Nuclear Fusion Propulsion is a promising path for rapid interplanetary travel

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Nuclear Fusion Propulsion is a promising path for rapid interplanetary space travel. The Charger Advanced Propulsion and Power (CAPP) laboratory was designed and built to explore the potential of Z-Pinch Pulsed Fusion, which has great applications within both the energy and propulsion sectors. SPARKY is a prototype Z-Pinch reactor designed to produce fusion reactions in pulses lasting about 50 ns. The results of fusion events will provide data for code validation and scaling to assist in planning for future propulsion systems and commercial energy production.

The diagnostics on the SPARKY system include a set of scintillator detectors to measure x-ray and neutron emissions. Scintillator detectors are constructed from photomultiplier tubes (PMTs) and special crystals. PMTs are held in a vacuum and are incredibly sensitive to the blue frequency of light. This tube is coupled with a crystal held in a dark chamber. This crystal is made of a material that is sensitive to a particular type of radiation, x-rays or neutrons in our case, and emits blue light during an interaction. This blue light is detected by the photomultiplier and converted into an electrical signal, allowing for the measurement and diagnosis of radiative systems. The CAPP laboratory has an abundance of spare photomultiplier tubes available for construction of scintillator detectors. Adequate off-the-shelf scintillators typically run at several thousand dollars per unit, are incredibly sensitive, and can measure only one type of radiation. PMTs are also susceptible to damage in strong electromagnetic environments, such as SPARKY. Therefore, it is in our interest to develop low-cost scintillator probes using available components, anticipating that early tests may lead to irreversible damage to some probes.

Developing an active array of this type has a variety of uses. This system will primarily be pointed at the SPARKY system to measure plasma events inside the vacuum chamber, as neutrons and x-rays are the primary output of plasma events that can be observed outside the chamber. An example application includes neutron spectrometry, which uses two probes spaced at least a foot apart to discriminate between electromagnetic and neutron signals. This information helps to determine which portion of the signal is x-ray and which is neutron. The comparison also determines which reactions produced neutrons. The CAPP laboratory contains multiple pulsed, high-amperage, and high-voltage systems active in the lab. Using a PMT setup will also confirm the safety precautions in place against fast neutrons and x-ray radiation, as well as inform if the current precautions are adequate.

Creating this sensor suite will demand time during the spring and summer. During the spring semester, the focus will be set on learning the operation of PMTs and researching the various models present in the lab. The second step will be to catalog the PMTs by characteristics provided by the manufacturer. In addition, we will convert a single PMT from “counter mode” (slow response) to “pulse mode” (quick response). The process is achieved by changing components on the resistor network connecting the pins of the PMT, and installing small capacitors across some of those pins. The CAPP laboratory has documentation for this process.

The materials required for the project will be acquired by the mentor and laboratory under other lab funding. The research is expected to occur during the summer. The first week or two will be devoted to determining the crystals necessary for the PMT array, reviewing processes for PMT conversion, and reviewing techniques to mate crystals to PMTs. The process of soldering resistors and capacitors, PMT-crystal coupling, and the 3D printing of the holster will take another two weeks. The next week will be dedicated to designing and constructing a safe setup to protect the PMTs from electromagnetic radiation. The remaining three to five weeks will be dedicated to experiments with SPARKY and other pulsed plasma sources, as well as writing up a presentation poster.

Cumulative Student GPA: [redacted]

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