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Triangulating the Position of Antimony Donors Implanted in Silicon

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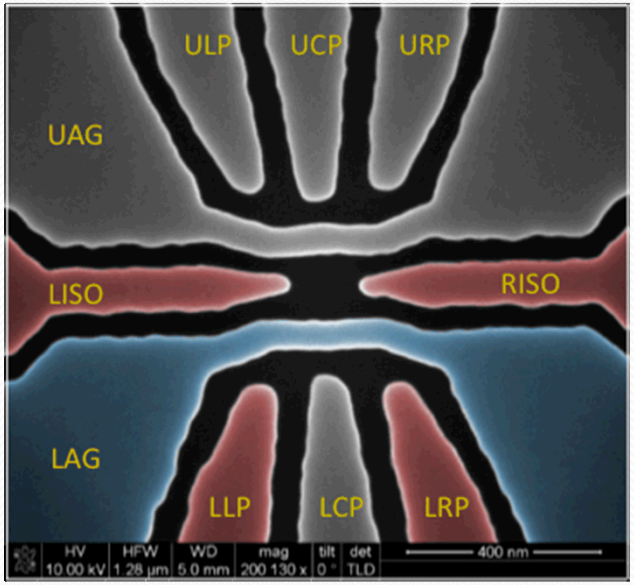
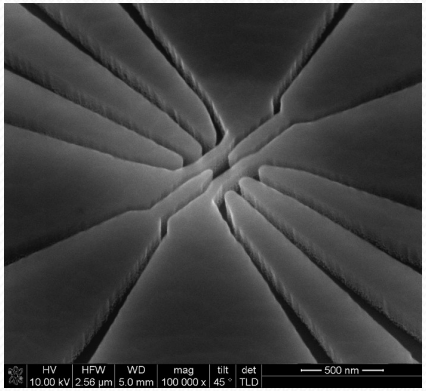
Outline

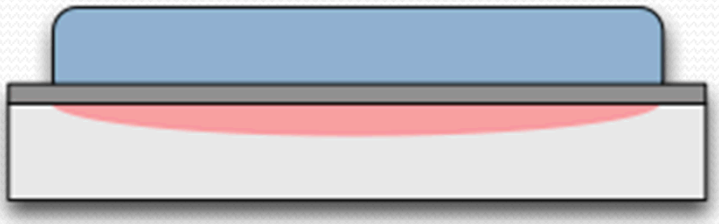
- The silicon device with donors
- What is an offset?
- Using experimental data to estimate donor position
- Numerical simulations allowing a more precise estimate of donor positions

