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IAA-PDC-15-P-71

Recent Improvement in the Theoretical Modelling of a Laser-Based Deflector for Asteroids

Nicolas Thiry(1)**, Massimiliano Vasile**(2
(1)(2)*University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XQ, +441415745162,*

Keywords: *Asteroid Mitigation, Laser Ablation, Deflection*

ABSTRACT

In this paper we present some recent advances in our theoretical model to predict the efficiency of laser ablation at deflecting an Earth-crossing asteroid. By comparison to traditional low-thrust mitigation strategies, such as a gravity tractor, laser-based methods do not require to use propellant to exert the deflection action as the ablated material is used to thrust the asteroid. The paper starts with the derivation of the material properties of an S-class asteroid from the available thermochemical data. Using these data, a new model was implemented in Matlab® to take into account the thermal losses during the ablation process whereas the Anisimov-Knight conditions are used to obtain a dependency between the theoretical mass flow and the local temperature at the vaporization front, assuming a sonic ejection velocity. Incorporating the different effects in the boundary conditions, the heat equation is solved through finite element methods for a given size and power input of the laser beam and the results are post-processed to derive the theoretical thrust that can be generated in vacuum. Repeating the simulations for a wide range of power inputs and beam sizes allows us to plot the predicted momentum coupling factor of a laser-based deflection system in function of its characteristics. The analysis is then extended to account for partial transparency of the material to the wavelength of the laser and for porosity. It will be shown that transparency changes the point of maximum heat with interesting consequences on the total yield of the ablation process. Last but not least the paper will present a revised model for a laser beam hitting a moving surface at an angle rather than perfectly aligned with the local normal.

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