



SELF-REFERENCED OPTICAL FREQUENCY COMB

An optical frequency comb (OFC) is a photonic tool similar to a gear in mechanics. It connects the optical frequency domain (THz) to the well-known microwave domain (MHz – GHz). This guarantees a “one to one” correspondence between frequencies that differ by more than five decades, and enables ultra-high optical frequencies to be directly resolved with standard electronics.

This Nobel-prize awarded technique has many direct applications in various fields, both industrial and scientific. To name a few: frequency comb spectroscopy, precision frequency transfer, distance measurement or low-noise signal generation.

Menhir Photonics' product strengths

High power per comb line
 > 50 μ W per line

GHz comb-lines
 spacing

f_{rep} and f_{CEO} actuators
 for stabilization

Application use case

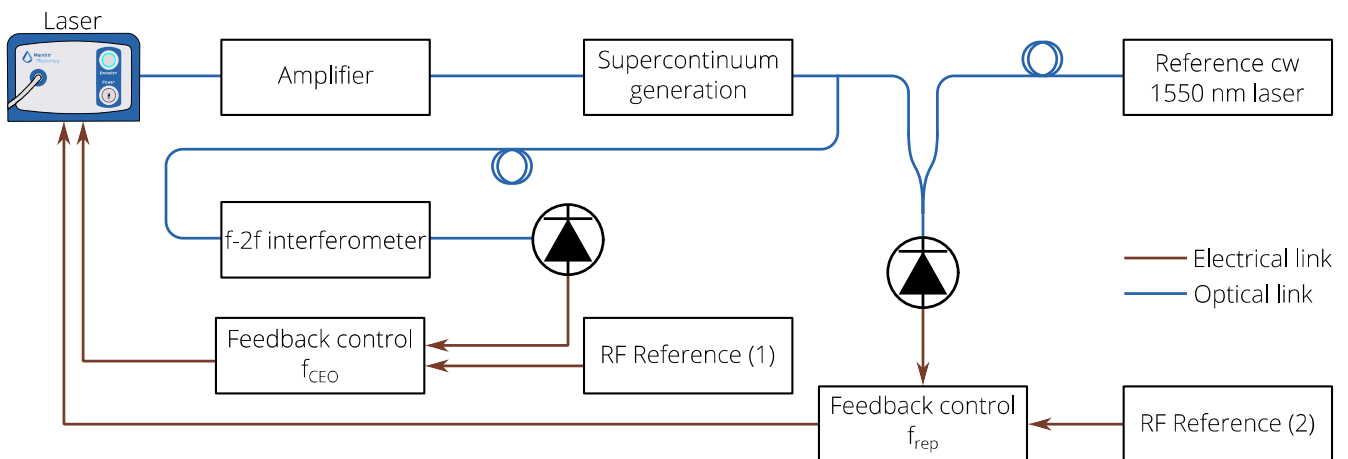


Figure 1 — Generation of a fully-stabilized optical frequency comb using the MENHIR-1550 pulsed laser as used in Reference 2. Illustration of the OFC generated by the laser output is given in Figure 2.

Optical frequency comb performance

A frequency comb is defined by only two parameters (f_{CEO} and f_{rep}) and a simple equation:

$$f_n = f_{CEO} + n \cdot f_{rep} \quad n: \text{comb line number} \quad (1)$$

The optical spectrum of a passively mode-locked laser is already a series of equidistant Fourier lines centered around the laser carrier frequency. To turn it into a stabilized frequency comb, one can self-reference the laser in order to measure and stabilize f_{CEO} and f_{rep} to fixed values.

Different groups all around the world construct OFCs with the scheme in Figure 1. The results reported in Reference 2 specifically used the MENHIR-1550 laser at 1.0 GHz to demonstrate a frequency comb with ultra-low residual noise on both f_{rep} and f_{CEO} . The “f-2f” interferometer provides an error signal for the stabilization of f_{CEO} , reaching an integrated phase noise lower than 500 mrad [100 Hz – 10 MHz] for a 1.0 GHz carrier. The additional stabilization of f_{rep} with an ultra-stable cw laser allows to reduce the overall laser noise to less than 50 mrad [100 Hz – 10 MHz] per comb line. Those results demonstrate that the MENHIR-1550 laser can drive state-of-the-art OFC to a new level of precision.

Density of comb lines

Not all the comb lines have equal power due to the limited spectrum of the laser. Figure 2 (left) displays the power spectrum of a typical MENHIR-1550 laser. Individual comb lines are shown in the Figure 2 (right), which is a zoomed region of the center of the power spectrum. The free-running linewidth of each comb line is less than 20 kHz. The OFC spectrum contains around one million individual lines within a -20 dBc bandwidth.

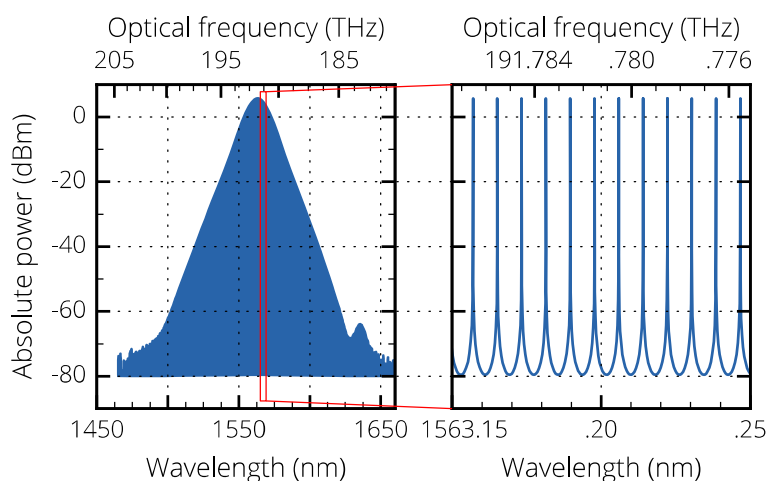


Figure 2 — Illustration of the frequency comb lines. Left: The spectral absolute power, containing roughly 10^6 lines (-20 dBc bandwidth). Right: Zoom on the central part of the spectrum. The comb lines are spaced by 1 GHz and have a linewidth < 20 kHz and SNR > 70 dBc.

References

1. T. Fortier and E. Baumann, *20 years of developments in optical frequency comb technology and applications*, Commun. Phys. **2**, 153 (2019)
2. D. M. B. Lesko, A. J. Lind, N. Hoghooghi, A. Kowligy, H. Timmers, P. Sekhar, B. Rudin, F. Emaury, G. B. Rieker, S. A. Diddams, *Fully phase-stabilized 1 GHz turnkey frequency comb at 1.56 μm* , OSA Continuum **3**, 2070 (2020)
3. P. Brochard, B. Rudin, F. Emaury, V. J. Wittwer, S. Schilt, T. Südmeyer, *Low-noise transfer of the spectral purity of an optical comb line using a feedforward scheme*, J. Eur Opt Soc-Rapid **16**, 4 (2020)

Related product: MENHIR-1550 at 1.0 GHz

Repetition rate	1.0 GHz
Average power	> 50 mW without amplifier
Central wavelength	1555 +/- 10 nm
Spectral bandwidth at -3 dB	> 10 nm (i.e. sub-250 fs pulses)