Coherent Laser Instrument Would Measure Range and Velocity

This lightweight, low-power, compact instrument could have a variety of uses.

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A proposed instrument would project a narrow laser beam that would be frequency-modulated with a pseudorandom noise (PN) code for simultaneous measurement of range and velocity along the beam. The instrument performs these functions in a low mass, power, and volume package using a novel combination of established techniques. Originally intended as a low resource-footprint guidance sensor for descent and landing of small spacecraft onto Mars or small bodies (e.g., asteroids), the basic instrument concept also lends itself well to a similar application guiding aircraft (especially, small unmanned aircraft), and to such other applications as ranging of topographical features and measuring velocities of airborne light-scattering particles as wind indicators.

Several key features of the instrument’s design contribute to its favorable performance and resource-consumption characteristics. A laser beam is intrinsically much narrower (for the same exit aperture telescope or antenna) than a radar beam, eliminating the need to correct for the effect of sloping terrain over the beam width, as is the case with radar. Furthermore, the use of continuous-wave (CW), erbium-doped fiber lasers with excellent spectral purity (narrow line width) permits greater velocity resolution, while reducing the laser’s power requirement compared to a more typical pulsed solid-state laser. The use of CW also takes proper advantage of the increased sensitivity of coherent detection, necessary in the first place for direct measurement of velocity using the Doppler effect. However, measuring range with a CW beam requires modulation to “tag” portions of it for time-of-flight determination; typically, the modulation consists of a PN code. A novel element of the instrument’s design is the use of frequency modulation (FM) to accomplish both the PN-modulation and the Doppler-bias frequency shift necessary for signed velocity measurements. This permits the use of a single low-power waveguide electro-optic phase modulator, while simultaneously mitigating the effects of speckle as a noise source in the coherent detection.

The instrument (see figure) would include a narrow-line-width CW laser, the output of which would be split into a local oscillator and signal arm. Within the instrument, optical beams would be routed, split, and combined by use of fiber and planar integrated optics. The signal arm beam would be frequency-modulated by the electro-optic phase modulator, fed by a serrodyne waveform generated either in software or hard-
Fiber Laser Generating Continuous-Wave, Narrow Line-Width Beam

Asymmetric Coupler

Phase Modulator

Receiver

Band-Pass Filter and Analog-to-Digital Converter

Digital Signal Processor and Digital-to-Analog Converter

Isolator

90° Polarization Rotation

Asymmetric Coupler

Telescope

Quarter-Wave Retarder and Spectral Filter

Circulator

Digital Signal Processor and Digital-to-Analog Converter

The Proposed Laser Instrument would perform ranging and velocimetry by use of a novel combination of established techniques. Integrated and fiber optics would be used to implement much of the functionality in a compact, lightweight package.