Characterization of an Adamantane Thruster by a Langmuir Probe

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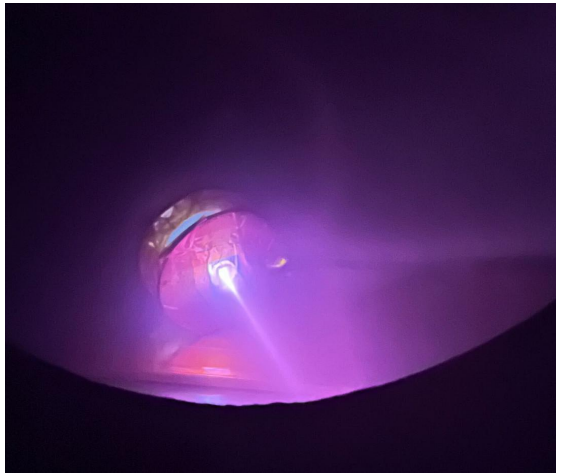
Motivations

ASPEN

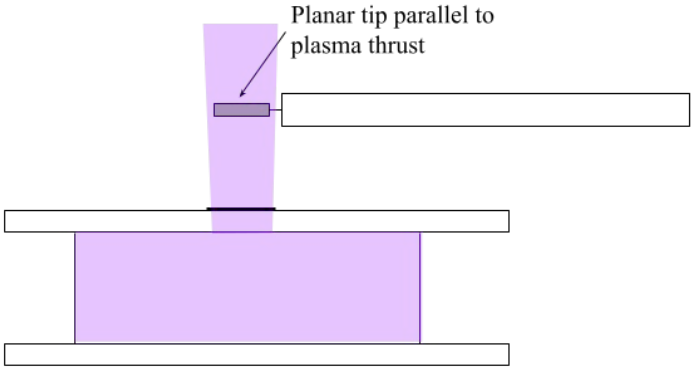
Advanced Spacecraft Propulsion & Energy Lab

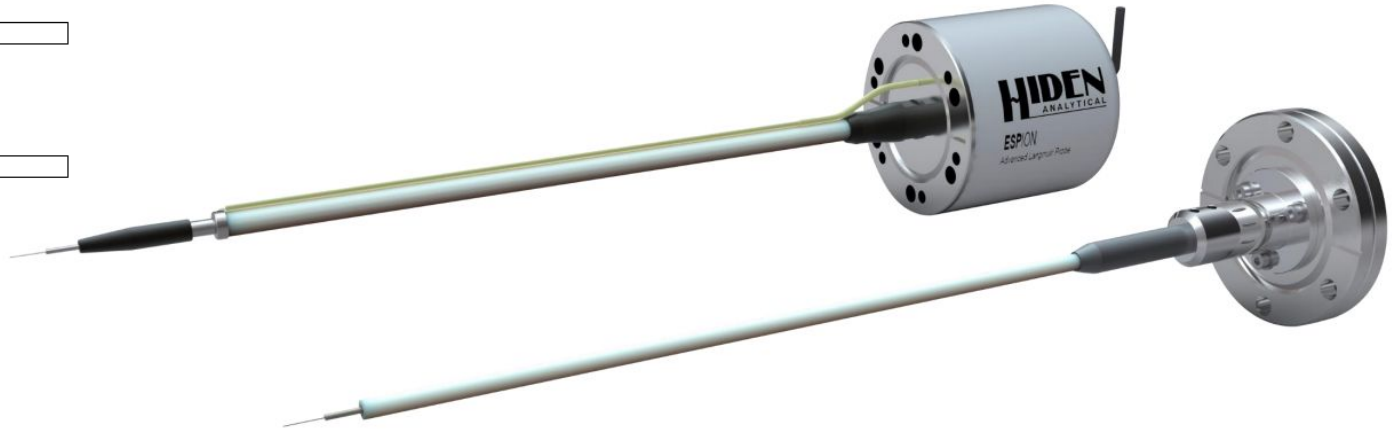
- Developing Adamantane-based electric propulsion thruster at USC ASPEN Lab
- Need to characterize the thruster
- Upcoming numerical simulations



Langmuir Probes

- Numerous methods of data collection were considered
- A langmuir probe at its core is a wire placed in to plasma

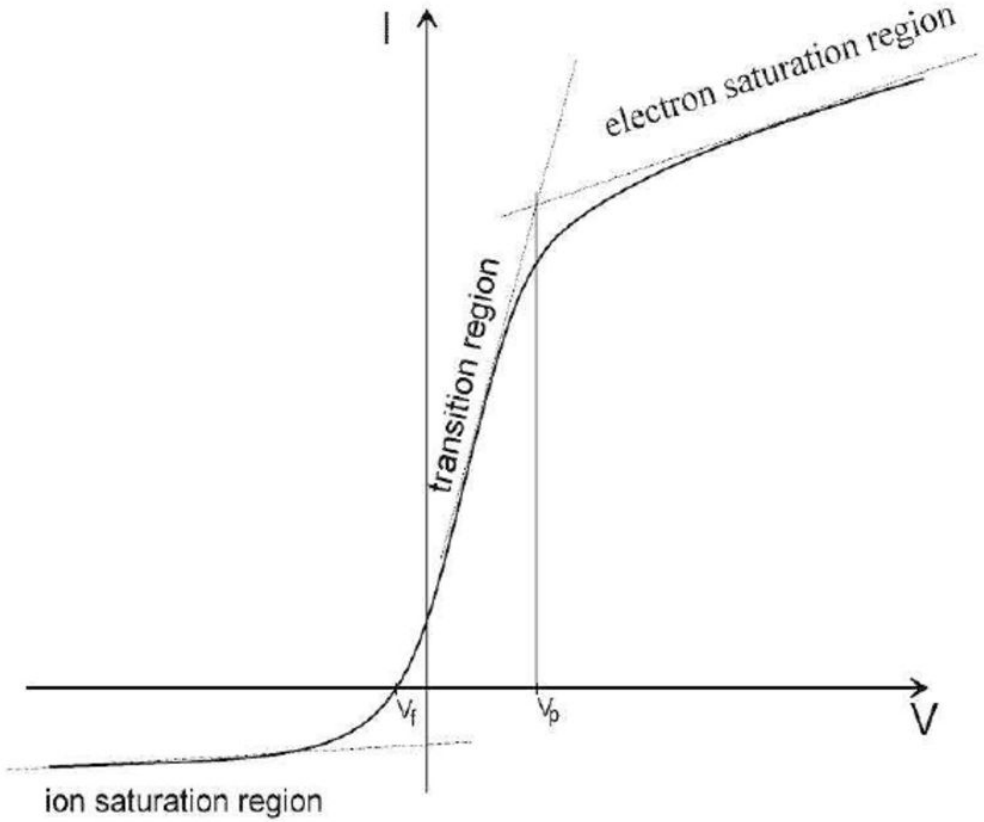




"Langmuir Probe ESPion." Direct Industry, Hidden Analytical. https://www.directindustry.com/prod/hiden-analytical/product-16750-2415737.html.

