Polarized Electron Source: Gatling Gun

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December 15, 2016

Outline

- Photocathodes
  - Quantum Efficiency
  - Gallium Arsenide
- Gatling Gun

Motivation

* New accelerator-collider technologies are needed to advance our understanding of the subatomic world

* eRHIC requires 50mA of 70% polarized current

  * Current technology only allows for 4mA to be extracted over 5.5 hours.

Photocathodes: Work Function

* Photocathodes will emit electrons if the energy of the incident photon is greater than the work function of that material via the photoelectric effect

Cathode Material	Work Function (eV)
Magnesium	3.6
Lead	4.0
Niobium	4.38
Copper	4.6
CsBr:Cu (Coated)	2.5
GaAs	4.69

Photocathodes

* Quantum Efficiency (QE):Defined as the ratio of electron emission vs. incident photons
* Types:
  * Metallic: very durable but have low QE even for high intensity lasers
  * Semiconductor: Have high QE even for low intensity laser but are extremely fragile.

Photocathodes: QE vs. Lifetime

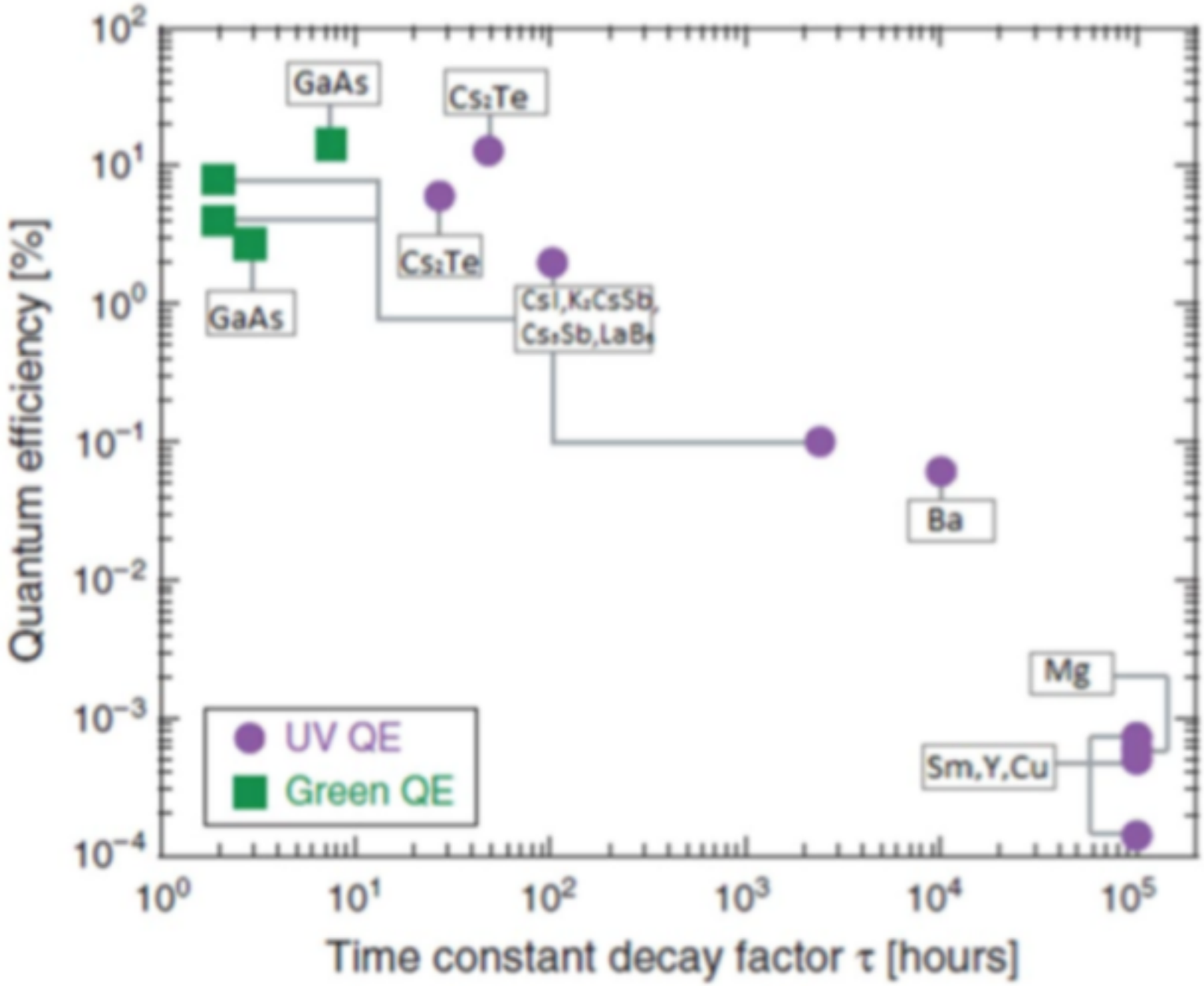
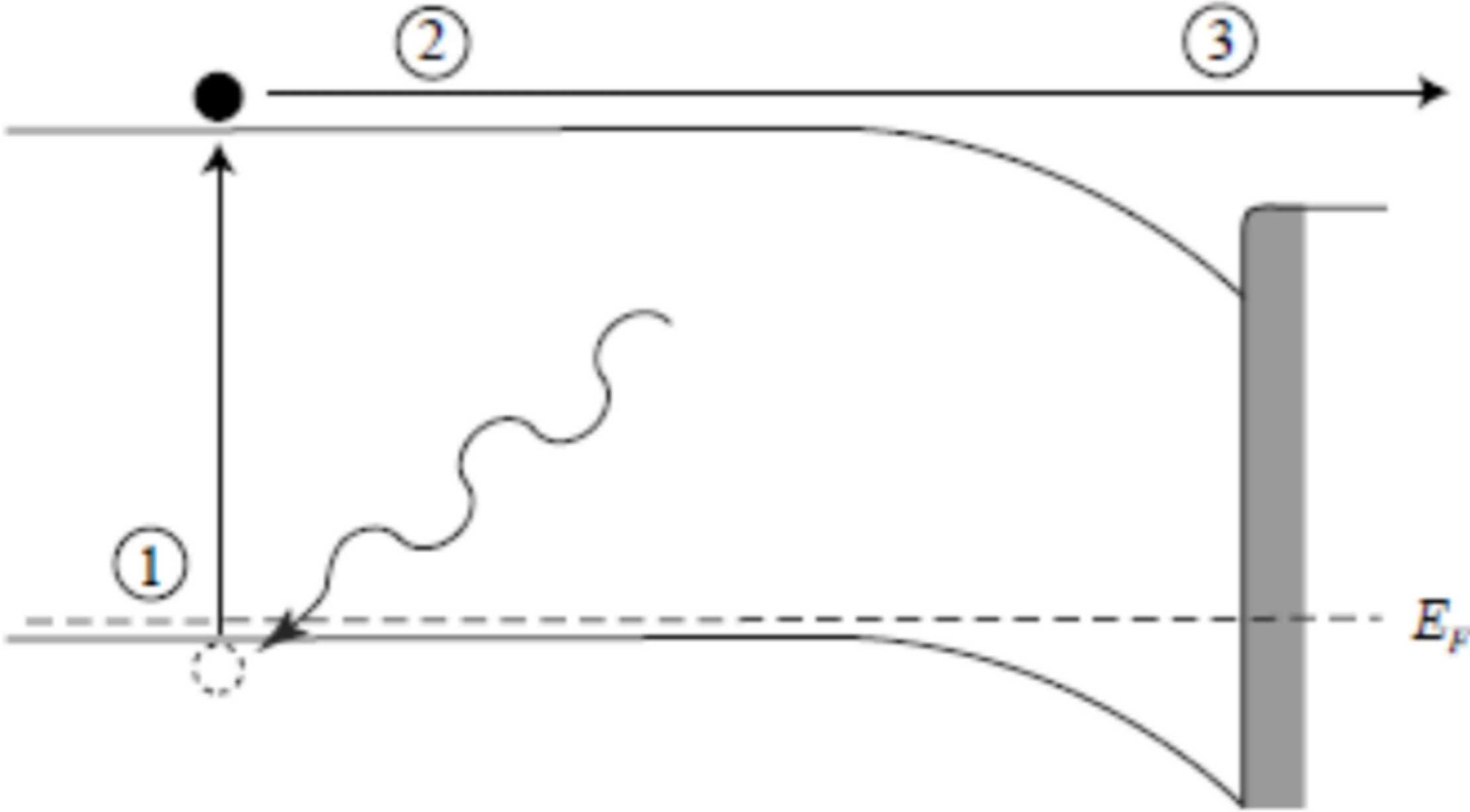


