Announcements

Basel – IBM Journal club every 1st Friday of the month (except next one)

Programme on the same website

Shuttling an electron spin through a silicon quantum dot array

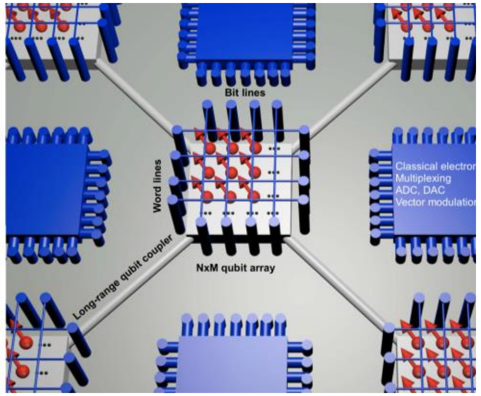
A.M.J. Zwerver[1], S.V. Amitonov[2], S.L. de Snoo[1], M.T. Mądzik[1],
M. Russ[1], A. Sammak[2], G. Scappucci[1], and L.M.K. Vandersypen[1*]
[1] *QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands*
[2] *QuTech and Netherlands Organization for Applied Scientific Research (TNO), Delft, The Netherlands*
(Dated: September 13, 2022)

Shuttling an electron spin through a silicon quantum dot array

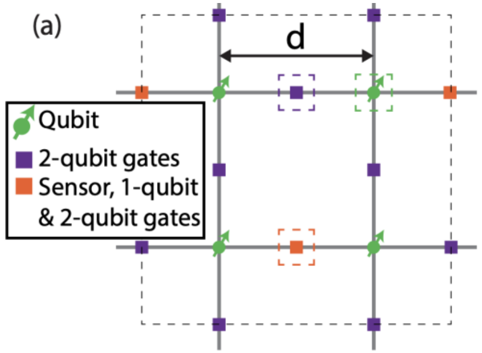
A.M.J. Zwerver[1], S.V. Amitonov[2], S.L. de Snoo[1], M.T. Mądzik[1],
M. Russ[1], A. Sammak[2], G. Scappucci[1], and L.M.K. Vandersypen[1*]
[1] *QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands*
[2] *QuTech and Netherlands Organization for Applied Scientific Research (TNO), Delft, The Netherlands*
(Dated: September 13, 2022)

A.M.J Zwerner → Post Doc (PhD on Intel MOS devices)
S.V. Amitonov → Fabrication now done only by TNO
Sammak/Scappucci → Material Growth

Motivation

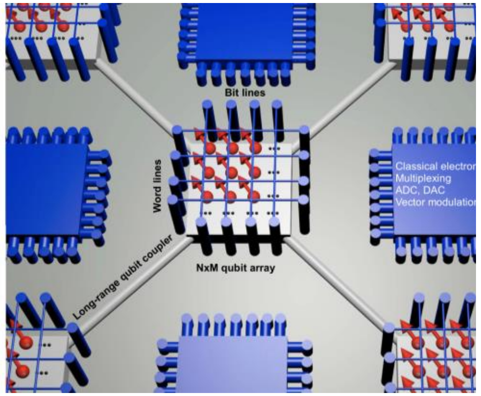


Interfacing spin qubits in quantum dots and donors LMK Vandersypen et al.

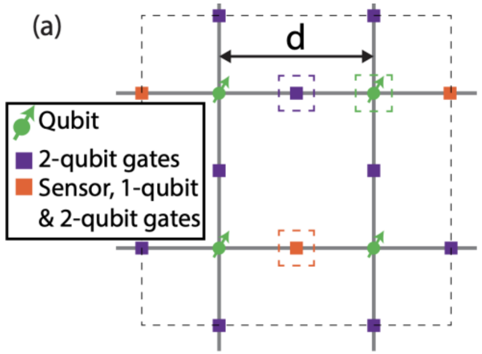


Spiderweb array: A **sparse** spin-qubit array Jelmer M. Boter et al.

