Presentation SSC09-II-1

Micro RF Ion Engine for Small Satellite Applications

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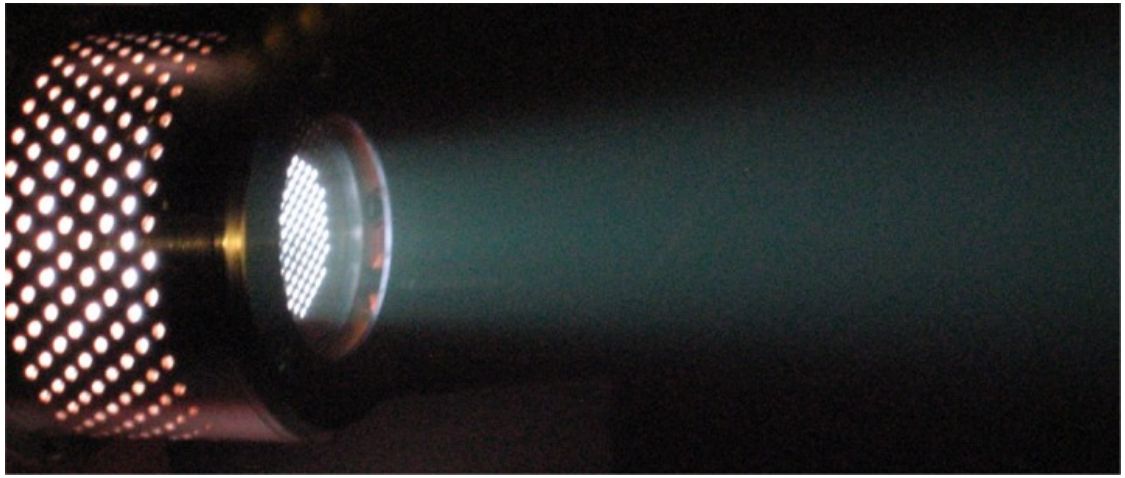


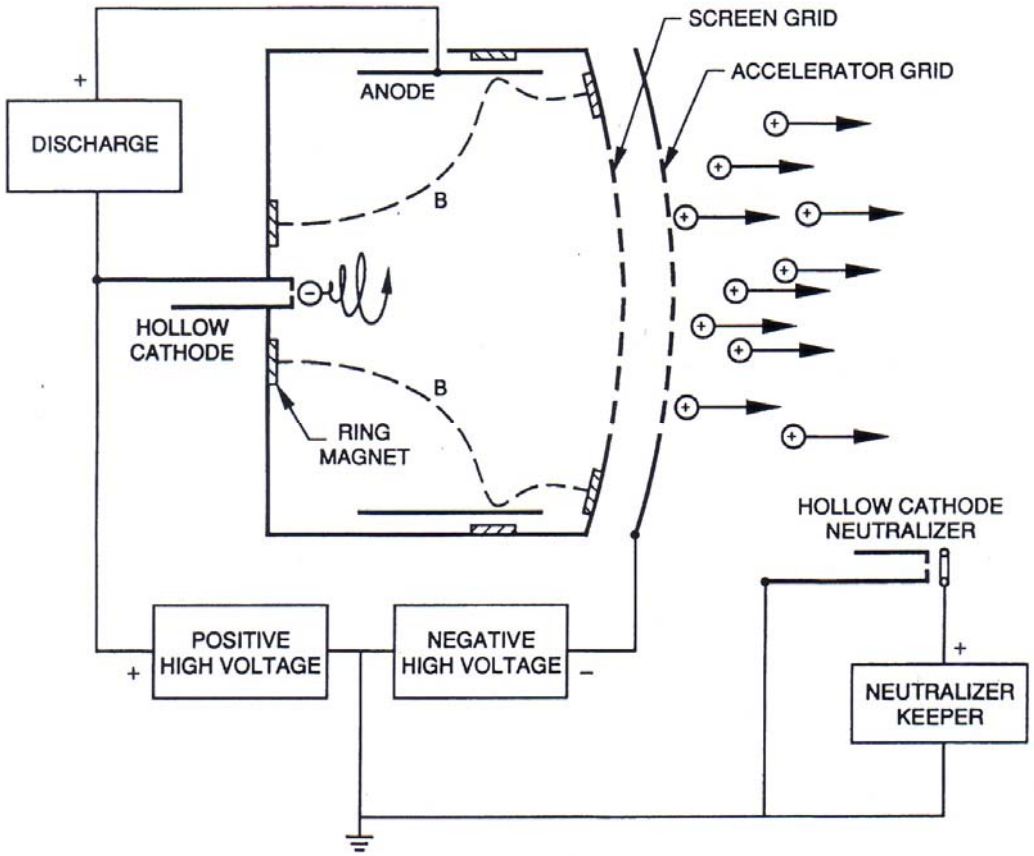
23th AIAA/USU Conference on Small Satellites

