An addressable quantum dot qubit with fault-tolerant control-fidelity

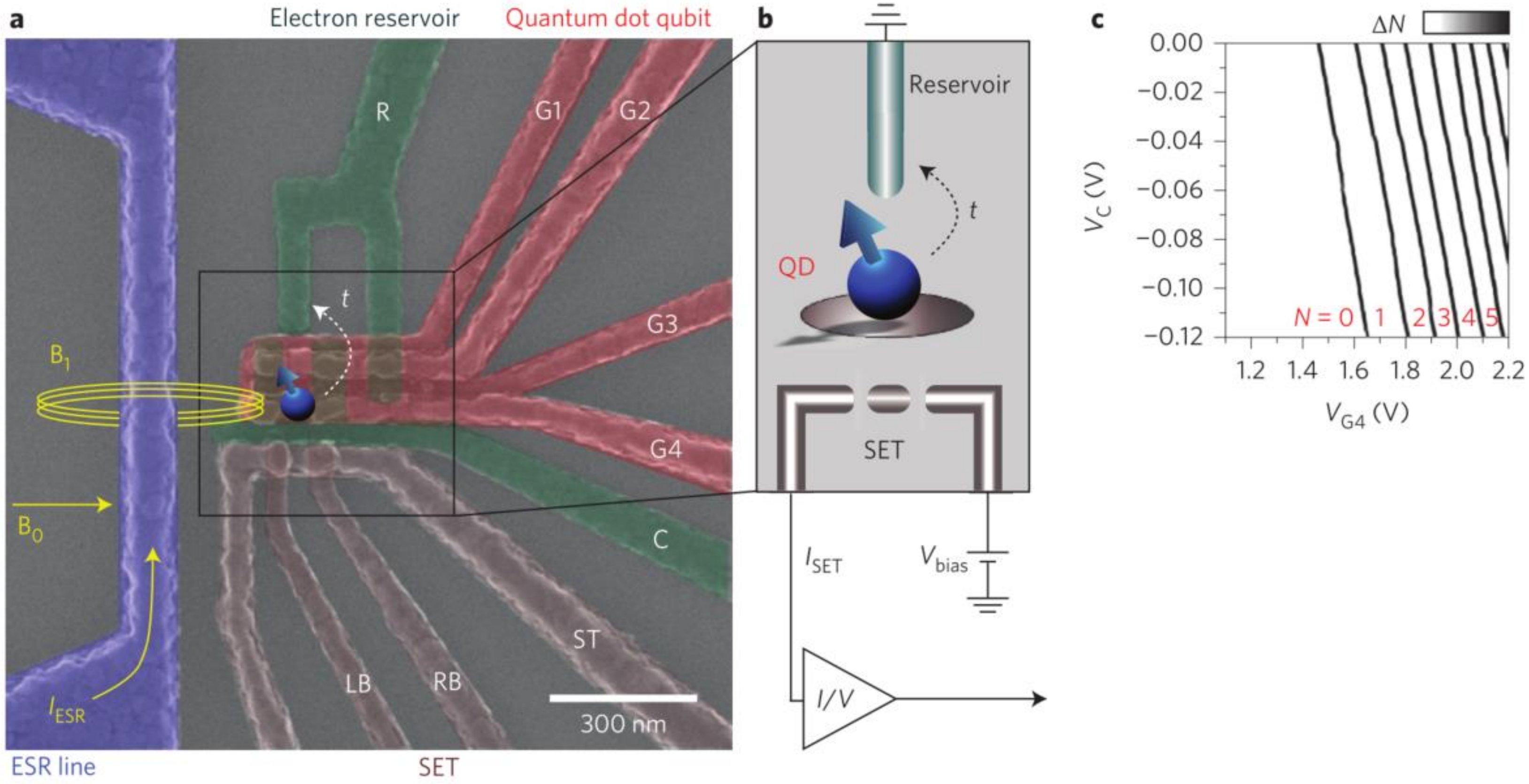
M. Veldhorst[1*], J. C. C. Hwang[1], C. H. Yang[1], A. W. Leenstra[2], B. de Ronde[2], J. P. Dehollain[1], J. T. Muhonen[1], F. E. Hudson[1], K. M. Itoh[3], A. Morello[1] and A. S. Dzurak[1*]

1 = University of New South Wales, Sydney, Austrailia
2 = University of Twente, Netherlands
3 = Keio Univeristy, Japan

