January 15, 2010

Rose Hills Foundation
Proposal for Summer Student Support

Project Title: "Developing electrostatic injection techniques for the delivery of fusion fuels to the focus of a high-power laser"

Faculty Advisor: Tom Donnelly (physics)
Student Researcher: Hong Sio

Student, Duration of Proposed Research, and Location

This proposal is a request for funding one summer-student stipend through the Rose Hills Foundation. The stipend would be for **Hong Sio**, who would do the proposed research at HMC. The start date is likely May 24 and the research will last ten weeks, ending on July 30. (Should we make rapid progress on this project, there is a possibility that we will travel to Austin for a few weeks to carry out experiments. I view this as relatively unlikely, but it is possible.)

Funding Request

One summer student stipend from the Rose Hills Foundation, $6,000

Overview

Our research efforts this summer will be directed at developing technology that supports laser-driven nuclear fusion. We propose to build and characterize a device that will inject micron-size spheres into the focus of an intense laser pulse. The spheres will be heated by the pulse, and thermonuclear fusion will be initiated. Our device would constitute an entirely new method of delivering fusion fuels to a laser pulse.

Our goal this summer is to improve the injection device that we have been working on for the last two years and, once we have it working and characterized, to take it the University of Texas at Austin where we will undertake fusion experiments with our collaborator. The work at Austin would likely take place in a summer following 2010.

Proposed Research

These days, laser pulses that generate multi-terawatts (1 terawatt = 10^{12} watts) of power are routinely produced. This power output is quite brief, lasting roughly a millionth of a billionth of a second, but is impressive nonetheless when compared to, for example, the power output of the entire US electrical grid, which is also a few terawatts. Many people have considered the possibility of using such powerful lasers to heat a fuel and initiate fusion, and our research follows in this tradition. Specifically, we address the problem of how to place fusion fuel into the focus of a laser pulse – without destroying the pulse itself – in a manner that allows fusion experiments to be carried out at a high repetition rate (~10 experiments per second).

We endeavor to build a device that uses electric fields to deliver sub-micron deuterated polystyrene spheres (fusion fuel) to the focus of a laser pulse. This is a unique approach to fusion fuel delivery. The delivery must be done in a vacuum, with high sphere density, and without the aid of a gas which might carry the spheres from a reservoir to the laser focus. (A gas can interact with the laser pulse and destroy its ability to focus to a small spot, thereby negatively affecting our ability to achieve high laser intensity at the position of the micro-sphere targets.)

We will construct the device by first laying the polystyrene spheres on a needle tip. We then use a pulsed electric field that charges the needle, and thereby the micro-spheres, to drive the spheres from the needle into the laser focus. This is an approach we began to experiment with last summer (see Fig. 1), but that is not yet reliable. This summer, we intend to coat the spheres with a thin layer of gold, using an evaporator, so that they can be more easily charged. Once eject from the needle, we will measure both the number and density of micro-spheres that result each time a needle is electrically pulsed.

Hong Sio, for whom funds are requested, will work on this project as part of a team of one or two other HMC students. Our efforts this summer are part of a larger collaboration with UT Austin: Once built, our device will be deployed at UT Austin (likely in a following summer) to undertake fusion experiments.