Overview

- Background on RF ion engines
- Development of Busek 3-cm micro RF ion engine
- Performance characterization
- Applications and sample mission
- Current work on further miniaturization for nano-satellite applications

Direct-Current Ion Engines

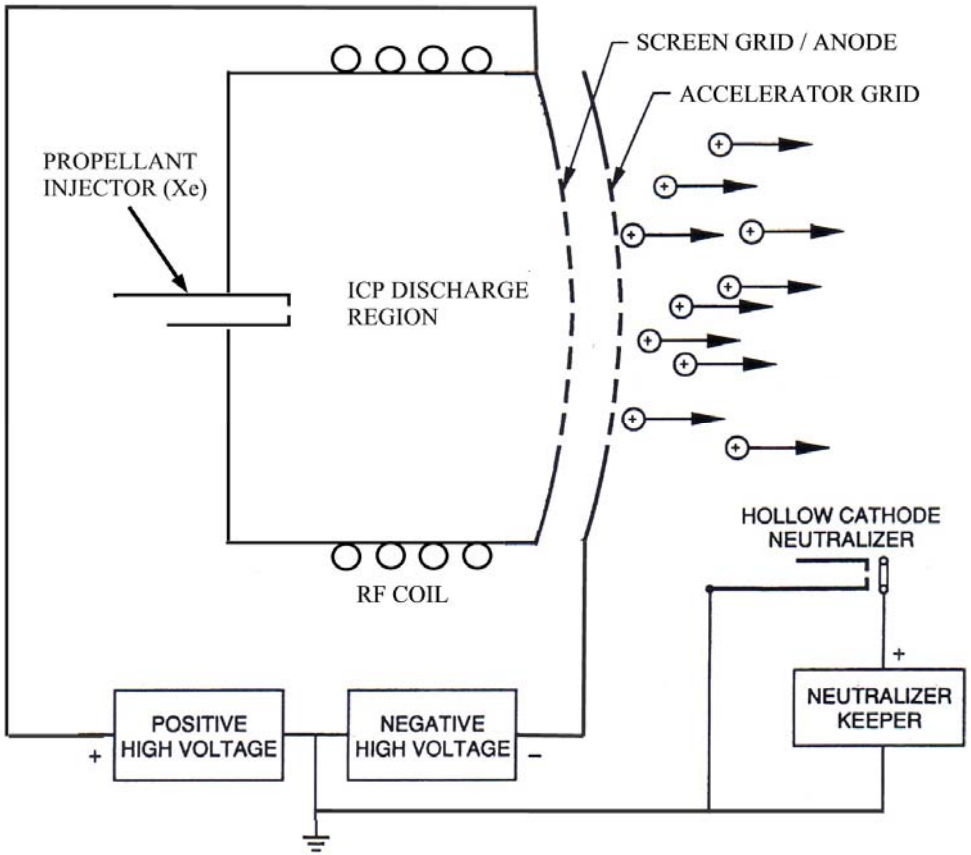
- Electrostatic thrusters; grids extract and accelerate ions to generate thrust
- Highest Isp in electric propulsion
- Ionization by direct electron bombardment; primary electrons emitted by internal hot cathode
- Applied magnetic field for electron confinement
- Very difficult to miniaturize due to internal cathode and magnetic structure!



