Franck-Hertz: Probing Atomic Structure

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Introduction: Electron Scattering

- Early success of the Bohr model
  - Explains spectral lines
- Scattering electrons off atoms
  - Tests the Bohr model
  - Provides information about atomic structure

Niels Bohr
http://nobelprize.org

Introduction: Experimental Goals

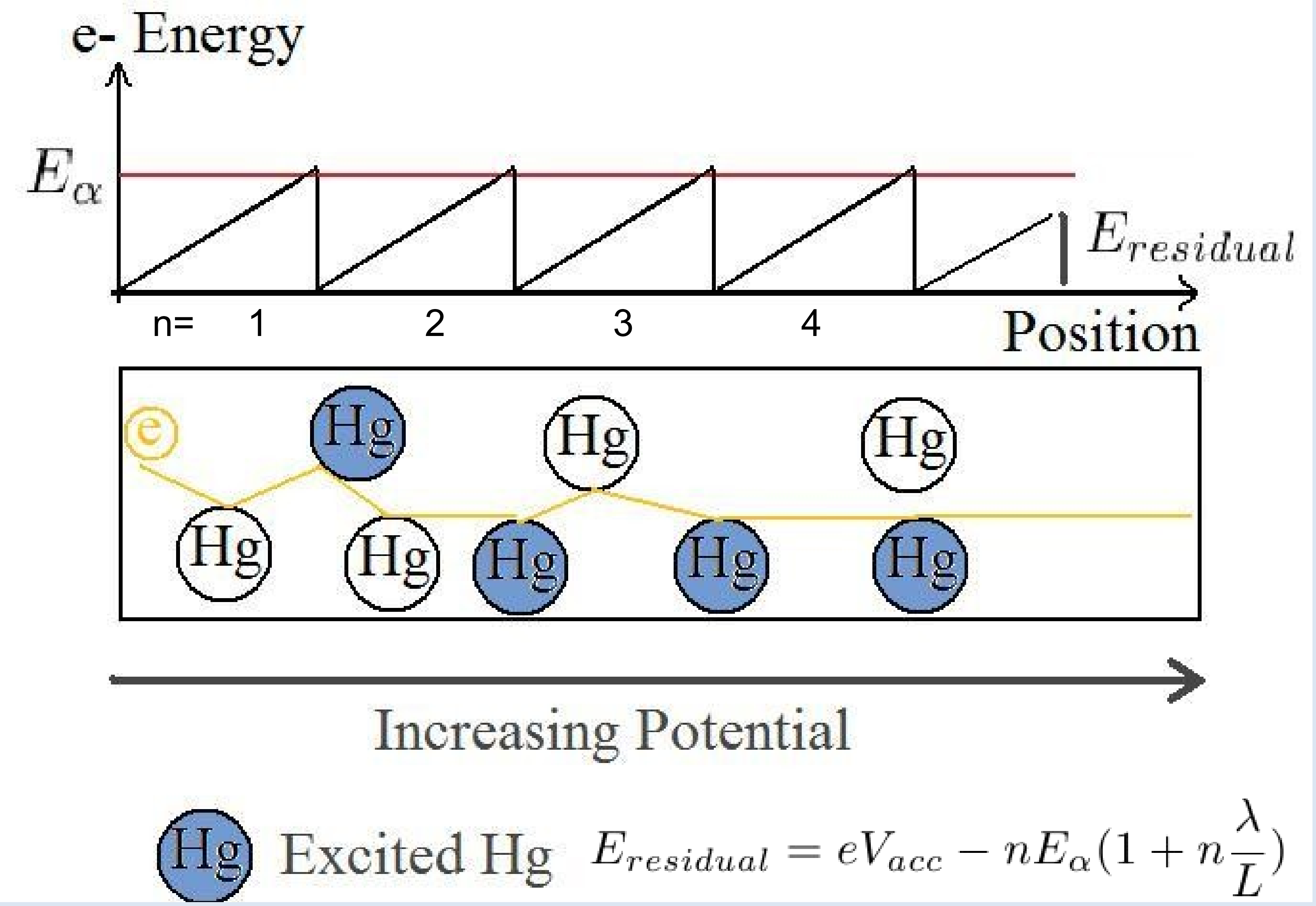
- Thermionic Emission
  - Qualitative description
- Franck-Hertz
  - Calculate first excited energy level of Hg from peak spacing
- Ionization Potential
  - Measure ionization energy of Hg

