Gate-Reflectometry Dispersive Readout of a Spin Qubit in Silicon

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arXiv:1811.04414v1

- FAM talk -

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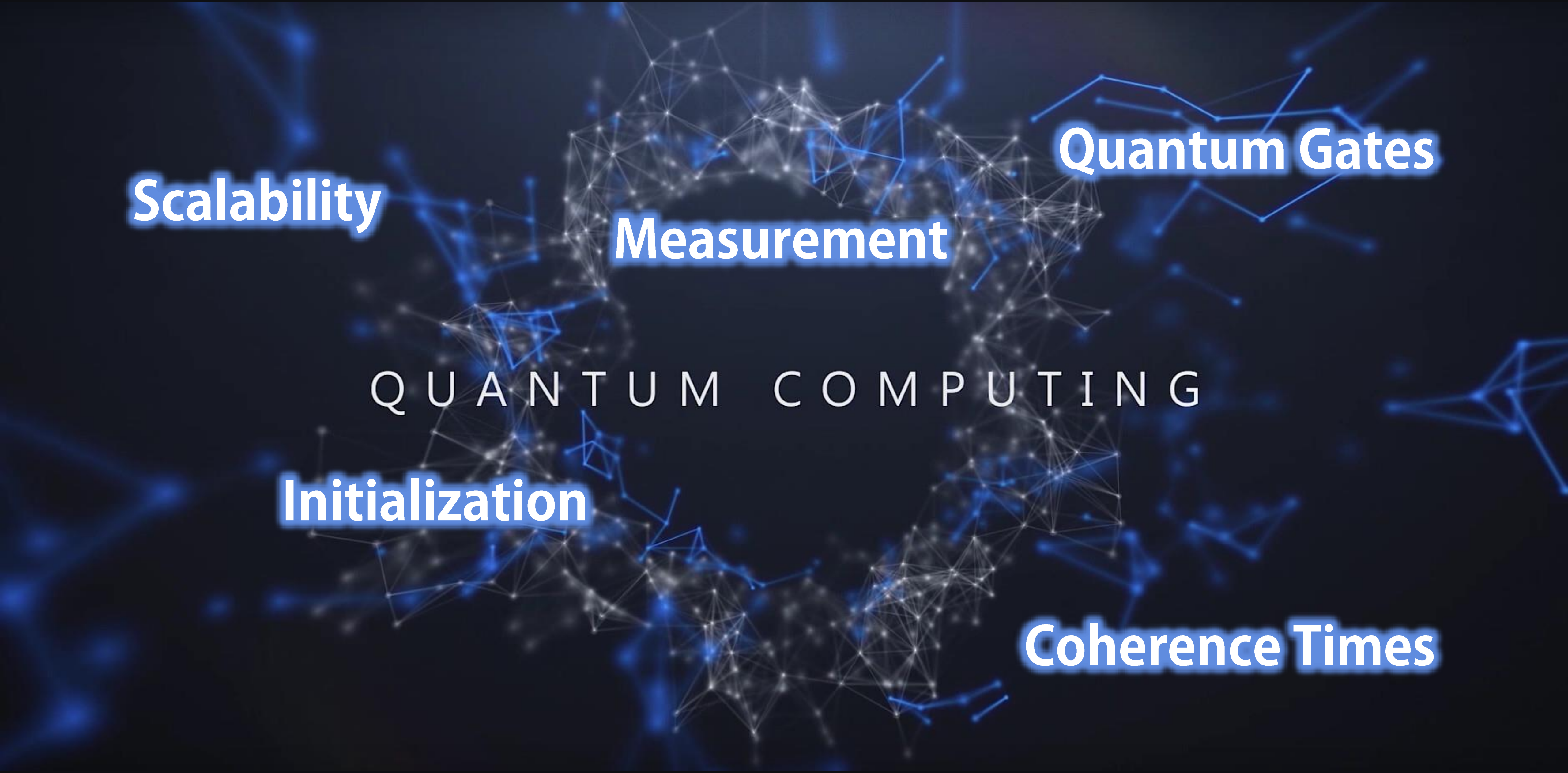
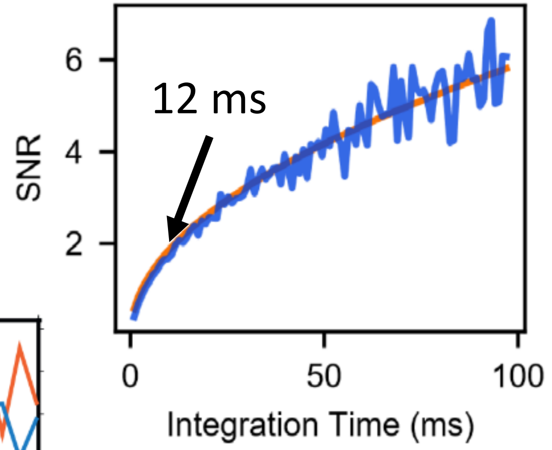
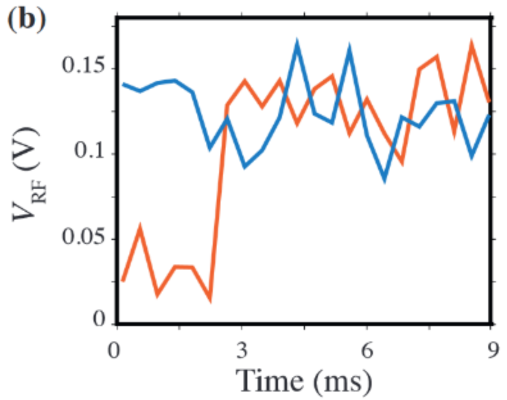