Schematic of a typical DC ion engine

Radio-Frequency Ion Engines

- Also electrostatic thrusters with high Isp capability
- RF coil induces alternating electric field, which energizes free electrons to ionize neutrals
- Plasma is self-confined through the induced EM field
- Varying RF power alone can control thrust rapidly and precisely
- No internal cathode and no permanent magnetic structure; longer life and easier to scale down



Schematic of a typical RF ion engine

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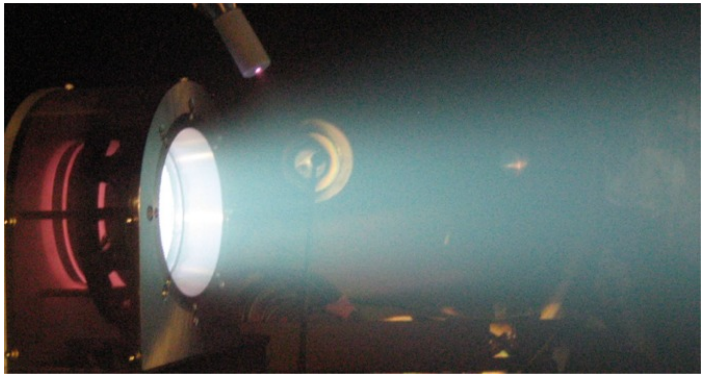
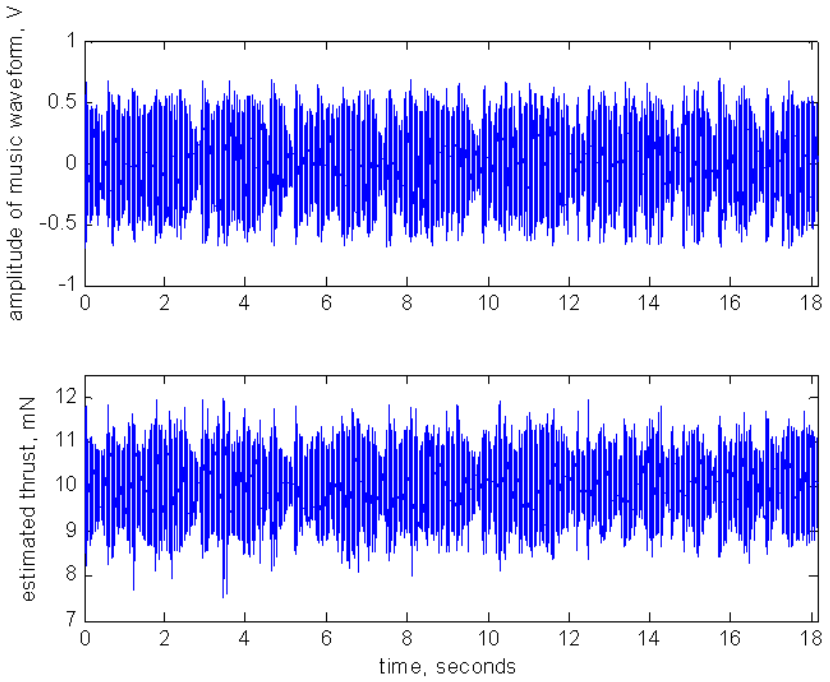
Rapid and Precise Thrust Actuation

- Precision thrust is a key characteristic of RF ion engines
- Demonstrating precise thrust with Busek's 7-cm RF ion engine
- Actuate RF power with a music waveform; constant grid voltage
- Record the response of the ion beam current ($J_{beam} \sim J_{anode}$ in ion engines)
- Turn the ion beam response into music and see if it matches the original melody – and it does!
- This demonstration exemplifies active disturbance-cancellation at 11 kHz frequency response



BRFIT-7



Play

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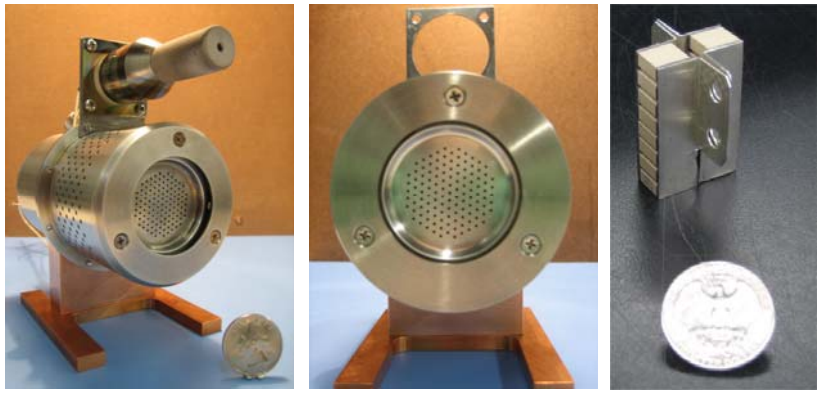
Busek 3-cm RF Ion Engine

