Core Concepts

Plasma Electron Temperature

Plasmas consist of both ions and electrons acting as a semi-coherent system. Using the common definition of temperature, the ions and electrons should be at the same temperature. However, when a potential is introduced to a plasma, velocities are predominately caused by electric field interactions. Because the electrons in the plasma have much smaller mass than the ions and neutrals, they have greater thermal velocity. Also because of this lower mass, when we introduce a floating potential, the electrons respond more strongly than the ions. Since temperature is a way of describing the average velocity of particles, this means that the electron temperature is greater than the temperature of ions and neutrals, even though they are part of the same body of plasma. The electrons' temperature is, in theory, dependent on pressure and the gas that has been ionized. We confirmed that the electron temperature is dependent on pressure, but also found an inverse relationship between changes in the base voltage and the temperature.

Equipment

The Langmuir Probe

The Langmuir probe we used inserts an electrode into a plasma and runs a varying electric potential through the system. By observing the resulting current, the plasma's temperature can be determined, among other things. The Keithley device was set up to control the bias, or sweeping, potential. Early physicists thought the plasma potential to be very similar to, if not the same as, the probe's floating potential — the potential at which the probe sits if there is no bias potential being added. However, a floating probe by definition doesn't receive

any net contribution from the plasma, so this isn't necessarily correct. The Langmuir probe instead measures the current in the plasma by comparing the potential inside the tube containing the plasma with the potential on the outside of the tube to calculate the plasma potential, then converting that data to current data.

Data Analysis

Plasma Temperatures at Varying Pressures

By increasing the pressure of the plasma, we would expect the electron temperature to decrease. Our measurements confirmed this, and the graphs show an associated steeper slope for the electron-dominated current, indicating a lesser temperature. However, we found that temperature doesn't vary the way we expected it to as we change the pressure. The data we found for temperatures at different pressures differed from our expected values by an order of magnitude. After finding that there was a relationship between the plasma temperature and the plasma's base voltage, our best guess is that the reason for this is that our predicting formula doesn't include the voltage, which should have an effect on the electrons' movement and therefore their temperature. We plotted our data and did most of our analysis in Python, using the libraries MatPlotLib, Bokeh, NumPy, and SciPy. Temperature calculations from the slopes given in Python were done in Mathematica due to some issues with the original code.

Sources

In addition to the sources provided as part of the lab, we drew information from the following:

http://home.sandiego.edu/~severn/langmuir_probes_amjp.pdf