Quantum Gates
Scalability
Measurement
QUANTUM COMPUTING
Initialization
Coherence Times

Motivation

- one of DiVincenzo‘s criteria: scalable physical system with well defined qubits
- readout for every single qubit has to be provided
  - QPC and SET: placed nearby and need additional gates
  - superconducting resonators (cQED): large footprint



- **gate based readout**: use what you already have
  - compact and simple
- single shot readout has been achieved in 2018
  - P. Pakkiam *et al.*, PRX **8**, 041032 (2018)
  - A. West *et al.*, arXiv:1809.01864v2
  - M. Urdampilleta *et al.*, arXiv:1809.04584 (2018)



- fast readout on µs scale (with low Q, lumped element resonator)
  - D. de Jong *et al.*, arXiv:1812.08609

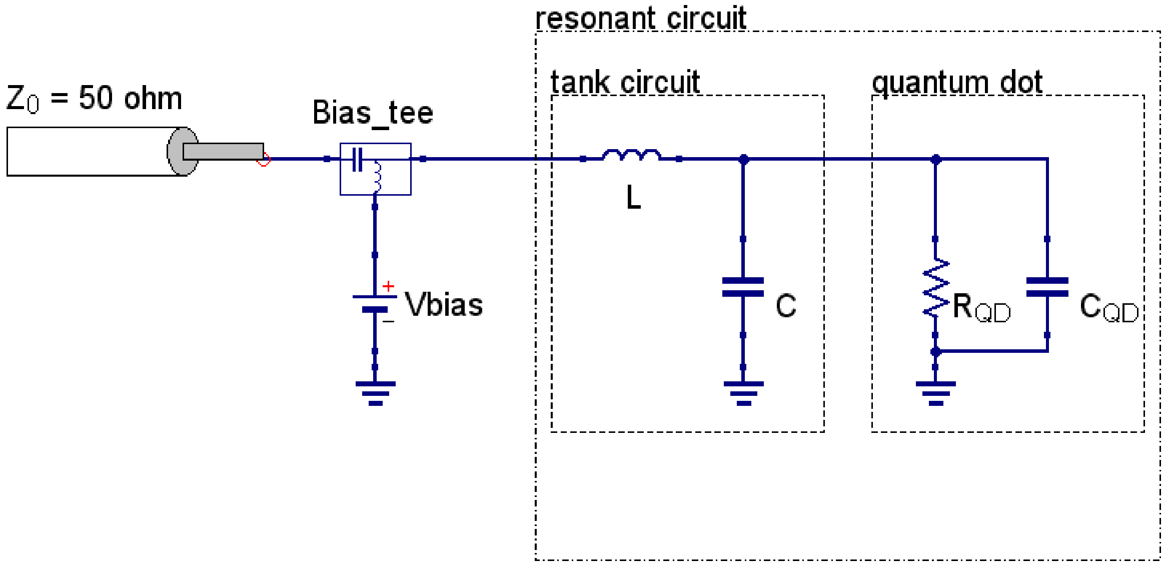
Gate Reflectometry

- reflection of an electromagnetic wave depends on change of impedance

$$A_{\text{refl}} = A_{\text{in}} \cdot \Gamma = A_{\text{in}} \cdot \frac{Z - Z_0}{Z + Z_0}$$

- match large impedance of quantum device to 50 Ω impedance by using a **tank circuit**

