Noise Correlations in a 1D Silicon Spin Qubit Array

M.B. Donnelly,[1, 2, 3, *] J. Rowlands,[1, 2, 3, *] L. Kranz,[1, 2, 3] Y.L. Hsueh,[1, 2] Y. Chung,[1, 2, 3] A.V. Timofeev,[3, 2]
H. Geng,[1, 2, 3] P. Singh-Gregory,[1] S.K. Gorman,[1, 2, 3] J.G. Keizer,[1, 2, 3] R. Rahman,[1, 2] and M.Y. Simmons[1, 2, 3, †]

[1] Silicon Quantum Computing Pty. Ltd., Level 2 Newton Building, UNSW Sydney, 2052, NSW Australia
[2] School of Physics, UNSW Sydney, 2052, NSW Australia
[3] Centre for Quantum Computing and Communication Technology, UNSW Sydney, 2052, NSW Australia

Introduction & motivation

Qubit will never be fully isolated from noise

=> Solution: (quantum) error correction

Introduction & motivation

Quick reminder of error correction:

- Given a bit string: e.g. “0 1”
- Simplest error correction method:
  - Duplicate the information 0 1 => 000 111
  - If a bit differs from its 2 “companions”, then flip it
    e.g. 010 111 => 000 111 ✓
- Problem, if there is 2 errors in the same “triplet”, no correction:
  - e.g. 110 111 => 111 111 ✗

Introduction & motivation

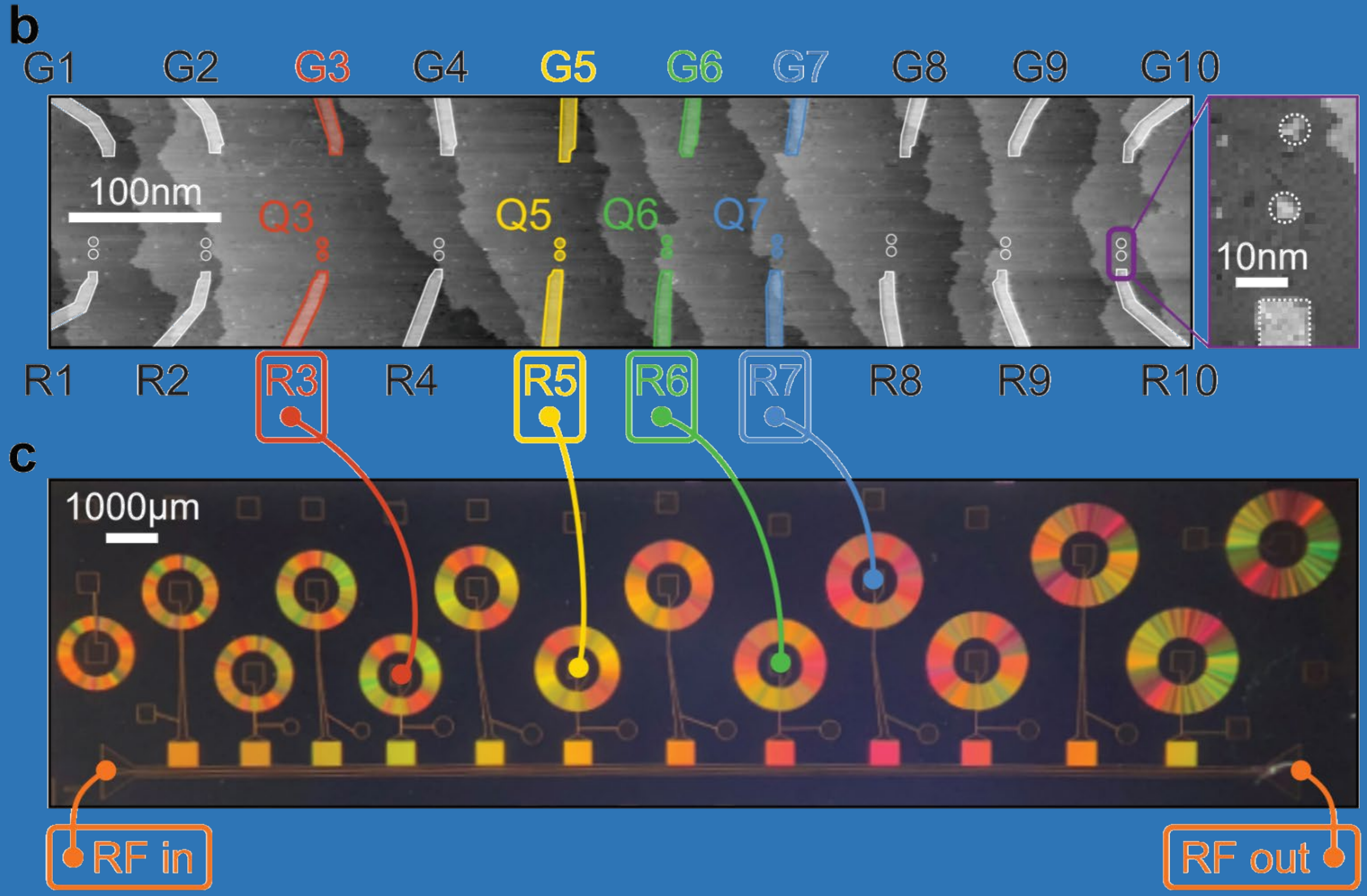
- No problem!
  Given the probability p to get an error is small, then probability to get 2 errors in a triplet is $p^2 \ll p$

