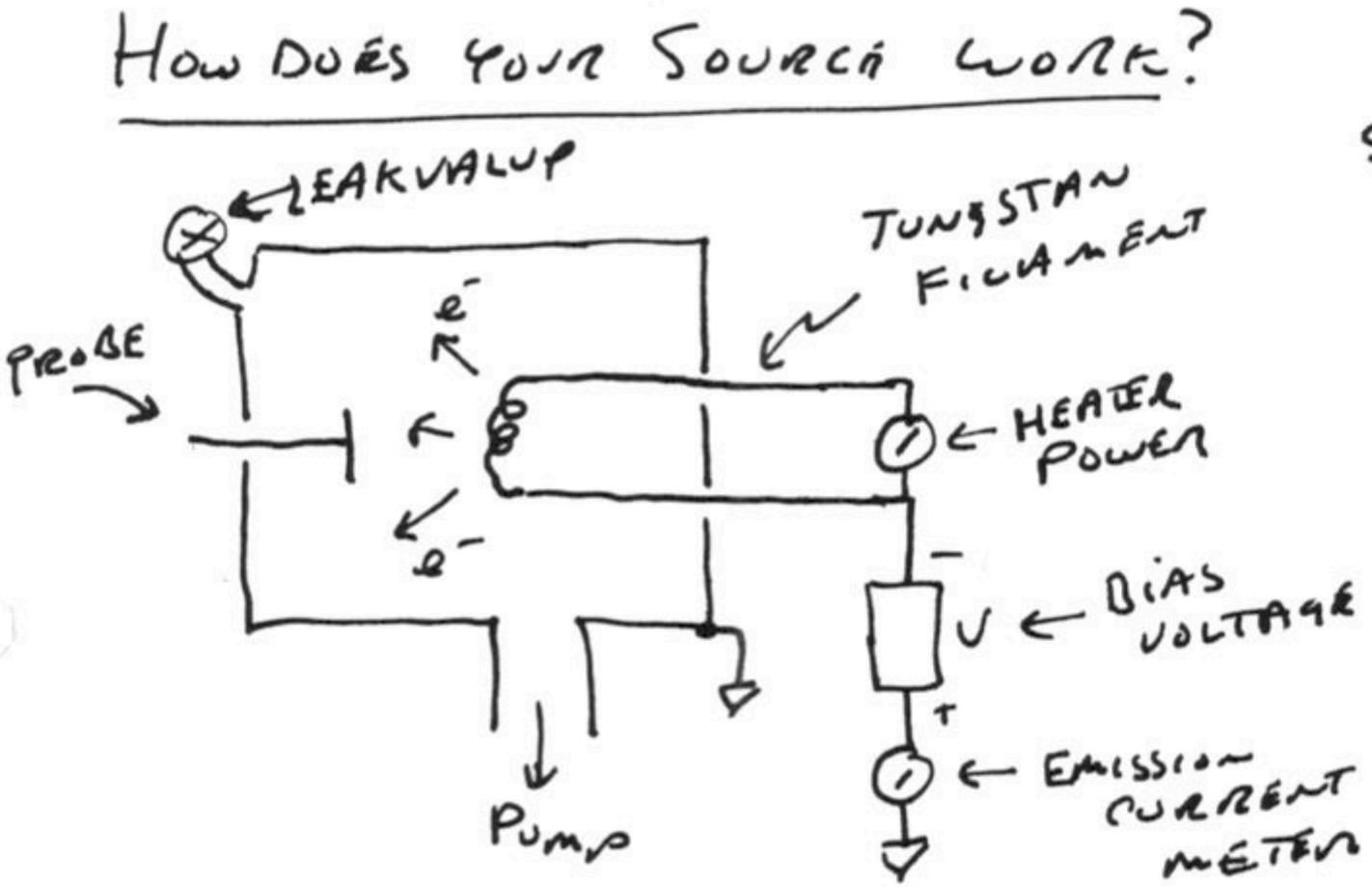
Plasma Experiment: Part 1

AP 4018
Columbia University

Objective

- Learn how to operate a low-temperature, partially-ionized plasma source
- Characterize the discharge dynamics and time-scales

How Does the Plasma Source Work?