Image credit: Wikipedia

Photocathodes: Spicer's Theory

* Photo excitation: electrons are stimulated by incoming photons and will move from the valence level to the conduction band
* Transport to surface
  * electron-electron scattering—metallic photocathodes
  * electron-lattice scattering—semiconductor photocathodes
* Escape to vacuum—Negative Electron Affinity

Spicer's Theory



Photocathodes: Gallium Arsenide

* Commonly used in modern accelerator applications
* III-V family semiconductor with a direct band gap
* Benefits
    * Can create polarized electrons
    * Fast response time
    * Long photon absorption length
    * Long electron diffusion length
* Lifetime is severely limited by
    * Vacuum-requires 10^{-12} torr
    * Field Emissions- From high electrostatic fields causes desorption of gas
    * Ion back-bombardment-Current ionizes residual gas in the chamber; resulting ions hit photocathodes

Field Emissions

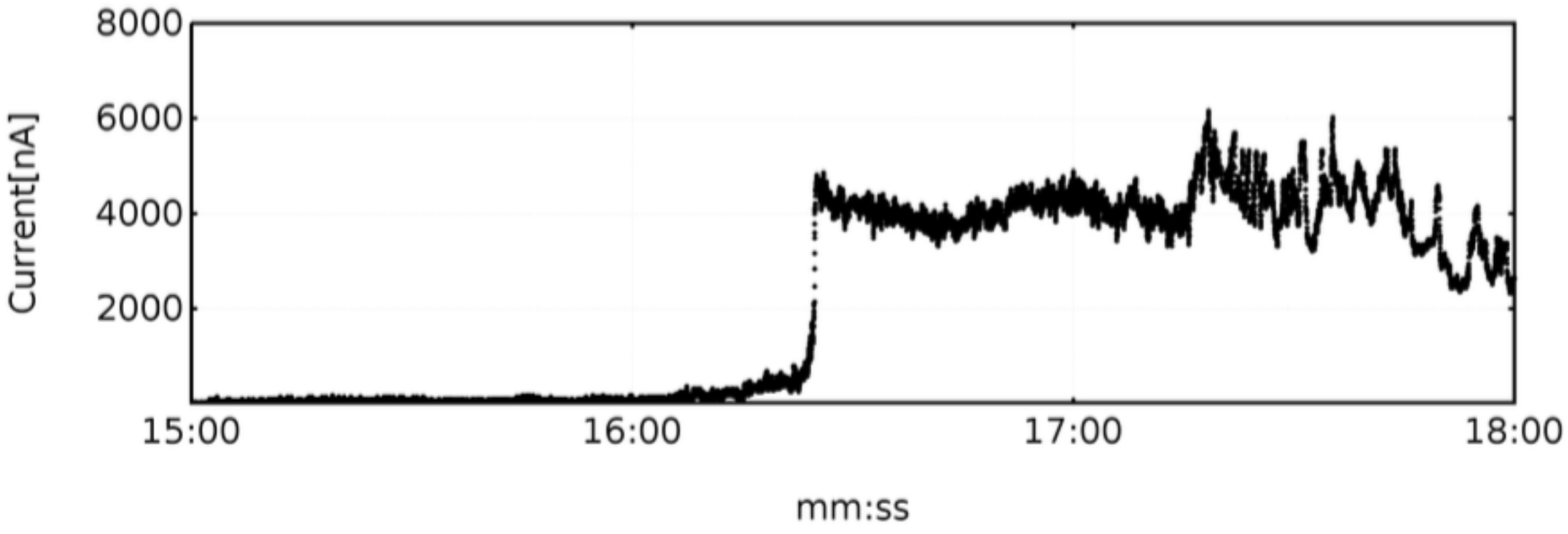


Image Credit: O. Rahman

Ion Back Bombardment

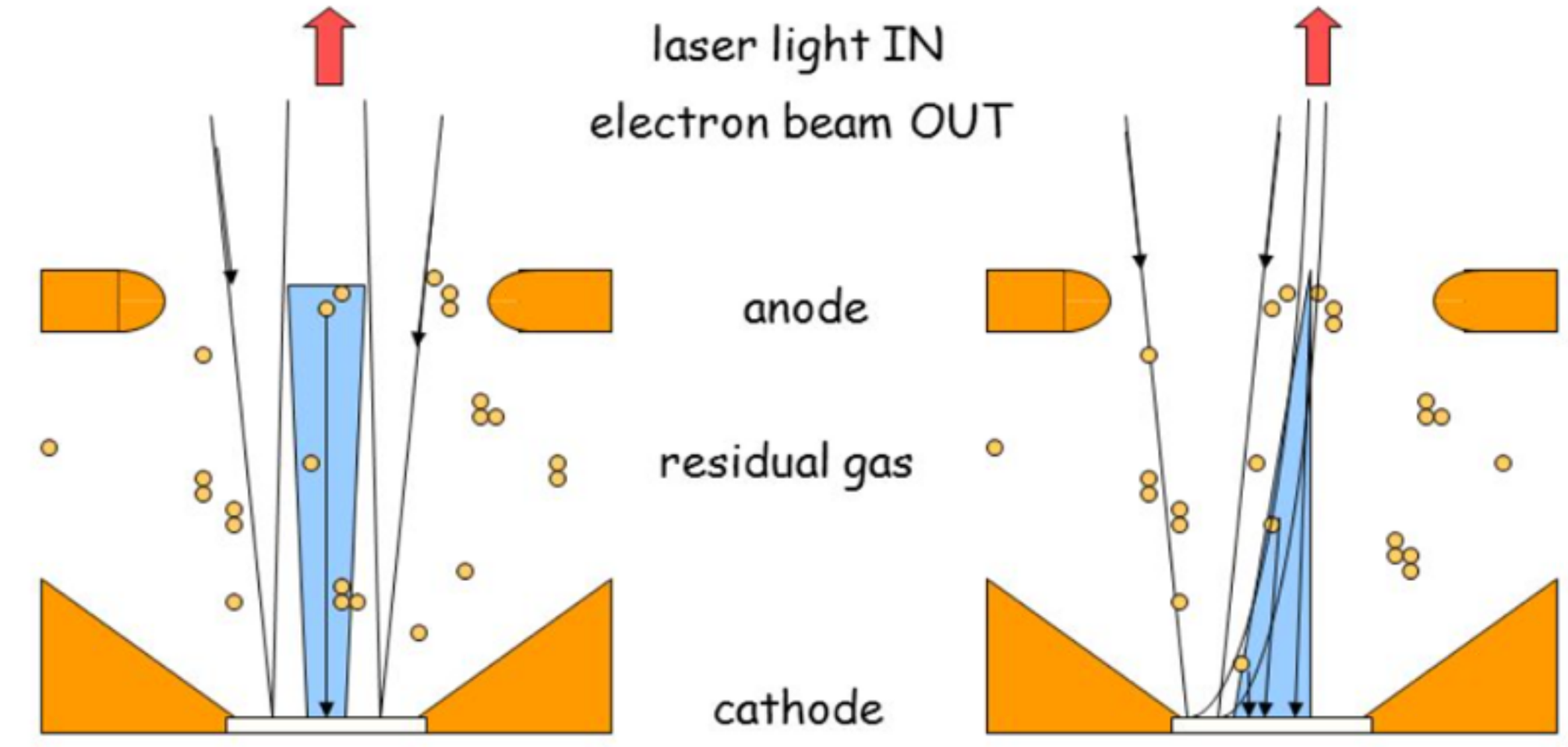
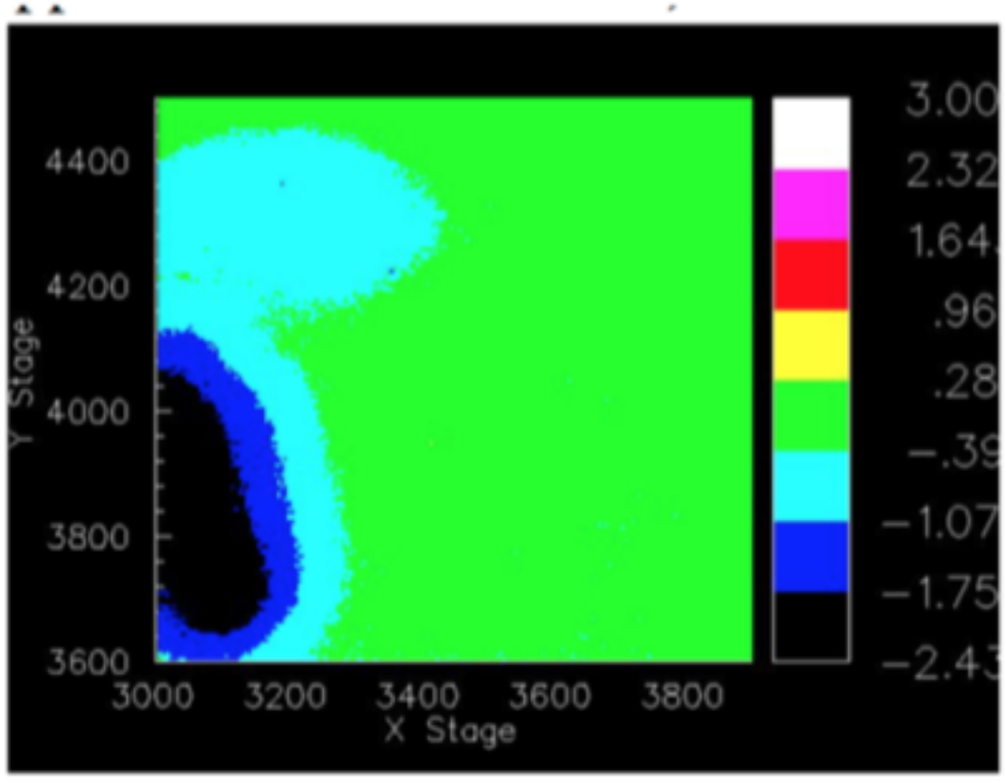


