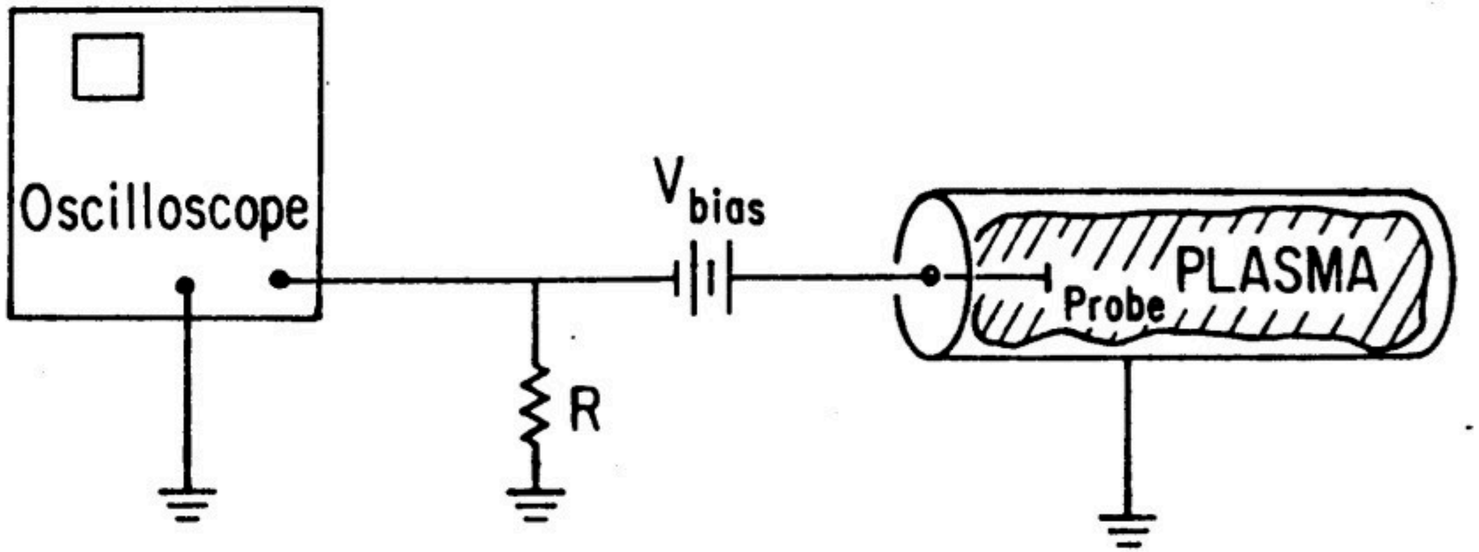
Plasma Experiment: Part 2
Langmuir Probe

AP 4018
Columbia University

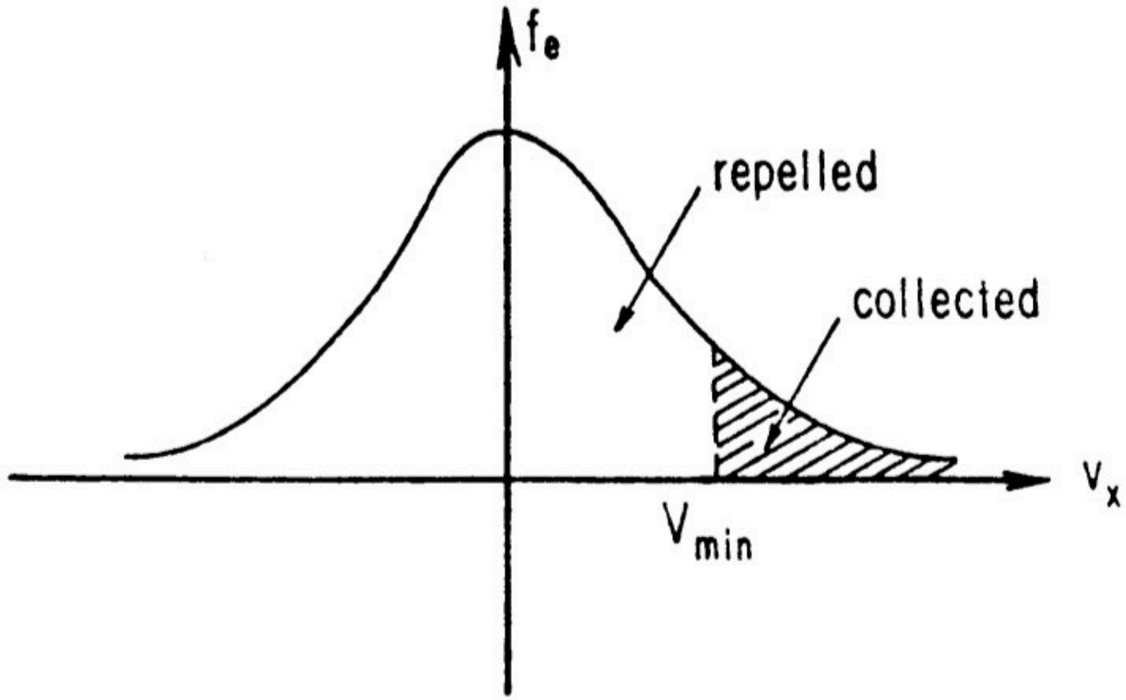
Objective

- Use a Langmuir probe to measure characteristics of the plasma and the electron distribution function
- Examine both Ar and He low-temperature discharges

What is a Langmuir Probe?



What is a Langmuir Probe?



Langmuir Probe Characteristics:
As the *difference* between the plasma and the probe voltage changes, a Langmuir probe collects different energy ranges of the particle distribution function.

