SAND2012-5298P

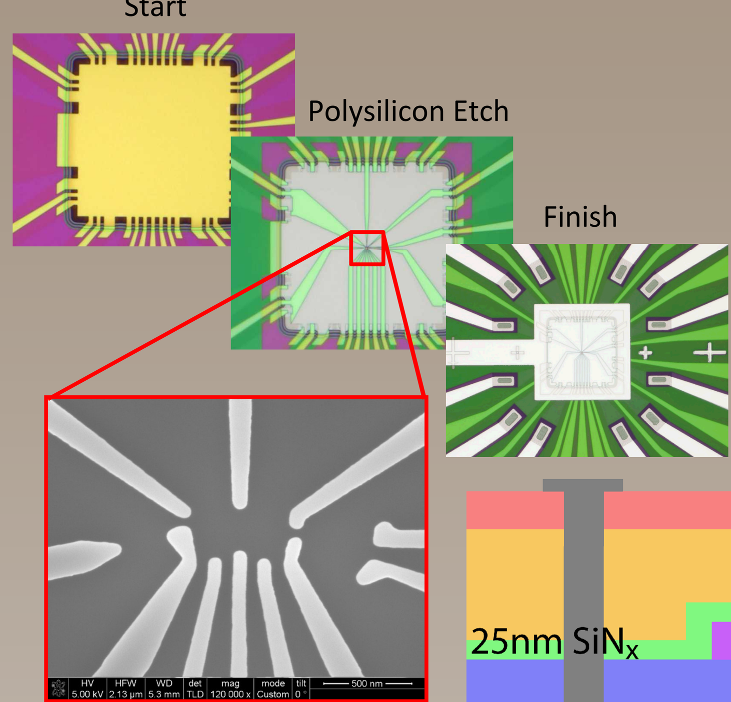
Exceptional service in the national interest

Sandia National Laboratories

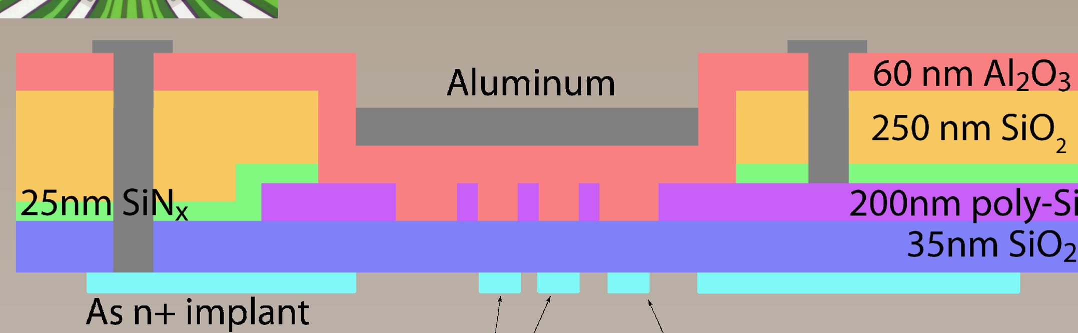
Electrometer sensitivity for spin readout

Nathan Bishop, Khoi Nguyen, Steve Carr, Joel Wendt, Erik Nielsen, Ralph Young, Lisa Tracy, Greg Ten Eyck, Jason Dominguez, Bev Silva, Tammy Pluym, Rick Muller, Mike Lilly, and Malcolm Carroll.

