

Effects of confinement and symmetries on the electrical manipulation of semiconductor spin qubits

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The electrical manipulation of spins based on intrinsic spin-orbit coupling (SOC) allows for compact and scalable, micromagnet-free designs of semiconductor qubits. In this talk, we discuss some aspects of the physics of SOC in semiconductor qubits, using a versatile formulation of electrically-driven spin manipulation based on a generalized g -matrix [1].

We illustrate our discussion with a hole spin qubit on silicon-on-insulator (SOI). Fig. 1(a) shows a model for such a qubit device. The hole is localized under a front gate on top of a silicon nano-wire, and is manipulated by a radio-frequency (RF) modulation on that gate resonant with the Zeeman splitting between the “up” and “down” spin states. The shape of the hole wave function can further be manipulated with a substrate back gate. The Rabi frequency (number of spin rotations per second) computed in this device is plotted on Fig. 1(b) as a function of the back gate voltage [2]. It shows two prominent peaks separated by a dip. We show how these trends result from strong confinement and from the bias-dependent symmetries of the hole wave functions. We discuss the implications of these results for the design of both electron and hole semiconductor qubits, and highlight the options to enhance the Rabi frequency and/or reduce the sensitivity of the qubits to charge noise.

[1] A. Crippa *et al.*, Electrical Spin Driving by g -Matrix Modulation in Spin-Orbit Qubits, Phys. Rev. Lett. **120**, 137702 (2018).

[2] Simulation are performed using the tight-binding and $\mathbf{k} \cdot \mathbf{p}$ methods.

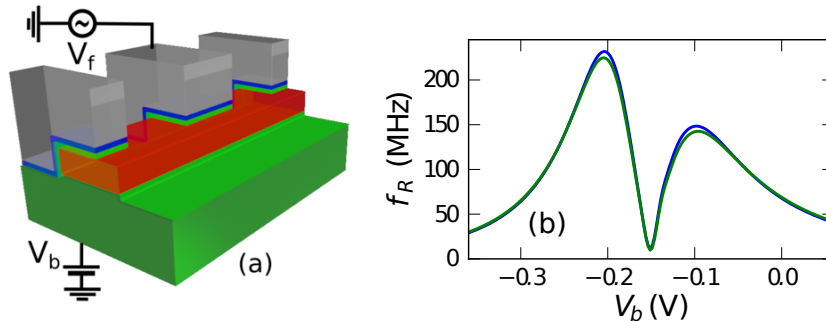


Figure 1: (a) 3D representation of qubit device on SOI (V_f : front gate voltage, V_b : back gate voltage, Red: silicon nanowire, Green: SiO₂, Blue: HfO₂, Gray: metallic gate). (b) Calculated Rabi frequency versus back gate voltage V_b at $V_f = -0.1$ V [$\mathbf{k} \cdot \mathbf{p}$ calculation to all orders in the magnetic field (green), or to first-order within the g -matrix formalism (blue)]. The RF amplitude on the front gate is 1 mV and the magnetic field is 1 T.