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Measurement of Time Varying Magnetic Fields with B-Dot Probes

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RCEU 2022 Project Proposal

Project Title

Measurement of time varying magnetic fields with B-dot probes

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I. Project Description

The goal of this project is to build a small B-dot probe to measure and map the magnetic field in a pulse magnetic nozzle. A magnetic nozzle is an electromagnetic equivalent to a rocket nozzle. However, instead of using the physical walls of the nozzle to accelerate and direct a hot gas to produce thrust as in the rocket nozzle, the magnetic nozzle generates strong magnetic fields to accelerate and direct plasma to produce thrust. The magnetic nozzle has applications to space-based plasma propulsion such as magnetoplasmadynamic thrusters or pulsed fusion propulsion. For pulsed applications, the magnetic nozzle also needs to be pulsed at the same rate to conserve energy, and because it is very difficult to sustain the high current needed to generate high magnetic field. This pulsed magnetic nozzle thus creates a time-varying magnetic field, which needs to be measured and characterized in order to better understand the design of these nozzles and how the plasma may behave.

One of the most common ways to measure time-varying magnetic fields is with at B-dot probe. B here refers to the magnetic field, and the dot refers to the time derivative, so $\dot{B}$. A B-dot probe in the simplest form is just a small coil of wire, or a solenoid. By Faraday's law of induction, a time-varying magnetic field creates an electric field in the wire, which generates a measureable current. So by placing the probe in the region of the pulsed magnetic field, one can measure the current from the probe and relate that to the changing magnetic field.

The student will design and construct the probes themselves, with assistance as needed. There will be some errors in the process and failed probes, but that is part of the learning and research process. Different probe sizes and number of winding will be tested to determine an optimal design for both size and resolution. An existing solenoidal magnetic field will be used to calibrate their probes. Once the calibration is complete, then probes will be tested in a pulsed magnetic nozzle currently being studied in the lab.

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

The student will read literature on B-dot probes and their use. They will build one or more probes and test them with known fields to calibrate the probes. They will assist in operation and testing of the pulsed magnetic nozzle, and specifically to measure the magnetic field with their B-dot probes.

b. Tangible Contributions by the Student to the Project *(10% of Review)*

The student's contribution will be to build a new diagnostic to measured time-varying magnetic field. This will be a very useful addition to our research into magnetic nozzles and pulse plasma propulsion.

c. Specific Outcomes Provided by the Project to the Student *(30% of Review)*

The student will gain an understanding of plasma propulsion, magnetic fields, and diagnostics. They will get hands-on experience with working in a research lab and conducting electromagnetic and plasma experiments. If the work is successful, they have the opportunity to present their work at a national conference such as AIAA SciTech or IEPC. I will cover the cost of the trip.

III. Student Selection Criteria

A student from engineering discipline or physics is desired. Any previous experience with plasma, electrical work, and hands-on experimental work would be beneficial. Rising junior or higher status.

IV. Project Mentorship *(30% of Review)*

During the summer semester, I spend 3-4 days a week personally at the lab. I may assist with the student projects or do work on my own. Thus, I will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate students who work with me and conduct research in the lab. Direct supervision, mentoring, and evaluation of the project by me will occur once a week at the regularly scheduled project meetings. In the meetings we will discuss the current status of the project, recent results, difficulties encountered, what to do next, and address any other issues that may come up. Indirect interactions and mentoring by graduate students and I will occur throughout the semester as part of the day to day activities. The student will report to me on the overall progress.

Safety and Contingency Plan

The PI’s lab is located in the Propulsion Research Center (PRC). The PRC’s safety procedures during COVID include: an online safety presentation and quiz, CPR/AED training, mandatory masking in the building, sanitization and hand washing, and record of people in the facility by card swipes. All people in the lab are required to comply with these procedures.

If the campus goes fully virtual or under quarantine, the project may be difficult to complete. A possible workaround is for me to ship the necessary probe and calibration materials to the student, and they can build the probes and test them with simple field at home. Then they can ship the completed probes to UAH and we can test them here with the pulsed magnetic field. Due to the high current involved in the capacitor pulse system, it would be too dangerous to do outside of the lab.