Anisotropy of single-spin relaxation and spin-valley mixing in silicon quantum dots

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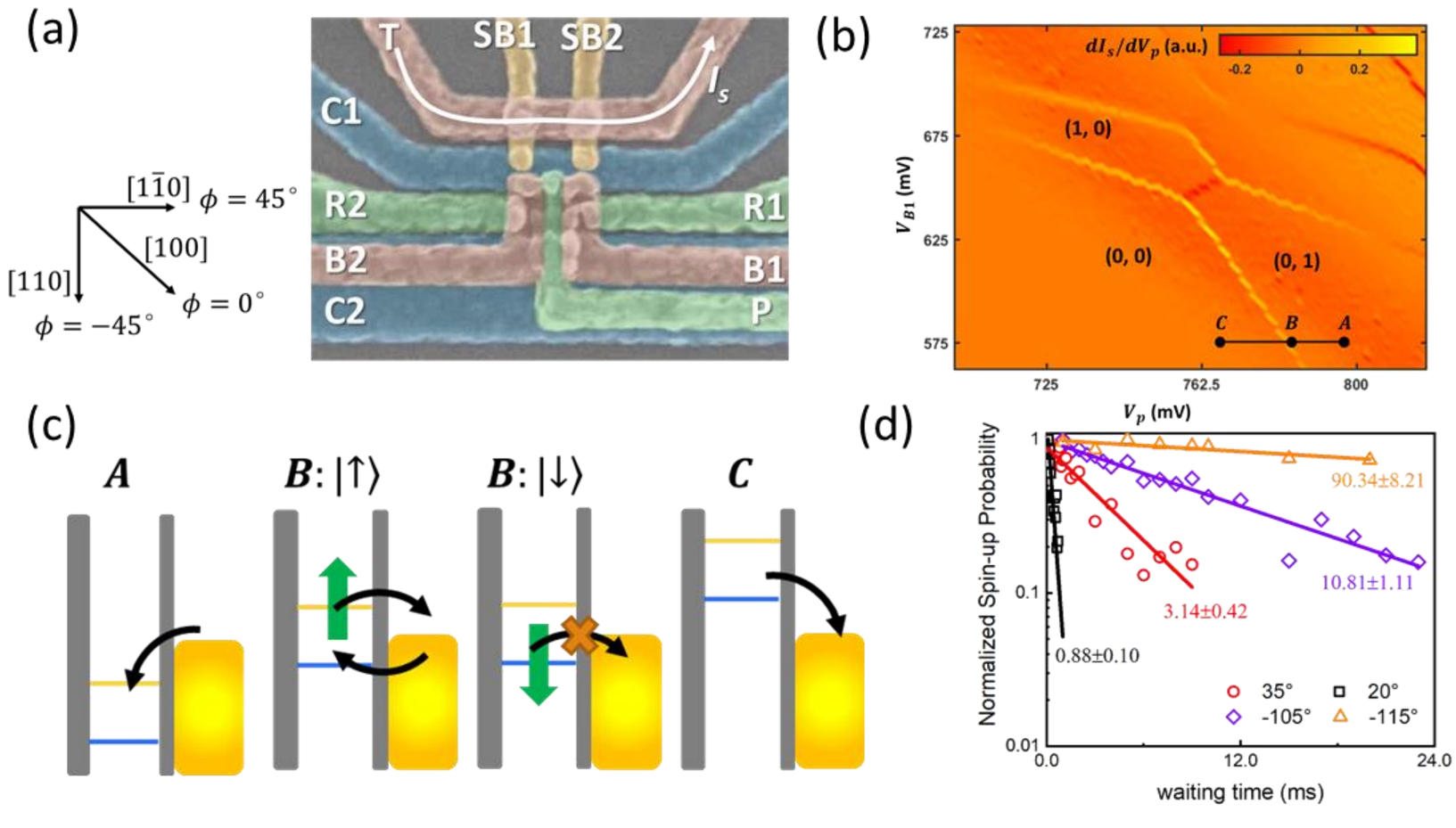
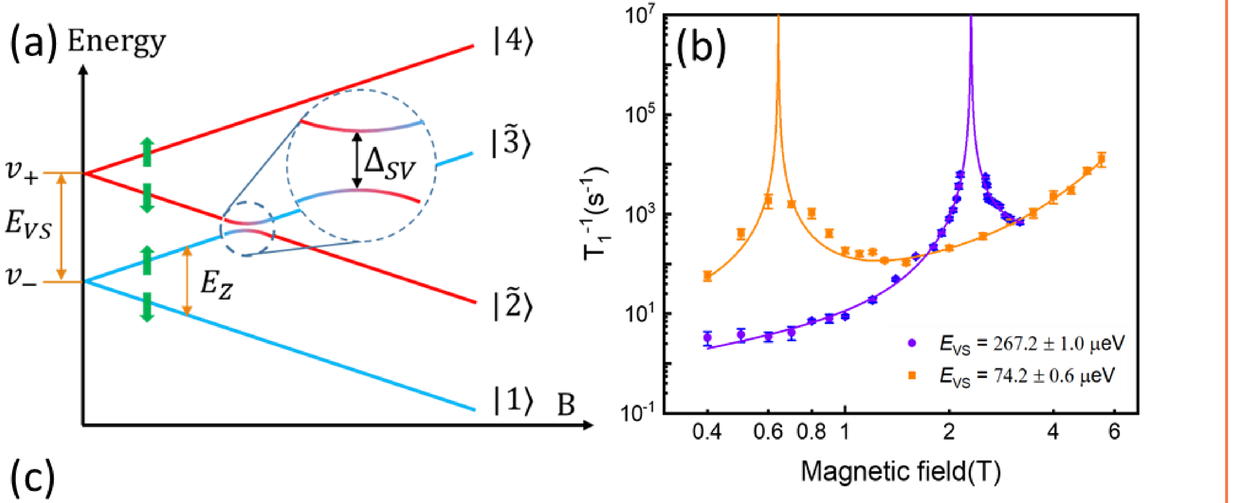
Motivation/Objective

