Interstellar Flight and Recycling Light: A Bilateral Study

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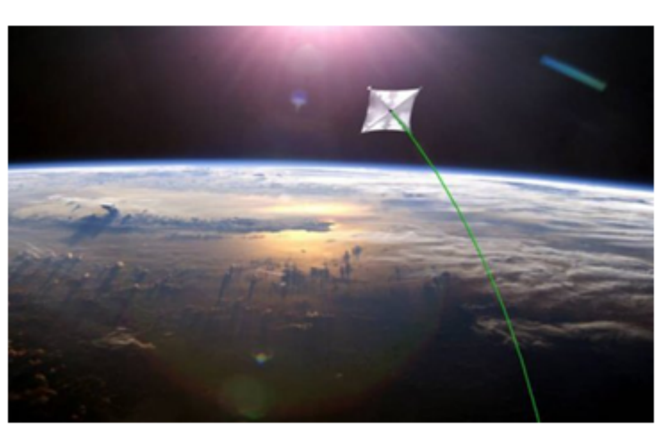
ABSTRACT

The impossible task of traveling 25.6 trillion miles to Alpha Centauri, our closest star, is now possible. Using a Directed Energy System for Targeting of Asteroids and exploRation (DE-STAR), a versatile, scalable phased-array laser system, it can be reached in a short 16 years. Our project entails carrying out both computational and experimental studies of specific uses of DE-STAR to investigate photon recycling and spacecraft propulsion. Photon recycling is a unique term used to describe a form of energy conservation relative to this project. This effect will greatly improve the efficiency of spacecraft making interstellar flight more plausible. What lies beyond our solar system is one of the biggest mysteries of mankind and it finally has the potential to be solved.

INTERSTELLAR FLIGHT

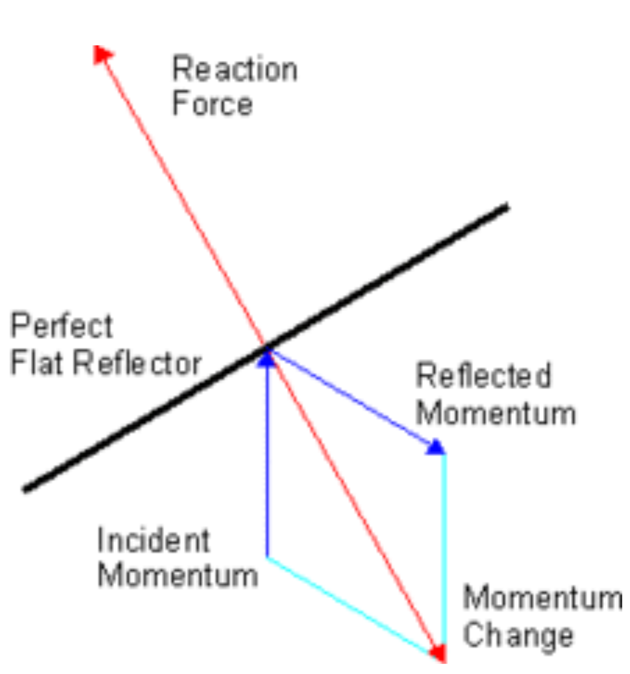
- DE-STAR will be propelling one gram wafer-sats that are one meter in diameter.

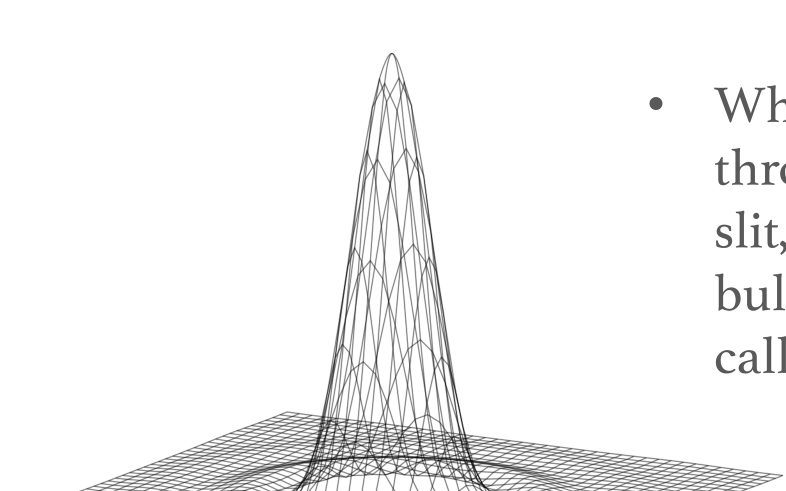


- Focusing a stream of photons into a concentrated beam makes a laser. Shining a laser on a mirror results in it being reflected at an inverse angle.
- Although photons are massless, they carry momentum. Because of this they can hit objects with force.

