Charge sensing and controllable coupling in a Si MOS double quantum dot

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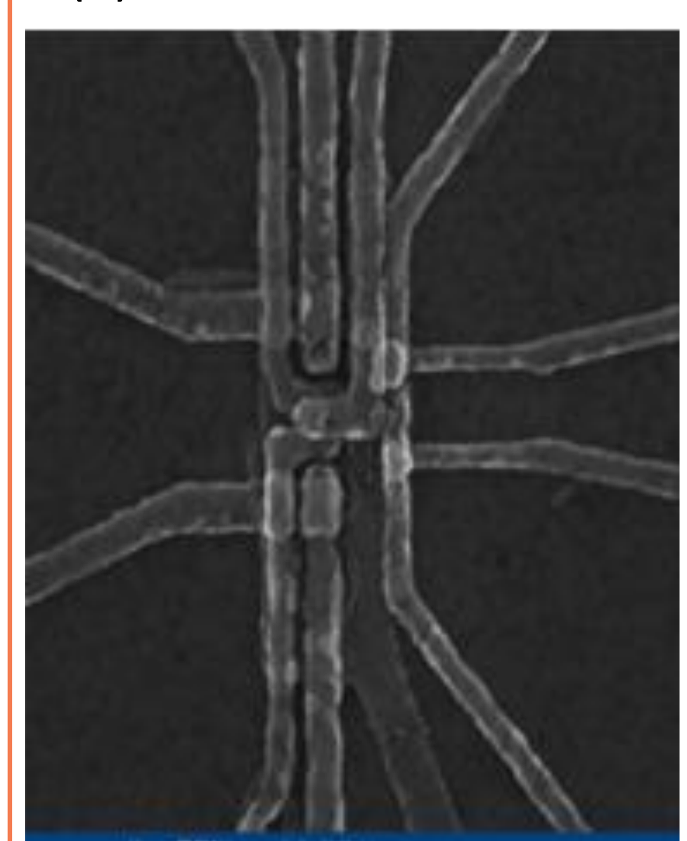
Motivation/Objective

- Spin qubits based on silicon quantum dots (QDs) provide a promising platform for large-scale quantum computation due to the long spin coherence time. In isotopically engineered silicon , hyperfine interaction is totally suppressed , leading to the realization of high-fidelity single and two-qubit gates.[1-2]
- In 2017, the S-O driven S-T qubit offers a relatively simple MOS implementation path.[3]
- Fabrication of several kinds of silicon nMOS quantum dots .
- Observation of charge stability diagrams using charge sensing
- The quantum dot can be tuned to a few-electron region and the inter-dot coupling can be tuned to a large extent.

Design and Fabrication of Si MOS quantum dots

(a)