Motivation

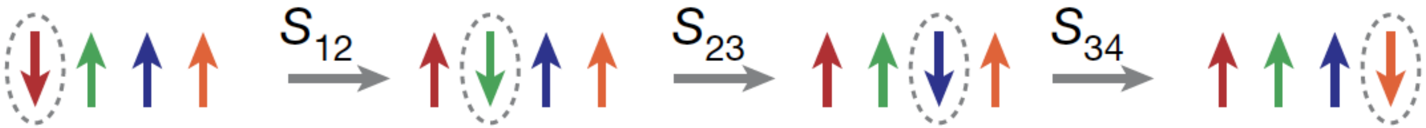


Interfacing spin qubits in quantum dots and donors LMK Vandersypen et al.



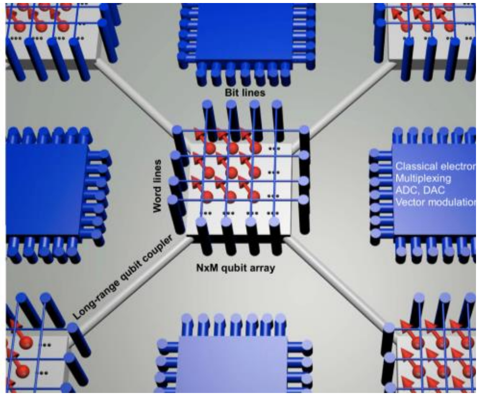
Spiderweb array: A **sparse** spin-qubit array Jelmer M. Boter et al.

SWAP

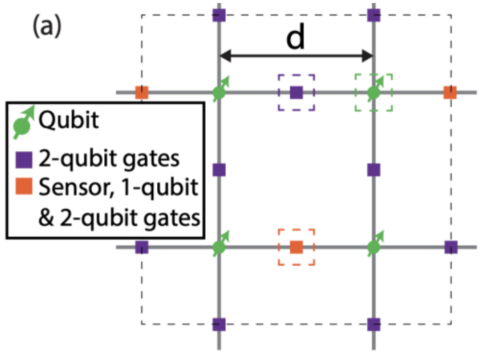


Coherent spin-state transfer via Heisenberg exchange
Yadav P. Kandel et al.

Motivation

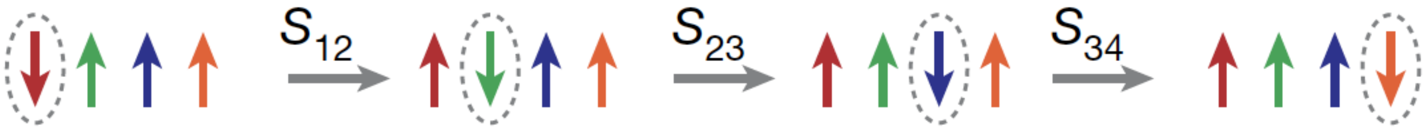


Interfacing spin qubits in quantum dots and donors LMK Vandersypen et al.



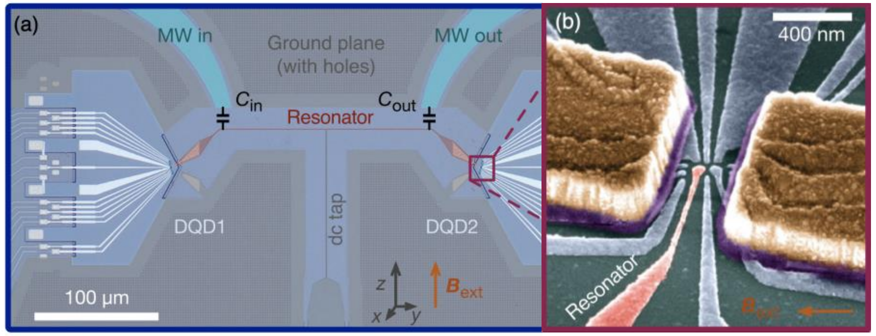
Spiderweb array: A **sparse** spin-qubit array Jelmer M. Boter et al.

SWAP



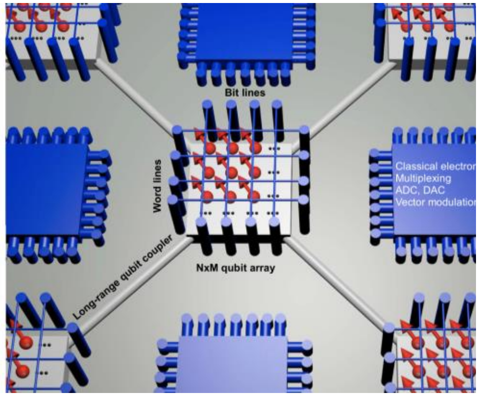
Coherent spin-state transfer via Heisenberg exchange
Yadav P. Kandel et al.

