High-fidelity on chip four-photon GHZ states

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Mutually entangled multi-photon states are at the heart of all-optical quantum technologies. Over the past two decades, major advances in their generation have been achieved by exploiting spontaneous parametric down-conversion, and free space apparatuses [1]. However, bulk optics and probabilistic sources limit scalability and thus real-world applications. We propose to generate multi-photon states making use of cavity embedded quantum-dot (QD) emitters that operate as an on-demand source of pure and indistinguishable single-photons [2] that we synchronize at the input of a reconfigurable chip.

In this work [3], we generate and characterize on-chip high-fidelity quadri-partite GHZ states and perform an integrated quantum secret sharing protocol as a proof-of-principle that our platform is application ready. We first demonstrate the on-chip high-fidelity high-rate generation and characterisation of 4-photon GHZ states using a bright single-photon source. The 4-photon GHZ generation rate of 0.5 Hz is remarkable. It allows to perform a complete characterisation of the 4-partite state through the reconstruction of its density matrix ρ_{exp} via full quantum state tomography (Fig. 1.b). The fidelity of the generated state to the target is *F*=(86.0±0.4)%, and the purity of the state is *P*=(76.3±0.6)%, setting a new state-of-the-art for integrated implementations of 4-partite GHZ states. In addition, we test non-classical correlations and certify entanglement, non-separability, and robustness of the generated state to noise using a semi device-independent approach. The violation of a Bell-like inequality characterizing 4-partite GHZ states exceeds the classical bound by more than 39 standard deviations. Finally, as a proof-of concept protocol harnessing the produced state, we implement with our reconfigurable device a quantum secret sharing protocol between four parties with sifted keys up to 1978 bits long and a qubit error rate of 10.87%, below the threshold of 11% required to guarantee a secure communication. These achievements demonstrate that our experimental platform consisting of QD solid state emitter and reconfigurable photonic chip is mature for the high-fidelity integrated generation and manipulation of entangled multi-photon states, setting a milestone in the implementation of photonic technologies protocols.

References

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Figures

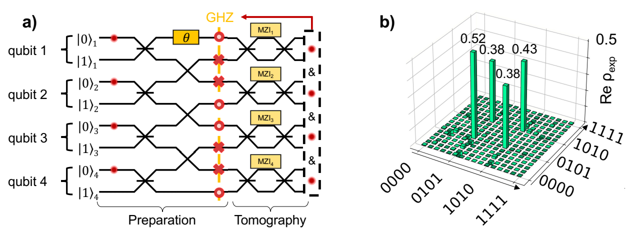

Figure 1: (a) Integrated path-encoded 4-GHZ generator injected by synchronised photons from QD source (red dots). (b) Experimental tomography of 4-GHZ states. The real part of the reconstructed density matrix ρ_{exp} from the experimental 4-photon tomography using maximum likelihood estimation.