# Transfer Oscillator Technique for Generation of Multiple Low-phase Noise Microwave Signals using Single Optical Frequency Comb

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Currently, the lowest noise microwave signals are generated via frequency division of high-stability optical references [1, 2] using optical frequency combs (OFCs). Traditionally, optical frequency division is implemented via tight phase-stabilization of an OFC to a high-stability optical reference. Photodetection of the comb repetition frequency enables the extraction of an electronic signal that preserves the frequency stability of the optical reference. A drawback of the latter technique is that it typically requires the use of combs with excellent passive stability. Additionally, tight phase locking means that one comb can only derive microwave timing signals from a single reference. The transfer oscillator method [3, 4] can overcome these disadvantages by utilizing a single, free-running OFC to transfer the stability of multiple optical references to the microwave domain via synchronous electronic "mix-out" of the comb characteristic frequencies, $f_{rep}$ and $f_{ceo}$.

The schematic of the proposed transfer oscillator scheme for microwave generation is shown in Fig. 1a, which employs digital and RF analog electronics to coherently suppress additive optical frequency comb noise. Using this technique, we transferred the phase stability of two high-Finesse optical sources at 1157 nm and 1070 nm to two independent 10 GHz signals using a single frequency comb. We demonstrated absolute phase noise below -106 dBc/Hz at 1-Hz from carrier ( Fig. 1b) with corresponding 1 second fractional frequency instability below $2\times10^{-15}$. Our work demonstrates a 50 dB improvement in close-to-carrier phase noise performance over the previous best results [4] using a similar technique, and the first demonstration of independent electronic signals from multiple optical references using a single optical frequency comb [5].

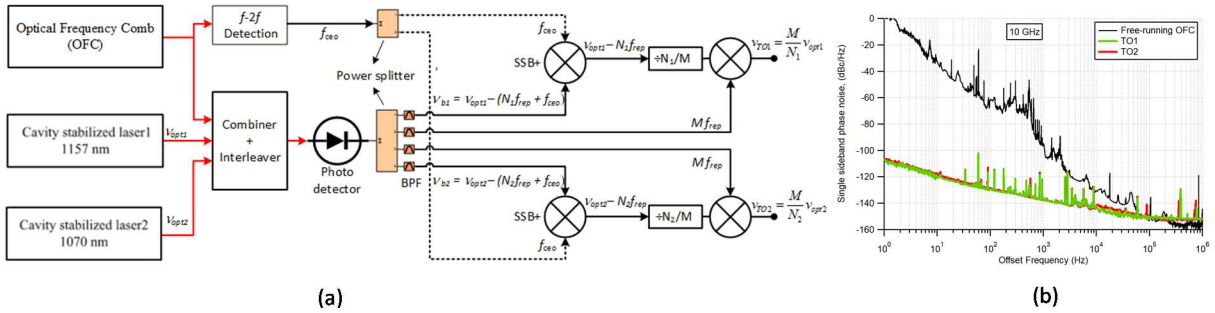


Fig. 1: a) Block diagram of the proposed scheme for the generation of microwave signals from optical signals by using a single OFC as a transfer oscillator. Electronic division by $N_1/M$ and $N_2/M$ is achieved with direct digital synthesis. BPF – Bandpass filter, SSB - Single sideband mixer, b) Phase noise comparison of the extracted 10 GHz microwaves signals: free running optical frequency comb (black), $\nu_{TO1}$ derived from optical source at 1157 nm (green), and $\nu_{TO2}$ derived from optical source at 1070 nm (red). The 10 GHz microwave signals were comapred against a Ti:Sapphire OFC. The following integer constants are used: $M = 20$, $N_1 = 518{,}907$ and $N_2 = 561{,}211$.

**References:**

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