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



- sensitive to change of quantum capacity
- detect change in amplitude and phase

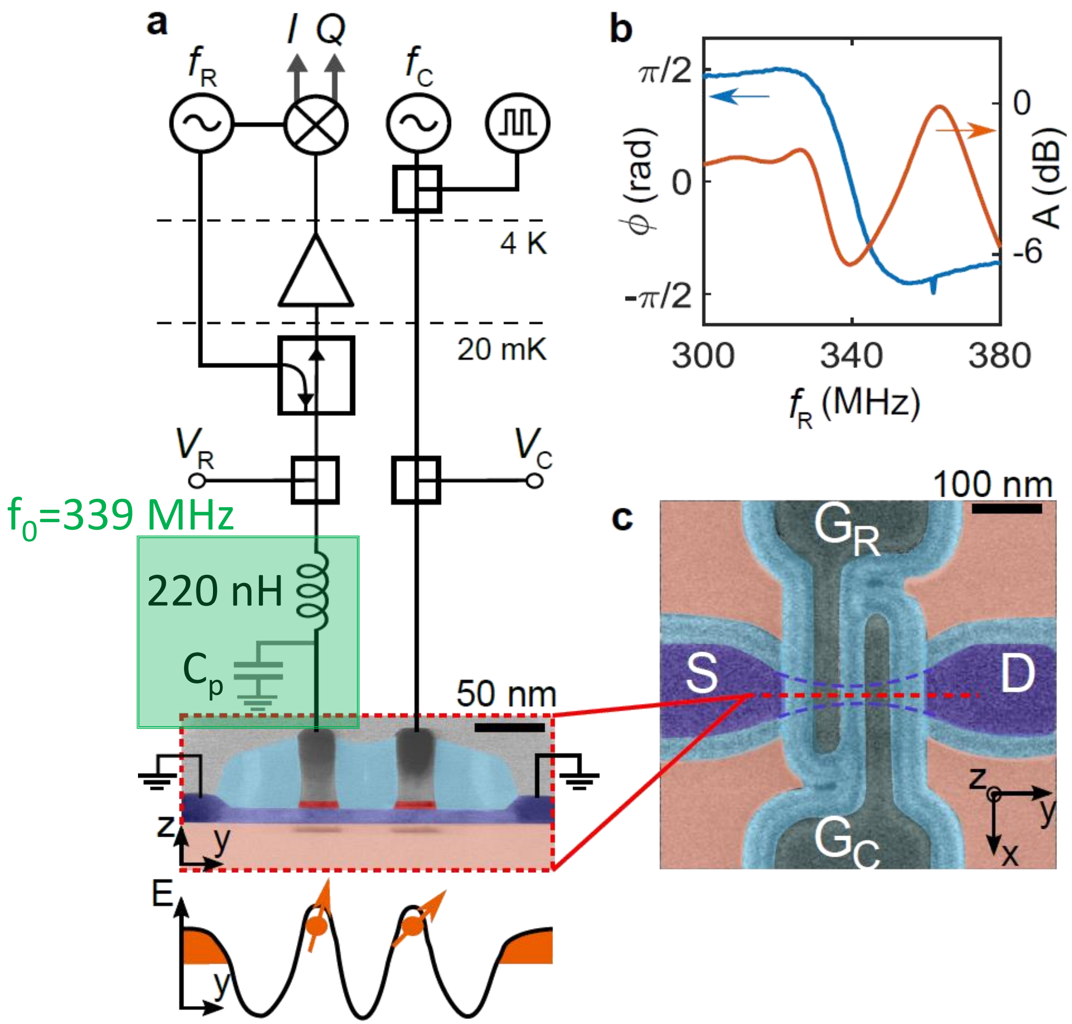
$$\Delta\phi \approx -\pi Q \frac{C_q}{C_p}$$

[1] Blog of Bruno Küng, Zürich Instruments, https://www.zhinst.com/blogs/brunok/rf-reflectometry-quantum-dots/