$$E^2 = (pc)^2 + (m_0 c^2)^2$$

- Radiation pressure: when the photon bounces off a reflective surface rather than being absorbed, it transfers nearly twice as much momentum to the object it hit.

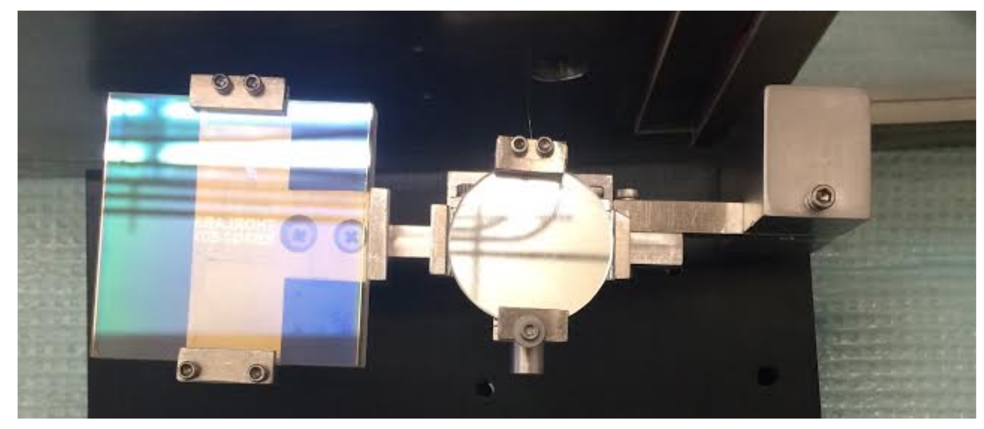




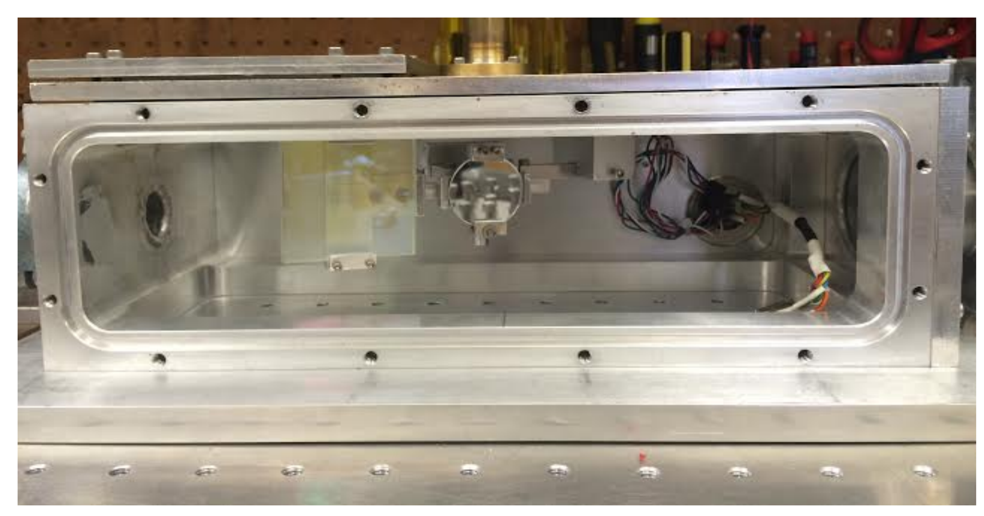
- When light is shown through a circular slit, it results in a bullseye type pattern called airy disks.