Langmuir Probes

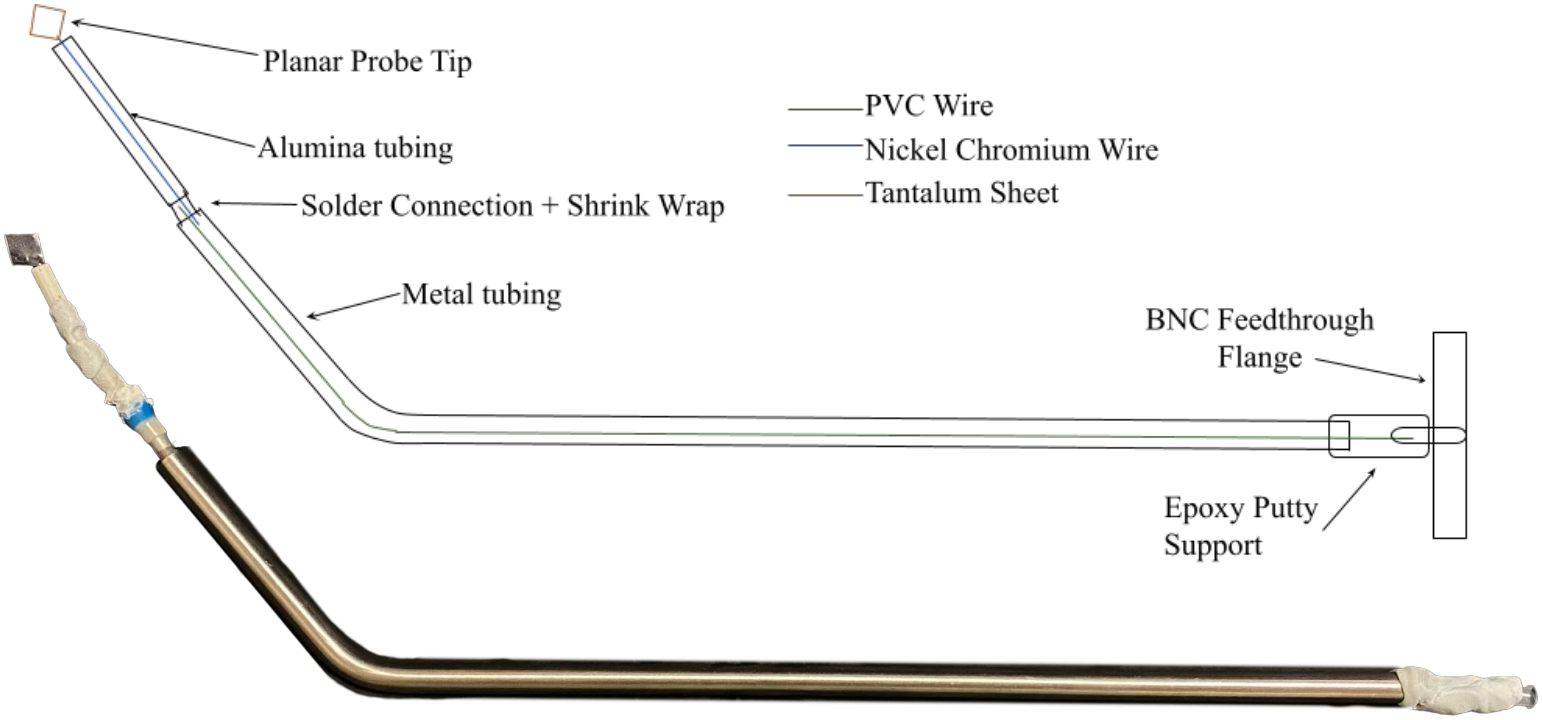
- Measures electrons and ions to produce an I-V curve
- I-V curve can be analyzed to determine plasma characteristics



Merikallio, Sini. (2007). Analysis and visualisation software for Demeter Langmuir probe instrument.