Outline

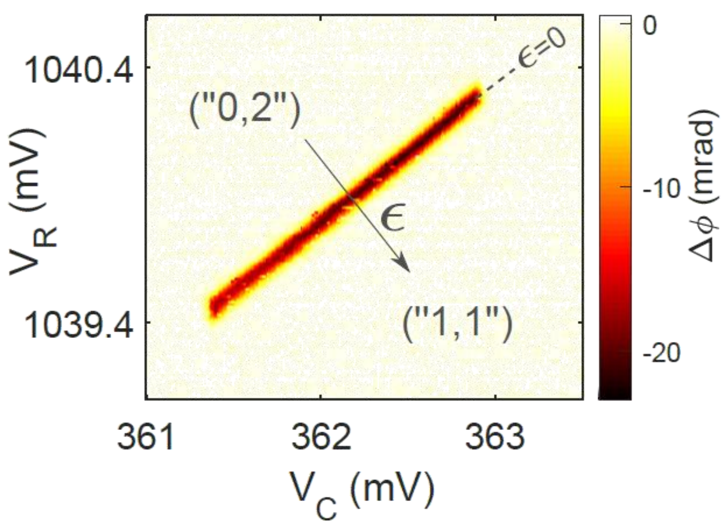
- Setup
- Electrical Control
- Coherent Control
- Summary and Outlook

The Setup



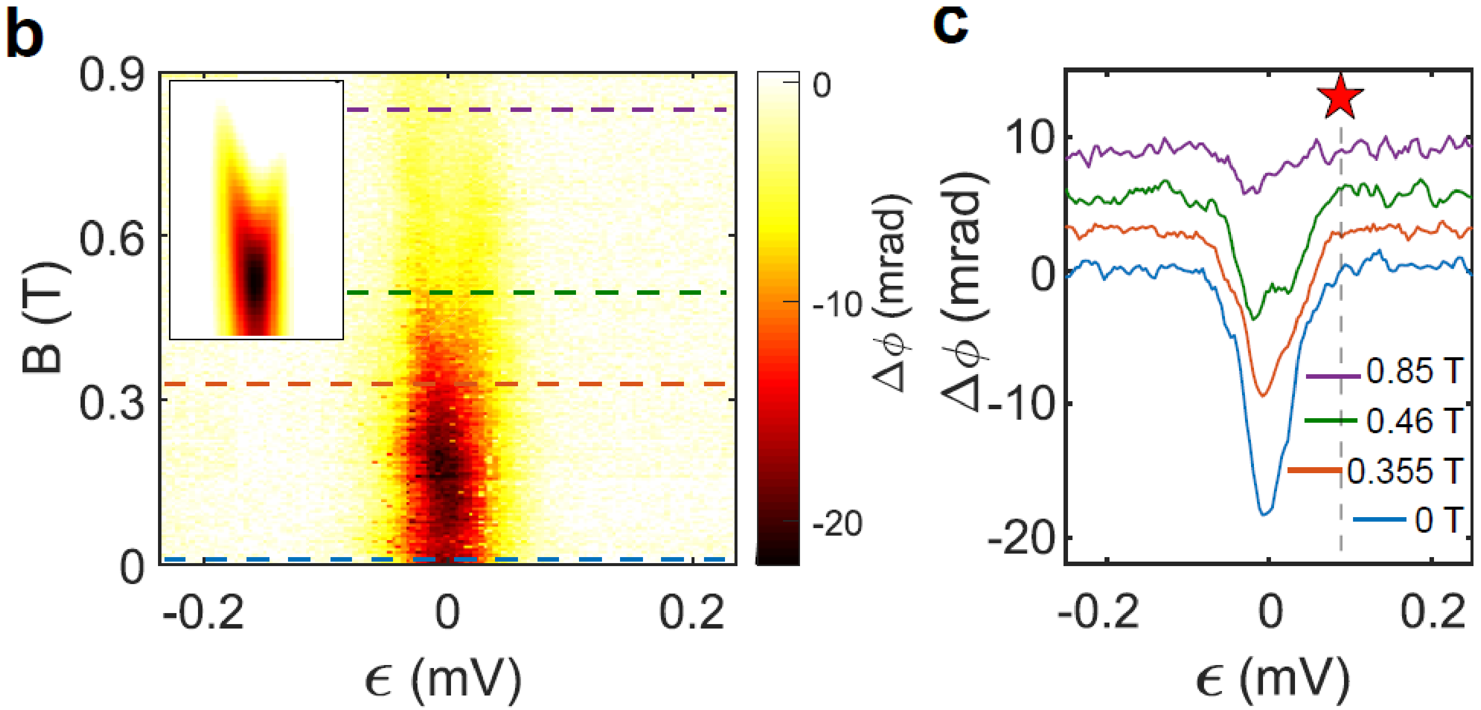
- p-type Si transistor (300 mm SOI wafer, CMOS)
- quality factor ~18
- phase response upon impedance change:

$$C_Q = -\alpha^2 \left(\frac{\partial^2 E_\pm}{\partial \varepsilon^2} \right) \qquad \alpha \simeq 0.58\,\mathrm{eV/V}$$



