Title:

A shuttling-based two-qubit logic gate for linking distant silicon quantum processors

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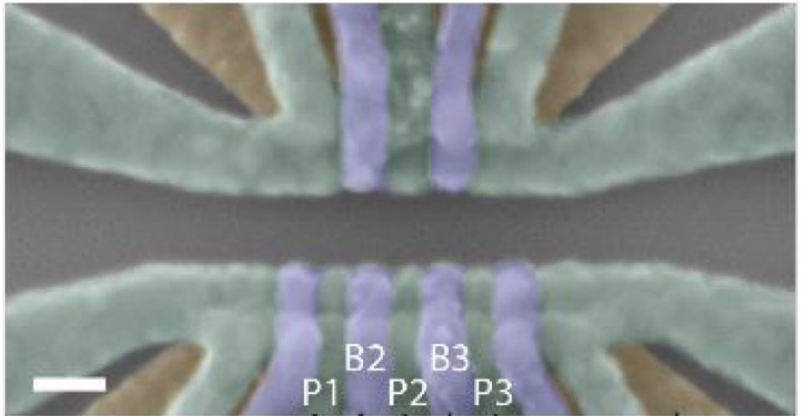
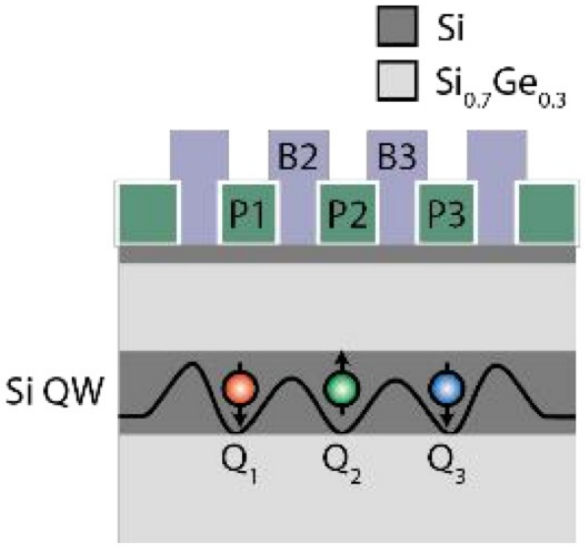
Fast universal quantum gate above the fault-tolerance threshold in silicon

Akito Noiri, Kenta Takeda, Takashi Nakajima, Takashi Kobayashi, Amir Sammak, Giordano Scappucci & Seigo Tarucha

Device

- Si/SiGe (QUTECH)
- 3 Al gate layers (Scr-Plg-Bar)
- Plunger : 65nm, Barrier : 25nm
- SET readout
- Can not tune exchange coupling with B gate (too thin)
- All Bs at 1V to allow coupling, above that hysterysis appears
- Essentially a Plunger-only device