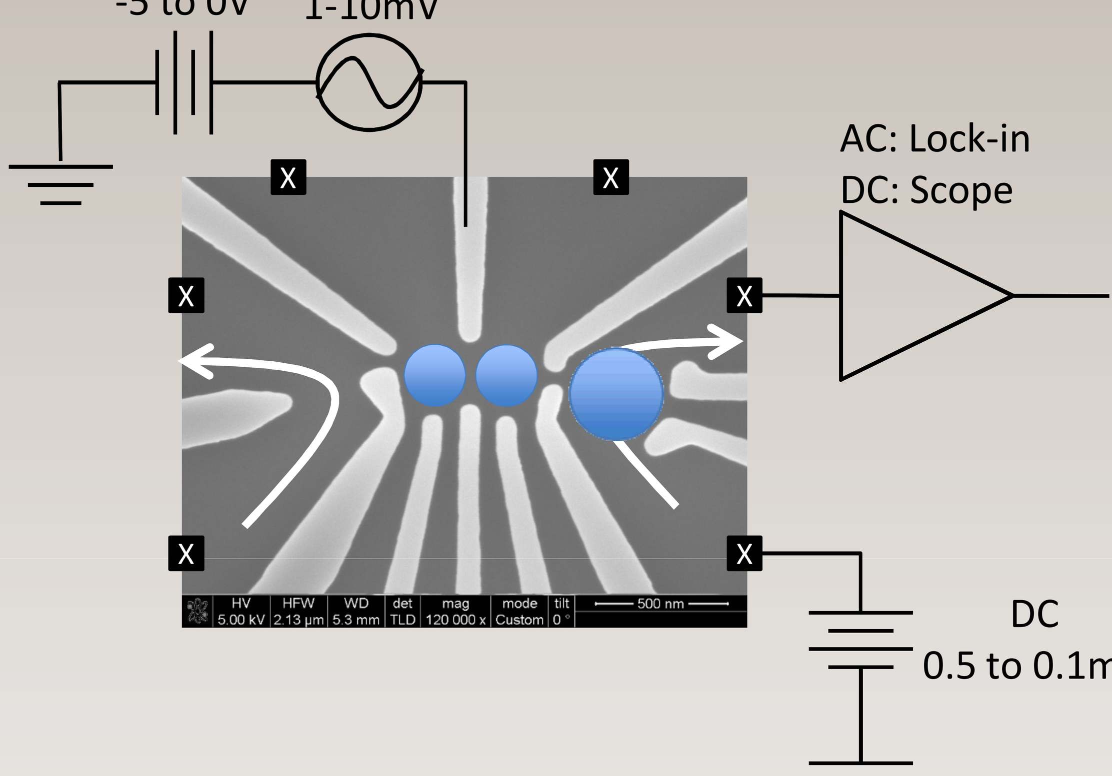
Quantum dots with integrated electrometers



1. Gate oxide growth (critical interface)
2. Polysilicon deposition and gross pattern
3. Ohmic contact implant and anneal
4. Encapsulation and metallization
5. EBL and fine patterning of polysilicon
6. AlOx deposition
7. Final metallization



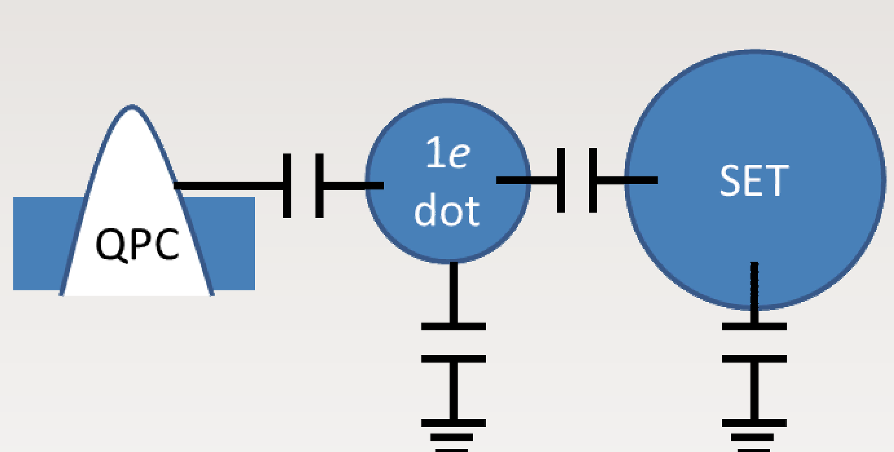
Measurement circuit



Charge sensing is fundamentally electrometry (charge counting). The ideal electrometer is:

