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DYNAMIC STABILITY OF FLEXIBLE LIGHTSAILS FOR INTERSTELLAR EXPLORATION

Abstract

The interstellar mission envisioned by the Breakthrough Starshot Initiative requires stabilized propulsion of flexible membrane-like lightsails via radiation pressure from a high power phased-array laser source which can accelerate the lightsail spacecraft to relativistic speeds. We report the first investigation of flexible, large area lightsail membranes driven by laser radiation pressure, which enables us to identify regimes for stabilized lightsail propulsion. To do this, we have developed a finite element model to describe the light-matter interactions for flexible ultrathin membranes. The model accounts for the mass density, mechanical compliance and optical constants of the flexible membrane, and makes use of a comprehensive dataset of optical, mechanical and thermal properties of ultrathin dielectric materials. Using this model, we can observe the time-resolved dynamics of the lightsail shape and center of mass trajectory under laser radiation pressure, and we can identify regimes of lightsail curvature and angular velocity for spinning lightsails that enables stabilized propulsion, for conditions of specular light reflection. We also have investigated the dynamics of flexible lightsail membranes with embedded nanophotonic metagrating structures that promote stabilized lightsail trajectories via anisotropic light scattering, for flat as well as curved membrane shapes.