Generation of superposition and entanglement in the photon-number basis with solid-state quantum devices

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Recent technological progress on semiconductor quantum dot devices, coupled to cavities (monolithic [1,2] and open cavities [3]), has demonstrated record values of single-photon *brightness* (probability of generating a single-photon per excitation trigger), *purity* (suppression of emitted multi-photon components) and *indistinguishability* (degree of identicality among the emitted single-photons).

This new generation of quantum photonic sources have unlocked the observation of fundamental phenomena: **superposition** and **entanglement** with photons are core properties for the implementation of quantum networks and quantum computation.

In this talk, first, I will discuss experimental results showing that the resonant laser driving of a quantum dot allows to **deterministically control** the coherent superposition in the photon number basis, yielding the states $\alpha|0\rangle + \beta|1\rangle$, where $|0\rangle$ and $|1\rangle$ are vacuum and single-photon states, and α and β coefficients can be controlled via the laser intensity [4].

In the second part of the talk, I will show recent experiments showing that two delayed, resonant laser pulses, exciting a quantum dot, deliver deterministic time-entanglement in the photon number basis, producing an entangled state $\alpha|00\rangle + \beta|11\rangle$ [5]. The generation of such photon entanglement is rooted to the atomic spontaneous emission mechanism, and it is scalable towards multi-partite entanglement simply by adding more consecutive laser pulses.

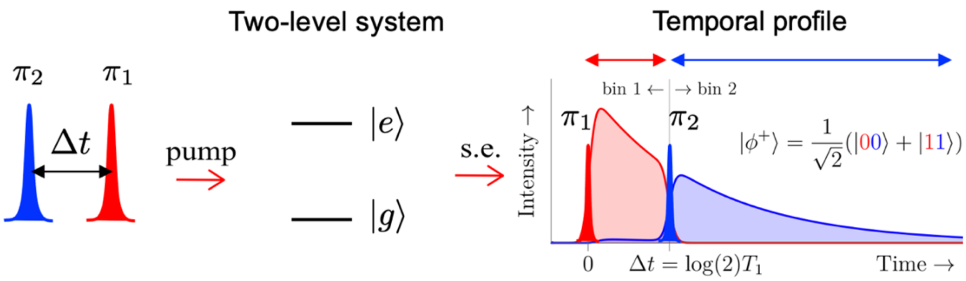

Figure 1. Schematic representation of the double π pulse excitation on a two-level system. The first [second] π-pulse excites the two-level atom at $t = 0$ [$t = log(2)T_1$], the emitted photonic wavepacket is a time-entangled Bell state: the first [second] temporal bin is encoded in a red [blue] color. The vacuum and single photon states are distributed in these time bins generating the Bell state $|\phi^+\rangle = (|00\rangle + |11\rangle)/\sqrt{2}$.

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[3] N. Tomm, et al., Nat. Nanotechnol. 16, 399 (2021).
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[5] S. C. Wein, et al., Nat. Photonics (2022).