Tunable spin-valley physics in a silicon quantum bit

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The electron spin in silicon has shown to be a prime candidate for quantum computing thanks to its excellent coherence properties due to the magnetic-free environment and the low spin-orbit coupling (SOC) in the conduction band. However recent experiments [1] have demonstrated electrical manipulation of the electron spin in a silicon nanowire CMOS device using SOC. Here comes a difficult challenge: how to keep the coherence properties and still be able to couple the spin to the electric field?

We propose an answer that relies on the spin-valley mixing which is controlled by tuning the valley splitting with the potential applied on the back electrode (Fig 1.). This allows to adiabatically go from a spin qubit, where quantum coherence is long, to a valley qubit, where manipulation is efficient. We will review our model for SOC and electrical manipulation and validate it against realistic tight-binding simulations and experimental data. Then to assess the validity of the approach we study the effect of noise (charge and phonon) and surface roughness variability in both modes. This approach can be implemented in other type of devices, provided that they respect specific criteria, opening new possibilities for the design of robust and electrically addressable silicon qubits.

[1] A. Corna *et al*, Electrically driven electron spin resonance mediated by spin-valley-orbit coupling in a silicon double quantum dot, npj Quantum Information **4**, 6 (2018)

[2] L. Bourdet and Y.-M. Niquet, All-electrical manipulation of silicon spin qubits with tunable spin-valley mixing, arXiv:1802.04693 (2018)

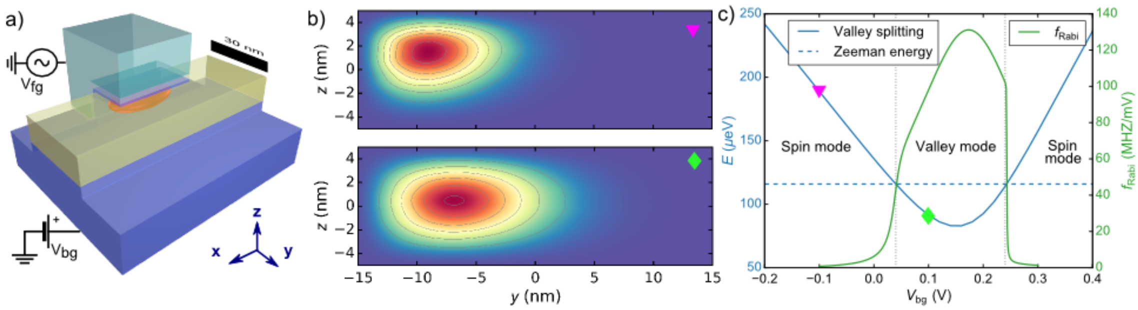

Figure 1: (a) 3D geometry of the device included in the simulations with schematic of the wavefunction. (b) Wavefunction density computed in tight-binding in the spin (up) and valley (bottom) modes. (c) Rabi frequency between the two lowest states and valley splitting as a function of potential. Manipulation is efficient only in the valley mode i.e when the valley splitting is lower than the Zeeman energy.