Towards scalability of high-rate cluster state generation with a 3D-cavity-enhanced semiconductor quantum dot

H. Huet,[1] N. Coste,[1] D. Fioretto,[1] N. Belabas,[1] S. C. Wein,[2] P. Hilaire,[2] R. Frantzeskakis,[3] M. Gundin,[1] B. Goes,[1] N. Somaschi,[2] M. Morassi,[1] A. Lemaître,[1] I. Sagnes,[1] A. Harouri,[1] S. E. Economou,[4] A. Auffeves,[5] O. Krebs,[1] L. Lanco,[1,6] and P. Senellart[1]

[1] *Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies, 91120, Palaiseau, France*
[2] *Quandela SAS, 10 Boulevard Thomas Gobert, 91120, Palaiseau, France*
[3] *Department of Physics, University of Crete, Heraklion, 71003, Greece*
[4] *Department of Physics, Virginia Tech, Blacksburg, Virginia, 24061, USA*
[5] *Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France*
[6] *Université Paris Cité, CNRS, Centre de Nanosciences et de Nanotechnologies, 91120, Palaiseau, France*

Multipartite entangled states such as cluster states are essential ingredients for measurement-based quantum computing, which offers a promising and scalable route towards the development of quantum information and technologies. With the use of a quantum dot confined in a three dimensional micropillar cavity, entanglement between two indistinguishable photons and a semiconductor spin was recently demonstrated [1] in our group, achieving a full first step of Lindner and Rudolph proposal [2] and yielding a high spin-photon and spin-photon-photon entanglement fidelity with an outstanding generation rate.

We extend this study further by investigating the influence of the magnetic field intensity and polarization of the excitation scheme on the generated state in order to improve the entanglement fidelity while preserving a high purity and indistinguishably of the emitted photons. This allows us to have a better control over the generated entangled state, thus providing building blocks for scalable and multidimensional cluster states.

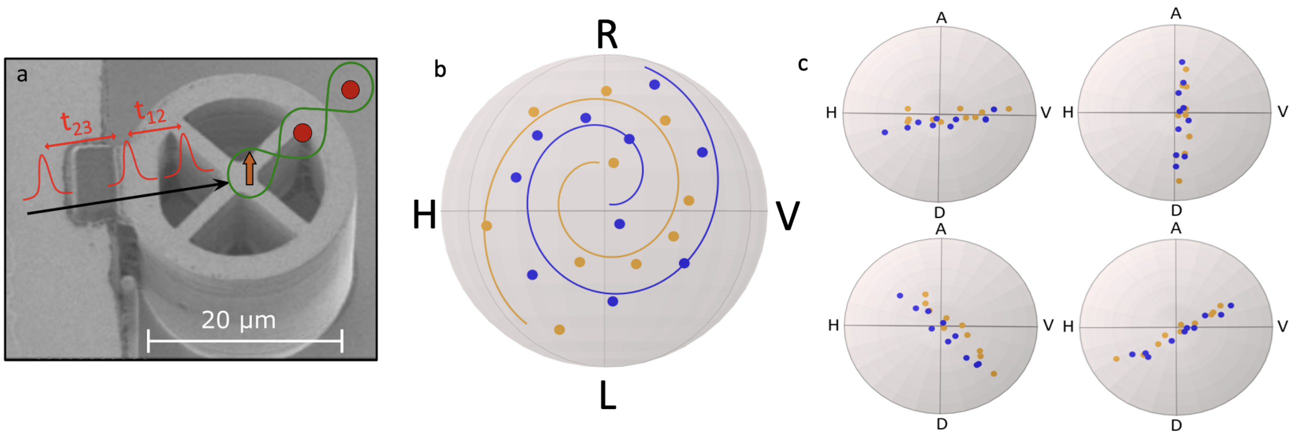

FIG. 1. a. Scanning electron microscopy image of the connected micropillar in which is embedded the InGaAs quantum dot. A train of linearly-polarized pulses leads to entanglement between the quantum dot spin and successively emitted photons. b. Polarization state of the second emitted photon represented in the Poincaré sphere, reconstructed with a full state tomography after measurement of the last photon in R (blue) or L (orange) polarization basis for variable delays between second and third laser pulse. c. Visual representation of the rotation of the second photon polarization trajectory in the Poincaré sphere for different linear polarization of excitation.

[1] N. Coste, D. Fioretto, N. Belabas, S. C. Wein, P. Hilaire, R. Frantzeskakis, M. Gundin, B. Goes, N. Somaschi, M. Morassi, A. Lemaître, . I. Sagnes, A. Harouri, S. E. Economou, A. Auffeves, O. Krebs, L. Lanco, and P. Senellart, "High-rate entanglement between a semiconductor spin and indistinguishable photons," (2022), arXiv :2207.09881.
[2] N. H. Lindner and T. Rudolph, Physical Review Letters 103, 113602 (2009).