Simple frequency comb offset detection from 0 to 80 degrees C

Summary: We utilize a new nanophotonic-chip packaging technique to enable the **Octave Photonics Comb-Offset-Stabilization Module (COSMO)** to detect the carrier-envelope-offset frequency (f_{CEO}) of a **Vescent Photonics 100 MHz, 1550 nm frequency comb** over a large temperature range, from below 0 to over 80 degrees C. This miniaturized and ruggedized COSMO exhibits minimal size, weight, and power consumption, demonstrates the ability to detect the f_{CEO} of laser frequency combs in field-based applications under harsh conditions.

Introduction: The Octave Photonics Comb-Offset Stabilization Module (COSMO) provides a convenient way to detect the carrier-envelope offset frequency of laser frequency comb. The COSMO utilizes a nanophotonic waveguide that confines the light to a ~1 micron mode diameter, enabling strong nonlinear optical effects, thereby allowing the COSMO to operate with very low pulse energies. However, coupling light into such a small waveguide is difficult, and previous versions of the COSMO would exhibit a decreased coupling efficiency as the temperature moved away from room temperature, requiring the use of thermo-electric cooler to regulate the temperature. Recently, Octave Photonics, working in collaboration with **Vescent Photonics** on a contract funded by the **Office of Naval Research**, has developed new fiber-to-chip bonding methods and packaging techniques that exhibit much lower change with temperature, enabling operation of the COSMO over a broad temperature range. Here we present measurements showing the performance of the COSMO from -2 to +83 degrees C, limited by the range of our temperature-controlled base plate.

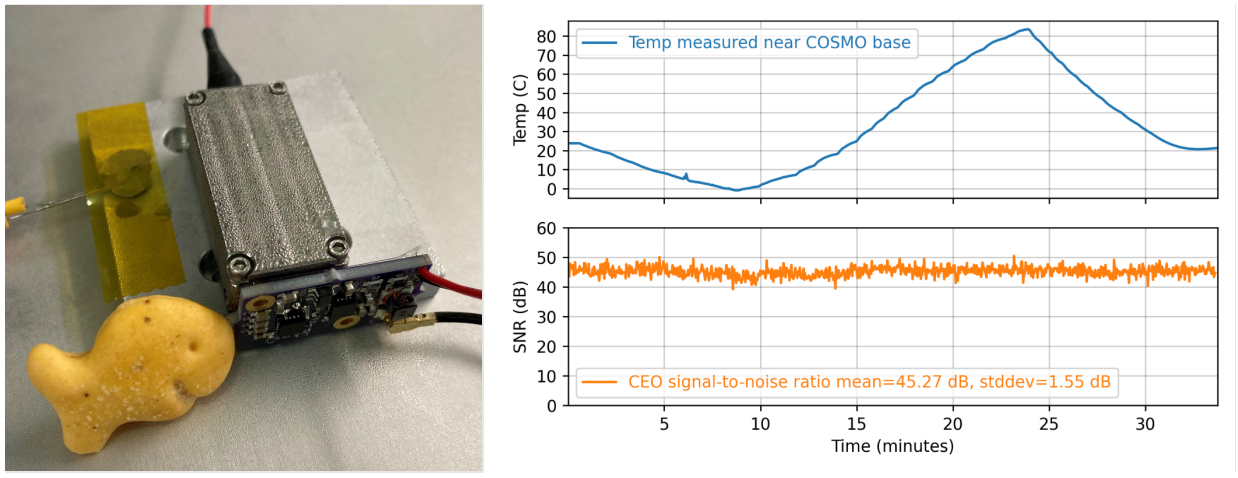

Figure 1. (left) The COSMO-mini condenses water at -2 degrees C during the temperature test. (right) The signal-to-noise ratio (SNR) of the carrier-envelope offset frequency (f_{CEO}) remains near 45 as the temperature is ramped from -2 to 82 degrees C. The SNR is sampled at 2-second intervals from spectra recorded with 100 kHz resolution bandwidth (RBW).

