Optical Space Communications At JPL

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(Invited Talk)

Abstract: Subsystem and system level technology development at JPL for free-space laser communications from both deep space and near-Earth is described. These include acquisition, tracking and pointing, laser transmitters, photon-counting receivers, coding, modulation, and communication systems.

NASA's scientific probes are generating an ever-increasing amount of data. Optical communications has the potential for delivering 100's of Mega-bit-per-sec (Mbps) from deep space and over 10's of Gbps from the earth orbit. These data rate are stressing for current conventional RF communications technology. A laser communication flight terminal consists of a few subsystems, including: laser transmitter assembly; acquisition and beam pointing assembly; opto-mechanical assembly; and electronics and processor assembly. The Ground terminal also includes optics (e.g. telescope), laser uplink and beacon, and pointing and downlink data-receiver. Each of these areas is being addressed at JPL. An example of each subsystem, with emphasis on deep space telecommunications, is briefly described below.

Laser Transmitter - The objective is to develop lasers with average power on the order of 10 W, peak power on the order of 2 kW per pulse and pulse repetition frequencies up to 30 MHz. Four different lasers with wavelength at about 1050 nm are being developed for the flight terminal. These are: Pulsed fiber amplifier; cavity-dumped bulk crystal, bulk crystal waveguide amplifier, and large core fiber amplifier. Figure (1) shows a picture of the high power cavity-dumped laser under development at JPL.

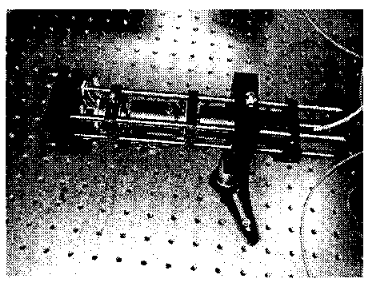


Figure 1. Cavity-Dumped Diode-Pumped Laser Operating at 10's of MHz Rate

Precision Beam Pointing - the objective is to develop technologies and algorithms to enable beam pointing with accuracy on the order of 100's of nrad or better. Current developments include: laser beacon tracking, Earth-image tracking in the infrared region, and precision star tracking. The required update rates for the pointing subassembly is reduced with the aid of angular sensors and inertial systems attached to the terminal. Figure (2) shows a schematic of the beacon-tracking concept with a focal plane array.

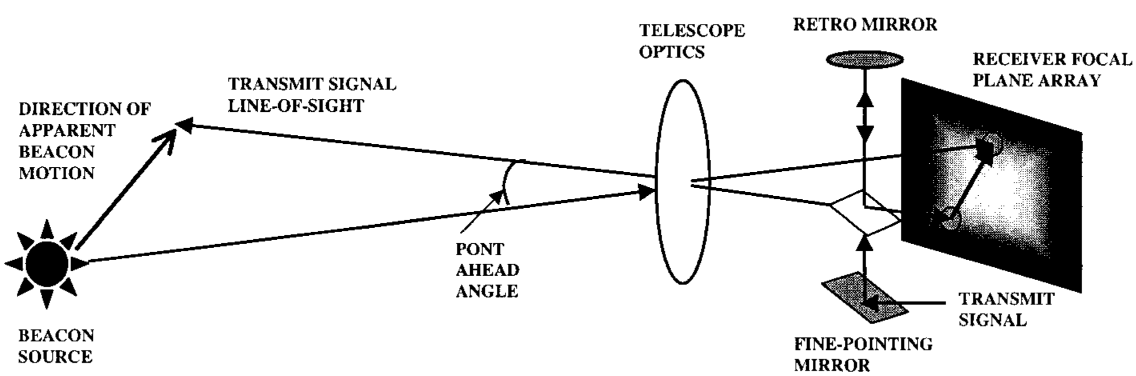
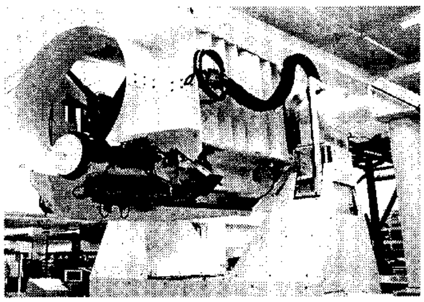
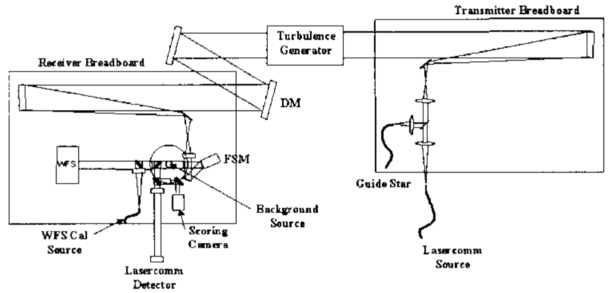


