Low-noise synthesis of microwave and millimetre-wave signals with optical frequency comb generator

S. Xiao, L. Hollberg and S.A. Diddams

The phase noise of a 20 GHz picosecond optical pulse train generated by a modulator-based optical frequency comb generator is analysed. The residual timing jitter is <10 fs for Fourier frequencies from 10 Hz to 10 MHz. Photodetection of the optical pulse train provides millimetre-wave signals with similarly low residual jitter at 40, 60, and 80 GHz with applicable powers of –7.5, –10.5, and –13 dBm, respectively.

Introduction: Photonic-based generation of microwave and millimetre-wave signals has been pursued by many groups over the years [1]. Common approaches involve modulating and/or mixing CW lasers to generate sidebands or beat frequencies over the range of approximately 30–300 GHz [2–5]. The optical beat frequencies are converted to high speed electrical signals via photodetection or photomixing. In this regard, an optical frequency comb generator (OFCG) based on a high-seed phase modulator inside a resonant Fabry-Pérot cavity [6,7] has some unique advantages. In a very simple package, it directly provides an array (separated by the modulation frequency) of precisely known optical frequencies spanning many terahertz in the 1.5 μm spectral region. In addition to the comb-like spectral structure, the time-domain output of the OFCG is a high-repetition-rate train of short pulses (<1 ps) [8–12]. Photodetection of the pulse train produces repetitive current pulses which themselves correspond to a comb of microwave and millimetre-wave harmonics extending up to the bandwidth of the detector. Thus, one can use low-noise and low-loss photonic techniques to synthesise a broad array of millimetre-waves, extending up to the bandwidth of the detector.

Experiment and measurement: Fig. 1 shows the experimental setup for signal generation and noise measurement. v_c: frequency of optical CW seed laser; PD: photodiode; SOA: semiconductor optical amplifier; SA: spectrum analyser; MZM: Mach-Zehnder amplitude modulator.

Fig. 1 Schematic experimental setup for signal generation and noise measurement

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modulator-based optical frequency comb generator. Our analysis indicates the resulting harmonics (20, 40, 60, 80 GHz) have low phase noise relative to the input 10 GHz modulation signal. Experimentally, the residual phase noise of the 20 GHz harmonic was measured, and an integrated timing jitter $\leq 10$ fs was achieved for Fourier frequencies between 10 Hz and 10 MHz. The measured noise is mainly limited by the optical amplifier’s noise. These results imply that the OFCG should be a useful tool for low-noise synthesis and the delivery of precise timing signals in microwave and millimetre-wave photonic systems.

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References

1 A recent review of the work in this field is found in, Special issue on microwave photonics, J. Lightwave Technol., 2008, 26, pp. 2336–2810