The silicon device

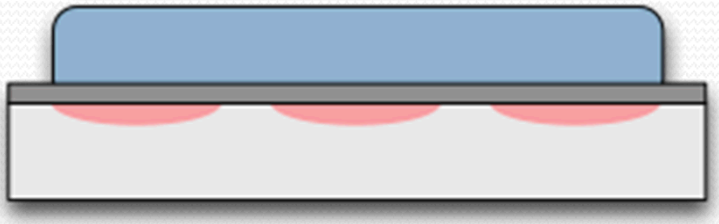




1. Apply a positive voltage to LAG to induce 2DEG.

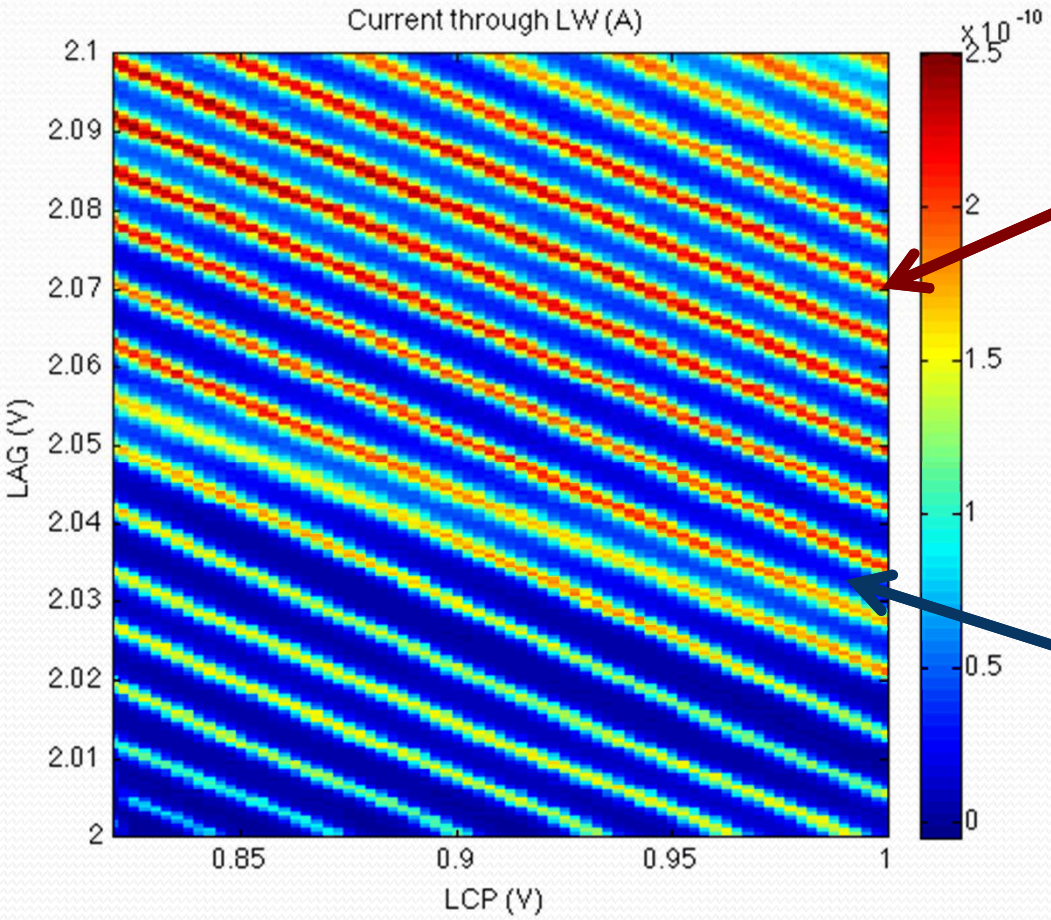


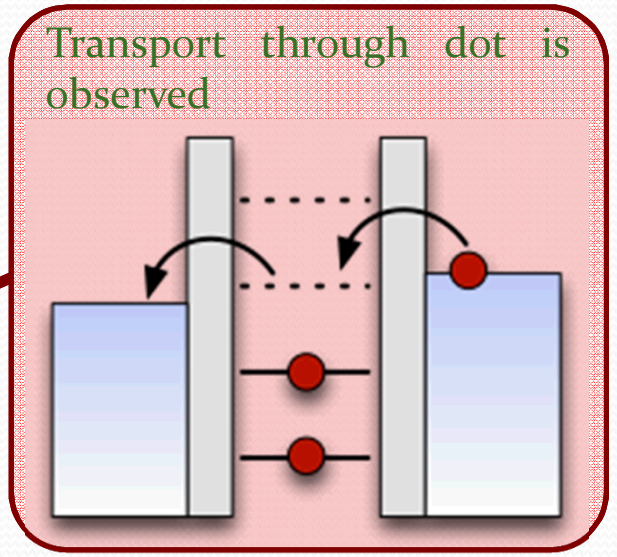
2. Apply negative voltages to LLP, LRP, LISO and RISO to form a dot.