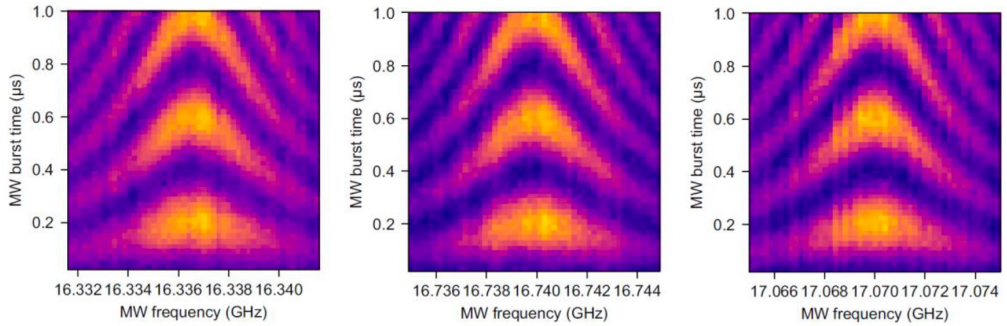


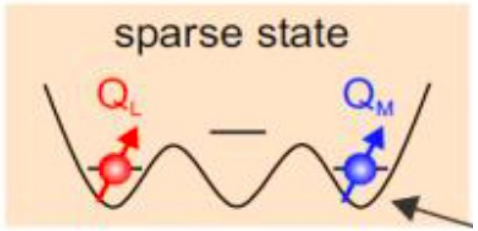


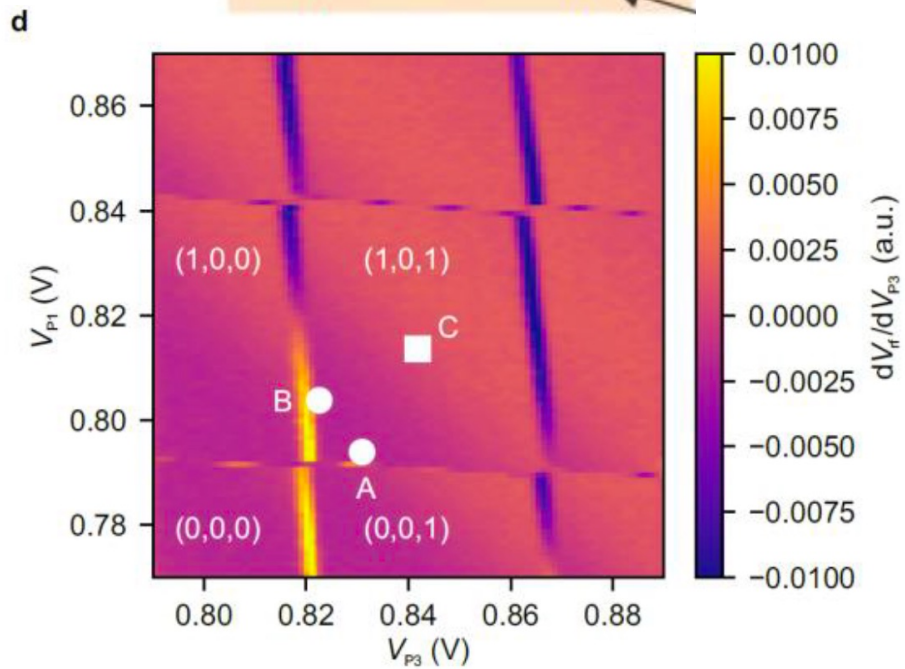
+ cobalt micromagnet (EDSR) -> DEz 403 MHz

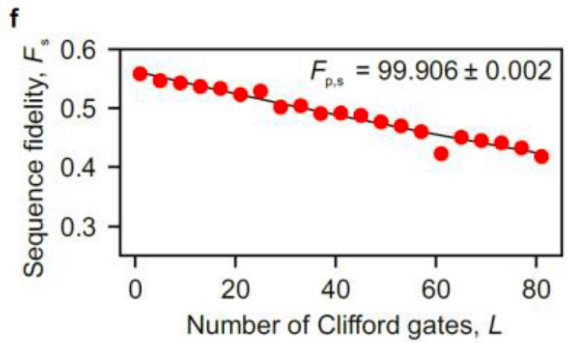
Sparse state

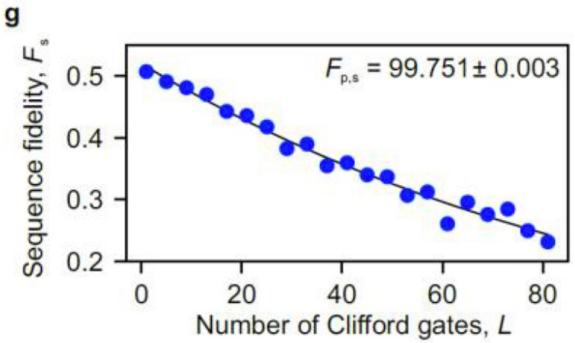
- 1 electrons on QD1 & QD3
- Intialization & Readout by energy selective spin tunneling with reservoirs (A & B)
- Not Virtual Gates CSD
- T^*2= 3 & 4 us -> echo 18 & 28 us
- Simultaneous CRB -> both Fs>99.7%