Image Credit: J. Lab

Ion Back Bombardment



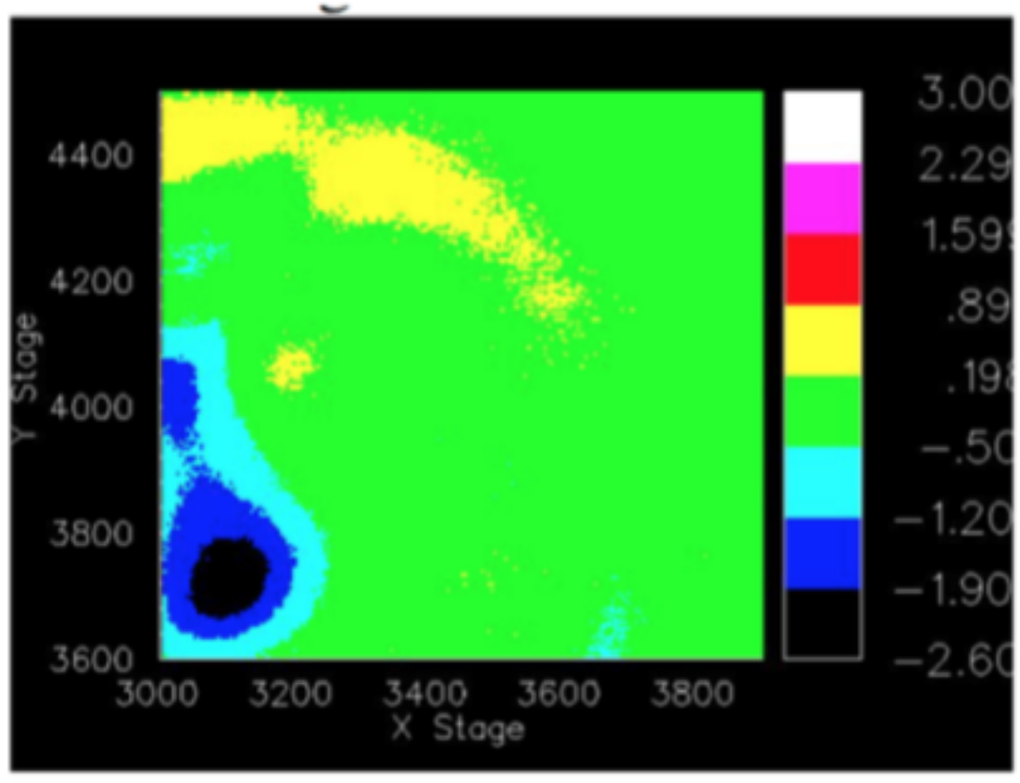


Image Credit: J. Lab

GaAs:
Polarization of Electrons

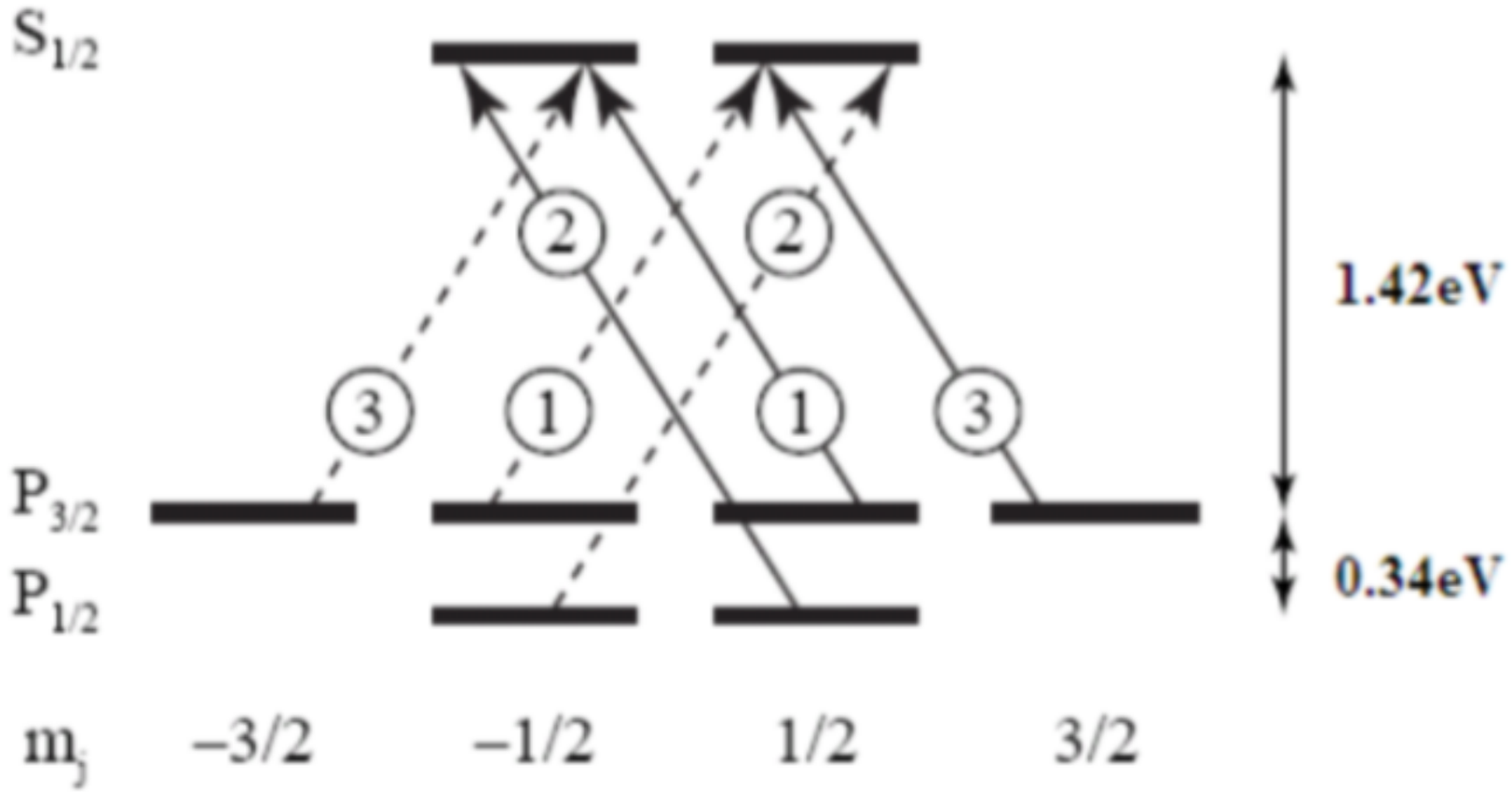


Image Credit: E.Wang

Negative Electron Affinity

