# Electrical control of a long-lived spin qubit in a Si/SiGe quantum dot

E. Kawakami[1‡], P. Scarlino[1‡], D. R. Ward[2], F. R. Braakman[1†], D. E. Savage[2], M. G. Lagally[2], Mark Friesen[2], S. N. Coppersmith[2], M. A. Eriksson[2] and L. M. K. Vandersypen[1*]

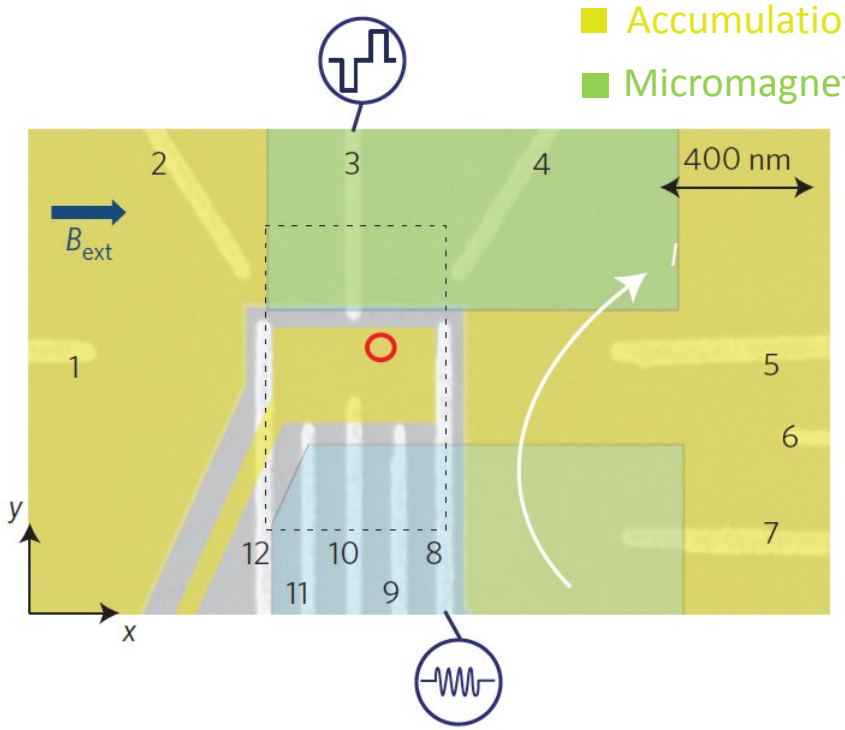
[1]Kavli Institute of Nanoscience, TU Delft, Lorentzweg 1, 2628 CJ Delft, The Netherlands, [2]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA; [†]Present address: Department of Physics, University of Basel, 4056 Basel, Switzerland; [‡]These authors contributed equally to this work.
*e-mail: l.m.k.vandersypen@tudelft.nl

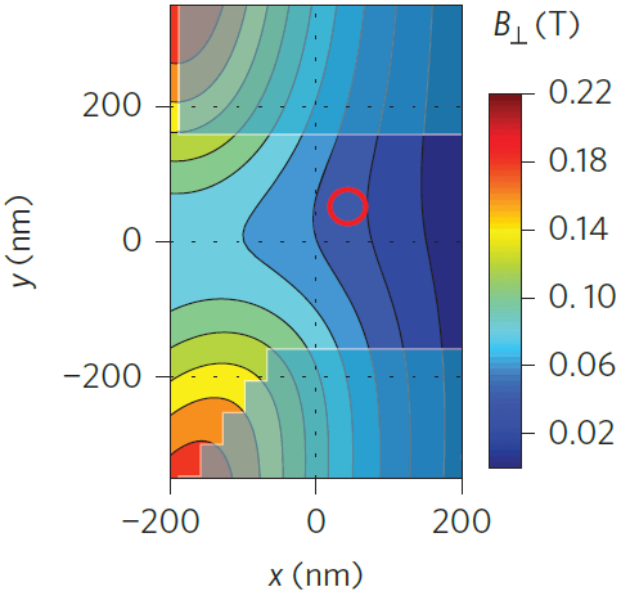
NATURE NANOTECHNOLOGY | VOL 9 | SEPTEMBER 2014 | www.nature.com/naturenanotechnology