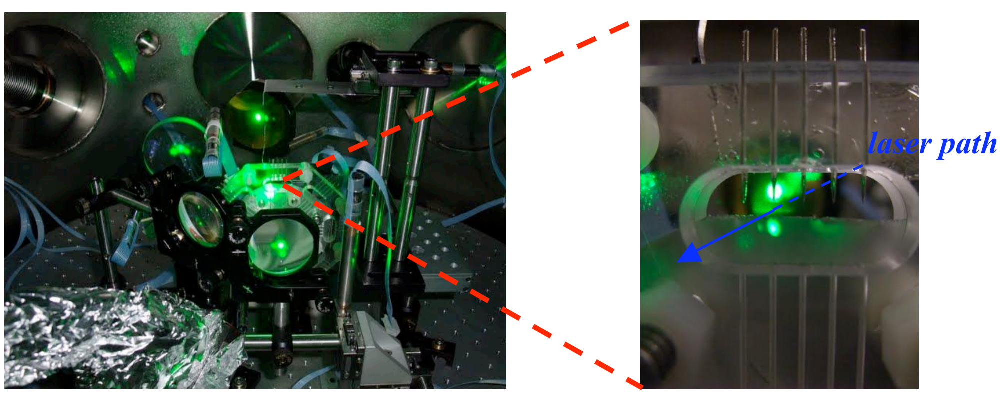

Figure 1. An image of our device prototype in a vacuum chamber at the University of Texas at Austin during the summer of 2009. The laser is aligned to focus directly beneath a single sphere-coated needle. The needles (one is used for each laser shot) are shown, blown up, on the right. The spheres are too small (500 nm) to be seen by the eye, but are driven from the needle into the laser pulse using a pulsed electric field. (A grounded pin is located directly below each sphere-coated needle.) A fresh needle is moved into place after each laser shot.

Student Teams and Additional Funding Requests
I view this project as particularly well-suited for a team of students. The project is complicated enough that having two or three students in the lab is helpful; it is useful for students to work in parallel on different facets of the research with the end goal of developing a functional device. For example, before we begin taking data, one student may work on refining the mechanical device in which sphere-coated needles will be placed (shown in Fig. 1), while a second student might experiment with optimal methods for coating needles with spheres. Or, farther down the road, one student might need to align the laser onto the sphere targets as another operates the detector system. Alternatively, while taking data, we may need one student to monitor the laser's behavior while a second student controls the data taking process. Finally, having two or three students working closely on a project has the benefits of them helping each other troubleshoot problems and brainstorm solutions.

This is the manner in which students operate while working with me during the semester, and it has been a productive approach to this research. To this end, I am also applying to HMC's CES for an additional summer student, and to the NSF for a supplement which may support a summer student.

Role of The Advisor
I work closely with my students each summer; typically, I am in daily contact with each of them. I see my role as helping the students understand their work in the context of larger societal issues (global energy needs and usage, in this case); assisting them as they daily encounter problems in the lab; teaching them the fundamentals of working in a lab, and how to work with sophisticated equipment; exposing them to real laboratory work as they think about career choices; and encouraging them as they grapple with difficult problems.

Broader Significance of the Project
Fusion is a promising alternative energy technology, but it is a technology that has remained elusive for the last half-century. Harnessing fusion power for our energy needs would contribute greatly to reducing the environmental (and political) problems that result from burning carbon-based fuels. It is with this long-term goal in mind that we undertake our research.

Educational Value
I view research as an important aspect of our students' education, therefore I view the funds requested for a summer-research student as directly tied to student education. The research students do with me – ranging from designing vacuum chambers, to writing LabView codes, to using lock-in amplifiers, to carrying out experiments at HMC and at an R1 university, to writing papers – is a significant enhancement to their classroom education and contributes strongly to their professional growth.

Feasibility
I believe that the proposed work is highly feasible because it builds on efforts we have made over the last two years. We have already designed, purchased and built the necessary vacuum chamber, and we have a working prototype of our sphere delivery system (see Fig. 1, above). We have a clear path for the work that needs to be accomplished this summer.

Leveraging External Support
My broader research program explores the physics of how high-intensity laser pulses interact with small particles, and it is supported by the NSF. Within this program, I carry out the fusion research I describe here. Therefore, funding is already in pace for the equipment and travel which may be necessary for the research proposed here. (The NSF grant does not, however, directly support summer students, thus this request.)

Strategic Goals Addressed
Because I am doing research with students that has direct application to renewable energy, I believe I fall under a few of the strategic goals:

- Developing the whole person
- Global engagement and social responsibility
- Experiential and interdisciplinary learning
- Innovation, leadership and impact in science, mathematics and engineering education