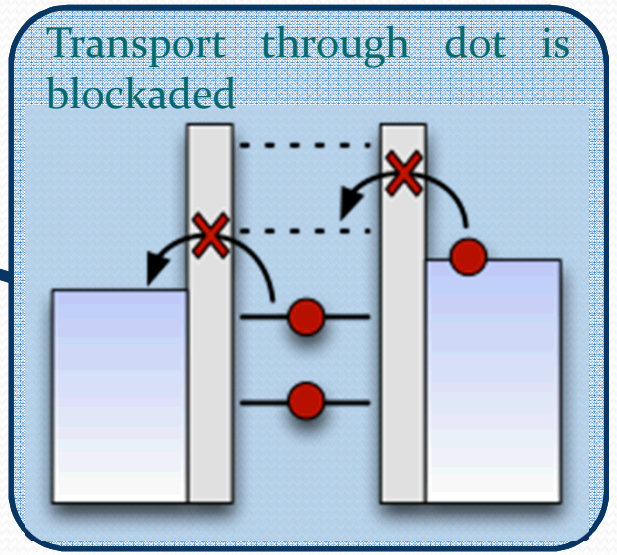


3. Control number of electrons on dot with LAG and LCP. Use upper wire as a charge sensor.

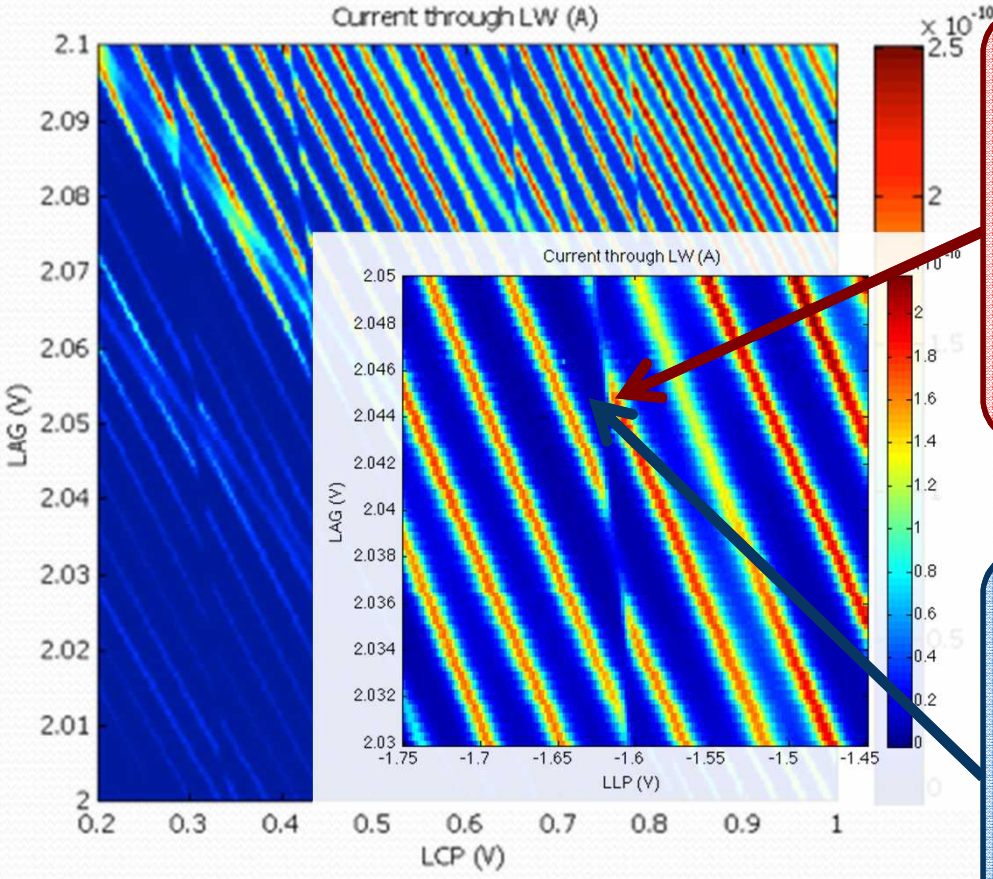
Coulomb blockade

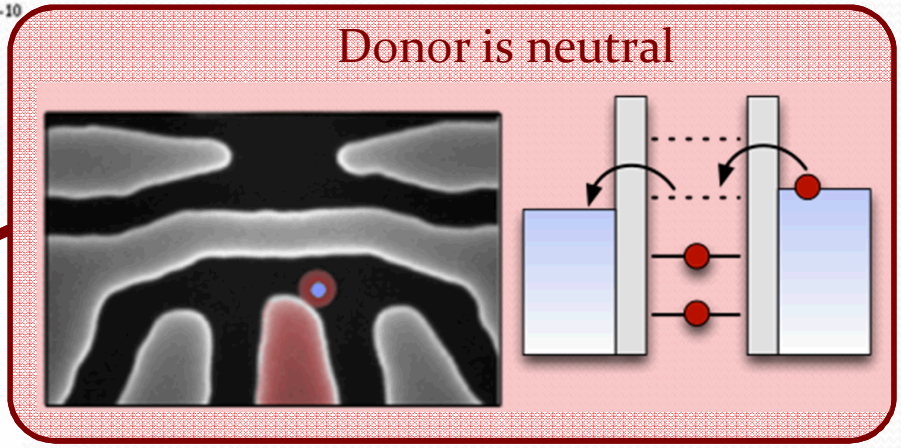


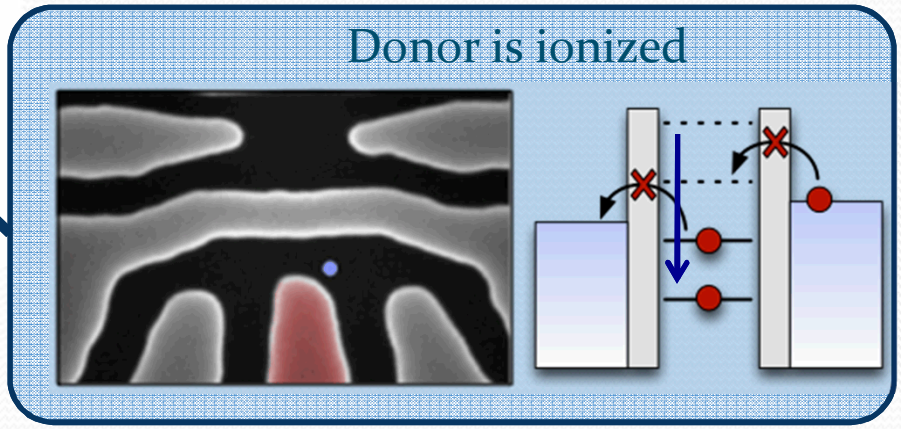




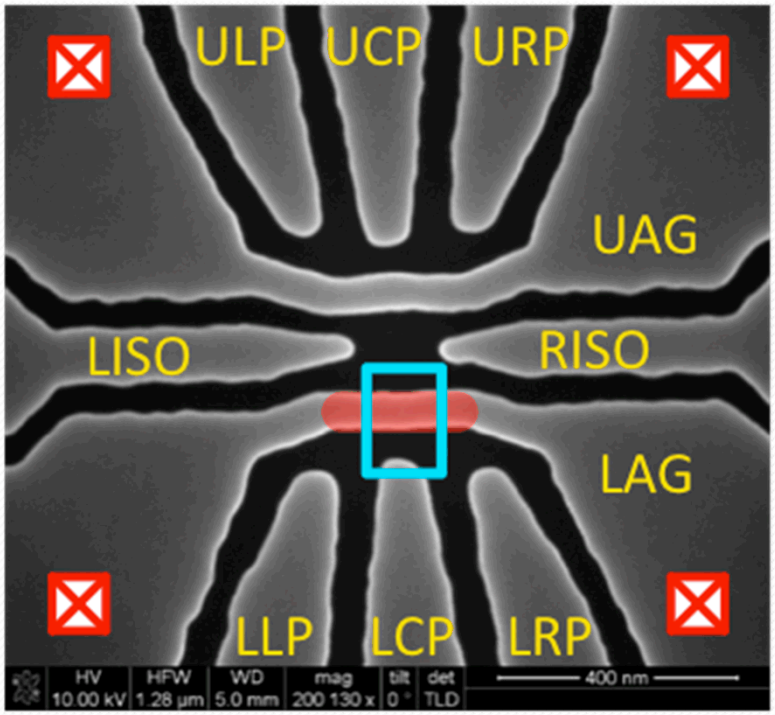
What is an offset?