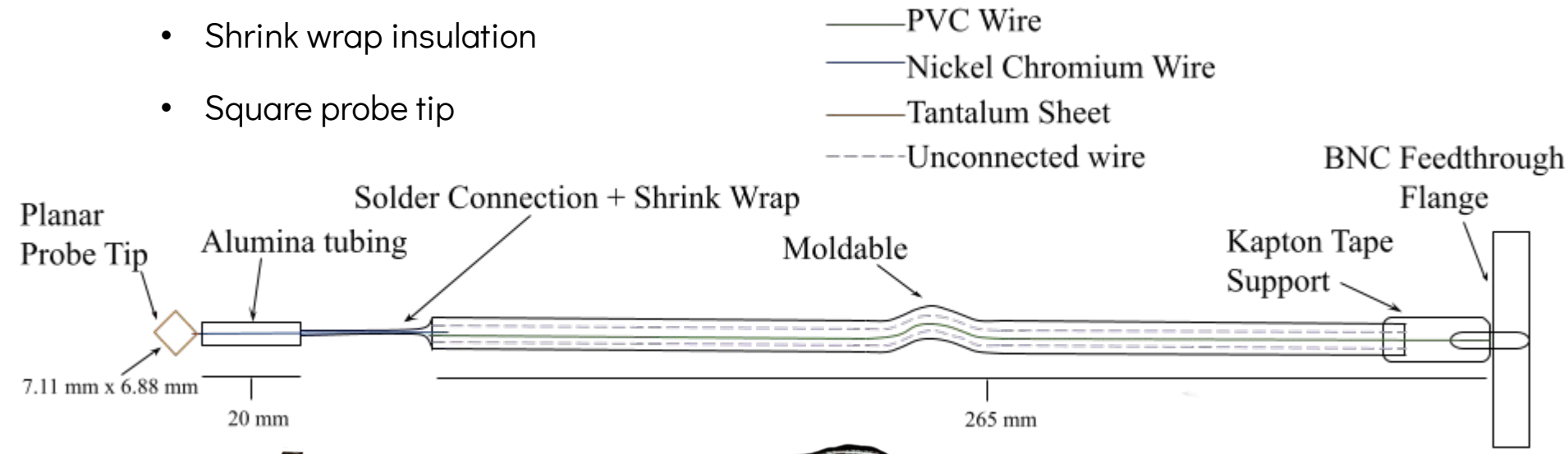
Probe Design

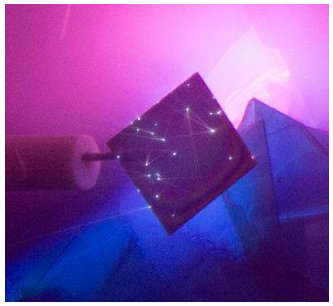
- Metal tubing exterior
- Square tantalum sheet probe tip

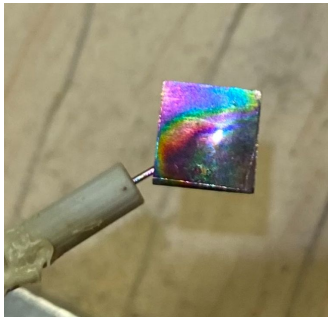


Probe Design

- Decided on moldable design for added flexibility
- Shrink wrap insulation
- Square probe tip