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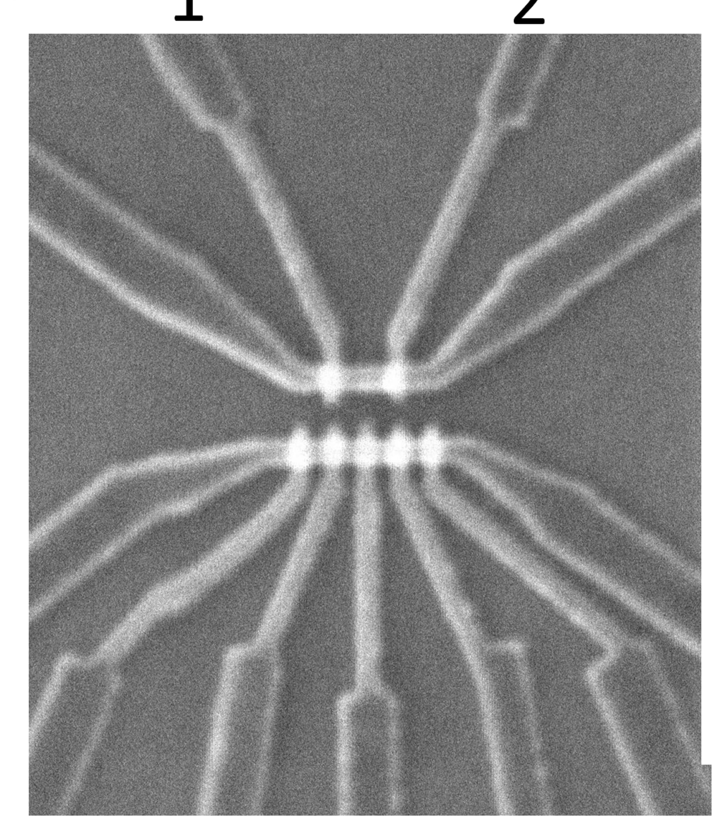
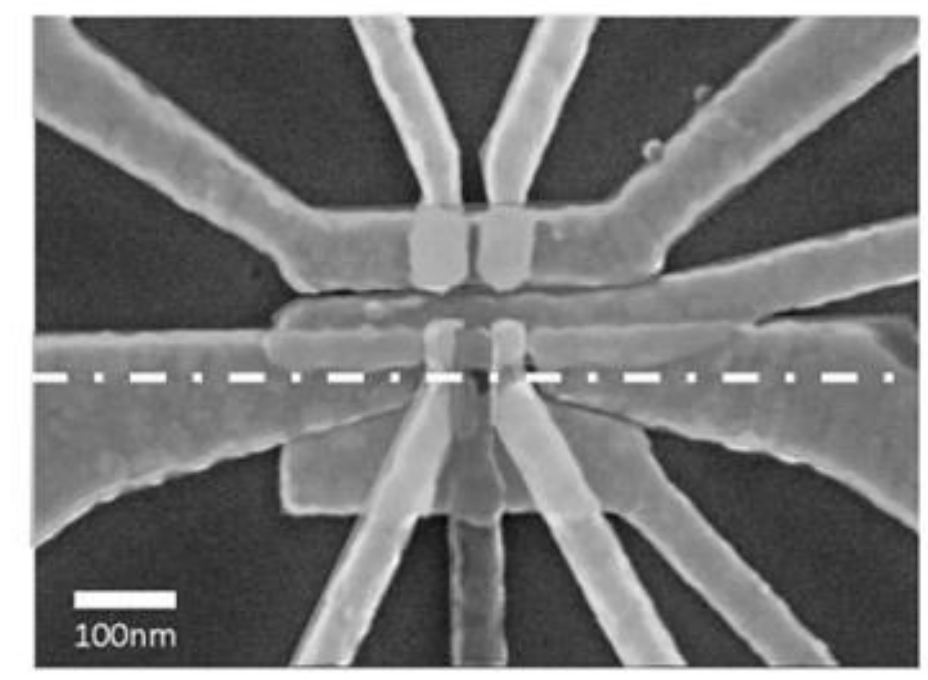


(c)