- Sensitive
- Does not saturate or lose sensitivity over a large number of single electron transitions
- Tunable independently of the DQD being monitored
- Fast

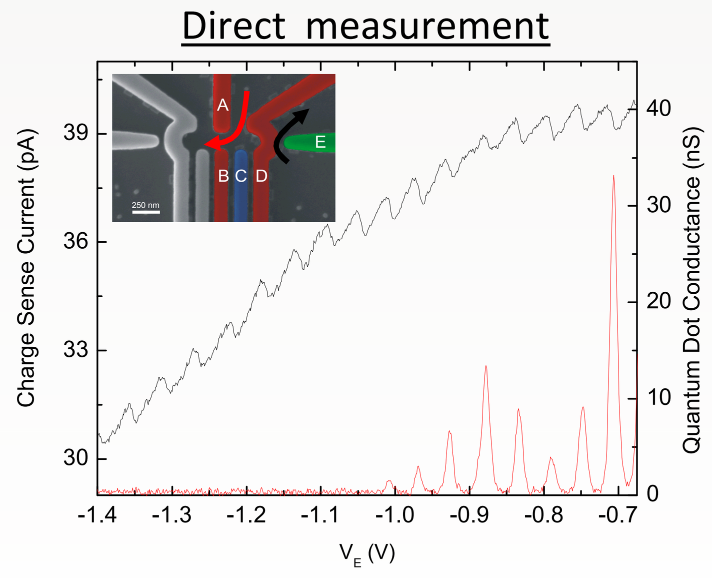
The largest factor affecting sensitivity is distance from dot to sensor. Other factors are the charging energy of the dot and intrinsic sensitivity of the electrometer (dIcs / dVcs).



A simple yet effective model is capacitance. Changing the electron number on the dot changes the potential on the sensor through a capacitive voltage divider. When the capacitive coupling between the dot and charge sensor is a large fraction of the total dot capacitance, the sensor response will be large.

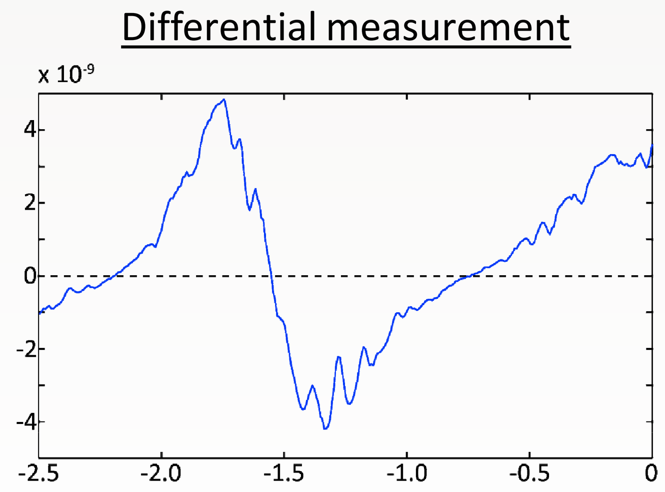
Direct vs. differential measurement

Direct measurement



- DC or quasi-DC measurement
- Suitable for **single shot readout**
- More difficult

