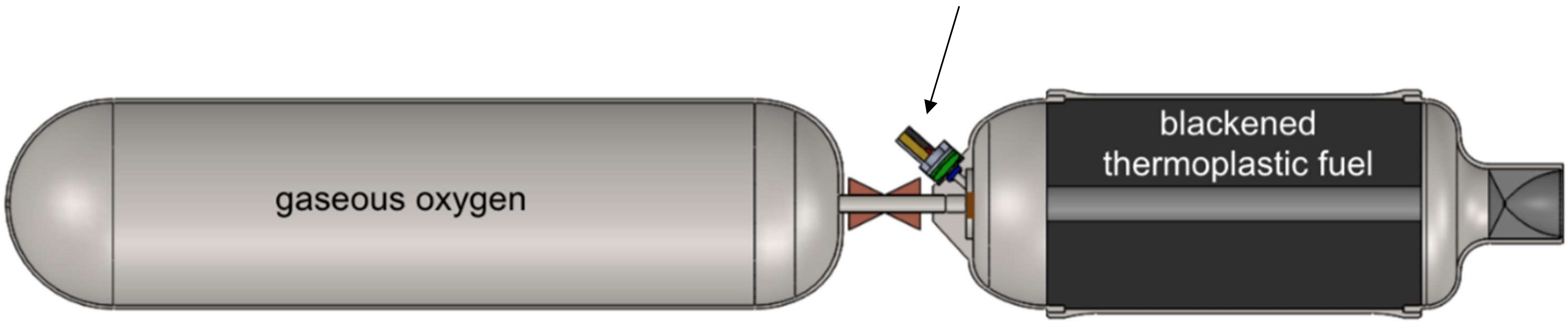
RPC 2020



Hybrid Rocket Concept

Virtual Research Presentation Conference

INVESTIGATION OF HYBRID ROCKET LASER IGNITION

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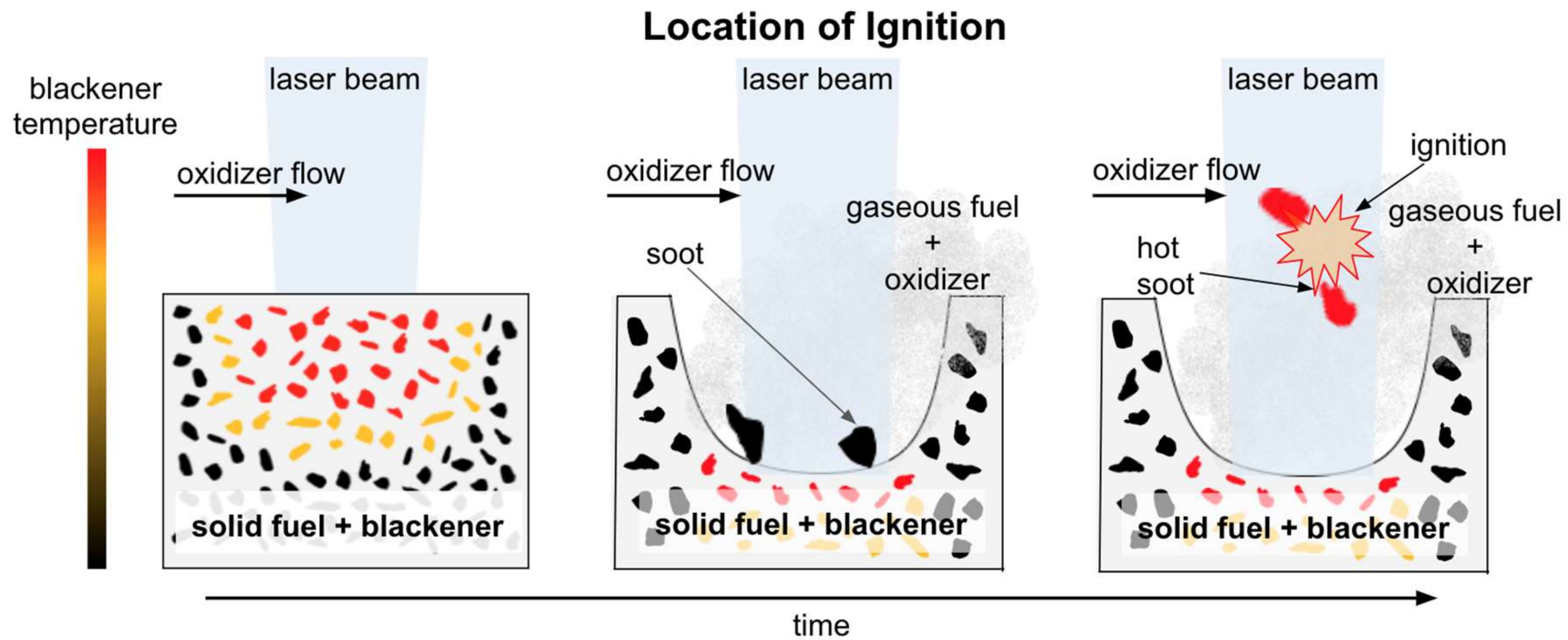
Program: SURP