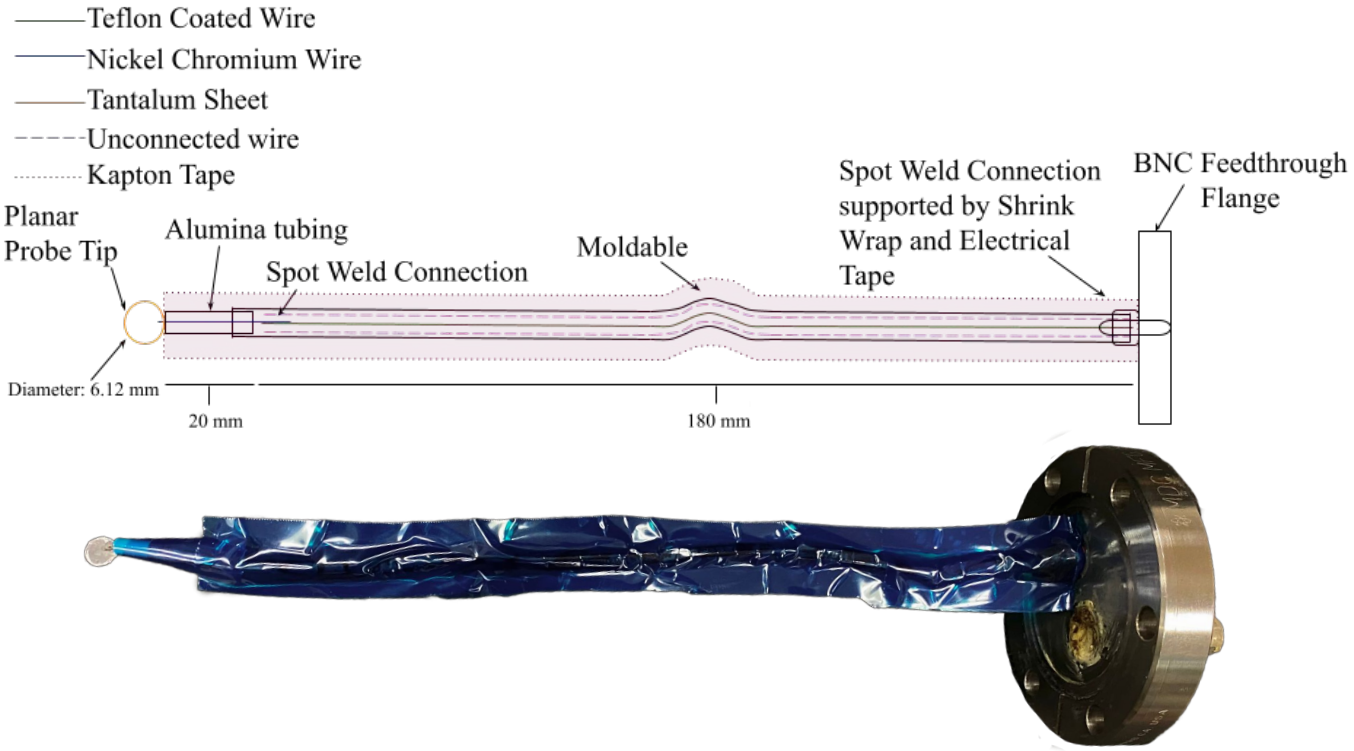






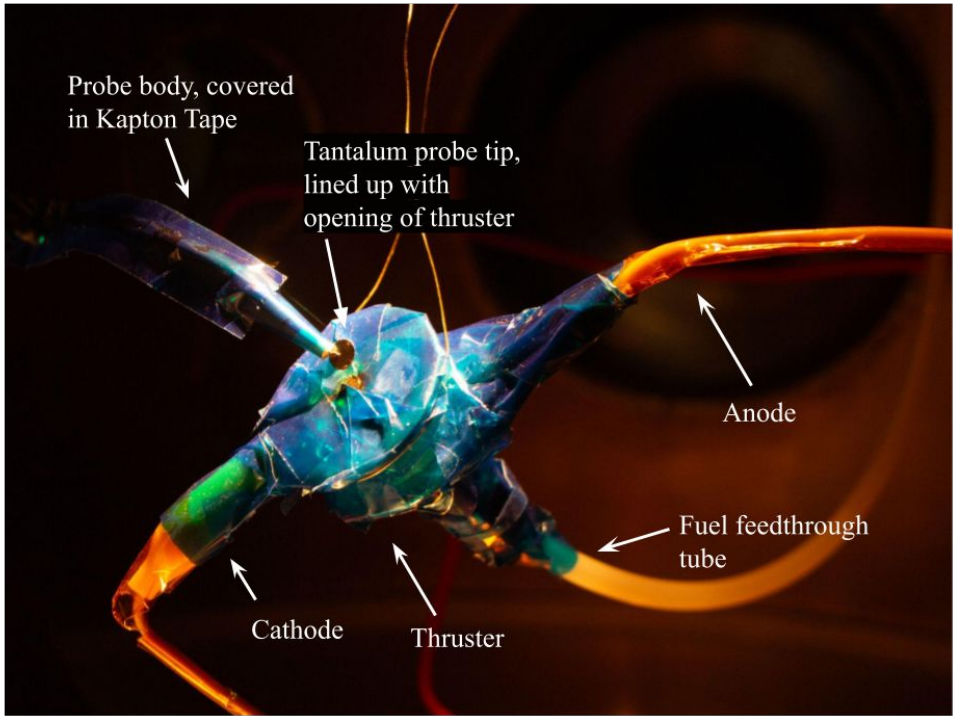
Probe Design

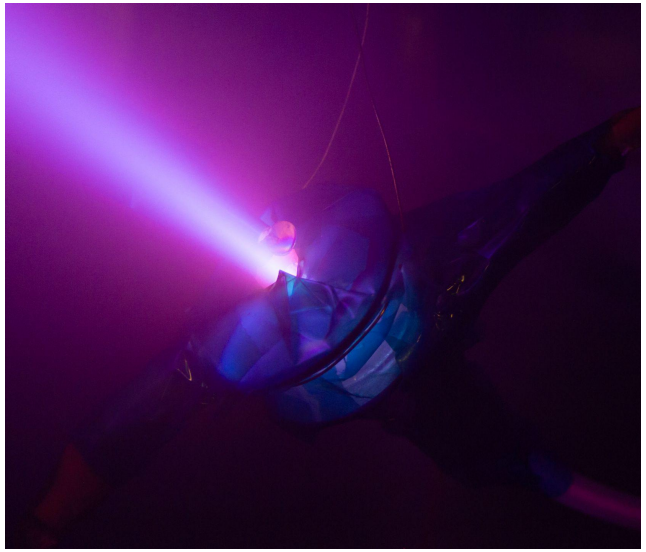
- Kept features that made the design moldable
- Added extra insulation
- Switched to a circular probe tip design

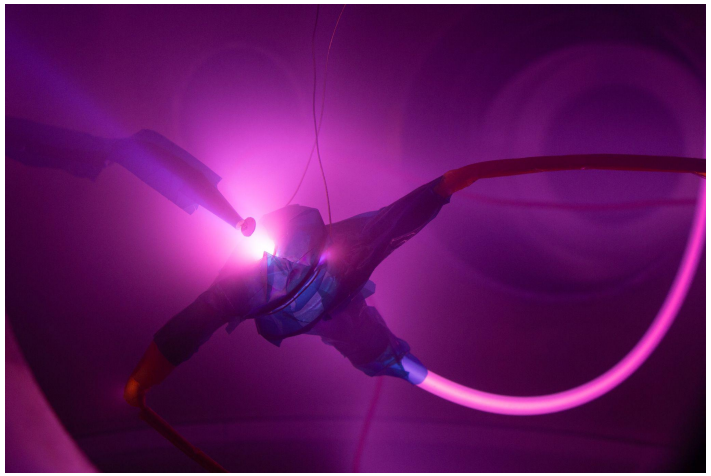


Experimental Setup

- Positioned probe tip near center of plume
- Probe tip close to plasma exit point on thruster

