Quantum State Transfer in Quantum dots Coupled to Quantum Cavities

The holy grail of quantum technology is to build a quantum computer that is scalable, fast, and small. One of the most promising routes to achieve this goal are spin qubits in quantum dots (also named artificial atoms) coupled to electromagnetic cavities. At the heart of this approach is the demonstration of strong coupling between spins and photons. The crucial requirements are long coherence times of the spin qubit, strong spin orbit interactions in the material, and easy integrability of quantum cavities and quantum dots which are hosting the spin qubits. In particular, by constructing highly coherent and controlled spin qubits, strongly coupled via quantum cavities, new architectures for quantum computation could be implemented with the potential to demonstrate multi-qubit algorithms and error-correction codes.

Recently spin-photon interfaces have been achieved both theoretically and experimentally for spin electrons in quantum dots.

We will theoretically investigate a novel scheme based in lateral quantum dots where the confined particles are holes instead of electrons. Their inherently strong spin orbit coupling and the near absence of decoherence due to nuclear spins are considered by many one of the most promising quantum bits for spin-based quantum computation. Furthermore, we will utilize two genuinely quantum-mechanical effects, such as spin orbit interaction, as key ingredients to achieve the control of multiple qubits.

In the present master project the aim is first to learn about spin qubits in quantum dots, then to analyze the interaction of both electrons and holes in quantum dots with electromagnetic fields and to learn the different possible schemes to transfer quantum states from one region to another distant one. Finally how to achieve spin-photon coupling in a quantum dot-cavity system will be explored.

The Master student will learn how to obtain theoretically the electronic properties of semiconductor quantum dots by means of simple models based in Hubbard Hamiltonians, he/she will learn which are the different spin qubits which have been proposed for both electrons and holes and the theoretical techniques and models which allow to couple them with external electric and magnetic time dependent fields. He/She will learn which are the main mechanisms for transferring quantum states in solid state platforms.

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