Dusty Plasma

Megan Mark

Abstract

Perfect plasma environments rarely occur in the natural world; instead, plasmas are often mixed with neutral particles and other trace elements, giving it the name of dusty plasma. Dusty plasma physics is a subject that is being researched extensively in the fields of space science, astrophysics, semiconductors, nuclear fusion, nano-technology, and crystal physics.

From research conducted, dusty plasma chambers are possible. A major dusty plasma chamber that can be used for reference is the Naval Research Lab's DUPLEX chamber. This chamber creates a dusty plasma within a clear chamber, in which all experiments can be easily observed. A dusty plasma chamber will serve as an asset to Embry-Riddle Aeronautical University for conducting research in plasma physics which has applications to a myriad of fields, as listed above. The purpose of this project is to construct the chamber to certain requirements and to accomplish the creation of dusty plasma. The main requirements are: the chamber walls shall be constructed from a clear material so the operator or observer will be able to directly observe the chamber environment and the experiment within, the chamber will be equipped with a wide variety of sizes and types of feedthroughs on both the top and bottom flanges of the chamber to provide several access ports to the chamber, the chamber shall safely mix "dust" into the plasma. Due to time constraints, running experiments with the

Introduction

A plasma is an electrified gas of charged particles, with equal amounts of positively charged and negatively charged particles, such that it is neutral. Some familiar examples of plasmas include a lightning bolt, neon lights, and the Aurora Borealis. Much of the universe consists of plasmas, including the Van Allen Radiation Belts, the solar wind, and interstellar nebulae.

Dusty Plasma consists of background plasma (electrons, ions, and neutral atoms) and charged microparticles (i.e., "dust"). A dusty plasma is an ionized gas containing dust particles, with sizes ranging from tens of nanometers to hundreds of microns. The interaction of the dust particles with the plasma and ambient environment results in a charging of the dust grains. The dust particles can be in the shape of spheres of rods or irregularly shaped pancakes. They are typically much more massive than the electrons and ions. The dust particles acquire an electric charge in the plasma (a very interesting feature), usually a negative one. Dusty

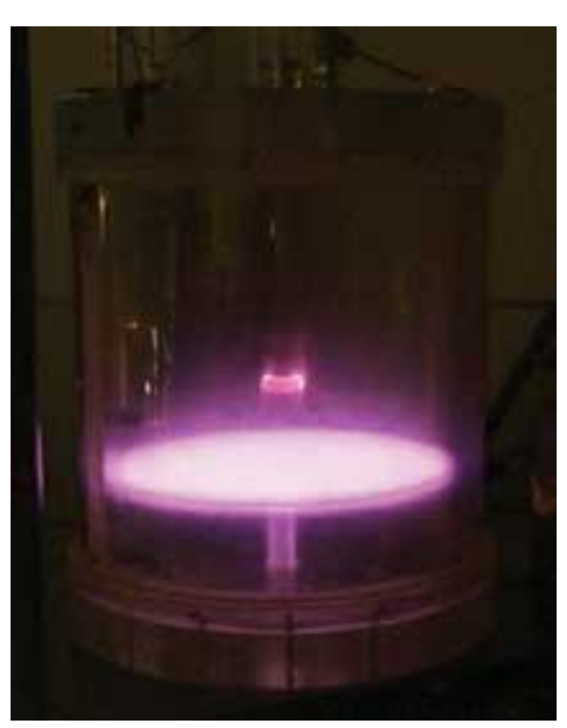

Figure 1: Dusty Plasma Experiment chamber located at the Naval Research

Acknowledgements

- Dr. Aroh Barjatya at Embry-Riddle Aeronautical University: Is the academic advisor for the project.
- Raymond Mark at Machining Solutions: Gave mechanical and machining advice. Assisted with the machining portion of parts on the CNC machine.
- Joseph Moszczienski at Northrop Grumman: Gave vacuum advice and is a contact for donations.
- Dave Bruderick at Sparton Electronics: Is the main contact for donations through Sparton Electronics (vacuum).
- Earl Mark at Sparton Electronics: Gave mechanical advice and is a contact for donations from Sparton Electronics (small parts).

