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DESIGN CONSIDERATIONS FOR RELATIVISTIC LASER SAILS

Abstract

Physics based methods have been developed to obtain accurate design estimates for the performance of relativistic interstellar laser sails and to identify technologies to mitigate losses inherent in the physics.

The physical principles that are applied include those of the Special Relativity and Quantum Mechanics. Special Relativity is especially difficult to apply consistently. A method used by [1,2] makes the application of the Special Relativity straightforward reducing the possibility of errors generated by neglecting important effects and by reducing mathematical difficulties.

Once launched, the spacecraft design must remain fixed and this dictates a design for the sail that must be able to respond to a broad range of possible events. Although physics based losses cannot be eliminated, or even reduced, technologies can be applied at the source to help reduce their effect at the sail.

These losses include: 1) the decrease in frequency, and hence energy, due to Doppler effects and 2) decreases in the intensity due to delays in the arrival of the photons. Including relativistic effects modifies these losses in non-obvious manners at the velocities necessary for interstellar flight. When the sail reaches one fourth of the speed of light the losses become significant at about 23 percent.

Some of these losses can be mitigated while others cannot. For example, free electron lasers can be used to keep the frequency (and hence the energy of the photons) constant at the sail and a phased array can be expanded in area to narrow the beam width. Expanding the area can be used keep the intensity constant at the sail. A phased array will also allow the beam direction to be precisely controlled.

Detailed mathematical models and results will be presented for Doppler and intensity losses, and beam width and beam direction control.

A straightforward method to include effects of relativity has been developed and applied to aid in performance estimates for relativistic interstellar laser sails. Although losses based on the physics remain the same their effects at the sail can be reduced significantly. Phased arrays will help with beam spreading and intensity compensation and free electron lasers can help mitigate Doppler effects.

References 1. Taylor, E.F., and J.A. Wheeler, Spacetime Physics, W.H. Freeman and Company, 1966. 2. Misner, C., K. Thorne and A. Wheeler, Gravitation, W. H. Freeman and Company, 1971.