Energy Spectrum

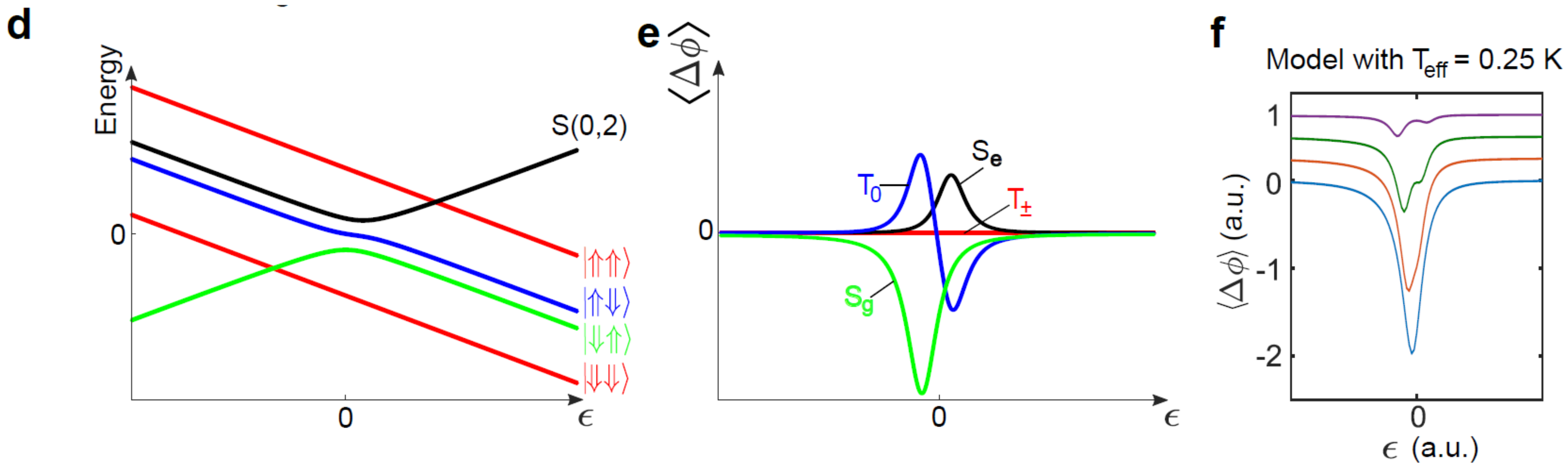
- not in the single hole regime
- determine charge parity from B-field dependence of interdot transition



[1] A. Crippa *et al.*, arXiv:1811.04414v1

Energy Spectrum

- singlet-triplet like energy spectrum
- g-factor difference in left and right dot splits the states at positive detuning
- T_- and T_+ do not yield a phase response, because the state is linear in ε