- Only true if the probability to get error are not correlated !

- Correlated errors are a bigger problem than uncorrelated error

=> Goal of the paper: investigate noise correlation in spin qubit

Device



- 10 Si:P quantum dots (QD) pairs, each controlled by a gate + tunnel coupled to a reservoir
- Spacing of ~75 nm between QD pairs
- Encapsulation with 45 nm of epitaxial Si
- Native SiO2 at the top

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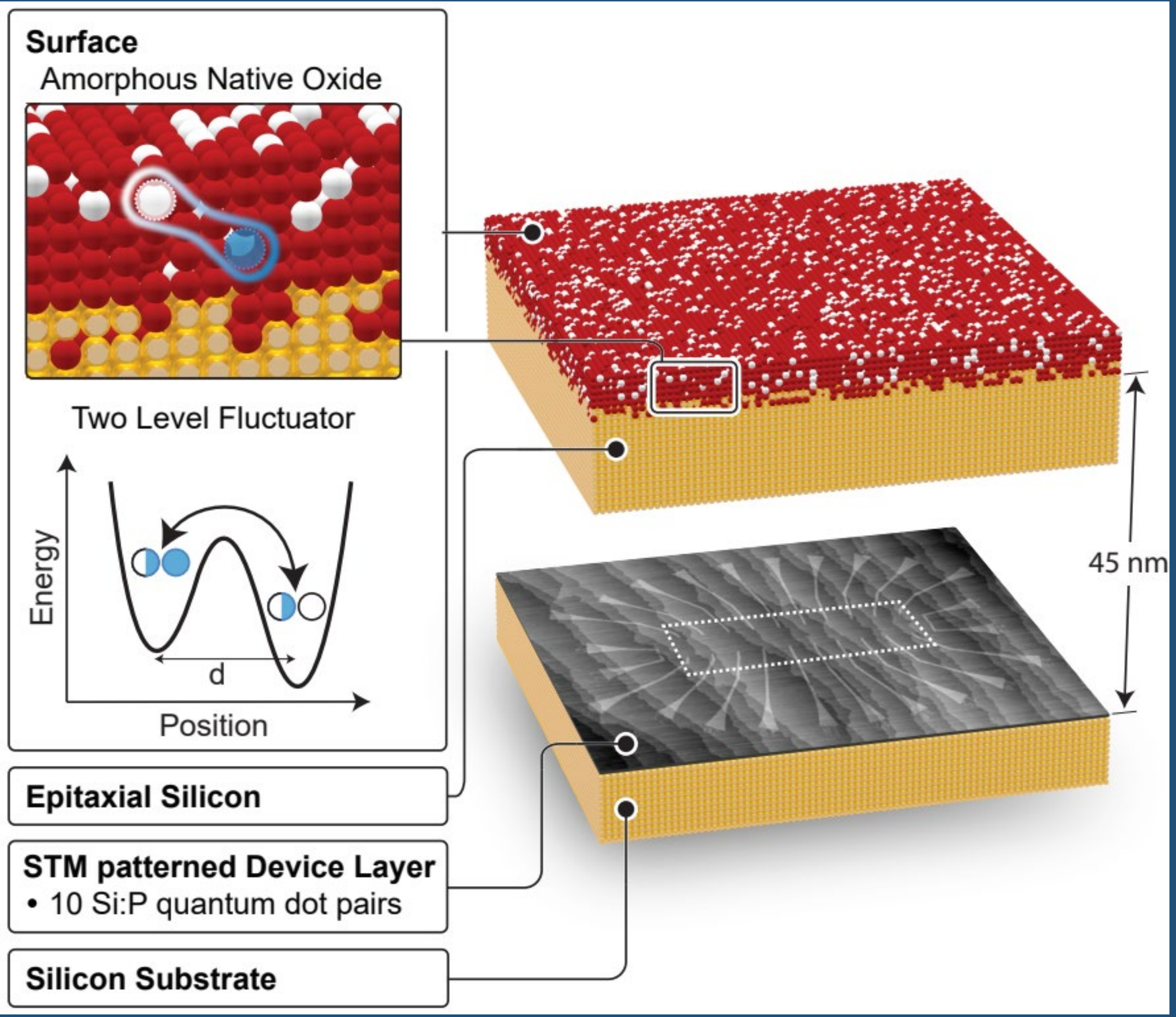
Device