Resonator mediated

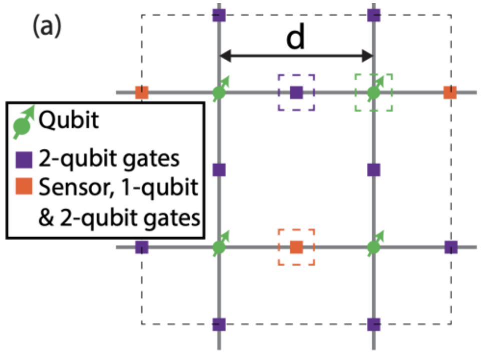


Coherent Spin-Spin Coupling Mediated by Virtual Microwave Photons
Patrick Harvey-Collard et al.

Motivation

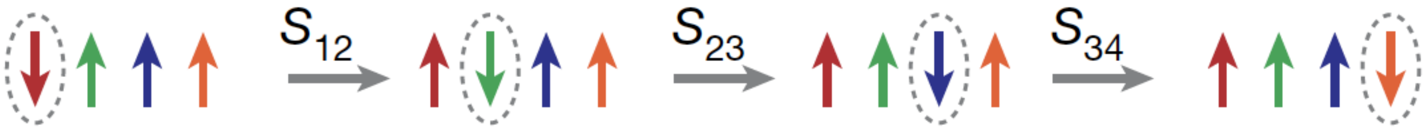


Interfacing spin qubits in quantum dots and donors LMK Vandersypen et al.



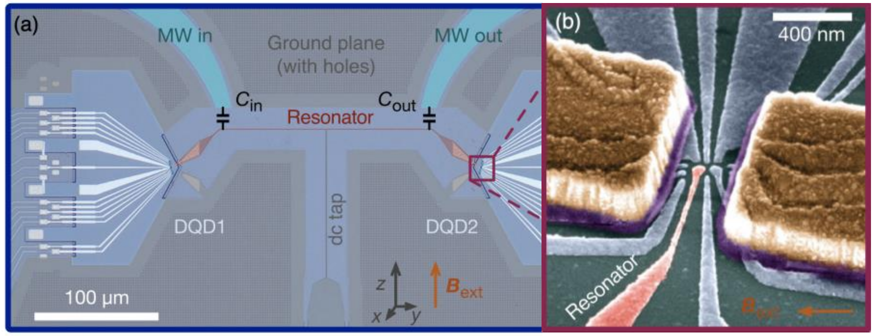
Spiderweb array: A **sparse** spin-qubit array Jelmer M. Boter et al.

SWAP gate



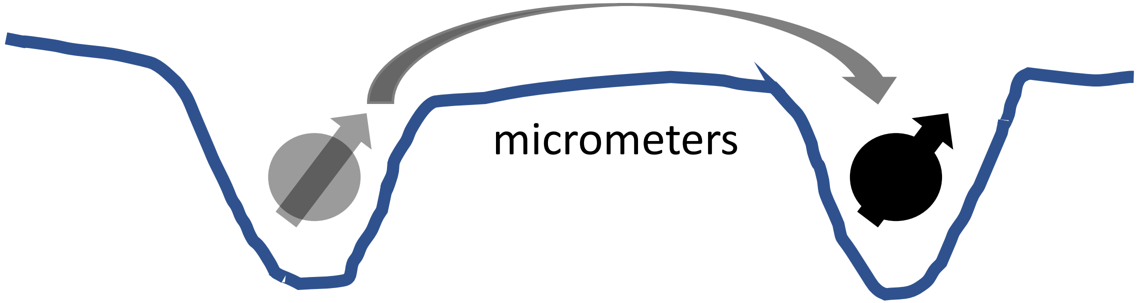
Coherent spin-state transfer via Heisenberg exchange
Yadav P. Kandel et al.