Theory: Thermionic Emission

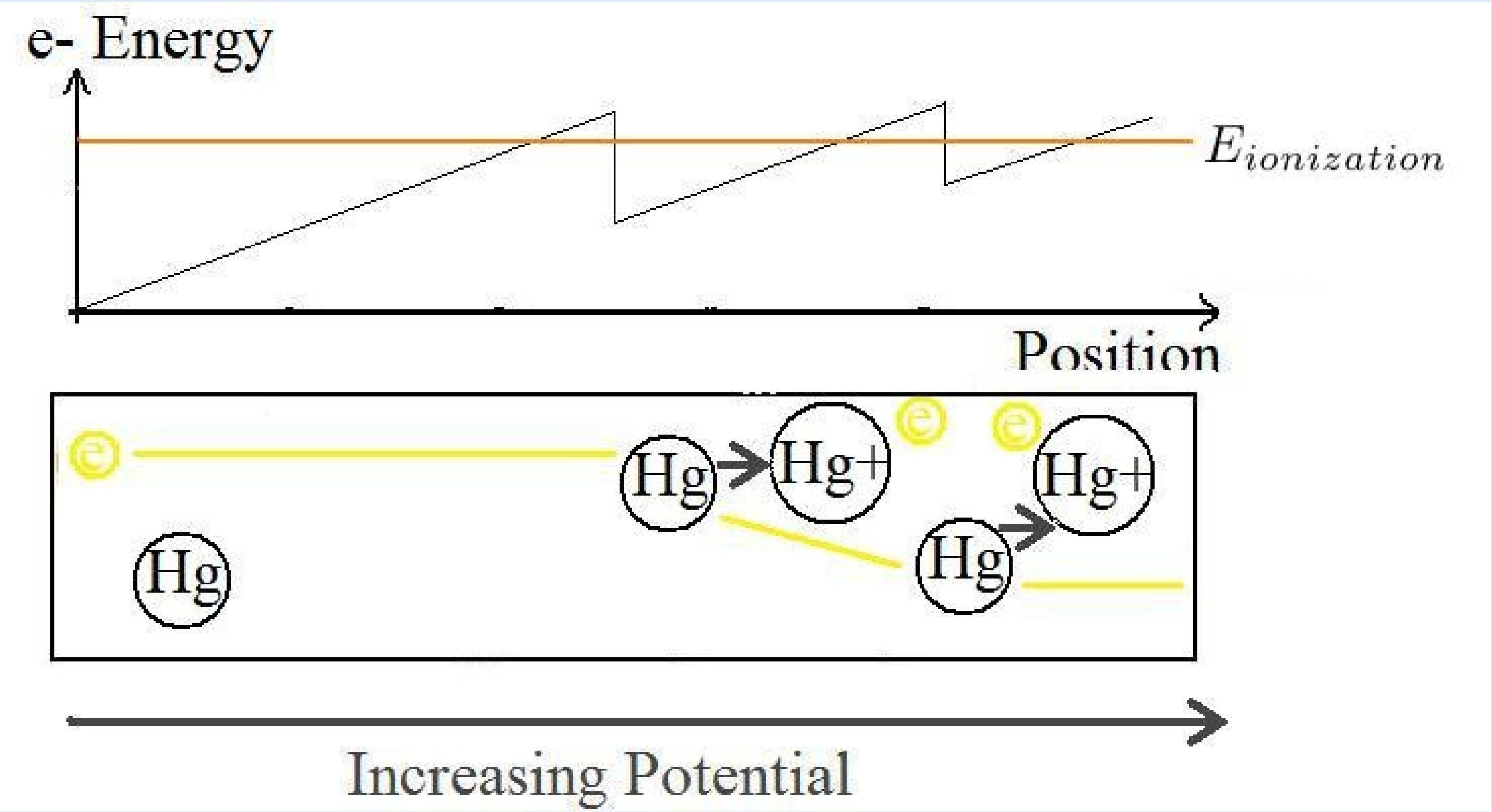
- Electrons in wire have a distribution of velocities
- Some electrons will have enough energy to escape the wire
- Gives rise to Richardson's Equation:

