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ULTRA LONG RANGE LOW POWER LASER COMMUNICATIONS

Abstract

We present our work on extremely long range low power laser communications, whose primary emphasis is for future missions outside the solar system for Breakthrough Starshot but with applications for probes within the solar system. We discuss the fundamental backgrounds to detection including the Earth's atmospheric emission and absorption for ground-based reception and transmission and the fundamental backgrounds for any system including zodiacal scattering and emission, unresolved stars, and the Cosmic Infrared Background (CIB), as well as host star emission for extra-solar missions. We focus on the wavelength range from 0.1 to 4 microns, though we present results which are applicable over a much larger range. We also explore the fundamental limits to data encoding using both PPM and other encoding techniques as well as robust error correction techniques and look at a variety of scenarios including data outages due to weather (for ground-based receiving), as well as other data interruption. While the general desire for laser communication systems is to enable extremely high speed communications capability, we explore another regime where energy and peak power become limitations in a system design and the use of laser communications for relatively low bandwidth but extreme power constraints are key metrics. Our work addresses the fundamental physics, astrophysics, and communication theoretic implications that are in play for any communications system, though we primarily focus on UV to IR wavelengths. We focus on extremely low mass systems where aperture sizes are modest for the spacecraft (typically 0.1-1m aperture) with average power levels of order 1mW with peak powers orders of magnitude larger allowing for multi-bit per photon data encoding and where novel techniques to achieve both transmission and reception are critical. In general, our work is focused on the regime where the transmitter and receiver are not causally connected on the time scale of relevant data packets and thus no requests for data repeats are possible. We also present our work on our optical phased array development that can be used for data communications in both transmit and reception for both conventional data throughput communications as well as simultaneous "power cover communications" and simultaneous transmission and reception. We present results from a series of recent papers we have published that explore the many issues that must be understood in this unique data communications area with wide applicability to more traditional laser communications applications.