- Goal is to develop a 100W micro thruster suitable for 25~100kg micro-satellites
- Target performance is 2-mN thrust and >2000-sec Isp with xenon
- Built-in miniature capacitor bank for circuit matching; matching frequency ~2 MHz designed according to discharge pressure
- High-temperature ceramic discharge chamber and internal structure to reduce coupling loss
- Prototype was successfully validated



Prototype of BRFIT-3

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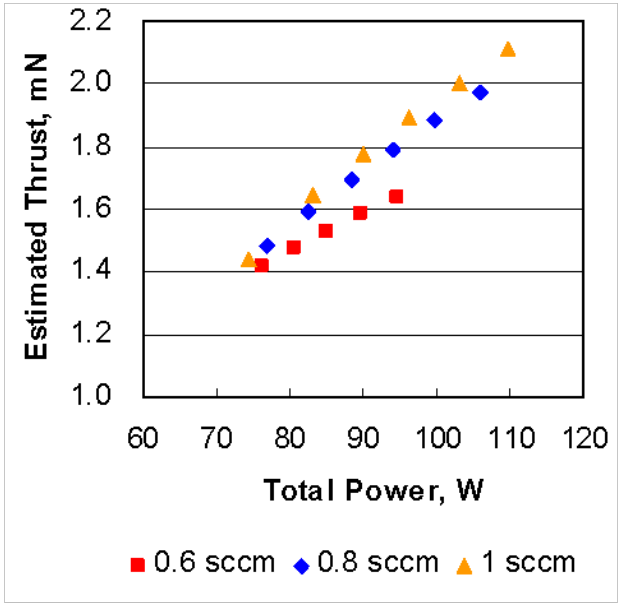
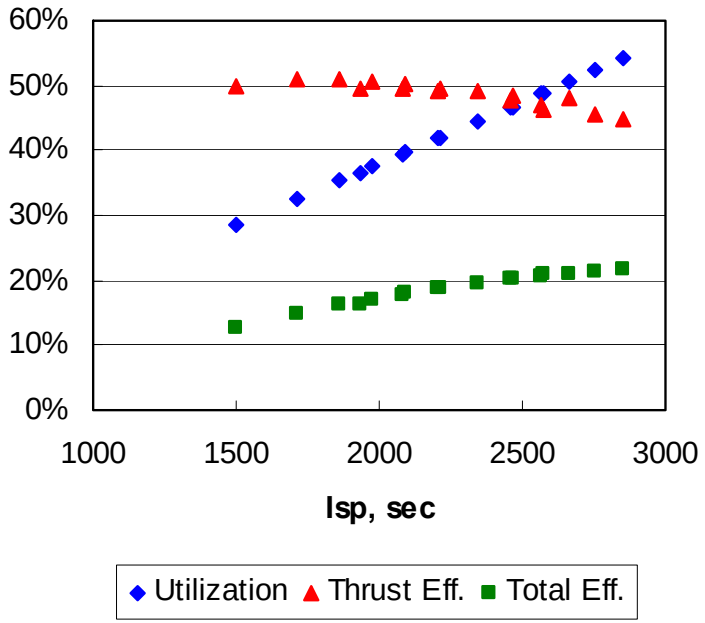
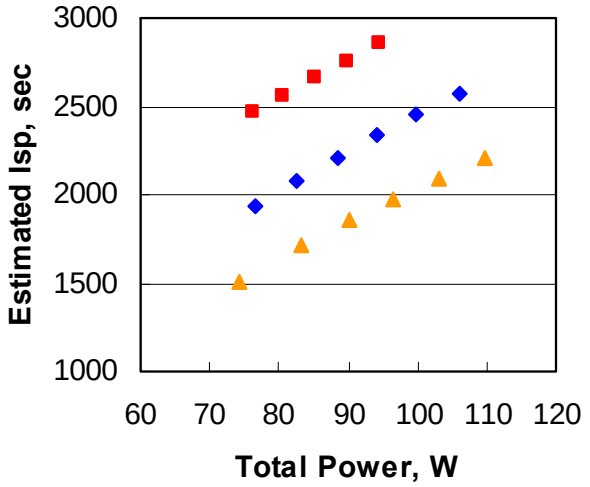
Performance Characteristics