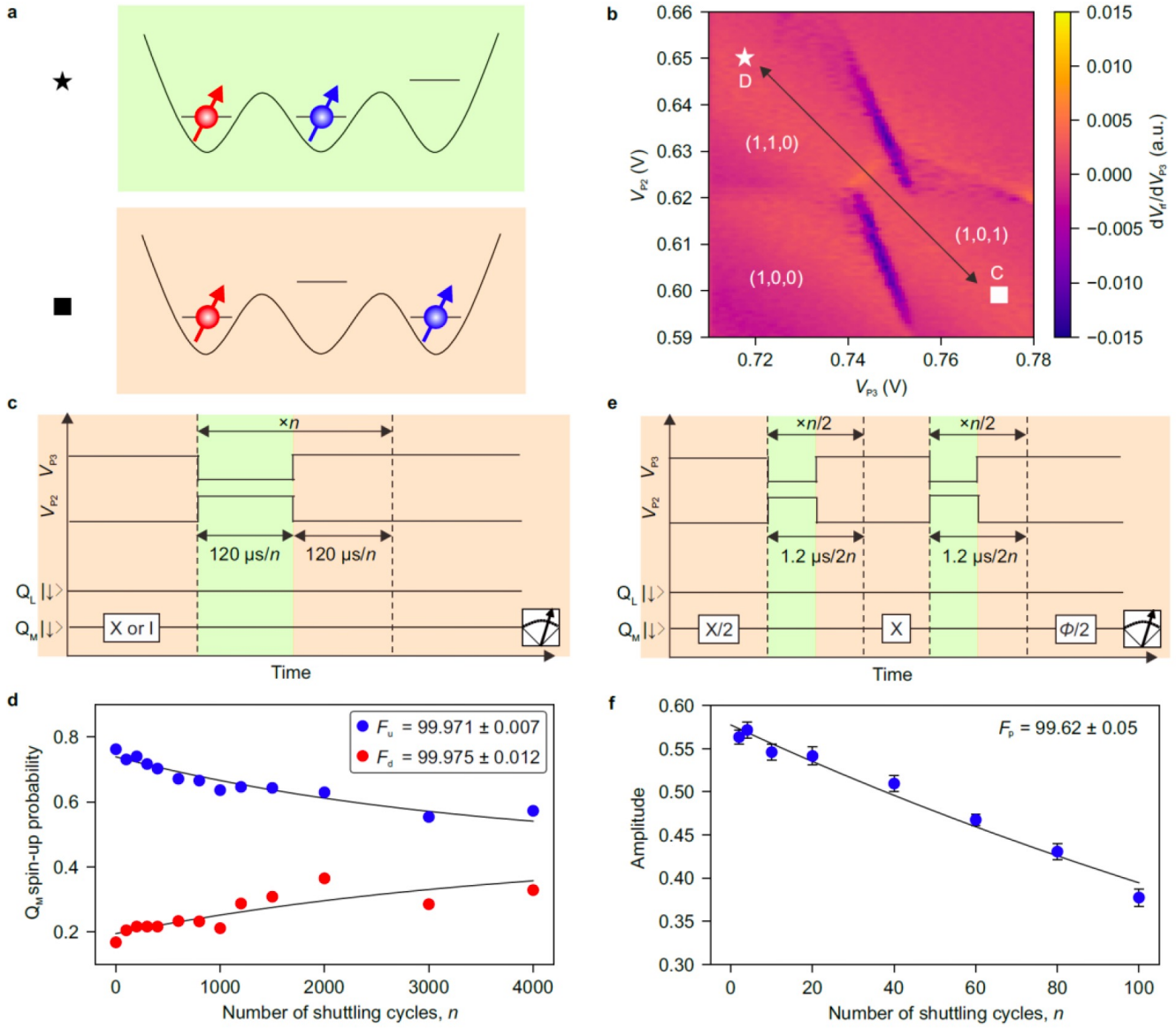




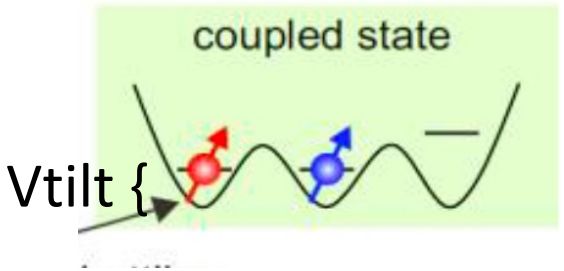
$J = 0.89 \pm 0.10$ kHz

Shuttling

- Tright : 20.2 GHz
- Perform spin polarization fidelity estimation >99.95% p.c.
- Perform spin coherence fidelity estimation >99.5% p.c.
- MOS 99.97% & 99.4% (UNSW 2021)
- ~500 dots (~45 µm) before coherence 1/e.
- Phase shifts (DEz) can be removed by a phase gate