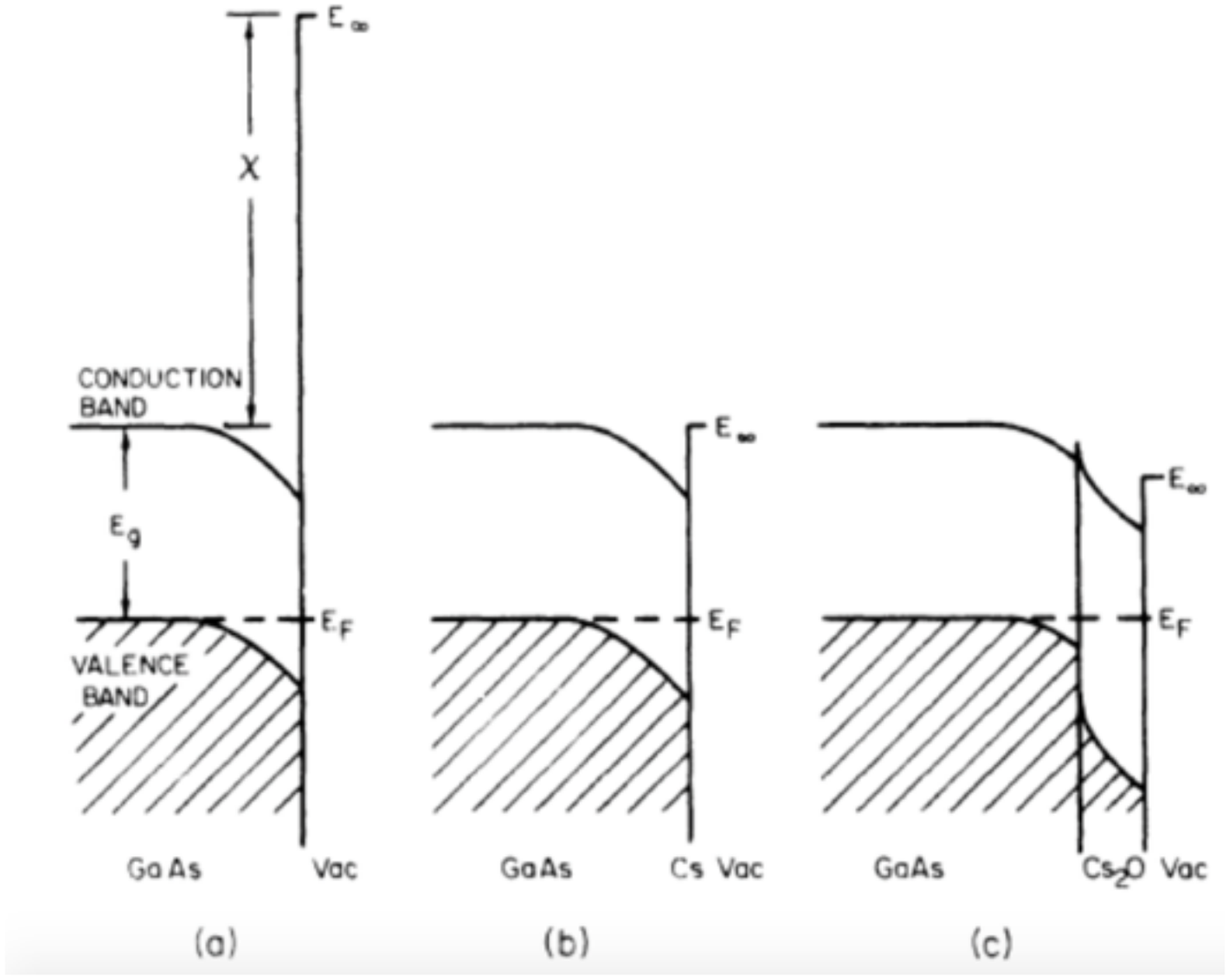


Image Credit:
USPAS

GaAs Activation

- Photocathodes are activated in a chamber separate from the gun itself
- Heat Cleaning
- Cs-O deposition
  - Yo-yo
  - Co-deposition

