LIDAR system offers peerless precision in remote measurements

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By combining the best of two different distance measurement approaches with a super-accurate technology called an optical frequency comb, researchers at the National Institute of Standards and Technology have built a laser ranging system that can pinpoint multiple objects with nanometer precision over distances up to 100 kilometers. The novel LIDAR ("light detection and ranging") system could have applications from precision manufacturing lines on Earth to maintaining networks of satellites in perfect formation, creating a giant space-based platform to search for new planets.

LIDAR transmits light through the air and analyzes the weak reflected signal to measure the distance, or range, to the target. NIST's new LIDAR, described in *Nature Photonics*, has a unique combination of capabilities, including precision, rapid updates from multiple reference points at the same time, and minimal "measurement ambiguity." The system can update measurements to multiple targets simultaneously every 200 microseconds.

Measurement ambiguity in a LIDAR system is due to the fact that, if the target is at long range from the instrument, the system can't distinguish between two different distances that are multiples of its "ambiguity range." The new NIST LIDAR has a comfortably large ambiguity range of at least 1.5 meters—large enough to check the coarse distance with widely available technologies such as GPS.

No other ranging system offers this combination of features, according to the new paper. NIST's LIDAR could enable multiple satellites to maintain tight spacing and pointing while flying in precision formations, acting as a single research instrument in space, the paper states. Formation flying has been proposed as a means to enhance searches for extraterrestrial planets, enable imaging of black holes with multiple X-ray telescopes on different satellites, and support tests of general relativity through measurements of satellite spacing in a gravitational field. The new LIDAR could enable continuous comparisons and feedback of distances to multiple reference points on multiple satellites. There also may be applications in automated manufacturing, where many parts need to fit together with tight tolerances, according to Nate Newbury, the principal investigator.

NIST's LIDAR design derives its power from combining the best of two different approaches to absolute distance measurements: the time-of-flight method, which offers a large ambiguity range, and interferometry, which is ultraprecise. The LIDAR relies on a pair of optical frequency combs, tools for precisely measuring different colors (or frequencies) of light. The frequency combs used in the LIDAR are based on ultrafast-pulsed fiber lasers, which are potentially smaller and more portable than typical combs that generate laser light from crystals.

The two combs operate at slightly different numbers of pulses per second. Pulses from one comb are reflected from a moving target and a stationary reference plane. The second comb serves as precise timer to measure the delay between the reflections returning from the target and from the reference plane. A computer calculates the distance between the target and the reference plane by multiplying the time delay by the speed of light.

More information: I. Coddington, W. C. Swann, L. Nenadovic and N. R. Newbury. Rapid, precise absolute distance measurements at long range. Nature Photonics. Published online May 24, 2009.

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