An all-optical quantum processor for iterative generation of quantum states

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Iterative schemes have a great potential for efficient production of complex quantum states of light[1]. This concept refers to generation protocols which build their target in several steps: they start from basic resources such as single-photon states, and generate states that are more and more complex through the implementation of simple quantum operations. This requires a multiple-registers quantum memory for the storage of intermediate states, together with a quantum processing unit, the whole constituting a basic quantum processor.

In this talk we will present an all-optical architecture for the implementation of such protocols, based on an optical cavity and fast optical switches coupled to a high-rate single-photon source [2]. First experimental results will be reported[3], showing notably high-rate generation of optical Schrödinger cat states. The ability of optical cavities to store such states while preserving their quantum properties, as the presence of negative values in their Wigner function, will be also demonstrated.

A main objective for this work is the synthesis of GKP states[4], also known as grid states. Such states were recently produced with an integrated photonic chip[5], but they cannot be used for quantum information processing at this stage. The synthesis of GKP states of adequate quality would be a major breakthrough, as it would allow scalable universal quantum computing with linear optics only (i.e. only with beamsplitters and homodyne detections).

[1] New J. Phys. 16, 053001 (2014)
[2] Phys. Rev. Lett. 122, 210501 (2019)
[3] Phys. Rev. Lett. 133, 173603 (2024)
[4] Phys. Rev. A 64, 012310 (2001)
[5] Nature volume 642, pages 587–591 (2025)