Journal Club Talk

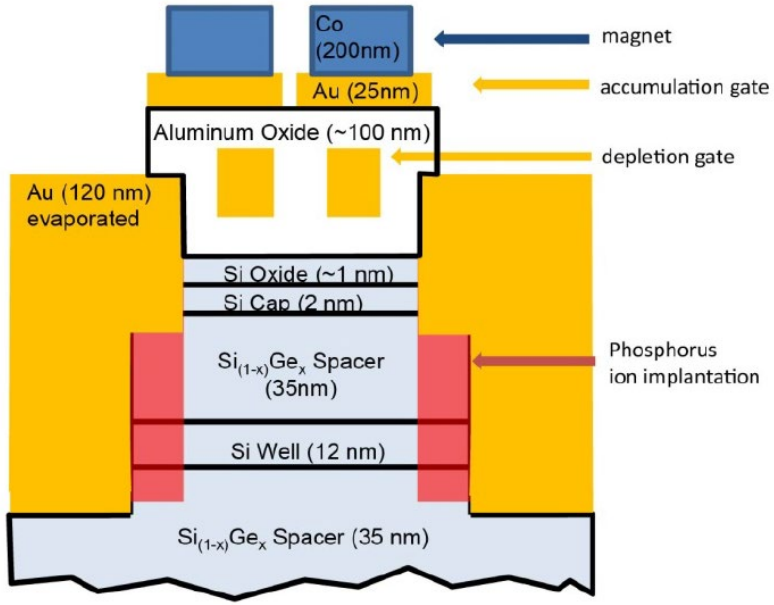
Simon Svab, 06/02/20

# Device

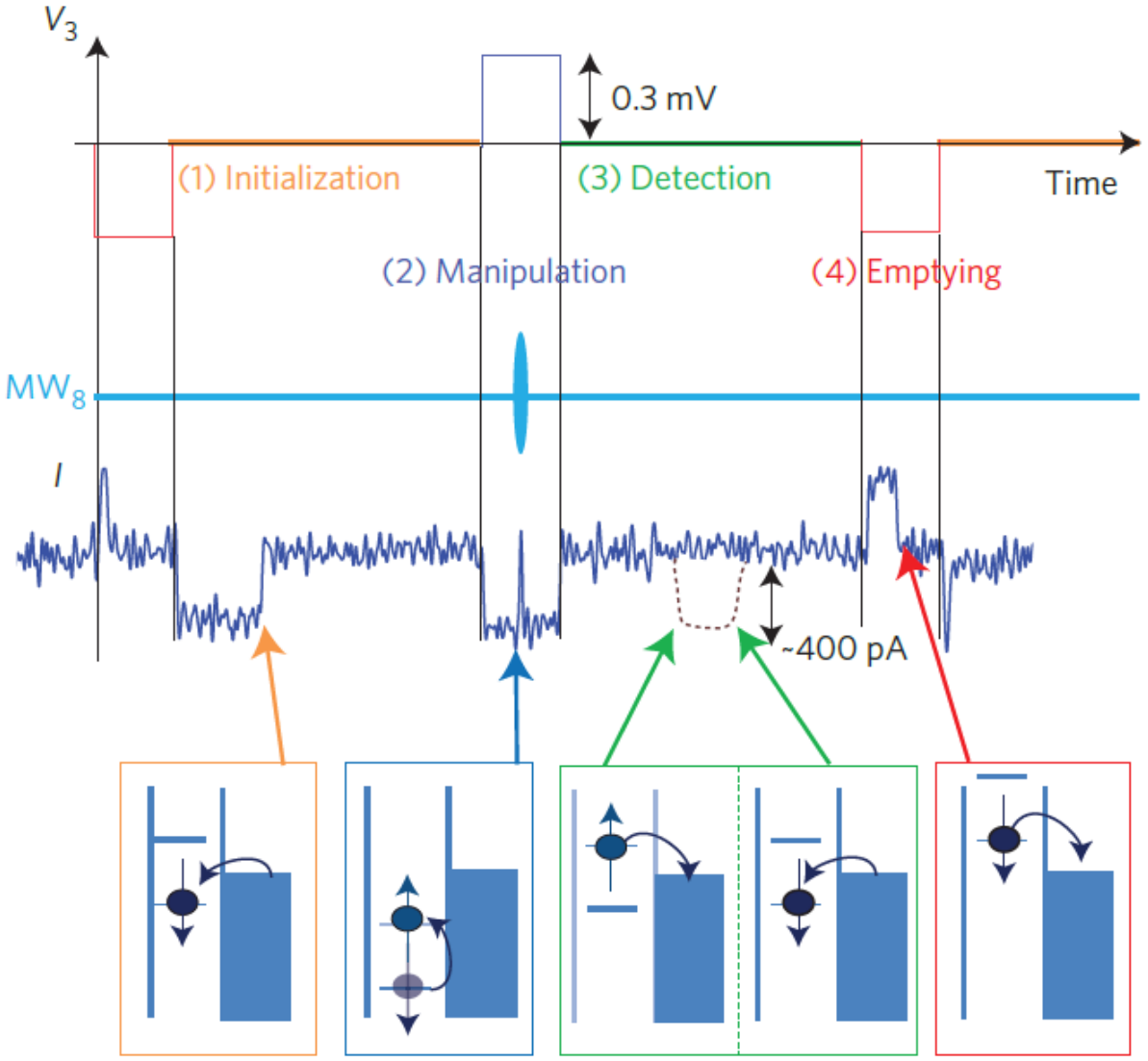



- Accumulation gates to induce 2DEG
- Depletion gates to form quantum dot
- Current is measured through sensor dot
- Co micromagnets for B-field gradient