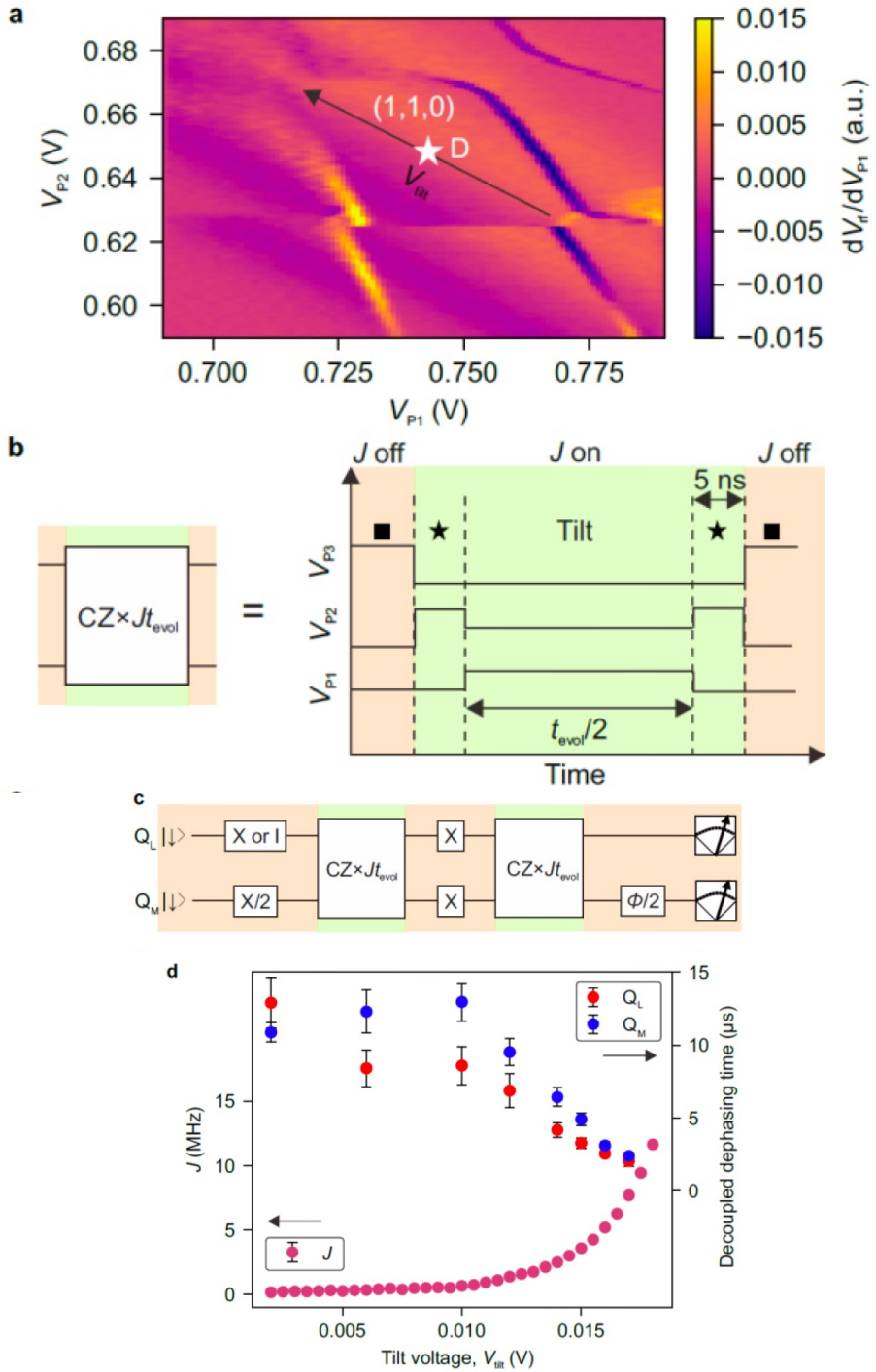


Shuttling Gate



- Vtilt -> detuning induced exchange interaction *J*

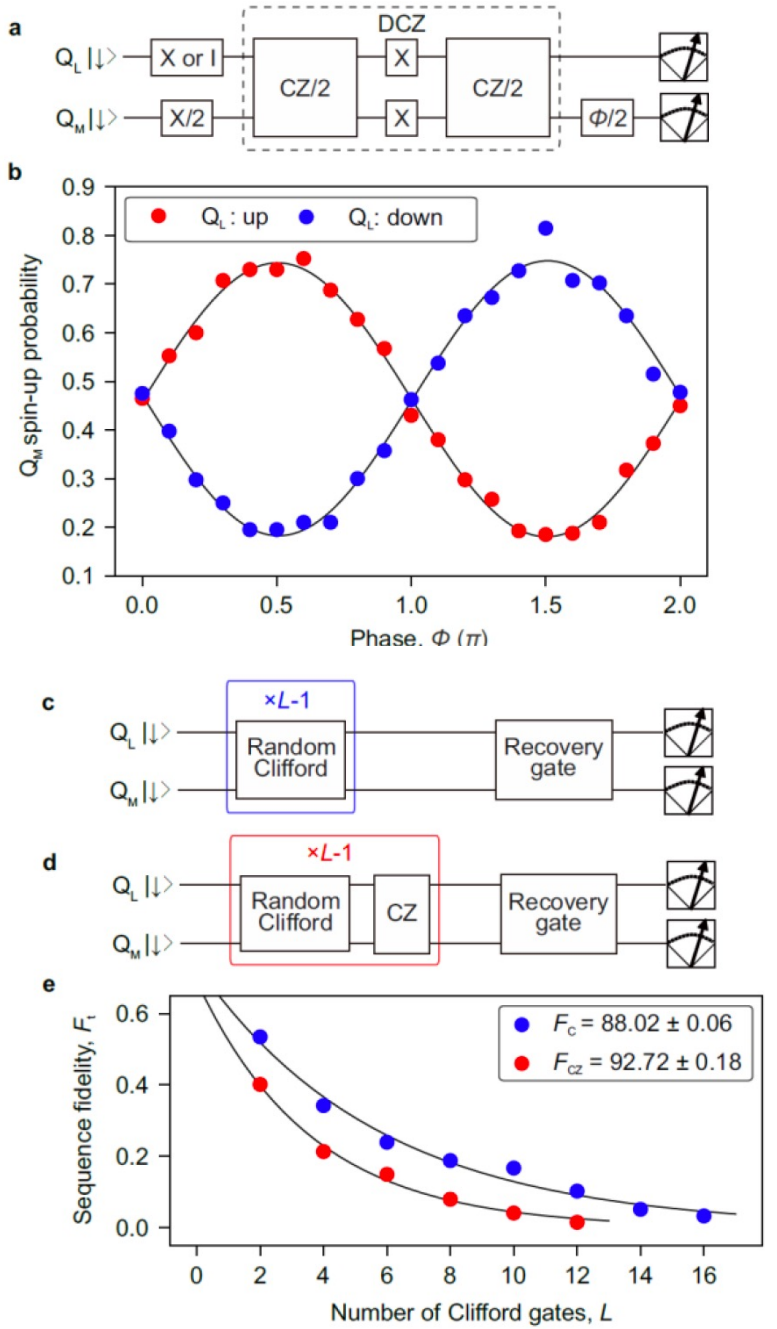
- 5ns wait time to avoid change transitions and no ramp time in pulse included
- Coherence drops – *J* increases with Vtilt
- Optimum for CZ, *V*tilt=0.012 V with *J*=1.25 MHz
- One thousand switching ratio of *J*



DCz shuttling gate

- $t$evol=1/2J=0.4 μs
- Decoupled CZ (DCZ) gate to suppress low-f dephasing during the c-phase evolution (by half time pi pulse)
- The obtained controlled phase is 1.003±0.01 π

- CRB -> Fc > 88% , Fcz >92.5%
- This is due to the slow $t$evol=0.4 μs
- Faster gate with use of barrier gate would improve it



Summary

- Successful impementation of shuttling gate
- Improvent of the turn-off of J between 2 Qubits (<1kHz)
- Low fidelity of CZ is due to absence of barrier tuning of J
- High fidelity of shuttling coherence achieved