RPC-242

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

- Laser ignition has been demonstrated to be possible in hybrid systems (solid fuel, gaseous oxidizer) using a **single, lightweight diode laser**.
- This approach leverages a **"heated particle" ignition mechanism** detailed in the figure below.
- **Past research has relied on natural char production** during fuel decomposition to create the soot needed for production of these heated particles.
- Unfortunately, **not all hybrid fuels produce this char layer**, greatly limiting the applicability of the laser ignition

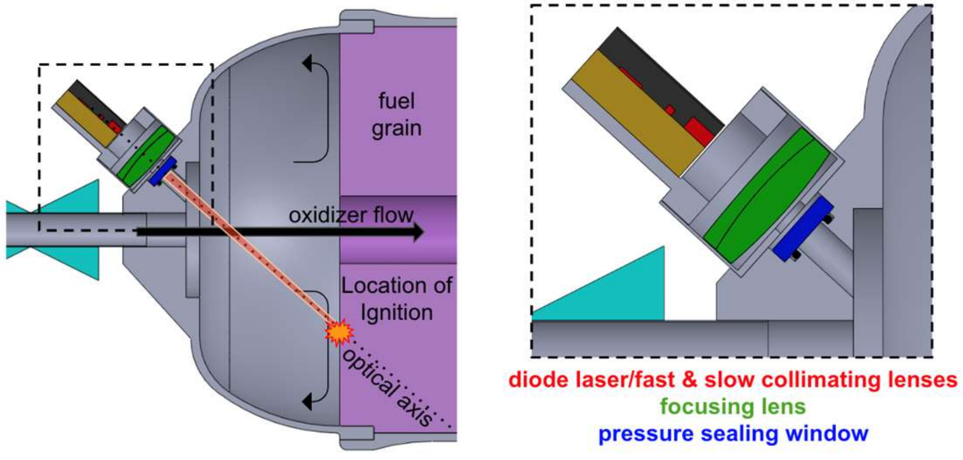


Laser ignition mechanism

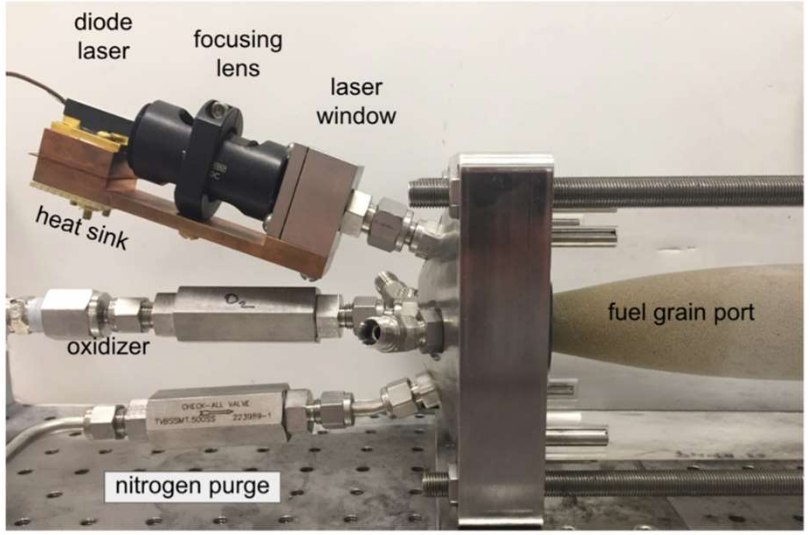
Problem Description

- Reference mission studies have shown that as the delta-V requirements are increased **beyond ~ 1 km/s (i.e. orbit insertion at Mars), a hybrid motor architecture will provide higher performance than bi-prop liquids** due to a greater propellant density [1].