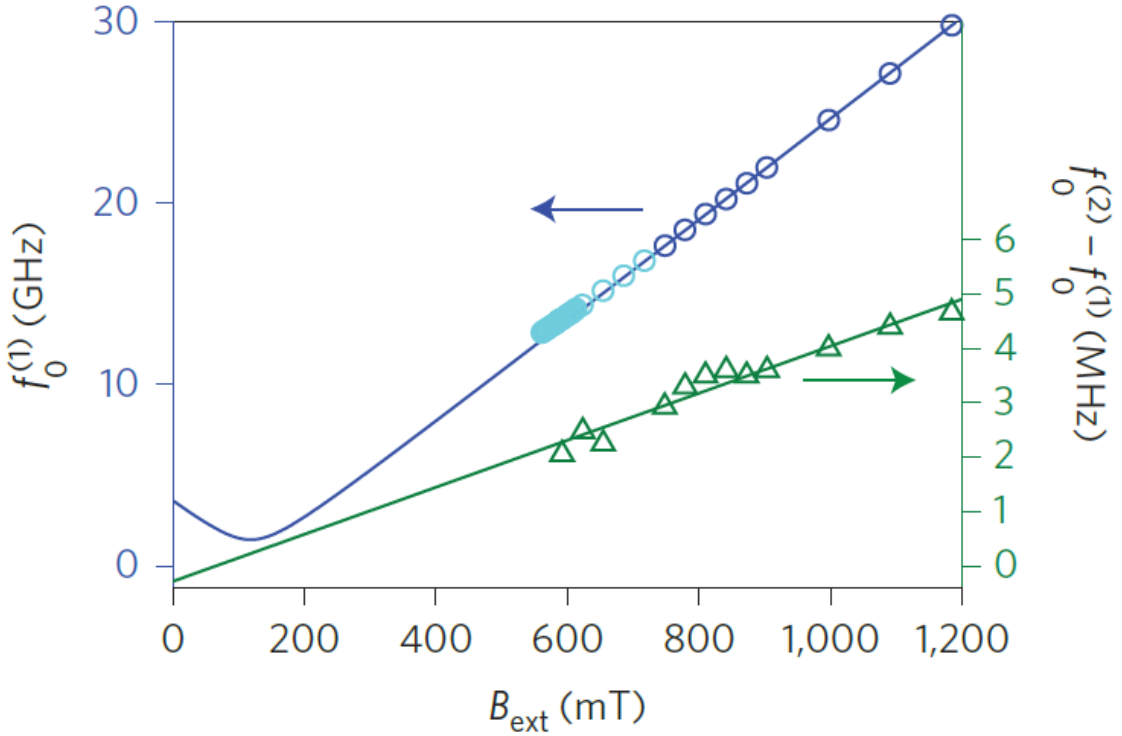


# Pulse scheme




- Four-step pulse scheme
- (1) 4ms, (2) 1ms, (3) 4ms, (4) 1ms
- Initialization/readout fidelities ~95%
- Repeating cycle 150-1000 times gives $P_{\uparrow}$

