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Electrodeless plasma thruster design

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The Elwing Company has designed, built and tested various configurations of its electrodeless plasma thruster technology. The new concept of ponderomotive accelerator has been created to overcome fundamental plasma density limitations in order to reach high thrust density. Among the many possible ways to create the electromagnetic field structures required to produce the ponderomotive force field, the work described in this article focus on the rationale behind the design actually retained for the first prototypes. The impact of the magnetic field geometry on the ionization stage and on the thrust vectoring stage is specifically discussed. The specific design modifications for use at low power (below 1kW) are also exposed.

Nomenclature

B	=	magnetic field
E	=	electric field
F	=	accelerating force
I	=	electrical current intensity
Isp	=	specific impulse
l	=	length
m	=	particle mass
m_e	=	electron mass
n	=	plasma particle density
n_e	=	plasma electron density
q	=	electrical charge of a particle
v_c	=	cyclotronic velocity of a particle in a magnetic field
ε_0	=	vacuum electrical permittivity
μ	=	adiabatic invariant or magnetic momentum of a charged particle in a magnetic field
ψ	=	potential
ω	=	applied electromagnetic field pulsation or angular frequency
Ω_{ce}	=	electron cyclotronic pulsation or angular frequency in a magnetic field
ω_p	=	plasma pulsation or angular frequency

I. Introduction

HIGHLY energetic missions, such as fast trip to outer planet or fast LEO-to-GEO orbit transfer, require propulsion systems able to produce high level of thrust at high specific impulse during long trusting period while being small, light and efficient. These missions will require combining together high Isp with small size, large thrust output and long lifetime. Specifically, combining large thrust with small footprint and long lifetime has proven to be very challenging. Indeed dense & energetic ion beams produce strong erosion which over time has a negative impact on propulsion system lifetime and efficiency. To overcome these limitations, the Elwing Company initiated the development of a family of thruster based on an electrodeless acceleration mechanism.

We will first present a detailed explanation of the ponderomotive force after brief analysis of the causes underlying the limitations implied by the use of simpler plasma acceleration mechanism. The second part will outline the general structure of an electrodeless plasma thruster with a special focus on the electromagnetic fields topology adapted to reach performance of interest for spacecraft propulsion. Then, we will review in details the various configurations of each subsystems studied to determine the first prototype configurations. Last, an overview

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