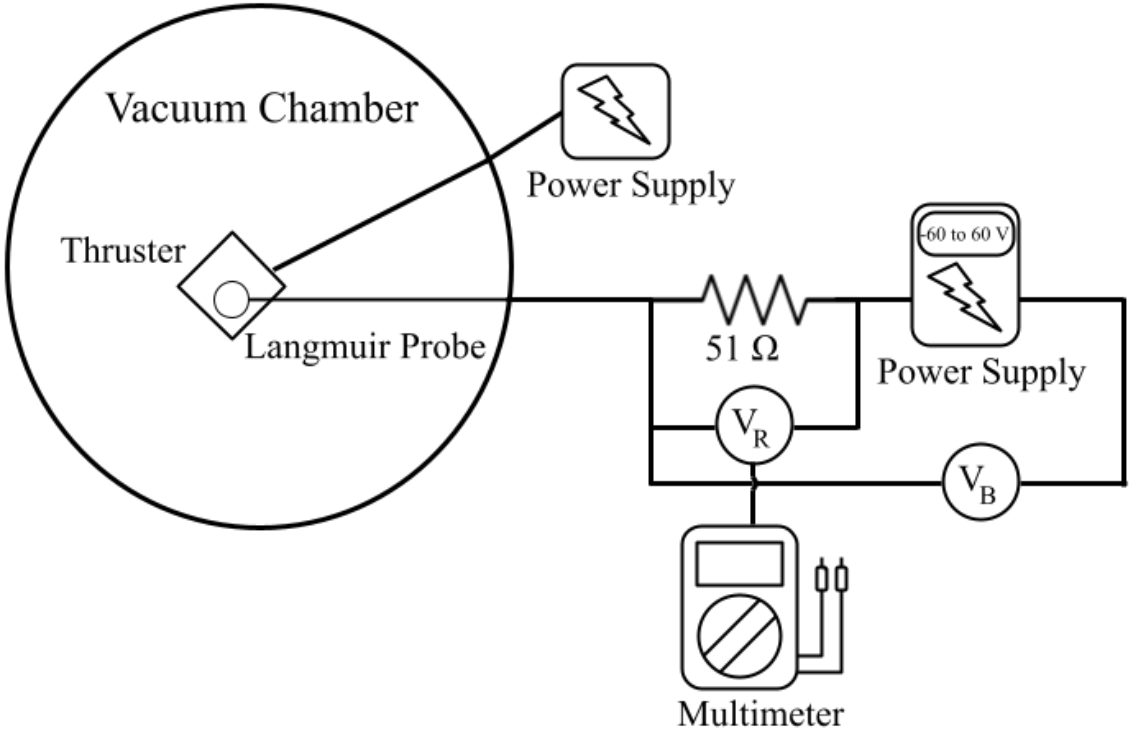






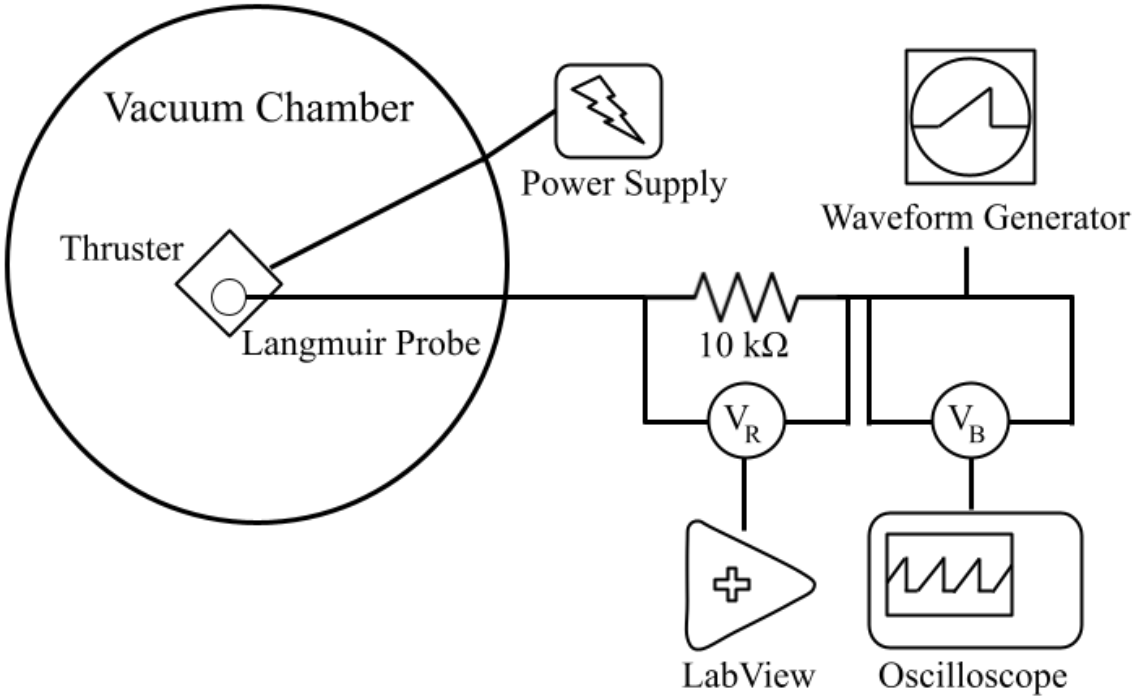
Manual Data Collection

- Manually adjusted voltage on variable power supply by increments of approximately two volts
- Bias voltage was stepped from -60 V to 60 V
- Experiment run at 50-150 mTorr



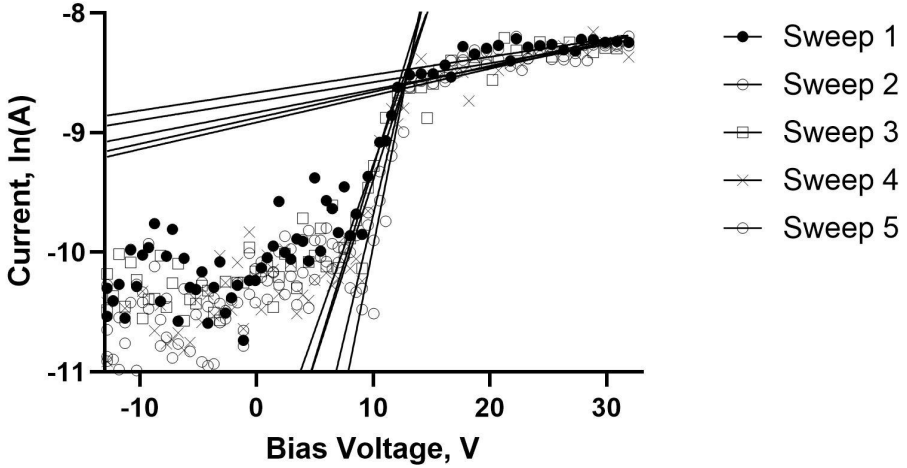
Automated Data Collection

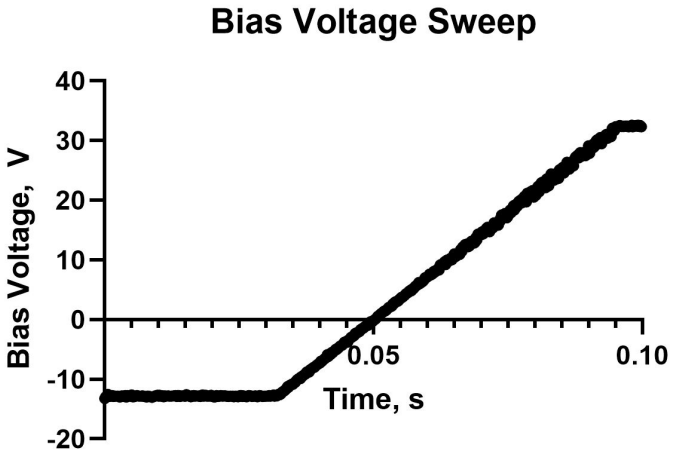
- A waveform generator varies a voltage in a sawtooth waveform (measured by an oscilloscope) and the voltage over a 10 kΩ resistor is measured using an analog DAQ device connected to LabView
- Experiment run at 120 ± 5 mTorr