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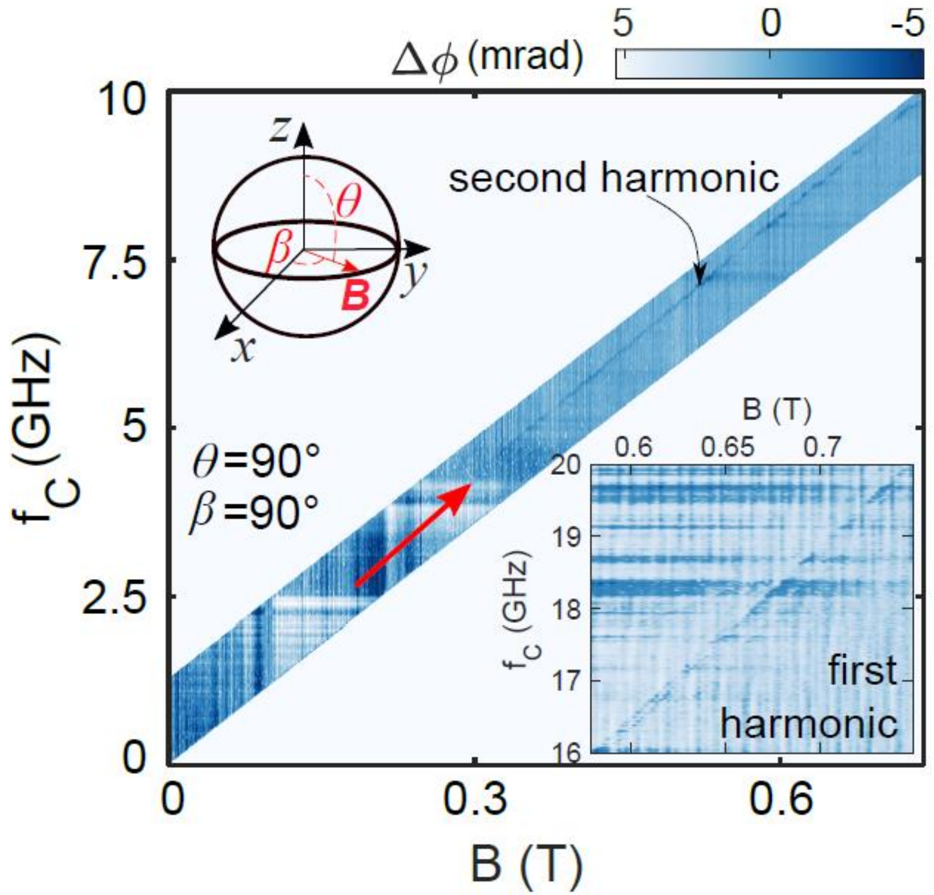
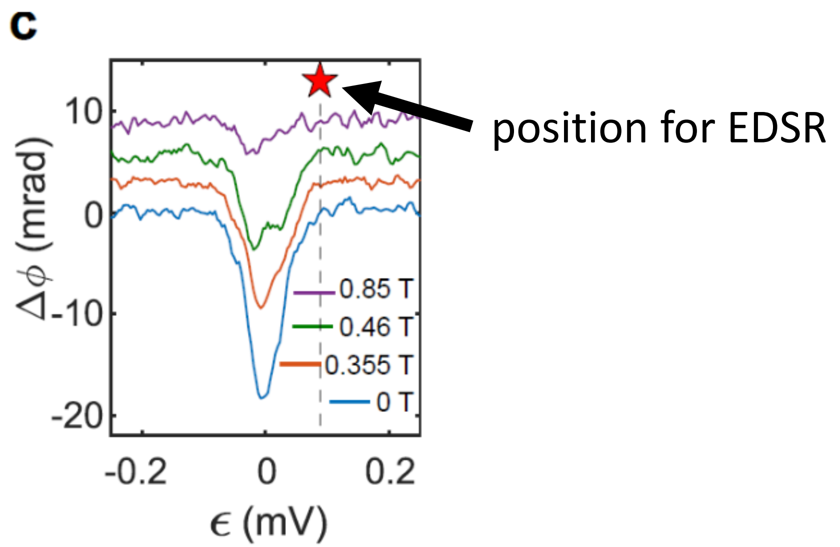
Electrical Control - EDSR



- matching condition: photon energy equals Zeeman splitting of spin states
- B parallel to nanowire
- second harmonic: g=1.735



