Using a Directed Energy System to Deflect Asteroids

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Abstract

Asteroid impacts on or near the earth are a serious and ongoing problem. Impacts of considerable sizes can cause millions of dollars in damage and result in many human casualties. The DE-STAR [1][5][6](**D**irected **E**nergy **S**ystem for **T**argeting of **A**steroids and exploRation) project aims to solve this issue by utilizing the asteroid in question. The idea behind this project is to use a directed energy system, in this case - a laser, to ablate the incoming asteroid and have the resulting mass ejection propel the asteroid out of earth's orbital path[1][2][3][4][5][6]. However, different materials have varying amounts of thrust when ablated that need to be considered before taking action. My specific project consists of testing an assortment of different materials and observing their respective thrusts in order to determine how asteroids of different compositions should be handled.

Keywords: Ablation, Asteroid, Directed Energy, DE-STAR, Mass Ejection

I.INTRODUCTION

Asteroid impacts can result in extensive damages to property and human livelihood. A logical course of action to prevent these damages is to prevent the collision. An asteroid's trajectory is unstable in that a perturbation of its momentum would drastically alter its course. The earlier in the asteroid's path that the perturbation is applied, the smaller the force needs to be in order to create an equal angle of deviation. The DE-STAR project proposes to alter the momentum of an asteroid using a directed energy system in which a control system focuses a modular array of lasers onto the surface of an asteroid. The combined intensity of the lasers would be strong enough to ablate a localized area, and the resulting mass ejection plume would act as a propulsion system. This method would require less resources and cause fewer side-effects than other solutions such as explosively dismantling the asteroid, or altering its trajectory through the gravitation pull of a large spacecraft. Furthermore, the nature of this project allows the asteroid to be acted on multiple times in case of complications with the propulsion process. Our project focuses on studying the dependence of the thrust on different laser power levels and on the materials in question. We are particularly interested in learning to control the propulsion force for common asteroid compositions. The immediate application of this technology is to regulate asteroid motion in the solar system. However, it can also be applied to furthering methods of asteroid mining and managing space debris[11].

II.METHODS

Before any tests were conducted, asteroid compositions had to be thoroughly researched. Since there are many classified groups of asteroids, research had to be done to find specific materials that were a realistic choice for a lab test. Many materials were discounted for testing, primarily metals, because their melting points were far too high for our laser to ablate or because they were simply too expensive. Furthermore, some materials that are common in asteroids would have been a safety hazard to ablate at a low pressure. For example, magnesium is commonly found in near-earth asteroids, but unless we could have reached a perfect vacuum, the magnesium's chemical reaction with oxygen may have resulted in a serious explosion. For these reasons, we ended up testing the materials shown in Figure 1.

Materials Tested	Basalt Tested
Quartz(SiO_2)	Porous
TuFF	Non-Porous
FeS	Ground-Up
Peridotite(Olivine)	Porous w/ Covering

Figure 1: Materials Tested: All samples that were used for testing.

There are a few different tests that can be run to determine the amount of thrust that an ablation gives off under different conditions. The setup of any test consists of balancing the torsion balance with the sample. The torsion balance consists of a sample holder and various adjustable counterweight to balance it, both in the x and y axis, as well as a mirror attached in the cen-