$$J = A_G T^2 exp(-\frac{\Phi}{kT})$$

Theory: Franck-Hertz

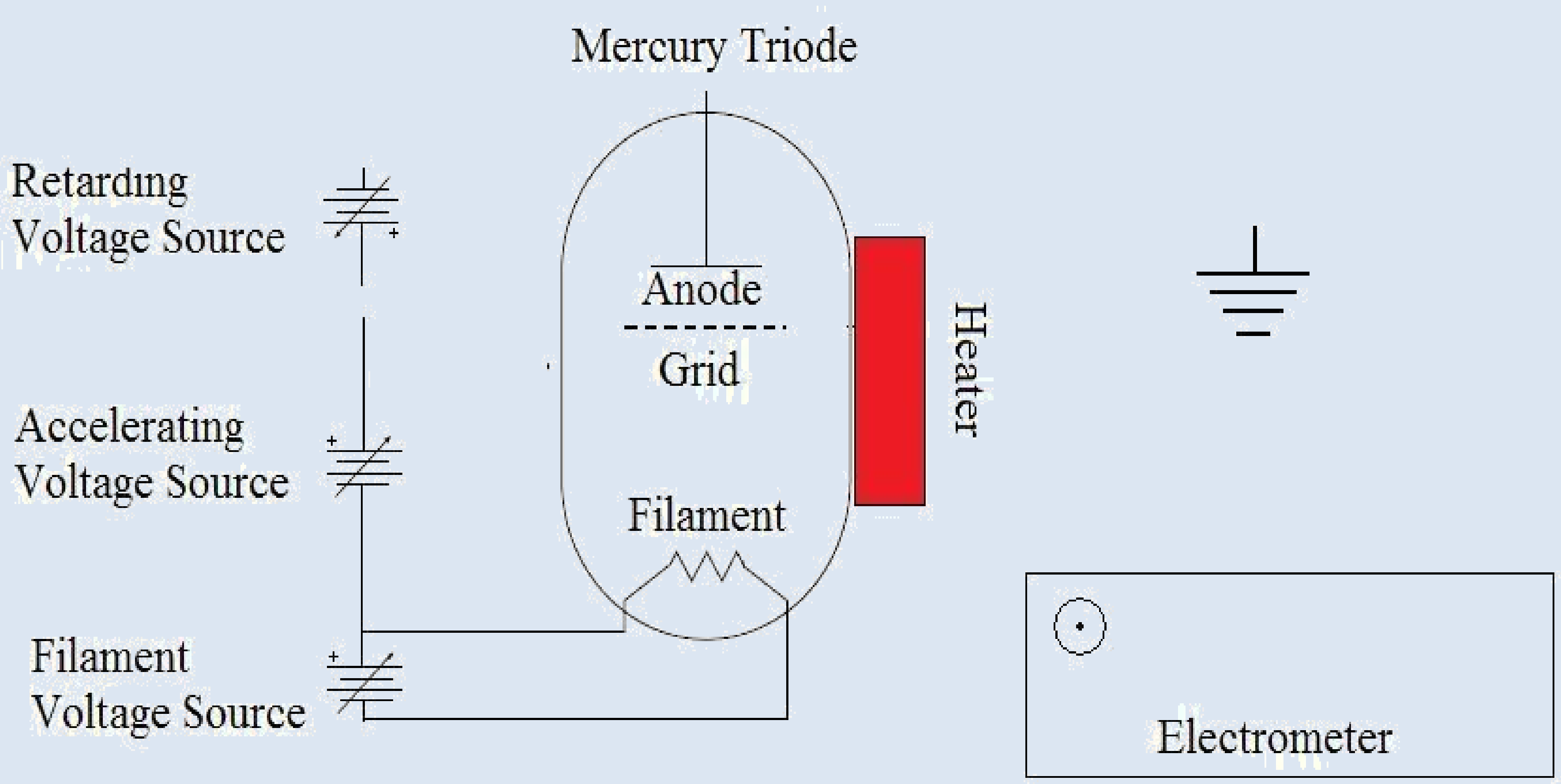


Theory: Ionization of Mercury



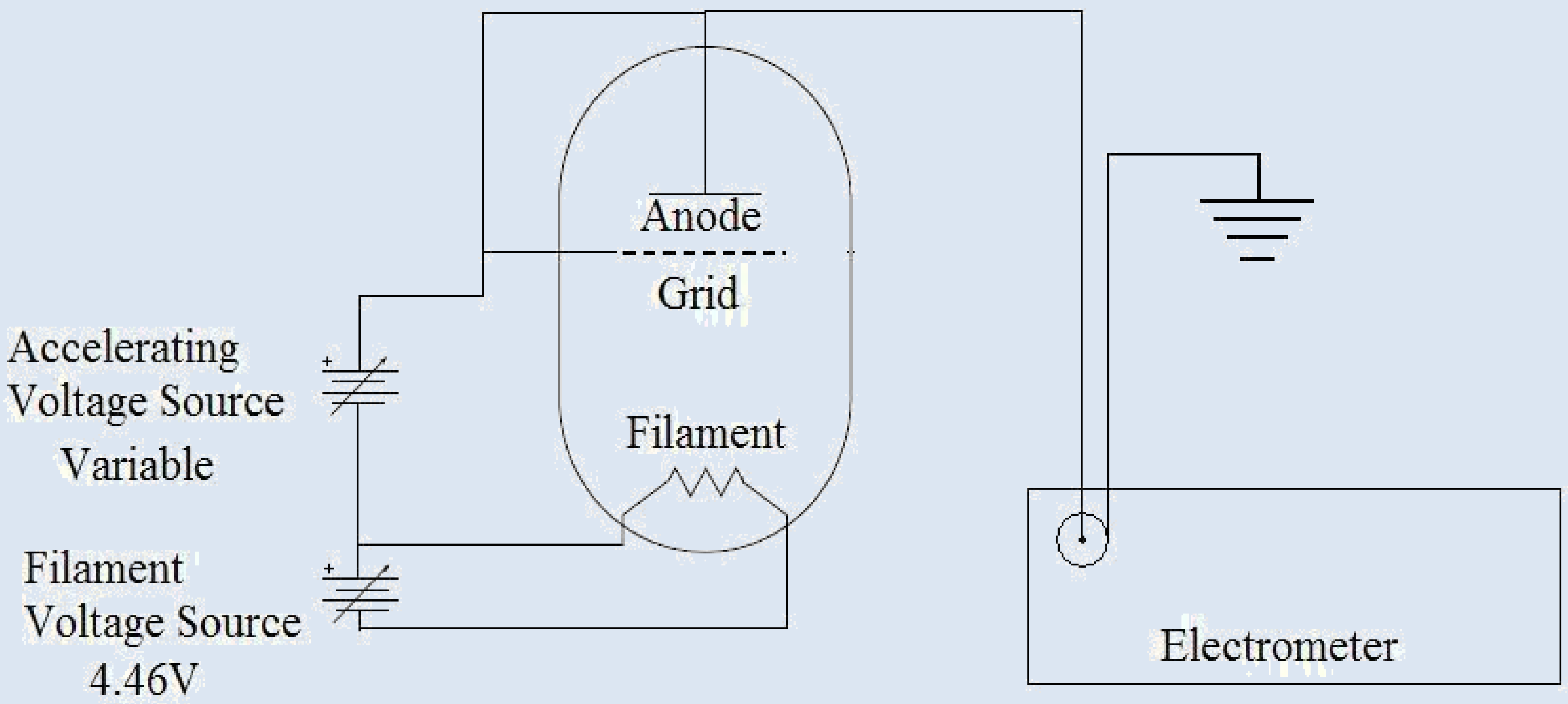
The production of mercury ions is highly dependent on the mean free path