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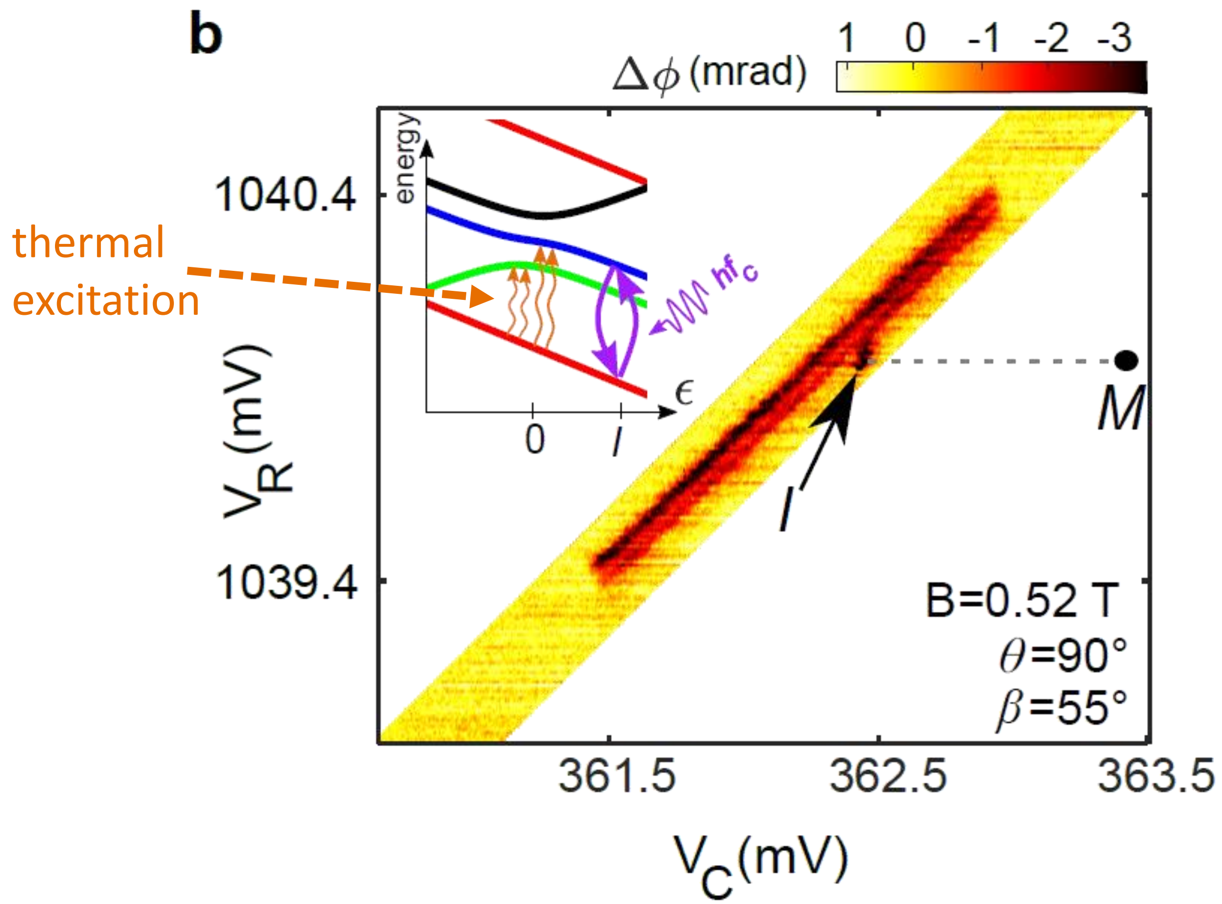
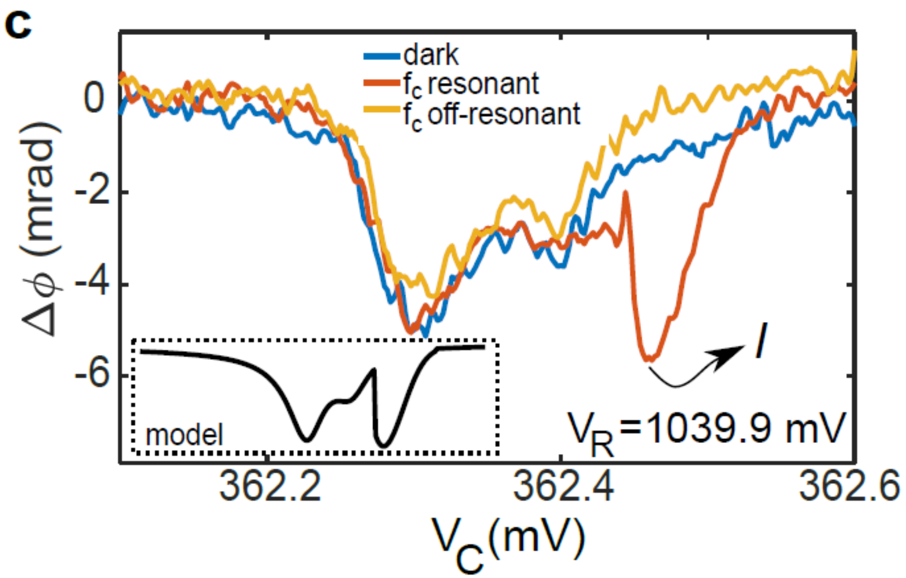
Resolve Single Spin Transitions



- phase signal is very distinct due to g-factor variation with gate voltages
- on resonance a peak is visible
  - indicates T_0 population driven by EDSR