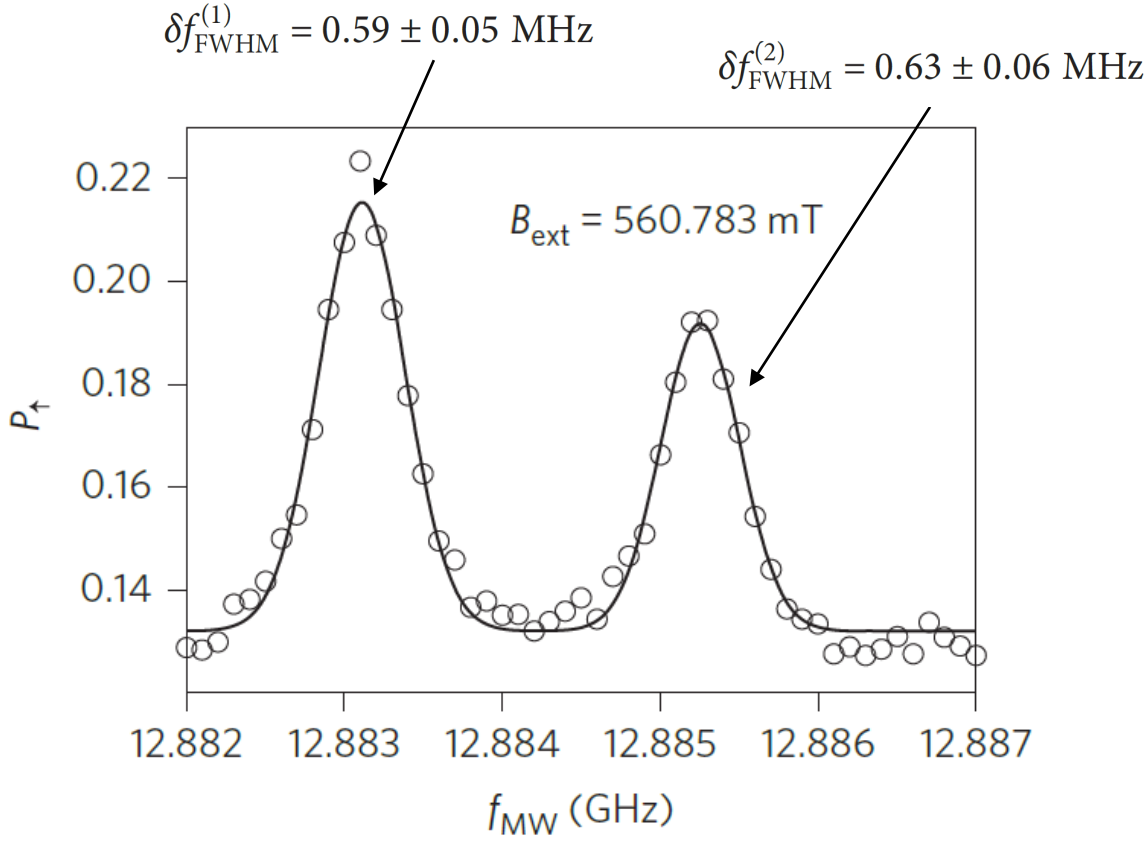
# Qubit spectroscopy




$f_0^{(1)}$: Resonance frequency of the lower-energy transition

$$g = 1.998 \pm 0.002$$

Two resonances

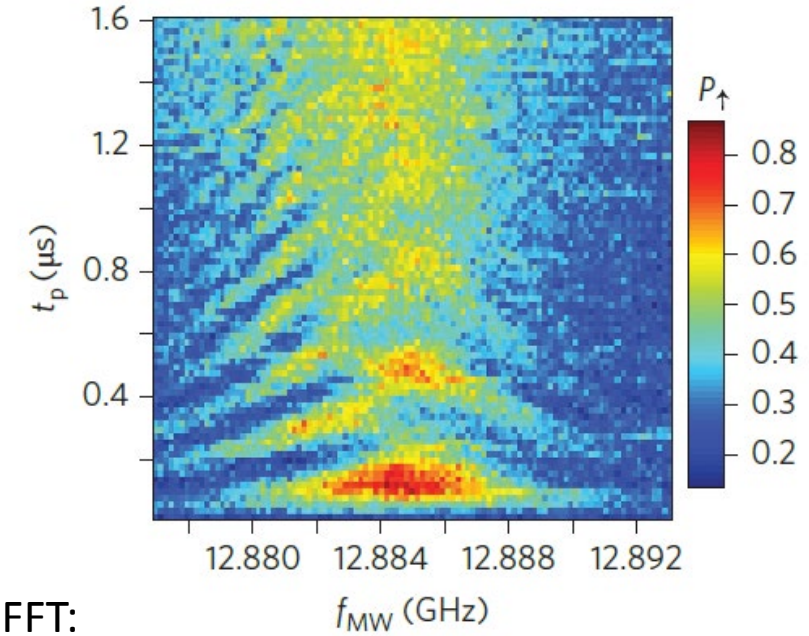



