Broadband RF photonic mixer based on an integrated microcomb source

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ABSTRACT

A broadband microwave mixer is demonstrated based on an integrated optical micro-comb source, with an operation bandwidth up to over 60 GHz, a conversion efficiency of -6.8 dB and a spurious suppression ratio of over 43.5 dB, and experimentally verify the RF performance up to 40 GHz. This approach to realizing microwave mixers offers reduced complexity, size, and potential cost for a wide range of applications to microwave systems.

Introduction

Microwave frequency conversion is an important function for signal transmission or processing applications including radio-over-fibre and radar systems [1-3]. Considering electrical microwave mixers are subjected to the electrical bandwidth bottleneck, photonic techniques can offer large bandwidths, high isolation and strong immunity to electromagnetic interference. The microwave mixer can be achieved using frequency combs or optoelectronic oscillators [4], however, such approaches still face limitations brought about by the employed external electrical local oscillator (LO) signal sources or the high spurious signals. Here, we report a broadband photonic microwave mixer based on an integrated Kerr comb source [5-7]. Soliton crystal combs [8-10] with a 48.9-GHz spacing are generated in an on-chip micro-ring resonator (MRR) and serve as a photonic LO. The photonic microwave mixer's performance are also experimentally verified with input RF frequencies up to 40 GHz, together with a conversion efficiency of -6.8 dB and a spurious suppression ratio of over 43.5 dB.

Experiment

The schematic diagram of the microwave mixer is shown in Fig. 1(a). To generate Kerr micro-combs, the pump power was set at ~ 30.5 dBm and the wavelength was swept from blue to red. As the detuning was changed further, distinctive 'fingerprint' optical spectra of soliton crystals were observed (Fig. 1(b)). Two comb lines at ~ 1541 nm of the soliton crystal combs were filtered out and modulated with RF signals with different frequencies up to 40 GHz. Then the optical signals were amplified and converted back into the electrical domain where the frequency mixing of the RF signal and LO signal was achieved upon photo-detection. The measured output electrical spectra of the photonic microwave mixer is shown in Fig. 2. Figure 2(a) shows the electrical spectra with $f_{\text{RF}} = 26$ GHz, which corresponds to an IF output at 22.9 GHz. The conversion efficiency (i.e., the power difference between the output IF signal and RF signal) reached -6.3 dB, with a spurious suppression ratio (i.e., the power difference between the output IF signal and spurious signal at $2f_{\text{IF}} - f_{\text{LO}}$) of 43.5 dB. Figure 2(b) shows the electrical spectra of the input RF signal and output IF signal with a span of 10 MHz, indicating a signal-to-noise ratio of over 70 dB and further confirmed the low noise performance of the photonic microwave mixer. The frequency relationship between f_{RF} and measured f_{IF} is clearly shown in Fig. 2 (c), as the input RF frequency f_{RF} varied from 40 GHz to 23 GHz (from Ka- to X-band), the converted IF output $f_{\text{IF}} = f_{\text{LO}} - f_{\text{RF}}$ varied from 8.9 GHz to 25.9 GHz (from X- to Ka-band) with a power variation less than 5 dB, verifying the ultra-wideband operation of our photonic microwave mixer.

Fig. 1. (a) Schematic diagram of the LO-free photonic microwave mixer based on an integrated optical frequency comb source. Amp: erbium-doped fibre amplifier. PC: polarization controller. MRR: micro-ring resonator. OBPF: optical bandpass filter. MZM: Mach Zehnder modulator. PD: photodetector. (b) Optical spectrum of the generated soliton crystal combs.

Fig. 2. Measured output electrical spectra of the photonic microwave mixer (a) with $f_{RF} = 26$ GHz, (b) the input RF signal and output IF signal with a span of 10 MHz, (c) with f_{RF} varying from 40 GHz to 23 GHz.

Conclusion

We demonstrate a broadband LO-free photonic microwave mixer based on an integrated Kerr comb source. 48.9-GHz spacing soliton crystal micro-combs served as a millimeter-wave LO for microwave mixing, enabling microwave frequency conversion up to the U-band (40-60 GHz). This microcomb based photonic microwave mixer is highly attractive for frequency conversion in radar and RoF systems, due to its ultra-high frequency photonic LO and greatly reduced system size, complexity, and potential cost.

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