Contents

- electron spin qubit in ^{28}Si (MOS)
- ESR stripline
- long coherence time (T_2 = 28ms)
- high control fidelity
- valley splitting

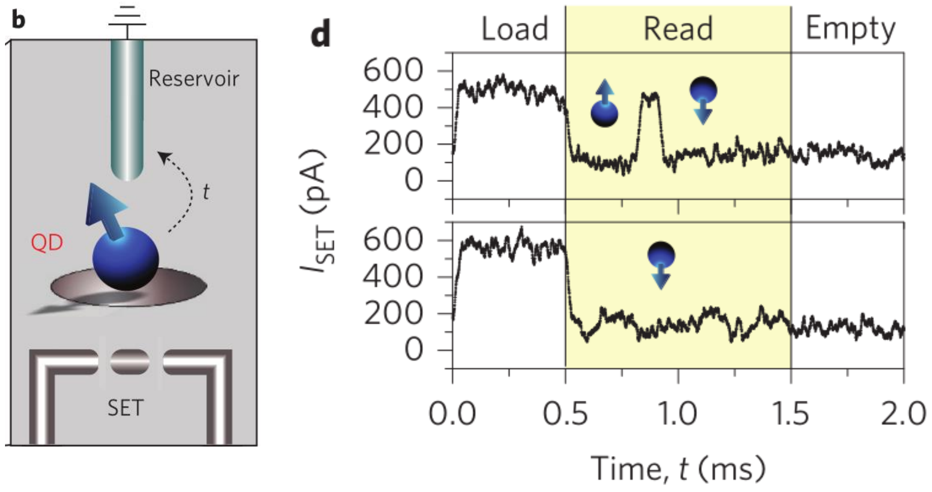
QD Device

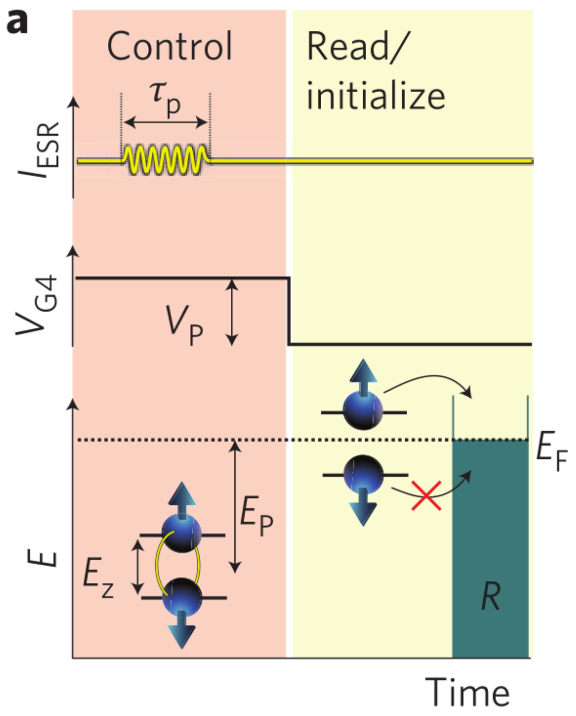


- QD coupled to 1 reservoir
- readout via SET (with feedback-loop)
- T = 50mK
- 3 layer Al-AlO gate stack on ^{28}Si