Figure 2. Laser Beam Tracking with a Multi-KHz Update Rate Focal Plane Array CCD

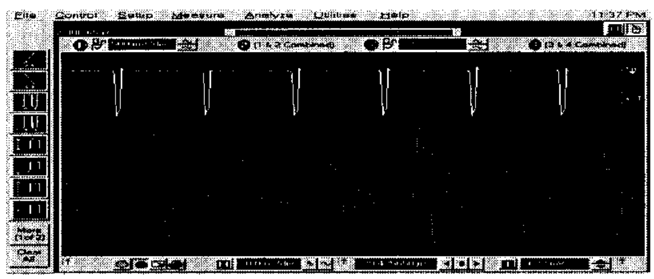
Ground receiver aperture - A dedicated 1-m aperture terminal capable of tracking both LEO and GEO spacecraft and daytime and nighttime operation has just gone into operation in Wrightwood, CA. This aperture finds limited use for deep-space applications, primary at close ranges and during the cruise phase of the mission. Use of existing astronomy telescopes and development of dedicated large (~10 m) aperture photon buckets is under development. Figure (3a) Shows an example of candidate ground receiver apertures. Daytime adaptive optics (AO) is being developed to narrow the field of view of the telescope for better background light rejection. Figure (3b) shows a schematic of the setup now under development.





Figures 3a and 3b. Dedicated 1-m Lasercomm Terminal, and Adaptive Optics Setup.

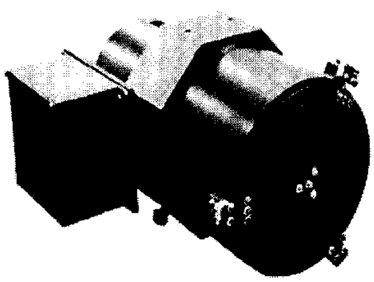
Photo-receiver – Cooled linear mode photon-county Si APDs with greater than 45% quantum efficiency, coupled with cryogenically cooled low-noise amplifiers are being evaluated. A version of these APDs includes textured surface and impurity doped Si to improve its quantum efficiency. Figure (4) shows an example of detected photons.

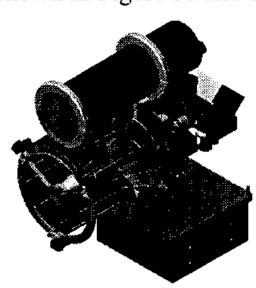


Figures 4. Photon Counting Cooled Si Detector in Sub Geiger Mode Operation

Modulation and coding - Improved codes for implementation along with the PPM (pulse position modulation) scheme have been devised. The serially concatenated iterative decoding along with PPM can provide optimal coding to about 0.7 dB of the channel capacity.

System Development - A version of our earlier system, called OCD (Optical Communication Demonstrator), equipped with focal-plane array acquisition and tracking is being built operating at 1550 nm for 2.5 Gbps communication from an un-manned aerial vehicle (e.g. Predator B) to the 1-m OCTL telescope on the Ground. Two different views of this terminal are shown in Figure 5a and 5 b.





Figures 5a and 5b. Two Views of the JPL's 10-cm Aperture Laser-communication Terminal