Averaged over 200 min

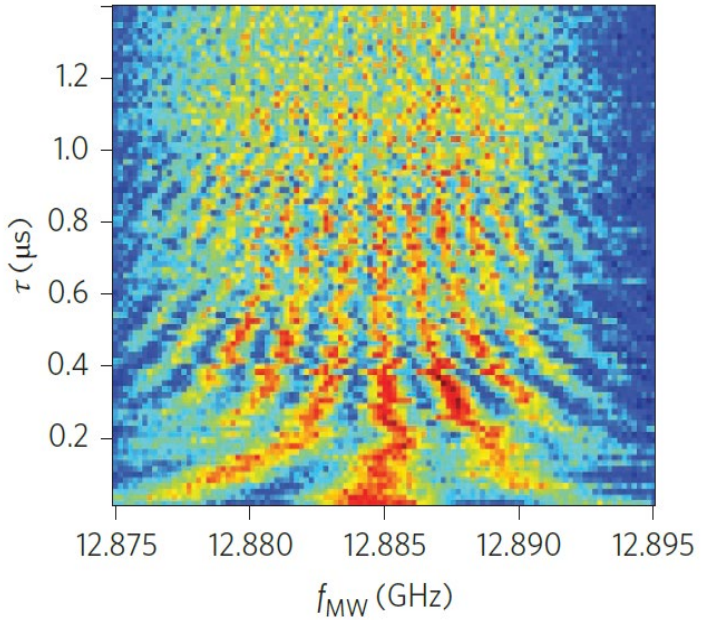
$$T_2^* = \frac{\sqrt{2}\hbar}{g\mu_B\sigma_B} = \frac{2\sqrt{\ln 2}}{\pi\delta f_{FWHM}} = 840 \pm 70 \text{ ns}$$

