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Studies in Additive Manufacturing Techniques for Pulsed Fusion Experiments

Jason Cassibry

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2. Faculty or Research Mentor

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3. Proposal Identifier: RCEU21-MAE-JTC-02

4. Project Description

Our research program endeavors to develop the technologies required for fusion propulsion and affordable terrestrial power. Fusion propulsion enables rapid, human piloted trips to Mars. The long duration in deep space exposes astronauts to debilitating microgravity effects on skeletal and muscle tissue and increases the risk of cancer from prolonged radiation exposure naturally occurring in space. Fusion can enable this trip with a roundtrip time of 4 months, making the trip to Mars both safe and routine. The realization of terrestrial power from fusion provides a new green source of electricity with a nearly inexaustible fuel source (deuterium). In our lab we are exploring a parameter space which could enable fusion breakeven with relatively small total energy and power requirements, greatly lowering the initial investment in a reactor. The undergraduate student working with us will help contribute to these efforsts.

Our fusion laboratory has recently moved to campus in the Executive Plaza area. We now have operational a 60 kJ pulsed power machine we call Sparky which is used to drive currents into small electrical loads called ‘targets’. One of our graduate students, Jacob Kinsey, is studying radiation shielding and solid state fusion targets assembled using additive manufacturing techniques. The student will work with the PI, Dr. Cassibry, and our staff in the construction and testing of solid state targets. This involves the use of our 3D printers, resins, and small amounts of lithium and lithium deuteride. Additively manufactured targets allows us to create and control the initial conditions of the fuel within these targets to help optimize the transfer of electrical power to the fuel, and we are leveraging a recently awarded research contract to study fusion yield scaling in this manner.

5. Student Duties, Contributions, and Outcomes

The student will work with Jacob Kinsey (graduate student), Sumontro Sinha (Research Associate), and the PI in designing and printing 3D targets from filament, resins, lithium deuteride powder. These targets may be electroplated with copper to provide conductivity on the outer surface. Our lab has been experimenting with techniques to make enclosures for containing100 μg of fusion fuel (lithium deuteride). Specific tasks by the student to complement

this ongoing effort will include creating CAD drawings, 3D printing of these enclosures, electroplating targets, and weighing the components to determine the mass of the materials present. These targets will then be tested on Sparky, in which a 60 kJ pulse of electrical current will vaporize and implode the targets. The output is carefully shielded and the high voltage is operated by our research associate Mr. Sinha, with support by all the students. These targets are expected to generate measurable fusion reactions during the discharge.

The student will also assist in providing inputs for presentations and conference papers using these data, and will lead on his/her poster for the von Braun symposium in the Fall of 2021. We have had success in this approach, as this summer one of our students, Shelby Westrich, won a best paper award in engineering. The student will be collaborating with her this coming year as well, leveraging her previous experience and success supported by the RCEU program.

There will be numerous contributions made by the student in this project. Construction of and use of these targets is straightforward, but serves a critical role in providing an important function while the lead staff focus on calibration and safe operation of Sparky and associated diagnostics. At no point will we be putting anyone at risk, as the tests will be conducted at safe levels. Specific outcomes for the RCEU student are related to the development and use of solid state fusion targets, familiarity with plasma diagnostics, calibration, and dissemination of the work through scholarly activities. In addition to the hands on laboratory experience, the student will be lead author on a paper presented at the Fall 2021 von Braun Symposium and will be a coauthor on the conference paper based on Mr. Kinsey's research.

6. Student Selection Critreia

Applicants need to have completed their first year of school by Summer 2021 and be a declared major in engineering, with preference given to aerospace engineering. The applicant is expected to have a 3.5 GPA. Required coursework includes Calculus C. Some experience with matlab, circuits (coursework and/or labwork), 3D printing, fusion, oscilloscopes, multimeters, and signal generators are desirable. The rest of the work will be taught on site, and the PI and the graduate student will work with the RCEU student to learn what is necessary in order to be successful. We emphasize scholarly activity through the dissemination of our research work through presentations, conference papers, and journal articles, and we expect the student to participate in this process with us.

7. Contingency Plan

The ongoing pandemic and other unpredictable setbacks may preclude the student from participating in the laboratory. In anticipation of such circumstances, the student will be able to perform other critical duties to help advance the research while working remotely. Specifically, we will have the student conduct four major tasks. First, he or she will design 3D targets using various CAD programs such as OpenScad and export these models to .stl files. Second, the student will set up and run simulations in our new 3D plasma code SPFMax, which recently had the electromagnetic field and circuit solver completed. The student will import the .stl files into input files to define the geometry, and simulate the physics of electrical discharge from Sparky through these targets. Numerical output includes spatial and temporal variations in temperature, density, magnetic field, and neutron yield. These results will then be compared with available

data from the experiments and/or be used for developing scaling laws. Finally, we will have the student post process the results and assist in writing a paper for the upcoming AIAA ASCEND conference in 2021 to be held next November. The student will be a coauthor on this paper.