EXPERIMENT

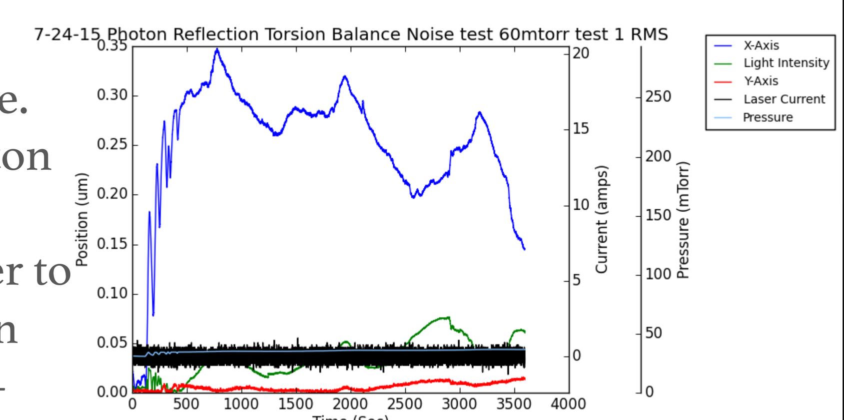
- A torsion balance was designed to be a force probe for the reflection of lasers between mirrors.

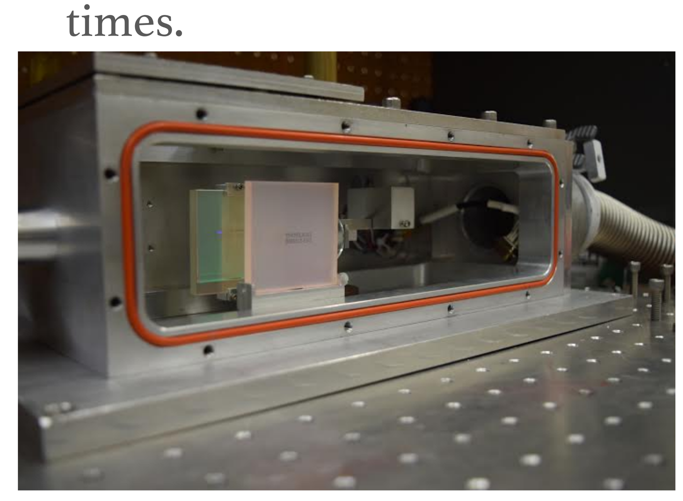


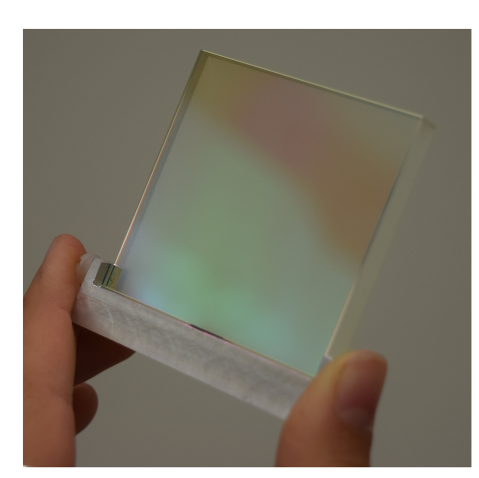
- Set in a vacuum chamber to simulate space like conditions.



- Analyzed noise levels of balance.
- Simulated photon recycling by angling the laser to bounce between the reflectors 2+ times.



