Development of Dielectric Barrier Discharge Thruster and PPU for Small Satellite Applications

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Background

Global demand for distributed Earth observation and satellite communication architectures has driven the rapid expansion of the small satellite (smallsat) market.

The volume and mass restrictions of smallsat architectures pose a challenge for propulsion. Existing high-I_{sp} electric propulsion (EP) systems, such as gridded-ion and Hall-effect thrusters, have difficulty scaling down to smallsat applications.

UW has teamed up with Aerojet Rocketdyne (AR) and Eagle Harbor Technologies (EHT) to develop and test an EP system with a specific mass much lower than existing technologies.

Innovation

UW SPACE Lab is developing a thruster based on the principle of a dielectric barrier discharge (DBD). DBDs typically consist of two electrodes separated by a thin dielectric insulator. Application of a high-voltage (~10's of kV) AC signal in the presence of process gas results in the formation of a plasma discharge between the electrodes.

While DBDs have been employed to generate plasmas as atmospheric pressure, their application to space propulsion is still relatively new.

The greatest advantages of DBDs are their inherent simplicity and small scale. This provides significant mass and volume savings compared to conventional high-I_{sp} devices.

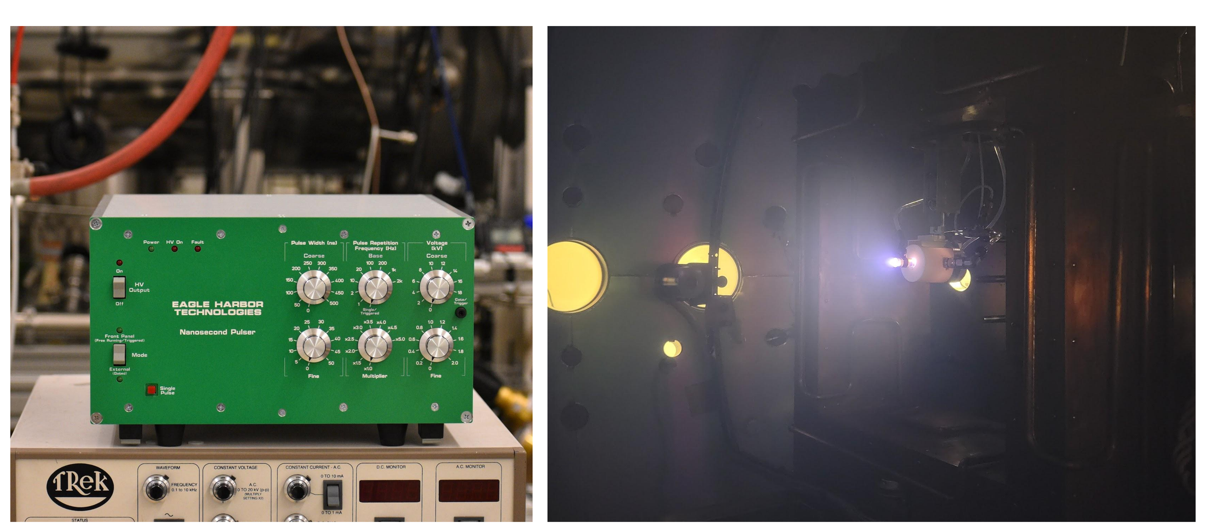

Figure 1. (Left) EHT Nanosecond Pulser power supply used for testing. Capable of pulses up to 20kV, 500ns, and 10kHz. (Right) Coaxial DBD operating on argon.

Project Description

Thruster Configurations

Two configurations were developed for testing the DBD concept; a coaxial central electrode design and a cylindrical wrapped electrode design.

Wrapped cylinder DBD	Coaxial DBD
¼" quartz tube diameter	½ " quartz tube diameter
Insulated wrapped electrode	Exposed central electrode

A variety of electrode geometries were tested for each configuration. Argon was used as the test gas at a range of flow rates (5-100sccm). Delivered power and thrust stand measurements were taken.