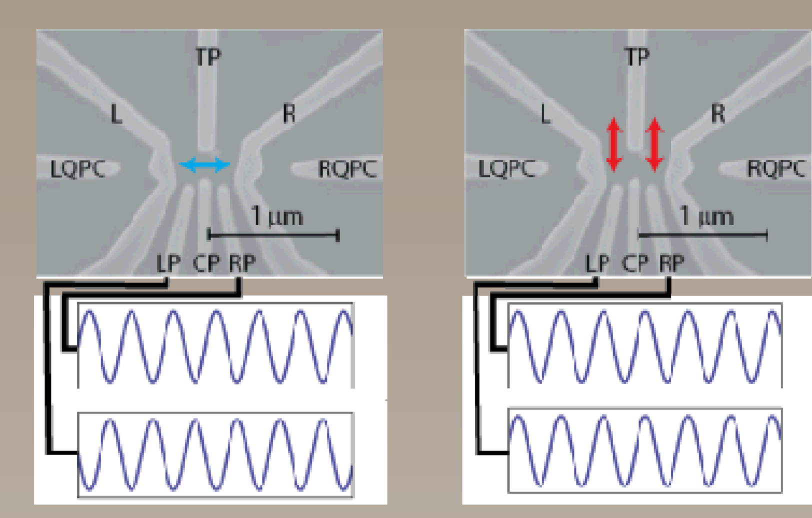
Differential measurement



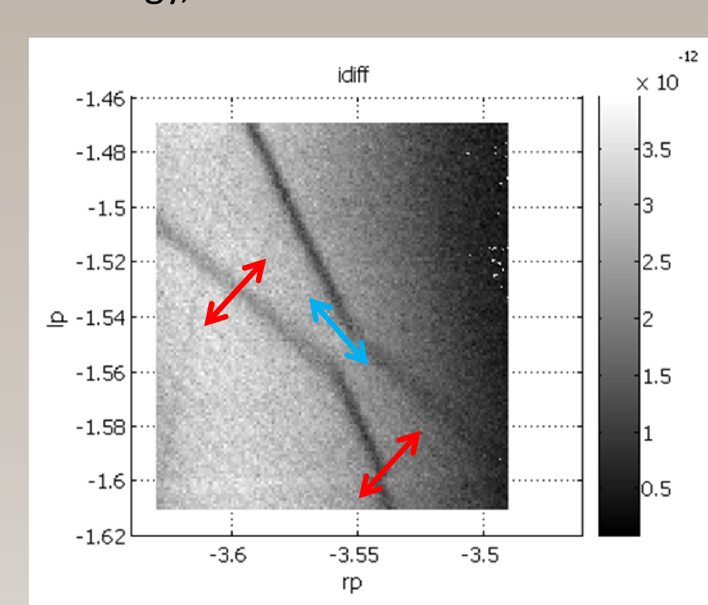
- AC measurement
- Can measure **tunneling rates**
- Faster (noise rejection)

