113 km absolute ranging with nanometer precision

Yan-Wei Chen[1,2,3] , Meng-Zhe Lian[1,2,3], Jin-Jian Han[1,2,3], Ting Zeng[1,2,3], Min Li[1,2,3], Yong Wang[4], Ali Esamdin[4], Qi Shen[1,2,3], Jian-Yu Guan[1,2,3], Lei Hou[1,2,3], Ji-Gang Ren[1,2,3], Jian-Jun Jia[3,5], Qiang Zhang[1,2,3], Hai-Feng Jiang[1,2,3], Jian-Wei Pan[1,2,3]

[1] Hefei National Research Center for Physical Sciences at the Microscale and School of Physical Sciences, University of Science and Technology of China, Hefei, China.

[2] Shanghai Research Center for Quantum Science and CAS Center for Excellence in Quantum Information and Quantum Physics, University of Science and Technology of China, Shanghai, China.

[3] Hefei National Laboratory, University of Science and Technology of China, Hefei, China.

[4]Xinjiang Astronomical Observatory, Chinese Academy of Sciences, Urumqi, China

[5]Key Laboratory of Space Active Opto-Electronic Technology, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai, China.

Email: qiangzh@ustc.edu.cn; hjiang1@ustc.edu.cn; pan@ustc.edu.cn

Accurate long-distance precision ranging plays a pivotal role in various applications, including very long-baseline interferometry, gravitational-wave observatory, satellite formation flying, geographical research, etc. The integration of the time-of-flight method with coherent laser interference in dual-comb interference enables high-precision ranging with a rapid update rate and an extended ambiguity range. Pioneering experiments have demonstrated unprecedented precision in ranging, achieving 5 nm @ 60 ms for 1.1 m[1] and 200 nm @ 0.5 s for 25 m[2]. Long-distance ranging remains technically challenging due to high transmission loss and noise. In this letter, we propose a two-way dual-comb ranging (TWDCR) approach that enables successful ranging over 113 kilometers. We employ air dispersion analysis and synthetic repetition rate technique to expand the ambiguity range of the inherently noisy channel beyond 100 km. The achieved ranging precision is 11.5 μm @ 1.3 ms, 681 nm @ 1 s, and 82 nm @ 21 s, as confirmed by a comparison of two independent systems. The advanced long-distance ranging technology is expected to yield significant implications for space research initiatives, such as the GRACE mission.

[1] Coddington, Ian, et al. Nature photonics 3.6 (2009): 351-356.

[2] Suh M G, Vahala K J.. Science, 2018, 359(6378): 884-887.