Integrated photonic quantum frequency combs for complex photon state generation

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A key challenge in today's quantum science relies in the realization of large-scale complex non-classical systems to enable, e.g., ultra-secure communications, quantum-enhanced measurements, and computations faster than classical approaches. Optical quantum frequency combs, characterized by many equidistantly spaced frequency modes which allow the storage of a large amount of quantum information, represent a powerful approach towards large-scale controllable quantum systems. Here, I discuss the realization of quantum frequency combs in on-chip micro-resonators and demonstrate their use for the generation and manipulation of quantum states with considerably enhanced complexity, particularly generating on-chip multi-photon as well as high-dimensional quantum states. Following such an approach permitted the first realization of discrete high-dimensional cluster states, laying at the basis of measurement based-quantum computing. Microcavity-based photonic frequency comb states and their coherent control using accessible telecommunications infrastructure can open up new venues for reaching the processing capabilities required for meaningful quantum information science.