- **To be competitive** with existing liquid propulsion units:
  - Hybrid motor needs a **robust and restart capable ignition** system
  - Need to **minimize mass and volume** wherever possible
  - **Single laser** can be powered by the satellite's electrical systems which tend to be lighter and require less volume as compared to the fuel tanks and plumbing needed for a torch igniter.
  - Laser system only requires a **small number of small optical components**



Laser igniter mounting configuration



Experimental implementation

Methodology

Project Objectives:

1) Demonstrate laser ignition of PMMA/GOX propellants with carbon-based fuel additives

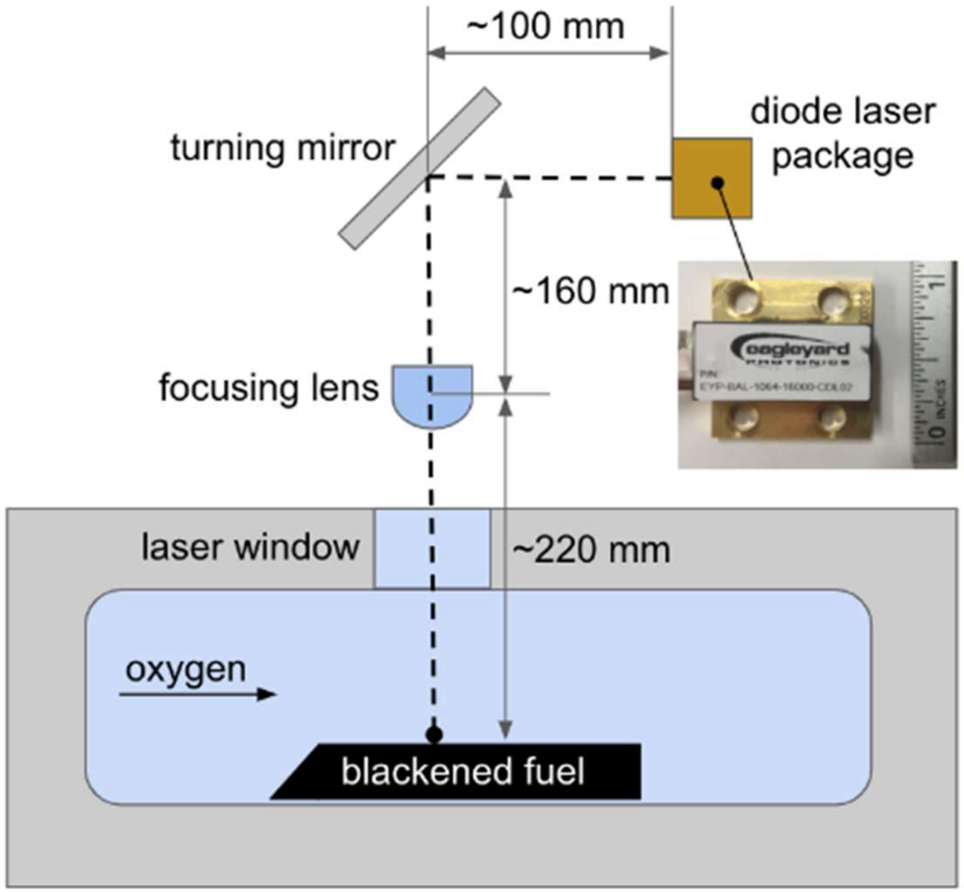
2) Compare ignition delay performance of PMMA/GOX with different fuel additives. Compare to past results using char producing fuels.

Methodology:

1) Produce baseline samples of PMMA (no ignition additive) for which laser ignition doesn't work and custom PMMA fuel samples (with ignition additive) in the lab containing **graphite powder**, **carbon black powder**, and **coal powder** additives.

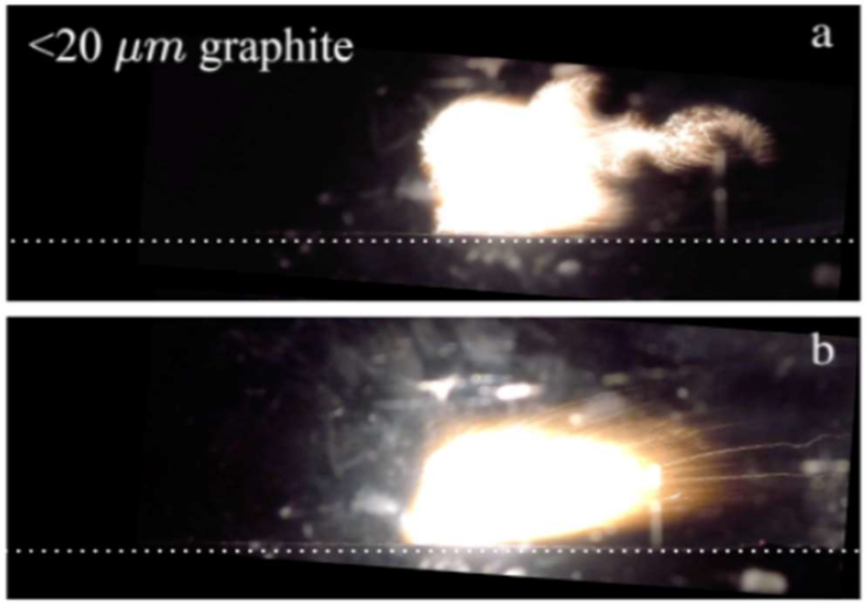
2) Multiple ignitions per fuel grain using setup shown to the right.