Experiment: A miniaturized version of the COSMO (COSMO-mini) was prepared using a special fiber-to-chip bonding technique that is intended to decrease the thermal dependence of the coupling loss. Additionally, the enclosure was designed to avoid straining the fiber-chip interface during temperature excursion. We connected the COSMO-mini to a Vescent Photonics 100 MHz, 1550 nm laser frequency

combs. The input power to the COSMO-mini is attenuated to about 20 mW (200 pJ). The carrier-envelope-offset frequency (f_{CEO}) signal from the COSMO-mini is recorded with an electronic spectrum analyzer (Rigol SSA 3021X). The COSMO-mini on a temperature-controlled plate that could ramp the temperature from approximately -5 to 85 degrees C. The actual temperature directly adjacent to the COSMO-mini was monitored using a thermocouple.

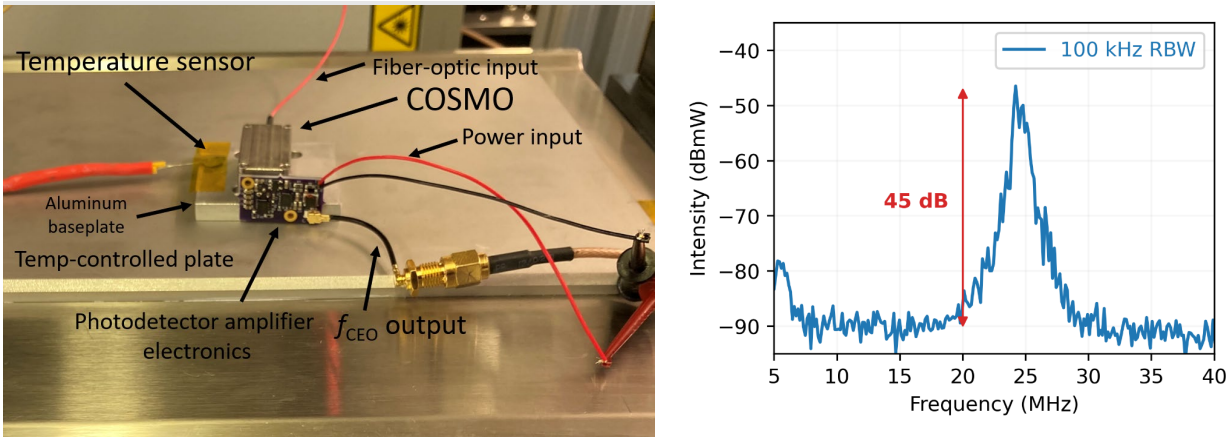

Figure 2. (left) The COSMO-mini on the temperature-controlled plate. The electronic circuit board is used to amplify the signal on the photodiode inside the COSMO-mini. (right) The carrier-envelope offset frequency (f_{CEO}) recorded with the spectrum analyzer demonstrated that f_{CEO} can be detected with approximately 45 dB signal-to-noise ratio.

Results: The temperature of the COSMO is ramped from room temperature down to -2 degrees C, up to 83 degrees C, and then back down to room temperature. During this time, the signal-to-noise ratio remains nearly constant at approximately 45 (Figure 1). When the COSMO-mini is at low temperature, it begins to condense water, and ~1 mm droplets are seen on the enclosure. However, the COSMO-mini appears unaffected by the condensed water. Three additional temperature cycles from approximately 0 to 80 degrees C were performed without noticeable degradation of performance. The temperature range explored was limited by the capabilities of the temperature-controlled plate. Additional tests will be required to explore the full operating temperature range of the COSMO enabled by these new packaging techniques.

Conclusion: Using newly developed packaging techniques, we have demonstrated fiber-to-chip coupling that does not change significantly as a function of temperature over the -2 to 82 degrees C range. This allows the detection of the carrier-envelope-offset frequency using the COSMO over a large temperature range, opening the possibility of field-based applications.

Links: Learn more at **octavephotonics.com, and vescent.com.**

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