Langmuir Probe ("Ideal") Characteristics

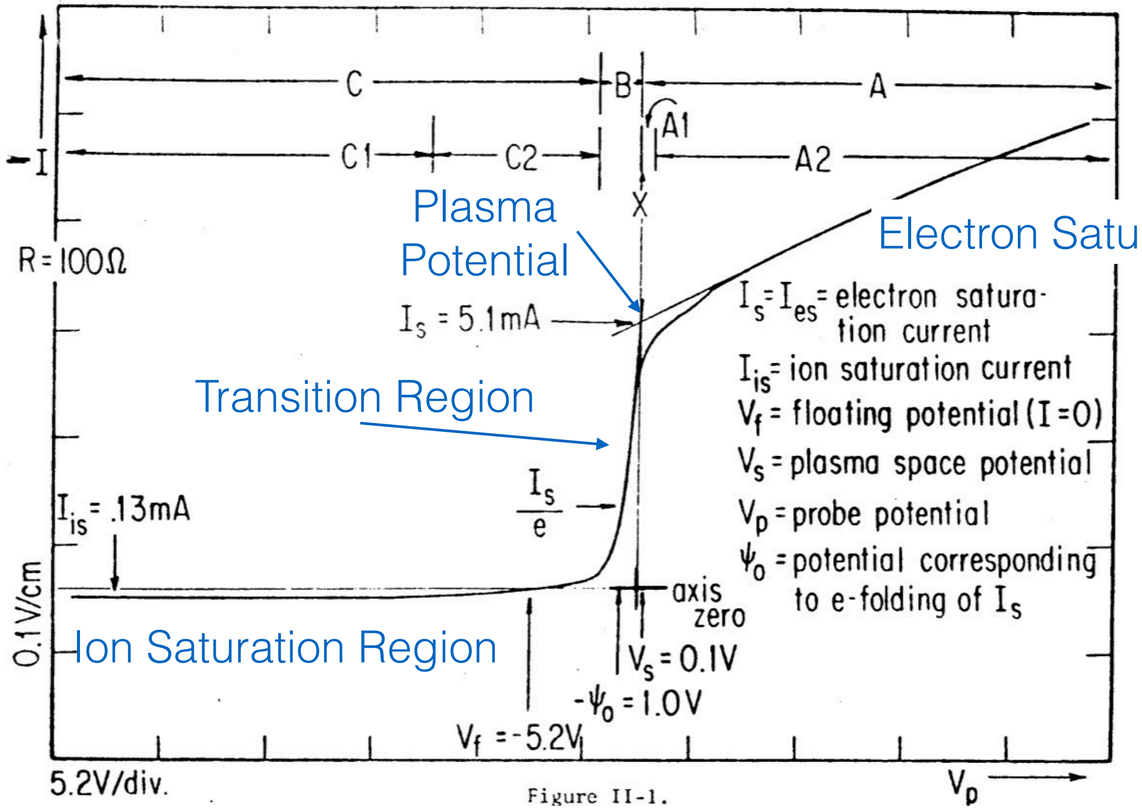


Figure II-1.

Electron Saturation Region

Floating Potential

Good Reference

Understanding Langmuir probe current-voltage characteristics

Robert L. Merlino[a)]
Department of Physics and Astronomy The University of Iowa, Iowa City, Iowa 52242

(Received 26 February 2007; accepted 14 July 2007)

I give several simple examples of model Langmuir probe current-voltage (I-V) characteristics that help students learn how to interpret real I-V characteristics obtained in a plasma. Students can also create their own Langmuir probe I-V characteristics using a program with the plasma density, plasma potential, electron temperature, ion temperature, and probe area as input parameters. Some examples of Langmuir probe I-V characteristics obtained in laboratory plasmas are presented and analyzed. A few comments are made advocating the inclusion of plasma experiments in the advanced undergraduate laboratory.
[DOI: 10.1119/1.2772282]

Am. J. Phys. **75** (12), December 2007 https://doi.org/10.1119/1.2772282

Basic Formula

Ion Current

$$I_i(V_B) = \begin{cases} -I_{is}\exp[e(V_P - V_B)/kT_i], & V_B \geq V_P, \\ -I_{is}, & V_B < V_P, \end{cases}$$

Ion Current

$$I_{is} = I_{\text{Bohm}} = 0.6en_i\sqrt{\frac{kT_e}{m_i}}A_{\text{probe}}.$$

Floating Potential

$$V_f = V_P + \left(\frac{kT_e}{e}\right)\ln\left(0.6\sqrt{\frac{2\pi m_e}{m_i}}\right)$$

$$I_e(V_B) = \begin{cases} I_{es}\exp[-e(V_P - V_B)/kT_e], & V_B \leq V_P, \\ I_{es}, & V_B > V_P. \end{cases}$$

