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ANTIPROTON CATALYZED MICROFISSION/FUSION PROPULSION

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ABSTRACT

Inertial confinement fusion (ICF) utilizing an antiproton catalyzed hybrid fission/fusion target is discussed as a potential energy source for interplanetary propulsion. A proof-of-principle experiment underway at Phillips Laboratory, Kirtland AFB, and antiproton trapping experiments at CERN, Geneva, Switzerland, are presented. The ICAN propulsion concept is described and results of performance analyses are reviewed. Future work to further define the ICAN concept is outlined.

I. INTRODUCTION

Inertial confinement fusion (ICF) can provide thrust and high Isp for propulsion applications from plasma created in antiproton-catalyzed microexplosions. The antiproton induced ignition of fission reactions under conditions of high compression has been described previously (Lewis 1991). Here we provide an overview of the full microfission/fusion concept, including a proof-of-principle experiment at the Phillips Laboratory to demonstrate subcritical antiproton-catalyzed microfission. Recent advances made by our group in the trapping of antiprotons are reviewed as well. The ICAN propulsion concept is discussed with regard to its features and performance, and our future work is outlined.

II. ANTIPROTON-CATALYZED MICROFISSION/FUSION

In 1992 large fission and neutron yields from antiproton annihilation at rest in a natural uranium target were observed (Chen et al. 1992). Calculations indicate that short bursts of

antiprotons could induce temperatures of several keV in a small compressed pellet. These conditions are appropriate for ignition of a hydrogen fusion burn within the microsphere. Targets with yields up to 100 GJ have been considered (Kanzleiter 1991). Compression is provided by light ion beams, such as from PBFA-2 (VanDevender and Cook 1986).

A proof of principle experiment at the SHIVA Star facility at the Phillips Laboratory, Kirtland AFB, is underway to demonstrate subcritical neutron multiplication due to antiproton fission in targets compressed to 10-40 Mbar pressure. Antiprotons are released from a Penning trap storage device, accelerated to 1.2 MeV by a radiofrequency quadrupole (RFQ), and focused onto the compressed target inside and imploding solid liner driven by the SHIVA Star capacitor bank. Figure 1 shows a close up of the target region, indicating the liner moving in rapidly and compressing a hydrogen working fluid. A short 50 ns burst of antiprotons ignites the target as it reaches peak compression.

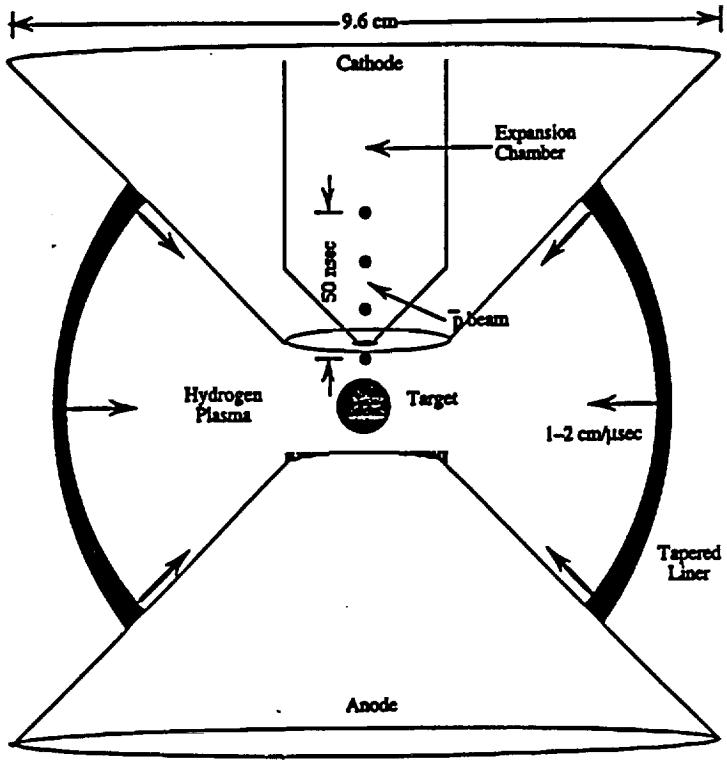

Figure 1. Solid Liner during Compression Cycle

III. ANTIPROTON TRAPPING EXPERIMENTS

In collaboration with the P-15 group at Los Alamos National Laboratory (Holzscheiter et. al., 1993), in July, 1993 we trapped up to 721,000 antiprotons from single beam shots at the Low

Energy Antiproton Ring (LEAR) at CERN. Figure 2 shows the Catcher Trap and transfer optics to the Portable Trap. With improved vacuum, using multipulse injection and electron cooling in the catcher trap we hope to trap and confine several milliion antiprotons before the end of 1994.