Resonator mediated

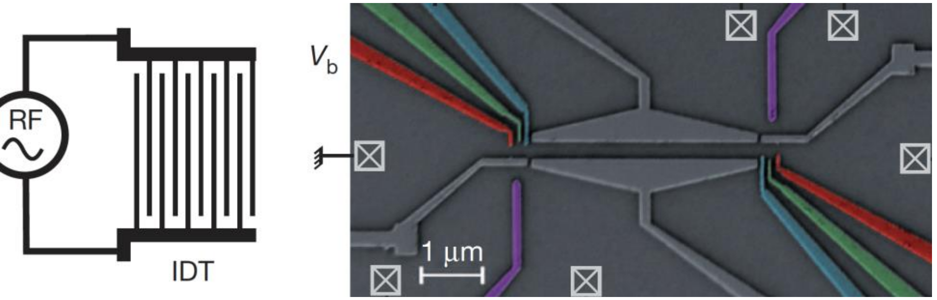


Coherent Spin-Spin Coupling Mediated by Virtual Microwave Photons
Patrick Harvey-Collard et al.

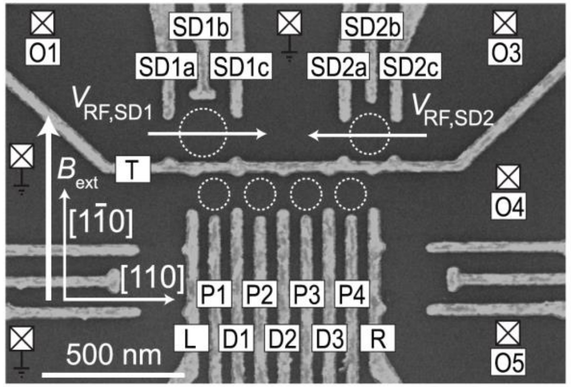
Electron transfer - Shuttling



Prior Art on Shuttling

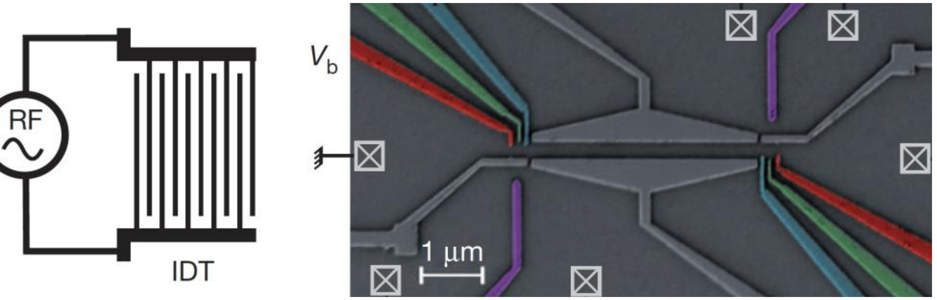


Electrons surfing on a sound wave
Sylvain Hermelin et al. (2019)

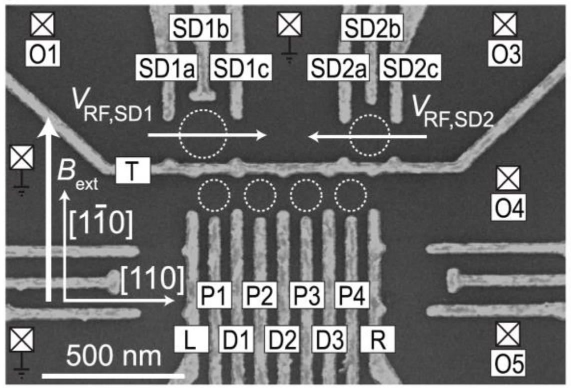


Coherent shuttle of electron-spin states
Takafumi Fujita et al. (2015)

