Single-shot readout of a flopping-mode spin qubit in a Si-MOS quantum dot

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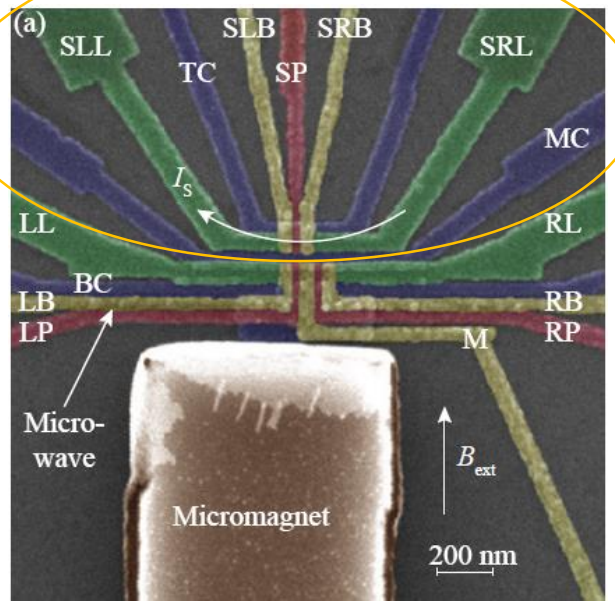
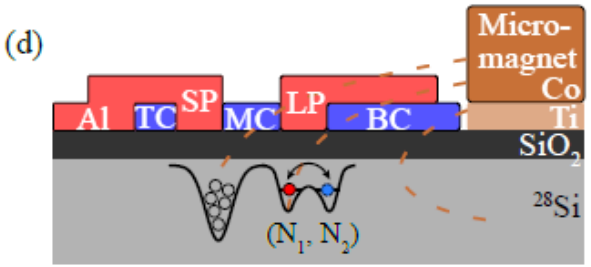
Motivation

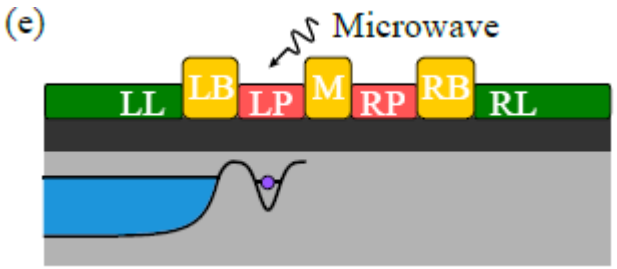
- long coherence, scalability, fab compatible
- Flopping-mode spin qubit
- Single-shot readout
- increase Rabi frequency
- constant dephasing time

