Galium Electromagnetic (GEM) Thruster Concept and Design*

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Abstract

We describe the design of a new type of two-stage pulsed electromagnetic accelerator, the gallium electromagnetic (GEM) thruster. A schematic illustration of the GEM thruster concept is given in Fig. 1. In this concept, liquid gallium propellant is pumped into the first stage through a porous metal electrode using an electromagnetic pump[1]. At a designated time, a pulsed discharge ($\sim$10-50 J) is initiated in the first stage, ablating the liquid gallium from the porous electrode surface and ejecting a dense thermal gallium plasma into the second state. The presence of the gallium plasma in the second stage serves to trigger the high-energy ($\sim$500 J), second-stage pulse which provides the primary electromagnetic ($\mathbf{j} \times \mathbf{B}$) acceleration.

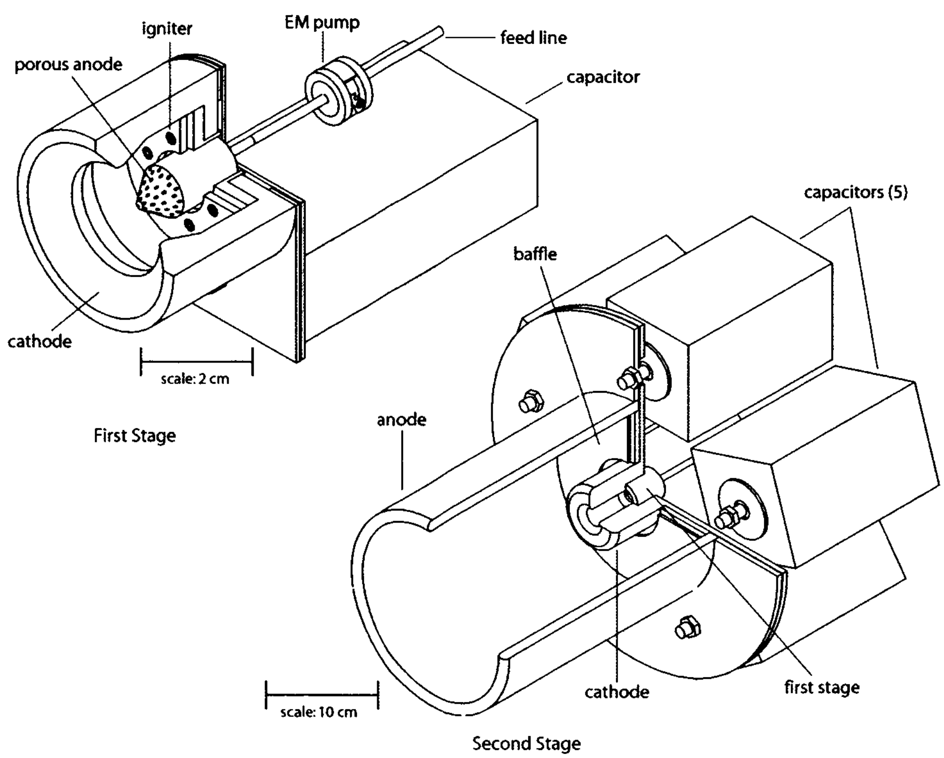

FIG. 1: Schematic illustration of the GEM two-stage PPT concept.

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There exists some precendent both for employing a two-stage acceleration scheme and for using a metal derived plasma as propellant. Turchi *et al.*[2] used an ablative Teflon plasma injector as the first stage of a rectangular two-stage accelerator and Gomilka *et al.*[3] used ablation products from a solid cadmium electrode in a coaxial two-stage device. In addition, acceleration efficiencies of over 50% have been reported in the literature for metallic plasmas[4].

The GEM thruster differs from other concepts in the following ways.

- The center electrode in the first stage is chosen to be the anode. Previous research has shown that markedly higher inner electrode erosion occurs in this case[5]. However, this outcome is desired in the GEM thruster as the liquid gallium from the anode serves as the propellant.
- The use of the gallium plasma as a trigger for the high-energy second stage eliminates the need for a high-current electrical switch in the system.
- The need for high-speed (and failure-prone) gas valves is eliminated through the use of a liquid metal propellant. In addition, gallium is very dense and can be stored in a relatively compact manner, providing for ease of system integration.
- Propellant in the GEM thruster is fed to the discharge chamber using of an electromagnetic pump, thus eliminating the need for moving parts.

The GEM thruster is a variant of a two-stage PPT design presented by Markusic *et al.*[6]. The primary differences are: a) the first stage design (propellant injection scheme), b) the GEM thruster uses gallium as propellant instead of lithium and c) the GEM thruster discharge energy is 500 J/pulse instead of 50 kJ/pulse.

In the present paper, we present the detailed design of the first-generation GEM thruster and present calculations and modeling aimed at giving insight into the thruster's operation and estimating its performance. One-dimensional analytical tools and the MACH2 code are used to model the temporal evolution of the current distribution and plasma properties within the discharge.

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[1] T.E. Markusic, "Liquid-metal-fed pulsed electromagnetic thrusters for in-space propulsion", *Proc. 2004 JANNAF Conference*, Las Vegas, NV, May 10-14, 2004.

[2] P.J. Turchi, C.N. Boyer, and J.F. Davis, "Multi-stage plasma propulsion", *17th International Electric Propulsion Conference*, Tokyo, Japan, May 28-31, 1984.

[3] L.A. Gomilka, A.I. Zemskov, L.N. Lesnevskii, and A.D. Pavlov, "A study of the plasma pulsed accelerator with the metallic propellants", *24th IAF International Astronautical Conference*, Baku, Azerbaidzhan SSR, Oct., 1973.

[4] D.L. Clingman, D.G. Gubbins, and T.L. Rosebrock, "Pulsed electromagnetic acceleration of metal plasmas", *AIAA Journal*, 2(2):328–334, Feb. 1964.

[5] E.Y. Choueiri, Princeton University, (Personal Communication).

[6] T.E. Markusic, Y.C.F. Thio, and J.T. Cassibry, "Design of a high-energy, two-stage pulsed plasma thruster", *38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference*, Indianapolis, IN, July 7-10, 2002.