Free-Space Optical Communication for Spacecraft and Satellites, including CubeSats in Low Earth Orbit (LEO)

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Abstract: A static system is described, and computed results for it are shown for laser beam transmissions from a Cubstat in low Earth orbit. This system can replace current architectures which use dynamical systems (moving parts).

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1. Introduction

A new method [1] is described for optical data transmissions from satellites using laser arrays for laser beam pointing. The system is simple, static, and compact, and provides accurate pointing, acquisition, and tracking (PAT). It combines a lens system and a VCSEL/Photodetector Array, both mature technologies, in a novel way for PAT. Preliminary analysis indicates that this system is applicable to transmissions between satellites in low-Earth orbit (LEO) and ground terminals. Current architectures use dynamical systems, (i.e., moving parts, e.g., fast-steering mirrors (FSM), and/or gimbals) to turn the laser to point to the ground terminal, and some use vibration isolation platforms as well. These dynamical systems could be replaced with the static system described here. Results of computer simulations will be shown for the application of this system to a CubeSat in LEO [2]. The computer simulations include modeling the laser source and diffraction effects from wave optics. These capabilities make it possible to model laser beam propagation over long space communication distances.

2. Technical Approach

As Fig. 1 shows, a signal laser beam (green or blue, with rightward arrows), transmitted from a ground terminal, enters the lens system, which directs it to an element of the pixel array (gray rectangle). Each element, or pixel, consists of a VCSEL component/Photodetector pair. The photodetector detects the possibly weak signal beam, and the VCSEL component returns a strong modulated beam to the lens system (green or blue, with leftward arrows), which sends it to the ground terminal. As the signal beam changes direction, e.g., from the blue to the green incoming direction, this change is detected by the photodetectors, and a laser adjacent to the detecting photodetector is turned on to keep the outgoing laser beam on target. The laser beams overlap so that the returning beam continues to point at the ground terminal. The VCSEL component may consist of a single VCSEL or a cluster of VCSELs.

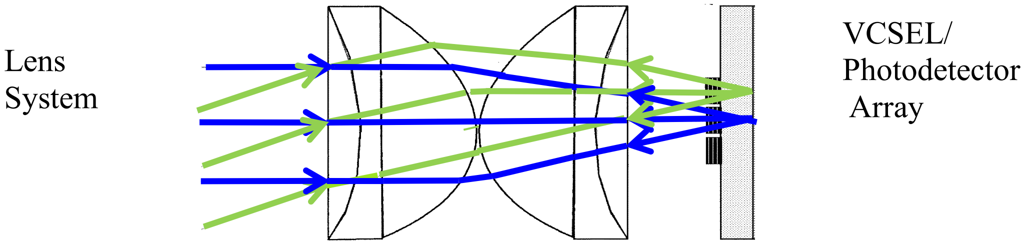

Fig. 1: Space Optical Communications using a Lens System with a Vertical Cavity Surface Emitting Laser (VCSEL)/ Photodetector Array

3. LEO Application

An application to NASA's Optical Communications and Sensors Demonstration (OCSD) program [2] will be made to show how this new lens system can be used to augment a laser pointing system on a CubeSat that uses star trackers for body pointing. The new lens system would provide a fine pointing capability to the OCSD lens system. With the resulting more accurate pointing, the power requirement would be substantially reduced and the resulting thermal load also reduced, thereby mitigating the current thermal load challenge. Figure 2 shows the irradiance and phase of the wave front at 611 km of propagation, a LEO distance, for a laser beam with a divergence of 0.14°, similar in divergence to a beam propagated in OCSD. The laser output power is 2 W. The irradiance has a Gaussian profile, and the phase is essentially flat, so that this beam is diffraction limited. The units for the distances are in mm and the spot size is about 1600 m.