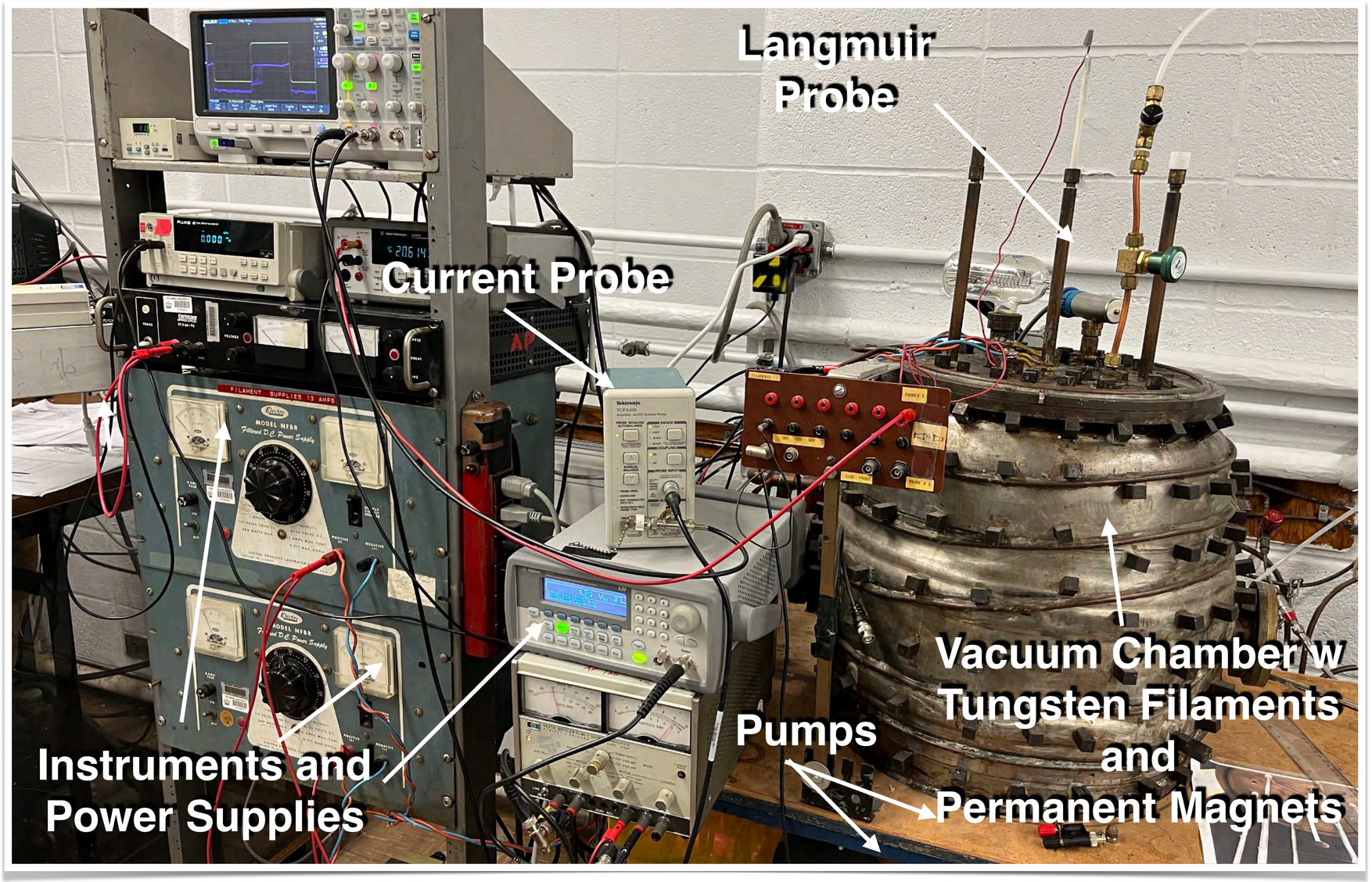


STEP 1: HEAT TUNGSTEN WHITE-HOT SO ELECTRONS ARE EMITTED

STEP 2: APPLY BIAS VOLTAGE ~ −50V TO ACCELERATE ELECTRONS INTO GAS

STEP 3: MEASURE PLASMA WITH PROBE CURRENT.

How Does the Plasma Source Work?



How Does the Plasma Source Work?

- Note: the chamber is covered with **permanent magnets** to provide *partial* “cusp” confinement.
- This source and chamber has not been studied well in the teaching lab for several years. You will be conducting *new* investigations.
- Finally, know that electrons will be more strongly magnetized and influenced by the wall cusp magnetic field than will be the ions.

What does this imply?