Device

SET



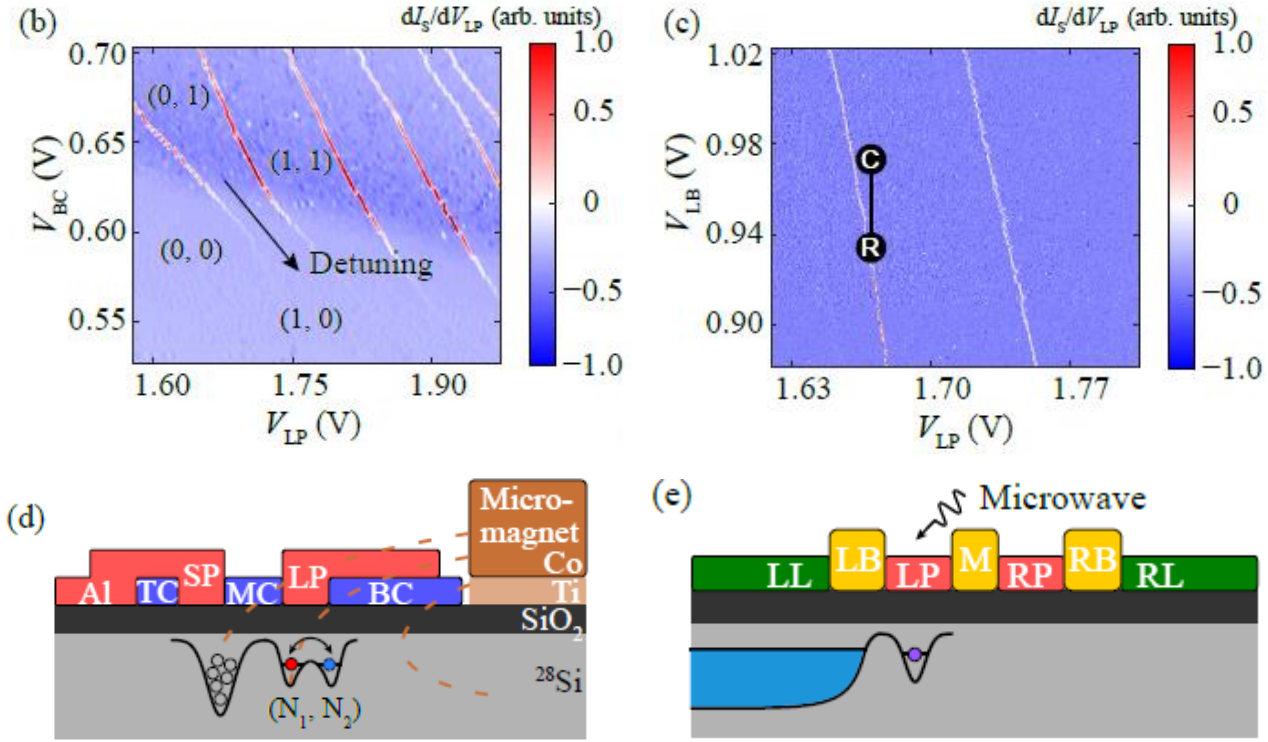




- natural silicon substrate
- 60 ppm enriched Si epi layer of 70 nm
- T = 183 mK
- Bext = 605 mT
- rectangular micromagnet
- fully magnetized micromagnet ~0.1 T/um
- microwaves at LP

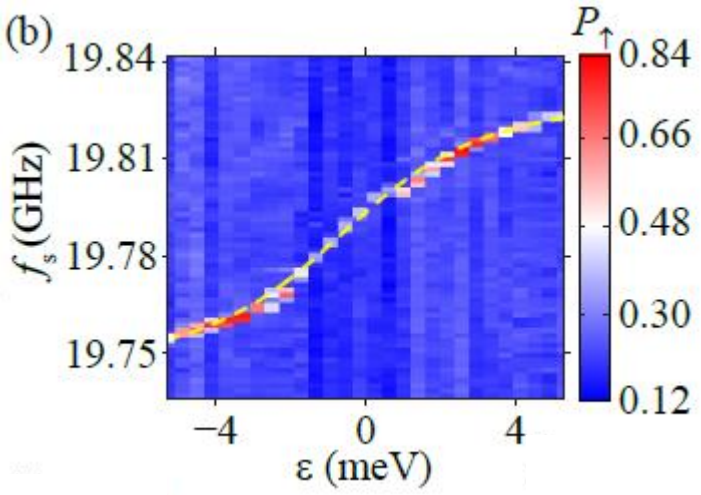
- channel created by MC and BC under reservoir gate LL
- dots under LP and BC

