Inertial-Electrosatic Confinement Fusor

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1 General Information

- Project Proposal Title: Fusion Reactor
- Name of School: Georgia Institute of Technology
- SPS Chapter Number: 2361
- Total Amount Requested: $2000

2 Abstract

The SPS Chapter at the Georgia Institute of Technology is constructing a fusion reactor in an effort to improve the current standards for efficiency and to demonstrate the phenomenon of fusion at the Atlanta Science Festival. The fusor will then be modified to conduct various experiments including, but not limited to neutron scattering and particle acceleration.

3 Proposal Statement

3.1 Overview of Proposed Project

Research Question
The SPS at Georgia Tech is seeking an answer to "How should the traditional fusion reactor model be modified to maximize its efficiency?"

Motivation
The motivation for this project was rooted in the intense curiousity of one of its members concerning fusion reactors, whose vision gradually expanded past merely producing and enhancing the device with his peers to sharing their freshly acquired knowledge with the public, in print and face-to-face.

Brief Description
A project such as this would entail the collection of various pieces of equipment and parts in order to build the fusion reactor, along with safety instruction, lab space, and time for completion.

Research Goals of the Project
The primary goals of this project are

(a) to create a safe, fully functional, and more efficient fusion reactor,

(b) to publish a research paper concerning improvements upon the current fusion reaction model discovered,

(c) to present and demonstrate to the public the process of fusion,

(d) to create a proton/neutron source for future research projects.

SPS Connection
The SPS mission statement reads that "The SPS exists to help students transform themselves into contributing members of the professional community." Through this project, the SPS Chapter at Georgia

Tech would not only be fulfilling that purpose through offering its members valuable research and group collaboration experience, but also through providing outreach to the local community off-campus at the Atlanta Science Festival. Furthermore, SPS members presenting their work on this project at the Festival would have the opportunity to develop meaningful relationships with other professionals in academia at the Festival.

3.2 Background for Proposed Project

In the early 1930s, P.T. Farnsworth first observed the existence of sustained, high-frequency, secondary emission discharge at the center of a vacuum tube.[1] By creating a very powerful, spherically symmetric electric potential within a vacuum, ionized deuterium can reach the relative velocities necessary to overcome the Coulomb barrier.[2,3] Although reactors of this variety do not yield positive energy output, inertial-electrostatic confinement fusors prove a cheap, viable, and relatively simple means for deuterium fusion in the amateur community. Large communities such as that found at fusor.net are devoted to assisting amateurs in the construction of table top reactors at a relatively cheap cost.[4]

Our project intends to combine the great base of knowledge already formed by the amateur community with the theoretical predictions and computer simulations of our SPS chapter. Fusion reactors of this variety have known drawbacks and inadequacies.[5] We plan to develop methods for minimizing these errors and inefficiencies, and perform experiments once constructed to further improve performance. We will summarize our work and contributions under the guidance of Dr. Nepomuk Otte, a physics professor at our university.

3.3 Expected Results

With this project we will at the very least construct a Farnsworth style inertial-electrostatic confinement fusion reactor. We endeavor to not only construct this apparatus, but also contribute to the amateur fusion community by improving the efficiency with mathematical models and simulations of the device. We have already performed calculations on plasma confinement apparatus geometry, and begun Monte Carlo simulations categorizing the various efficiencies. Once constructed, we intend to continue improving the design and experiment with different plasma confinement cage geometries. The device also stands as a neutron source, and we can measure the effects on neutron cross section as a function of various apparatus parameters.

3.4 Description of Proposed Research – Methods, Design, and Procedures

(a) **Power Supply**
The power supply is such that a traditional wall outlet supplying 120 V will power the fusor. A high voltage transformer steps up the primary voltage 31 times and feeds to a six-stage Cockroft-Walton multiplier. The components of the power supply are rated to withstand approximately 10,000 V sustaining each stage of the multiplier to reach the intended voltage of about 22,000 V to feed through to the vacuum chamber. Such high voltages on the secondary side of the transformer require high voltage wire with coaxial grounding capability to ensure safety.

