Photon-Counting Airborne Microlaser Altimeter

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ABSTRACT

Under NASA's Instrument Incubator Program, we have recently demonstrated a scanning, photon-counting, laser altimeter, which is capable of daylight operations from aircraft cruise altitudes. The instrument measures the times-of-flight of individual photons to deduce the distances between the instrument reference and points on the underlying terrain from which the arriving photons were reflected. By imaging the terrain onto a highly pixellated detector followed by a multi-channel timing receiver, one can make multiple spatially-resolved measurements to the surface within a single laser pulse. The horizontal spatial resolution is limited by the optical projection of a single pixel onto the surface. In short, a 3D image of the terrain within the laser ground spot is obtained on each laser fire, assuming at least one signal photon is recorded by each pixel/timing channel.

The passively Q-switched microchip Nd:YAG laser transmitter measures only 2.25 mm in length and is pumped by a single 1.2 Watt GaAs laser diode. The output is frequency-doubled to take advantage of higher detector counting efficiencies and narrower spectral filters available at 532 nm. The transmitter typically produces a few microjoules of green energy in a sub nanosecond pulse at several kilohertz rates. The illuminated ground area is imaged by a diffraction-limited, off-axis telescope onto an ungated segmented anode photomultiplier with up to 16 pixels (4 x 4). The effective receive aperture is about 13 cm. Each anode segment is input to one channel of a "fine" range receiver (5 cm detector-limited resolution), which records the times-of-flight of the individual photons. A parallel "coarse" receiver provides a lower resolution (>75 cm) histogram of atmospheric scatterers and centers the "fine" receiver gate on the last set of returns, permitting the fine receiver to lock onto ground features with no a priori range knowledge. In test flights, the prototype system has operated successfully at mid-day at aircraft altitudes up to 6.7 km (22,000 ft), with single pulse laser output energies of only a few microjoules, and has recorded kHz single photon returns from clouds, soils, man-made objects, vegetation, and water surfaces. The system has also demonstrated a capability to resolve volumetrically distributed targets, such as tree canopies and underlying terrain, and has performed wave height measurements and shallow water bathymetry over the Chesapeake Bay and Atlantic Ocean. The signal photons are reliably extracted from the solar noise background using an optimized Post-Detection Poisson Filter.