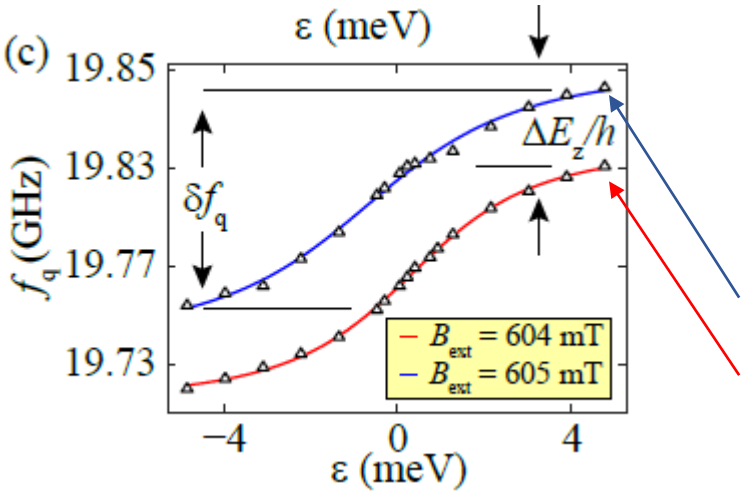
Device operation

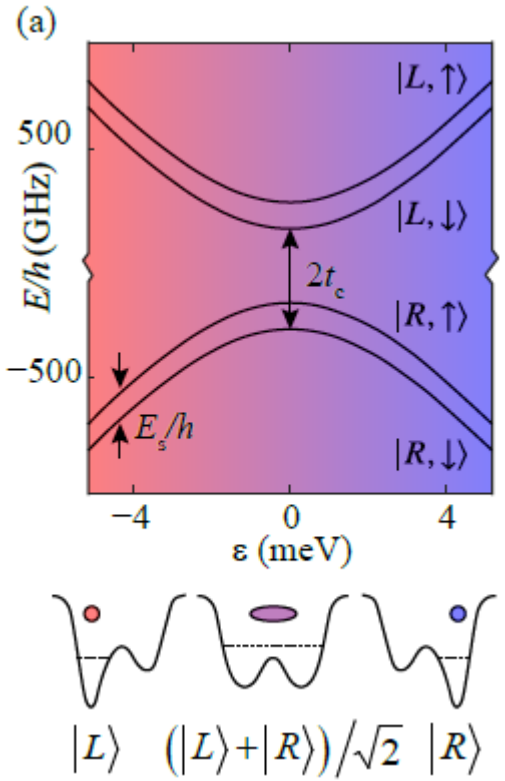


- tunnel rate controlled by LB
- qubit pulses on LB
- Elzerman single-shot readout at R
- initialization into $|\downarrow\rangle$
- EDSR bursts with f_s at manipulation point C
- adiabatic transition between R and C

EDSR







$2t_c \approx 900$ GHz

$2t_c \approx 700$ GHz

- Elzerman readout with fixed tunnel rate of 150 Hz for $|\downarrow\rangle$
- two step pulse on gate LB
- microwave pulse ±2 MHz around f_s for 100 us to identify f_q
- basis: $|L\downarrow\rangle$, $|L\uparrow\rangle$, $|R\downarrow\rangle$, $|R\uparrow\rangle$

$$H = \frac{1}{2}\begin{pmatrix} -\varepsilon - E_{z1} & -2t_{SO} & 2t_c & 0 \\ -2t_{SO} & -\varepsilon + E_{z1} & 0 & 2t_c \\ 2t_c & 0 & \varepsilon - E_{z2} & 2t_{SO} \\ 0 & 2t_c & 2t_{SO} & \varepsilon + E_{z2} \end{pmatrix}$$

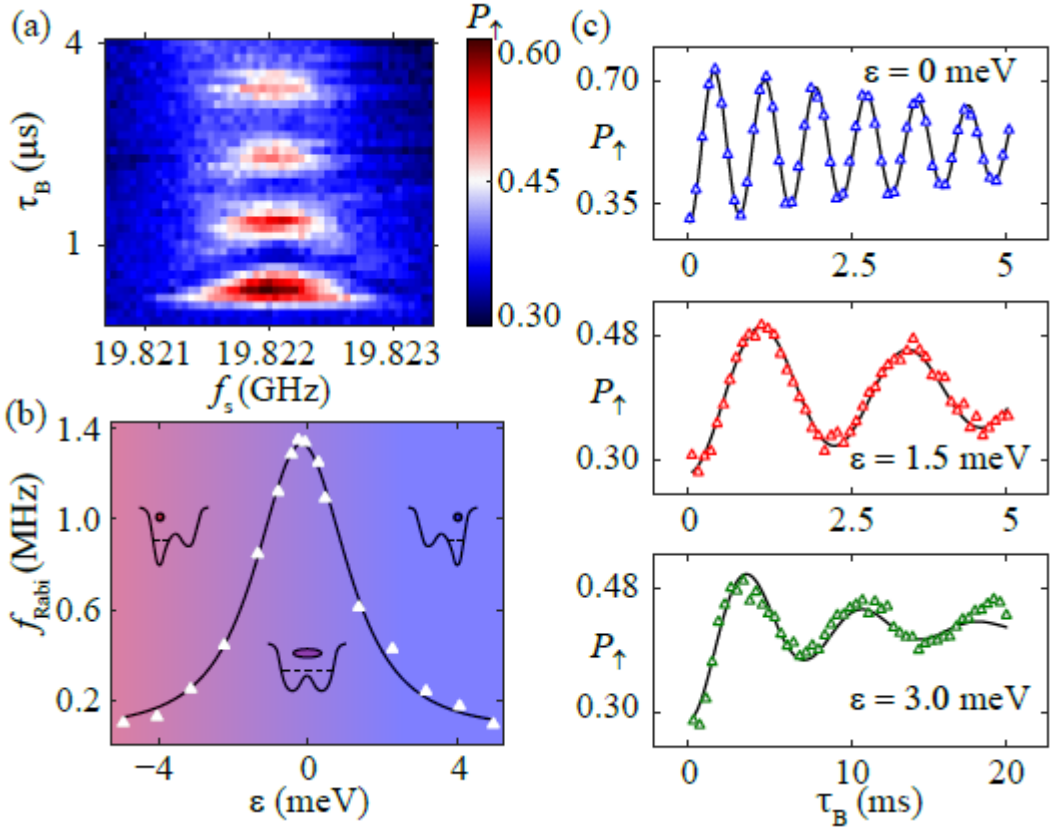
- $2t_c$ – interdot tunnel coupling
- $2t_{SO}$ – synthetic spin-orbit coupling

