PHOTONIC MICROWAVE FREQUENCY MIXING USING AN OPTICALLY INJECTED SEMICONDUCTOR LASER

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Abstract

The nonlinear dynamics of an optically injected semiconductor laser are investigated for radio-over-fiber (RoF) downlink transmission through photonic microwave frequency mixing. Subject to optical injection from a master laser, the single-mode slave laser exhibits a variety of nonlinear dynamical behaviors such as stable-locking, period-one (P1) oscillation, period-two (P2) oscillation, and chaos.

By properly adjusting the injection conditions, the slave laser in the P1 oscillation acts as a broadly tunable photonic microwave oscillator. When an external current modulation at an intermediate frequency (IF) is applied to the slave laser, the P1 oscillation is modulated accordingly. Frequency mixing yields up-converted frequencies at both the upper sideband (USB) and the lower sideband (LSB). As the photonic microwave generated through P1 oscillation can go beyond the relaxation resonance frequency due to nonlinear dynamics, photonic microwave frequency up-conversion beyond the laser bandwidth is achieved. Experimentally, a 2.5-Gbps-grade semiconductor laser is applied to generate P1 oscillation at 18 GHz. It is shown that the up-conversion bandwidth is limited by the direct modulation response of the slave laser with a linear operational range of more than 20 dB. When binary phase-shift keying (BPSK) data is modulated on the IF signal, it is up-converted to the USB and LSB for downlink transmission simultaneously. Data up-conversion from an IF of 2 GHz to a subcarrier frequency as high as 20 GHz is experimentally demonstrated. After transmission over a 4-km single-mode fiber to a base station, the data is recovered with a bit-error rate (BER) below $10^{-9}$. Only low-cost lasers are used and there is no requirement on high-speed electronic mixers or external modulators. Numerical simulations support the feasibility of extending the approach to the technologically important window at 60 GHz. Furthermore, the chaotic state
of the optically injected semiconductor laser is examined for power-over-fiber (PoF) applications. The stimulate Brillouin scattering (SBS) threshold is significantly increased by driving the laser into chaotic oscillation, which has a bandwidth much broader than the Brillouin linewidth. By comparing with the free-running state, the chaotic state provides a 22-fold increase of the maximum output power to 838 mW, after transmission over a 5-km single-mode fiber. Upon optoelectronic conversion using a photovoltaic (PV) cell, the obtained electrical power of 44 mW is adequate for advanced low-power RoF remote units.
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