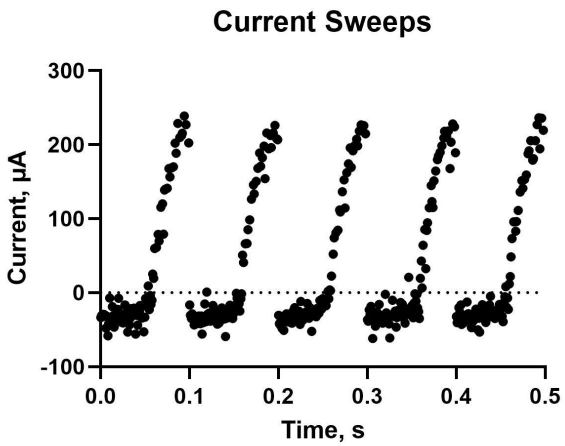


Data Processing

- Collected data with LabView
- Processed to create I-V curve







Data processed from ambient plasma

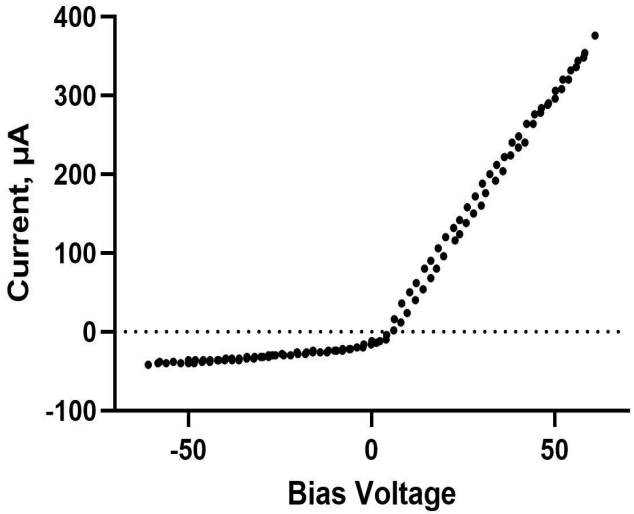
Results

- Propellant flow produced higher electron densities and temperatures
- Data collection methods produced differing values

	Automated Data Collection		Manual Data Collection	
Property	Ambient Plasma	Propellant Flow	Ambient Plasma	Propellant Flow
n_e, m^{-3}	$4.17 \times 10^{17} \pm 10.9\%$	$5.79 \times 10^{17} \pm 11.9\%$	1.4×10^{15}	1.53×10^{15}
T_e, eV	$2.90 \pm 22.0\%$	$5.68 \pm 18.1\%$	8.2	22.8
Φ_p, V	$12.63 \pm 2.3\%$	$12.32 \pm 5.1\%$	15.4	61.9
Φ_f, V	$9.90 \pm 6.4\%$	$5.39 \pm 30.5\%$	4.49	-1.25

Discussion

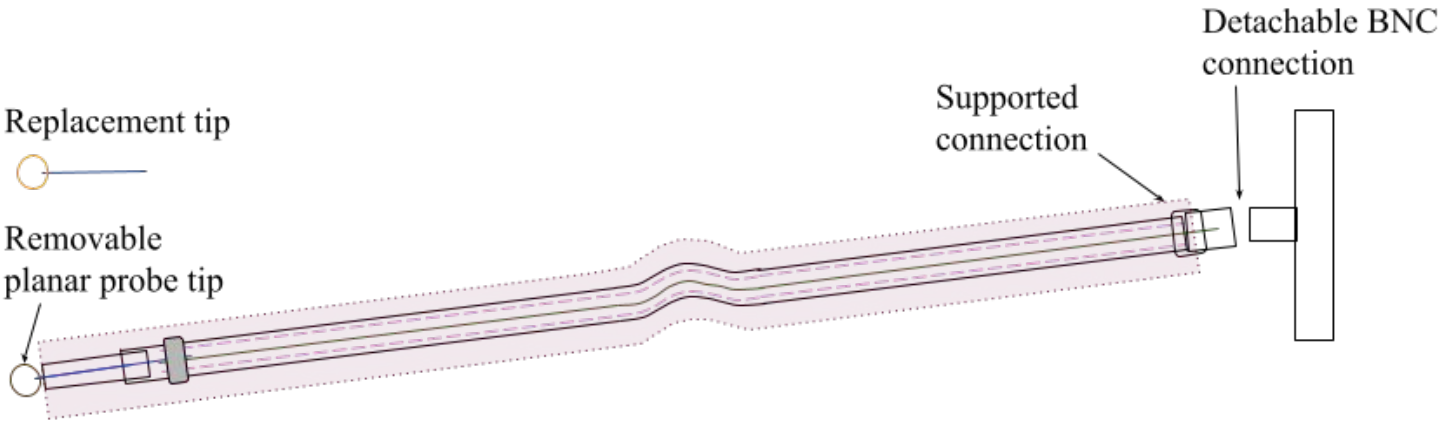
- Methods differ in results, but both indicate electron density and temperature values for propellant flow is higher than for ambient plasma
- Many assumptions were made, such as the plasma being relatively cool
- Error was observed in data collection, potentially originating from a slow sweep time or a probe contamination.



Hysteresis observed in the I-V curve of ambient plasma recorded manually

Future Plans

- Modular probe design to allow for more rapid iteration
- New thruster to be tested
- Future development of more diagnostic tools



Q & A

Contact Information

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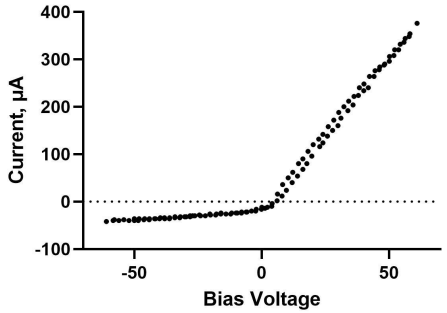
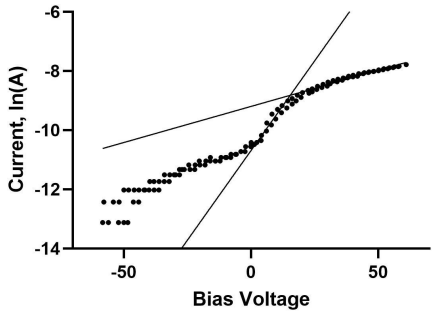
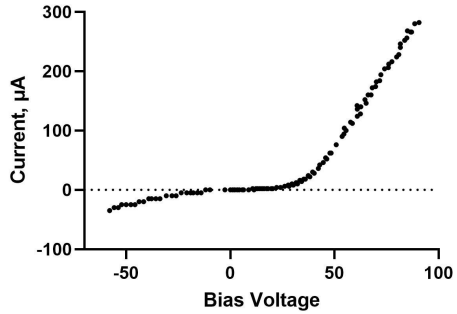
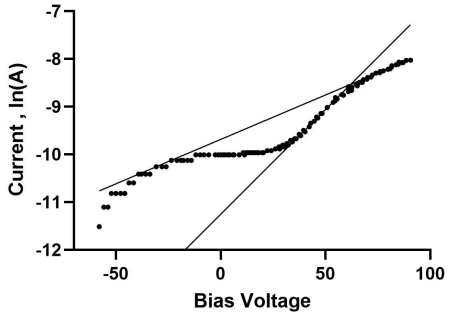
Bonus slides





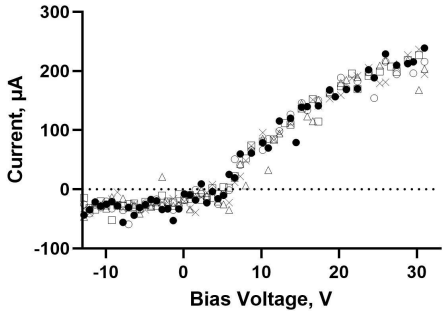
Data from automated method showing a) I-V trace of the probe in ambient plasma and b) $\ln(I_{probe}-I_{sat})$ plotted against bias voltage.