3) Use a high-speed camera to capture ignition event and determine ignition delay

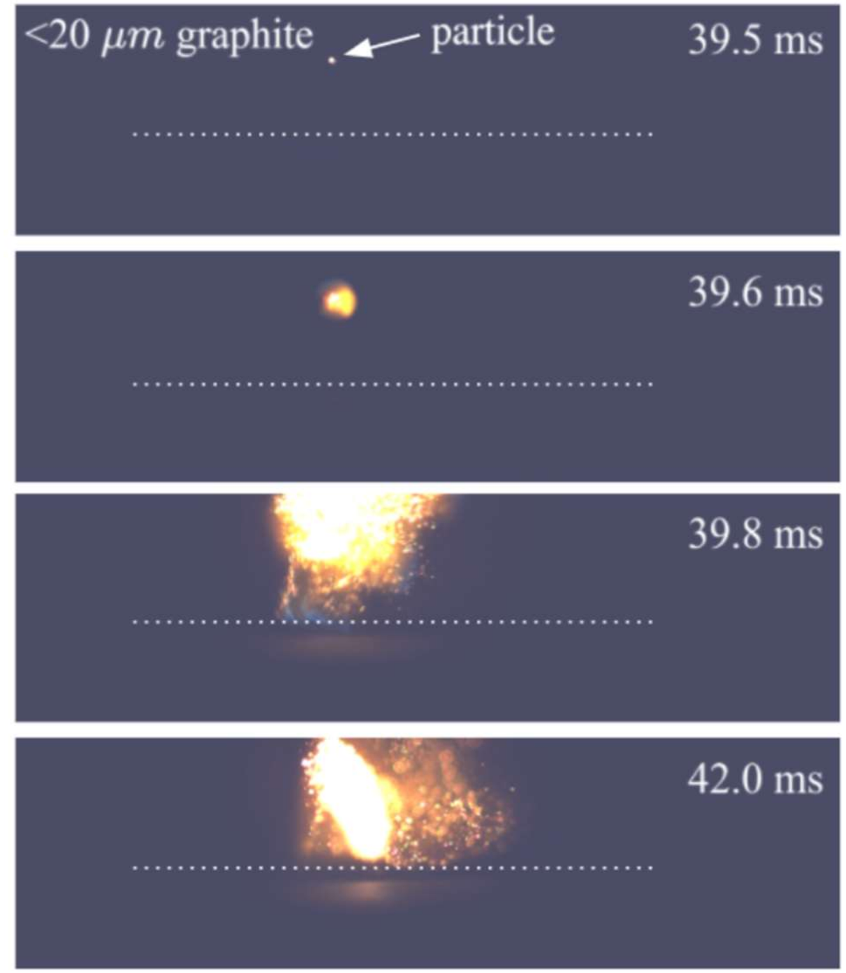


Combustion chamber with visualization windows used to study laser ignition event. High-speed camera imaging through side window.

Results



Ignition captured at 60 frames per second. Images a and b are consecutive video frames.



Ignition captured at 10,000 frames per second. Timestamps are relative to laser turn-on.

- Testing was successful. **All 3 additive types produced ignition.**
- **20-micron graphite produced the shortest ignition delays** because it had to fastest response time to the flow of oxidizer.
- With these results it is shown to be **possible to directly laser ignite PMMA/GOX**, the propellants being pursued by JPL

Publications and References

References

Elizabeth Jens, Ashley C. Karp, Barry Nakazono, Daniel B. Eldred, Matthew E. DeVost, and David Vaughan. "Design of a Hybrid CubeSat Orbit Insertion Motor", 52nd AIAA/SAE/ASEE Joint Propulsion Conference, AIAA Propulsion and Energy Forum, (AIAA 2016-4961)

Publications

D. Dyrda, et al. (2020) "Diode Laser Ignition of a Poly(Methyl Methacrylate) and Gaseous Oxygen Hybrid Motor," *Journal of Propulsion and Power*, Advance Online Publication, doi: 10.2514/1.B37832.

D. Dyrda, V. Korneyeva, and B. J. Cantwell (2020) "Diode Laser Ignition Mechanism for Hybrid Propulsion Systems," *Journal of Propulsion and Power,* Advance Online Publication, doi: 10.2514/1.B37834.

Dyrda, D., Cantwell, B.J., "Fuel Additives For Laser Ignition of Poly(methyl methacrylate) and Gaseous Oxygen Hybrid Motors," AIAA Joint Propulsion Conference, August 2020.