Charge sensing experiments

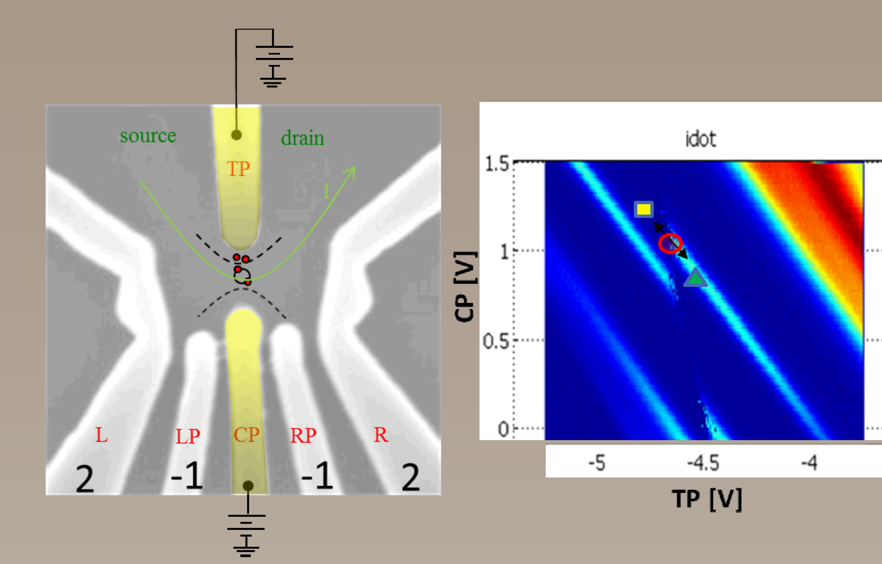
Double quantum dot – charge transfer



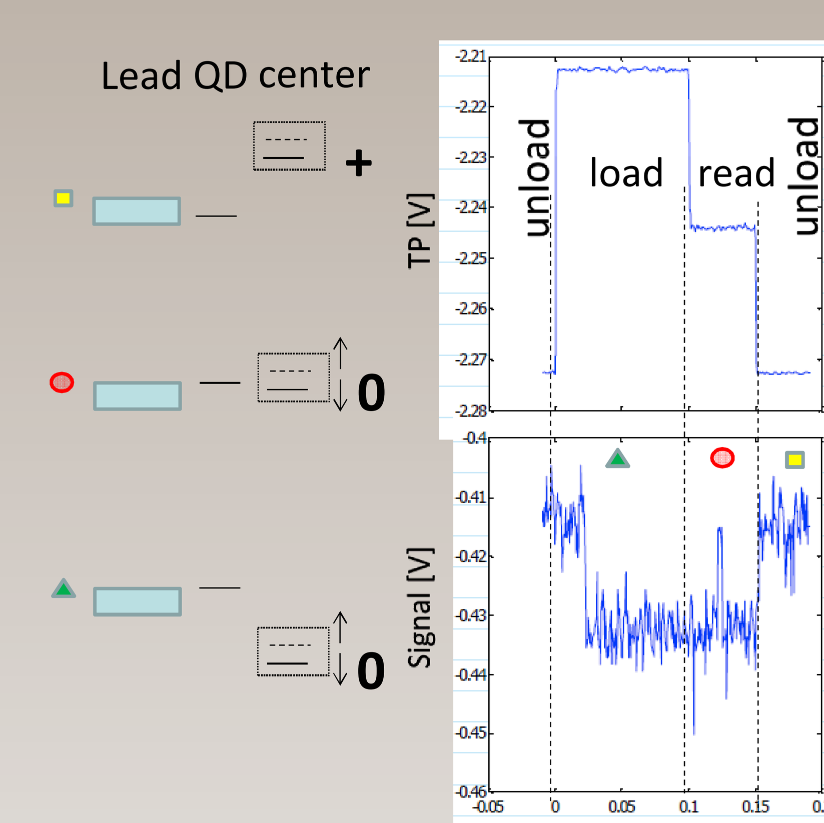
- Transfer charge either from dot to dot or dot to 2DEG
- Differential technique
- Measure Pauli blockade, dot charging energy, etc.



Spin readout



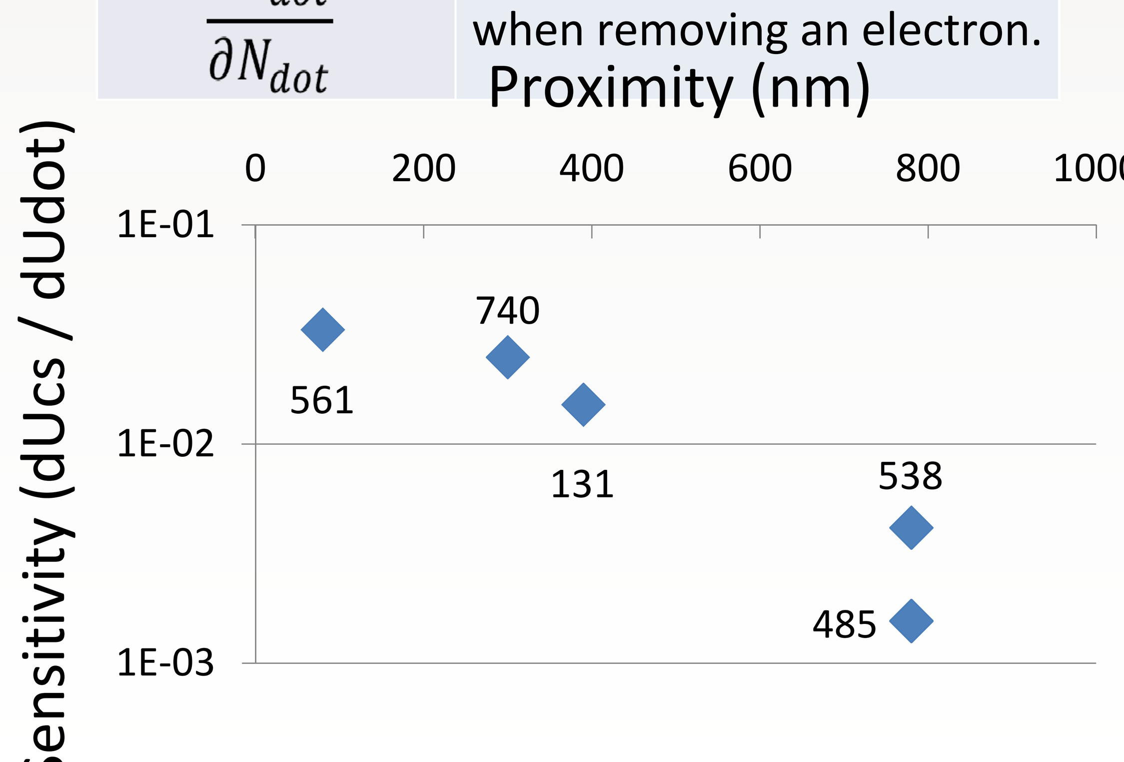
- Transfer charge either from dot to donor
- Direct technique
- Measure electron spin localized to Sb donor