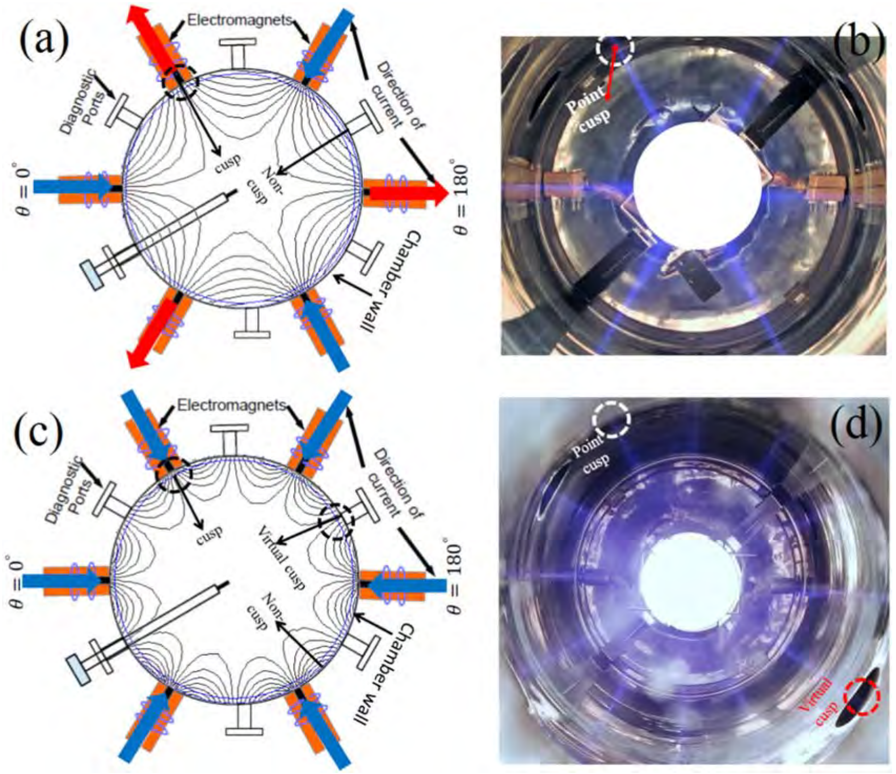
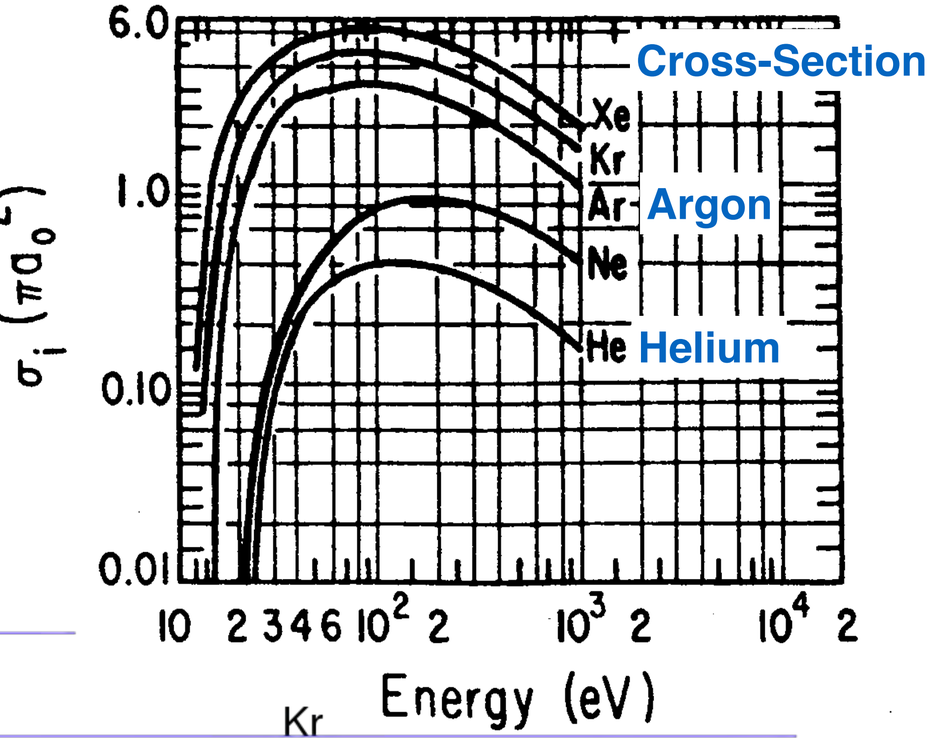


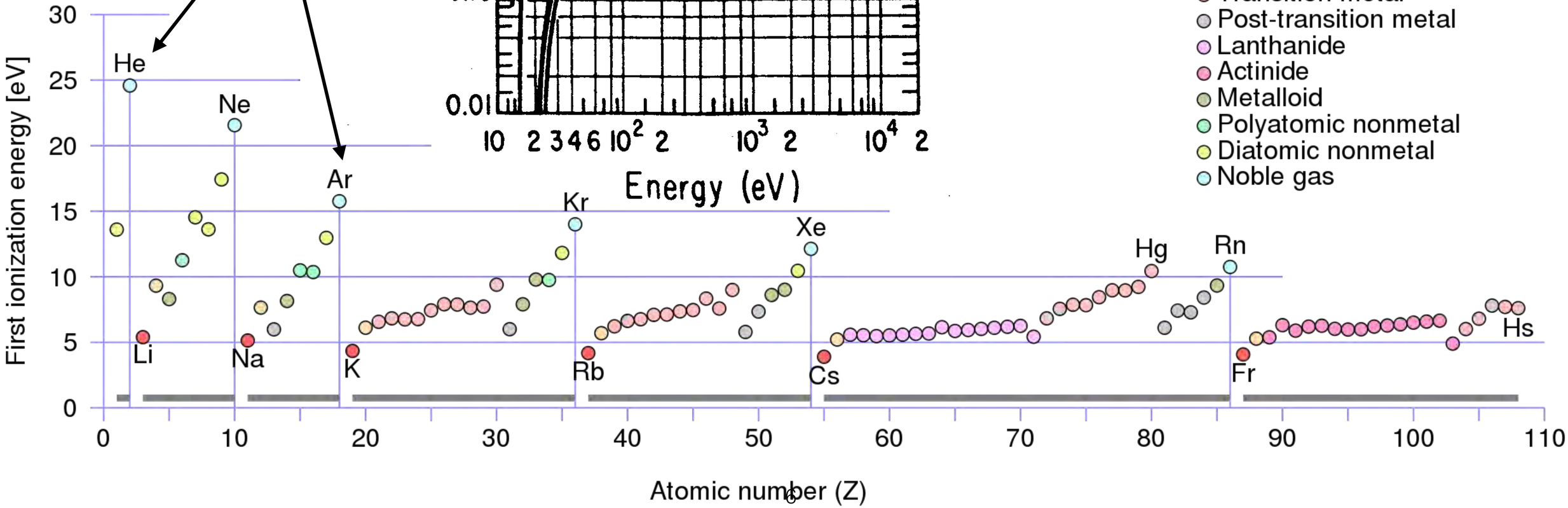
Figure 4. (a) and (c) shows the arrangement of electromagnets over the chamber, diagnostic ports, Langmuir probe for diagnostic and magnetic field lines simulated using FEMM in SPSM and TPSM configuration respectively. Arrow in figures shows the current direction in electromagnets. Figure (b) and (d) shows the pictures of plasma confined in SPSM and TPSM observed through the viewport from one end of the device, the center region of bright glow of filaments has been shadowed to capture the feeble light from wings or the cusp regions.