Plasma ignition has been observed at relevant flow rates. Preliminary thrust stand measurements show no benefit of the DBD above cold gas in current regimes, but this is likely because the circuit is not depositing significant power into the plasma

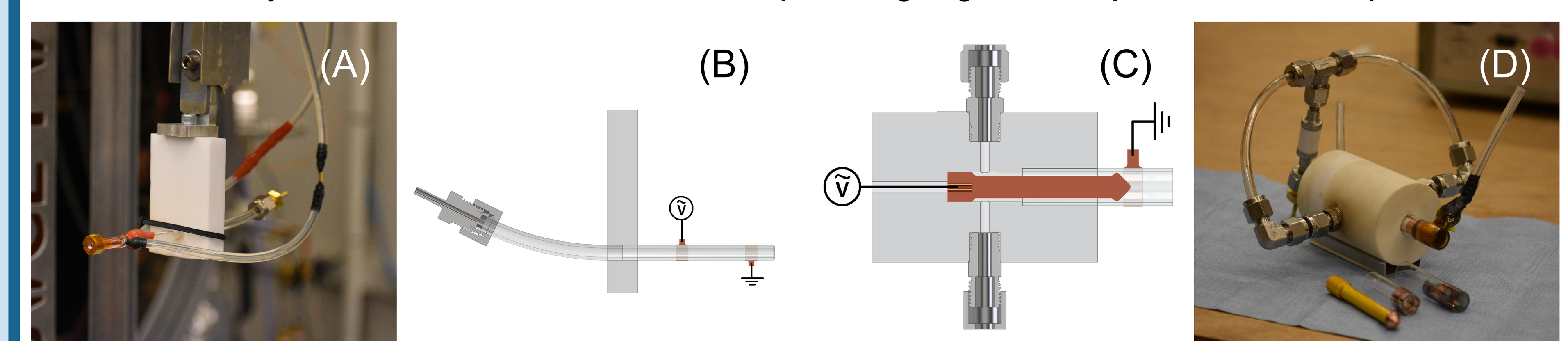

Figure 2. A) Cylindrical device mounted on thrust stand. Electrodes potted using SiO2, silicone, and polyimide tape B) schematic for cylindrical thruster, electrodes were tested at multiple axial locations, single soft-tube gas feed epoxied into the body of the thruster C) schematic for coaxial device with spiked anode. D) Coaxial device, alternate quartz tubes and anode also pictured. Single gas feed is split to injection ports to produce even gas distribution in channel.

PPU

- Apparent power of 50 W and voltage output between 10 to 25 kV
- Microcontroller-based oscillator subsection to control base frequency, duty cycle, burst frequency, and burst ratio
- Power-weight ratio of 0.66 kg/kW, with maximum weight of 33 g

