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Generation and Processing of Quantum Optical Microcombs on a Silicon Photonic Chip

Biphoton quantum frequency comb (BQFC) sources generate high-dimensional entangled states in the frequency domain and represent a powerful resource for quantum information processing. Their coherent manipulation requires frequency-bin processors capable of performing reconfigurable unitary operations on frequency bins with high fidelity and success probability. In this work, we present a fully integrated silicon photonic quantum frequency processor that monolithically combines a microring resonator source for BQFC generation, high-speed phase modulators, and a microring-resonator-based line-by-line waveshaper. We demonstrate coherent manipulation of frequency bins by implementing a 50/50 frequency beamsplitter without post-selection, achieving a fidelity of 99.3% and a success probability of 94.7%, well above the single phase-modulator limit of 66.7%. To further demonstrate correct operation in the quantum regime, we realize reconfigurable quantum walks using on-chip–generated BQFCs. Our monolithically integrated silicon source and quantum frequency processor represent a significant step toward fully integrated silicon-based quantum frequency information processing.

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