$$I_{es} = \frac{1}{4}en_e v_{e,th}A_{\text{probe}},$$

Two-Temperature T_e: Comments

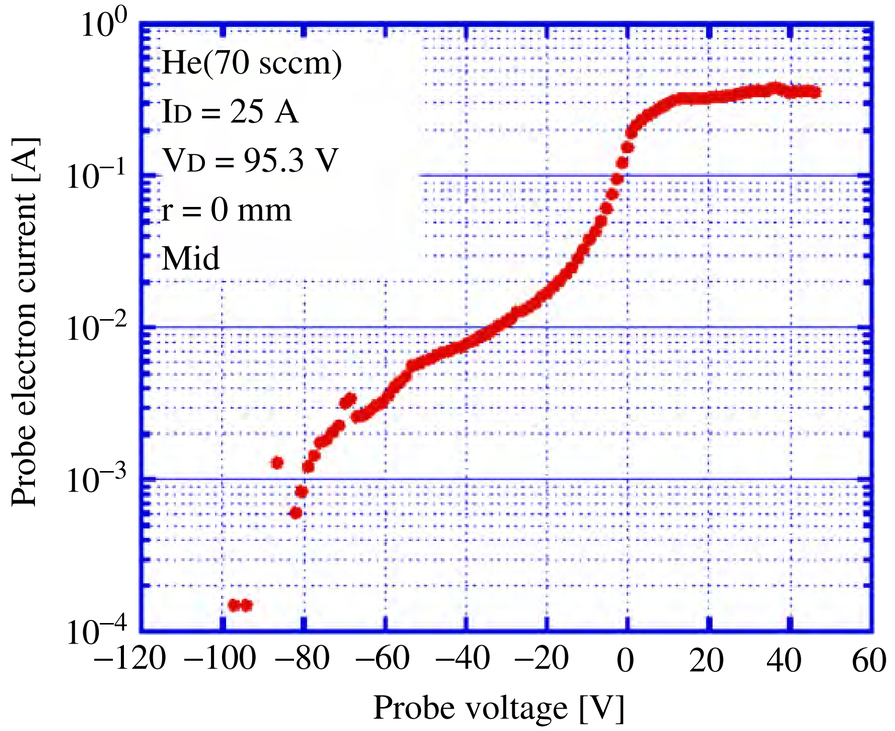


Fig. 11. Semilogarithmic plot of probe electron current versus probe voltage

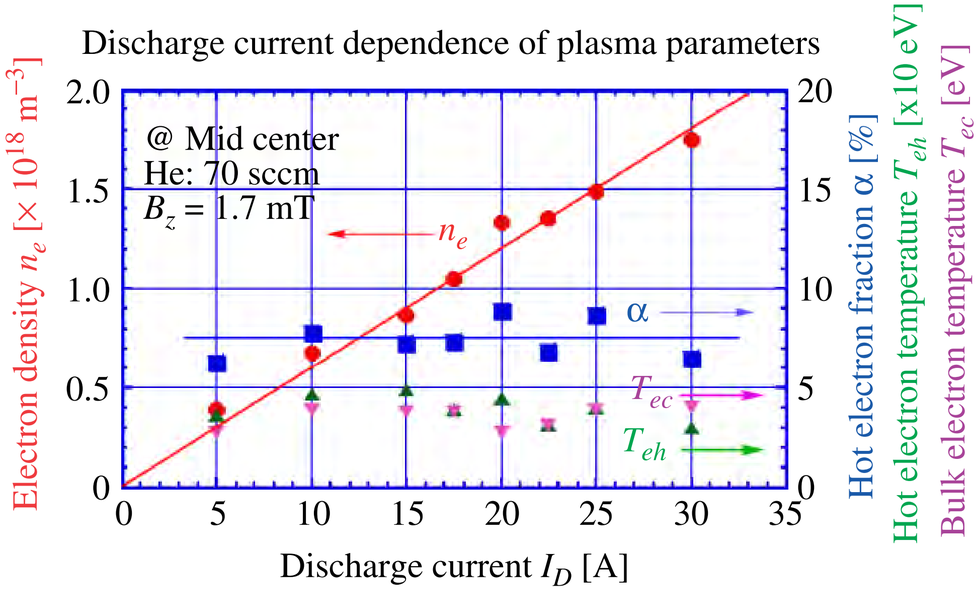
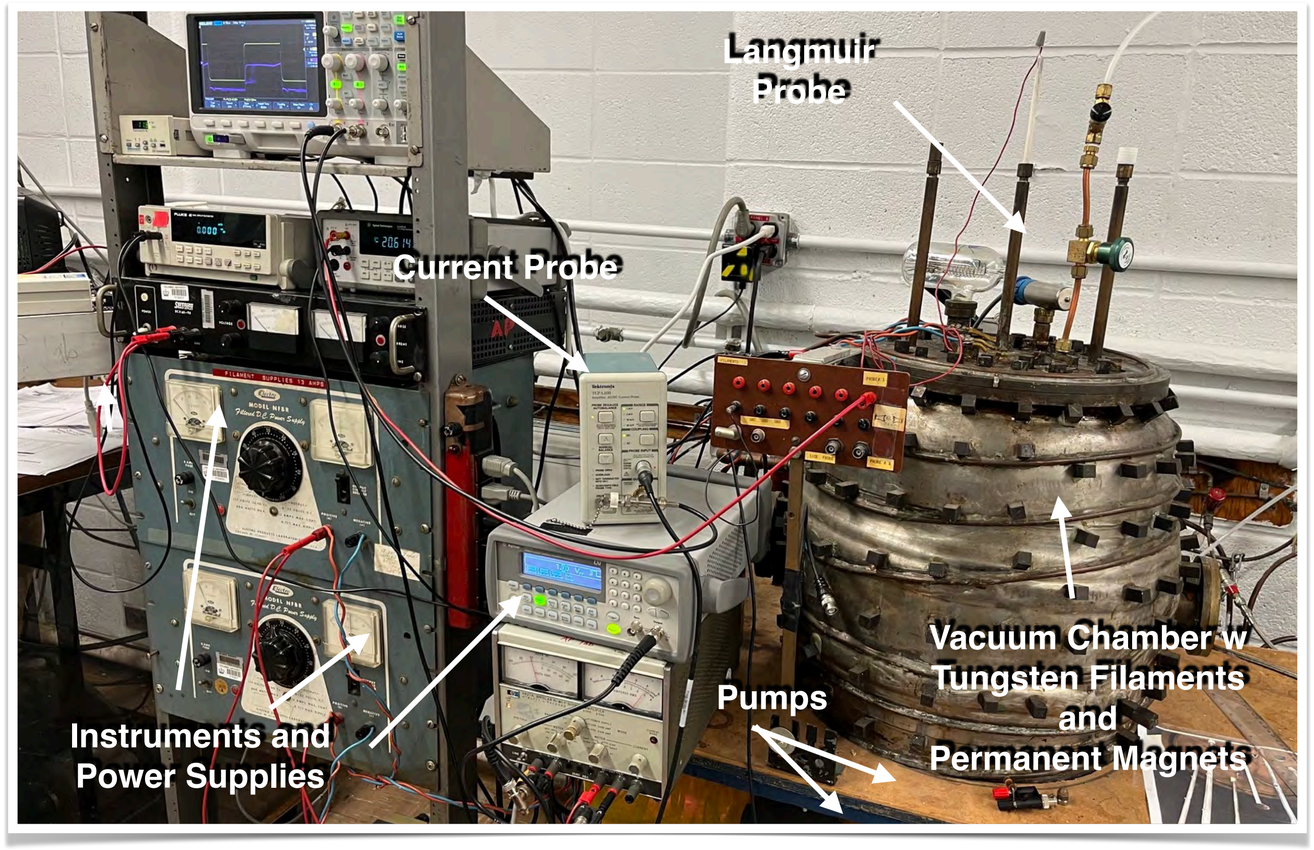
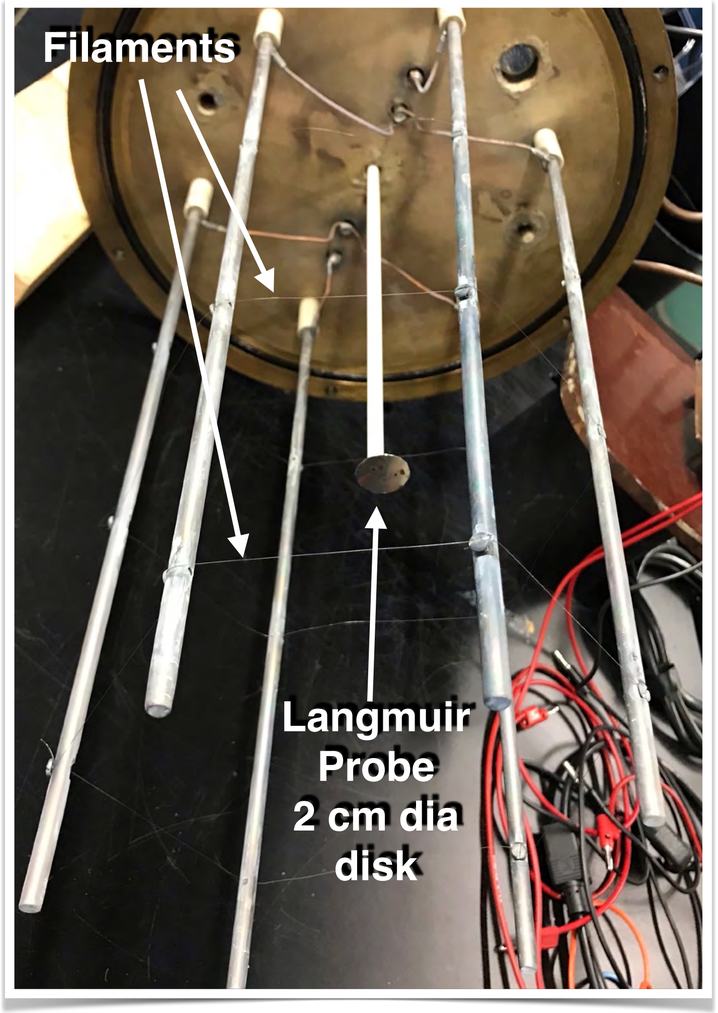


