Rigid Light Sail Dynamics and Control for Launch and Acceleration Using Controlled Optical Metamaterials

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Abstract

Lightweight Spacecraft propelled by laser beams focused on rigid light sails are one approach for the Breakthrough Starshot initiative, which seeks to send probes to Alpha Centauri. One critical challenge is the initial launch and control of the spacecraft as lasers propel it through space, which this paper examines. A large laser phased array system on earth is proposed to power the launch of these small spacecraft, which are jettisoned off an orbiting platform into space. The challenge is to control the attitude of the rectangular flat sail as it is hit by the laser beam as the earth rotates and accelerate it under control in the direction of Alpha Centauri. Photonic metamaterials (including photonic crystals) are one likely option to control the spacecraft moving from orbital velocities to 0.2c under extreme acceleration. For a rectangular sail the metamaterial surfaces would likely be on the corner edges, controlling the optical properties, which would affect the attitude and acceleration. A sensitivity study shows how much optical property variation is needed to control the spacecraft. Although, today there are no metamaterials capable of low absorptivity, prerequisite for these sails, the different metamaterial approaches are examined to see the most promising technologies, thus giving metamaterial researchers the roadmap to develop the needed materials and technologies. Also, a brief discussion is given on other mechanical approaches for control. An algorithm to control the spacecraft is presented, based on the two most promising metamaterial approaches, where an initial launch attitude is assumed. The paper examines the impact of space dust and particles on the spacecraft during acceleration to see if there are control issues. This paper is submitted for the day 2 session Sails and Beams.

Keywords: Spacecraft Dynamics, Metamaterials, Light Sail, Project Starshot, Spacecraft Control

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