Reducing the SWaP of comb-based optical time transfer

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Use of time programmable frequency combs has been shown to support optical time transfer at the quantum limit with performance sufficient to support state-of-the-art optical clocks[1-2]. However, deployment of free-space optical time transfer systems on future aeronautical and orbital platforms will require further system development to meet stringent requirements for size, weight, and power (SWaP)[2]. Here we present a comb-based optical time transfer node composed of a combination of a commercial electro-optics package, off-the-shelf optical components, and fusion deposition manufactured (FDM) modules.

The use of FDM enables rapid prototyping with various thermoplastics to reduce wasted volume, while increasing modularity. This coupled with prototyping of optical transceivers based on standard fiber-optic components allows for rapid testing of new time transfer approaches. Additionally, for sensitive electronics requiring shielding from external electromagnetic interference, FDM

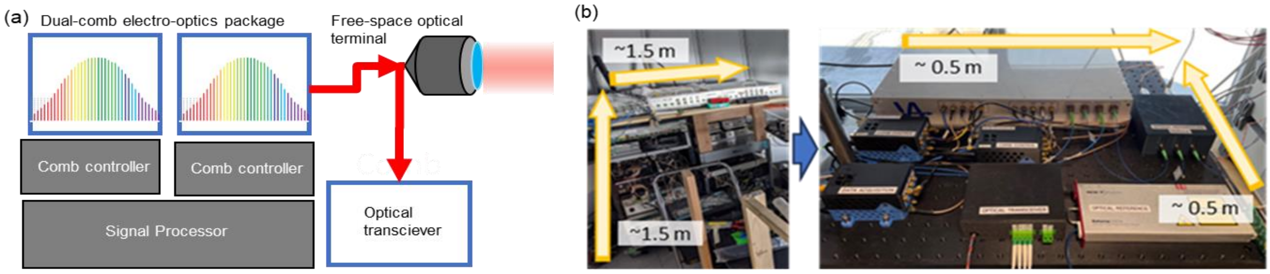

Fig. 1: (a) Cartoon of required sub-systems for tracking comb approach to optical time transfer. Advances in commercially available dual-comb electro-optics packages as well as comb controllers have greatly reduced the SWaP envelope of timing nodes. Use of standard telecommunications components and FDM modules allows for rapid reconfiguration of the optical transceivers for fast prototyping of new approaches to time transfer while maintaining low-SWaP. (b) Photographs illustrating recent SWaP reduction of a timing node through use of commercially available sub-systems.

modules are compatible with electroplating using conductive graphite paint or directly using conductive plastic filaments. Here, we will demonstrate optical time transfer and ranging while adhering to these principal approaches to simultaneously advance optical time transfer and ranging while reducing the systematic SWaP.

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[1]C. Flood *et al*., "Optical Ranging and Synchronization for Distributed Sensing with Small Satellite Formations," *(EFTF/IFCS)*, Toyama, Japan, 2023, doi: 10.1109/EFTF/IFCS57587.2023.10272109

[2] Caldwell, E. D., *et al.* Application of quantum-limited optical time transfer to space-based optical clock comparisons and coherent networks. *APL Photonics* **9**, 016112 (2024)