Activation: Heat Cleaning

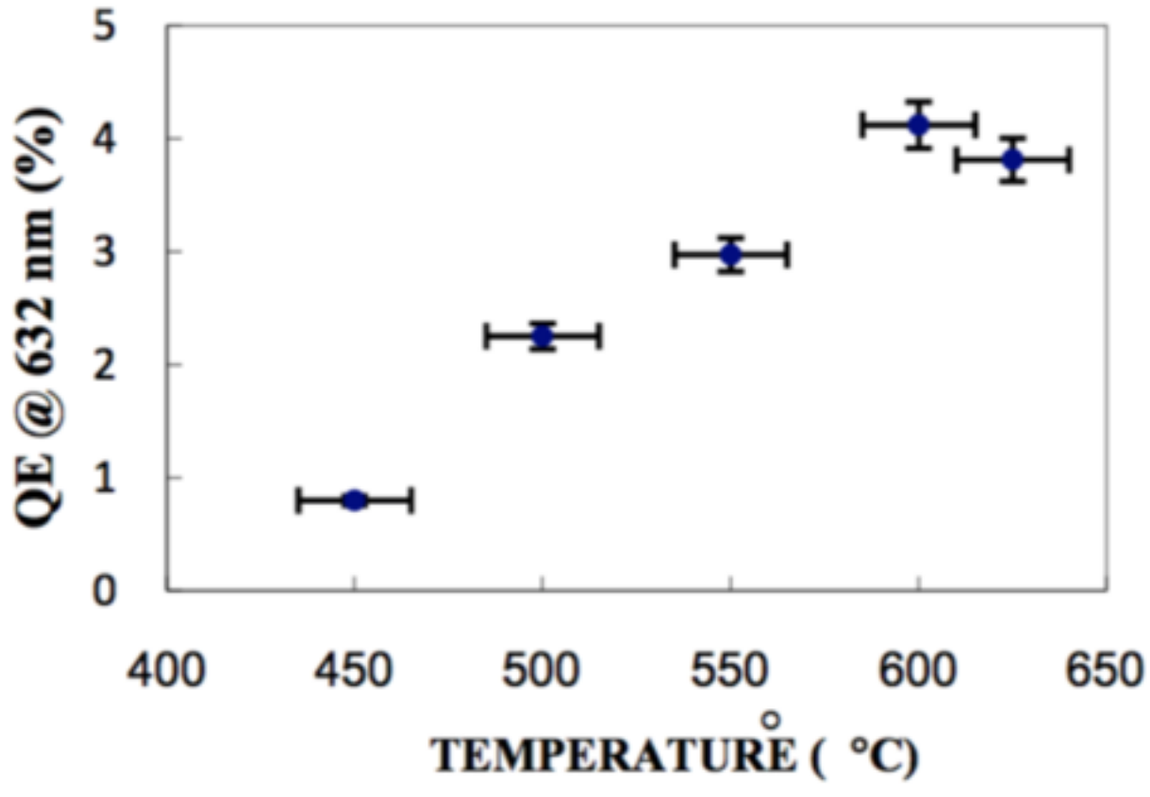


Image Credit: N. Chanlek

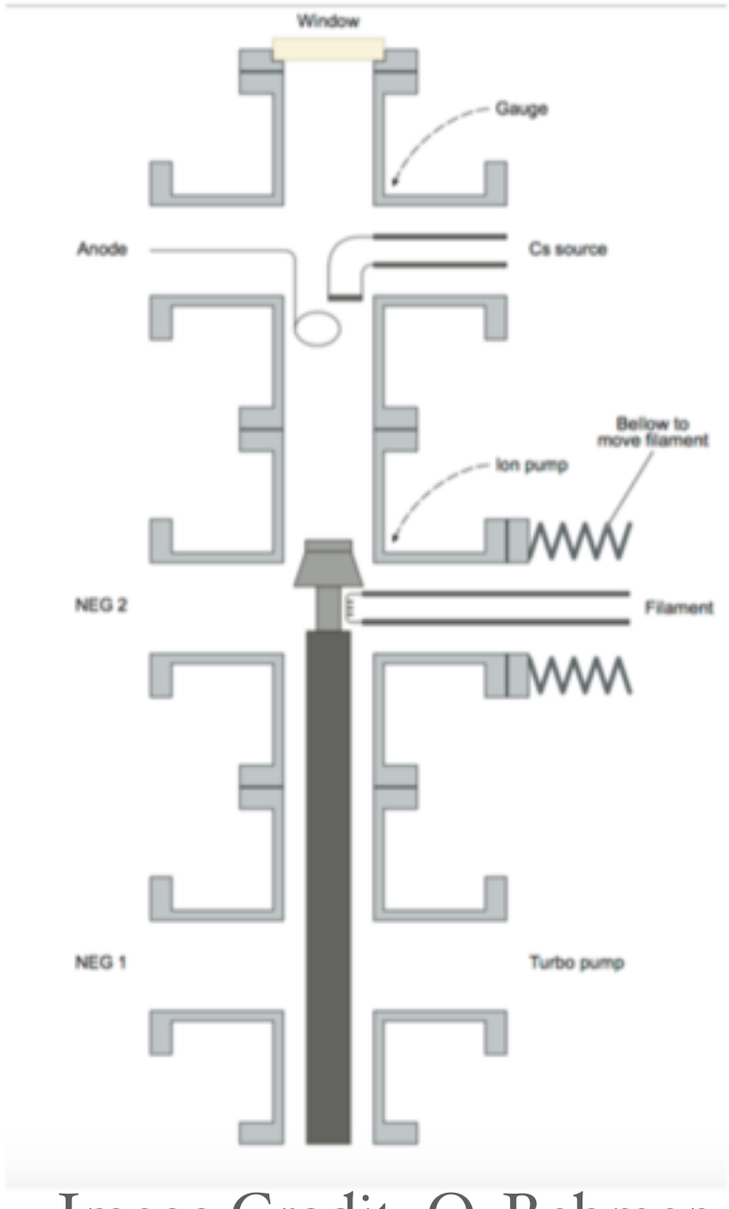
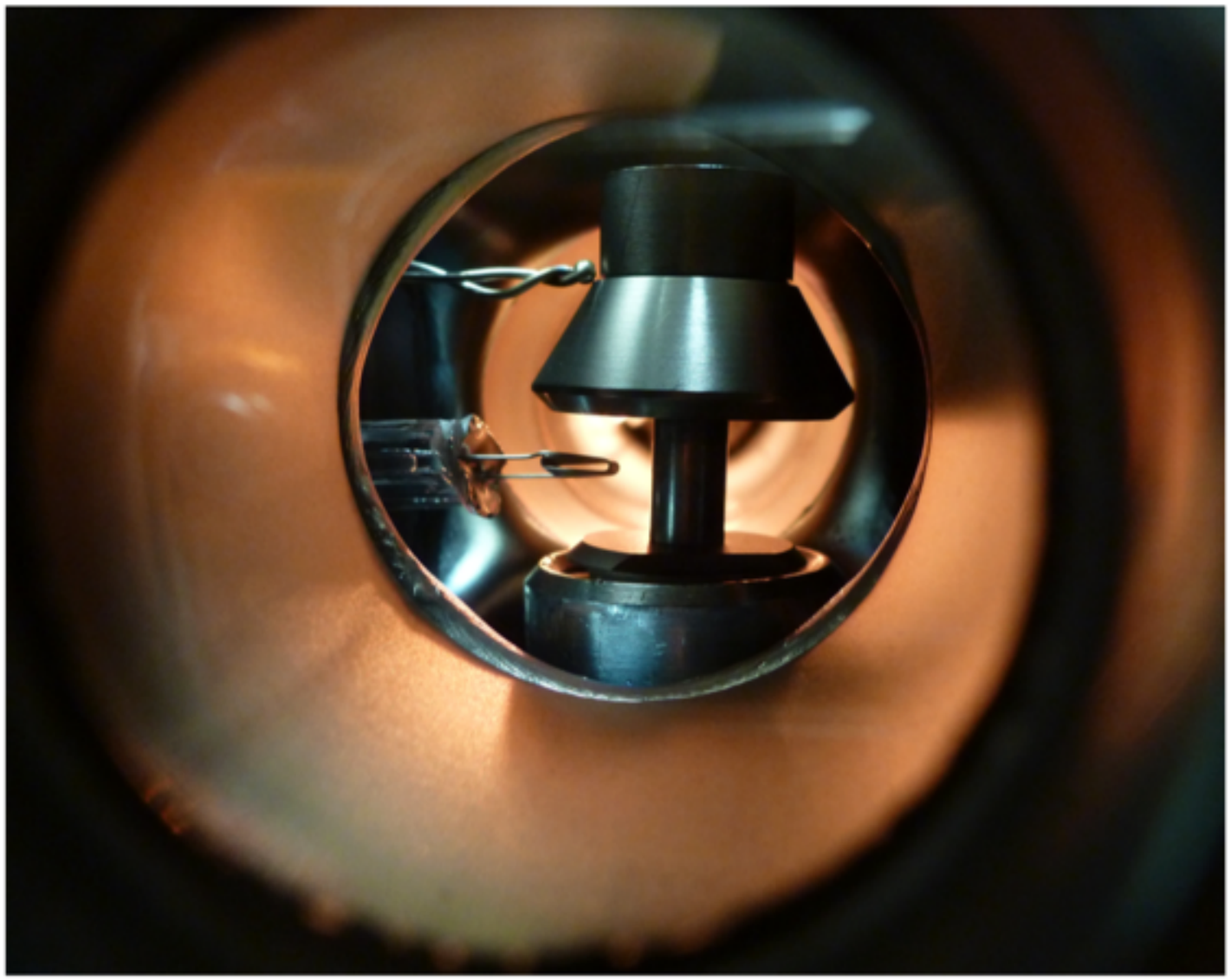