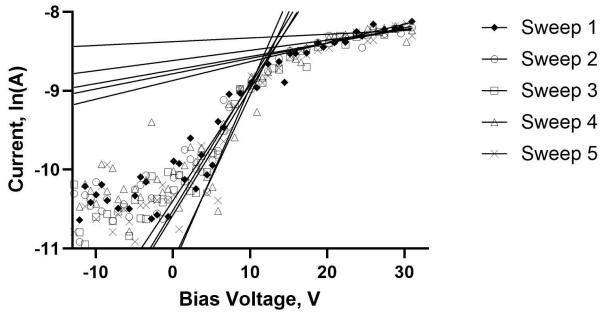




Data from manual method showing a) I-V trace of the probe in adamantane plasma and b) $\ln(I_{probe}-I_{sat})$ plotted against bias voltage.

Bonus slides





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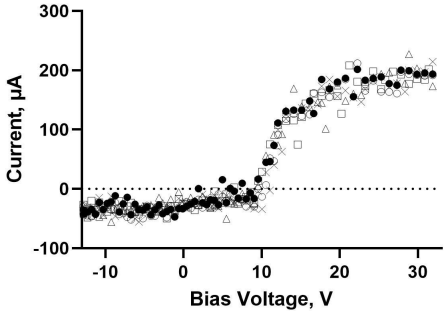

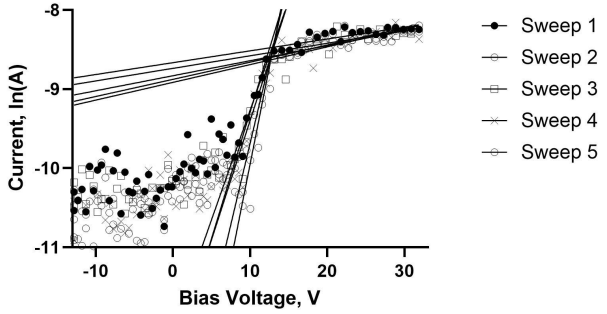

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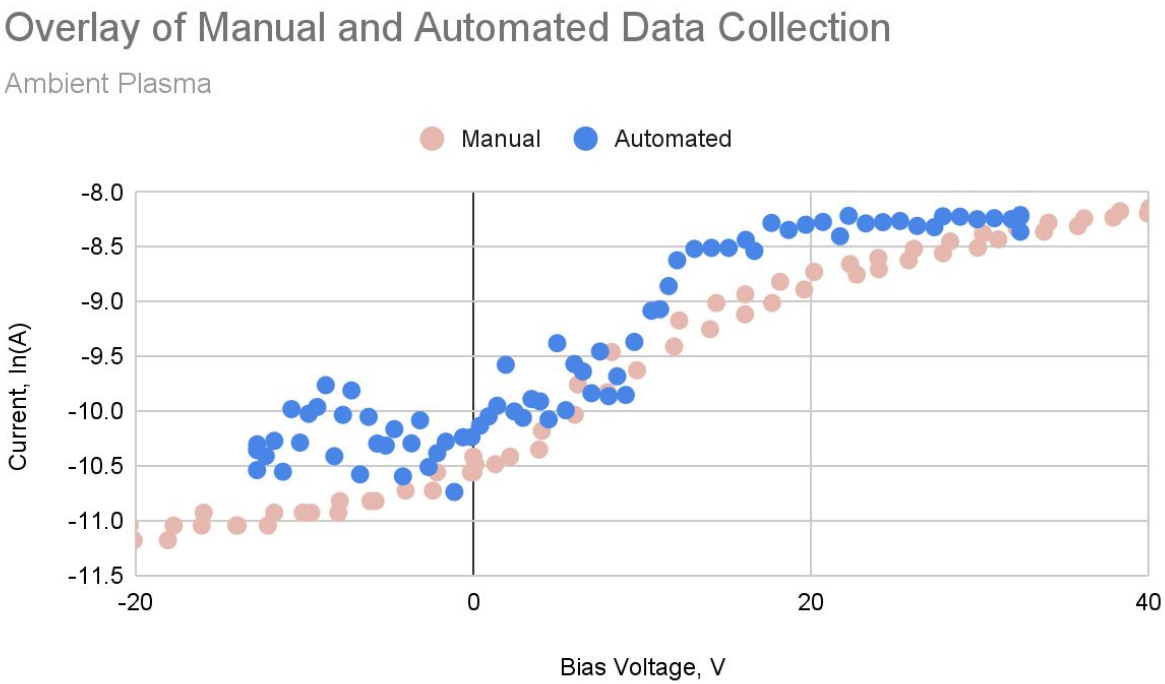