Setup: Overview



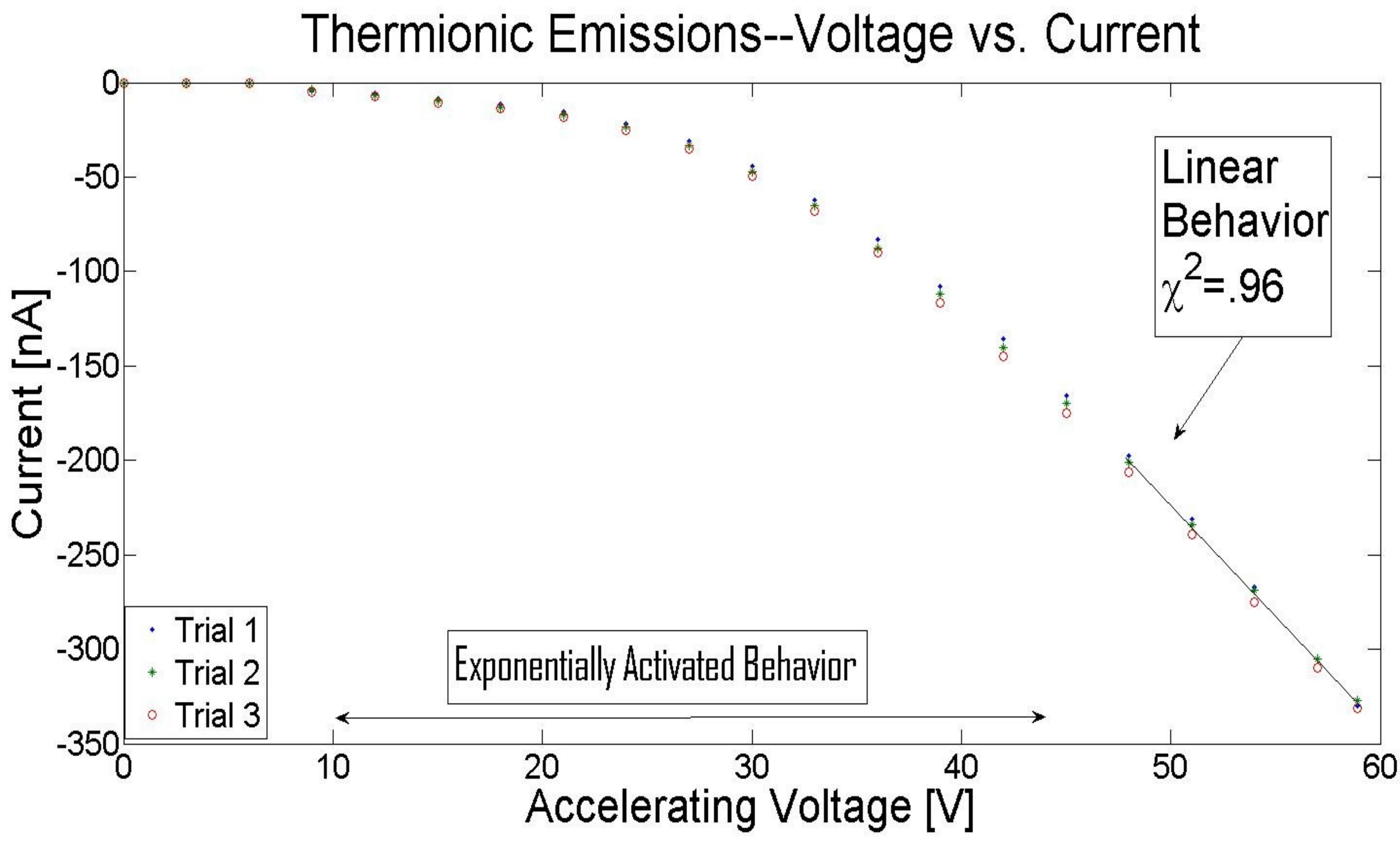
Adapted From: http://web.mit.edu/8.13/www/07.shtml

