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DEVELOPMENT OF A MAGNETICALLY ENHANCED LASER-ABLATIVE PLASMA THRUSTER

Abstract

This work introduces the development of a novel magnetically enhanced electric propulsion architecture, where the plasma source is provided by means of laser-ablation. This involves the removal of a thin layer of propellant material by focusing ultra-short laser pulses ($10^{-12} - 10^{-15}$ s) on a metal or liquid surface, creating plasma, which results in nN-N thrust levels for high repetition rate laser sources. The resulting discharge is then confined and accelerated by a magnetic nozzle.

Since laser-ablated plasma can possess a directed initial velocity of >10 kms^{-1}, significant specific impulses on the order of 10000 s can be expected. Moderate laser efficiency can produce very high propulsive electrical efficiency, as laser energy can be used to drive exothermic reactions in the propellant. Variable specific impulse and constant-momentum exhaust profiles are achieved by adjusting laser intensity on the propellent, changing the focal-spot area and/or laser-pulse duration, which causes specific impulse to vary across the range of 100-10000 s. Thrust can be varied independently of specific impulse by changing the laser-pulse repetition rate, so the laser-ablative plasma thruster is a multi-mode device. Accurate control of laser parameters can produce a minimum-impulse bit as small as nNs and especially low RMS thrust-noise; thus, laser thrusters can be an enabling technology for next-generation gravity missions and drag-free satellites.

A novel plasma diagnostics tool has been developed by combining nN-resolution thrust-balance measurements with high speed pulsed digital holography, laser-induced fluorescence, and volumetric ion current analysis in a dedicated thermal vacuum chamber. The holography can capture events, in 3D, occurring in the nanosecond regime. The propellant surface before and after ablation will be analysed with a white light interferometer. In combination with fully kinetic simulations, this has allowed the first characterisation of the laser-ablative plasma thruster. A preliminary numerical and experimental campaign has been undertaken to assess the effects of changing laser parameters, thruster geometry, magnetic field strength/topology, propellant type/topology and combined spatial, temporal and polarisation laser pulse shaping. The efficiencies of several candidate polymer propellants are assessed, and the propulsive performance is seen to approach 0.1 mN/W. Proposed propellant delivery systems will also be discussed, including rolling tape, pellet and suspended polymer in ionic liquid.