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Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond (4)

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VAPORIZATION OF INTERPLANETARY DUST DURING THE ACCELERATION PHASE OF A LASER-DRIVEN LIGHTSAIL

Abstract

The interaction of the main laser of a laser-driven lightsail with dust grains of the interplanetary media is considered. During the acceleration phase of the lightsail, the impact of dust grains on the lightsail is of particular concern due to the impact event compromising the low laser absorptivity of the sail. This could cause significant deposition of laser energy into the sail, resulting in its total destruction. Thus, the potential use of the drive laser to significantly deplete the number of dust grains in the volume to be swept by the passage of the sail would be highly advantageous and warrants further study. Use of a 100-GW-class laser to clear the lightsail flight path prior to acceleration is found to be impractical due to the large volume that would need to be cleared. The laser light diffracted around the sail and transmitted through the sail, on the other hand, can have a significant interaction with dust grains that are immediately ahead of the sail, particularly for the case of a dielectric sail that would be significantly transparent in order to maximize acceleration. Initially, the laser profile is modeled as a normal Gaussian distribution and the simulated intensity profile of the light diffracted around the sail is obtained using expansions under the standard paraxial approximation. This technique is extended to more realistic profiles that would be synthesized from a phased-array beamer. The laser–dust particle interaction is modeled via accepted models for continuous laser-driven ablation, and materials characteristic of the interplanetary media (silicate, ferrous, and carbonaceous material) are considered as the target dust material. Both idealized (spherical) and more realistic (aggregated) grain morphologies are considered. Monte Carlo simulations using state-of-the-art models for size and mass distributions of interplanetary dust grains provide guidance in determining if the drive laser can also have a significantly beneficial effect on the number of dust grains that will strike the sail during the acceleration phase. The use of Fresnel zone plates integrated into the sail that would focus and intensify the diffracted light ahead of the lightsail, enhancing the vaporization of grains, is also explored.