Setup: Thermionic Emission

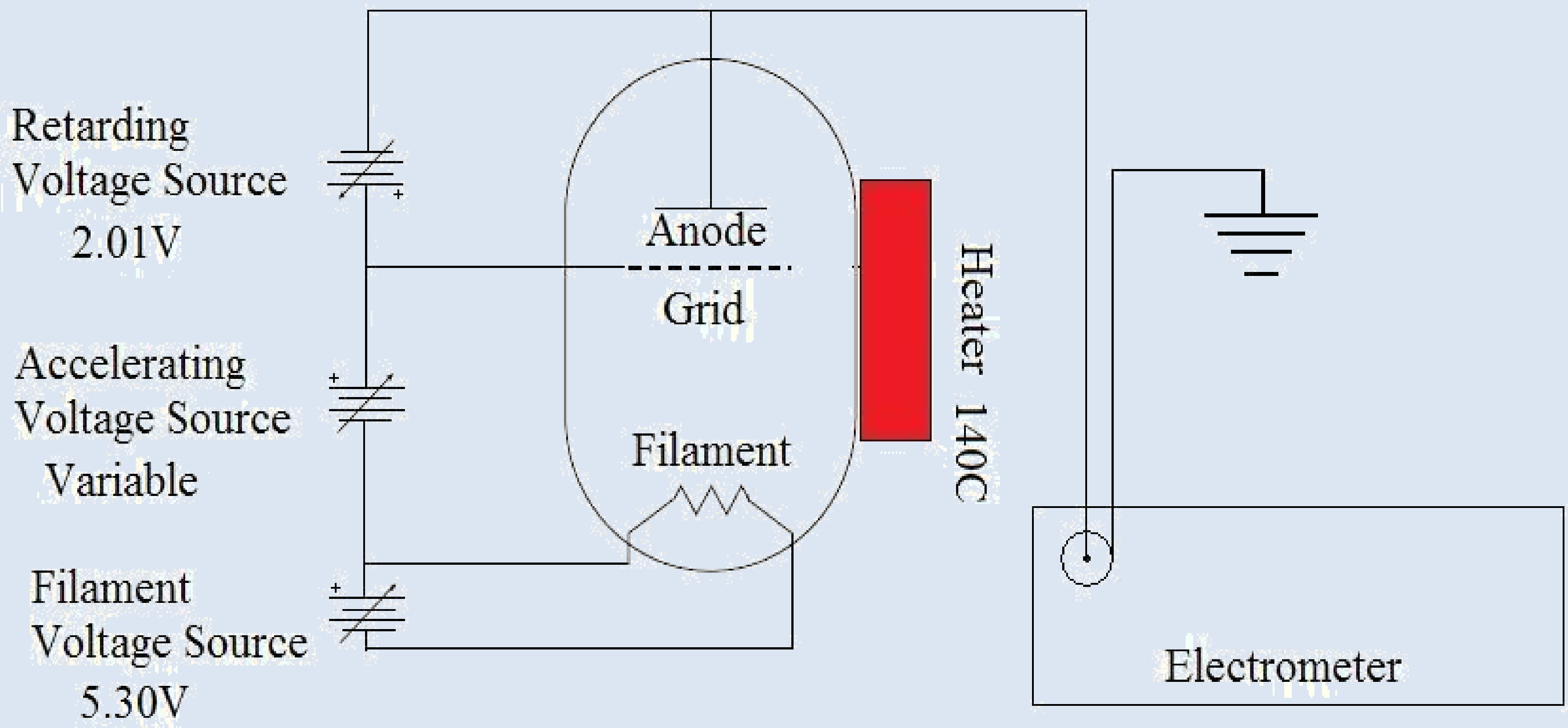


Adapted From: http://web.mit.edu/8.13/www/07.shtml

Data Analysis: Thermionic Emissions



Setup: Franck–Hertz