Fig. 12. Discharge current dependence of plasma parameters: the electron density, the fraction of hot electron component, and the temperature of bulk and hot electrons

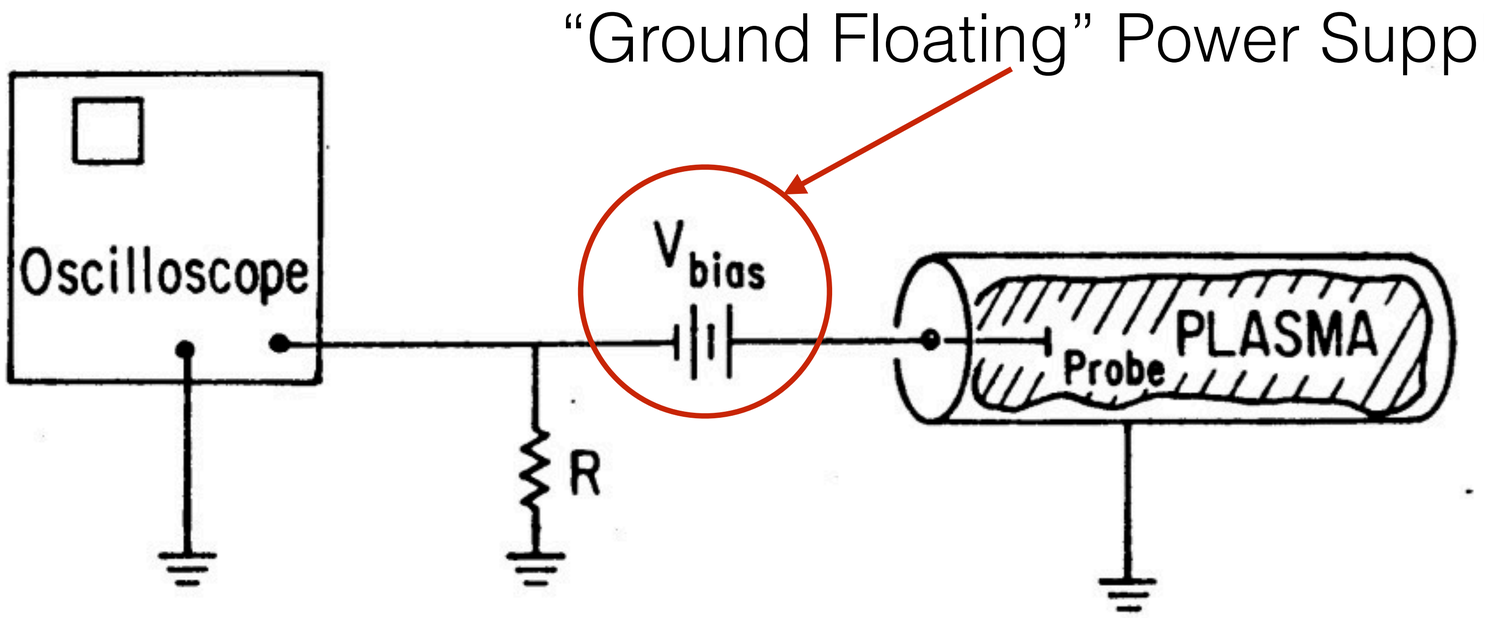
Shuichi Takamura, "Characteristics of the Compact Plasma Device AIT-PID with Multicusp Magnetic Confinement," IEEJ Trans 2012; 7(S1): S19–S24; http://doi.org/10.1002/tee.21801