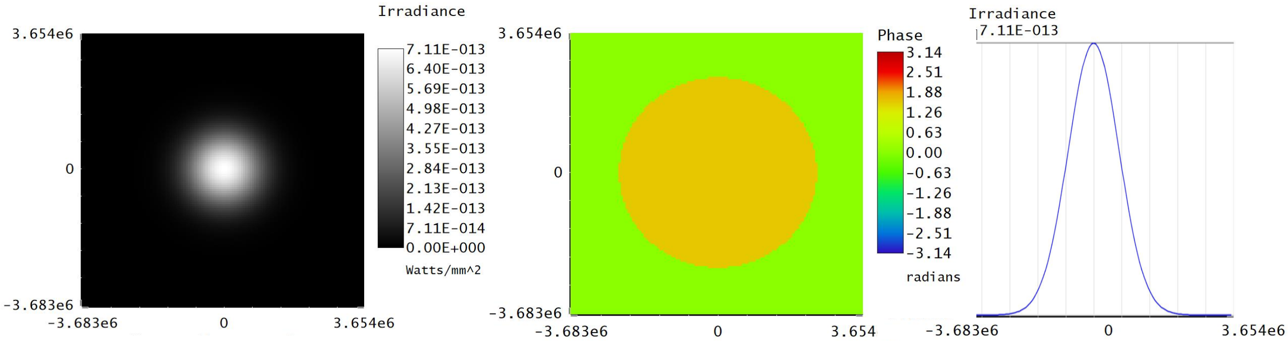

Figure 2: a) irradiance, b) phase, c) Y-coordinate cross- section of irradiance

Figure 3 shows the irradiance and phase of the wave front at 611 km for the laser beam from a new lens system modeled on that shown in Fig.1. The laser beam has a divergence of 0.0174° and the diameter of the spot size at the image plane is about 200 m. The output power from the laser cluster is 30 mW. The irradiance has a Gaussian profile, and the phase is essentially flat, so that this beam is diffraction limited. The units for distances are in mm.

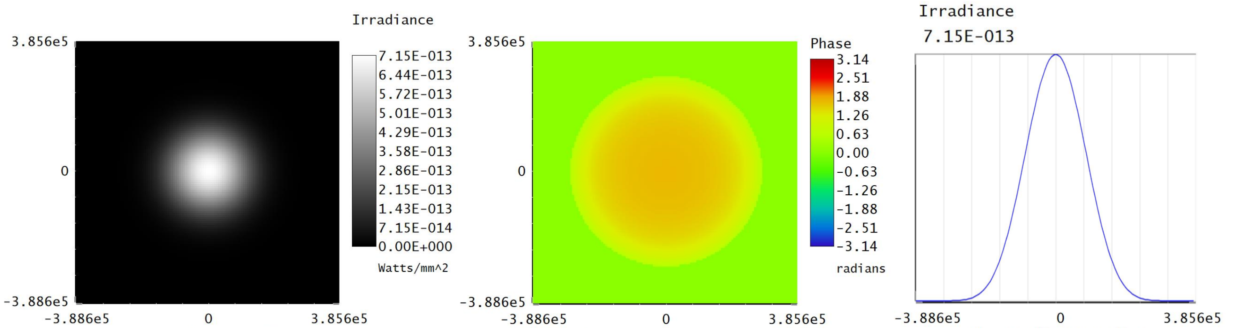

Figure 16: a) irradiance, b) phase, c) Y-coordinate cross- section of irradiance

By using a laser/photodetector array with 64 elements, the laser beams could cover the same area as the single laser shown in Fig. 2. By detecting the signal beam from the ground terminal, only one laser would need to be turned on to send the data down, leading to a significant reduction in required laser output power.

3. References

[1] Peter M. Goorjian, "A new laser beam pointing method using laser arrays", Paper 10910-51, Conference 10910, Free-Space Laser Communications XXXI, SPIE Photonics West 2019, San Francisco, California, February 2-7, 2019
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[2] T.S. Rose et al., "Optical communications downlink from a 1.5U cubesat: OCSD program" Paper 10910-28, Conference 10910, Free-Space Laser Communications XXXI, SPIE Photonics West 2019, San Francisco, California, February 2-7, 2019.
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