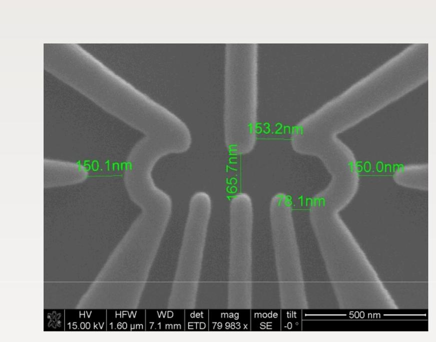


Electrometer sensitivity

$$\frac{\partial I_{cs}}{\partial N_{dot}} = \frac{\partial I_{cs}}{\partial V_{g,cs}} \frac{\partial V_{g,cs}}{\partial U_{cs}} \frac{\partial U_{cs}}{\partial U_{dot}} \frac{\partial U_{dot}}{\partial N_{dot}}$$

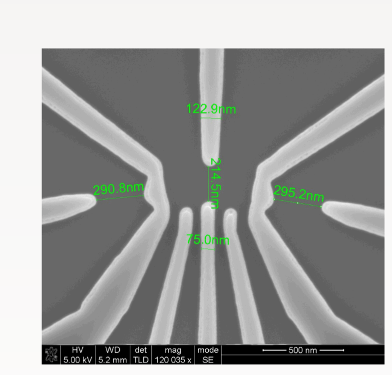
Parameter	Comment
$\frac{\partial I_{cs}}{\partial N_{dot}}$	Magnitude of measured response
$\frac{\partial I_{cs}}{\partial V_{g,cs}} \frac{\partial V_{g,cs}}{\partial U_{cs}}$	Sharpness of peak (disorder dominated).
$\frac{\partial U_{cs}}{\partial U_{dot}}$	Coupling between dot and CS. Design parameter!
$\frac{\partial U_{dot}}{\partial N_{dot}}$	Change in dot potential when removing an electron.





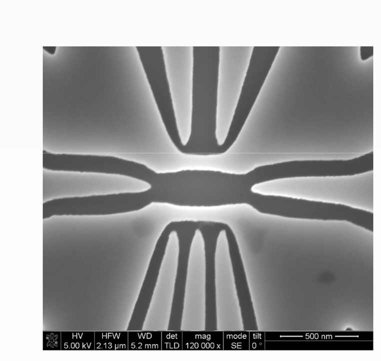
Ottawa Fanned Mod

Device 131



Ottawa Thin 270nm

Device 485
Device 538



Gated Wire V4

Device 740

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP
LDRD
AQUARIUS™ Adiabatic quantum architectures in ultracold systems