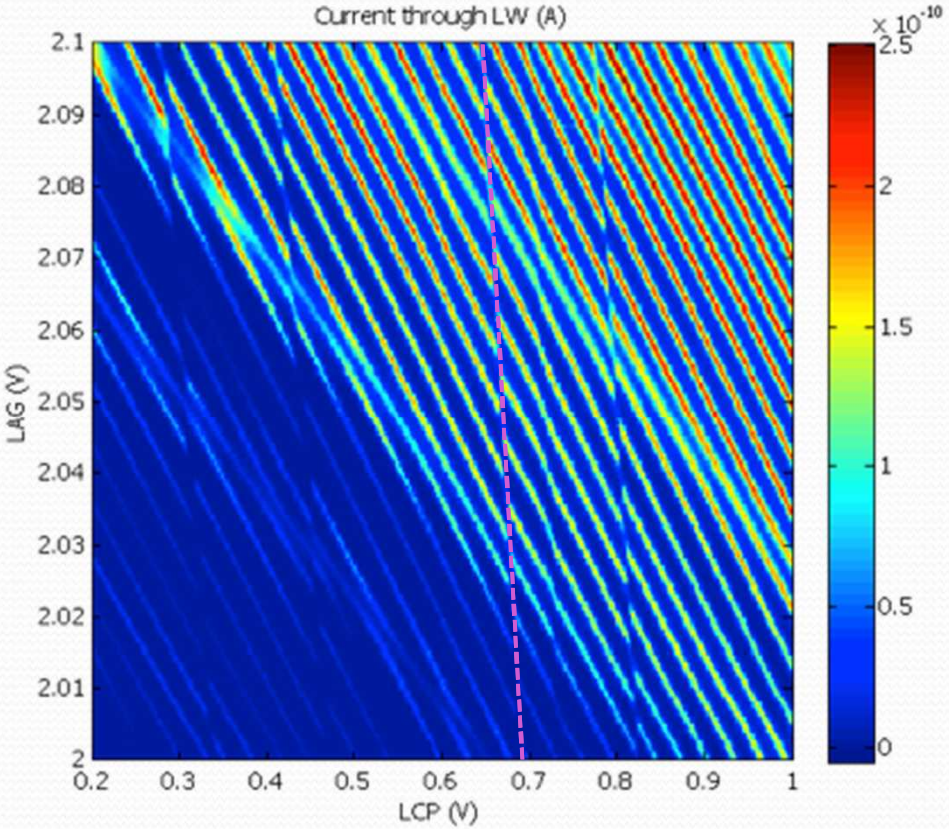






Triangulating donor position



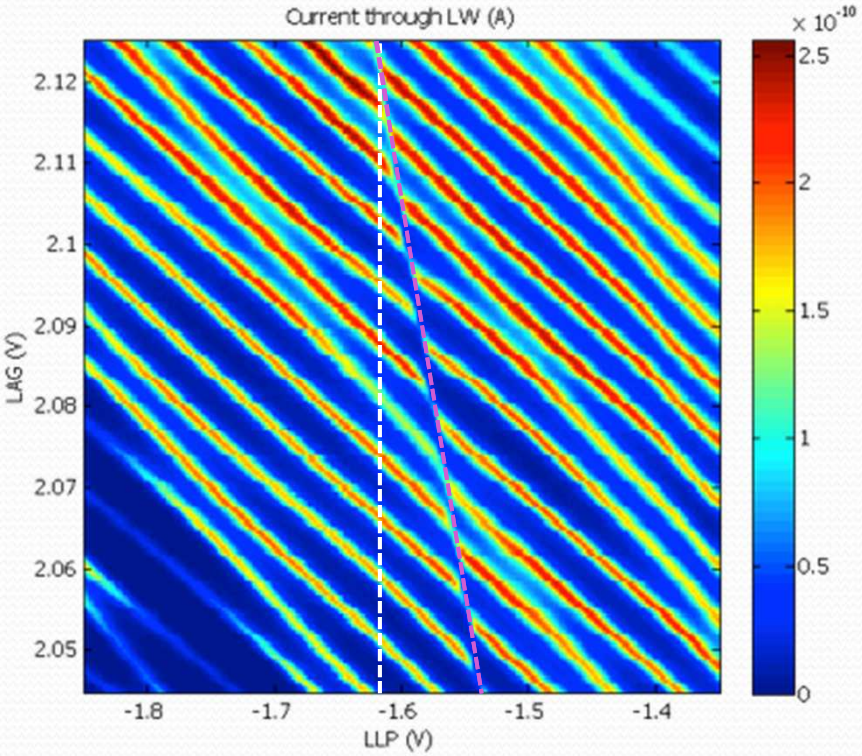


Natural Si device implanted with Sb donors on both sides of the lower wire.

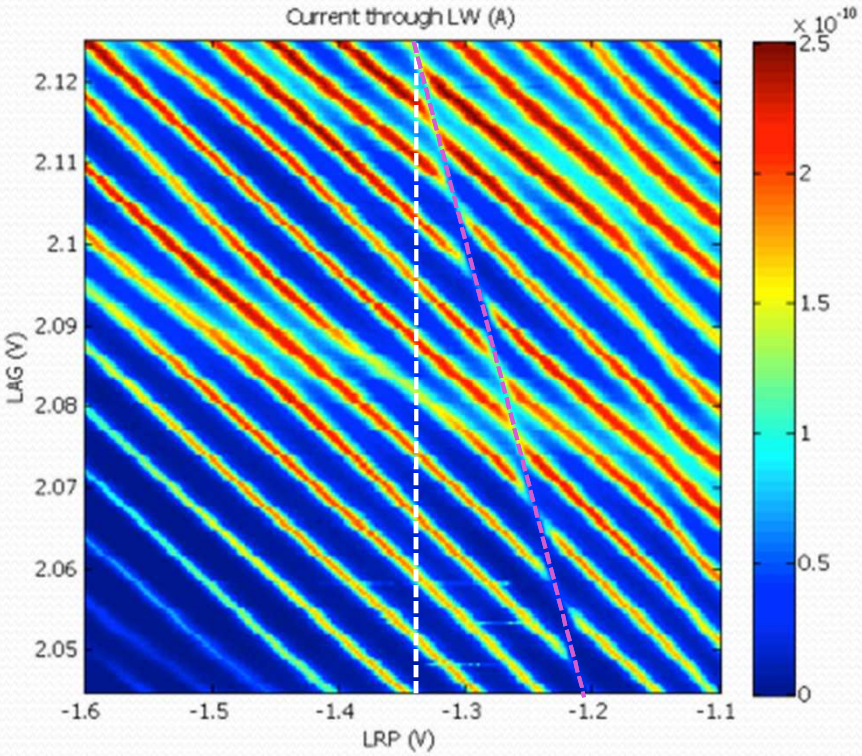
Several offsets can be seen.

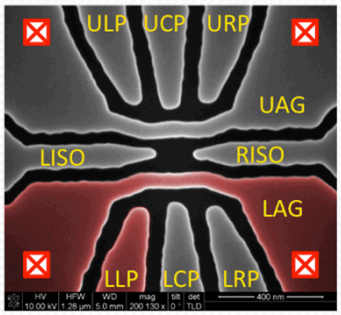
We would like to determine the location of the donors causing these offsets.

