Optical Control of Linear Cluster State Generation with a Semiconductor Quantum Dot in a Micropillar Cavity

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Multipartite entangled states such as cluster states are essential ingredients for measurement-based quantum computing [1], which offers a promising and scalable route towards the development of quantum information and technologies. Photonic graph states, composed of mutually entangled photons, stand out as compelling candidates due to the non-interactive nature of light. Ensuring the capability to produce these quantum states in a controlled fashion thus becomes crucial for various applications.

We address in this work the deterministic generation and optical control of linear cluster states harnessing the spin-photon interface provided by a semiconductor InGaAs Quantum Dot (QD) embedded in a micro-pillar cavity with electrical control. Our protocol uses the optical selection rules of the QD charged with a single electron to produce a one-dimensional cluster state [2] composed of a spin and two photons at a high rate and with high indistinguishability [3]. To generate this quantum state, we use a train of three linearly-polarized laser pulses separated by time intervals t_{12} and t_{23} (Fig.1a) to excite the QD. By tuning the polarization of the excitation pulses, we demonstrate the ability to modify the resulting cluster state, as evidenced by changes in the polarization state of the emitted photons. We perform quantum state tomography as function of the delay between successive excitation pulses to quantify this effect (Fig.1b,c), thereby demonstrating optical control over the generated entangled state. This provides the building blocks for further scalable and multidimensional entangled states.

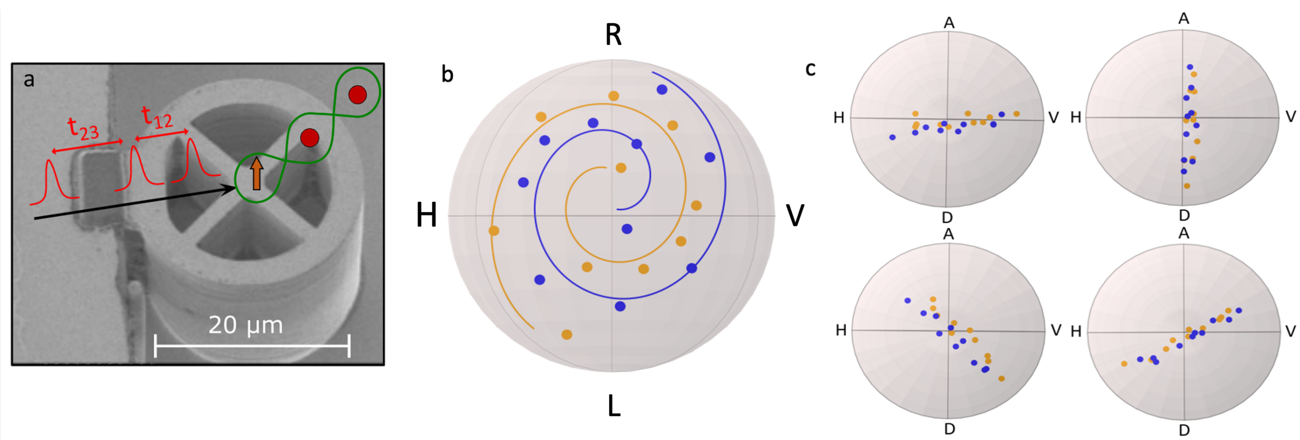

Fig. 1. **a.** Scanning electron microscopy image of the electrically-connected micropillar in which the InGaAs quantum dot is embedded. A train of linearly-polarized pulses leads to entanglement between the quantum dot spin and successively emitted photons. **b.** Polarization state of the second emitted photon represented in the Poincaré sphere, reconstructed with a full state tomography after measurement of the last photon in R (blue) or L (orange) polarization basis. Each point represents a measurement for different delay t_{23} between the second and third laser pulse. **c.** Measured rotation of the second photon polarization trajectory in the Poincaré sphere for different linear polarizations of excitation.

References

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