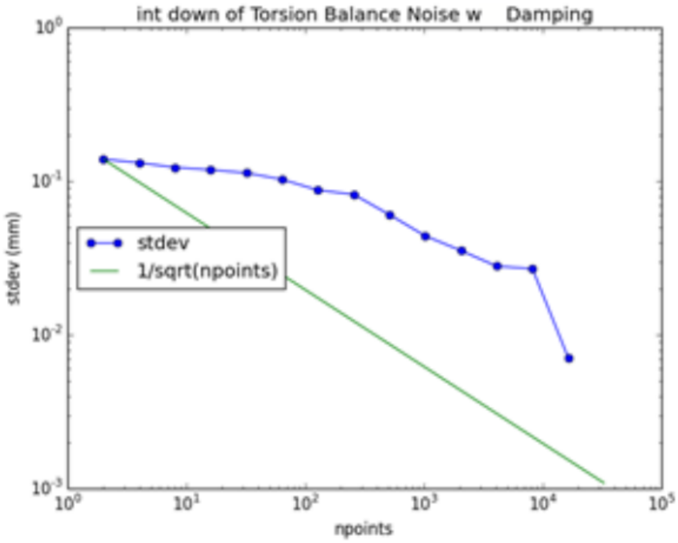

Figure 2: Example of a test run without an ablation. The eddy current decreases the duration of tests by decreasing the noise of the system.

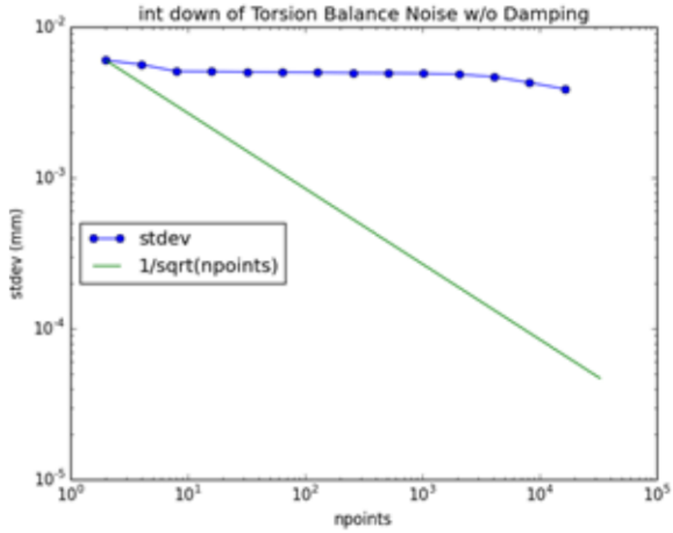

Figure 3: Example of a test run without an ablation. This test was run without an eddy current in place. As you can see the noise of the system is substantially higher.

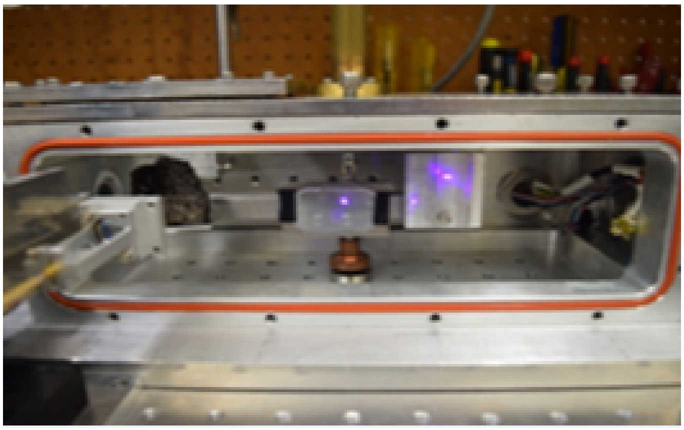

Figure 4: The Vacuum chamber without front door attached. The laser lens can be seen pointing in on the left.

ter. The mirror is used to reflect the measurement laser pointer's movement through a detector outside of the vacuum chamber. When the torsion balance moves as a result of a mass ejection from the ablation, the reflection of the laser pointer moves as well and is measured by the detector. That is how the thrust is measured throughout the ablation. Once the torsion balance is balanced, it is suspended on the torsion fiber inside the vacuum chamber.
One vital component in our lab setup is the noise dampening system. By placing magnets underneath the copper base of the torsion balance, we create a magnetic field that reacts back on its source, ie. the torsion balance. Without the eddy current, data has to be taken for a substantially longer time in order to get an accurate thrust measurement. This effect can be seen in the differences between Figure 2 and 3. We asses the the noise of our measurement system without turning on the main laser. As can be seen in Figure 2, the noise of our setup can be drastically decreased by the eddy current.[2][5][11]