LLP vs LAG

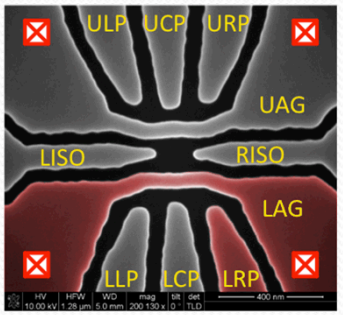


LRP vs LAG

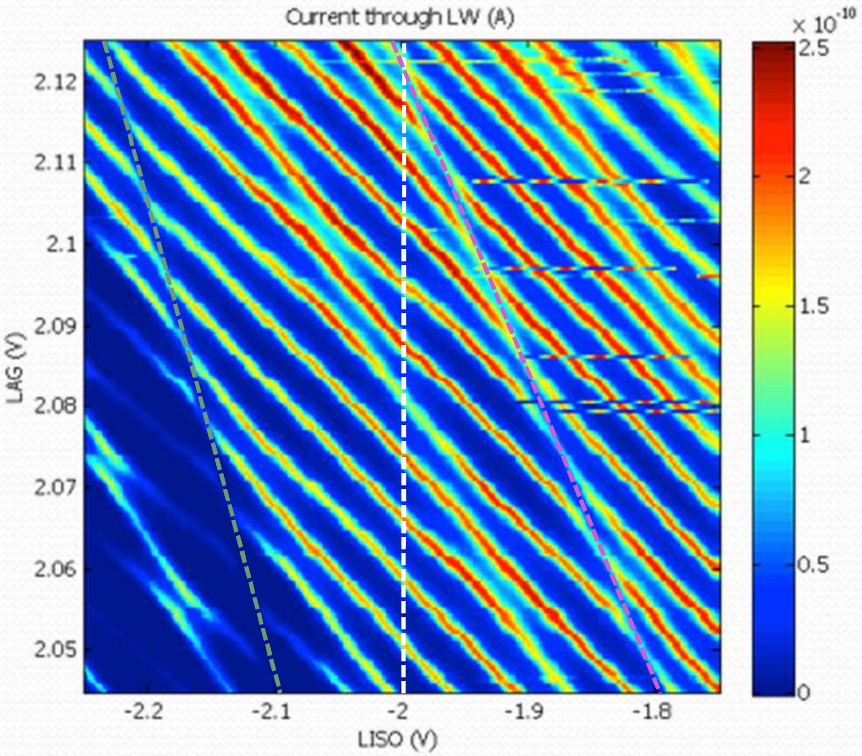




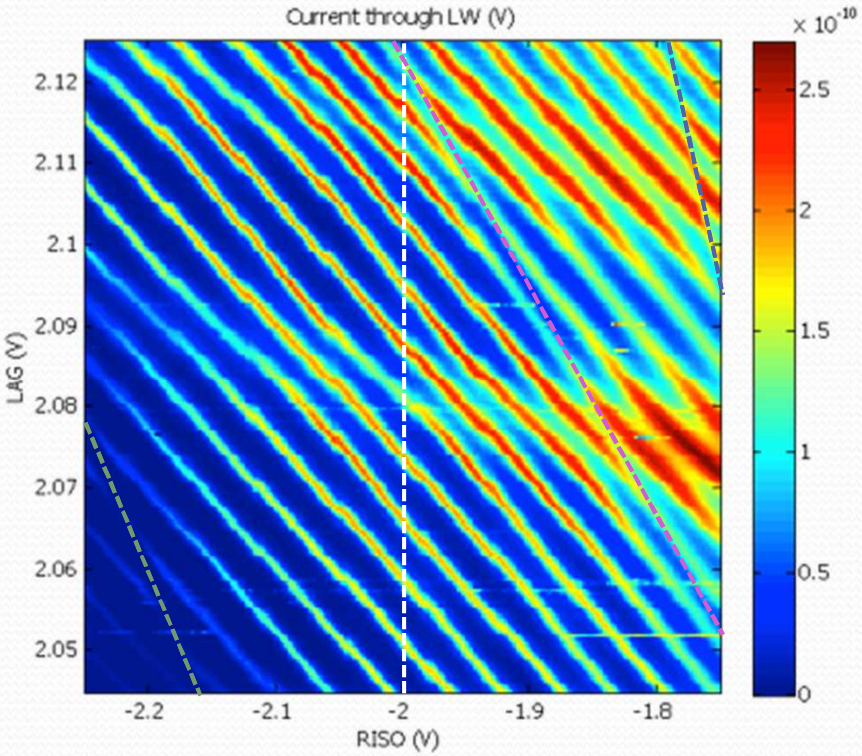
- The white line corresponds to the same parameters in both graphs.
- The offset highlighted in pink is caused by the same donor.
- The slope of the offset is steeper in LLP than in LRP, so the donor is situated to the left of LCP.