From Meenakshee Sharma et al 2020 Plasma Res. Express 2 045001
https://doi.org/10.1088/2516-1067/abc1fc

Ionization by Electron-Impact



Our Gas



Plasma Production and Loss

Plasma Production = Plasma Loss

$$(\text{beam density} \times \text{beam velocity} \times (\sigma\, n_{gas}) \times \textit{efficiency}) = (\text{plasma density} \times C_s/L)$$

$\propto$ Emission Current

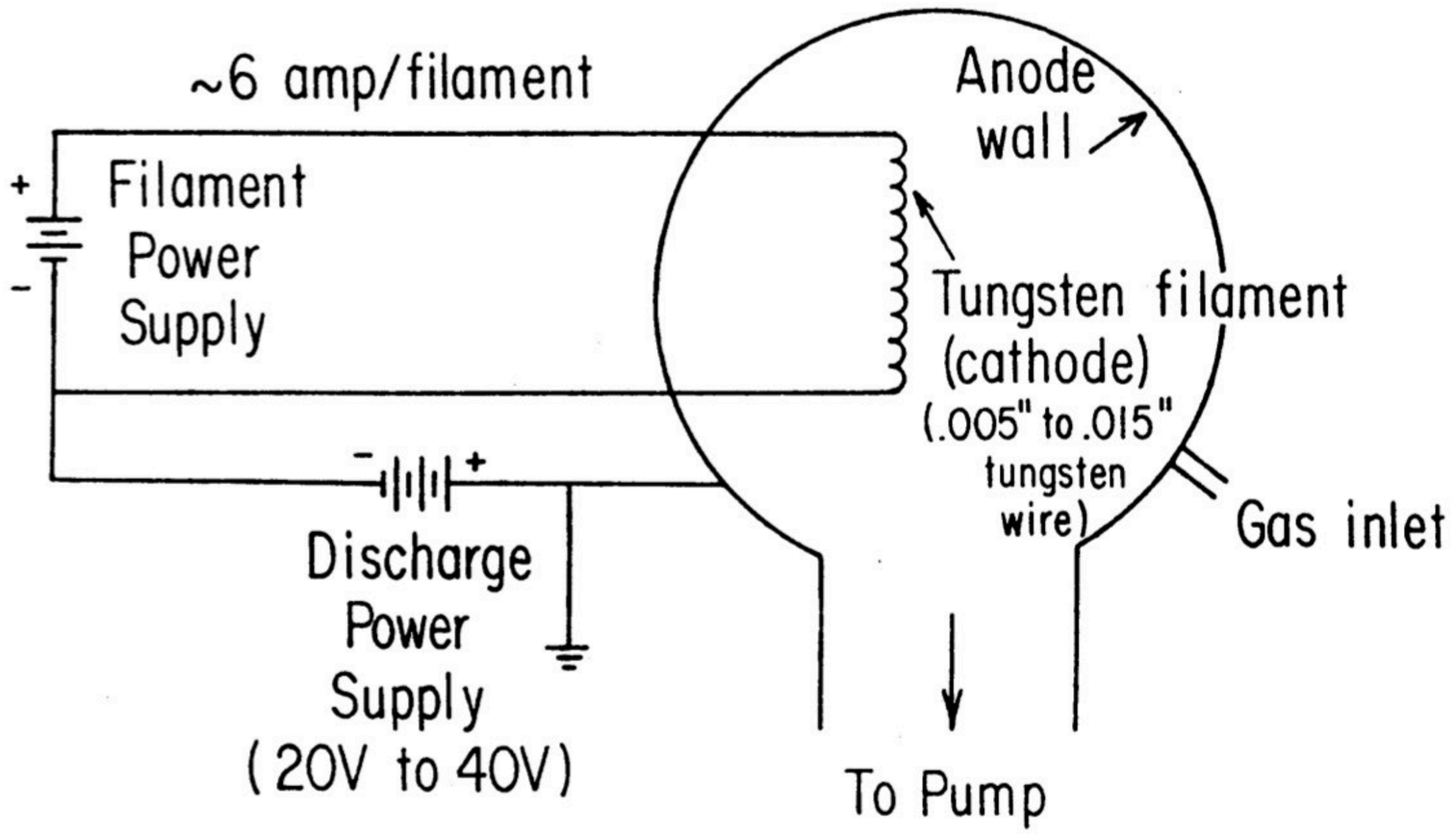
Gas Fill Pressure

Ambipolar Loss Rate

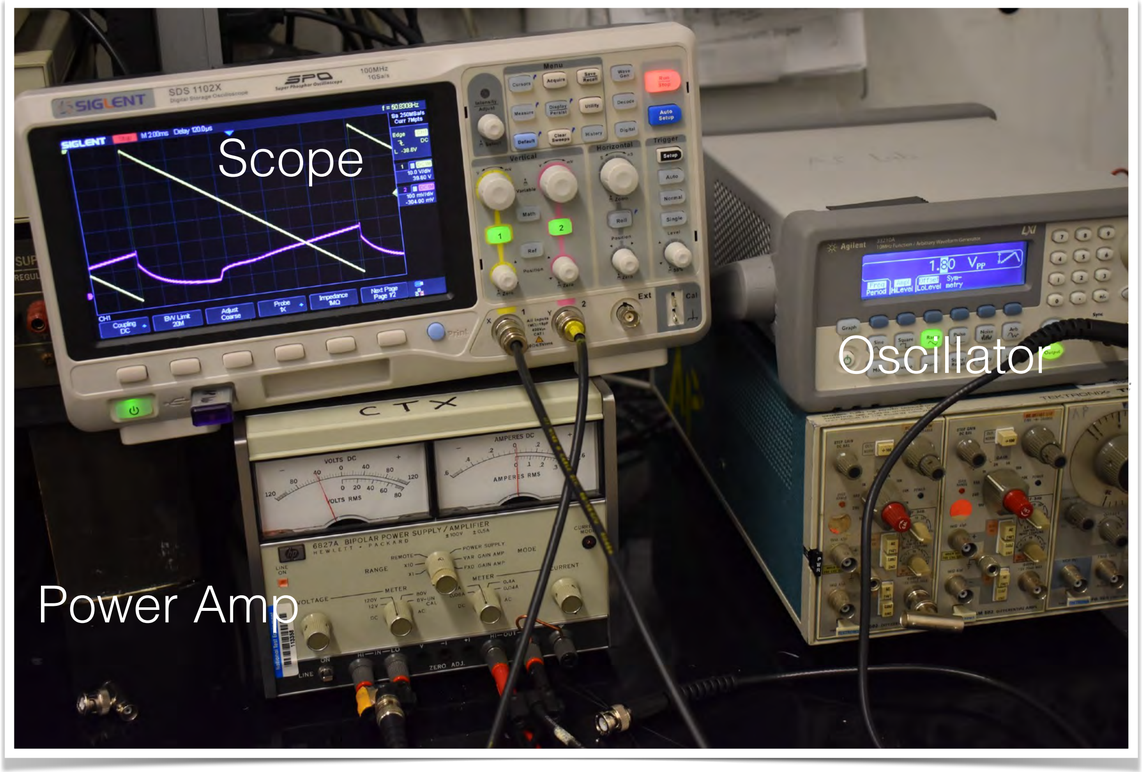
C_s = Ion Sound Speed $\approx 10^6 \sqrt{(T_e/M_{amu})}$ cm/sec