Once the torsion balance is in place with the magnets, the vacuum chamber is sealed and the main pump is turned on. The vacuum chamber can be seen in Figure 4. When the pressure reaches a low enough point, the turbo molecular pump is turned on to bring the pressure down even further in an attempt to simulate a space like environment. Since different sample have different amounts of outgassing, a uniform pressure for all samples cannot always be reached in the same amount of time. When the desired vacuum is reached, the test can be started. There are two different types of tests that can be conducted: a regular ablation test and a power test. In a regular ablation test, the code that records the thrust measurements from the detector is turned on and after a minute of noise data, the laser is run for two minutes followed by another minute of noise data to end the test. A power test consists of running a minute of noise data followed by the laser being turned on at 15 Amps for 30 seconds, then off for 30 seconds. This process is repeated in increments of 5 Amps until the laser reaches its full potential at 35 Amps, after which the test is once again ended with a minute of noise data. The purpose of this test is to record how much thrust different samples give off under different conditions, in this case - different Amps. For both of these tests, pressures are manually recorded before and after the laser is turned on. The full setup can be seen in Figure 5.

The second array of test that can be run are based on the physical characteristics of the sample. Asteroids

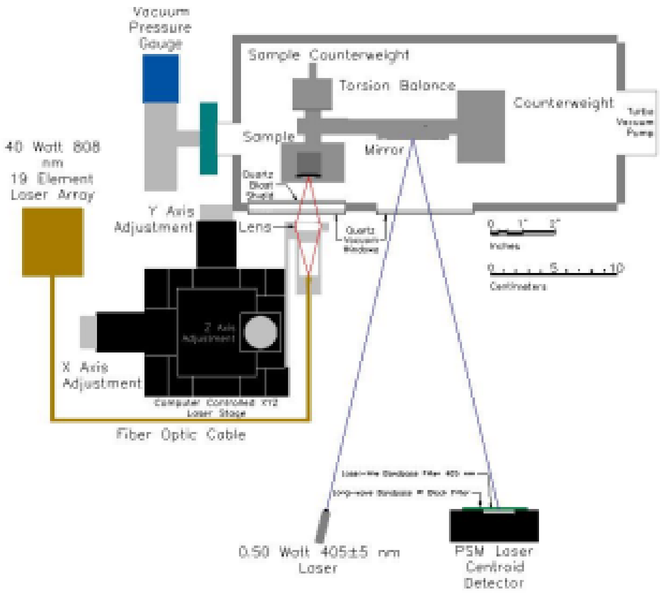

Figure 5: The lab Setup used for all tests. This is as viewed from above.

generally do not have a uniform composition. All asteroid are covered in a layer of sand called regolith. The constant collisions with other asteroids in space causes little bits of the colliding asteroids to break off and stick to the surface. Beneath that layer, an asteroid can either be porous or non-porous. In order to determine the thrust that these types of rock give off, we ran regular ablation and power tests on porous, non-porous and ground up basalt

III.RESULTS

We have found that the porous basalt results in higher thrust measurements than the non-porous basalt. This can be seen in Figure 6. The porous basalt resulted in a maximum of 105 microns (35 Amps) and the non-porous basalt resulted in a maximum of 60 microns (35 Amps). The ground up basalt resulted in significantly lower thrust measurements than any of the other test, only reaching a maximum of 4 microns (35 Amps). However, when we ran an additional test of porous basalt covered in ground up basalt in order to simulate a real asteroid's regolith covering, the maximum thrust was 100 microns (35 Amps). That approximately matched the porous basalt results.