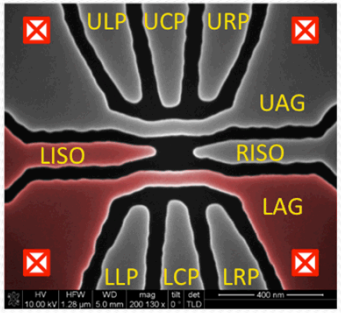


LISO vs LAG

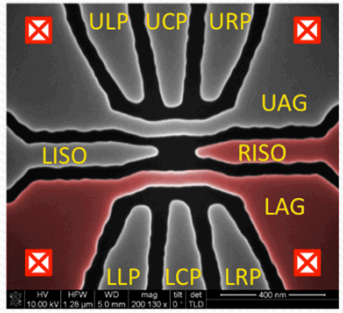


RISO vs LAG

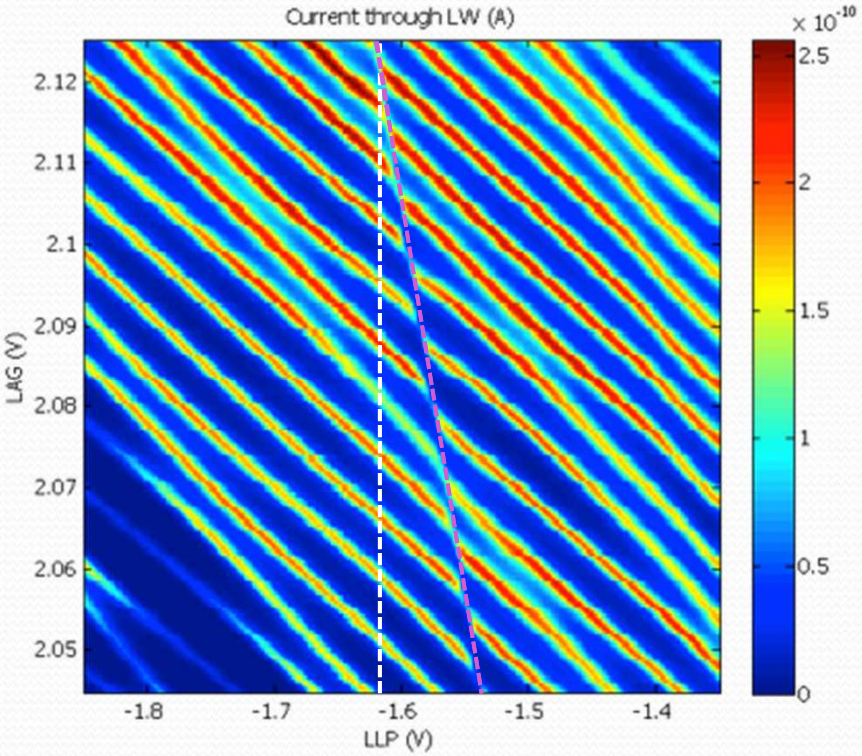




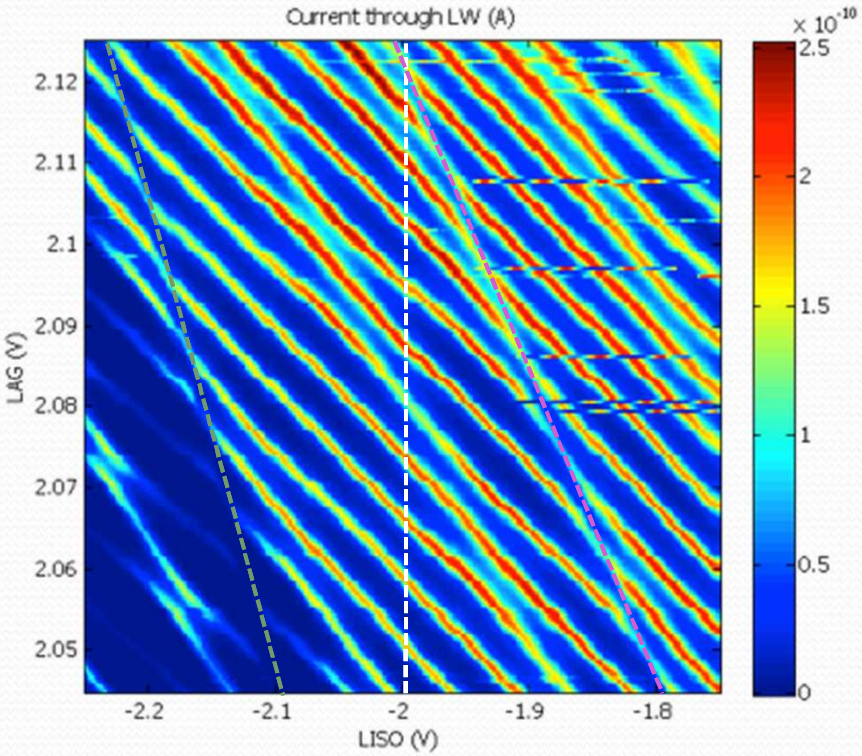
- The white line corresponds to the same parameters in both graphs.
- The offset highlighted in pink is caused by the same donor.
- The slope of the offset is steeper in LISO than in RISO, so the donor is situated to the left of LCP.