Bonus slides

$$I_{sat} = \quad - I_{probe} \tag{1}$$

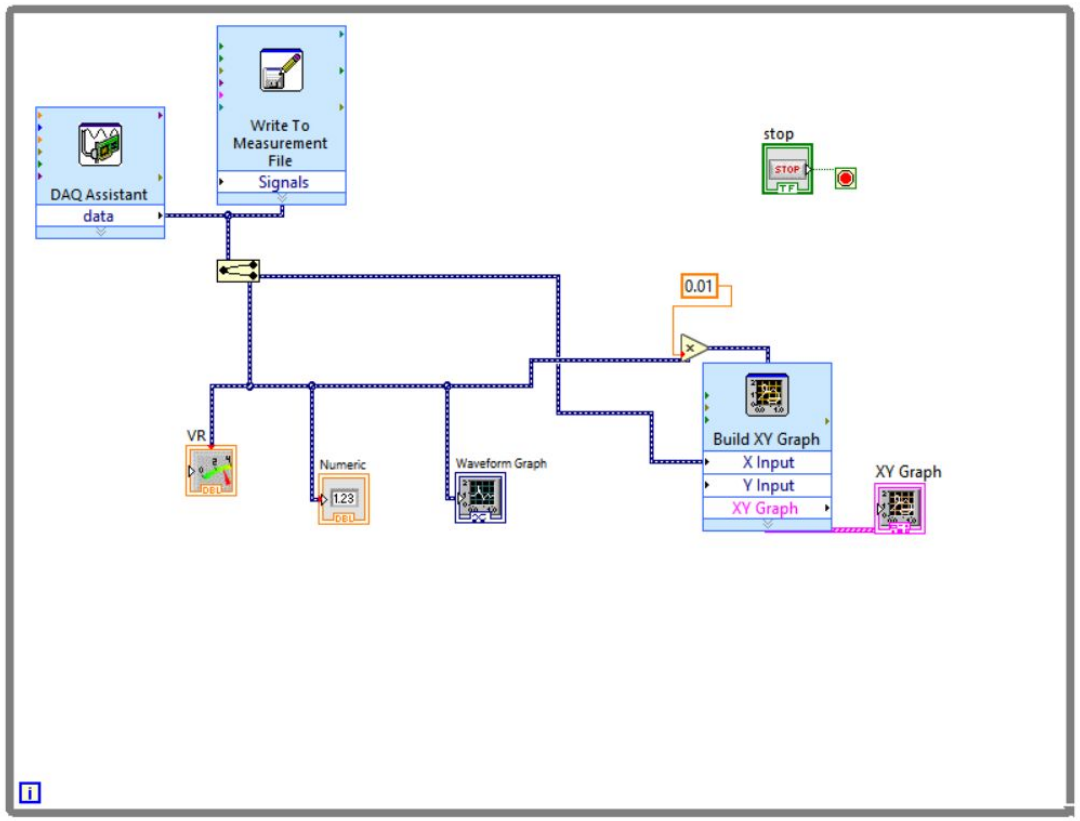
$$ln(I_{probe} - I_{sat}) = q(V_{bias} - \phi_f)/kT_e \tag{2}$$

$$slope = \frac{q}{kT_e} \tag{3}$$

$$I_{sat} = I_{bohm} = 0.6qA_s qn_e \sqrt{\frac{k_b T_e}{M}} \tag{4}$$

$$n_e = \frac{I_{sat}}{qA_s 0.6} \sqrt{\frac{M}{k_b T_e}} \tag{5}$$

Bonus slides



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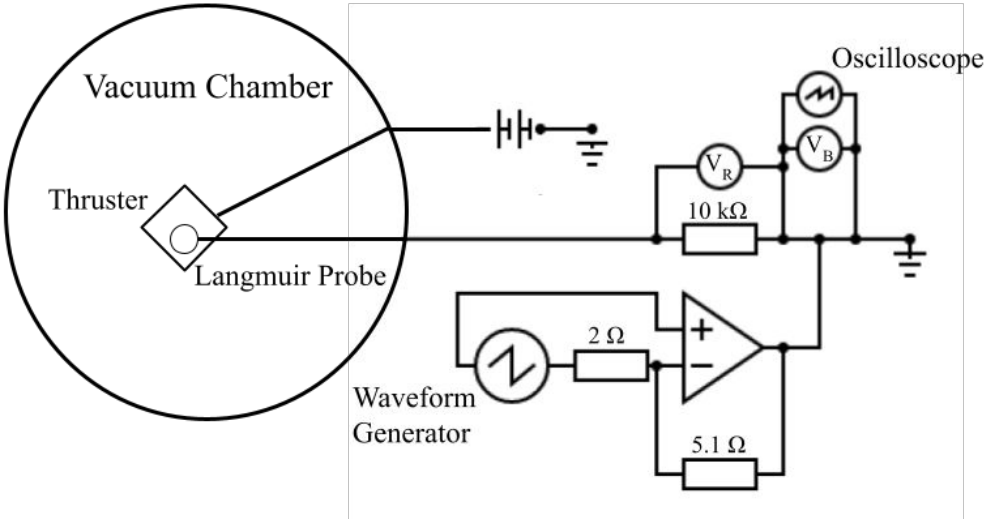

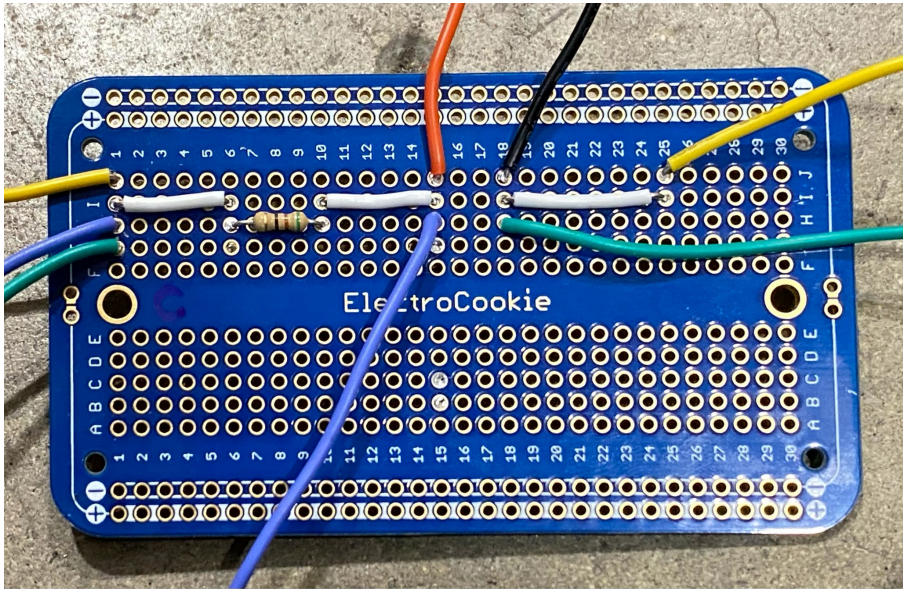

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