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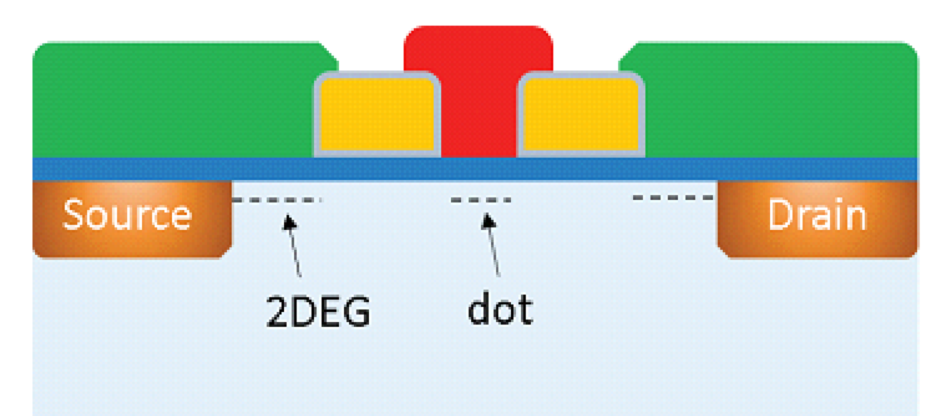
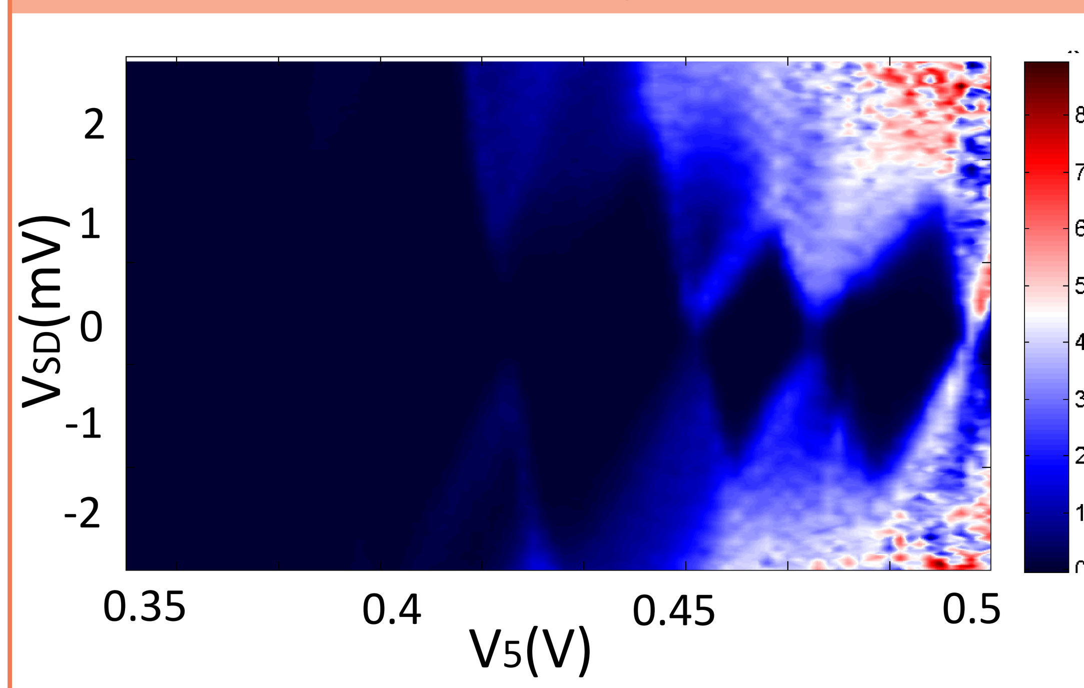
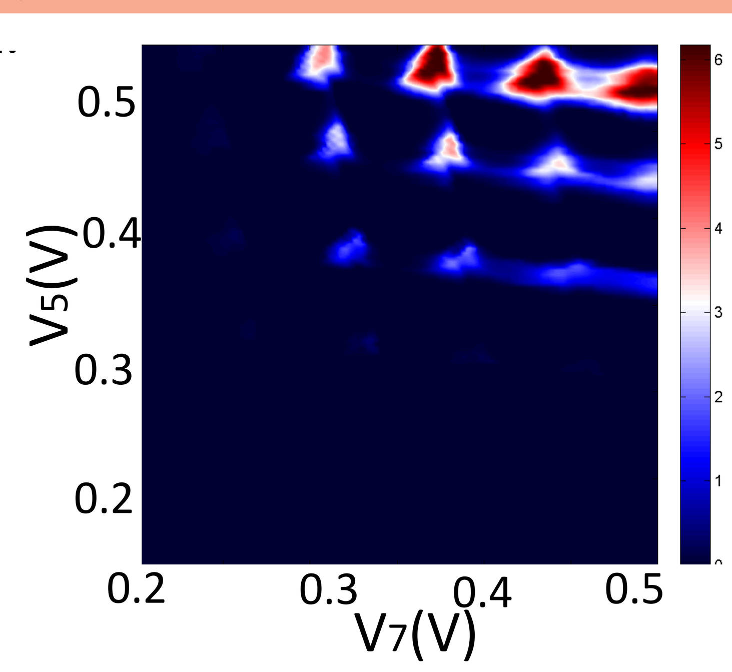