RF and spin readout

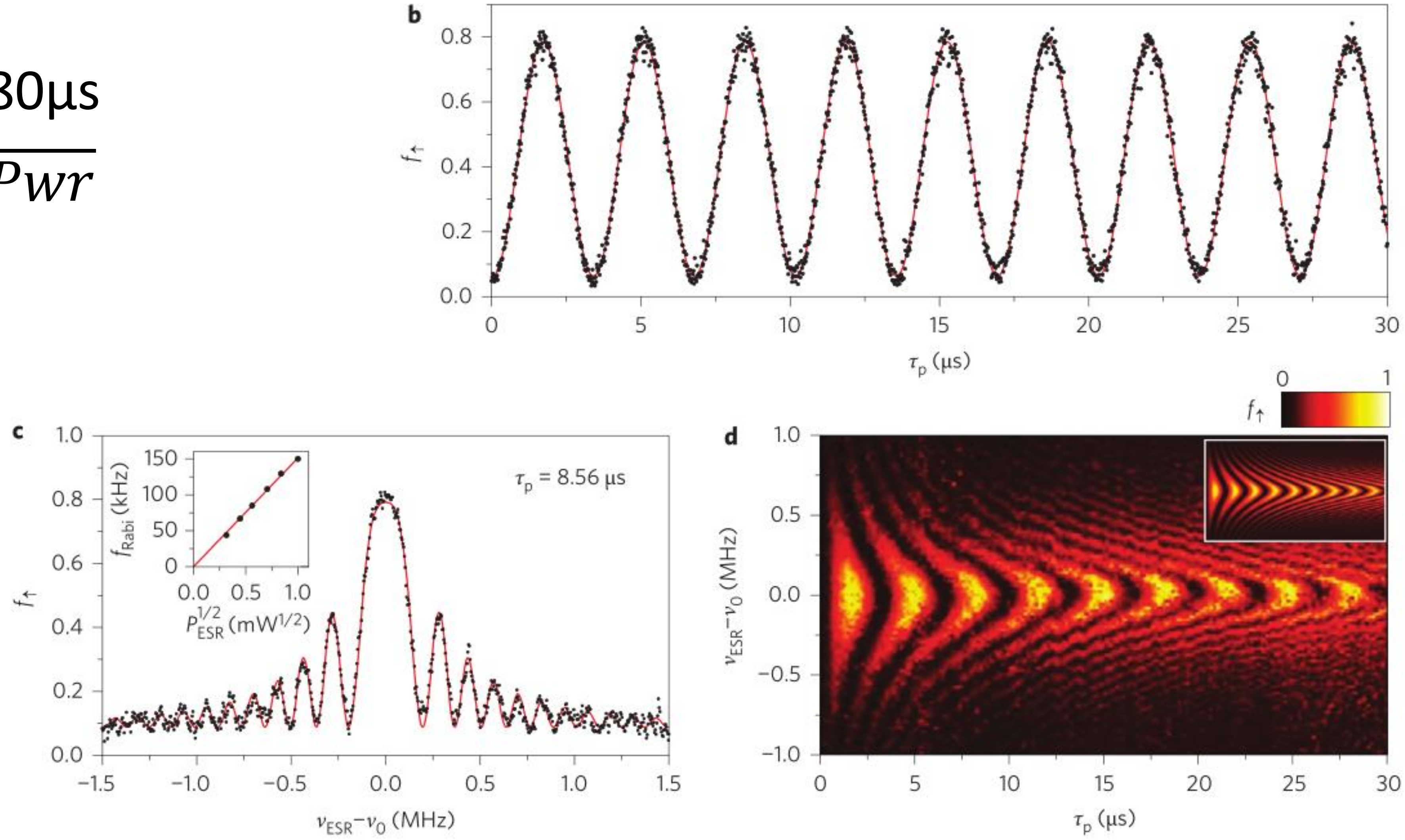
- spin-selective tunnelling to reservoir
- single-shot spin readout
- AC B-field by AC current through transmission line
- B = 1.4T, g ~2, f_{MW}=39GHz