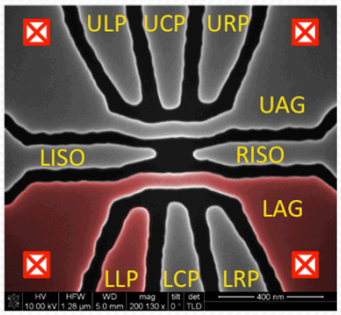


LLP vs LAG

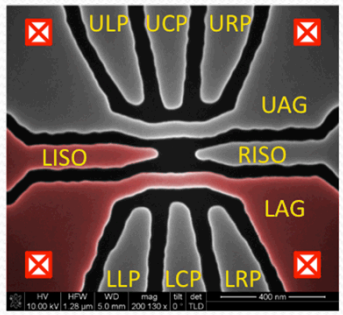


LISO vs LAG

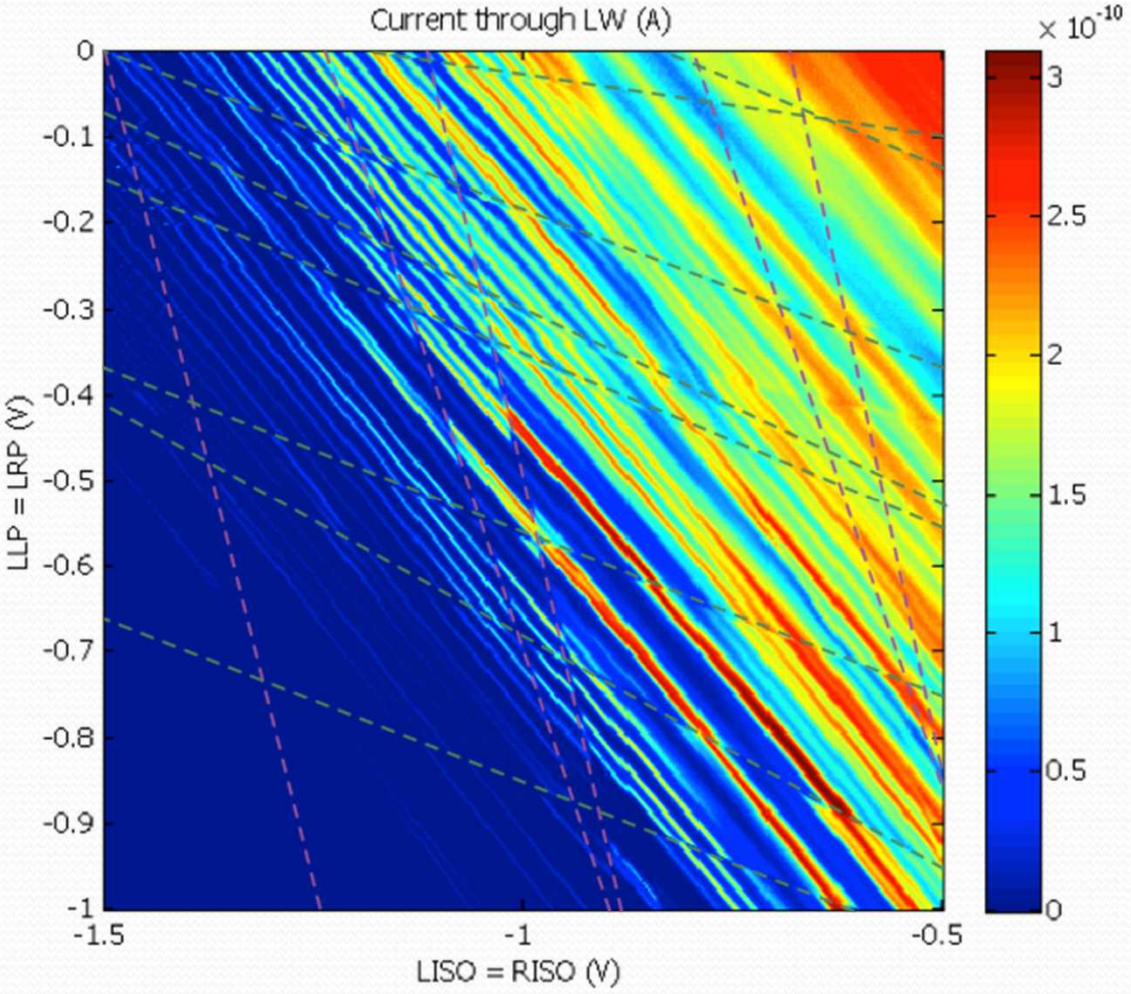




- The white line corresponds to the same parameters in both graphs.
- The offset highlighted in pink is caused by the same donor.
- The slope of the offset is steeper in LLP than in LISO, so the donor is situated below the wire.



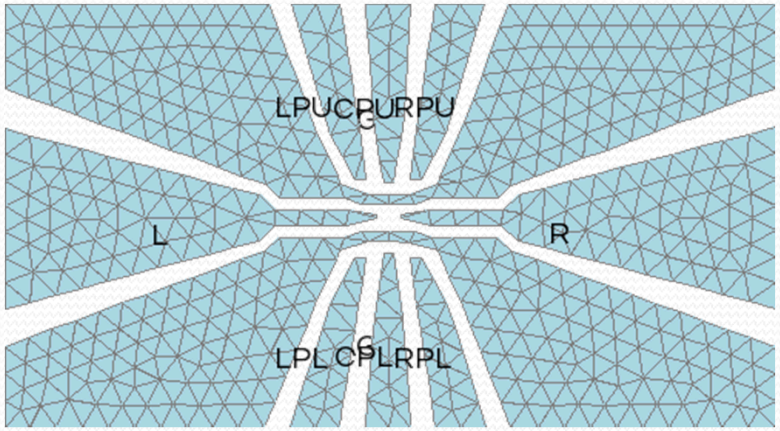
Identifying donors on either side of the wire

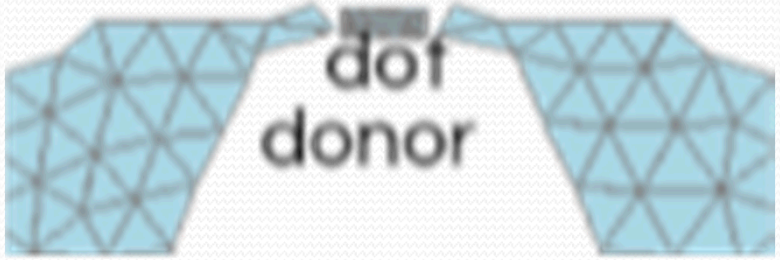


- Donors that are more strongly coupled to LISO=RISO than to LLP=LRP have been implanted above the lower wire.

- Donors that are more strongly coupled to LLP=LRP than to LISO=RISO are located below the lower wire.

Calculating the position of the donor numerically.



