# Photodetection of ultrashort optical pulses for low phase noise microwave generation

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Optical frequency division, where an ultra-stable optical frequency reference is coherently divided to the microwave domain, has shown the ability to produce microwave signals with spectral purity rivaling the best microwave oscillators. Frequency division is accomplished by locking an optical frequency comb to the ultra-stable reference and photodetecting the comb's output pulse train. This results in an electrical pulse train whose spectrum is an array of frequency tones at the optical pulse repetition rate ($f_{rep}$) and harmonics. Measurements at 10 GHz have demonstrated absolute phase noise below -100 dBc/Hz at 1 Hz offset, reaching a floor of nearly -180 dBc/Hz at 10 MHz offset[1].

To fully exploit the low phase noise potential of the ultra-stable reference and optical frequency comb, noise limitations associated with photodetection must be mitigated. Under short pulse illumination, photodetectors (PDs) quickly saturate, limiting the microwave power and the resulting signal-to-noise ratio. This problem is exacerbated when the microwave frequency of interest is 10-100x $f_{rep}$. Amplitude-to-phase noise conversion during photodetection can corrupt the microwave phase stability, as can PD flicker noise. Results and limitations of techniques to reduce the impact of photodetection noise, including the use of highly linear, high power handling PDs[2], short pulse illumination to reduce the impact of shot noise of the phase stability[3], optical amplification and pulse interleaving to increase the attainable microwave power, will be presented.

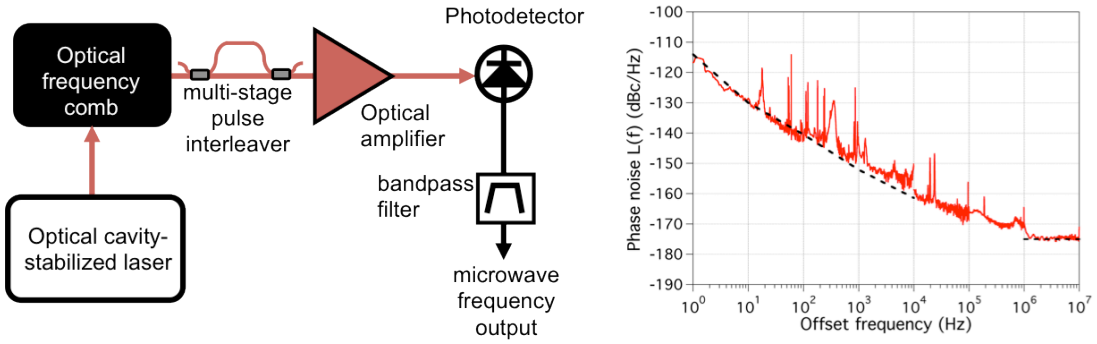


Fig. 1: Right: Schematic of optical frequency division for low noise microwave generation, including optical amplification and optical pulse interleaving. Left: 10 GHz phase noise of two optical frequency dividers locked to the same optical reference. Close-to-carrier photodetection limitations and optical amplifier limited noise floor are shown as the two dotted lines.

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[1] T. Fortier, et al., "Photonic microwave generation with high-power photodiodes," Opt.Lett., vol. 38, p. 1712 (2013)

[2] Z. Li, et al., "High-power high-linearity flip-chip bonded modified uni-traveling carrier photodiode,: Opt. Express, vol. 19, p. B385 (2011)

[3] F. Quinlan et al., "Exploiting shot noise correlations in the detection of ultrashort optical pulse trains," Nat. Photon., vol. 7, p. 290 (2013)