Methods and Materials

The primary purpose of this project is to construct, calibrate, and test a dusty plasma chamber to be used by plasma physicists and students for many years. The proposed Dusty Plasma Chamber design was based on the Dusty Plasma Experiment conducted at the Naval Research Laboratory [1]. The *original* proposed chamber consists of an 8-foot tall, 12-inch diameter, polycarbonate tube which contains the plasma and serves as the overall structure for the chamber, as seen in Figure 2. However, several design changes have been made to accommodate for a more functional chamber and to fit within a small budget, in which the new design is seen in Figure 3.

The polycarbonate tube is transparent, which allows for visual observations of experiments. Metal flanges are mounted on the top and bottom of the tube are the primary structure for the top and bottom of the Dusty Plasma Chamber. The feedthroughs planned for this experiment include a gas feedthrough, a thermocouple feedthrough, and an electrical feedthrough.

The vacuum in the chamber will go to 10-6 torr for the duration of an experiment. This will be achieved by a roughing pump and a turbomolecular pump.

Inside the Dusty Plasma Chamber, the primary features are an anode and a cathode disk, which together generate the electrical field which ionizes the gas and produces the plasma. The anode-cathode pair will range

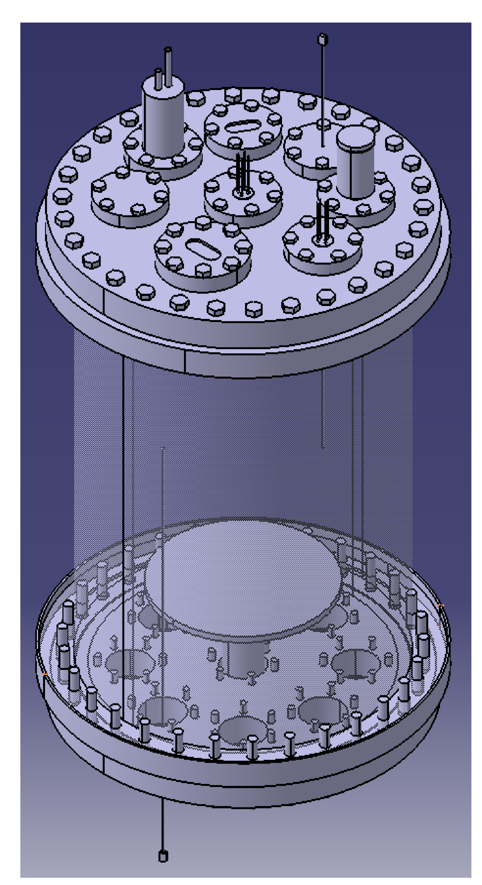

Figure 2: Original CAD drawing of the Dusty Plasma Chamber

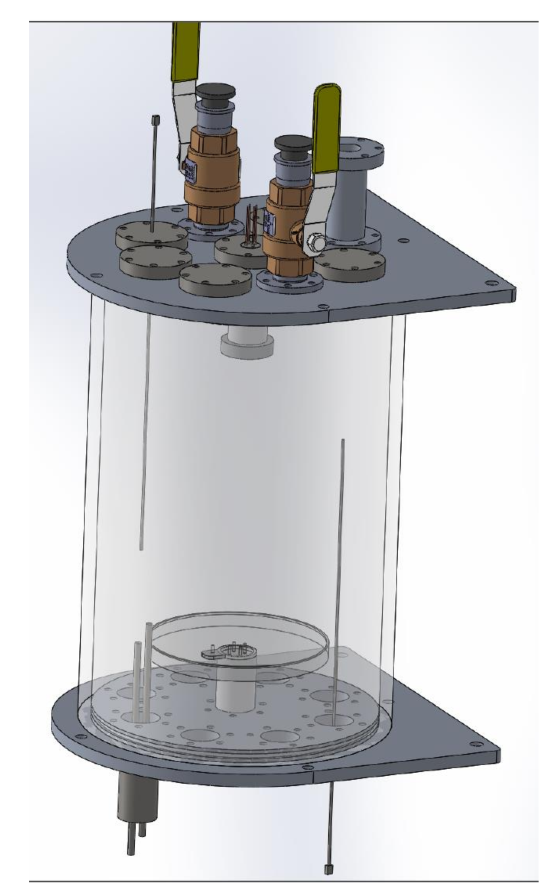

Figure 3: Modified chamber designs that was used for manufacturing and construction

Results

The DPC is currently being prepared to start testing for a voltage drop and creation of a plasma. The major work and modifications completed thus far include:

- "Duster" designs were added to the chamber to safely release dust into the chamber along with other additions and changes
- Removing the acrylic flanges and adding a boss to the flanges
- The top and bottom flanges were redesigned to account for the dusters and for the mounting system
- A mounting system was designed to hold the chamber vertical, allow space for the vacuums, and provide a work area/desk
- Testing of the roughing pump and vacuum pump with the chamber in small increments and applying modifications to compromise leaks
- Placement of the anode/cathode and prepping for a test with the power source

Once every component is in place and the vacuum is at our goal vacuum (10-6 torr), the power source will be turned on to very low current and a low voltage. The voltage will be increased in very small increments and the current will be increased only a small amount. Once the chamber has proven reliable with a combined vacuum

Conclusion

This project has provided experience with mechanical engineering, electrical engineering, manufacturing, plasma physics, and vacuum technologies as part of an individual senior design project for the Bachelor of Science degree in Engineering Physics. It will provide an outlet for future students and professors to learn more about space plasma and to conduct experiments. The design and concepts for the objectives and requirements have been completed and the DPC has been built. The chamber vacuum has also been tested and is ready for voltage testing. Once the voltage drop has been tested, plasma creation will be the primary short term goal.

Figure 4: Close up photo of the cathode attached to the bottom flange.

Figure 5: Progress photo of the tubbing, the end flanges, the turbomolecular pump, the gas flow controller, and the active digital gauge controller.

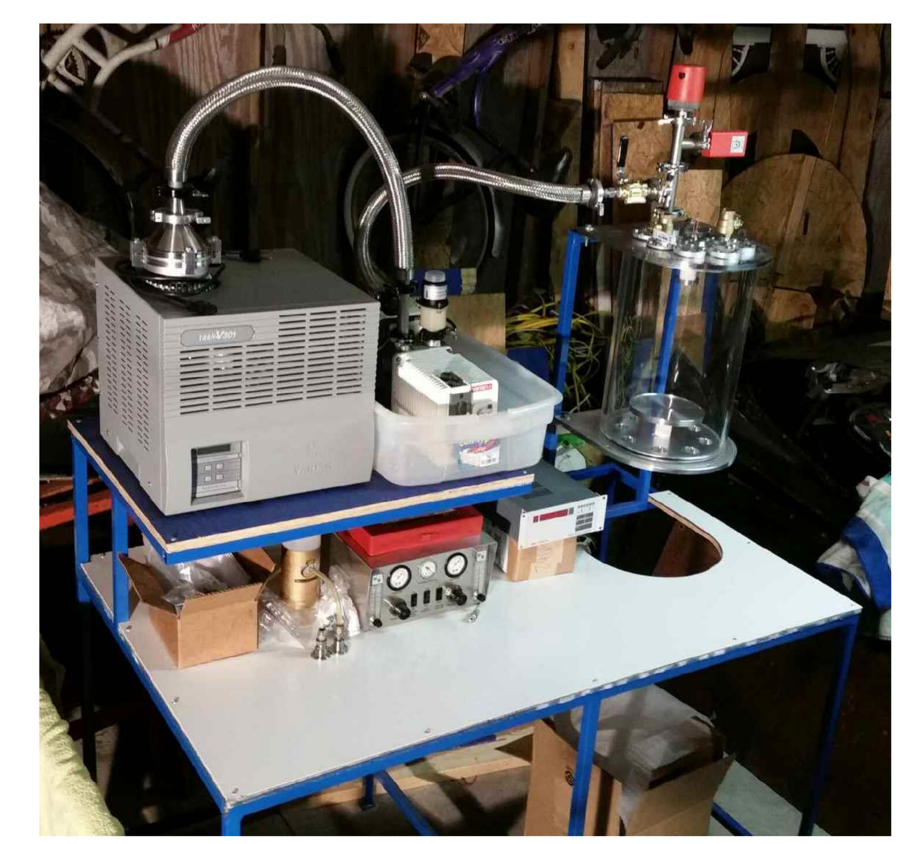

Figure 6: The chamber assembled with all components for testing.

Literature Cited

[1] E. Thomas Jr., W. E. Amatucci, C. Compton and B. Christy, "Observations of structured and long-range transport in a large volume dusty (complex) plasma experiment," Physics of Plasmas, vol. 9, no. 7, pp. 3154-

Further Information

Megan Mark

Engineering Physics Undergraduate with Applied Mathematics Minor

Embry-Riddle Aeronautical University

megandianemark@gmail.com