Positron Propulsion for Interplanetary and Interstellar Travel

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Abstract

Current state of the art in-space propulsion systems fail to meet requirements of 21st century space missions. Antimatter propulsion has been identified [1] as a candidate mechanism that could safely transport humans and/or robotic systems with drastically reduced transit times, providing quicker scientific results, increasing the payload mass to allow more capable instruments and larger crews, and reducing the overall mission cost. Propulsion systems based on antimatter have been considered in several manifestations [2,3], however, significant technical barriers have kept the cost of usable antimatter well outside the realm of propulsion applications, despite the substantial performance advantages. Each design is a trade-off between mass and complexity, but they all share high specific impulse (I_{sp}) well above those obtained from even the most ambitious electric ion-propulsion. The primary challenge of an antimatter propulsion system is conversion of the annihilation products into propulsive force. One way to do this is by catalyzing a fusion reaction(s), resulting in fast charged particle products that can be guided to produce thrust [4]. Traditional laser or particle fusion-driver systems have high mass and power requirements that are not practical for any near-term space applications [5]. Positrons are the easier form of antimatter to obtain - over the past 20 years the cost of usable positron production has decreased, and the techniques have become more widely known [6]. Our solution to antimatter propulsion is based on using electron/positron annihilation induced fusion reactions, first proposed in the 1990's [7], but never experimentally measured due to the limited access to cold positron beams. Recent advances in cold positron production [8], creation of dense deuterium clusters on metallic substrates [9] and measurement of positron catalyzed fusion reaction cross section will be presented. We will show that a radioisotope positron catalyzed fusion propulsion system is possible, capable of >100mN thrust with $>10^6$ I_{sp}. Initial design of an in-orbit demonstration flight spacecraft utilizing the 3U-6U Cubesat architecture will be presented. Using commercial GPS, better than 10m orbital-position accuracy can be obtained, ensuring 99.99% confidence in the measurement of 1 deg. inclination change, decoupled from any in-track perturbations (e.g. atmospheric drag). While radioisotope sources are sufficient for missions within the Solar System, a regenerative source of positrons will be required to reach thrust levels and transit times required for interstellar travel. We present initial analysis of a positron source generation concept based on DD fusion neutron capture reaction $^{78}Kr(n,\gamma)^{79}Kr$ [10]. This is a type of radioisotope 'breeder' fuel cycle would allow for much higher positron source intensities and thrust levels >kN required for an interstellar mission. This paper should be submitted to the day 1 session.

Keywords: Antimatter, Positrons, Fusion propulsion

References:

[1] 2015 NASA OCT Roadmap TA02: In-Space Propulsion Technologies (http://www.nasa.gov/offices/oct/home/roadmaps/index.html) 2.3.5 Antimatter Propulsion
[2] Smith, G. NIAC Phase I Final Report "Positron Propelled and Powered Space Transport Vehicle for Planetary Missions"
[3] McNutt, A Realistic Interstellar Explorer, NIAC 7600-039 Final Report, 2002
[4] Keane, R. Beamed Core Antimatter Propulsion, Journal of the British Interplanetary Society 2012
[5] Lindl, John, et al. "Review of the national ignition campaign 2009-2012." Physics of Plasmas 21.2 (2014): 020501.
[6] Krause-Rehberg, R. Positron Annihilation in Semiconductors: Defect Studies 1999
[7] Morioka, Nuclear Fusion Triggered by Positron Annihilation in Deuterated Metals, Il Nuovo Cimento, Vol107a,1994
[8] Weed, et al Array Structures for Field Assisted Positron Moderation and Corresponding Methods WO Patent App. PCT/US2012/042,049
[9] Badiei, Shahriar, Patrik U. Andersson, and Leif Holmlid. "High-energy Coulomb explosions in ultra-dense deuterium: Time-of-flight-mass spectrometry with variable energy and flight length." International Journal of Mass Spectrometry 282.1 (2009): 70-76.
[10] Mills Jr, A. P. "Suitability of 79 Kr as a Reactor-Based Source of Slow Positrons." Nuclear science and engineering 110.2 (1992): 165-167.

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