Optical control of excitonic states in GaAs/AlGaAs and InAs/GaAs quantum dot molecules

A. Chapuis[1,*], **P. Atkinson**[1], **A. Raymond**[1], **B. Eble**[1], **V. Voliotis**[1]

[1] Sorbonne University, CNRS, Institut des NanoSciences de Paris, 4 Place Jussieu, 75252, Paris, France

Qubits with long coherence times, when used with strong light-matter coupling, allow for transferring quantum information between static, matter qubits and flying, light qubits. Semiconductor quantum dots (QD) systems are promising candidates for quantum communication protocols. Moreover, the specific transitions' optical selection rules allow for a mapping between light polarization and spin states' transitions which is a valuable tool for coherent control with light pulses. We propose to build such a spin-photon interface on an InAs/GaAs double quantum dot structure embedded in a diode, where the thin tunnel barrier between the dots allows for coherent coupling of the electronic states. Our goal is to define robust spin qubits with one or two charge carriers on the ground state that present long coherence times [1] and can be manipulated with optical pulses [2].

Quantum dot molecules (QDMs) are systems that allow the existence of excitons, either direct (where both electron and hole are confined within the same QD) or indirect (where they are confined in different QDs [3]). Since indirect excitons present a much stronger dipole moment, their energy can be easily tuned with the application of an electric field along the growth axis of the structure.

By performing micro-photoluminescence maps as a function of the applied bias, one can observe an anticrossing between direct and indirect neutral exciton transitions. But with singly-charged or multiple-charged exciton states, one can see more complex structures arising. Indeed, the 3 charges of a trion can either be confined with the same QD or shared across both, when the energy levels are in resonance for a given value of the applied field.

One can also observe "X-patterns", signatures of tunnelling of the hole left after electron-hole recombination. We analyze such a pattern to measure tunnel coupling and to probe the fine structure of the hole states [4].

Using numerical simulation tools, we recreate the measured X-pattern and explain the different photoluminescence lines. Resonances between excited states in the different dots are evidenced allowing to map the electronic structure of the coupled QDs.

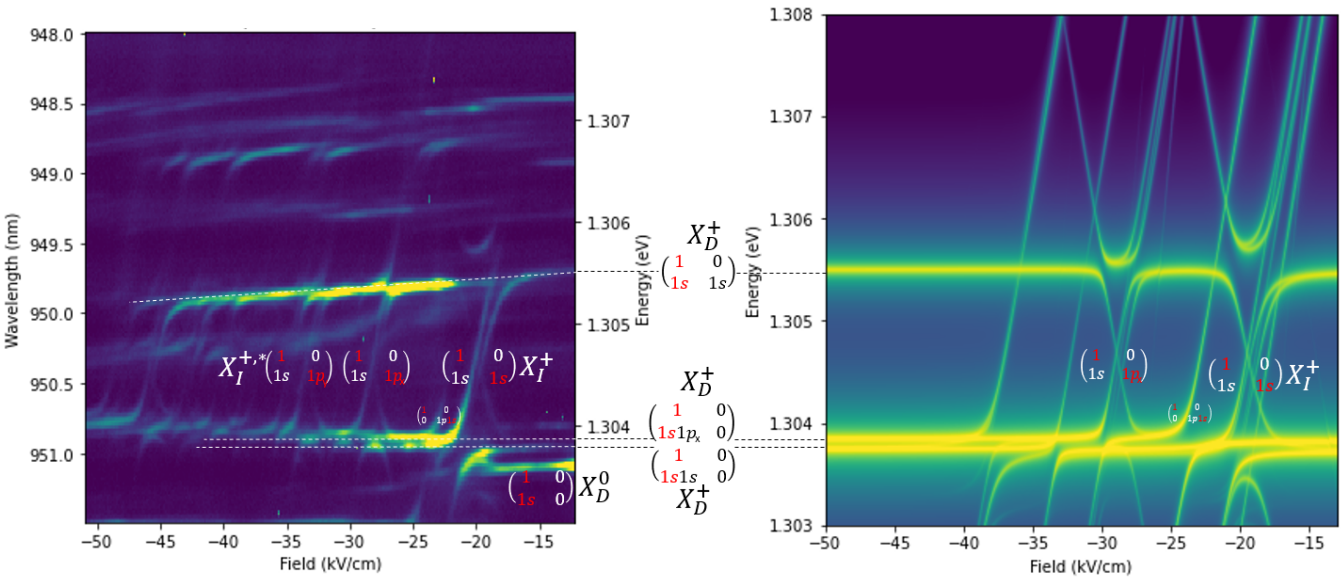

Figure 1: Left : Experimental X-pattern between states with 1 electron and 2 holes. One can see the direct (indirect) positive trion : X_D^+ (X_I^+) but also indirect excited states with holes in p states $X_I^{+,*}$. Right : Simulation of the photoluminescence of all states containing 1 electron and 2 holes that can either exist in an s or p_1 state.

References

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*E-mail: chapuis@insp.jussieu.fr