Probe within Plasma Source …

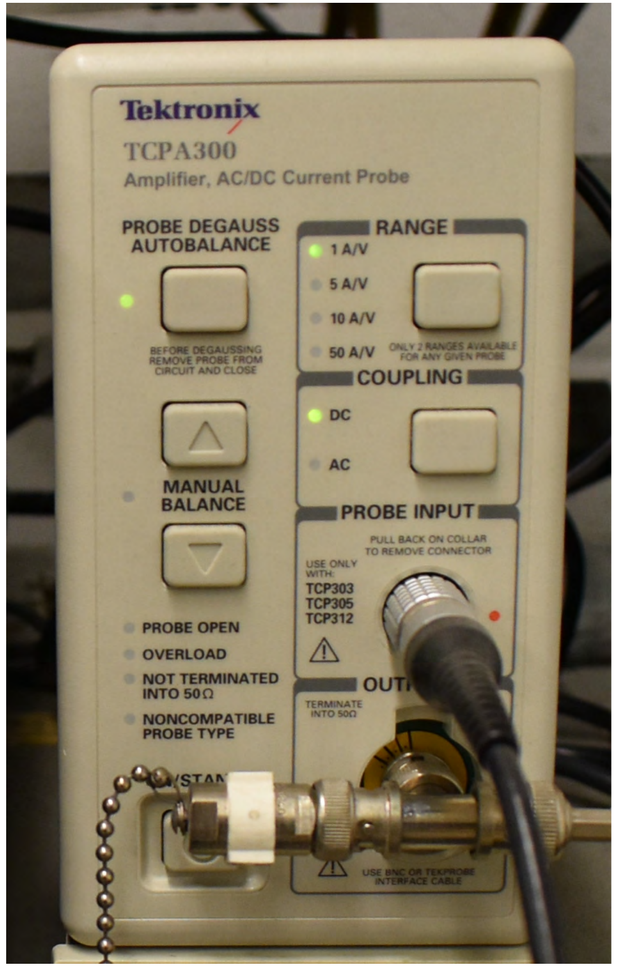




I-V Sweep for Probe Characteristics

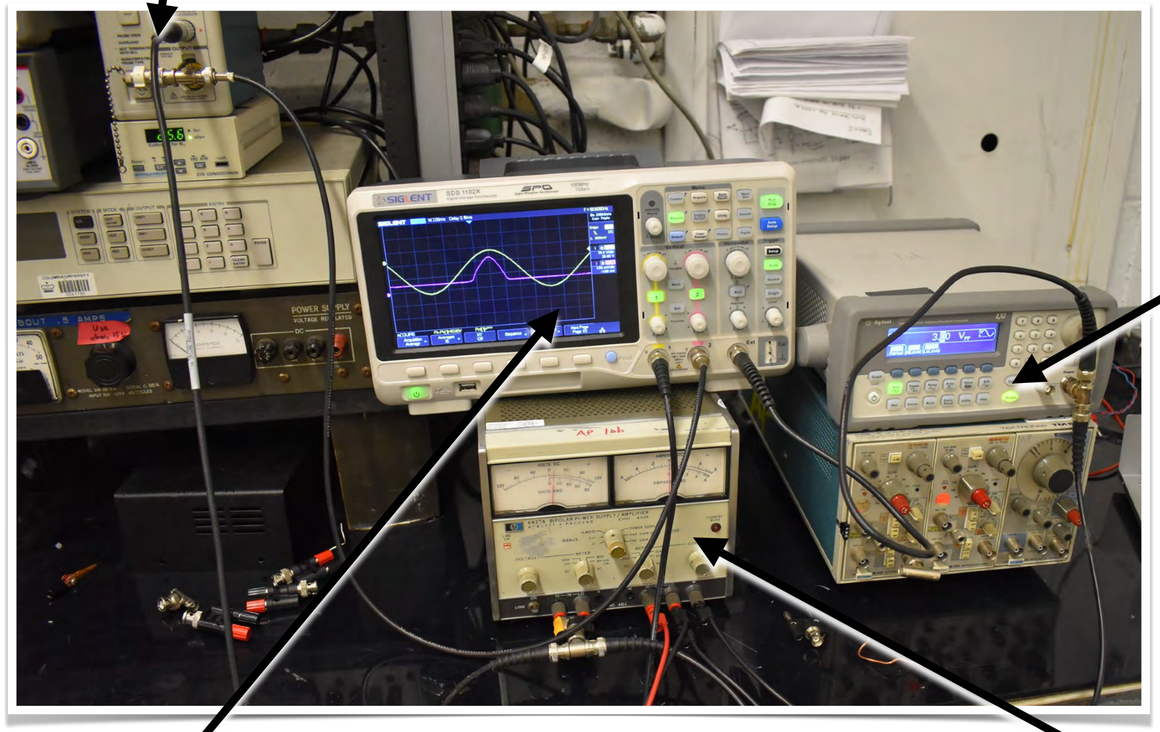


I-V Sweep First Attempt



1 V/A

Current Probe



Voltage Oscillator

