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

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EXPERIMENTAL STUDY OF DYNAMICS OF A LIGHTSAIL UNDER SIMULATED
ACCELERATION

Abstract

The dynamics of a thin (micron) lightsail under photon pressure loading representative of laser-driven interstellar flight is studied. Unlike solar sails that are typically stabilized via stiffeners or booms, the ultrahigh acceleration requirements for interstellar flight will necessitate that the spacecraft itself be a nearly uniform, thin film material that would be subject to material instability (e.g., buckling and wrinkling) under the load of the drive laser. The use of gasdynamic techniques are able to impulsively apply loads (order of 100 Pa) representative of a 100 GW-class laser acting on a meter-scale sail. This laboratory set-up is thus able to test thin films that are lightsail candidate materials (e.g., dielectric thin films) under realistic loading conditions. The subsequent motion of the film is monitored via ultra-high-speed videography and photonic Doppler velocimetry, permitting the transient dynamics and instability of the sail material to be resolved with sub-microsecond temporal resolution. The instability of the thin film material under dynamic loading is modeled from two perspectives: First, the dynamics of membranes with a variable state of stress throughout the membrane, and secondly, as a Rayleigh-Taylor instability between the differential conditions on either side of the thin film, with the film itself having a stabilizing influence similar to surface tension. Both approaches offer considerable insight into the subsequent dynamics, and enable a modest laboratory-scale shock tube to act as a dynamic testing facility for candidate lightsail materials.