Rabi

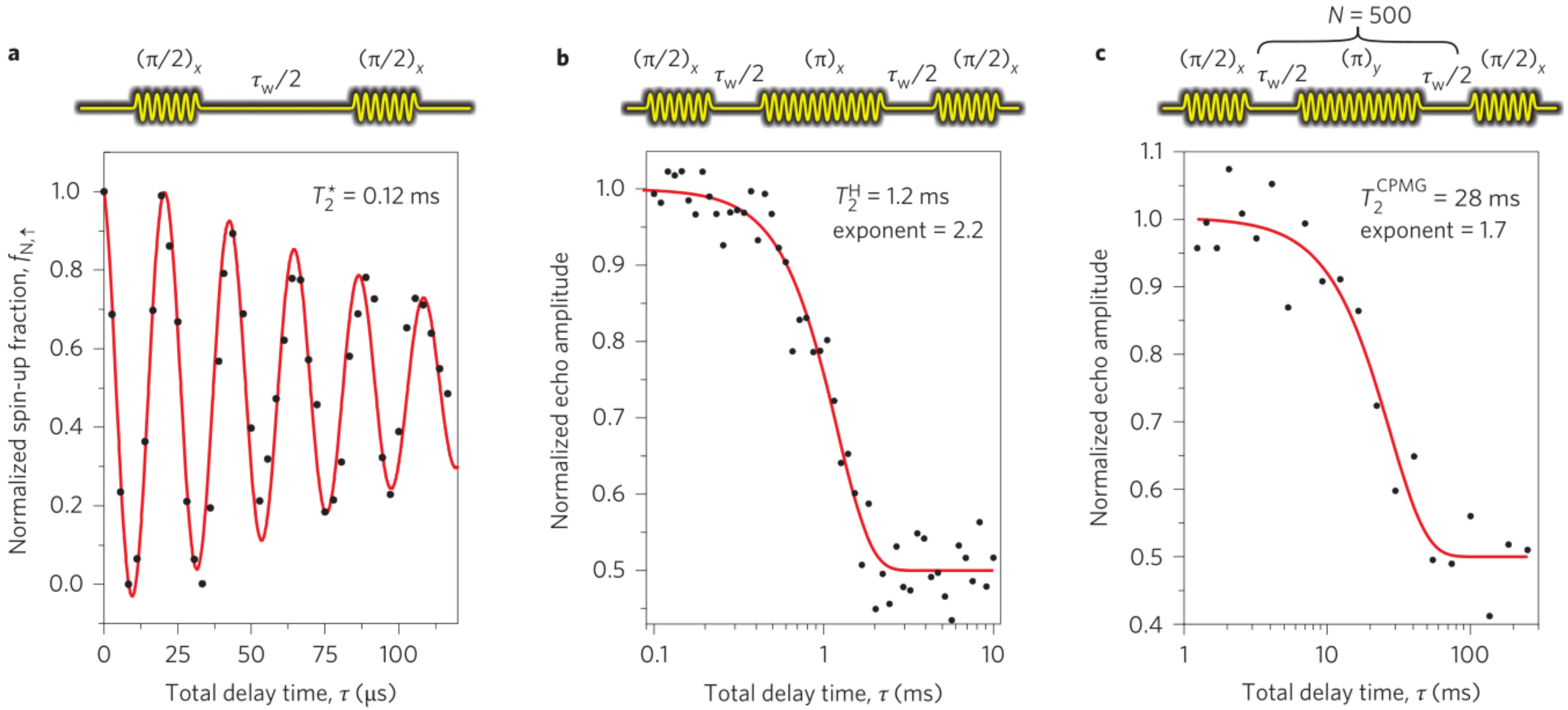
- T_2^{Rabi} ~ 380µs
- $f_{Rabi} \propto \sqrt{Pwr}$
- t_π= 1,8µs



Ramsey, Hahn and CPMG

- $T_2^* = 120\mu s$
- $T_2^H = 1.2ms$
- $T_2^{CPMG} = 28ms$
- different exponents -> different noise spectra