- Demonstrated 1.4-2.1 mN thrust and 1500-2850 sec Isp with 70-110 total power (RF + ion beam power)
- Optimum Isp @ 2500 sec; thrust efficiency starts to decline significantly and total efficiency flattens







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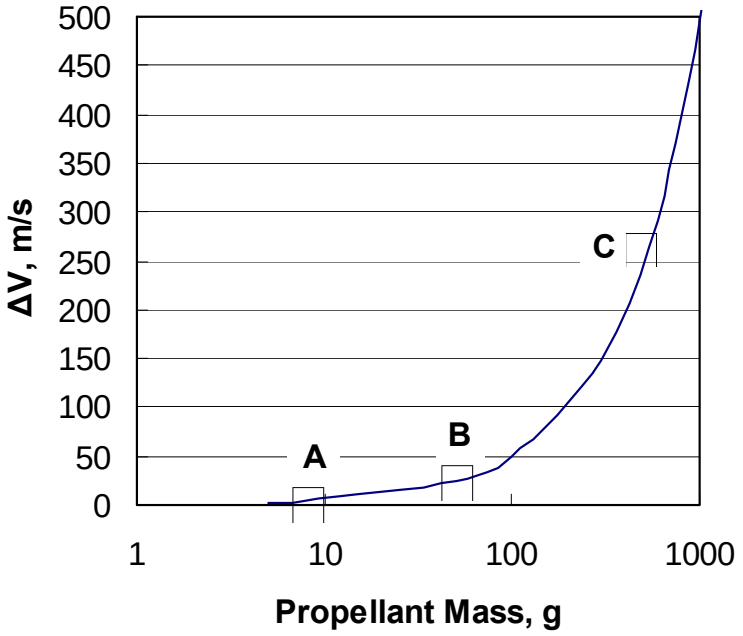
Applications and Sample Missions

Applications

- Formation flights
- Spacecraft initial stabilization
- Station-keeping and active drag compensation

Sample Missions

- Onboard on a micro-satellite with 50 kg wet mass
- Propulsion system dry mass ~3 kg
- Nominal performance at 2-mN thrust and 2500-sec Isp
- ACS + drag compensation at LEO for 10 years requires 0.6 kg propellant
- Orbit transfer within LEO requires 0.5 kg propellant



Mission	Description	ΔV	Fuel Mass
A	ACS per year (at LEO 400 km)	~4 m/s	8 g
B	Drag comp. per year (at LEO 400 km)	~25 m/s	50 g
C	Initial orbit rise* (LEO 300–780 km)	264 m/s	535 g

* will take 76 days

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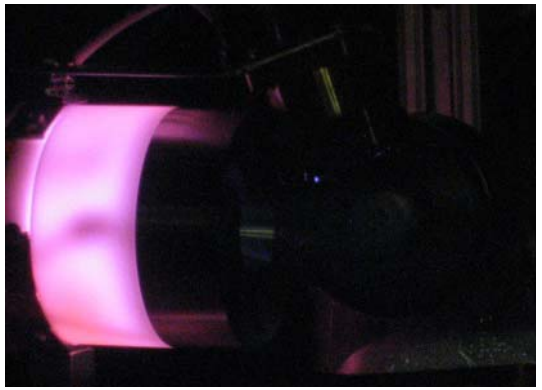
Further Miniaturization of RF Ion Engines

- Goal is to develop a micro RF ion engine suitable for sub 10 kg nano-satellites
- Propulsion system dry mass < 0.8 kg
- 10-20W total power; can be flown on CubeSat
- Operates at 5-50 μN but capable of reaching 100 μN; maximum Isp is 1800 sec
- Demonstrated CNTFE cathode as neutralizer; propellant-less, < 1 W
- Prototype was successfully validated



Prototype of BRFIT-1 w/ CNTFE neutralizer

Conclusion

- RF ion engines have longer life and easier to scale down than DC ion engines
- Busek has developed a 100W-class micro RF ion engine suitable for micro-satellites under 100 kg
- Optimum 2 mN thrust and 2500 sec Isp; enables long-term missions within LEO
- A 10W-class prototype under development can potentially be flown on CubeSat

Come see the prototypes of the micro RF ion engine at the Busek booth!