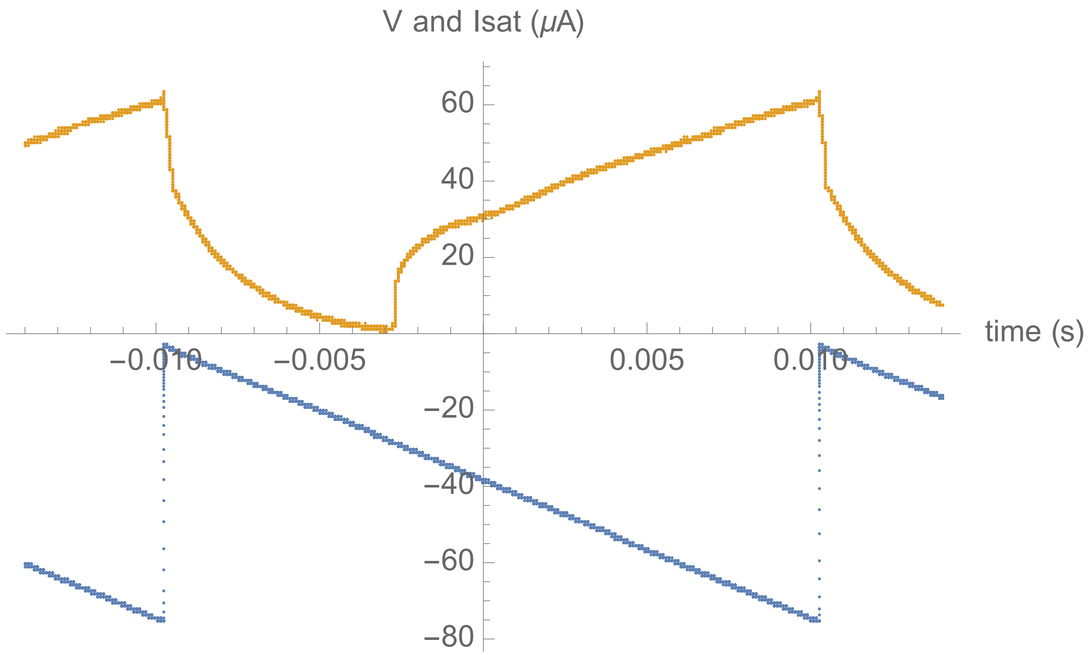
Plasma Production and Loss

- Key measurements:
  - Filament Emission Current
  - Filament Voltage
  - Plasma Ion Saturation Current (from Probe)
  - Gas neutral pressure
  - Atomic Mass (4 or 40)



