Description of the Photonic Associates "LPT" thruster

The LPT (Figure 1) is the first new microthruster in the past 30 years. It is also the first thruster device in the new field of chemically augmented electric propulsion invented by PALLC and developed over the past six years SBIR and STTR funding. We are now seeking venture capital to go to market with it.

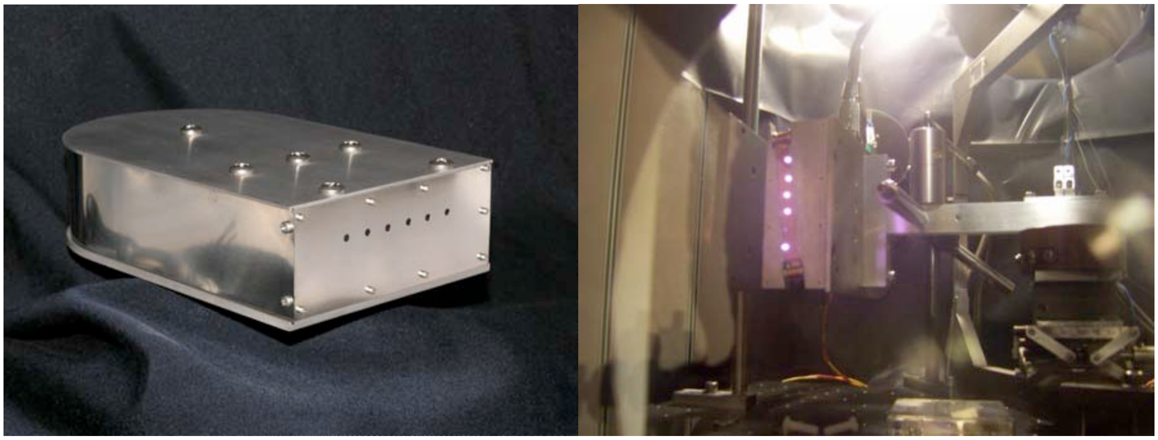

Figure 1: The Laser Plasma Thruster

Its operation is based on laser-controlled ignition of an energetic material in a proprietary fuel tape (Figure 2). The fuel cannot detonate in an uncontrolled way. Because the firing rate and tape speed can be controlled over a factor of 100 in the current design, thrust can be varied from 0.1 to 10 millinewtons and the energetic efficiency is 130%, because of the contribution of the chemical energy in the tape coating. As a result, we have the highest thrust to power ratio in the business. We also have the lowest minimum impulse bit in the business because of the small amount of momentum, or impulse, generated by a single laser pulse, since it normally operates at up to 360 pulses per second.

Differentiation

Table 1 shows a technical comparison with our competition.

Unique features of the LPT are:

- Thrust/Electrical Input Power: 500μN/W (five times the nearest competitor). This is important for minimizing usage of expensive spacecraft power.
- First new technology in electric micro-propulsion in 30 years.
- Smallest minimum impulse bit in the business. This is important for precision.
- First demonstration of chemically-augmented electric propulsion. This is important for being able to give 133% exhaust efficiency, well above any competitive device.
- Only the fuel, not the engine erodes (unlike other electric microthrusters). This is a very important difference.
- Dimensions & mass: 4x10x15cm, 0.5kg.
- Can restart in microseconds.

- Infinitely throttleable thrust.
- Driven by 65% efficient diode lasers.
- Thrust range: 100mN – 10mN
- Specific Impulse: 200 seconds (corresponds to exhaust velocity of 2km/s)
- TRL level: 6
- Vectoring can be done by selective firing of the six output ports.

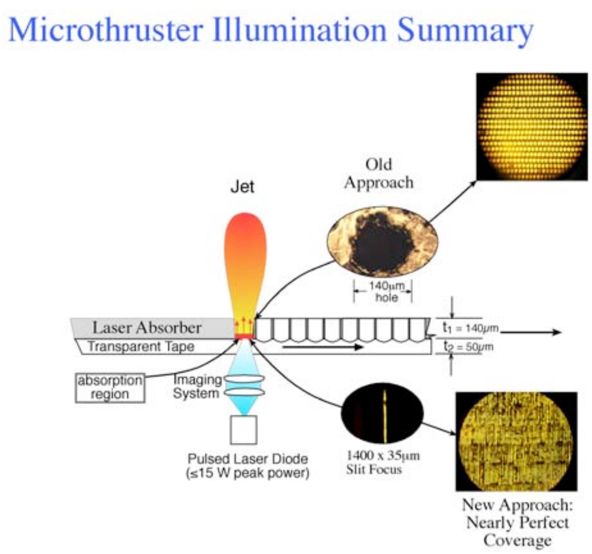

Figure 2: Operating principles

Future Development Path

We plan to develop two exciting, advanced versions of the LPT which will have very little competition. All device performance claims are backed up by experimental data from our R&D program. These are the Laser Minithruster and the high performance Macrothruster.

