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Femtoseconds Laser Fusion Propulsion and Power Generation System: A Relativistic Approach

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We are still developing and optimizing this protocol

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Abstract

Triple hybrid propulsion relies on merging solar, laser and nuclear energies. Nowadays, a highly demand is to maximize thrust and performance levels to enable more capabilities for space exploration. In this research, a theoretical study on merging solar, laser and nuclear in a single propulsion system is discussed. The system is composed of solar concentration unit, laser source, hybrid heat exchanger and nozzle. The propulsion system uses solar and laser systems as power sources. Laser fusion process occurs inside the heat exchanger using hydrogen and radium as propellants. Natural materials as graphite and silicon can be used efficiently for power generation. Preliminary results show that the accumulation of 500 mJ from power sources at pulse time 34 femtoseconds, thrust level can reach about 70 GegaNewtons and the momentum coupling coefficient is about 4.85 N/W. Results identify this idea as the most probable to breakthrough relativistic propulsion systems. Modeling shows unprecedented results which reflect the importance of such methods to revolutionize space propulsion systems either for launching or deep space exploration missions.

Image Attribution

Figure 1 Change of gaunt factor w.r.t energy

Figure 2 Change of electron density w.r.t energy

Figure 3 Change of thrust w.r.t energy

Figure 4 Change of momentum coupling coefficient w.r.t energy

Hybrid Propellant Model

- 1 Following the absorption explosion theory for mathematical model of plasma ignition which is treated as continuous heating of the target surface until the evaporation of the solid target reached. Plasma ignition depends on laser irradiance flux following the threshold phenomena. A Schematic for triple hybrid engine is shown in figure. From energy conservation law, assuming that the radiation absorbed by is transformed into vapor jet. The mass flux density the solid target j is given by:

$$j = \left(\frac{1-R}{q} \right) I$$

where, I is the radiation intensity, R is the material reflectance and q is specific heat of evaporation per unit mass. Mass flux density as a function of temperature and pressure if surrounding medium is given by:

$$j(T) = (1-R)p(T) \sqrt{\frac{M}{2\pi T}} j(T_{\text{vap}})$$

Where M is the evaporated particle mass. Evaporation threshold can be developed by:

$$I_{\text{vap}} = \left(\frac{q}{1-R} \right) j(T_{\text{vap}})$$

Following Bunkin's and Prokhorov's simplified gas-dynamic theory of the laser ablation propulsion, the jet thrust is determined by the following relation:

$$F = G U_e$$

Where G is the target material mass consumption and U_e is the exit nozzle velocity. Merging fluid model and plasma model can fully solve the plasma ignition problem.

Preliminary results is a comparison between graphite laser ablation (from references) with radium CO_2 laser pulse used for the ablation process. Plasma temperature of radium increased 3 times more than graphite under the same conditions.

Hybrid Model Preliminary Results

- 2 The gaunt factor of Radium is higher which increase the inverse bremsstrahlung absorption coefficient in plasma.