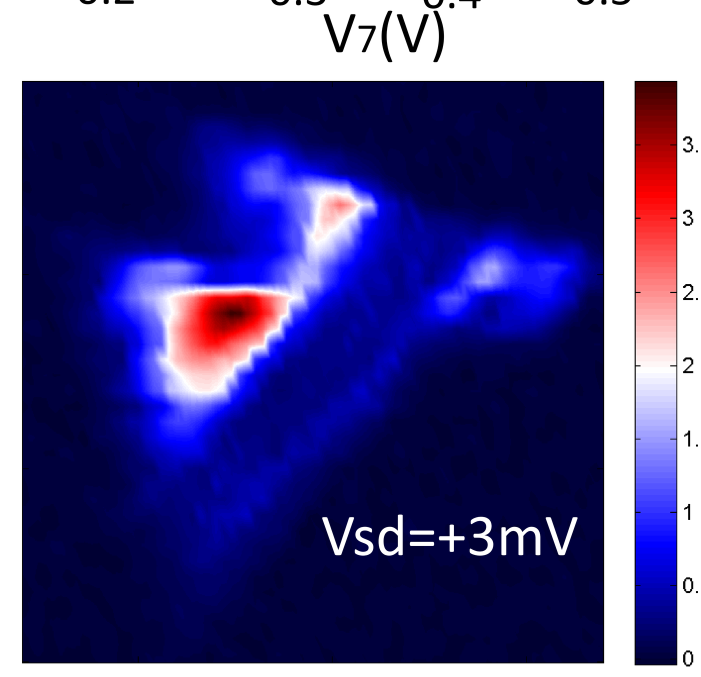
- Scanning electron micrograph (SEM) of three typical Si CMOS quantum dot with a SET as a charge sensor, where a white dash dotted line shows position of the cross section.
- Cross section of a Si CMOS quantum dot, dotted lines denote where 2DEG and quantum dot form.

