Few Photon Photonics in waveguides: Continuous frequency conversion in the single photon limit.

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Light-matter interaction is one of the most fascinating topics in physics. Its enhancement using few-level-systems (FLS) in cavities has lead to the rich field of Cavity Quantum Electrodynamics. More recently, it has been realized that enhanced light-matter interaction can be realized in quasi-one-dimensional waveguides, such as dielectric waveguides, superconducting strips, photonic crystal waveguides, plasmonic waveguides, etc. Different types of waveguides may work at different frequency ranges and different physical conditions (like temperature), but they all profit from the confinement of the field and the reduced dimensionality in light propagation.

Several results are known in these one-dimensional quantum-electrodynamics (1DQED) systems, but the large majority of them have been obtained considering one incoming photon, and within the rotating-wave-approximation, valid for small couplings between the photon field and the FLS, which conserves the total number of excitations (be it a photon or an excitation of the FLS). Considering more than one photon (but few) interacting with several qubits new effects are expected due to the finiteness and the photon-photon interactions. However, the theoretical analysis is notoriously difficult and has only been performed for a few cases concerning two and three photons treated.

In this talk we will present our numerical approach, based on the Matrix Product States time evolution, for scattering processes involving few photons (1 -10) through several emitter arrays. Finally, we will present a a novel effect. Whenever the coupling between the emitter and the waveguide is sufficiently strong, a continuous frequency conversion is possible at the single photon level.