# Universal qubit control

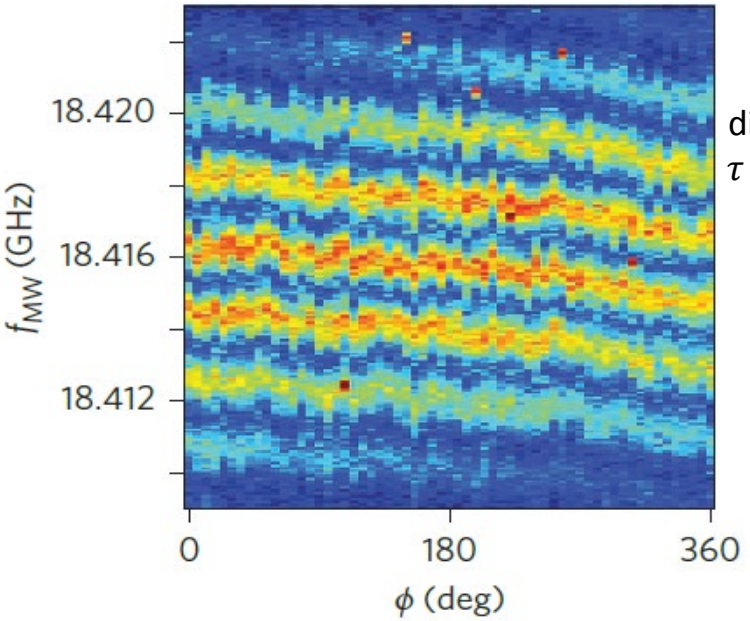
Chevron pattern




Ramsey interference



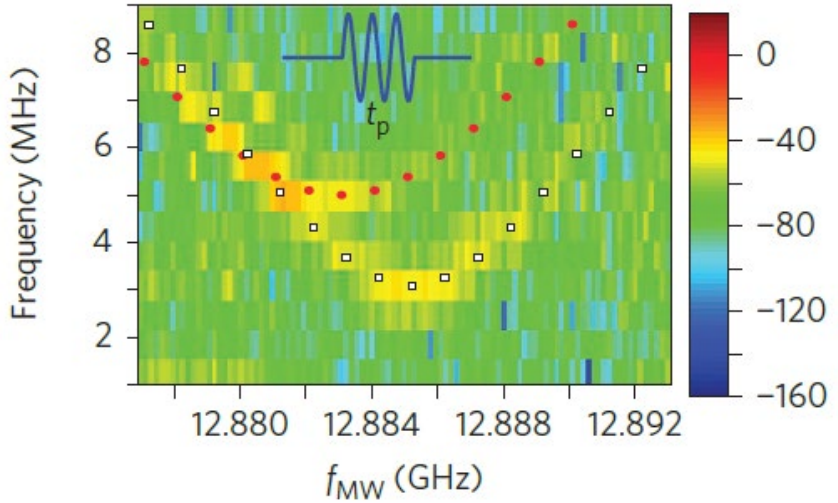

Two-axis control

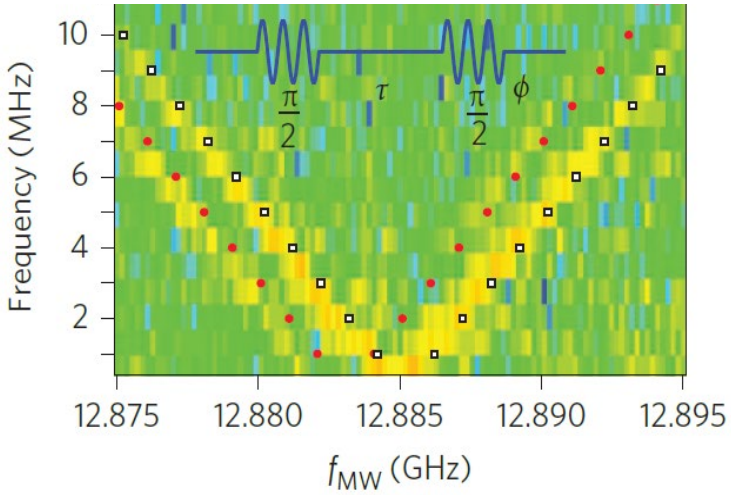


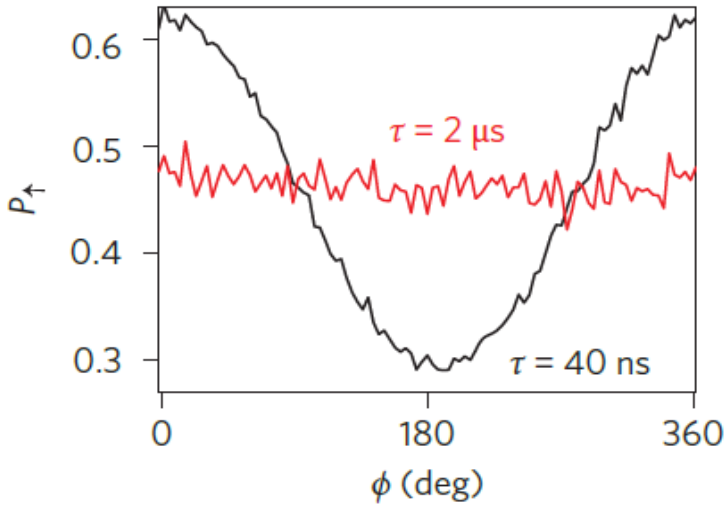

diff. B

$\tau = 400ns$

FFT:

