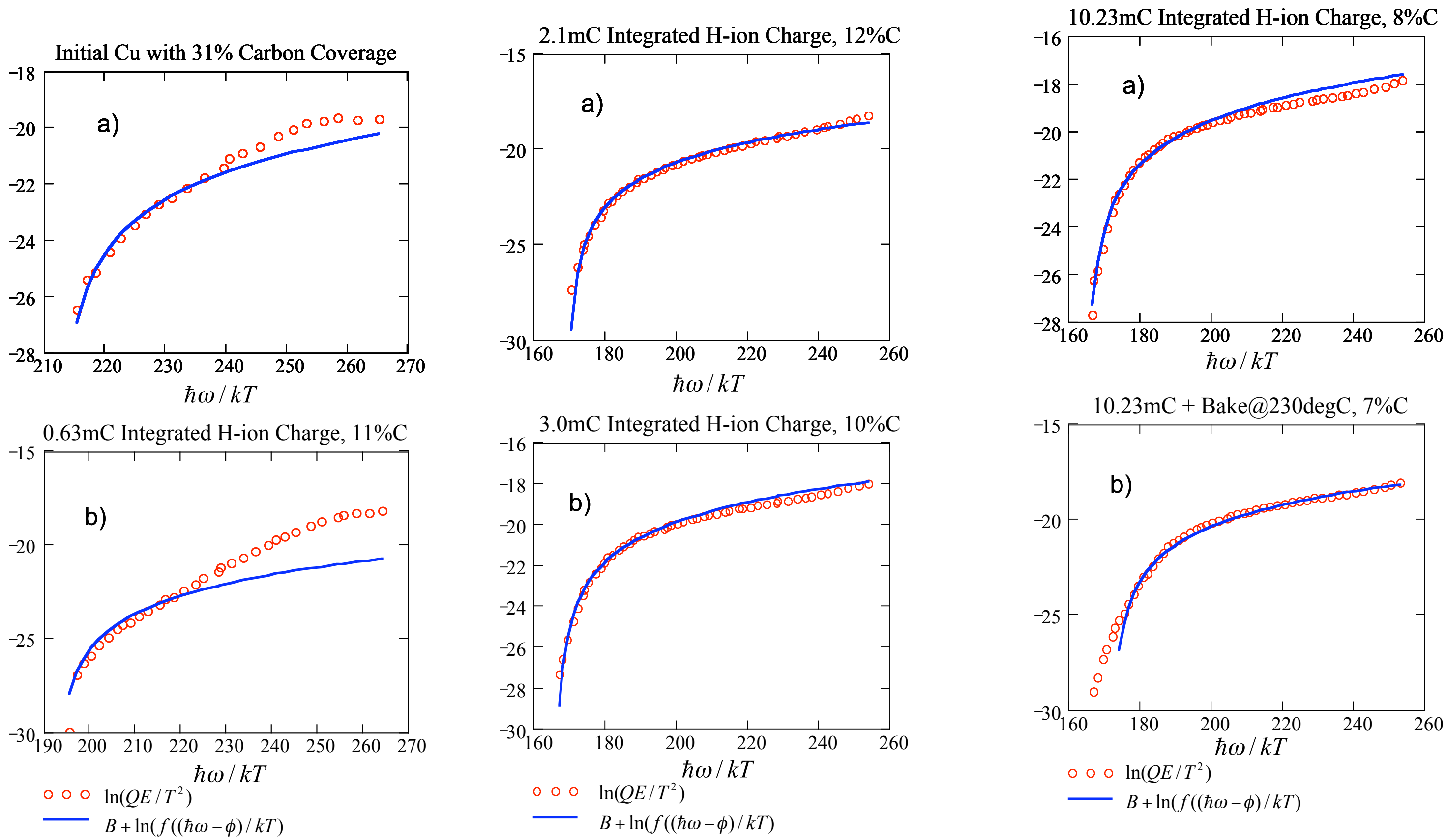


# Fowler Plots with increasing H-ion Exposure

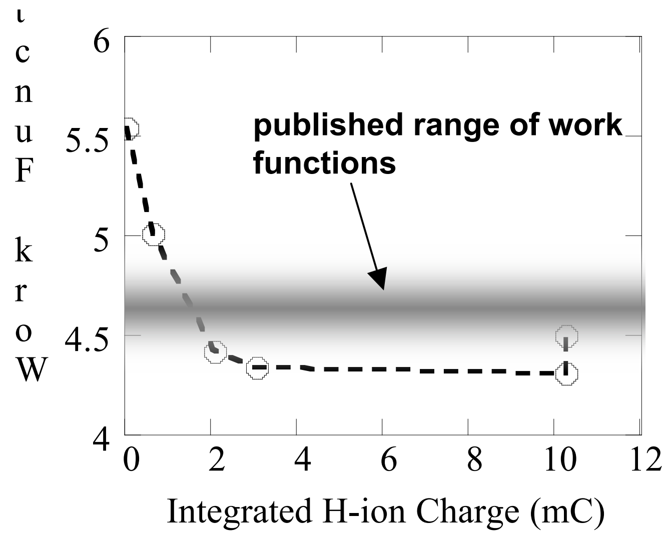
$$\ln\left(\frac{QE}{T^2}\right) = B + \ln\left(f\left(\frac{\hbar\omega - \phi}{kT}\right)\right)$$

$$f(x) = e^x - \frac{e^{2x}}{4} + \frac{e^{3x}}{9} - \dots \quad \text{for } x \le 0$$

$$f(x) = \frac{\pi^2}{6} + \frac{x^2}{2} - \left(e^{-x} - \frac{e^{-2x}}{4} + \frac{e^{-3x}}{9} - \dots\right) \quad \text{for } x \ge 0$$



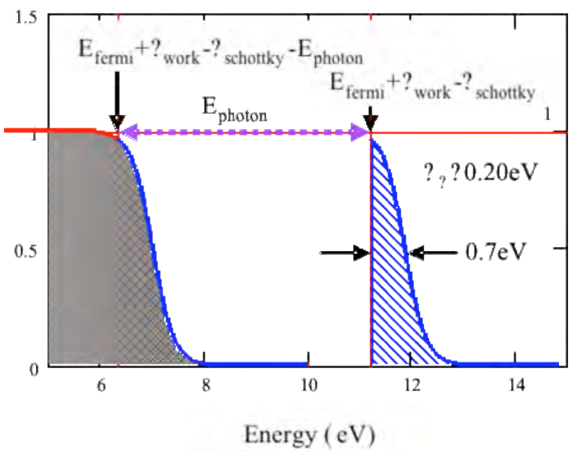
# Work function vs. exposure to H-beam




**Theoretical Work Function:**
**3.9 eV: Hodges & Scott, Phys. Rev B7,73(1972)**
**4.1 eV: Lang & Kohn, Phys. Rev. B1,4555 (1970)**

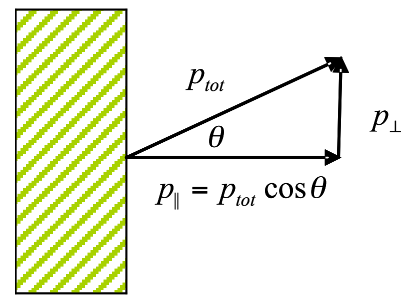
**For a truly clean surface, the measured work function is in reasonable agreement with theory (~10-15% higher than theory)**

# Photoemission from a simple metal




$$\frac{p_{\parallel}^2}{2m} > E_{fermi} + \phi_{work} - \phi_{schottky}$$

$$\cos\theta_{\max} = \sqrt{\frac{E_{fermi} + \phi_{work} - \phi_{schottky}}{E + \hbar\omega}}$$




## Quantum Efficiency

$$QE = (1-R)\frac{\int\limits_{E_{fermi}+\phi_{work}-\phi_{schottky}-\hbar\omega}^{E_{vac}} dE \int\limits_{\cos\theta_{\max}(E)}^{1} d(\cos\theta) \int\limits_{0}^{2\pi} d\phi \;\; DOS_{F-D}(E_{fermi}, E)}{\int\limits_{0}^{E_{vac}} dE \int\limits_{0}^{1} d(\cos\theta) \int\limits_{0}^{2\pi} d\phi \;\; DOS_{F-D}(E_{fermi}, E)}$$