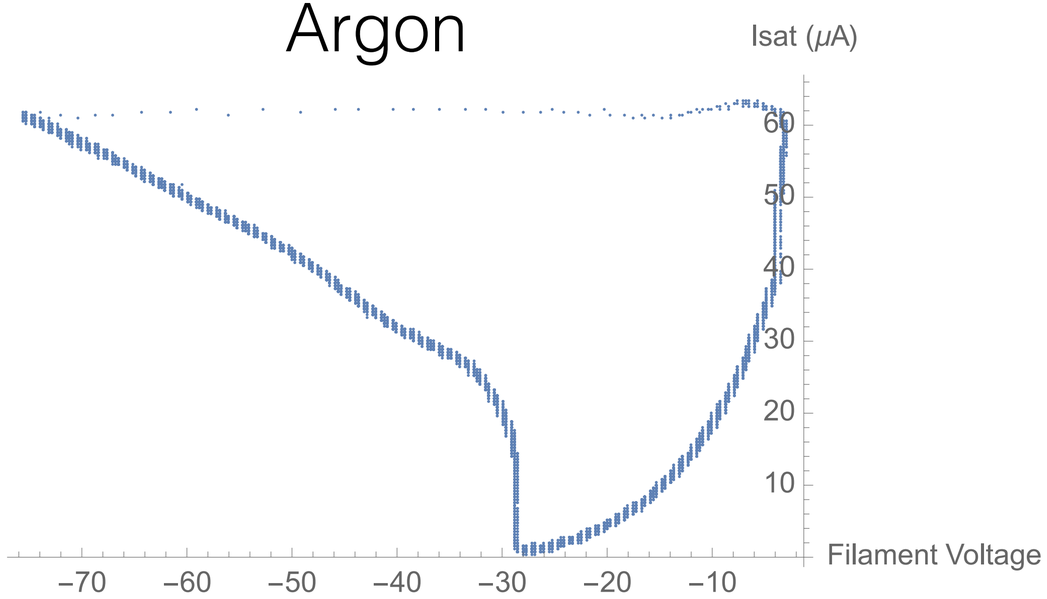
Sweeping the Filament Voltage



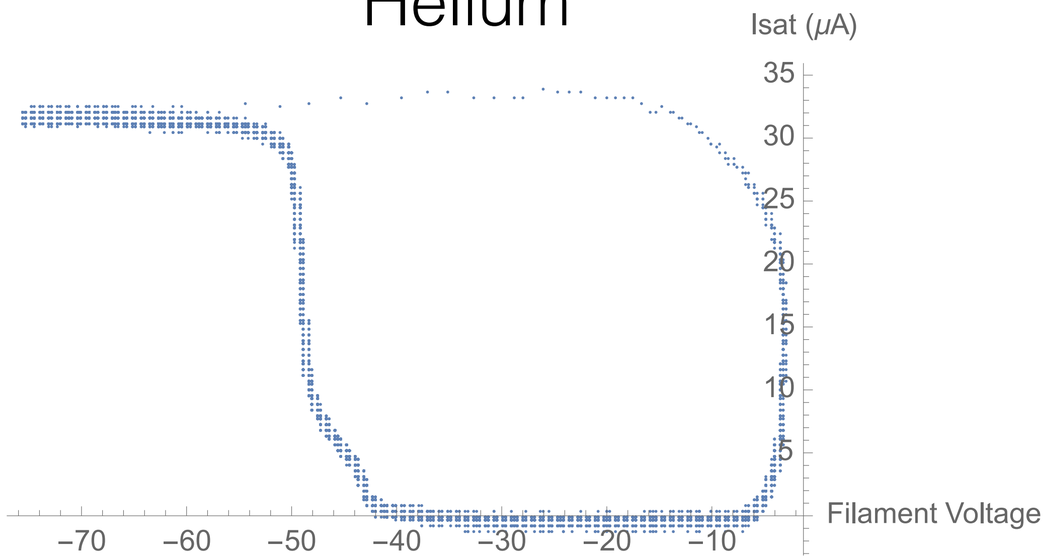


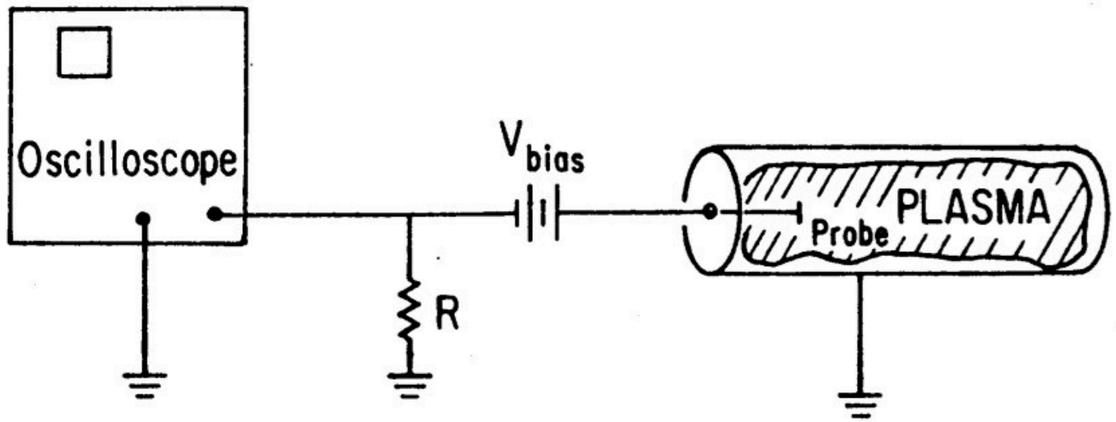
Sweeping the Filament Voltage

Argon



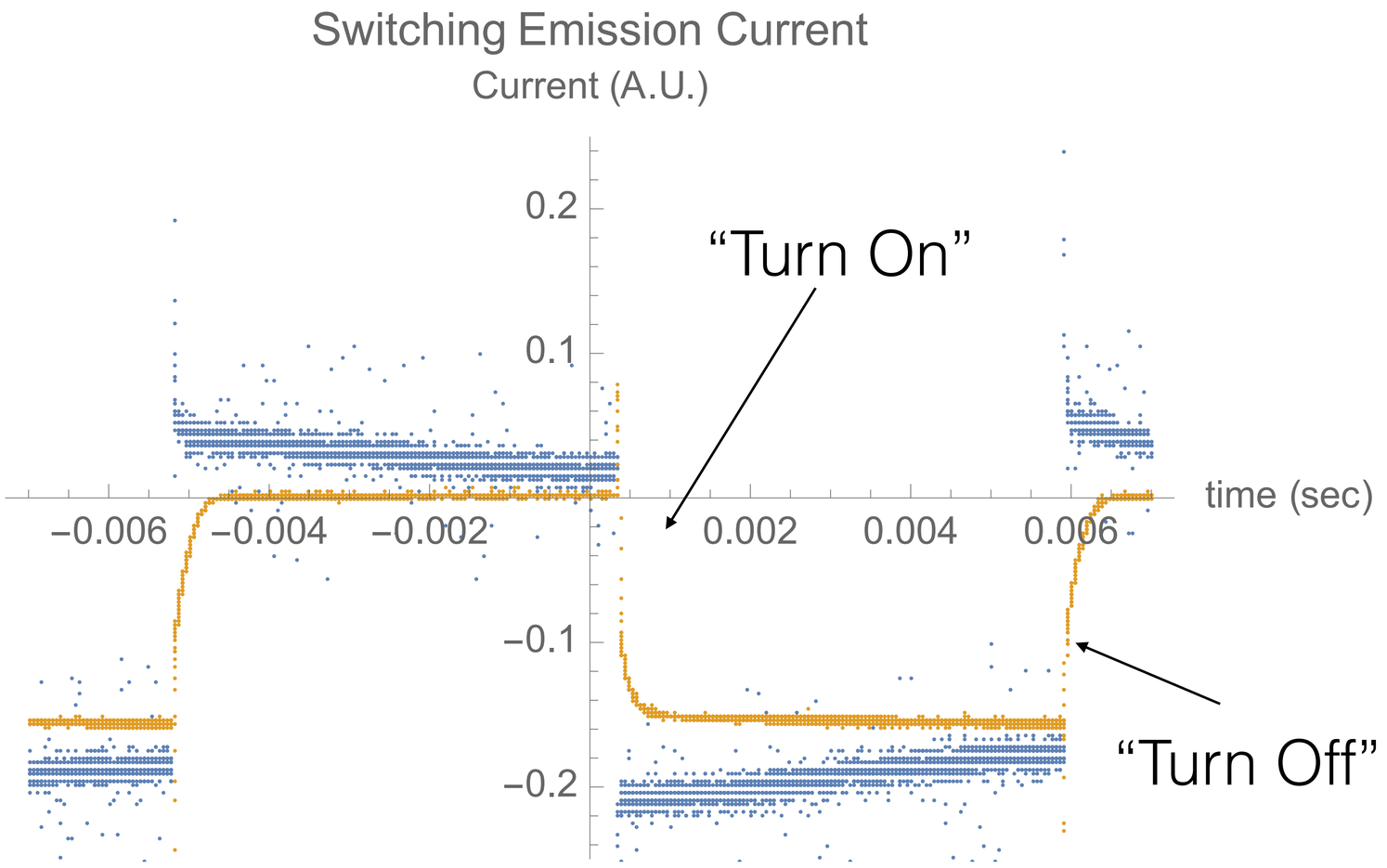
Helium