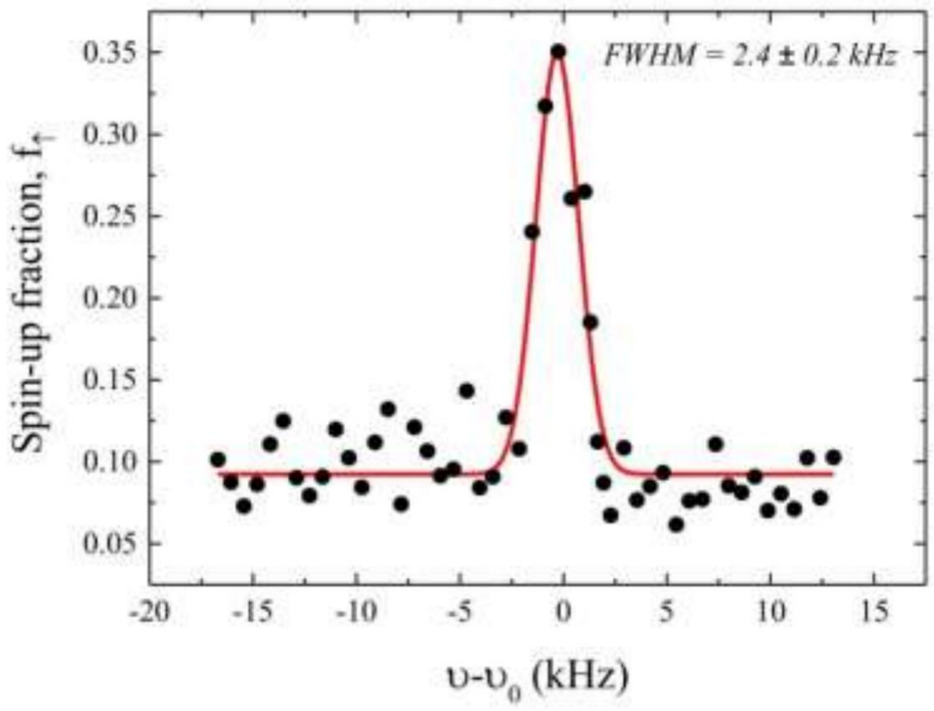
- 10^5 operations before decay

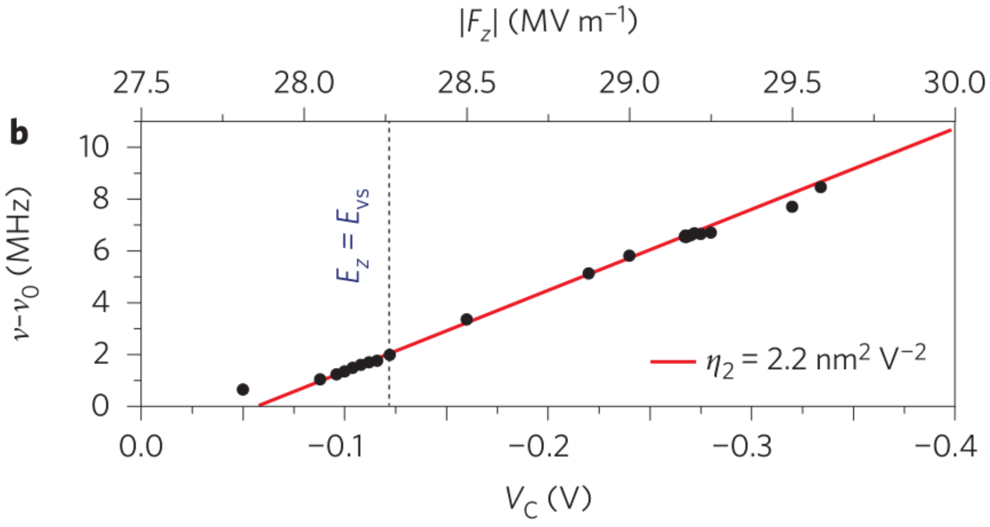


Linewidth

- T_2* = 120µs → thin linewidth ν = 2.6kHz
- agrees with linewidth measurement at Pwr=-20dbm (no more power broadening)
- electrically tunable g-factor

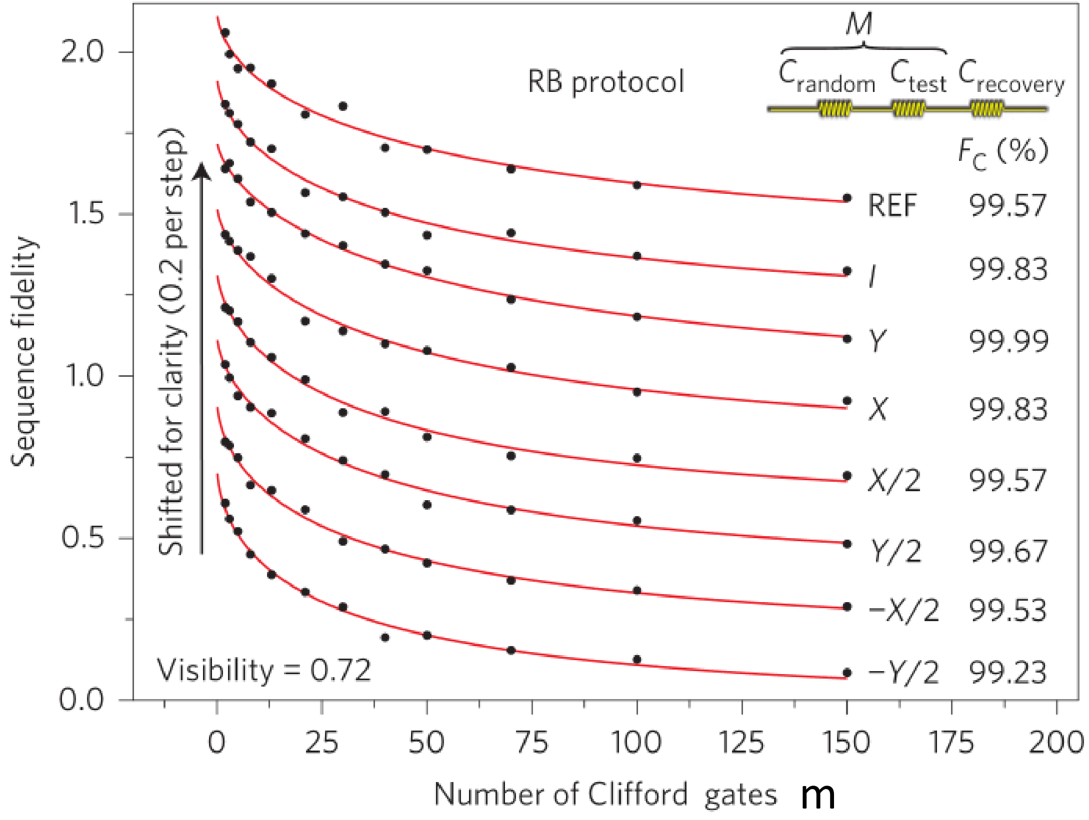
→ idea: high qubit addressability in array