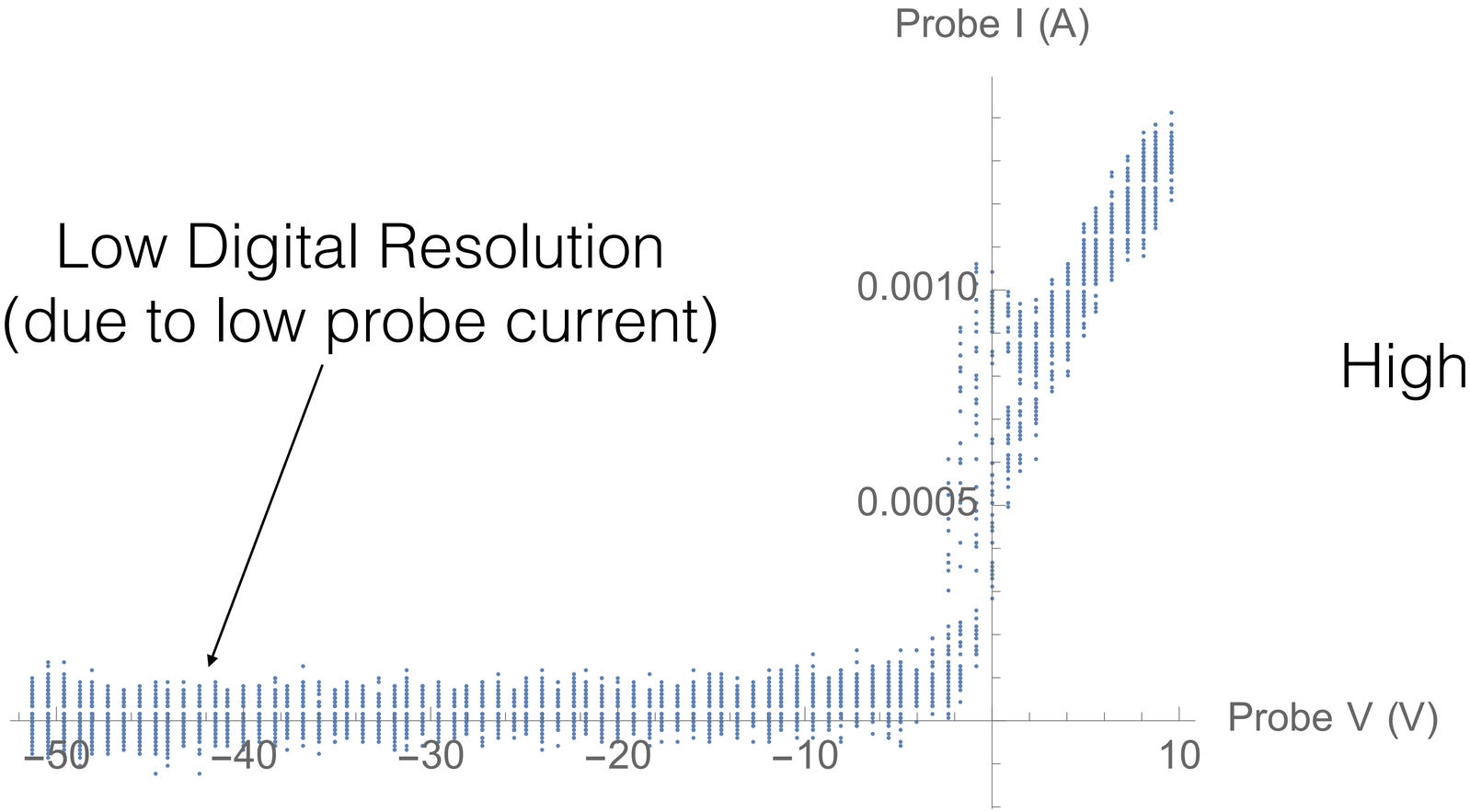
Digital Oscilloscope

Voltage x10 Amplifier

I-V Sweep: Example from Last Year
(no magnetic cusps)

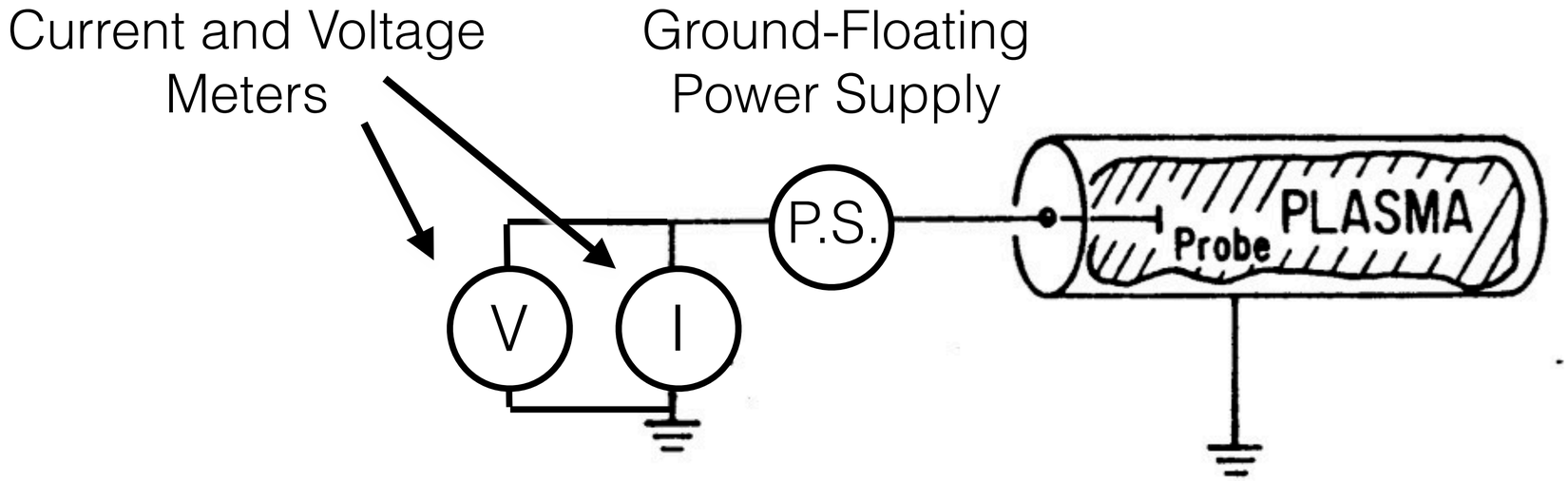
Helium @ 4.5 mTorr (Indicated) ; Filament: 75 V and 7mA emission