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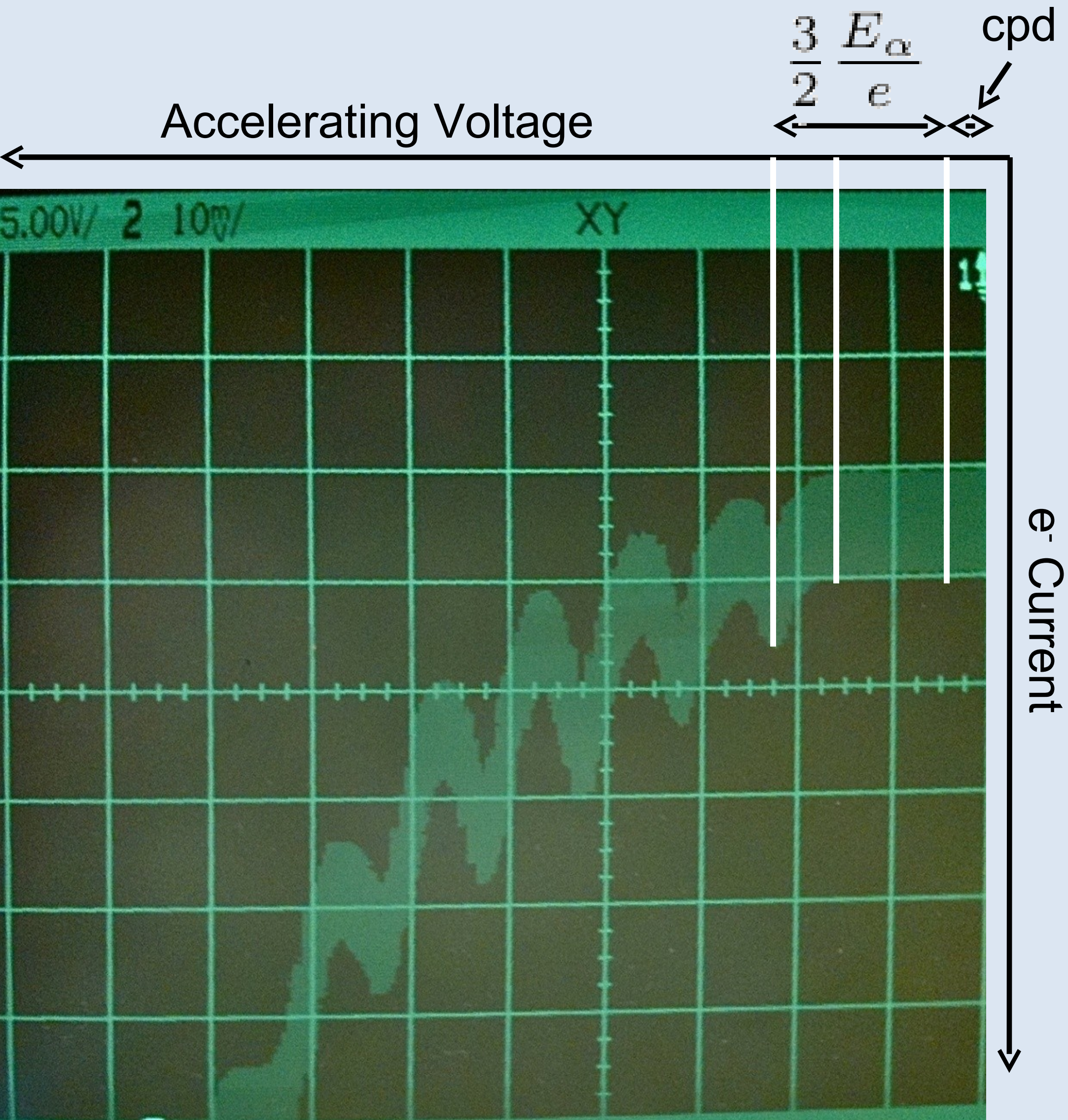
Data Analysis: Franck-Hertz



- Statistical errors dominate: 0.10V
- Additional Sources:
  - Scope Resolution: 0.035V
  - Elastic Scattering: 0.005V

