Abstract/Details

Silicon Nitride Microring Resonators: Classical and Quantum Applications

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Abstract (summary)

During the last decade, optical frequency combs have had a

significant impact in the fields of precision metrology and astronomy. In more recent years, silicon nitride (SiN) microring resonators (MRR) have proven to be a useful platform for the miniaturization of these frequency comb sources. My research expands the knowledge in this field in two directions. Firstly, from the classical point of view, it explores the use of SiN MRRs for the generation of a single cavity soliton. In this area, we re- ported cavity soliton formation and its corresponding frequency comb with a smooth sech2 shape, high coherence and low-intensity noise. Also, taking advantage of our unique drop-port architecture, we were able to observe the intra-cavity field showing a single pulse of 74 fs through time-domain measurements. Furthermore, using the characterized regions in the pump power and detuning space, we were able to gen- erate a single cavity soliton breather, and we demonstrated a ? phase shift between the oscillation of the pump and the comb lines. Secondly, from the quantum point of view, this project investigates SiN MRRs as a source of entangled photon pairs for quantum information processing technologies. In this direction, we have reported a source of comb-shaped entangled photon pairs, also called biphoton frequency combs, on a chip. We were able to generate up to 10 sidebands of entangled photon pairs with a free spectral range of 380 GHz and a high coincidence to accidental ratio. Further- more, we characterized the time and frequency correlations between these comb lines via a joint spectral intensity measurement. The pairwise energy-time entanglement verification and the potential use of this source in quantum communications have been demonstrated using Franson interferometry and nonlocal dispersion cancellation, respectively. To show that the generated entangled photons are in a coherent superposition of frequency bins, we used a biphoton frequency comb with 50 GHz free spectral range and used a phase modulation technique to overlap contigu fre- quency bins, creating indistinguishability and interference

patterns. We measured interference visibilities up to 93%, higher than the 71% required for entanglement verification. For this experiment, we also estimated the density matrix of the source using a quantum state tomgraphy technique. We were also able to overlap three frequency bins and we measured a CGLMP parameter $I_3 = 2.63$, which violates its classical upper bound of 2. This violation demonstrates the high-dimensional en- tanglement of signal and idler photons from the selected frequency bins. This novel high-dimensional frequency-bin entangled source of photon pairs has a potentially high impact in areas like quantum computing and quantum communications due to its low cost, robustness, compactness, and scalability.

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