January 14, 2010

Center for Environmental Studies
Research Proposal – Summer 2010

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

Faculty Advisor: Tom Donnelly
Student Researcher: Brendan Folie

Abstract

Our research efforts this summer will be directed at developing technology that supports studies of laser-driven fusion. We propose to build and characterize a device that will electrostatically inject micron-size deuterated spheres into the focus of an intense laser pulse. The spheres will be heated by the pulse, and thermonuclear fusion will be initiated. This 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.

Starting Date, Duration and Location of Proposed Research

This proposal is a request for funding one summer-student stipend. The stipend would be for Brendan Folie, who will do the proposed research at HMC. The start date is likely May 24 and the research will last ten weeks, ending on July 30.

Funding Request

One summer student stipend

Proposed Research

These days, laser pulses that generate multi-terawatts (1 terawatt = 10^{12} W) 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 a few terawatts. Many people have considered the possibility of using such powerful lasers to heat a fuel and initiate fusion. Our research follows in this tradition. Specifically, we address the problem of how to place fusion fuel into the focal volume 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 Hz).

We endeavor to build a device that can electrostatically deliver sub-micron deuterated polystyrene spheres (fusion fuel) to the focus of a high power 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, because the gas can interact with the laser pulse and destroy its ability to focus to a small spot (and thereby make it unable to achieve high intensity).

We will do this by laying polystyrene spheres on a needle tip, and then using a pulsed electric field 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. We also hope to measure the number and density of spheres that are ejected each time a needle is electrostatically pulsed.

Brendan Folie, 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.

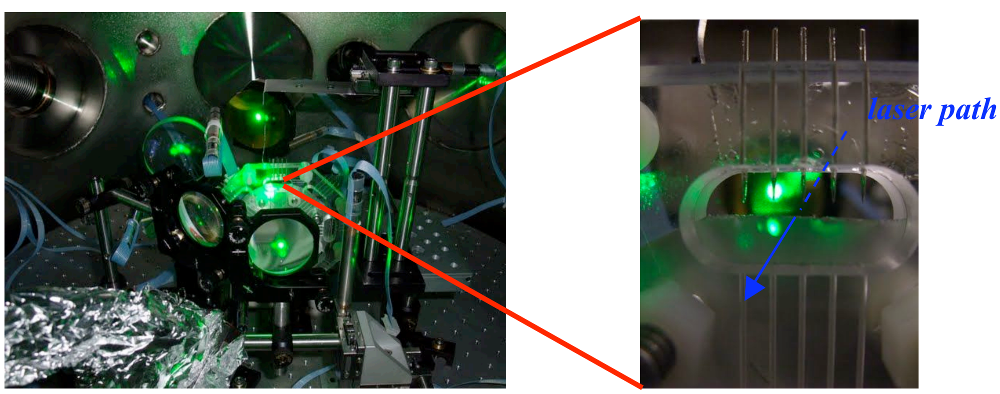

Figure 1. An image of our device prototype in a vacuum chamber at the University of Texas at Austin during the summer of 2009. The laser is aligned to focus directly beneath a single sphere-coated needle. The needles (one is used for each laser shot) are shown, blown up, on the right. The spheres are 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.

Significance of the Project for Environmental Quality
Fusion, the focus of my research efforts, 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.

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 and built the necessary vacuum chamber, and we have a working prototype of our sphere delivery system (see Fig. 1, above). Further, the research is supported by the NSF, which pays for the necessary equipment and travel (but, oddly, not summer students).

Budget
I request funds for one summer student, at HMC rate for a rising senior.