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A faster source to generate optical Schrödinger cat states

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The field of quantum information consists in exploiting quantum superposition of information bits to bring new perspectives for multiple applications such as quantum communications or quantum computing. Our team works on the development of one possible way to encode quantum information with light. Indeed, it is possible to use coherent state coding, with optical Schrödinger cat states, as a basic resource for quantum communications, for basic quantum gates, or the production of more complex quantum states of light. For all this reasons these states are interesting ones, and we are working on their generation on free-propagating light pulses, focusing on the increase of the generation rate (currently limited to a few hundreds of hertz) to unlock future potential applications.

The experiment is conducted with a Ti:Sa Laser at 850nm (76MHz, 4ps) and includes a single photon pair source (second harmonic generation in first exaltation cavity followed by fluorescence parametric down conversion in a second cavity), a single photon detection system (spatial and spectral filtering + avalanche photodiode), a 60 meters delay line to synchronize the electronic systems, a quantum memory cavity (including a very fast Pockels Cell) that can store single and two photon Fock states for instance [1], a homodyne detection system and a phase measurement path.

The generation and storage of our Schrödinger cat states is obtained through the manipulation of the polarization of single photons stored inside our quantum memory cavity, and through a conditioning with our homodyne detection system. We have been able to generate Schrödinger cat states inside the quantum memory cavity and to store them during 184ns before releasing and measuring them to reconstruct their Wigner function.
The first tests of our protocol has led us to a generation rate of about 100Hz with a corrected fidelity of almost 50% and a visible negativity of the Wigner function.[2]. These performances are expected to improve in the future.

The major point of this experiment is that the presence of the quantum memory cavity enables us to increase the generation rate by a factor N, where N is the number of storage turn in the quantum memory cavity. Furthermore, the storage of the cat states would enable us to use them for growing protocols [3].

For this conference, we would present our cat states generation protocol, our first or new results of generated and stored cat states, and the possible improvements to increase this generation rates up to the kilohertz or more.

References:
[1] Bouillard et al. "Quantum storage of single-photon and two-photon fock states with an all-optical quantum memory." PRL 122.21 (2019): 210501.
[2] Cotte et al. "Experimental generation of coherent-state superpositions with a quantum memory." PRR 4.4 (2022): 043170.
[3] Etesse et al. "Iterative tailoring of optical quantum states with homodyne measurements." Optics Express 22.24 (2014).

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