When Probe is Biased ***Negatively***
Current = Ion Saturation Current
Proportional to Plasma Density

More: What are the production rates and times?



- Emission Current (A.U.)
- Isat (A.U.)

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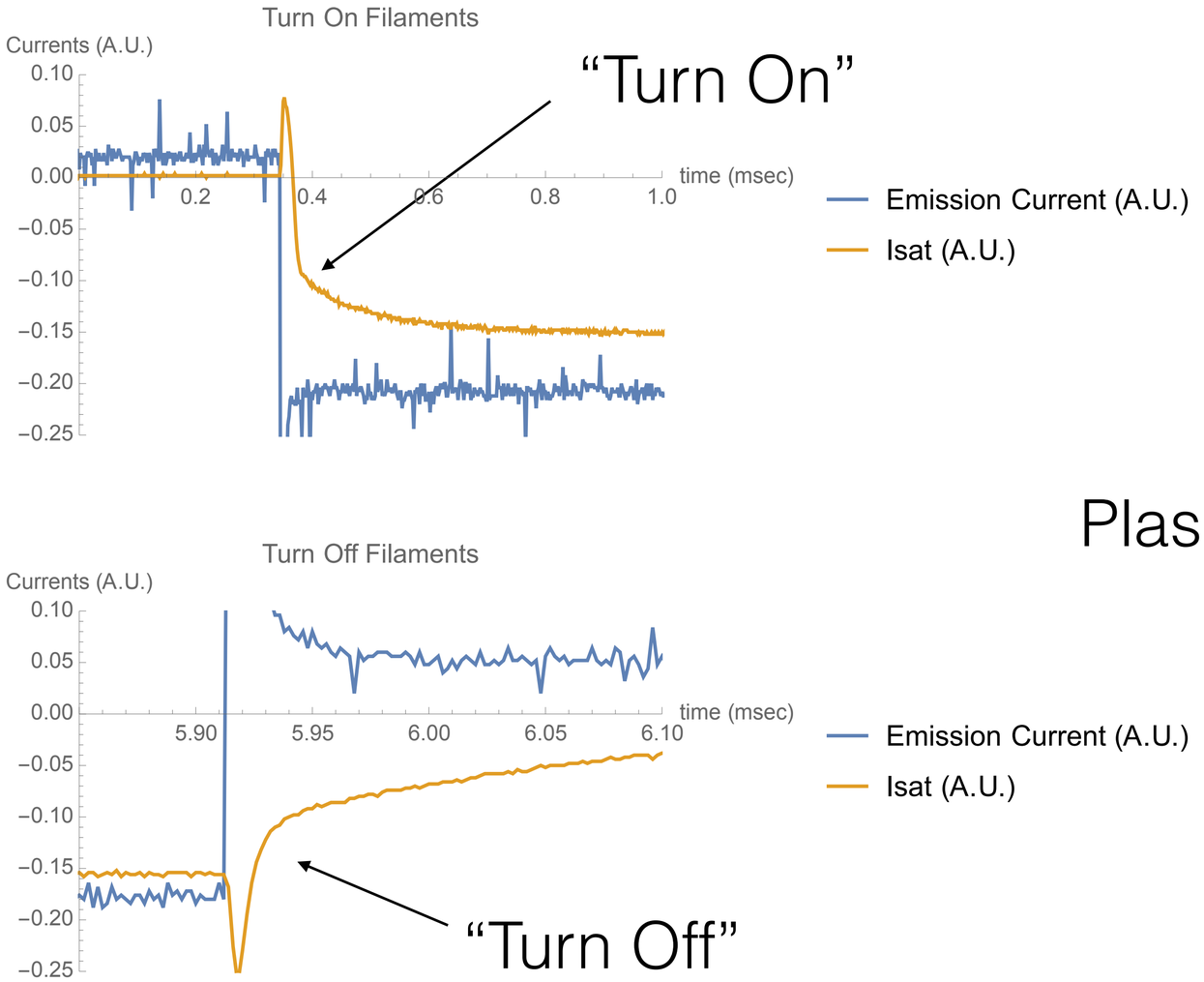

Plasma Loss Time ~ L/C_s

Summary: Plasma Part 1

- Learn how to operate a low-temperature, partially-ionized plasma source
- Measure the how the plasma density varies with filament bias voltage, gas pressure, and atomic mass
- Examine the plasma build-up and loss rates