Low Digital Resolution
(due to low probe current)



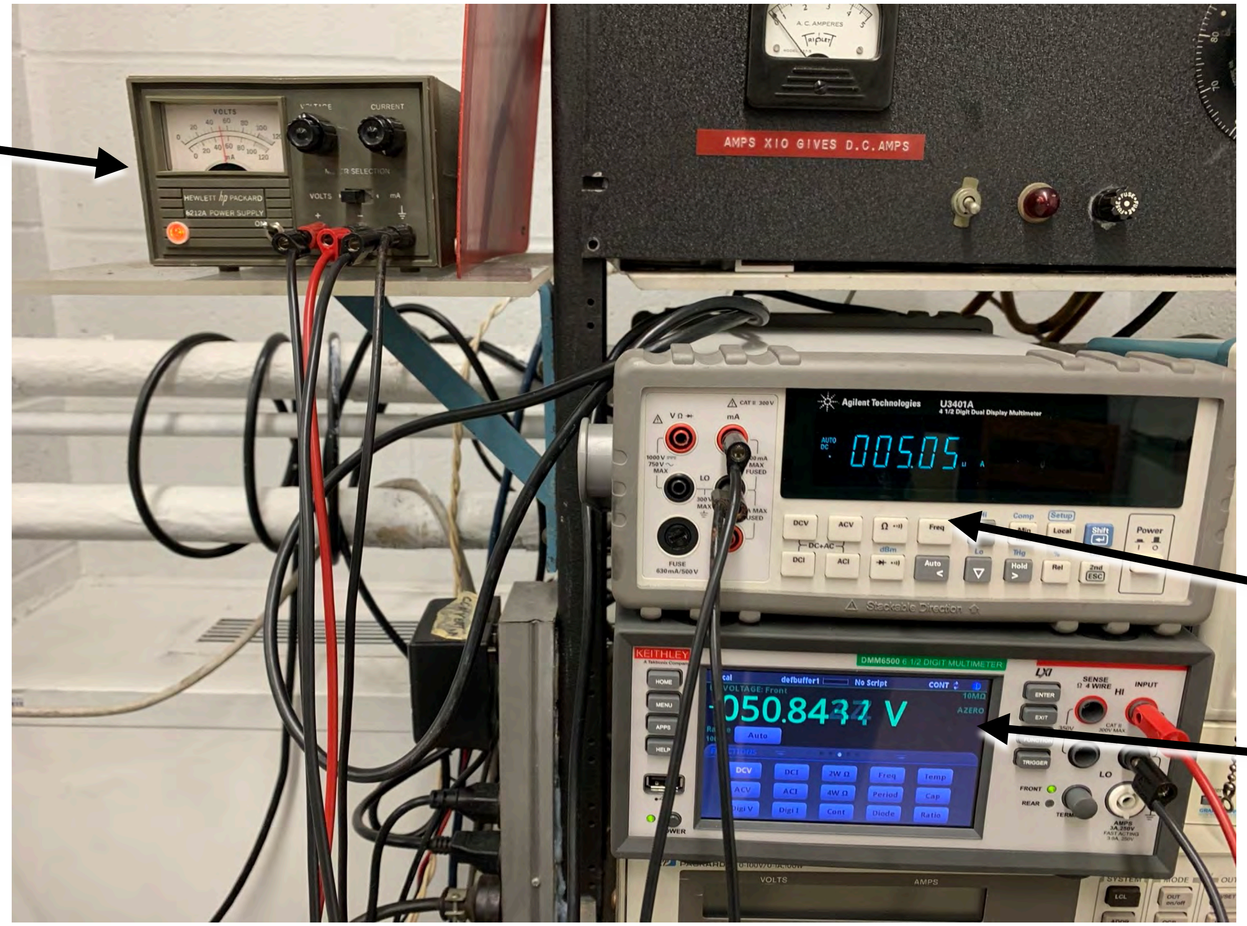
This year:
Higher Plasma Density &
Larger Probe