Image Credit: O. Rahman

Heat Cleaning



Activation: Yo-yo Method

* Alternates inputs of Cs and Oxygen

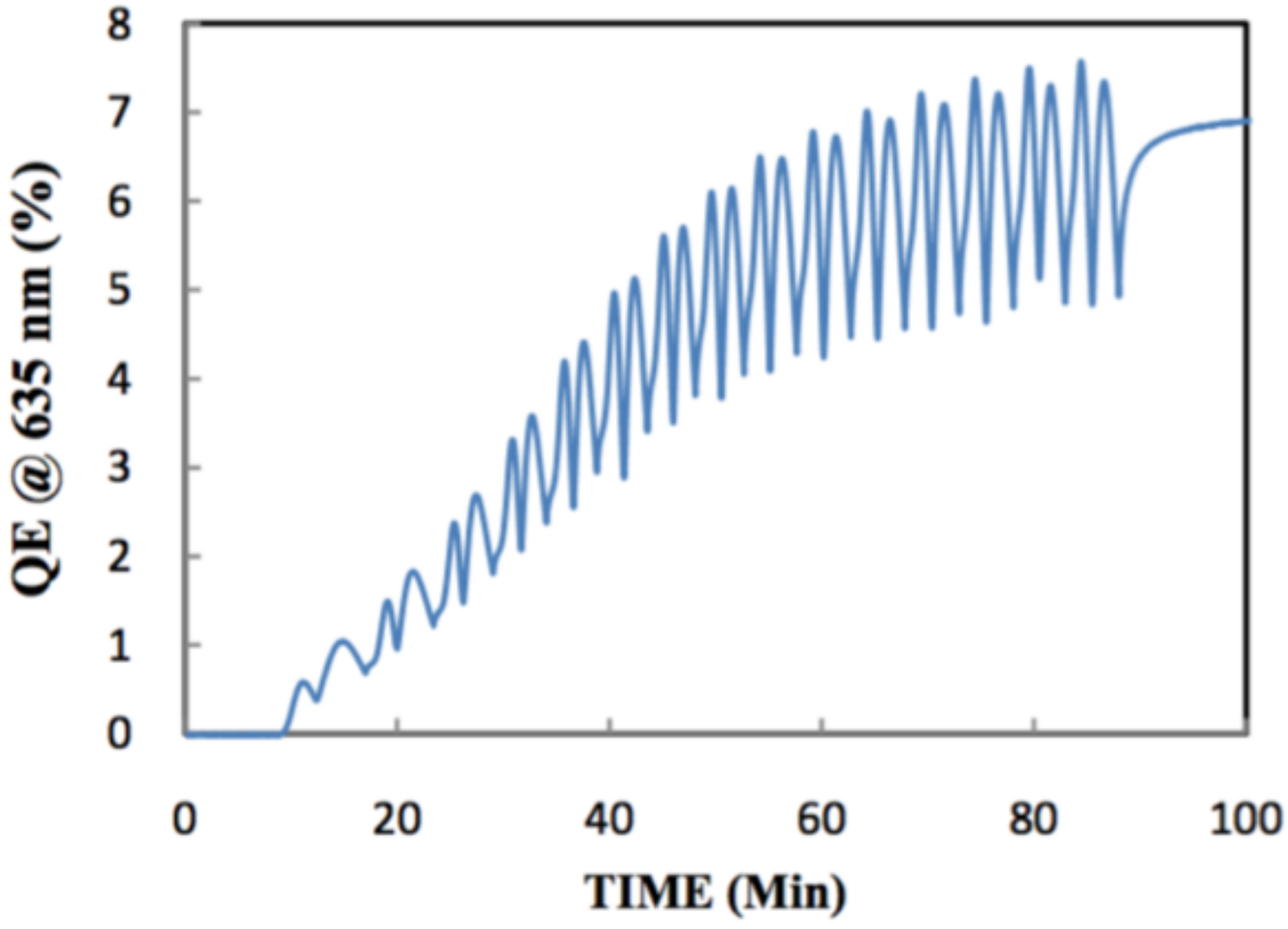
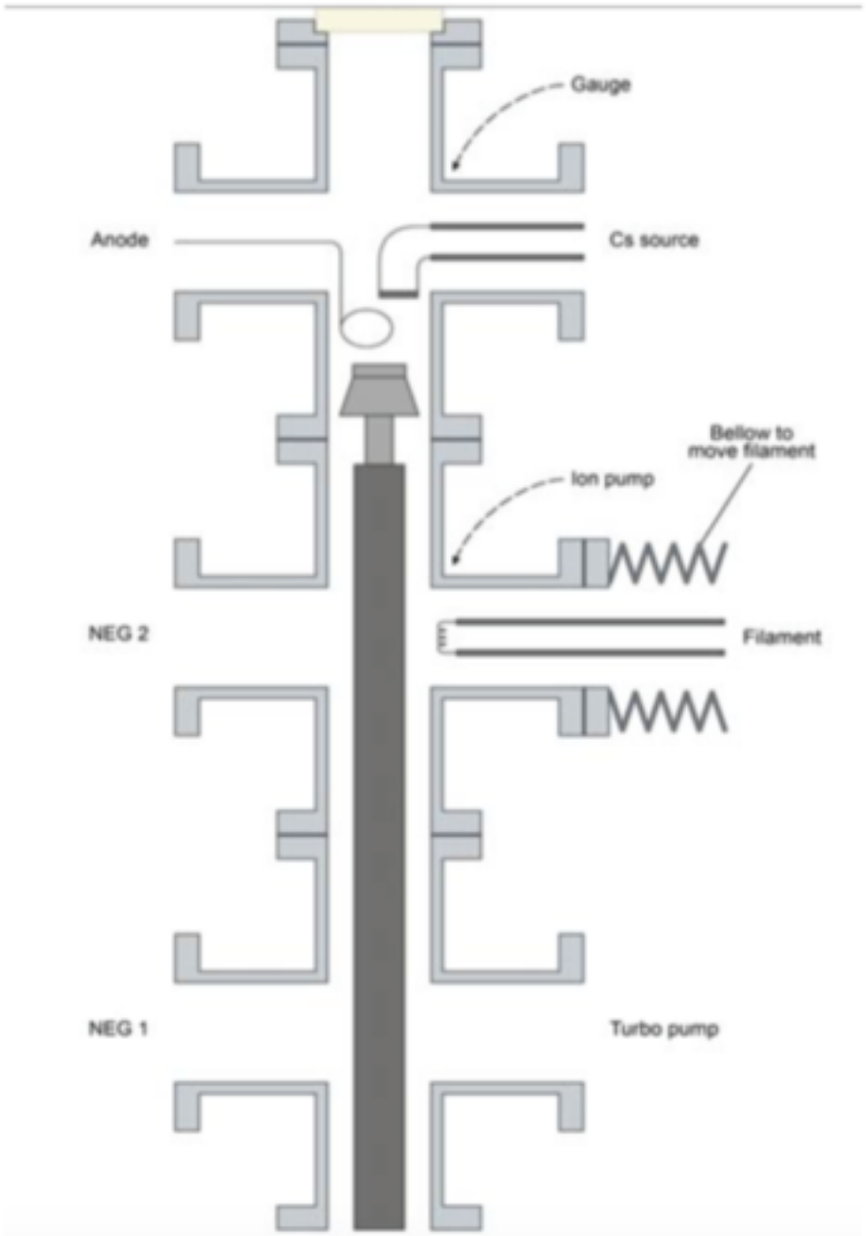


Image Credit: N. Chanlek

Activation: Co-Deposition



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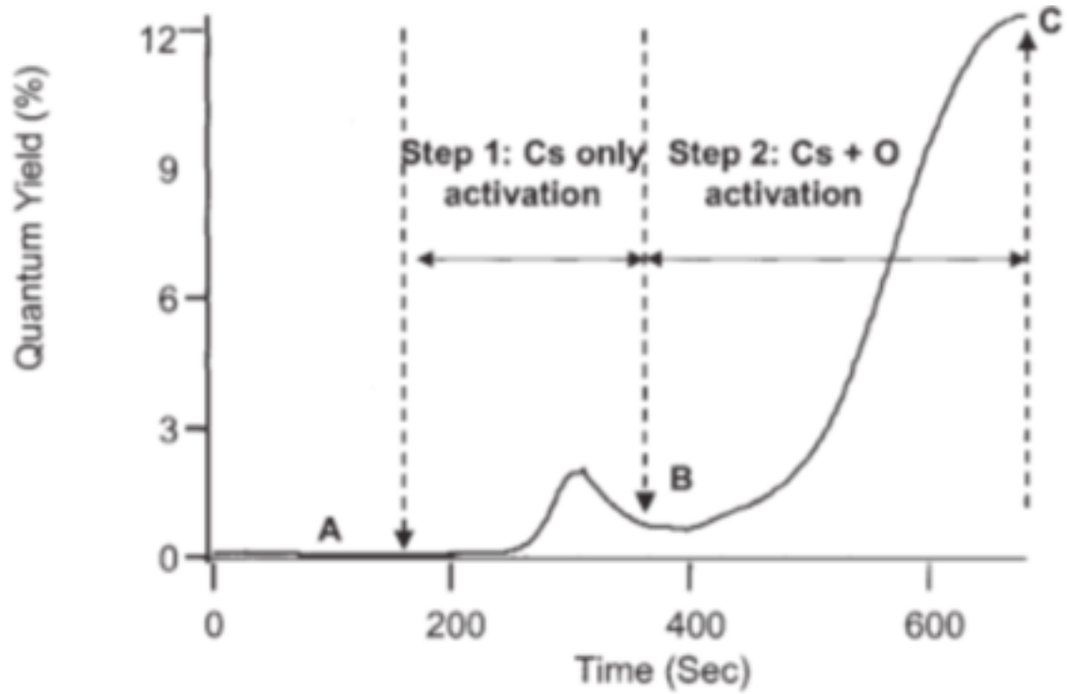