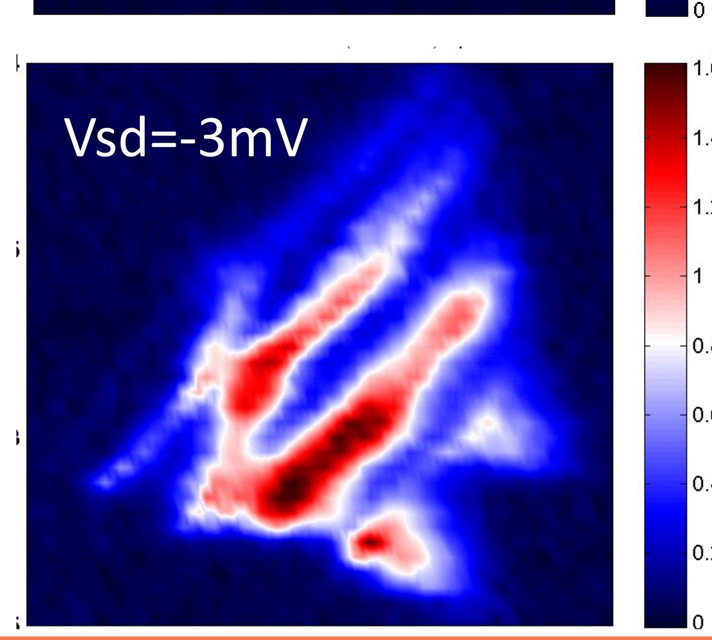
DC transport in silicon quantum dots



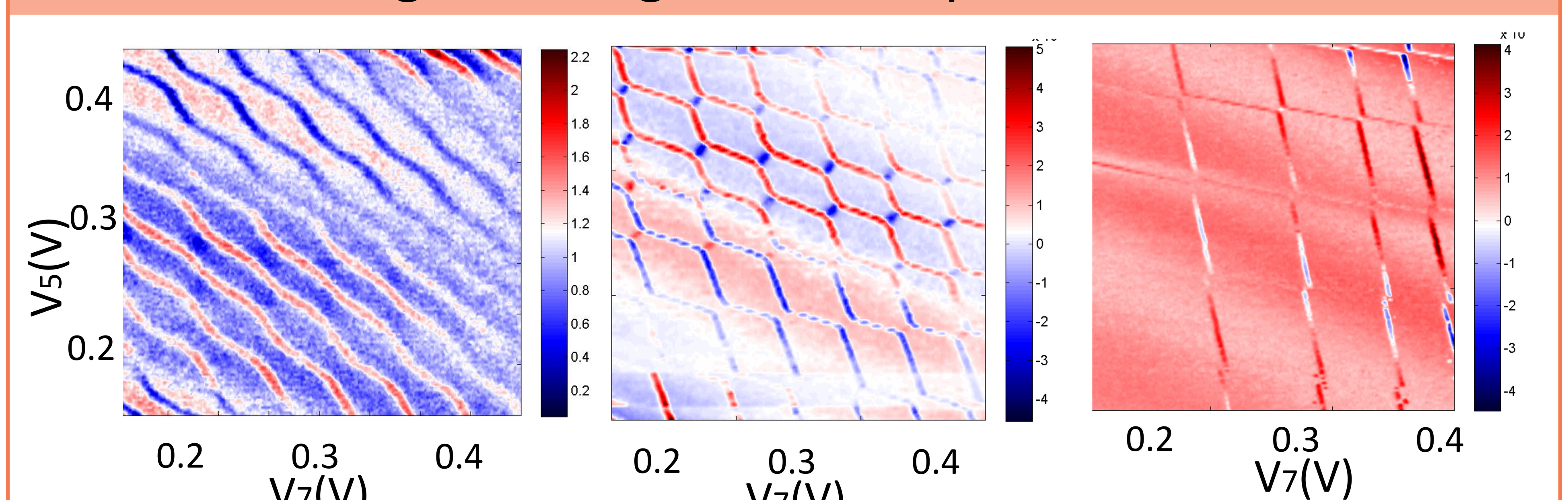


- Coulomb diamonds measured in transport current through the single quantum dot tuned by gate G5.
- The charge stability diagram with Vsd = 2.0mV and $V_{G3}=V_{G4}$=-0.6V. The source-drain current (Isd) is measured as a function of bias on gates G5 and G7.
- Detailed gate G5 vs G7 map showing inter-dot transition of（m，n+1）--（m+1,n）. The source-drain bias is set to +3mV(up) and -3mV(down) and the excited states were measured.