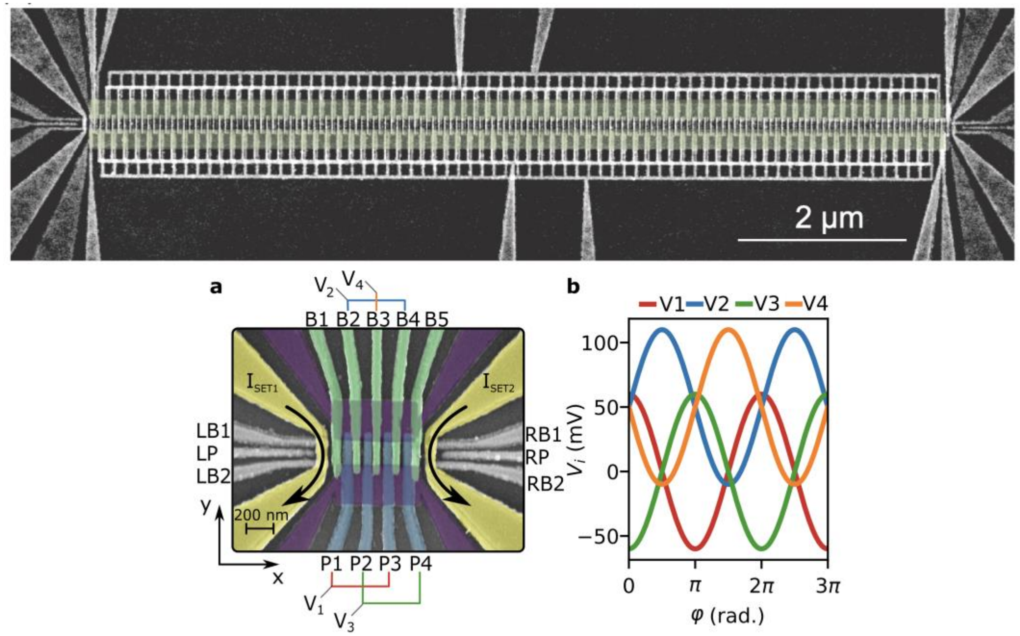
Prior Art on Shuttling



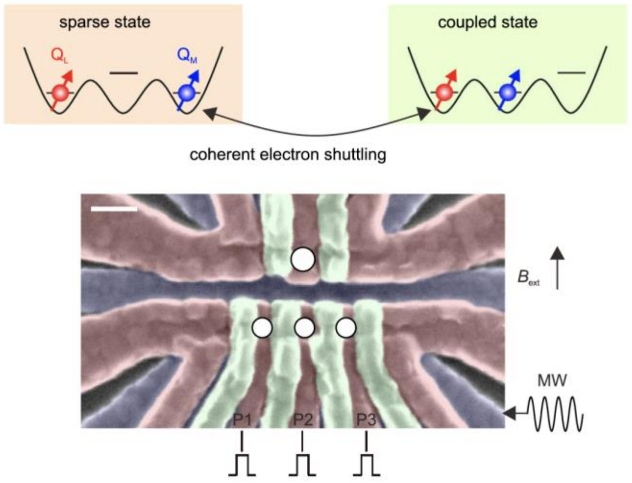
Electrons surfing on a sound wave
Sylvain Hermelin et al. (2019)



Coherent shuttle of electron-spin states
Takafumi Fujita et al. (2015)



Conveyor-mode single-electron shuttling in Si/SiGe for a scalable quantum computing architecture Inga Seidler et al. (2022)