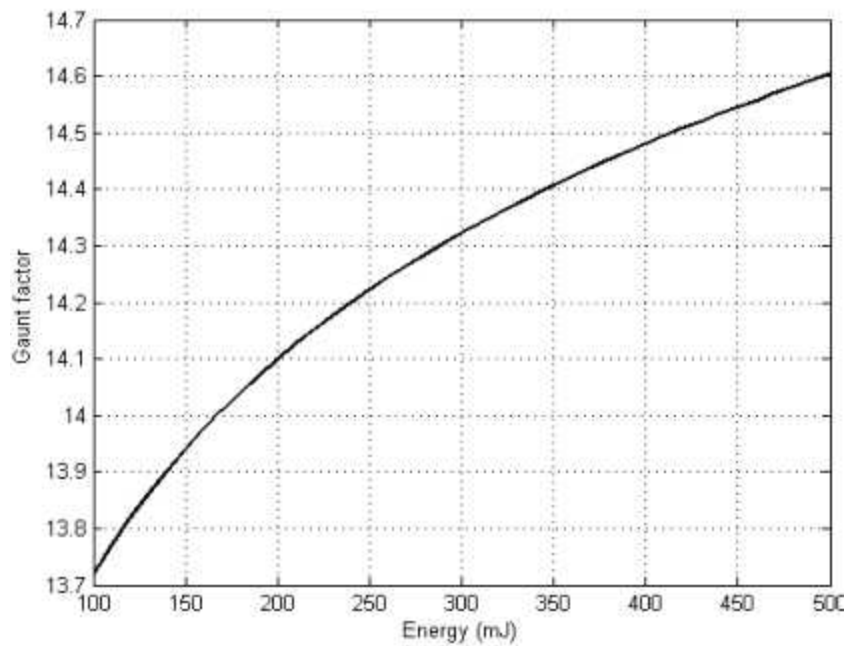


Figure 1 Change of gaunt factor w.r.t energy

High mass flux density and electron density occurs on the exposure of radium to laser femtoseconds pulse radiation. Plasma temperature reached about 3.5×10^3 eV.

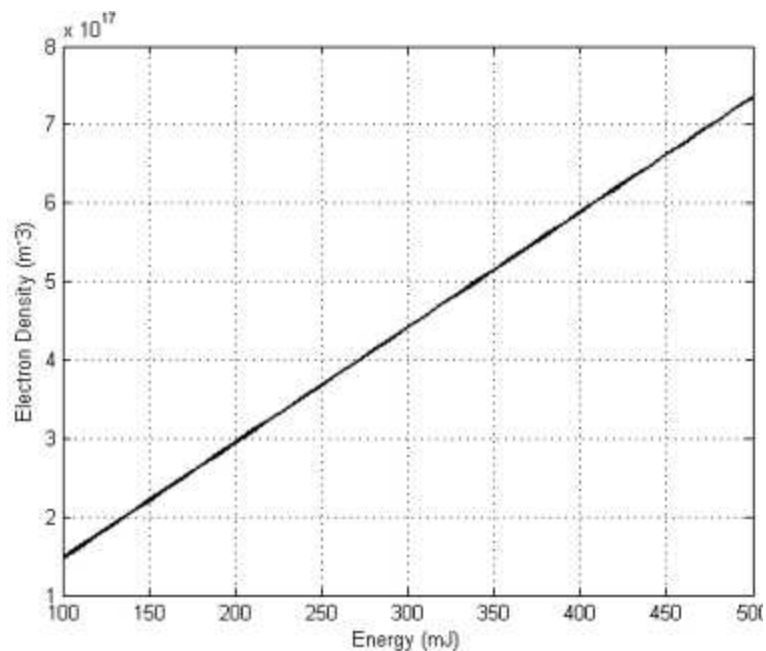


Figure 2 Change of electron density w.r.t energy

Thrust exceeds 70 giga newtons at 34 femtoseconds laser pulse.