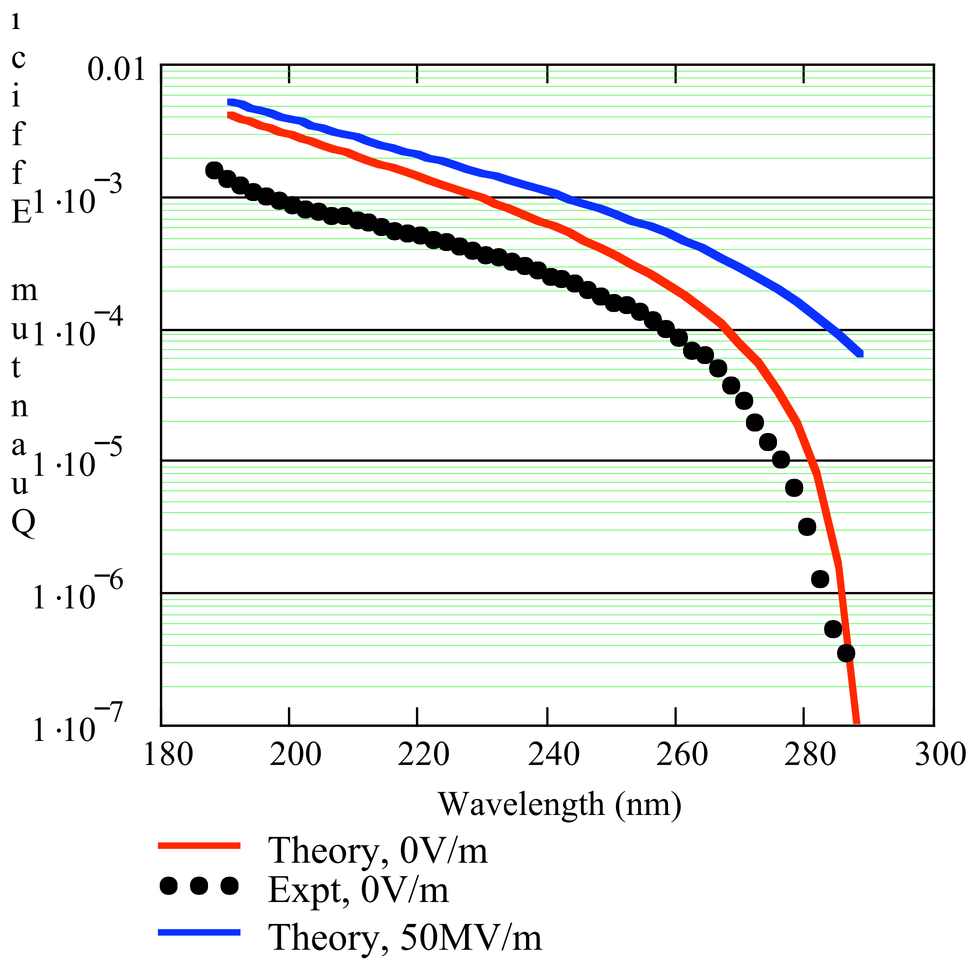
## Mean-Square Transverse Momentum

$$\left\langle p_{\perp}^2 \right\rangle = \frac{\int\limits_{E_{fermi}+\phi_{work}-\phi_{schottky}-\hbar\omega}^{E_{vac}} dE \int\limits_{\cos\theta_{\max}}^{1} f(\theta) d(\cos\theta) \int\limits_{0}^{2\pi} d\phi \;\; p_{\perp}^2 DOS_{F-D}}{\int\limits_{E_{fermi}+\phi_{work}-\phi_{schottky}-\hbar\omega}^{E_{vac}} dE \int\limits_{\cos\theta_{\max}}^{1} d(\cos\theta) \int\limits_{0}^{2\pi} d\phi \;\; DOS_{F-D}}$$