Image Credit: M. Poelker

Gatling Principle

* Electron beam will be extracted from 20 individual cathodes illuminated in sequence. Each cathode contributes 2.5 mA

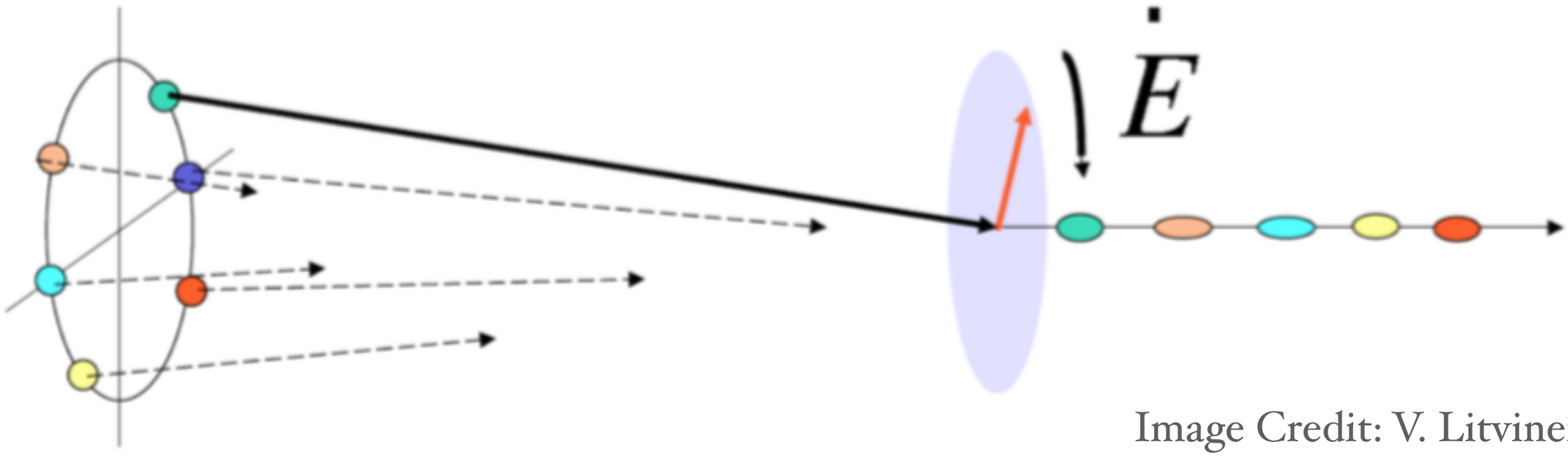
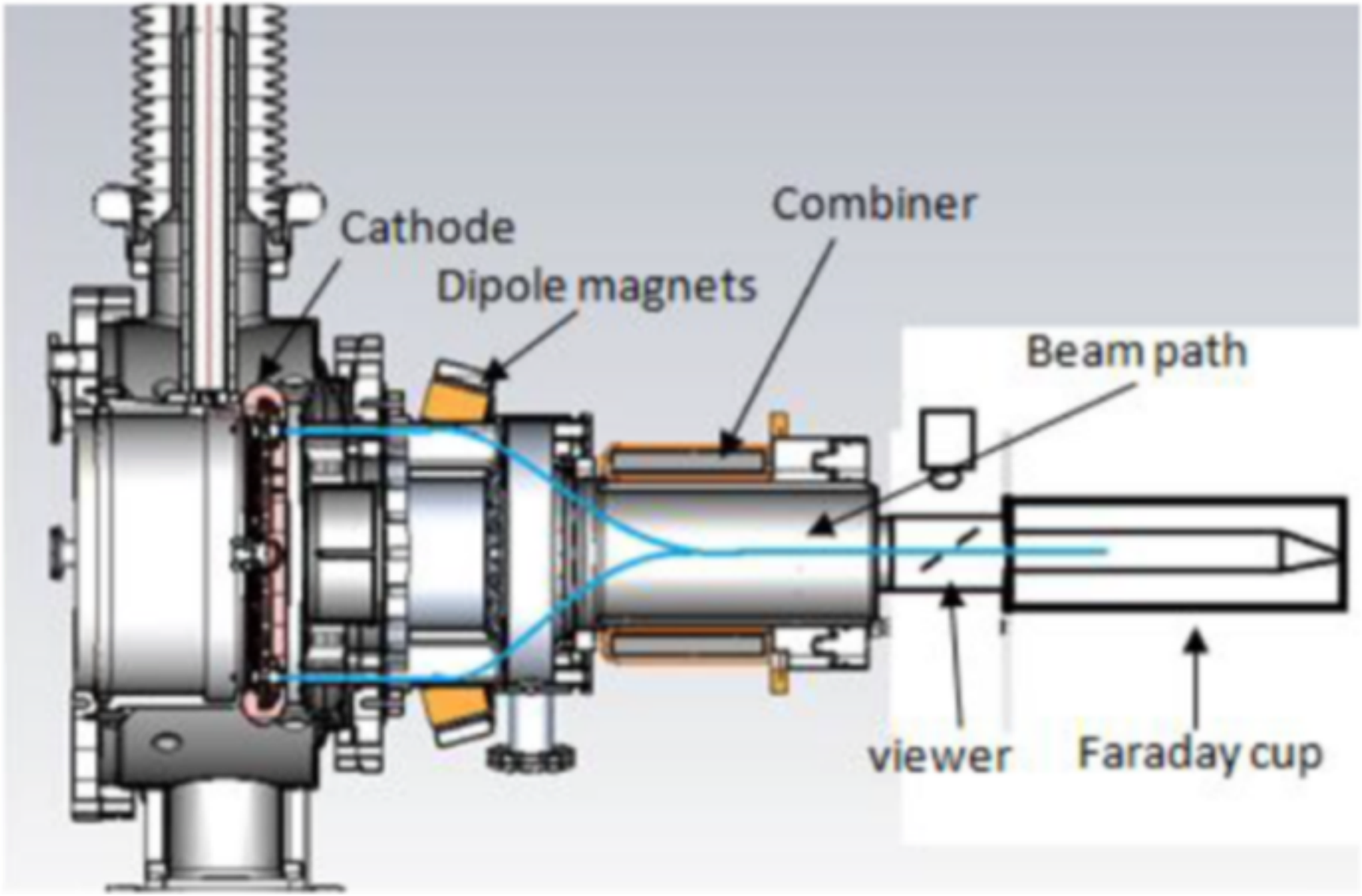