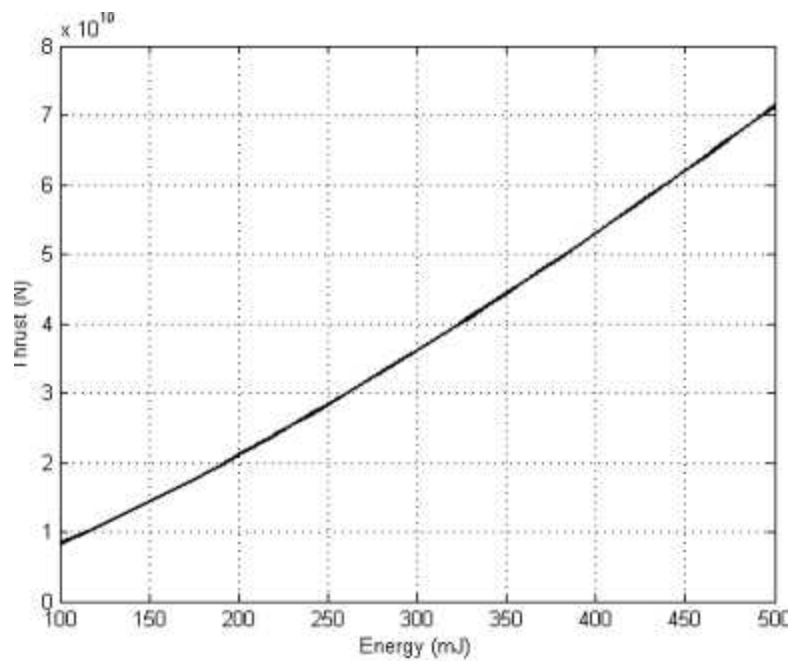


Figure 3 Change of thrust w.r.t energy

The momentum coupling coefficient reaches about 4.85 N/W which is a very high value compared to all currently existed models.

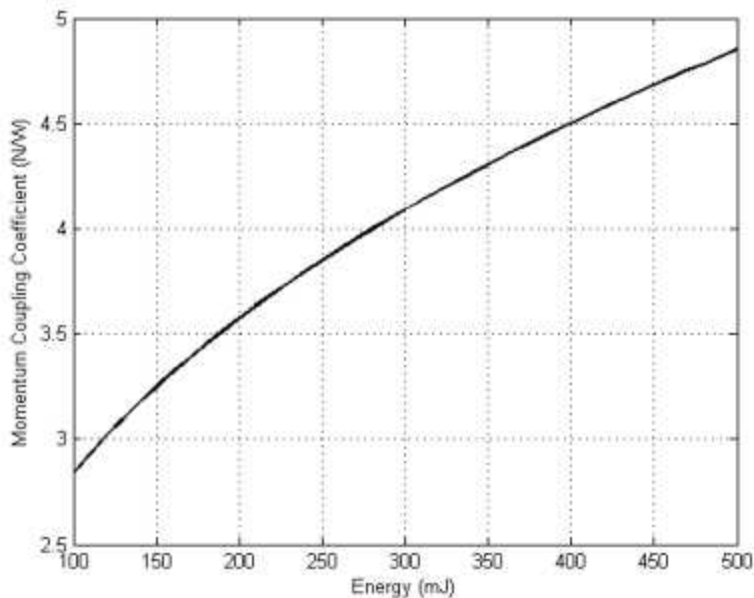


Figure 4 Change of momentum coupling coefficient w.r.t energy



Protocol references

- [1] Rezunkov, Y. A., *High Power Laser Propulsion*, Springer, 2022, Chaps. 1,2,4.
- [2] Phipps, C., Birkan, M., Bohn, W., Eckel, H. A., Horisawa, H., Lippert, T., Michaelis, M., Rezunkov, Y. A., Sasoh, A., Schall, W., Scharring, S., Sinko, J., "Review: Laser-Ablation Propulsion," *Journal of Propulsion and Power*, Vol. 26, No. 4, July–August, 2010. doi: 10.2514/1.47373
- [3] Michaelis, M., and Andrew Forbes, A., "Laser propulsion: a review," *South African Journal of Science*, July/August, 2006 doi :10.10520/EJC96573
- [4] M.A. Mossallam, B.M. Elhadidi and I.M. Shabaka, "Concentrated Solar Power Utilization in Space Vehicles Propulsion and Power Generation", Department of Aeronautics and Aerospace, Cairo University, Cairo, Egypt, December 2012.
- [5] M.A. Mossallam, "A Comparison between Laser Beamed Thruster and Solar Thermal Thruster", AIAA Scitech, National Harbor, MD, USA, January 2023.
- [6] M.A. Mossallam, "Performance Study on Laser Hydrogen Space Propulsion and Power Generation System", Protocols.io, Springer Nature, November 2025 <https://dx.doi.org/10.17504/protocols.io.xmvnm4b1og3p/v1>