Non-adiabatic transitions between valley states in a Si/SiGe heterostructure

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Besides orbital and spin degrees of freedom (DOF), electrons in silicon possess valleys, which are due to the crystal structure [1]. In particular, for silicon spin qubits it is necessary to create a wide enough energy gap between the valley states to limit the overlap with the spin DOF [2]. However, small imperfections in the growth process, for instance interface steps in silicon/silicon-germanium (Si/SiGe) heterostructures, can complicate the engineering of the so-called valley splitting, i.e the energy gap between the two lowest energy valley states [3].

In this talk, after quickly reviewing valley physics in silicon, I will discuss the specific example of a quantum dot in a Si/SiGe heterostructure with a single-atomic step at the Si/SiGe interface. As a result of the step, an anti-crossing appears in the spectrum [4], with an energy gap tunable by an electric field [5]. Interestingly, by taking advantage of the ubiquitousness of interface steps, usually considered an inconvenience for silicon spin qubits, we can induce Landau-Zener transitions between the valley states which are controllable by the electric field. Since the spectrum resembles that of a silicon charge qubit [2], we expect that this system could be used as a qubit based on the valley degrees of freedom.

[1] F. Zwanenburg et al., *Reviews of Modern Physics* Vol. 85, No. 3 (2013).

[2] A. Chatterjee et al., *Nature Reviews Physics* Vol. 3, No. 3, p. 157177 (2021).

[3] B. Tariq et al., *Physical Review B* Vol. 100, No. 12 (2019).

[4] P. Boross et al., *Physical Review B* Vol. 94, No. 3 (2016).

[5] A. Gardin et al., *Physical Review B* Vol. 105, No. 7 (2022).