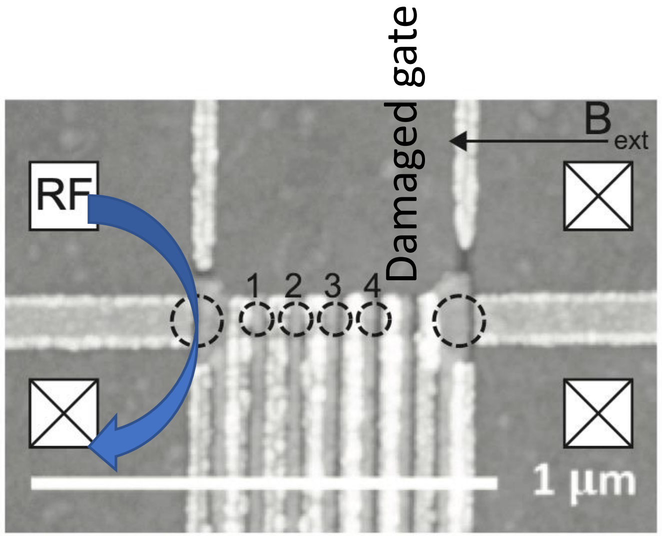


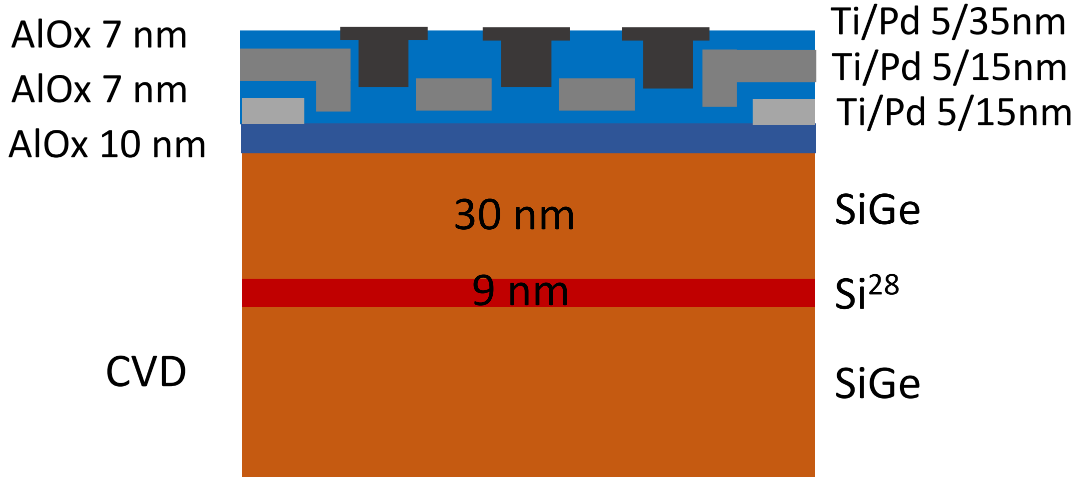
A shuttling-based two-qubit logic gate for linking distant silicon quantum processors
Akito Noiri et al. (2022)

Device

Si^{28}/SiGe 3 layer

5 QDs + 2 SETs/Reservoirs

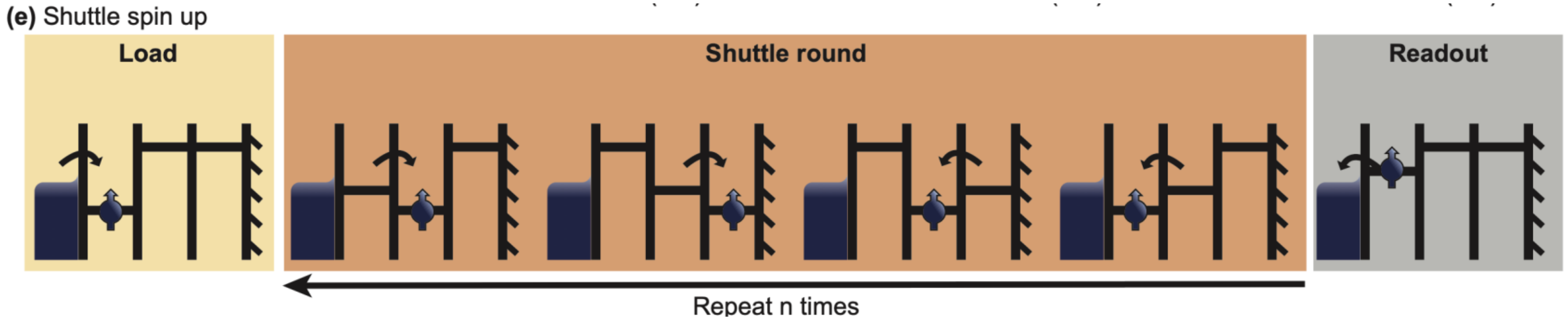




- Yield of devices low – leakage between gates
- Valley spitting random – can be 50-150 µeV no PSB many times
- B → 1.3 T , Ez → 150 µeV

