Simplified Optics and Controls for Laser Communications

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A document discusses an architecture of a spaceborne laser communication system that provides for a simplified control subsystem that stabilizes the line of sight in a desired direction. Heretofore, a typical design for a spaceborne laser communication system has called for a high-bandwidth control loop, a steering mirror and associated optics, and a fast steering-mirror actuator to stabilize the line of sight in the presence of vibrations. In the present architecture, the need for this fast steering-mirror subsystem is eliminated by mounting the laser-communication optics on a disturbance-free platform (DFP) that suppresses coupling of vibrations to the optics by ≥60 dB. Taking advantage of microgravitation, in the DFP, the optical assembly is free-flying relative to the rest of the spacecraft, and a low-spring-constant pointing control subsystem exerts small forces to regulate the position and orientation of the optics via voice coils. All steering is effected via the DFP, which can be controlled in all six degrees of freedom relative to the spacecraft. A second control loop, closed around a position sensor and the spacecraft attitude-control system, moves the spacecraft as needed to prevent mechanical contact with the optical assembly.

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Coherent Detection of High-Rate Optical PPM Signals

Quantum-limited performance is achievable.

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A method of coherent detection of high-rate pulse-position modulation (PPM) on a received laser beam has been conceived as a means of reducing the deleterious effects of noise and atmospheric turbulence in free-space optical communication using focal-plane detector array technologies. In comparison with a receiver based on direct detection of the intensity modulation of a PPM signal, a receiver based on the present method of coherent detection performs well at much higher background levels.

In principle, the coherent-detection receiver can exhibit quantum-limited performance despite atmospheric turbulence. The key components of such a receiver include standard receiver optics, a laser that serves as a local oscillator, a focal-plane array of photodetectors, and a signal-processing and data-acquisition assembly needed to sample the focal-plane fields and reconstruct the pulsed signal prior to detection. The received PPM-modulated laser beam and the local-oscillator beam are focused onto the photodetector array, where they are mixed in the detection process. The two lasers are of the same or nearly the same frequency. If the two lasers are of different frequencies, then the coherent detection process is characterized as heterodyne and, using traditional heterodyne-detection terminology, the difference between the two laser frequencies is denoted the intermediate frequency (IF). If the two laser beams are of the same frequency and remain aligned in phase, then the coherent detection process is characterized as homodyne (essentially, heterodyne detection at zero IF).

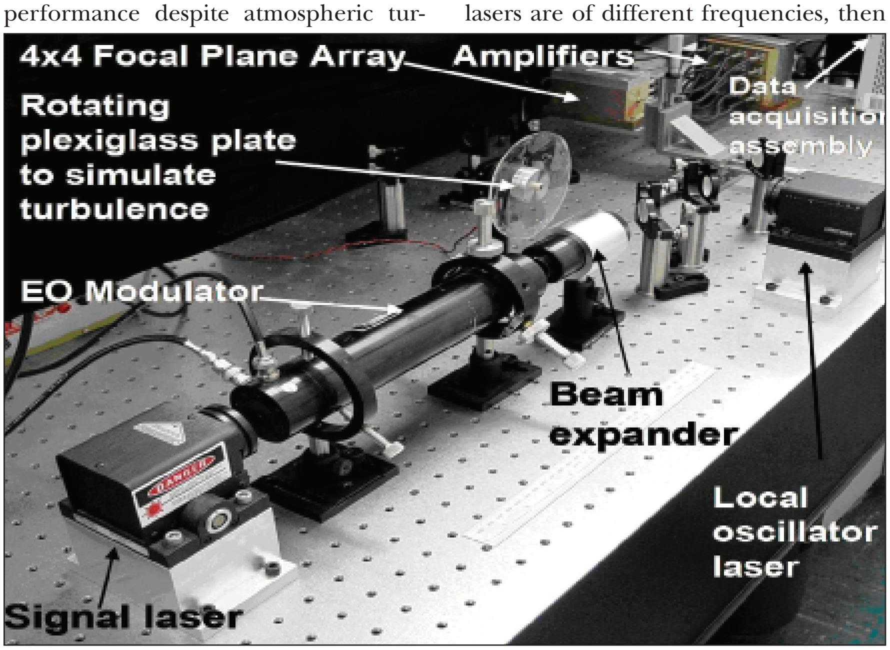

Figure 1. A **Coherent Optical Receiver** as it is set up for experiments at NASA's Jet Propulsion Laboratory.

As a result of the inherent squaring operation of each photodetector, the output current includes an IF component that contains the signal modulation. The amplitude of the IF component is proportional to the product of the local-oscillator signal amplitude and the PPM signal amplitude. Hence, by using a sufficiently strong local-oscillator signal, one can make the PPM-modulated IF signal strong enough to overcome thermal noise in the receiver circuits: this is what makes it possible to achieve near-quantum-limited detection in the presence of strong background.

Following quantum-limited coherent detection, the outputs of the individual photodetectors are automatically aligned in phase by use of one or more adaptive array compensation algorithms [e.g., the least-mean-square (LMS) algorithm]. Then the outputs are combined and the resulting signal is processed to extract the high-rate information, as though the PPM signal were received by a single photodetector.

In a continuing series of experiments