Comparison of low-noise microwave generation from ultrafast fiber and DPSSL frequency combs

V. Dolgovskiy[1], N. Bucalovic[1], S. Schilt[1], G. Di Domenico[1], P. Thomann[1], S. Grop[2], B. Dubois[2], V. Giordano[2], M. C. Stumpf[1,3], S. Pekarek[3], U. Keller[3], T. Südmeyer[1]

1. *Laboratoire Temps Fréquence, Université de Neuchâtel, 51 Avenue de Bellevaux, CH-2000 Neuchâtel, Switzerland*
2. *FEMTO-ST Institute, Time and Frequency Dpt., 26 Chemin de l'Epitaphe, 25030 Besançon Cedex, France*
3. *Department of Physics, Institute of Quantum Electronics, ETH Zurich, 8093 Zürich, Switzerland*

Ultrastable microwave generation is essential for numerous applications such as high precision radar systems, advanced long baseline interferometry, or frequency standards. Until recently, the highest short term frequency stability was obtained from cryogenically-cooled microwave resonators. A break-through in the search of simpler reference oscillators was achieved in 2011. Microwaves generated by optical frequency division demonstrated relative frequency instabilities $<8\cdot10^{-16}$ at 1 s [1]. In the system, a Ti:sapphire (Ti:S) frequency comb transferred the stability of the optical reference frequency to the microwave domain. Extremely stable frequency division has also been achieved from ultrastable Er:fiber-combs [2]. However, fiber combs generally exhibit a significantly higher intrinsic noise level than Ti:S combs and require advanced noise suppression techniques. A promising alternative are frequency combs from ultrafast diode-pumped solid state lasers (DPSSLs). Similar to Ti:S lasers, they operate with high-Q cavities and moderate intracavity nonlinearities, resulting in a low fundamental quantum noise limit and a free-running carrier envelope offset (CEO) beating signal with a narrow linewidth. Furthermore, they can achieve high output powers without any amplification and have proven to operate at tens of gigahertz repetition rate. Recently, we reported the first full stabilization of a 1.5-µm Er:Yb:glass DPSSL comb, achieving excellent noise properties [3] that make it attractive for ultra-low noise microwave generation using a simple scheme without the need for CEO subtraction.

Here, we present the first comparison of microwave generated with the Er:Yb:glass comb referred as ERGO and with a commercial Er:fiber comb (MenloSystems). Moreover, we used for the first time a compact and low-cost planar-waveguide external cavity laser (PW-ECL) [4] as optical reference, which was stabilized to a high-finesse Fabry-Perot cavity. We evaluate the microwave signal at 10 GHz with the novel transportable ultra-low instability signal source ULISS [5], based on a cryocooled sapphire oscillator developed at the Femto-ST in Besançon. ULISS offers a relative frequency stability (Allan deviation) better than 3×10^{-15} for 1 s < τ <10,000 s, which makes it very effective for the evaluation of microwave signals generated from optical frequency standards. A similar relative frequency stability of 5×10^{-15} at 1 s was obtained with both combs (Fig. 1b), attributed to the present limit of our ultra-stable laser source. However, we observe that the phase noise of the microwave generated from the ERGO comb is up to 20 dB lower than obtained from the Er:fiber comb in a large Fourier frequency range of 100 Hz - 100 kHz (Fig. 1c).

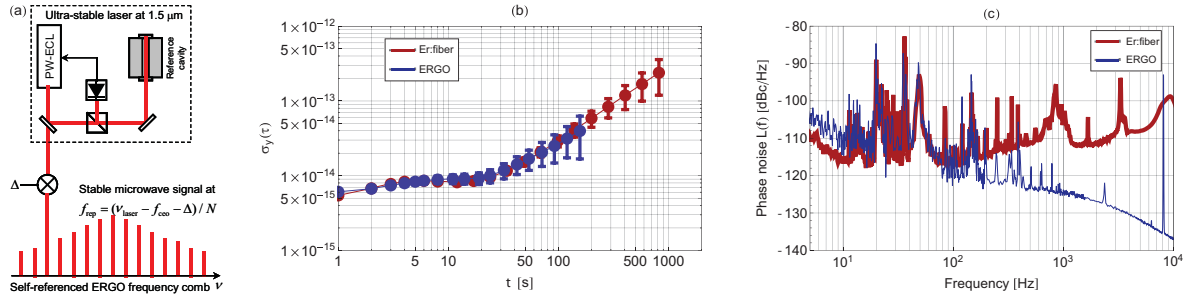

Fig. 1 Microwave generation from ultra-stable PW-ECL with Er:fiber and ERGO combs. (a) Schematic representation. (b) Allan deviation. (c) Phase noise relative to the 10 GHz carrier.

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