- Spin qubits based on silicon quantum dots (QDs) provide a promising platform for large-scale quantum computation due to the high control and readout fidelity as well as compatibility with modern semiconductor technology [1-2].
- A double quantum dot (DQD) in silicon was fabricated and a charge stability diagram was measured by charge sensing.
- Single-shot readout of single spin in silicon quantum dot and measurement of spin relaxation times [3].
- Spin-valley mixing (SVM) was characterized by measuring spin relaxation rate (T_1^{-1}) as a function of strength and orientation of the external magnetic field [4].

Single-shot readout of a single spin in silicon quantum dot



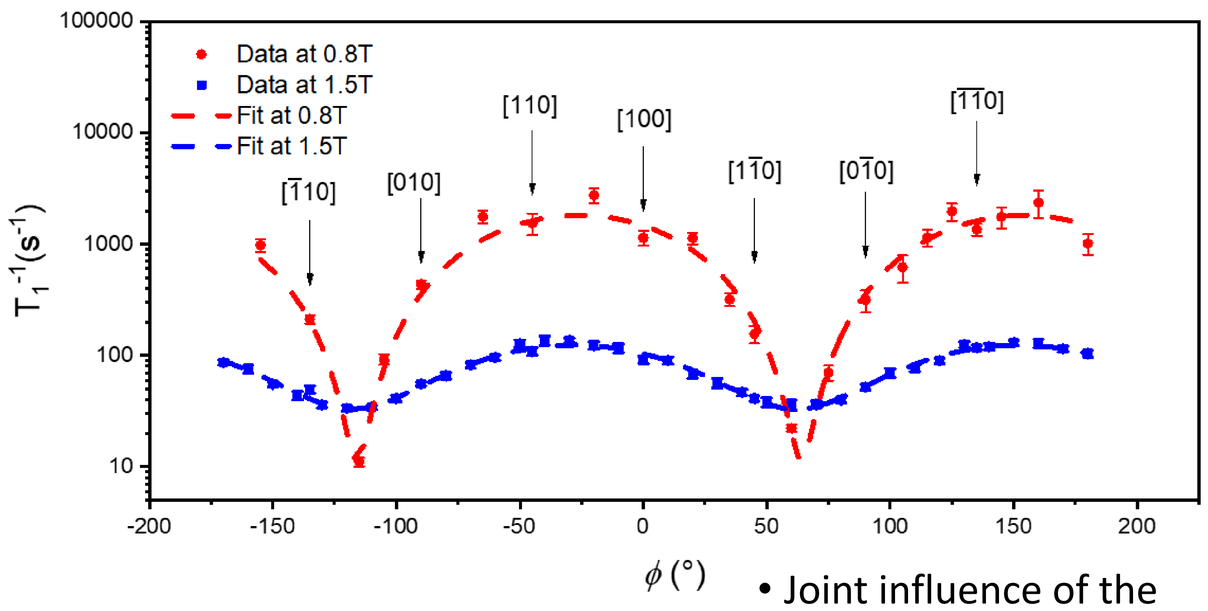
Tunable valley splitting



- SVM can cause a 'hot spot' when measuring T_1^{-1} as a function of magnetic field strength.
- Different values of valley splitting were measured as a function of gate voltage V_P.

$$T_1^{-1} = \Gamma_{0,sat} + \left(c_{\mathrm{J}}\omega_Z + c_{\mathrm{ph}}\omega_Z^5\right)F_{SV}(\omega_Z) + c_{\mathrm{p}}\omega_Z^p$$

Anisotropy of spin-valley relaxation rate



$$T_1^{-1} = \Gamma_{SV}(\varphi) + \Gamma_0$$

$$\Gamma_{SV}(\varphi) = \mathrm{A}[\sin\varphi - (\alpha_+/\alpha_-)\cos\varphi]^2$$

B	0.8 T	1.5 T
α_D/α_R	2.9033	3.302
Γ_0 (Hz)	11.4136	32.79108

- Joint influence of the Rashba term (α_R) and Dresselhaus term (α_D) of SVM causes a sinusoidal variation of T_1^{-1} as a function of rotation angle of in-plane magnetic field.
- From the position of the minimal T_1^{-1} the ratio of α_D and α_R can be inferred.

Future Directions

- Coherent control of single spin using electron spin resonance (ESR).
- Fidelity characterization of single-spin qubit.
- Implementation of single- and two- qubit logic gates.

References

[1] C. H. Yang, K. W. Chan and R. Harper *et al.*, Nat. Electron. **2**, 151-158 (2019).

[2] W. Huang, C.H. Yang, and K. W. Chan *et al.*, Nature. **569**, 532-536 (2019).

[3] C. H. Yang, A. Rossi, R. Ruskov and *et al.*, Nat. Commun. 4: 2069 (2013).

[4] P. Huang, X. Hu., Phys. Rev. B. **90**, 235315 (2014).