1) Laser Minithruster

Expected performance parameters are shown in Table 2. This device still uses solid fuel as in Figure 2, but has a smaller footprint, much smaller volume and mass and higher I_{sp}. Higher I_{sp} is achieved at the same 1ms pulsewidth by focusing more tightly on the fuel tape. Shorter focal length optics also help reduce the footprint.

Table 1. Technical comparison of electric microthrusters

Thruster	Thrust (µN)	Specific Impulse I_{sp} (s)	Engine Mass (kg) 1)	Thrust/ Power (µN/W)	Precision [MIB (µN-s)] 2)	Commercial Developer
Cold Gas	20,000	65	2.5	---	200	Surrey U.
Colloid	20	1,000	20	180	4	Busek Co.
Laser Plasma Thruster (LPT)	10,000	200	0.5	500	0.1	Photonic Associates

1): Including capacitors, pulse forming unit, electronics, propellant, thruster and thruster support structure

2): MIB is the minimum impulse bit, the smallest amount of momentum the device can generate. Small is good, because small MIB gives proportionately more precise control of the satellite.

Table 2. Existing vs. Proposed Performance

Parameter	*Present msLPT*	*Proposed mini-LPT*
Thrust	*0.1 – 10 mN*	*0.05 – 4 mN*
Rms Thrust Noise	*5%*	*1%*
Fuel Tape Dimensions	*30 m x 8 mm*	*30 m x 4 mm*
Number of Lasers	*6*	*3*
Focal Distance	*48 mm*	*12 mm*
Laser Spot Dimensions	*1.4 mm x 30 μm*	*1.4 mm x 8 μm*
C_m	*0.5 mN/W*	*0.2 mN/W*
I_{sp}	*200 s*	*500s*
Ablation Efficiency $\eta_{AB} = (P_{optical}/P_{thrust})$	*205%*	*205%*
Thrust Efficiency η_T	*133%*	*133%*
Minimum Impulse Bit	*100* nN-s	*100 nN-s*
Volume	*670 cm³*	*270 cm³*
Mass	*0.5 kg*	*0.25 kg*
Electrical Power	*20 W (max)*	*20 W (max)*
Lifetime Impulse	*50 N-s*	*20 N-s*
Fuel Capacity	*44 g*	*22 g*
Type of Laser	*JDSU 6396 diode*	*JDSU 6396 diode*
Ablation Fuel	*Carbon-doped glycidyl azide polymer*	*IR-dye-doped glycidyl azide polymer*

2) 1N-class variable I_{sp} Laser Macrothruster

Given development support, our macrothruster will have essentially no competition. It will be built in a 20kg package and our calculations have indcated performance which cannot be matched by current technology. The smoothly variable I_{sp} feature is crucial to this statement. Instead of diode lasers, it will use diode-pumped fiber amplifiers with overall electrical efficiency of 35 – 50%. I_{sp} is varied by changing pulse duration from 10ns to 1ms, and by changing the focal spot area. Fuel will be a proprietary polymer. Fourteen fiber laser amplifiers are focused on a slit from which the fuel emerges. Selective firing of these lasers can provide vectoring in one dimension. Two engines mounted orthogonally can provide full steering for a microsatellite.

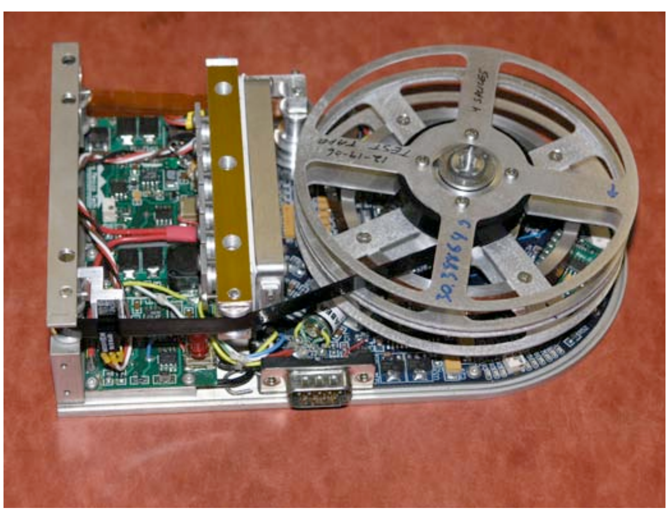

Figure 3: LPT internal view.

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