(b) **Vacuum**
To reach the relative particle velocities to achieve fusion, we must reduce non-deuterium collisions. The vacuum chamber is covered in flanges; some have special feedthroughs necessary for creating the vacuum or allowing the high voltage into the chamber. The vacuum pumps create pressures 10^{-4} to 10^{-6} torr inside the chamber. The high-voltage power supply will enter via the high-voltage feedthrough and connect to the tungsten cage.

(c) **Tungsten Cage**
The plasma containment within the vacuum is brought about by a tungsten cage. The current design

is composed of outer and inner concentric spherical cages. The outer, larger cage is connected to the positive end of the power supply and the inner cage is connected to the negative end. The high voltage difference creates an electric field that accelerates the deuterium to the center of the configuration where fusion will occur. The cage is highly resistive, so virtually all the voltage generated by the power supply is dropped across the cage, and the high resistance quells current so that power consumption is limited.

(d) **Theory** We are in the process of developing computational models that will simulate the fusion process within the vacuum chamber. By integrating the equations of motion for an arbitrary Hamiltonian, we may more easily theoretically determine the cage geometry of maximum efficiency before construction. We also have performed and will continue to perform calculations for these geometries' expected neutron cross sections. We will compare our calculations to the final measurements after construction.

3.5 Plan for Carrying Out Proposed Project

The personnel involved in this project consist of a group of approximately eight SPS members, each working on separate parts of the project who will bring their individual pieces together. Some members are currently working in more than one area. For example a few are working on the theory involved in creating a more efficient fusion reactor while others are procurring funding to obtain the needed materials. At least two members have engineering backgrounds (one majoring in electrical engineering, another in mechanical engineering; both have garnered skills which would assist greatly in the construction of the fusion reactor). Lab space has already been procured for the development of the fusion reactor, courtesy of Professor Otte, who has also graciously offered his assistance in publishing a paper over the conducted research.

3.6 Project Timeline

- January 2015 - Begin physical construction of fusion reactor
- March 15, 2015 - The fusion reactor should be fully functional
- March 21, 2015 - The SPS Chapter will present its findings to the public and conduct demonstrations at the Atlanta Science Festival
- April 2015 - Begin conducting experiments with neutron scattering
- June 2015 - End experiments with neutron scattering; Begin fusion reactor modification to create particle accelerator

4 Budget Justification

In support of this project, we have received great help from our university. We have received a vacuum chamber on the order of \$20,000 and four vacuum pumps totaling an estimated \$12,000. The Office of Radiological Safety has loaned us three radiation detection devices for use in neutron production verification and safety. Dr. Nepomuk Otte has allowed us work space in his lab for construction purposes as well. To supplement the remaining costs of this project, our SPS chapter has proposed a bill to our Student Government Association and received \$600 for electronics, and we are currently selling t-shirts as a modest fundraiser. Unfortunately we still require funding for vacuum chamber flanges, deuterium, and other miscellaneous vacuum chamber accessories (as detailed in the budget). Although we have received such help from our department and school in general, we still require the final portions of funding necessary to sustain a vacuum and contain the plasma. With help from this SPS Chapter Research Award we can purchase the remaining parts and begin construction.

References

[1] Hirsch, R.; Inertial-Electrostatic Confinement of Ionized Fusion Gases, *Journal of Applied Physics*, vol. 38, no. 11, **1967**.

[2] Brennan, J; Coyne, J; Energy Dependence of the D-D Reaction Cross Section at Low Energies; Journal of Research of the National Bureau of Standards - A, vol. 68, no. 6, **1964**.

[3] Elmore, W; Tuck, J; Watson, K; On the InertialâĂŘElectrostatic Confinement of a Plasma, *AIP Physics of Fluids*, vol. 2, no. 239, **1959**.

[4] Ligon, T; The World's Simplest Fusion Reactor, And How to Make It Work, *Analog of Science Fiction and Fact*, **2007**.

[5] Rider, T; A general critique of inertialelectrostatic confinement fusion systems, *Physics of Plasmas*, vol. 2, no. 6, **1995**.