I-V Sweep Historical Method



I-V Sweep Historical Method

Ground-Floating
Power Supply



Current Meter

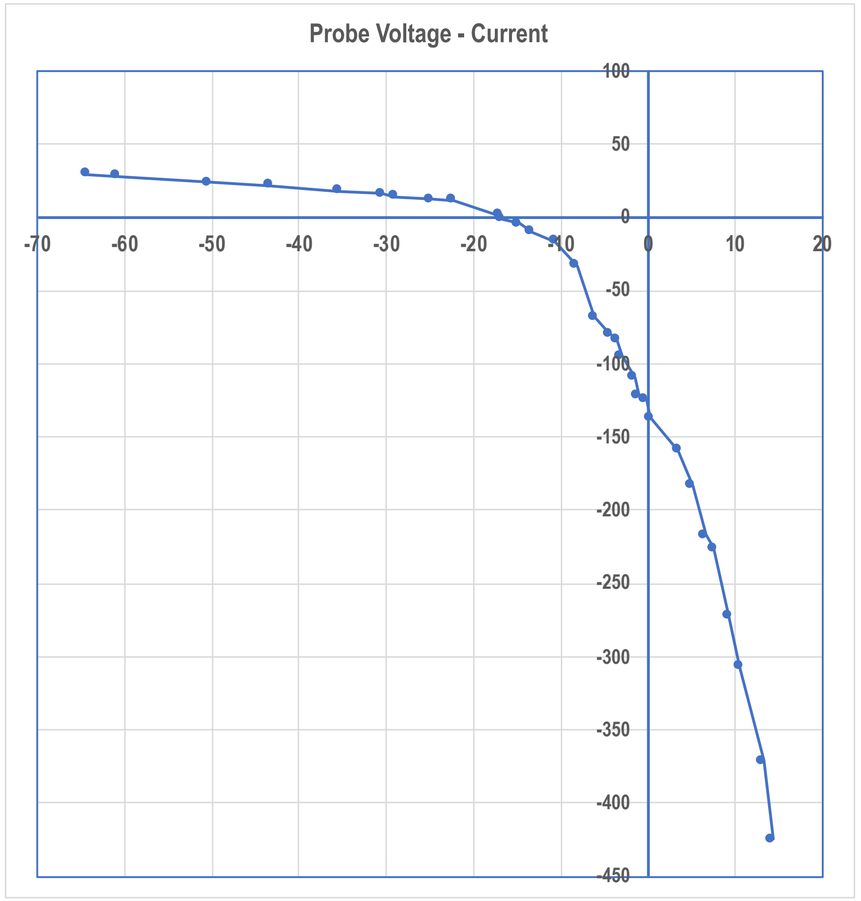
Voltage Meter

** Note: 10 MΩ

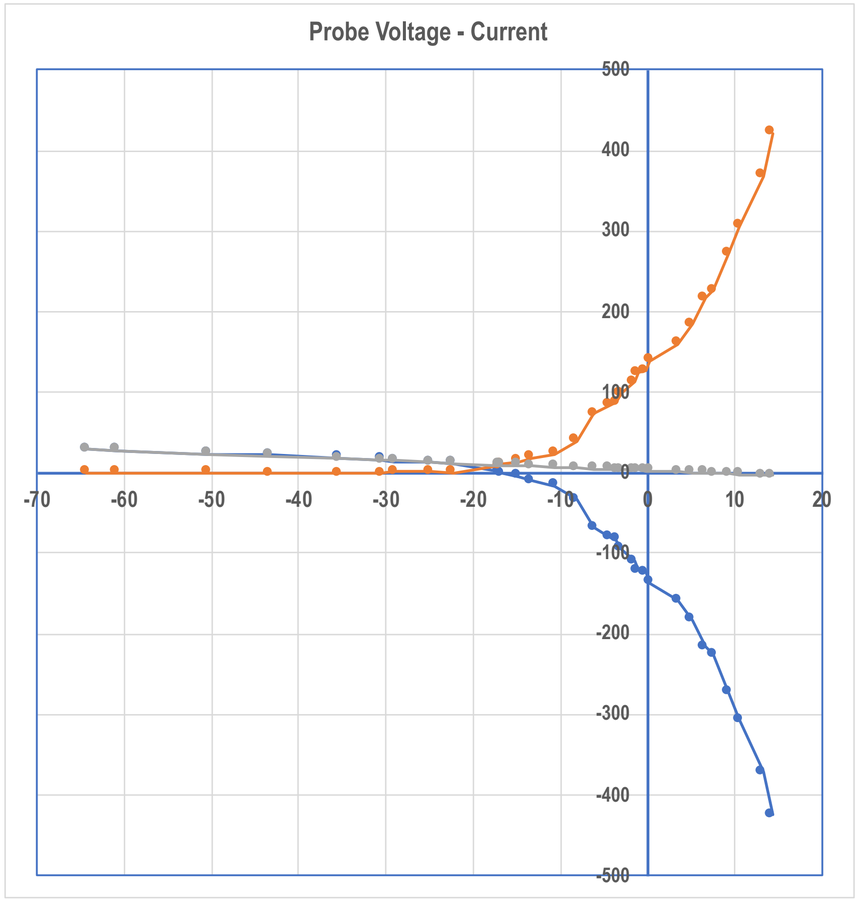
Recorded by Slow-Mo Video

I-V Sweep Historical Method: Example

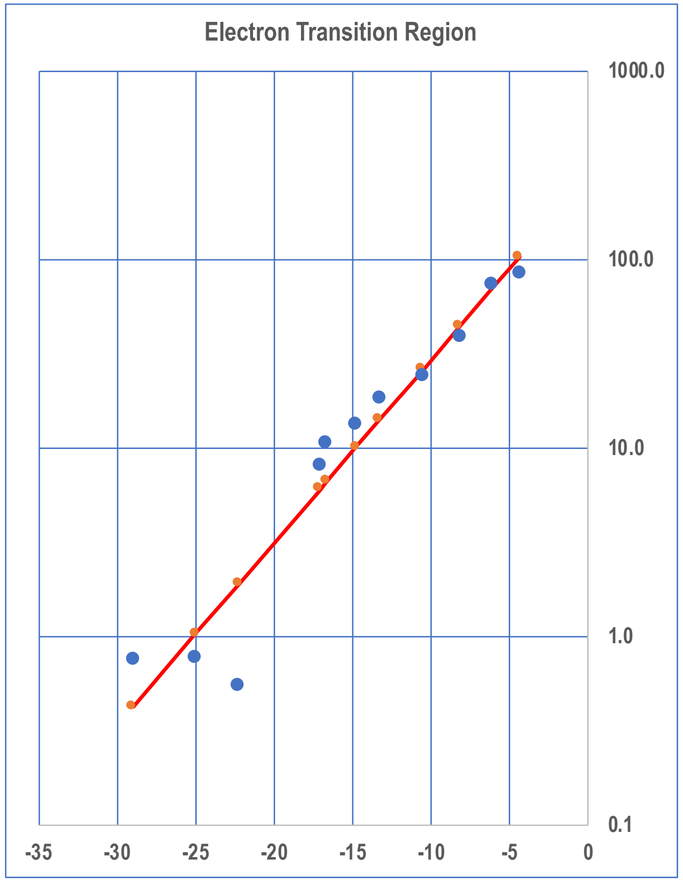
Ar @ 37 mTorr (Indicated) ; Filament: 70 V and 16 mA emission



Plasma Probe Current (subtracting 10 MΩ)



Ion and Electron Current



Electron Current Transition Region

Summary: Plasma Part 2

- Use a Langmuir probe to measure characteristics of the plasma and the electron distribution function
- Examine both Ar and He low-temperature discharges