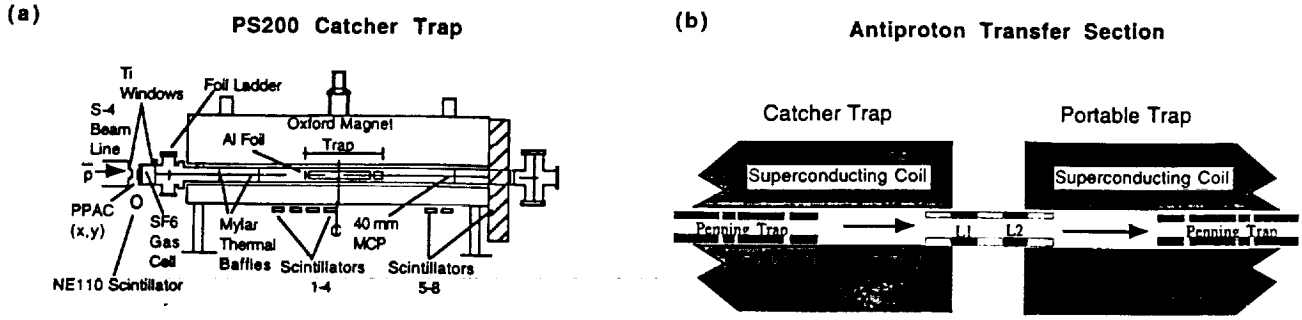

Figure 2. Schematics of (a) Catcher Trap and (b) Transfer Optics to the Portable Trap

IV. ICAN PROPULSION SYSTEM

The ICAN propulsion concept envisioned by our group is a derivative of the MEDUSA canopy concept proposed by Solem (1994), which is itself a variant of the ORION pusher plate system (Augenstein 1991). In the ICAN concept, a large, hemispherical canopy two km in radius is used to intercept debris from the explosion, transferring its momentum to the spacecraft via the expansion and contraction of the canopy, which serves as the shock absorber necessary to smooth out the acceleration. A detailed version of the canopy is shown in Figure 3, where we have used titanium for the canopy because of its high operating temperature and tensile strength.

The principle concerns associated with the ICAN system are momentum transfer to the canopy from the high energy propellant ions, along with the associated performance and sputtering damage, the radiation damage caused by neutrons and x-rays reradiated by the expanding propellant, and canopy heating. To assist us in investigating these issues, several computer codes have been developed to simulate energy release in the microfission/fusion target, absorption by the propellant, and MHD and radiation transport mechanisms in the expanding propellant. Canopy damage and momentum transfer are evaluated using the TRIM sputtering code (Biersack and Eckstein, 1984).

We have chosen as a prototypical target one which releases 98 GJ of energy. This energy is produced in a target consisting of a bout 1.0 g of nuclear fuel. The nuclear fuel is in a molar ratio of 9:1 of DT:U. Initially, the proportions of energy produced in the target are 83% radiation,