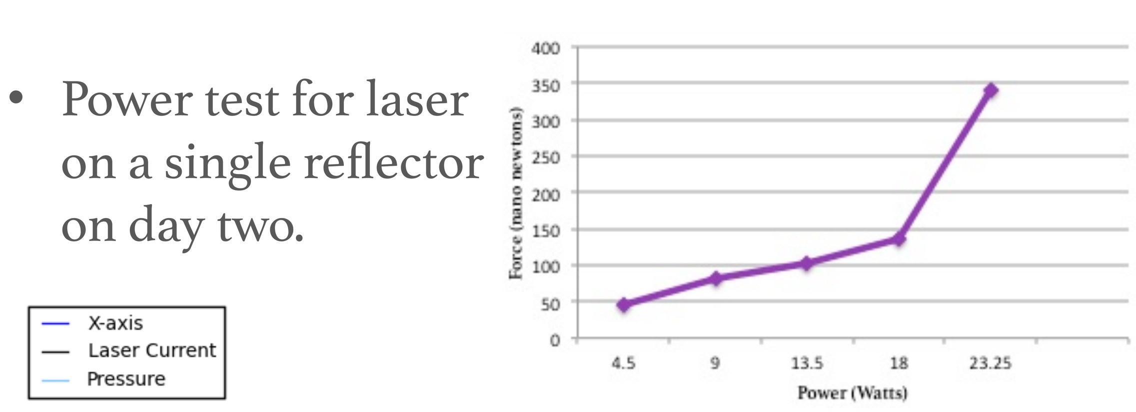


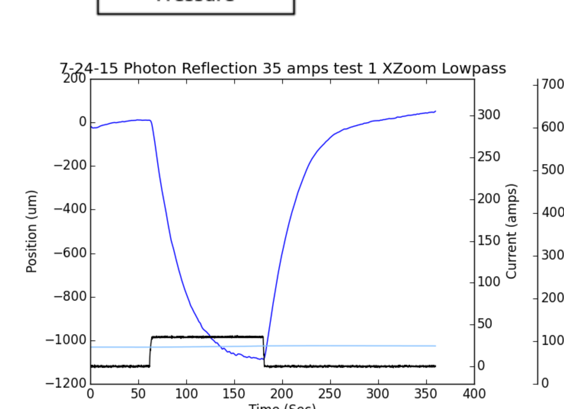


- Future methods include shining the laser through a hole in a mirror directly aligned with the reflector.

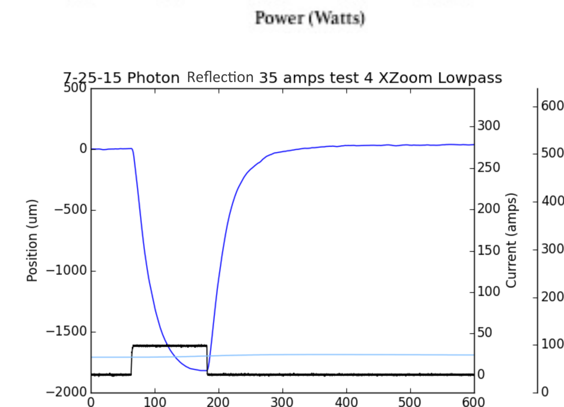
TEST RESULTS

- Power test for laser on a single reflector on day two.