Electron shuttling protocol

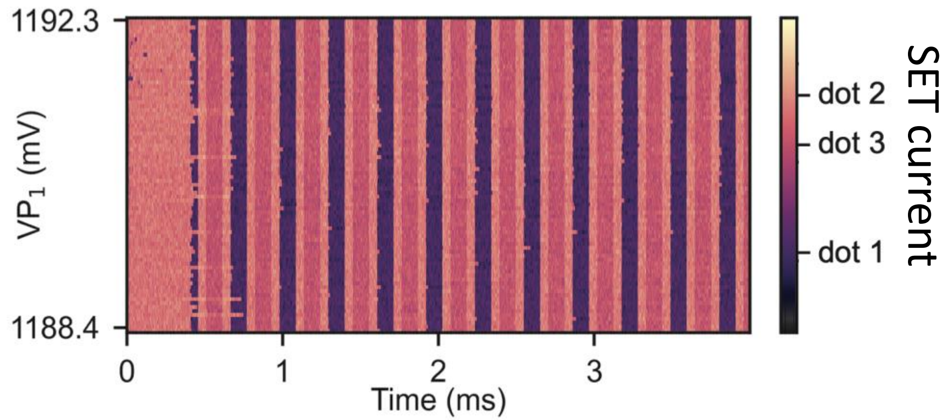
- Load an electron (→ Latching due to low tunnelling rate)
- Abruptly pulse to a point close to but before the anticrossing,
- Ramp through the anticrossing (2 μs over a ≈ 300 μeV detuning range)
- Abruptly pulse far beyond the anticrossing.
- Readout (spin selective)



Tunnel couplings 4-7 GHz

Deplete the rest of dots

Charge transfer as sensed by the SET
Time in each QD 100-400 μs



Spin shuttling

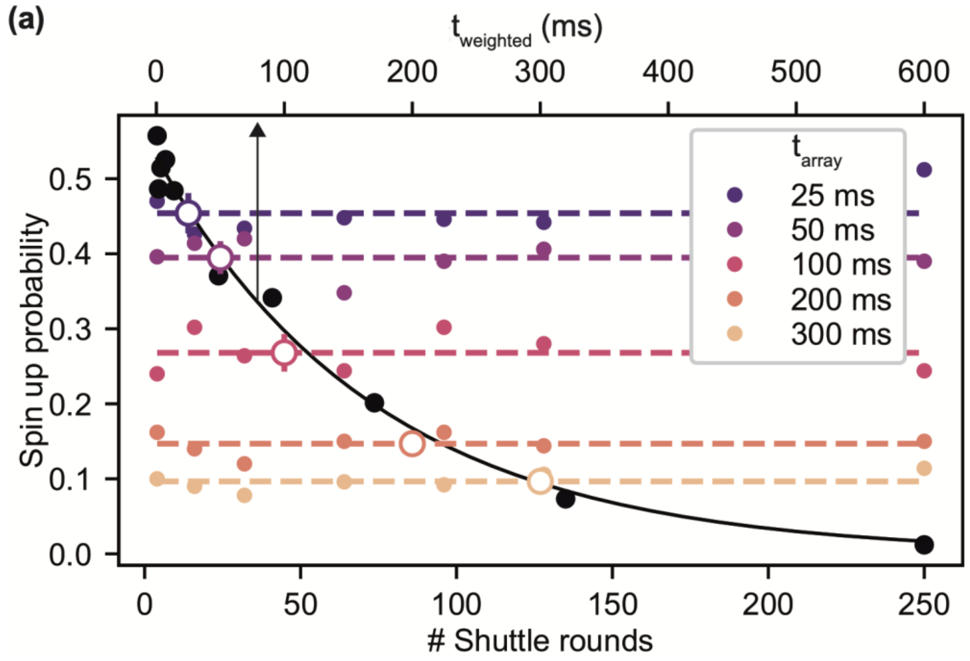
$$T_{1,1} = 129 \pm 33 \text{ ms}$$

$$T_{1,2} = 257 \pm 79 \text{ ms}$$

$$T_{1,3} = 152 \pm 48 \text{ ms}$$

$$T_{1,\text{weighted}} = 170 \pm 18 \text{ ms}$$

$$3(1/T_{1,1}+1/T_{1,2}+1/T_{1,3})^{-1} = 164 \pm 47 \text{ ms}$$



- No indication of T1 suppression due to shuttling
- Shuttling T1 agrees with respective T1 od each dot
- Fastest wait time between shuttling is 12.5 μs

Discussion & Conclusion

- Absence of micromagent – SOI – Nuclear spins leads to large T1 during shuttling similar to the original T1 of each dot
- Fastest shuttling needed for a useful scheme that can characterize T2*
- Conveyor-mode is the scalable route but larger valley spitting and dot homogeneity is needed
- *How SOI can influence this in a hole spin shuttling ?? (coming next…)*