Randomized benchmarking

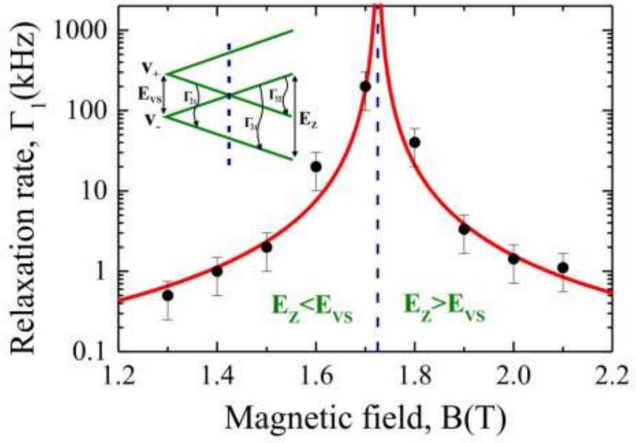
- goal: calculate gate error
- apply random series of (interleaved) gates, then recover
- get gate fidelity from sequence fidelity decay (visibilty does not matter)
- fit f = A*exp(-(b*m)$^{\alpha}$)   , F_C = 1 – b
- single gate fidelity: F_S = 1-b/(2*1.875)
- →F_C > 99% „fault-tolerant“

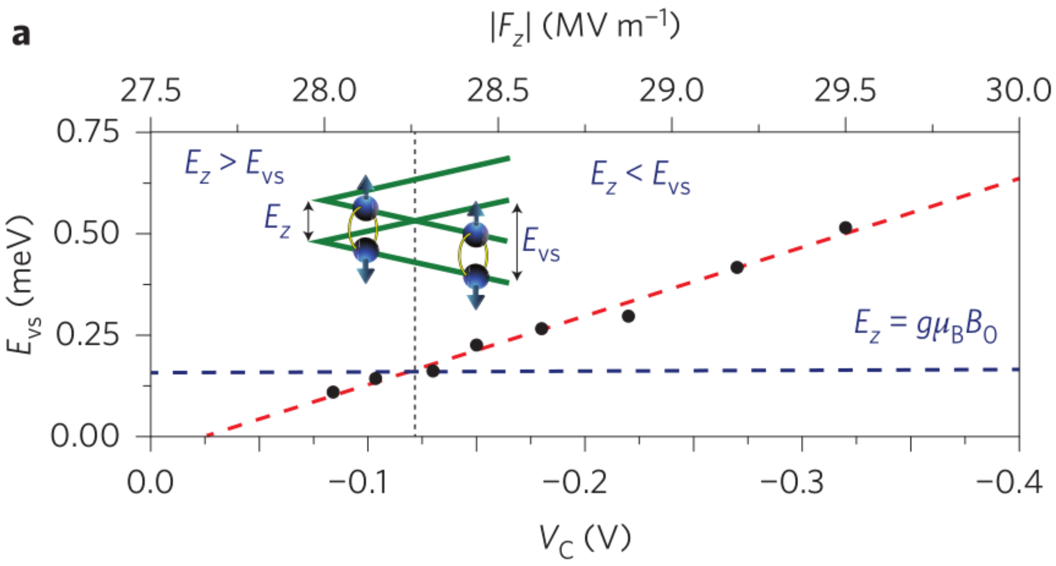


More about RBM: J.T. Muhonen et al., Condensed Matter 27 (2015)

Valley splitting

- $E_Z = E_V$ is relaxation sweet spot
- valley splitting $\propto F_Z$ and agrees with previous device
- qubit can be operated in $E_Z > E_V$ or $E_Z < E_V$ regime





Conclusion

- electrons in ^{28}Si → very long coherence $T_2^* = 120\mu s$
- CPMG improves coherence by factor 200
- address qubit electrically with tunable g-factor
- fault-tolerant gate fidelity > 99%