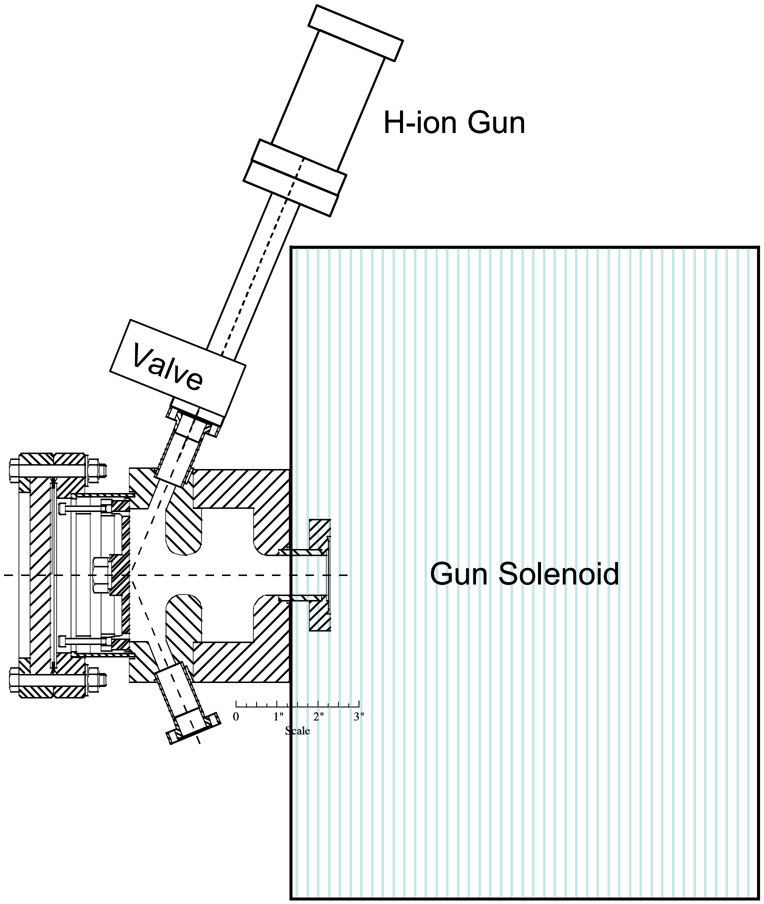
- QE dependents upon the reflectivity, the density of states and kinematical filtration