The second series of tests that we ran were regular tests on various materials. Since different materials have different properties, they have contrasting amount of thrust when ablated. Many of the results we received from the different samples were relatively predictable; they can be seen in Figure 7. By checking the material's transmittance, the measure of the light absorbed versus light

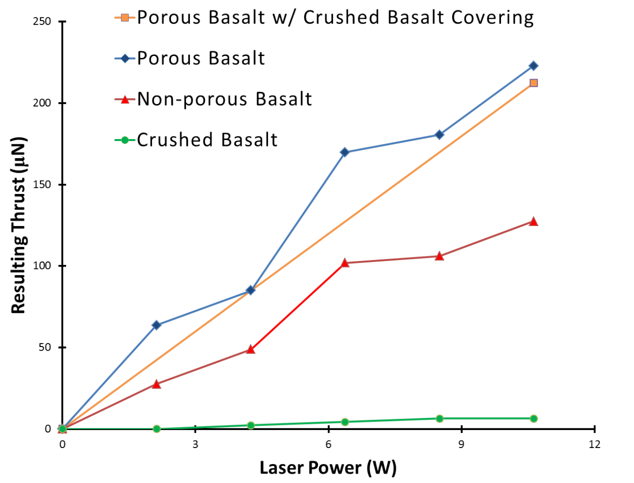

Figure 6: Thrust measurement results for different forms of basalt.

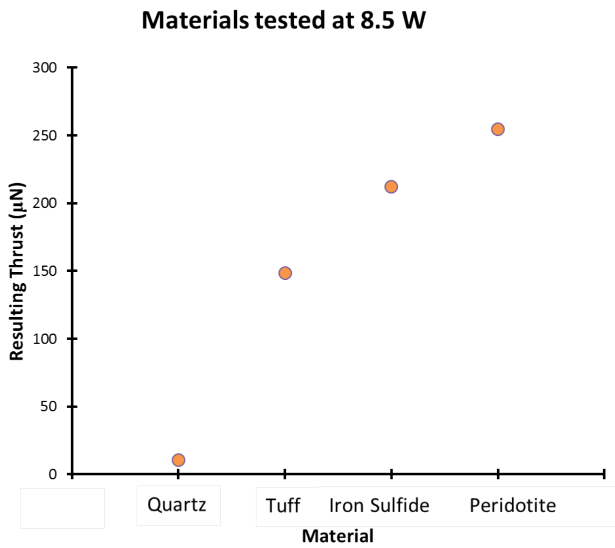

Figure 7: Thrust measurement results for different materials.

transmitted through, we know how much of the laser is actually going into the ablation and how much is just passing through. The higher the transmitted percentage, the lower thrust measurement we receive through a laser ablation. For example, Quartz has a high transmittance percentage and did not result in a visible ablation or any thrust, while Basalt, which has a significantly lower transmittance percentage, had a very high thrust measurement.

There were a few problems that arose throughout the testing process. The sensor that detects the movement of the measurement laser was picking up some of the reflected light from the main laser and the data was inaccurate. To fix this, we attached 2 filters onto the sensor. One blocks the main laser's wavelength and the other lets in only the measurement laser's wavelength. Another issue was a potential leak in the vacuum chamber that was preventing the pressure from going to an acceptable level. A continuous problem that we have not been able to fix, is the drifting of the torsion balance on the torsion fiber. When the balance drift, the data does not return to zero when the laser is turned off, and gives us offset data [11].

IV.CONCLUSION

Our results show that materials with a high transmittance will have the lowest thrust measurement and vice versa. The experiments we have ran are the minimal amount of testing that needs to be done in order to create a substantial database. Since the proposed future of this project is to have an automated computer system automatically deflect asteroids with the proper laser power and thrust, many additional samples need to be tested. We will also have to test more samples with a higher powered laser to see if the thrust always increases with the power

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REFERENCES

[1] Lubin, P., Hughes, G.B., Bible, J., Bublitz, J., Arriola, J., Motta, C., Suen, J., Johansson, I., Riley, J., Sarvian, N., Clayton-Warwick, D., Wu, J., Milich, A., Oleson, M., Pryor, M., Krogen, P., Kangas, M., and O'Neill, H. "Toward Directed Energy Planetary Defense," Optical Engineering, Vol. 53, No. 2, pp 025103-1 to 025103-18 (2014).

