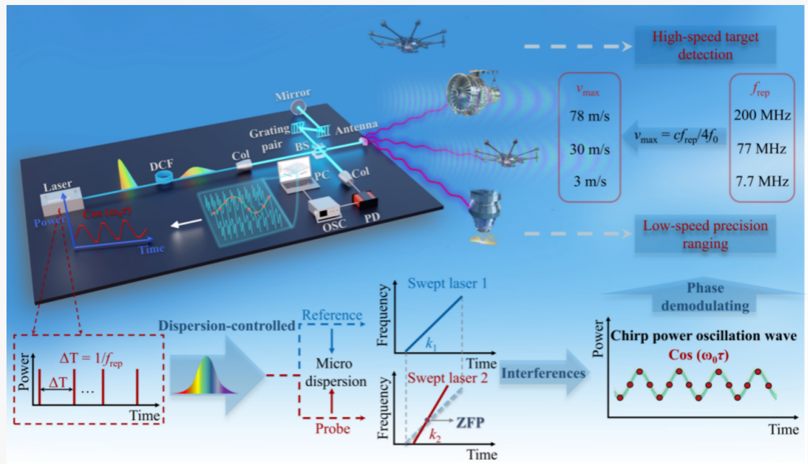
Precise motion tracking and velocimetry using chirped power oscillation wave

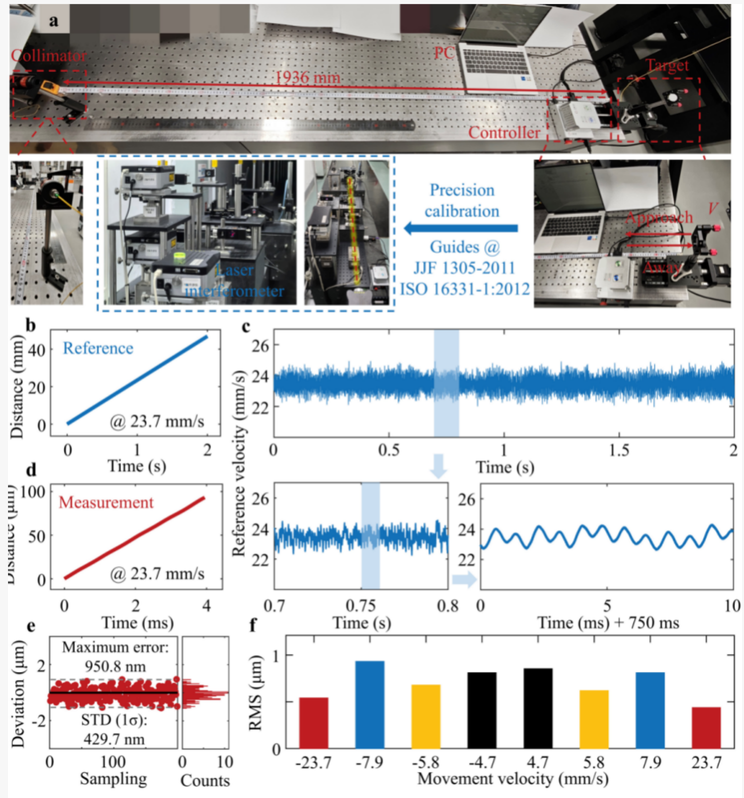
GA, UNITED STATES, May 14, 2026 /EINPresswire.com/ -- Precise high-speed motion tracking is vital for advanced manufacturing and robotics, yet existing methods force a trade-off between speed and directional accuracy. Now, scientists in China have developed a technique based on chirped power oscillation waves using dispersion-controlled dual-swept lasers. It achieves sub-micrometer displacement precision at MHz update rates, and even reveals hidden mechanical vibrations in motion-control equipment, opening a new path for smart ranging systems.



The Michelson interferometer-based measurement system detects the motion displacement trajectory of high-speed operating devices by precisely identifying the variation patterns of the CPOW in the interference signals.

Precise high-speed motion tracking and velocimetry are critical underlying technologies in fields such as advanced manufacturing, robotics, and modern physics. Existing detection methods, including Doppler velocimetry and dual-comb interferometry, suffer from inherent limitations in their system mechanisms that prevent directional unambiguity detection without a trade-off between speed and precision. Consequently, they struggle to meet the demands for precise monitoring of high-speed moving components in precision manufacturing scenarios such as advanced process nodes.

In a new paper(doi: https://doi.org/10.37188/lam.2026.033) published in Light: Advanced Manufacturing, a team of scientists, led by Professor Tao Zhu from the Laboratory of Optoelectronic Technology & System (Ministry of Education), Chongqing University, China, and Professor Baicheng Yao from the Key Laboratory of Optical Fiber Sensing and Communications (Ministry of Education of China), University of Electronic Science and Technology of China, along with their collaborators, have developed a high-speed motion detection technique based on chirped power oscillation waves (CPOW). This innovative method uses dispersion-controlled dual-swept lasers (DCDSL) to generate CPOW through laser interference, enabling high-precision dynamic displacement and velocity measurements. By monitoring the high-signal-to-noise-ratio intensity oscillations at the zero-frequency point (ZFP) of the CPOW, the system retrieves dynamic displacement with sub-micrometer accuracy and derives velocity through differentiation. Experiments successfully reveal rapid velocity fluctuations of an electronically controlled translation stage on millisecond timescales. Unlike conventional Doppler velocimetry, this method eliminates the need for Fourier transform analysis of frequency differences by directly using time-domain intensity signals, thereby overcoming the fundamental limitation of frequency resolution in short time windows and breaking the inherent trade-off between update frame rate and measurement precision. This technology opens a new pathway for advanced, fast, and high-precision LiDAR systems.



Real-time displacement trajectory detection results of the target and their statistical analysis.

This dynamic measurement method is based on the interference principle of dual-swept lasers. Two swept-frequency laser beams with precisely controlled dispersion generate a ZFP during interference, which corresponds to the intersection of the two swept-frequency curves. As the target moves, the intensity of the interference signal at this zero-frequency point undergoes periodic oscillations, forming a CPOW. By capturing this time-domain intensity signal with a high-speed photodetector and performing phase demodulation on the CPOW, the time delay induced by target motion can be directly extracted. From this, a dynamic displacement trajectory with sub-micrometer accuracy is retrieved, and the instantaneous velocity is further obtained through differentiation.

“Unlike conventional Doppler velocimetry, this method does not require Fourier transform analysis of frequency differences and relies solely on time-domain intensity information. Therefore, it overcomes the limitation imposed by frequency-domain resolution on the measurement update frame rate, enabling high-precision, high-frame-rate dynamic displacement and velocity measurements on timescales ranging from nanoseconds to milliseconds.”

“This technique successfully captures the instantaneous velocity amplitude and frequency fluctuations induced by motor vibrations, demonstrating its excellent sub-micrometer accuracy and wide velocity-range adaptability in dynamic displacement detection.” they added.

“The experiment validates its sub-micrometer precision and millisecond-level response capability in the detection of precise dynamic displacement and instantaneous velocity. In the future, by integrating on-chip optical frequency combs and photonic integration technologies, this CPOW method is expected to evolve into an advanced ultrafast LiDAR system, demonstrating broad application prospects for dynamic tracking and high-speed velocimetry in fields such as ultra-precision manufacturing and health monitoring." the scientists forecast.

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