Soutenance de thèse

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Multi-photon quantum interference and entanglement

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Abstract :

In this PhD work, we study key features for optical quantum information processing, namely the possibility to perform quantum interferences and generate entanglement with many photons. We use a semiconductor quantum-dot (QD) embedded in a monolithic micropillar optical cavity as a bright source of pure and indistinguishable single photons. Interfacing such high-performance single-photon sources with reconfigurable glass photonic circuits fabricated using femtosecond laser micromachining, we manipulate up to four photon on chip. We first explore the measurement of multiphoton indistinguishability, a non-trivial task for state of $n > 2$ photons. It is defined as the overlap of the multiphoton state with the pure state made of n identical photons. We use a scalable interferometer design that has $N = 2n$ modes and includes a cyclic array of beam splitters to experientially quantify the indistinguishability of a 4-photon state on an 8-mode integrated version of this interferometer. We measure a 4-photon indistinguishability of 0.81 ± 0.003, providing a first reference value and benchmark of four-photon indistinguishability. Then, we demonstrate high-fidelity high rate generation of a 4-partite GHZ states on chip, and perform a first proof-of-principle of a real-world application by demonstrating a 4-partite quantum secret sharing protocol. We achieved a fidelity of F=86% to the target GHZ state, and a state purity of P=76.3%. We have certified the genuine entanglement of the generated state with a semi device-independent approach within 39 standard deviations. In our quantum key distribution protocol, we reach a QBER of 10.87%, just below the 11% threshold to ensure a secure communication. Finally, we study remote two-photon interference with photons generated from independent remote electrically tunable bright single-photon sources deterministically fabricated using the in-situ lithography technique. We measure 2 photon interference from four pairs of remote independent bright single- photon sources using pulsed excitation schemes. Us- ing resonant excitation, we show that we can reach up to $V=54.8\pm1\%$ without any spectral filtering, and $V=69\pm1\%$ when the single-photon are filtered to reduce the impact of charge noise.