Soutenance de thèse

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Generation of entangled states of spins and photons with a semiconductor quantum dot

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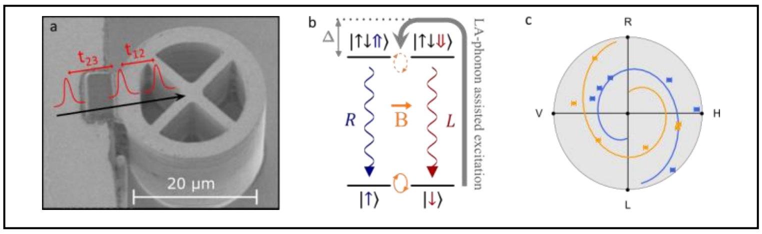
Abstract :

Semiconductor quantum dots embedded in photonic cavities are promising emitters of single photons for photonic quantum technologies. In addition, a semiconductor quantum dot can confine a single charge carrier (electron or hole) whose spin can be used as a local memory, leading to interesting applications. In 2009, it was proposed to use such charged quantum dots to emit large entangled states comprising the confined spin and many photons. These so-called cluster states are of particular interest for scalable, measurement-based photonic quantum computing. The challenge in generating these quantum states lies in the combination of efficient photon generation with control over the confined spin: while both aspects have been demonstrated separately, their combination has remained so far elusive.
In this thesis, we use semiconductor quantum dots to experimentally generate entangled states of spin and photons. To do so, we rely on an off-resonant, phonon-assisted excitation technique to generate single photons in an efficient manner, while preserving access to the spin via the emitted photons polarization. We explore the physics of single spins in the quantum dot, characterizing in particular their coherence properties. We then use a charged QD-cavity device to generate three-partite entangled states at high rates, comprising the spin and two indistinguishable photons, thereby demonstrating for the first time the implementation of the 2009 proposal with a quantum dot in a 3-dimensional photonic cavity. Finally, we also explore the use of neutral quantum dots to generate hyperencoded quantum states, where a single photon is in a superposition of several degrees of freedom.



a. Scanning electron microscopy image of the device. A train of linearly-polarized pulses leads to entanglement between the spin and successively emitted photons. b. Energy levels and optical selection rules of the charged quantum dot under small (< 100mT) transverse magnetic field. c. Projection of the measured Bloch vector of the second emitted photon while scanning t23, after measurement of the last photon in R (yellow) or L (blue).