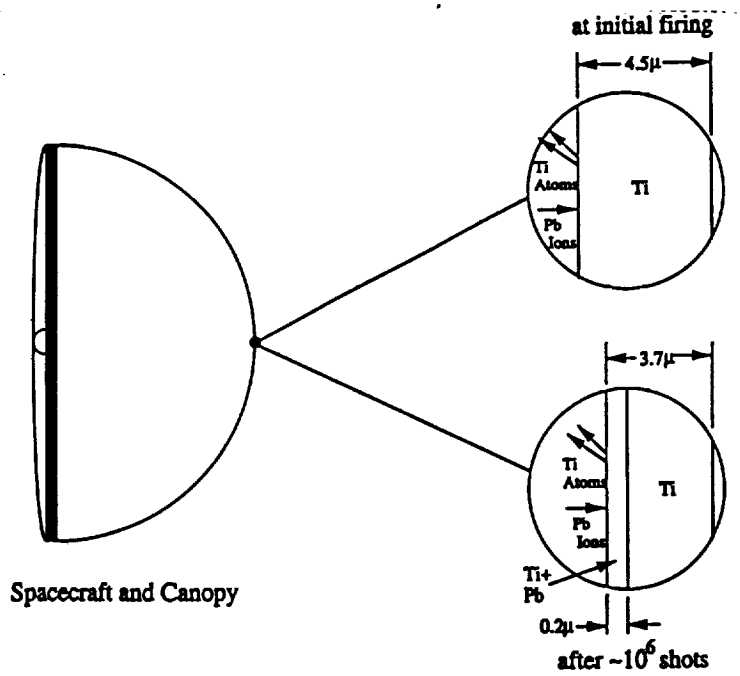

Figure 3. ICAN Canopy Structure

15% neutron kinetic energy, and 2% random ion and electron kinetic energy. A high Z propellant, lead, was chosen due to its high absorption cross-section with respect to the radiation generated by the ICAN target.

Accurate simulation of the propellant expansion process following the deposition of this energy requires a sophisticated model, including an accurate equation-of-state, a radiation transport model, and a thermal conduction model. Our Plasma Propulsion Dynamics (PPDYN) code utilizes a single-temperature radiation model in a one-dimensional MHD code to determine the amount of energy deposited in the propellant. Analysis of the propellant performance yielded the thrust and Isp curves shown in Figure 4, as a function of the propellant mass per shot. A clear tradeoff exists between thrust and Isp, which plays a significant role in mission analysis.

V. FUTURE WORK

We are presently working to expand the capabilities of our plasma propulsion dynamics code to allow analysis of alternate propellants and mixtures of propellants in an effort to enhance performance and decrease canopy damage. In addition, we have begun analyzing various mission scenarios which utilize the high-Isp, low thrust ICAN system. Alternative canopy structures and materials also need to be considered in order to minimize sputtering damage and maximize system performance.

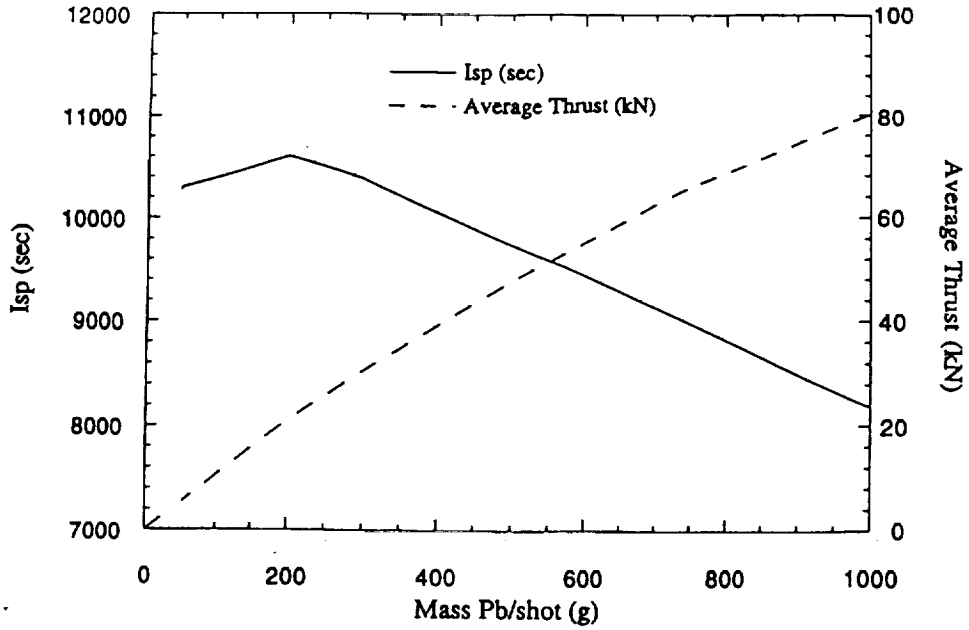

Figure 4. Thrust and Isp vs. Propellant Mass at 1 Hz Firing Rate

VI. ACKNOWLEDGMENTS

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