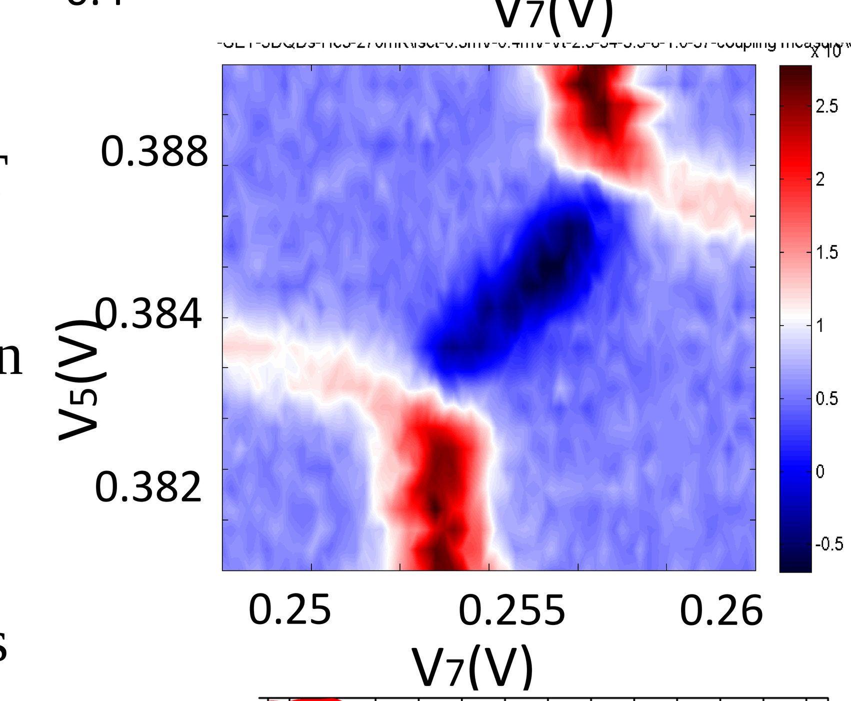


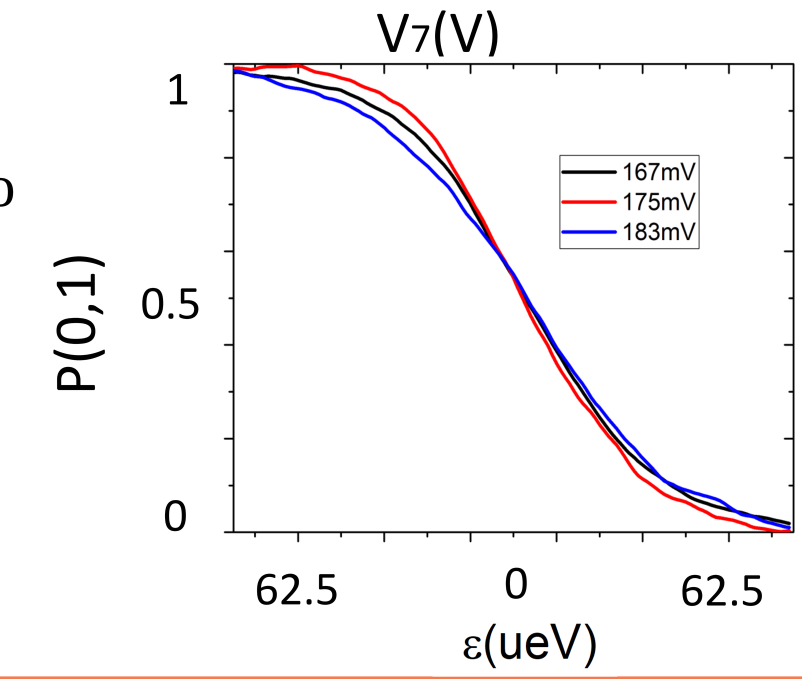


Charge sensing in silicon quantum dots



- Representative stability diagrams of a double quantum dot measured by the SET charge sensor . Images showing the SET transconductance dI_{SET}/dV_R as a function of gate voltages V5 and V7 at different middle gate voltages V6.
- Comparison of these figures demonstrates the ability to use the middle gate 6 to tune the DQD from a strongly coupled regime to a weakly coupled regime .
- Plots of P(1,0) as a function of detuning at different V6 values, showing tunable inter-dot tunnel coupling at the (1,0)–(0,1) inter-dot charge transition.





Future Directions

- Define single and double dots in the few electron regime.
- Implement single- and two- qubit logic gates using ESR.
- Realize EDSR driven S-T qubit in Si–nMOS and Si-pMOS system.

References

[1] M. Veldorst, A.S. Dzurak *et al.*, Nature Nanotechnology **9**, 981 (2014).

[2] M. Veldhorst, C.H. Yang, and A.S. Dzurak *et al.*, Nature **526**, 410 (2015).

[3] Ryan M. Jock *et al.*, arXiv:1707.04357v1 (2017).