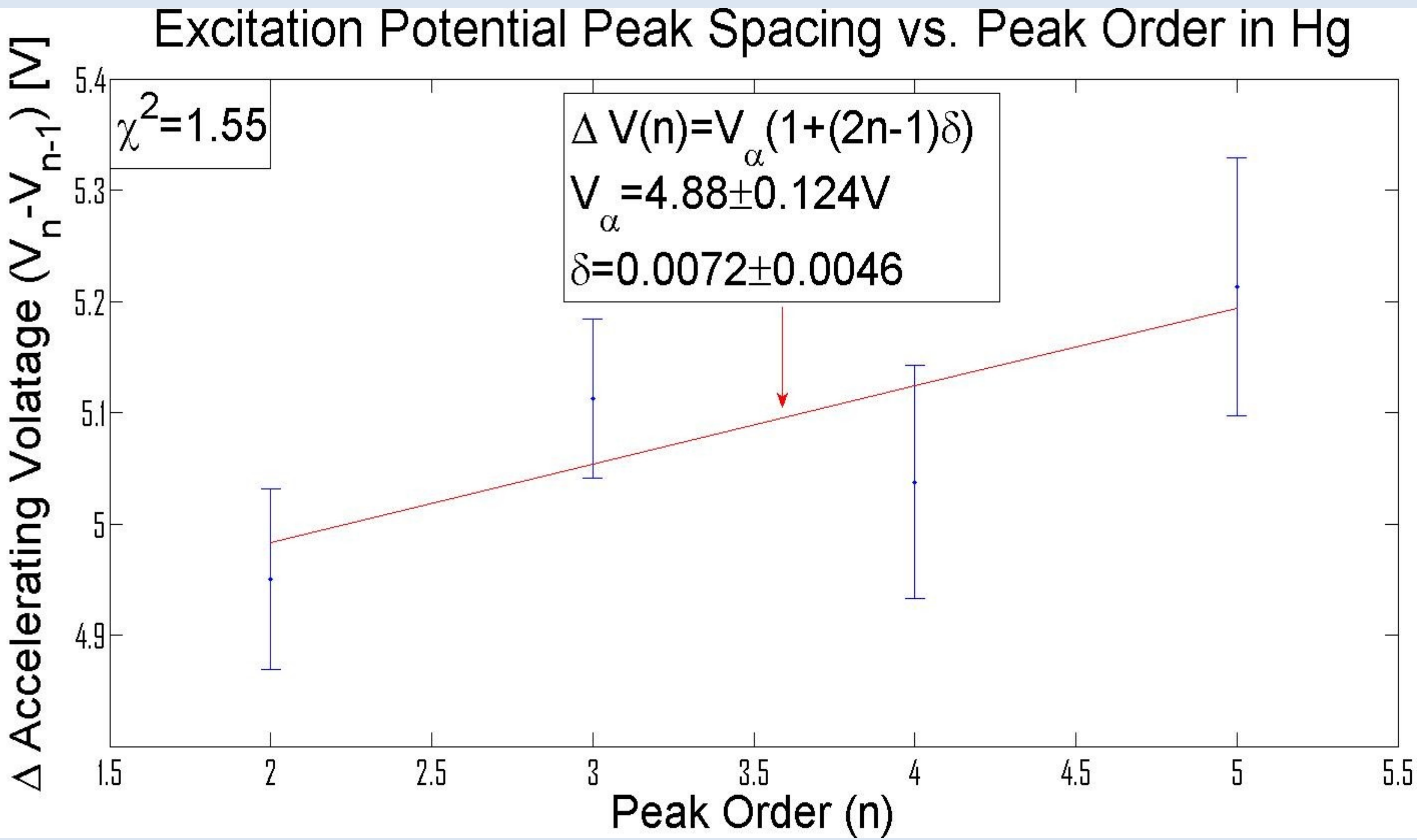
Data Analysis: Franck-Hertz

- Spacing between peaks fit to:

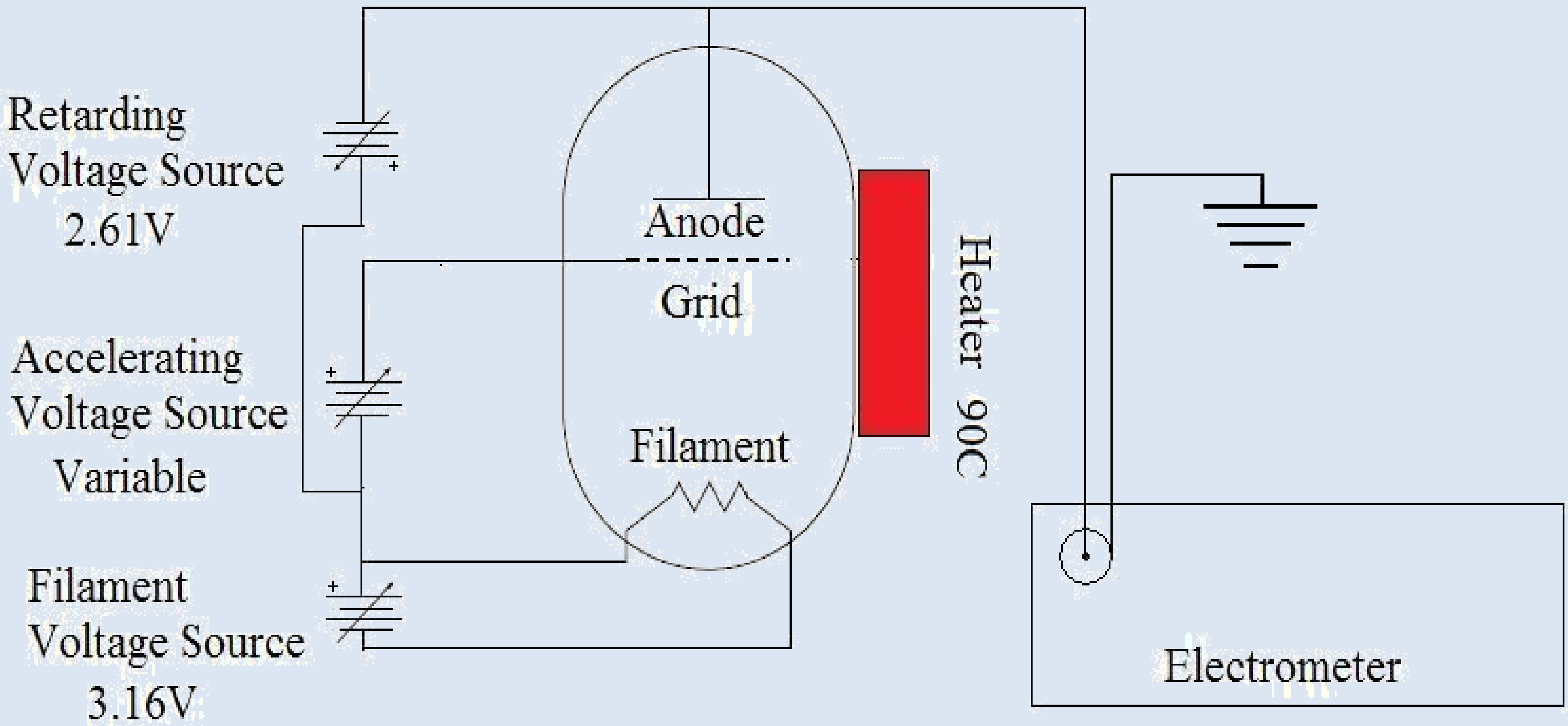
$$\Delta V(n) = \frac{E_\alpha}{e}\left(1 + (2n-1)\frac{\lambda}{L}\right)$$