- 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



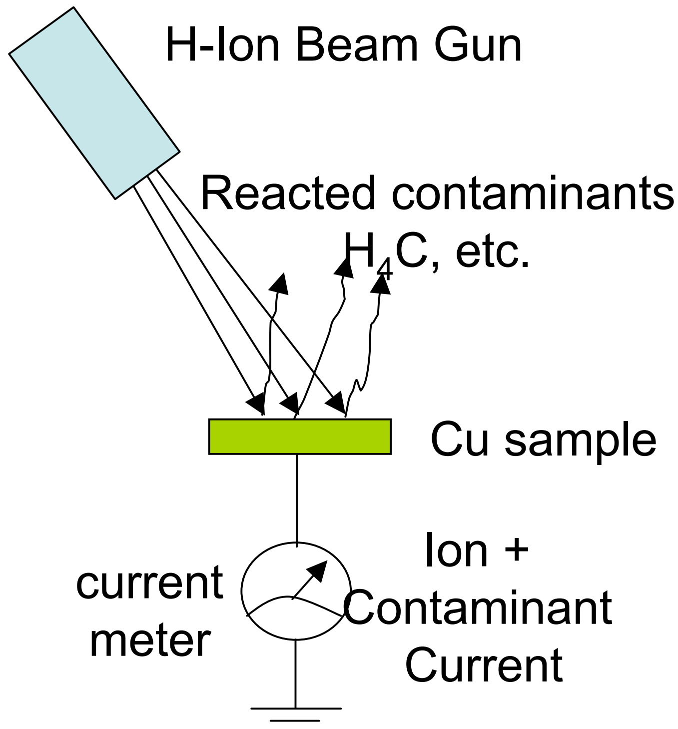
# Possible Implementation on S-band Gun



# Cathode Cleaners

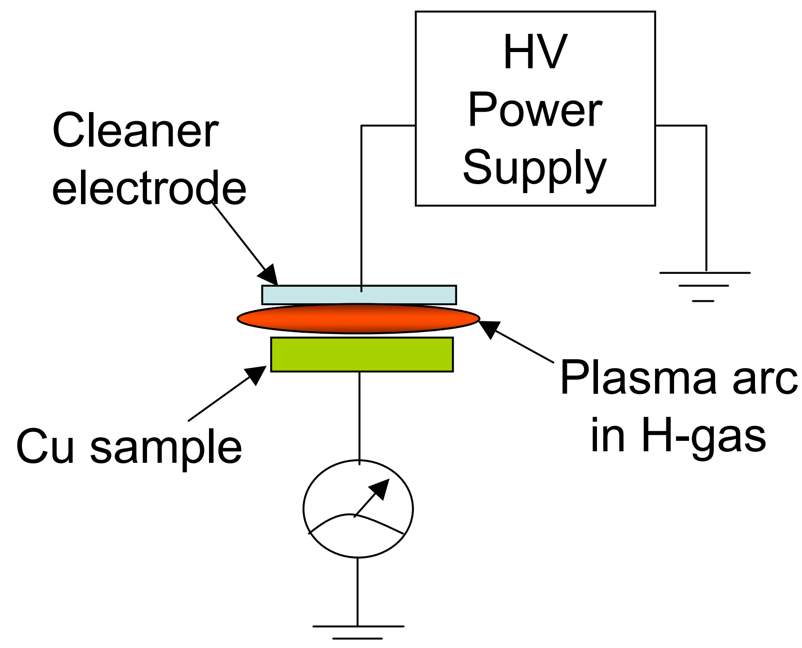
## H-Ion Cleaning

(potentially useful for quick in-situ cleaning)



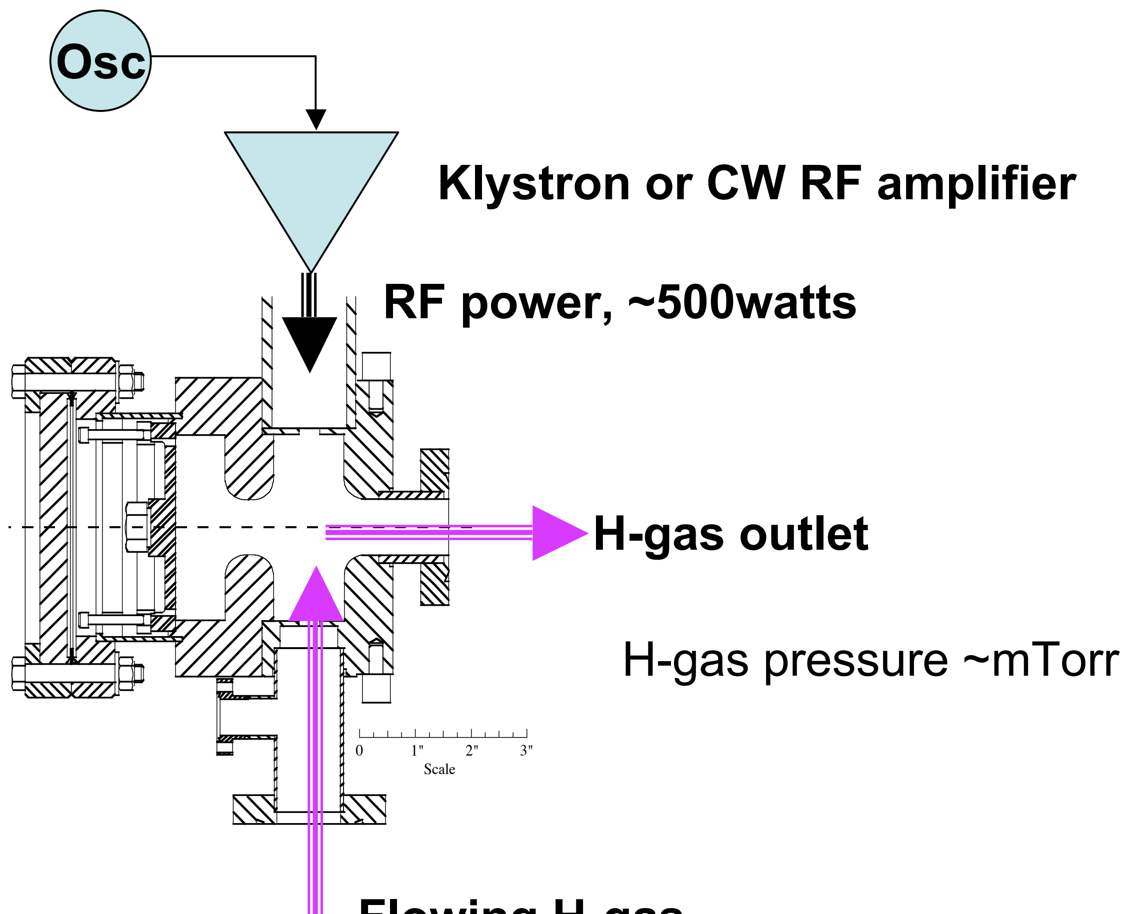

## H-Plasma Cleaning

(potentially useful for cleaning entire surface area of cathode before installation)




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

# *RF Plasma Cleaning of Gun & Cathode*



## *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**