Daytime-Capable Integrated Laser Communication & Ranging for LEO Quantum Satellites

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Abstract

High-precision satellite-to-ground ranging is critical for quantum key distribution (QKD) and global quantum internet. QKD's strict spatiotemporal synchronization and orbit requirements for satellite-ground links make millimeter-level ranging indispensable for stable QKD transmission, reliable key distribution, and quantum network interconnection [1].

Conventional satellite laser ranging (SLR) delivers millimeter-level precision, yet its reliance on onboard retroreflectors and high-pulse-energy ground transmitters introduces excessive mass, complexity and cost, making it unsuitable for miniaturized quantum satellites [2,3]. To solve this, we propose an integrated laser communication and ranging technique tailored for quantum satellites: sharing a single optical platform and signal-processing unit, it enables simultaneous high-rate data transmission and high-precision ranging for resource-constrained QKD microsatellites, eliminates the need for onboard retroreflectors, and achieves millimeter-level accuracy with compact, low-cost terminals, resolving the core limitations of traditional SLR.

On-orbit validation on the "Jinan-1" quantum microsatellite achieves ~5 mm ranging precision day and night, with stable bidirectional 156.25 Mbps communication links. This capability directly supports QKD link synchronization, orbit fine-tuning and protocol optimization, advancing quantum satellite laser terminal development, underpinning satellite-ground QKD engineering, and offering a lightweight, low-cost, high-precision solution for LEO quantum constellations and global quantum internet.

References

[1] Y. Li, W.-Q. Cai, J.-G. Ren, et al., Nature 640, 47–54(2025).

[2] M. Toyoshima, J. Light. Technol.39, 693–699 (2021).

[3] M. Wilkinson, U. Schreiber, I. Procházka, et al., J. Géod. 93,2227–2247 (2019).

Figures

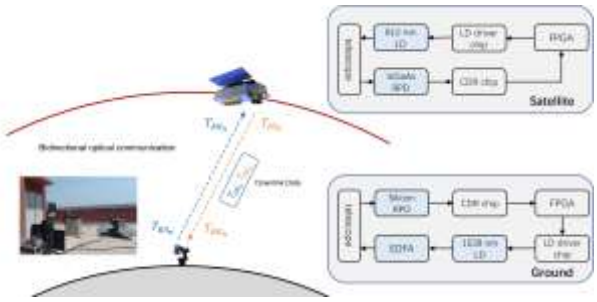

Figure 1: Hardware Architecture of Bidirectional Laser Communication Between "Jinan1" and Ground Station.

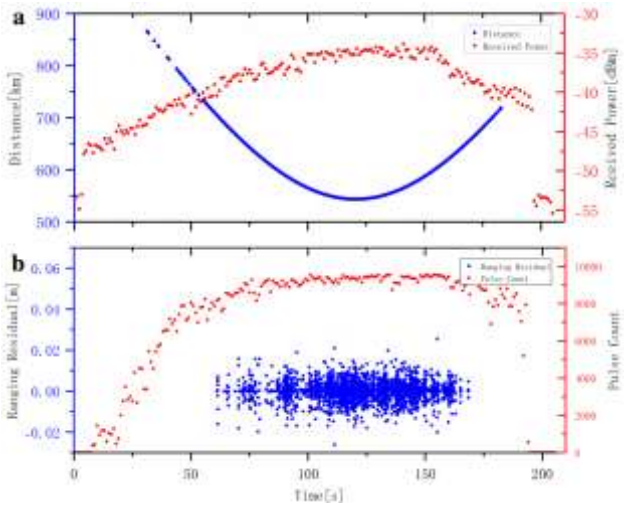

Figure 2: (a) satellite-to-ground ranging results and ground received power. (b) Ranging residual after removing polynomial fit and Synchronization pulses count.