Image Credit: V. Litvinenko

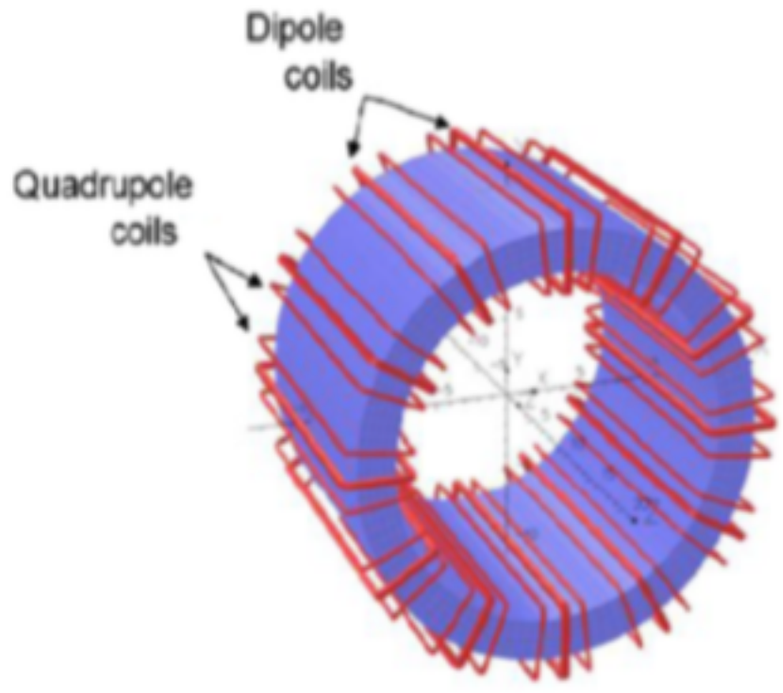
Gatling Gun

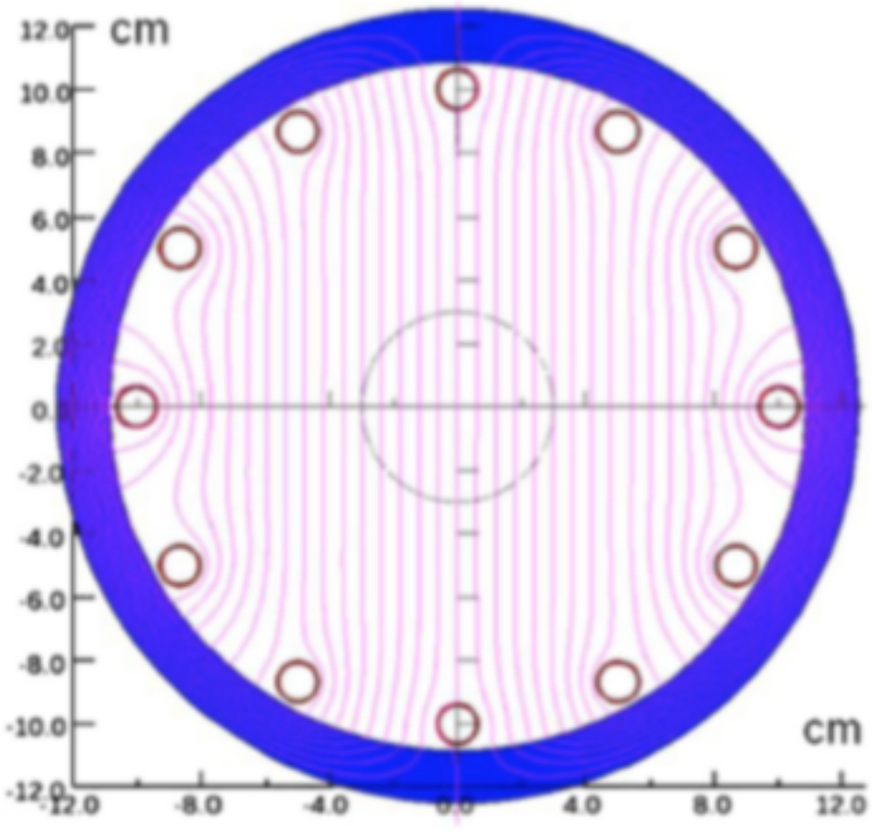
* P= 10^{-11} torr
* Main Components:
  * Cathode Magazine: holds 20 cathodes, 18 degrees apart
  * DC Gap: Accelerates beam across 45-55 kV potential
  * Beam dynamics: Dipoles and Combiner magnet alter beam trajectory
  * Beam Diagnostics: A Yttrium Aluminum Garnet (YAG) crystal visualize the beam

Gatling Gun: Side View



Combiner Magnet

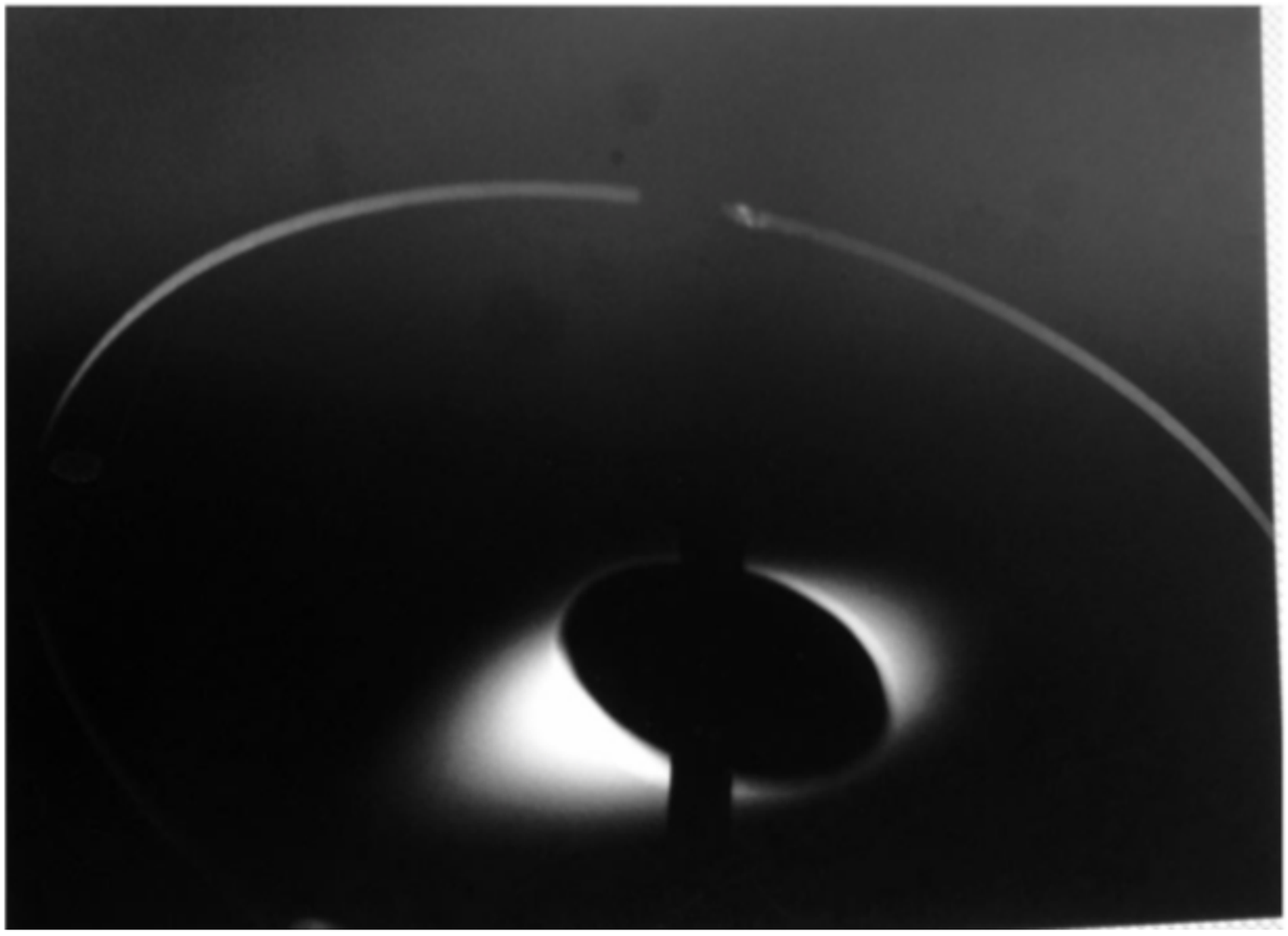




$$I_D = I_{0D} cos(\omega t + \Phi_D)$$

Image Credit:
E. Wang

YAG Crystal



Thank you!

Dipole Magnet