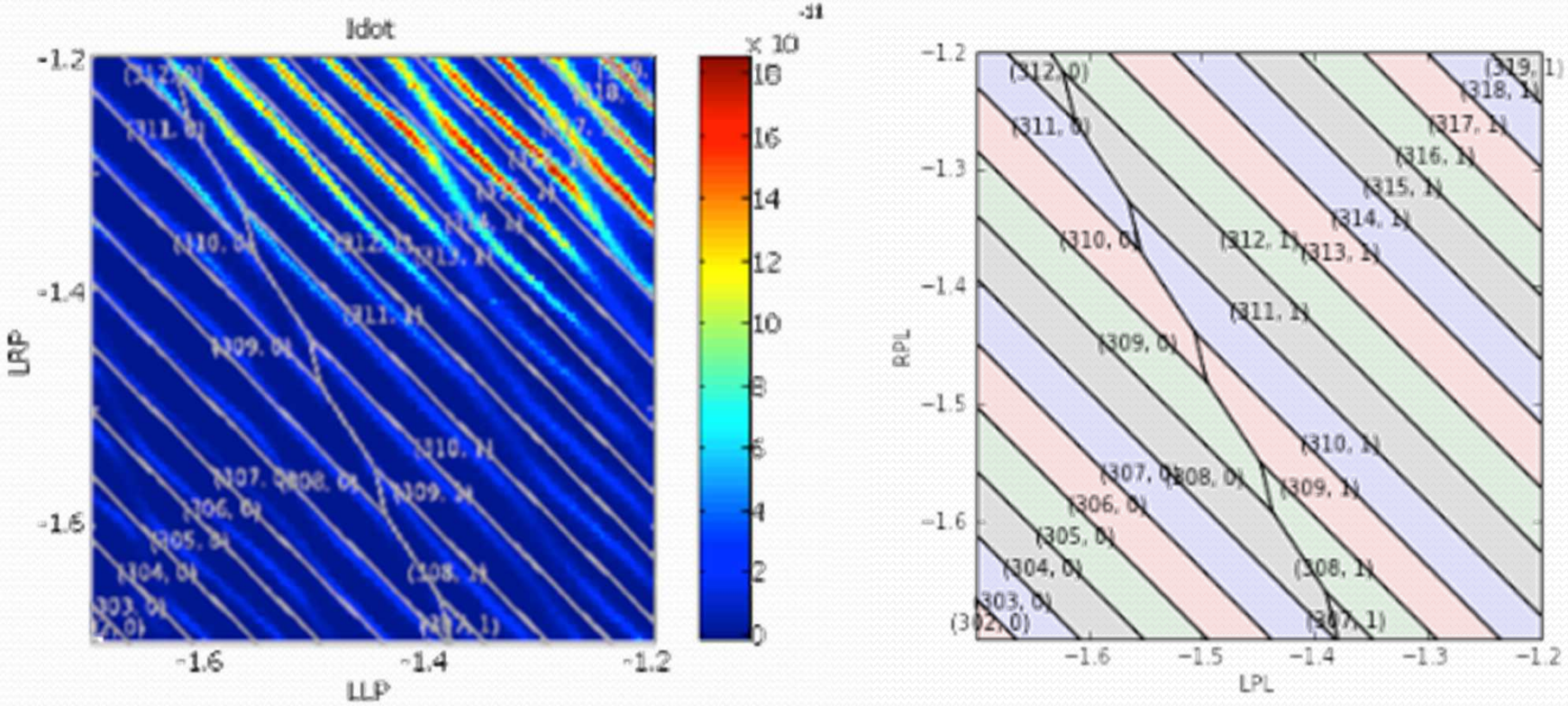


- Determine the size of the dot from the spacing in the CB lines.
- The donor is taken to be a metallic sphere.

- Extract the slope of the offset and the size of the offset from as many experimental plots as possible.

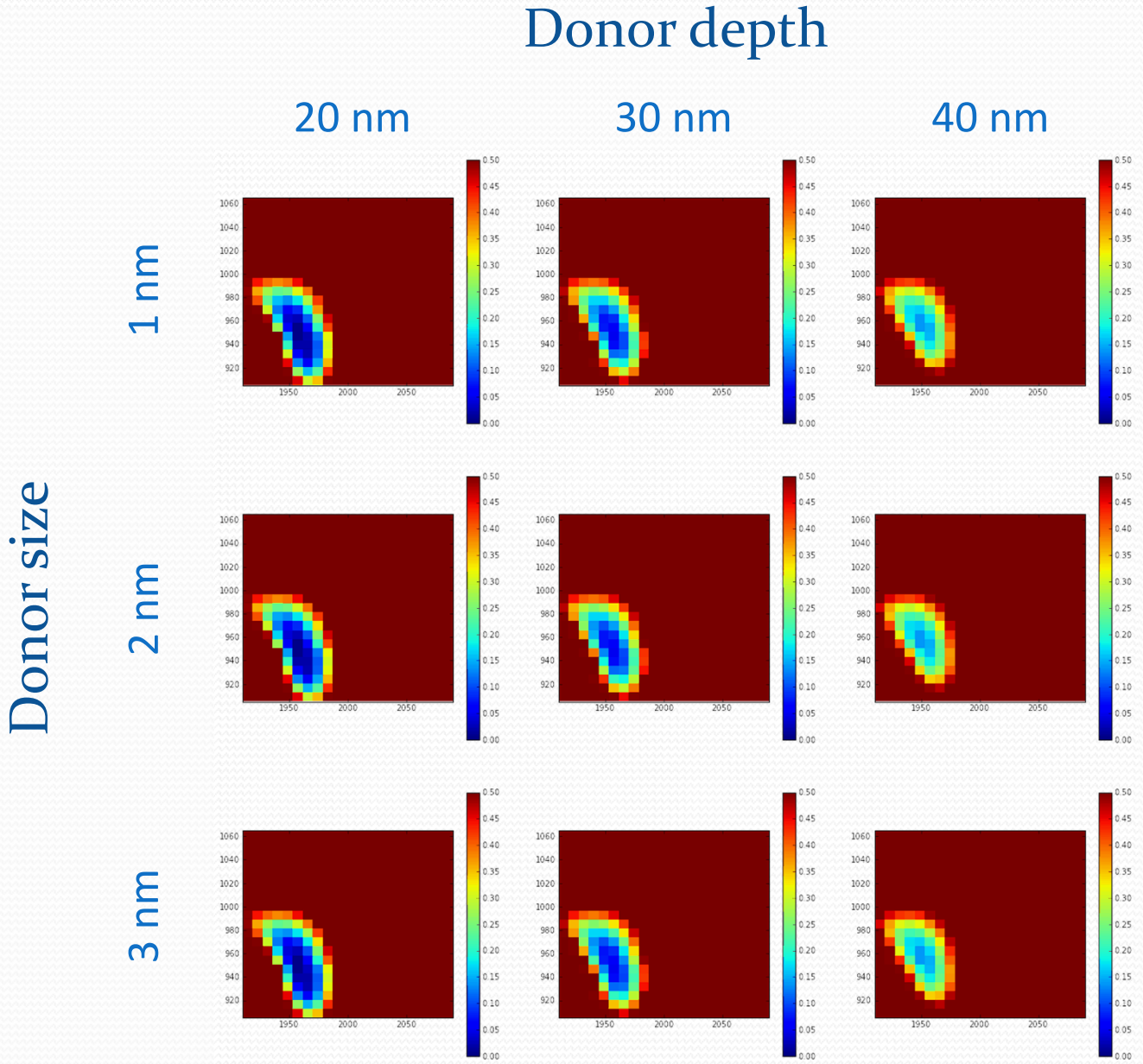
Methods, results and images from Erik Nielsen

Reproducing experimental results



The position of the donor in the simulation will impact the slope of the offset and the size of the offset. Simulations are done for different donor positions until a good fit is obtained.

Determining donor position



Conclusion

- Donors situated near the quantum dot cause offsets in the Coulomb blockade lines.
- The slope and size of these offsets depend on the position of the donors with respect to the gates of the device.
- The approximate position of a donor can be determined by comparing the slope of its offset when different gates are swept.
- Trying to reproduce the experimental data with the numerical model allows us to find the position of the donor with greater precision.