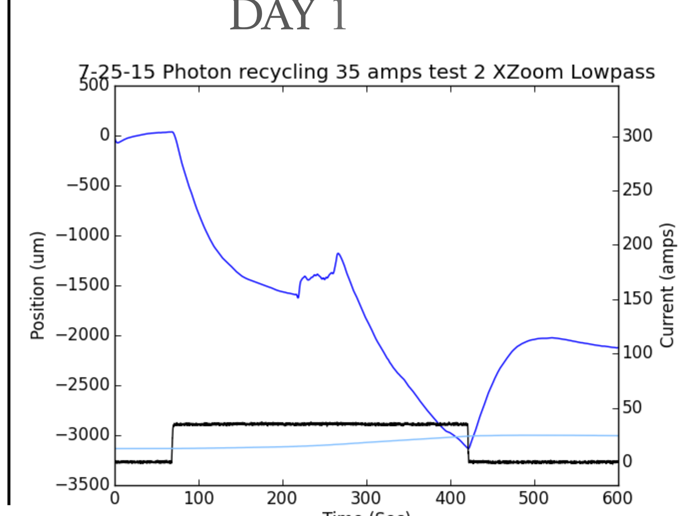




DAY 1



DAY 2

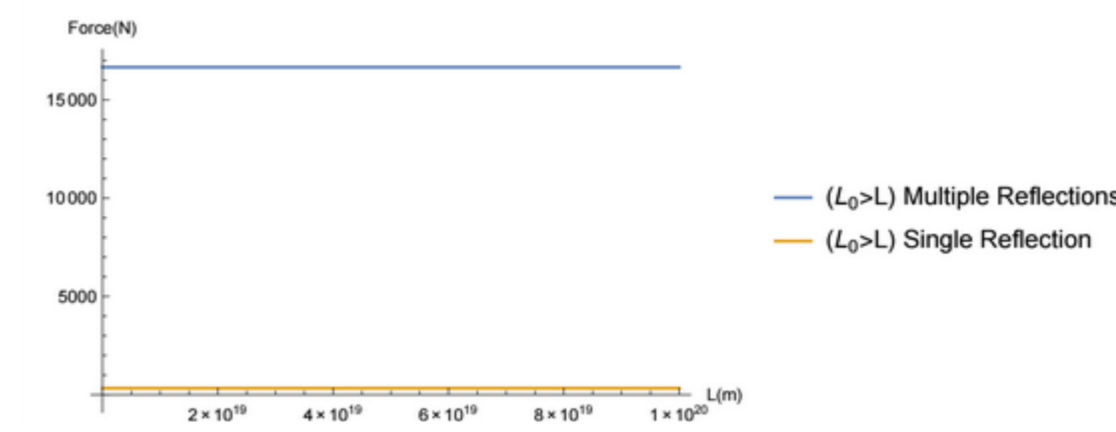


- Force graphs for a single reflector vs. a force graph for two reflectors (photon recycling)

THEORETICAL

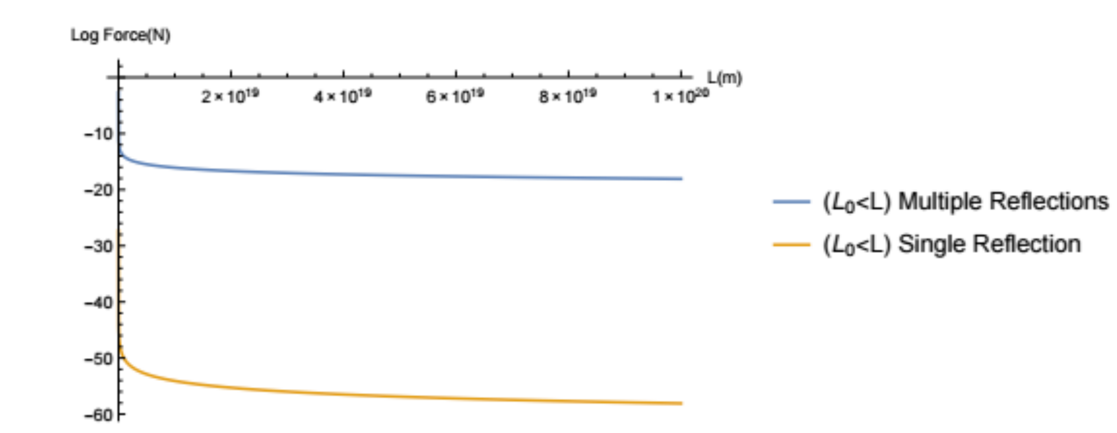
Force vs. Length $L_o > L$ $$F_{NR} = \frac{1+\alpha_2}{c} P_0$$

L = length between spacecraft and laser array
L_o= max distance before beam diameter is greater than spacecraft diameter



Force vs. Length $L_o < L$ $$F_T = \frac{1+\alpha_2}{c} P_0 \Gamma_0 \frac{1}{1-x}$$

- Laser beam diameter is greater than diameter of the spacecraft
- Force becomes negligible



- These are the theoretical results for infinite bounces.

DISCUSSION

- Graphs depict that by adding a second reflector we get double or triple amount of force than on just one reflector.
- Discrepancies between the amount of force on one reflector from days one and two occur due to:
  -stretched torsion fiber, made for a thinner fiber diameter
  -amount of photons that hit reflector/ how the laser was angled
  -angle of second mirror across from the original reflector
- Photon recycling works!

REFERENCES

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[2] Travis Brashears(1), Philip Lubin(1)), Gary B. Hughes(2), Kyle McDonough(1), Sebastian Arias(1), Alex Lang(1), Caio Motta(1), Peter Meinhold(1), Payton Batliner(1), Janelle Griswold(1), Qicheng Zhang(1), Yusuf Alnawakhtha(1), Kenyon Prater(1), Jonathan Madajian(1), Olivia Sturman(1), Jana Gergieva(1), Aidan Gilkes(1), Bret Silverstein(1), "Directed Energy Interstellar Propulsion of WaferSats," Nanophotonics and Macrophotonics for Space Environments VII , SPIE (2015)
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