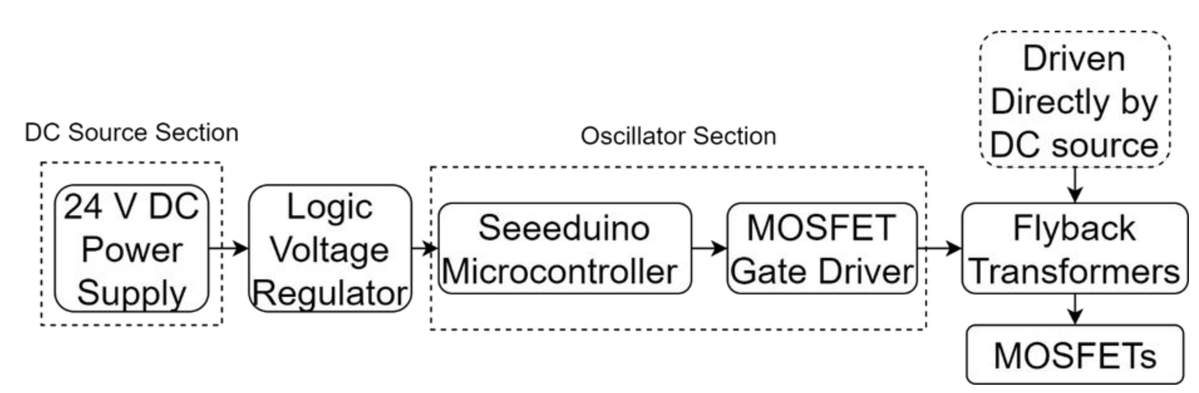

Figure 3. The block diagram of the proposed PPU

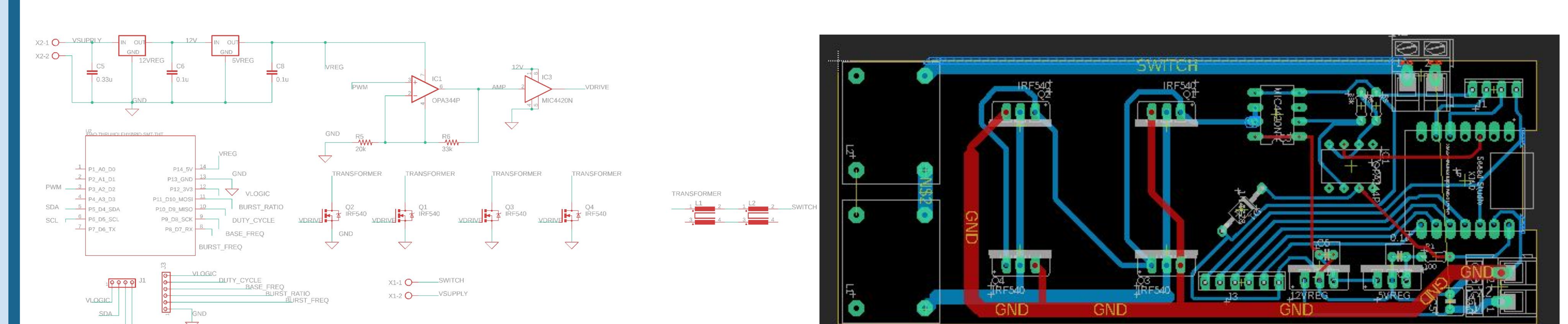

Figure 4. Schematic and board of proposed PPU with Arduino microcontroller-based oscillator.

Anticipated Impact

SmallSat market cap projected to grow from $3.1 billion in 2021 to $7.4 billion by 2026

Successful development and characterization of a DBD thruster and PPU operating on 50-500W of power could transition into the development of a flight-ready electric propulsion system for smallsat applications. The requirements for such a system are:

- Low cost
- Low specific mass (mass per unit power) PPU
- Lightweight thruster
- Compact system

Path Forward

Project Milestones

- Development of ~100 W DBD thruster
- Performance characterization over propellant mass flows ~0.1-10 mg/s and input powers ~10-120 W on argon
  - Measure thrust, specific impulse, and thrust efficiency
  - Generate scaling laws for DBD thrusters
- Design of flight capable PPU to support the development of an eventual flight system

Next Steps

- Exploration of additional device configurations including planar geometries
- Development and analysis of circuit model for DBDs to inform future designs

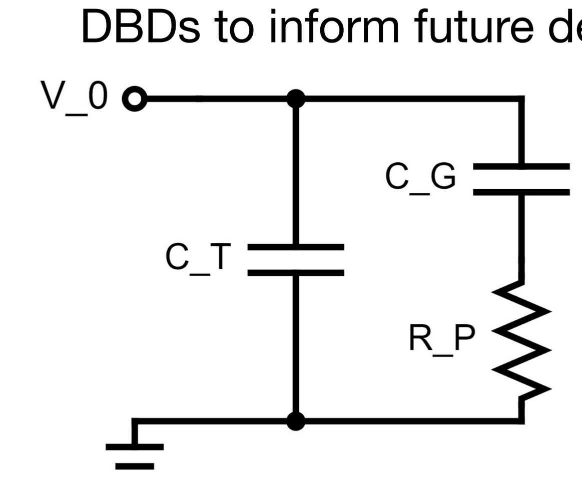

Figure 5. Circuit model for DBD which includes capacitance from electrode separation and glass. Plasma is modeled as a simple resistor