A Photonic Clockwork for Deployed Timing and Radar

Andrew Attar[1], Henry Timmers[1], Nate Phillips[1], Bennett Sodergren[1], Evan Barnes[1], Alina Spiess[1], Cole Smith[1], Guangning Yang[2], Hannah Tomio[2], Kurt Vogel[1], Kevin Knabe[1]

[1]Vescent Technologies, Inc., Golden, CO, USA
[2]NASA Goddard Space Flight Center, Greenbelt, MD, USA

Email: aattar@vescent.com

We present an environmentally robust photonic RF/microwave clockwork with low size, weight, and power (SWaP) for next-generation, field-deployable timing and radar applications. Compared to microwave references, optical local oscillators offer superior fractional frequency stability and phase-noise performance. When transferred with high fidelity into the RF/microwave domain, this “optical advantage” promises unparalleled performance across both private-industry and government (*e.g.*, defense and space-agency) applications including very-long-baseline interferometry (VLBI), alternative positioning, navigation, and timing (PNT), multi-static synthetic aperture radar (MSAR), and geodetic sensing. However, this potential has yet to be fully realized outside the metrology lab primarily due to the high-SWaP and excessive environmental susceptibility of both the optical reference itself as well as the optical frequency comb (OFC) required to transfer the optical stability into the RF/microwave domain. Here, we present two demonstrations of a low-SWaP, environmentally robust photonic clockwork used to make a high-fidelity optical-microwave link with the stability and phase-noise performance relevant to the applications described above. Additionally, operational-testing results of the OFC subsystem under application-relevant environmental conditions will be presented to show pathway to field deployment of this critical subsystem.

In one demonstration, the environmentally robust OFC subsystem is integrated with a miniaturized prototype of the cavity-stabilized laser built for the Laser Interferometer Space Antenna (LISA) at NASA Goddard Space Flight Center (GSFC) [1], generating a photonically derived 100 MHz output with an instability of $<2.5\times10^{-14}$ at 1 s and reaching 5×10^{-15} between 5-10s (See Figure 1a). These results demonstrate a preliminary pathway for the use of these two low-SWaP subsystems in the timing system of NASA’s Event Horizon Explorer.

In another demonstration, the OFC is used to transfer the pristine phase noise of an all-fiber, ultranarrow-linewidth laser (integrated linewidth of 30 Hz) into ultralow-noise X-band microwaves at 10 GHz. As shown in Figure 1b, the measured 10 GHz microwave phase noise is limited by the noise floor of the testing apparatus and is superior to state-of-the-art direct microwave references, including a commercial active Hydrogen MASER and a low-noise 10 GHz Wenzel oscillator.

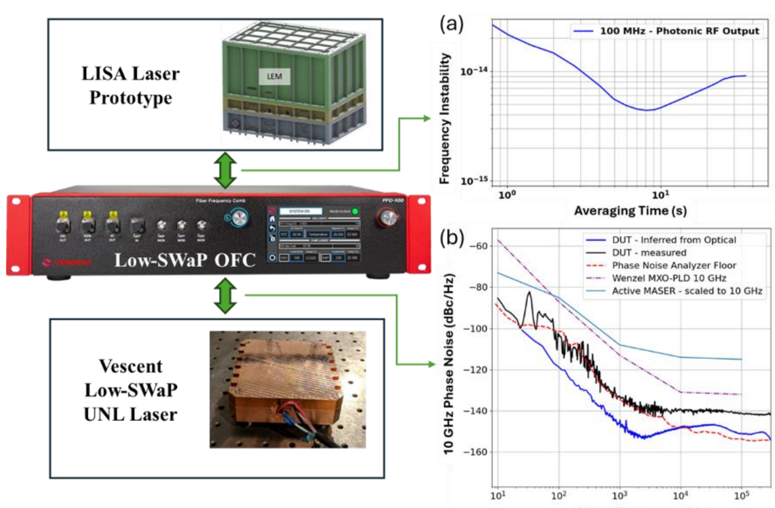

Figure 1. (a) Fractional frequency stability of the photonically generated 100 MHz output of the OFC locked to the LISA laser prototype [1]. (b) 10 GHz phase noise of the photonically generated microwaves produced via optical frequency division of a low-SWaP ultranarrow linewidth laser.

[1] A.W. Wu and K. Numata, “Progress of the US Laser Development for the Laser Interferometer Space Antenna (LISA) Program,” IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, p. 4276-4279, 2022