[2] Kosmo, K., Pryor, M., Lubin, P., Hughes, G.B., O'Neill, H., Meinhold, P., Suen, J., C., Riley, J., Griswold, J., Cook, B.V., Johansson, I.E., Zhang, Q., Walsh, K., Melis, C., Kangas, M., Bible, J., Motta, Brashears, T., Mathew, S. and Bollag, J. "DE-STARLITE - a practical planetary defense mission," Nanophotonics and Macrophotonics for Space Environments VIII, edited by Edward W. Taylor, David A. Cardimona, Proc. of SPIE Vol. 9226 (Aug, 2014).

[3] Hughes, G.B., Lubin, P., Griswold, J., Bozinni, D., O'Neill, H., Meinhold, P., Suen, J., Bible, J., Riley, J., Johansson, I.E., Pryor, M. and Kangas, M. "Optical modeling for a laser phased-array directed energy system (Invited Paper)," Nanophotonics and Figure 16. Various pictures of mass ejecta, sparks, plume, and bubbles due to laser ablation. These pictures show the environment at the sample while laser ablation is occurring. See online video. 13 Macrophotonics for Space Environments VIII, edited by Edward W. Taylor, David A. Cardimona, Proc. of SPIE Vol. 9226 (Aug, 2014).

[4] Johansson, I.E., Tsareva, T., Griswold, J., Lubin, P., Hughes, G.B., O'Neill, H., Meinhold, P., Suen, J., Zhang, Q., J., Riley, J. Walsh, K., Brashears, T., Bollag, J., Mathew, S. and Bible, J. "Effects of asteroid rotation on directed energy deflection," Nanophotonics and Macrophotonics for Space Environments VIII, edited by Edward W. Taylor, David A. Cardimona, Proc. of SPIE Vol. 9226 (Aug, 2014).

[5] Lubin, P., Hughes, G.B., Kosmo, K., Johansson, I.E., Griswold, J., Pryor, M., O'Neill, H., Meinhold, P., Suen, J., Riley, J., Zhang, Q., Walsh, K., Melis, C., Kangas, M., Motta, C., and Brashears, T., "Directed Energy Missions for Planetary Defense," in press, Advances in Space Research – Special Edition, Elsevier 2015.

[6] Lubin, P. and Hughes, G.B., "Directed Energy Planetary Defense," invited chapter in "Handbook of Planetary Defense", Springer Verlag, in press 2015.

[7] Popova, O.P., Jenniskens, P., Emel'yanenko, V., et al. "Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization," Science: Vol. 342 no. 6162 pp. 1069-1073, 29 November 2013.

[8] Glasstone, S., and Dolan, P. The Effects of Nuclear Weapons, Third Edition, Washington: Department of Defense, 1977, ch. 2.

[9] Morrison, D, Harris, A.W., Sommer, G., Chapman, C.R. and Carusi, A. "Dealing with the impact hazard." Asteroids III (ed. W. Bottke et al., Univ. Ariz. Press) (2002): 739-754.

[10] Gibbings, M. A., Hopkins, J. M., Burns, D., & Vasile, M. (2011)

[11] Brashears,T., Lubin, P., Hughes,G.B., Meinhold, P.,Suen, J., Batliner, P., Motta, C., Griswold, J., Kangas, M., Johansson, I., Alnawakhtha, Y., Lang, A., Madajian, J., "Directed Energy Deflection Laboratory

Measurements," 4 th IAA Planetary Defense Conference, Univ. Cali. Santa Barbara. (2015):1-12.