- The contact potential:
  - Given by the location of the first peak minus $\frac{3}{2}\frac{E_\alpha}{e}$
  - Measured Value: 3.55 ±0.17 V

Data Analysis: Franck-Hertz

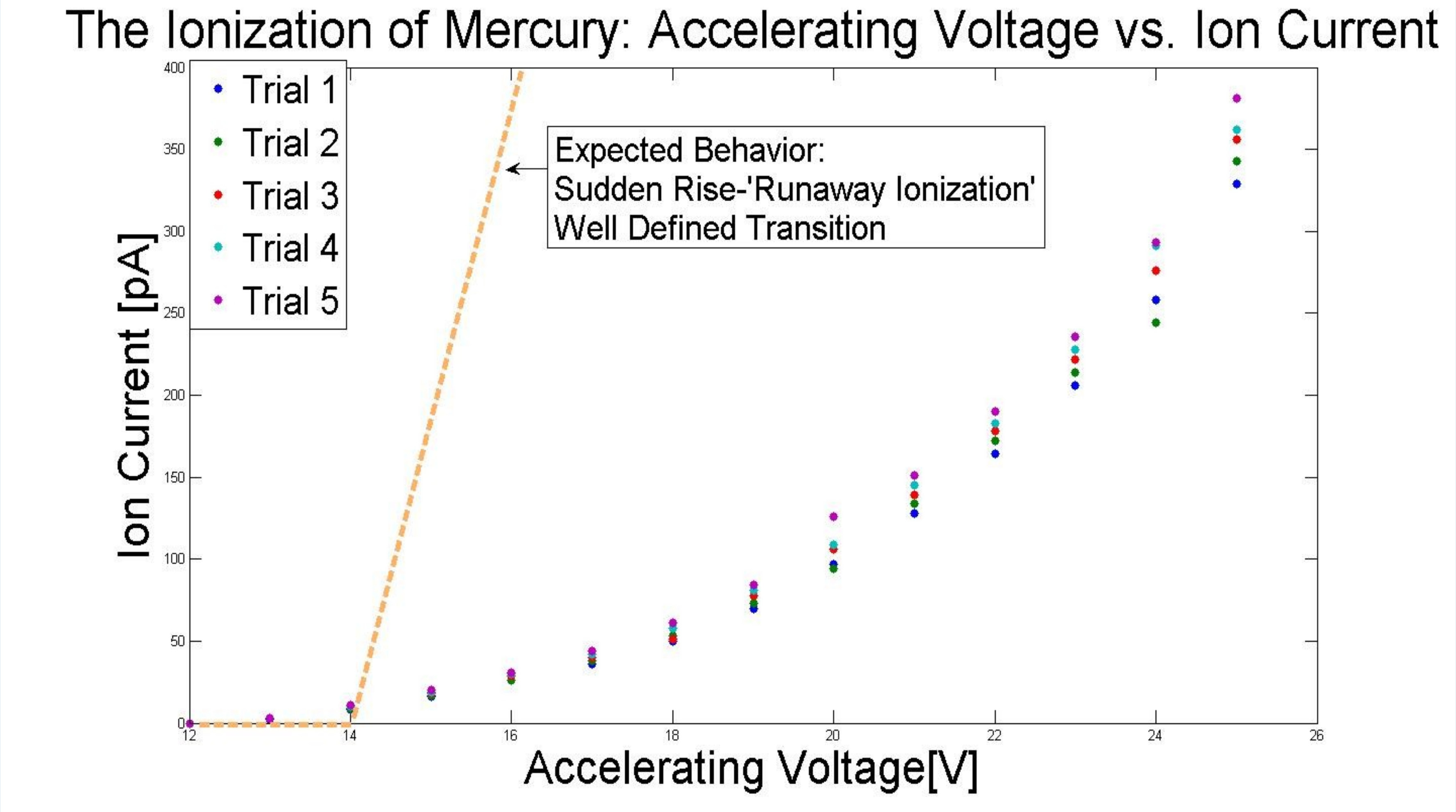


Setup: Ionization



Adapted From: http://web.mit.edu/8.13/www/07.shtml

Data Analysis: Ionization of Mercury



- Correction for contact potential:

$$E_{ion,true} = E_{ion,obs} - eCPD$$

Data Analysis: Ionization of Mercury

- Reasons for Error
  - High Temperature: 90° C
    - Data From Tess Smidt and John Ruszczynski suggests 75° C is optimal
    - Excitation rather than ionization occurs
  - Low Filament Voltage ≈3.16V
    - Fewer electrons available

Conclusion: Franck-Hertz

- First excited energy
  - Measured: 4.88 ±0.12 eV
  - Actual (Spectrographic): 4.86 eV
- Supports a quantum model of the atom

Conclusion: Ionization of Mercury

- High temperature and an incorrectly set filament voltage produced data without runaway ionization
- Estimated ionization energy:
  - Calculated: 9.00 ± 0.53 eV
  - Actual: 10.44 eV
- If performing the experiment again
  - Lower temperature $\approx 75°$ C
  - Higher filament voltage ≈ 5 V

Questions?