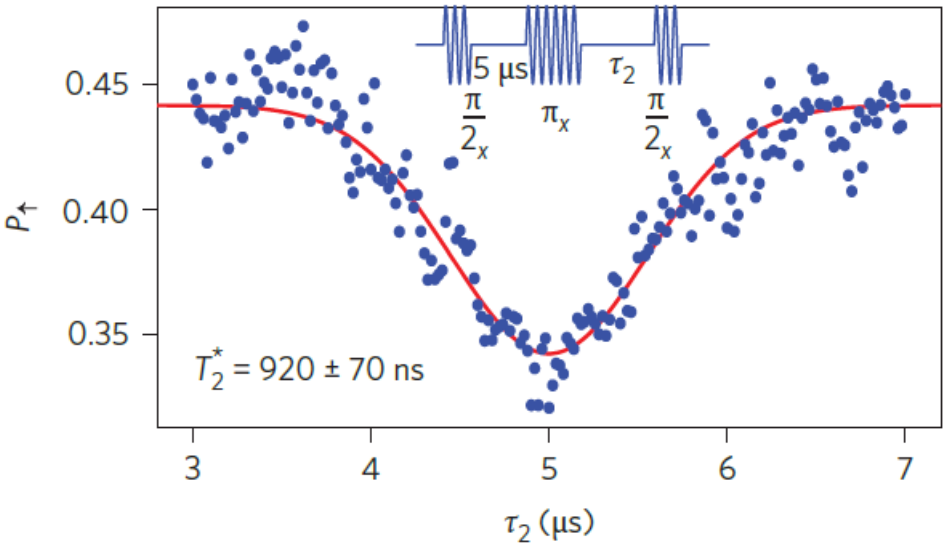


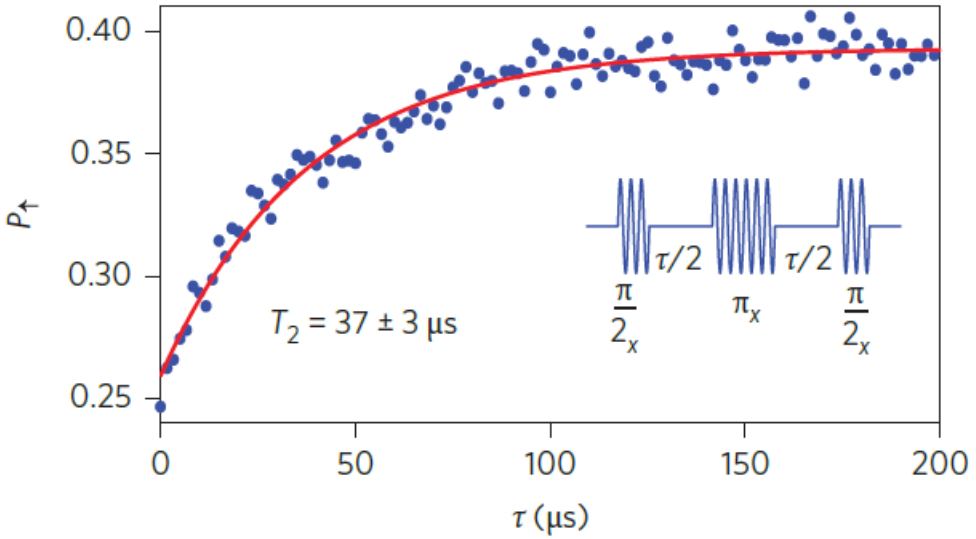



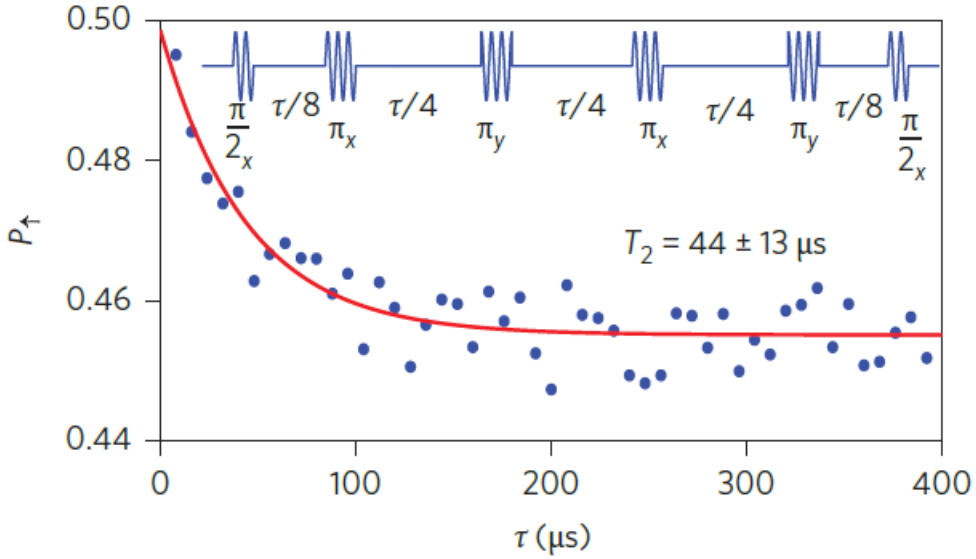




-> numerical simulations: $\epsilon_1 : \epsilon_2 \approx 0.3/0.7$

# Spin-echo techniques




$T_2^*$ consistent with value from linewidth

# Summary

- Demonstration of all-electrical two-axis control
- System: Single-electron spin qubit in Si/SiGe quantum dot
- $T_2^*$ ~1 µs, $T_2$ ~ 40 µs
- EDSR occurs at two closely spaced frequencies
- Higher-freq. Resonance has ~1.5 times slower Rabi oscillations than lower-freq. resonance
- Relative amplitude of oscillations at lower/higher resonance frequency is ~30/70; attributed to two lowest valley states; in agreement with simulations