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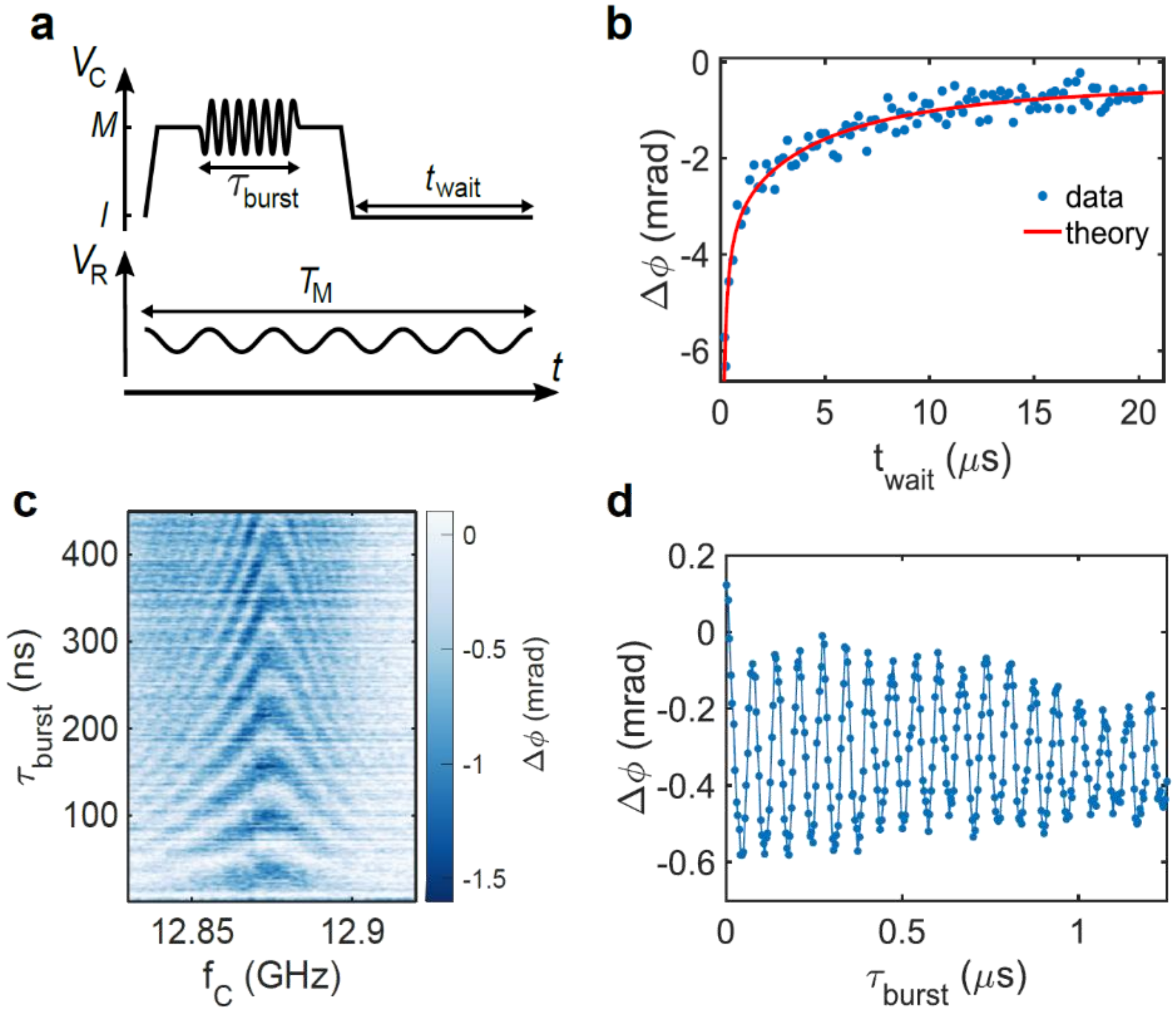
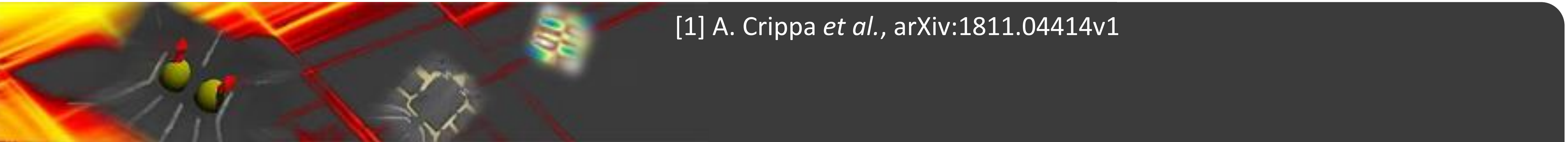
Coherent Spin Control



- spin qubit protocol:
  - initialize at point *I*, manipulate in (1,1) region at point *M*
- τ_{Burst} drives transitions $|\Uparrow\Uparrow\rangle \leftrightarrow |\Uparrow\Downarrow\rangle$
- T_1 = 2.7 ± 0.7 µs
- f_{Rabi}=15 MHz



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Summary and Outlook

- Qubit **operation** and **readout** with RF signals
- resolve
  - energy spectrum
  - single spin transitions
- coherent control of spin transitions
  - EDSR
  - Rabi oscillations

- study anisotropy of T_1
- improve T_1 by reducing backaction of amplifier

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