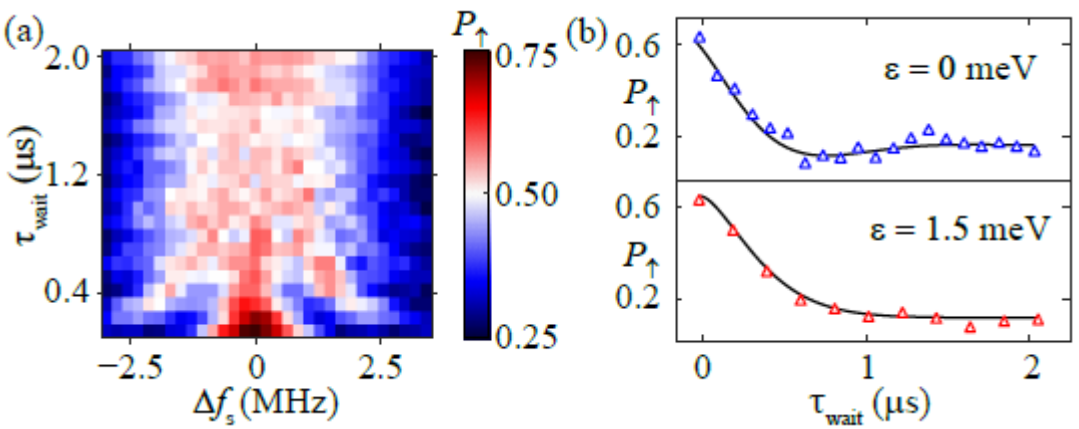
$$f_q \equiv E_s/h. \qquad \Omega = \sqrt{\varepsilon^2 + 4t_c^2}$$

$$E_s \simeq E_z - \frac{E_z^2 - \varepsilon^2}{2E_z(\Omega^2 - E_z^2)}(g\mu_B b_\perp)^2 - \frac{\varepsilon}{\Omega} g\mu_B b_z.$$

- fit $2t_c$

Rabi oscillations, Ramsey fringes





$$f_{\mathrm{Rabi}} = 4t_c^2 g\mu_B b_\perp \Omega_c/\Omega|\Omega^2 - E_z^2|.$$

- f_{Rabi} = 1.3 MHz at zero detuning
- f_{Rabi} = 0.13 MHz at detuning 3.0 mV
- T_2^{Rabi} = 5-7 us, almost constant
- T_2^* = 0.42 us

Conclusions

- flopping-mode EDSR in Si-MOS
- one order of magnitude increase of f_{Rabi} at zero detuning
- measured T2* and T2Rabi almost independent of fRabi

- better performance for Ge heavy holes, phosphorus donor qubits