Dusty Plasma

Megan Mark

Abstract

Perfect plasma environments easily occur in the natural world, instead, plasmas are often mixed with neutral particles and other trace elements, giving rise to the name dusty plasma. Dusty plasma physics is a subject that is being researched extensively in the fields of space science, astrophysics, semiconductors, nuclear fusion, nanotechnology, 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 DUSTPLAS 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 plasmas. The main requirements are: the chamber walls shall be crystal physics.

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 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 plasmas 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.

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 ½-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 electric field which ionizes the gas and produces the plasma. The anode-cathode pair will range

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 dustors 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
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- 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

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- Once every component is in place and the vacuum is at our goal vacuum (10^-6 torr), the power source will be

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 plasmas 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.

Literature Cited


Further Information

Megan Mark
Engineering Physics Undergraduate with Applied Mathematics Minor
Embry-Riddle Aeronautical University
megandianemark@gmail.com