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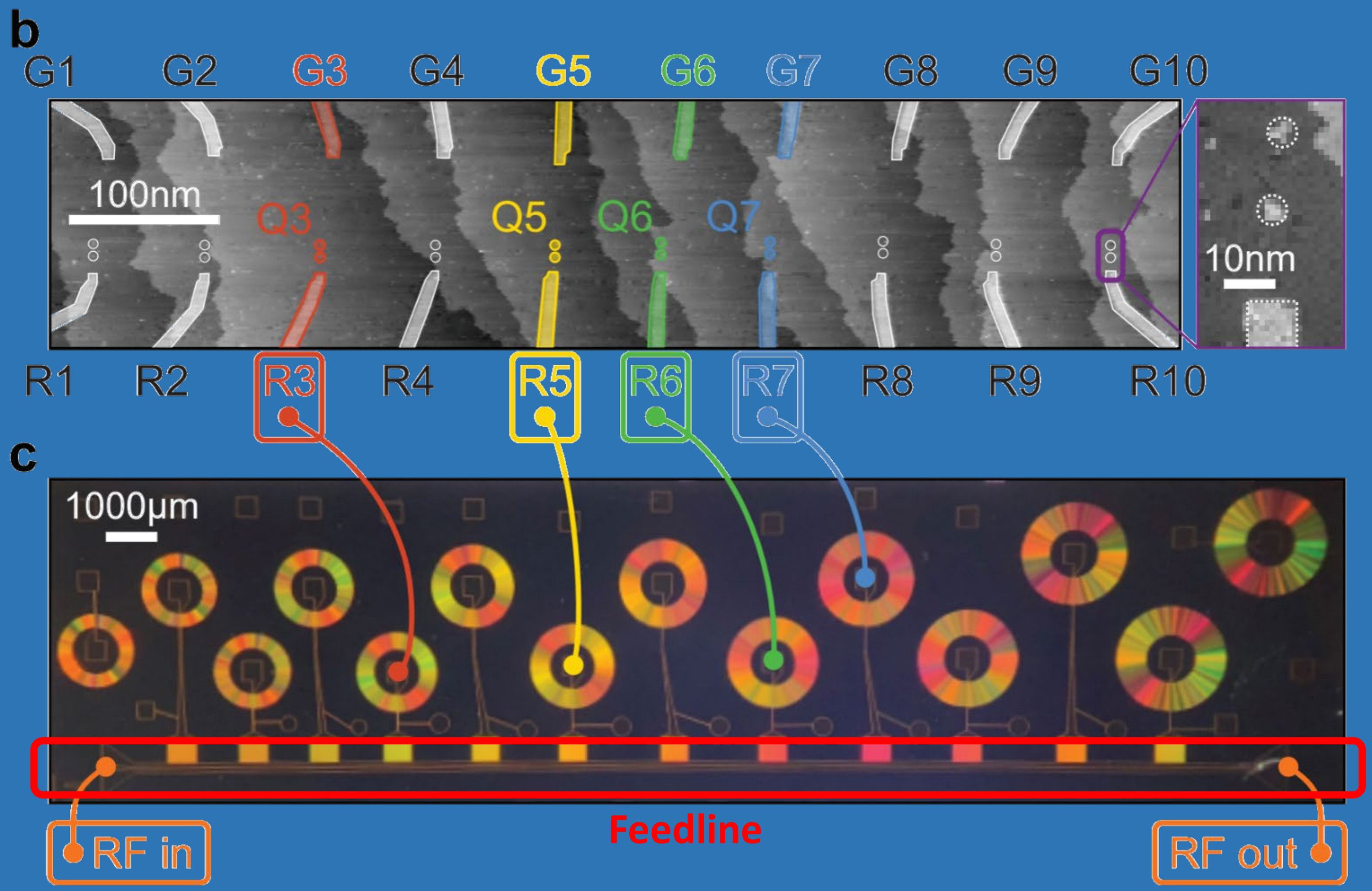
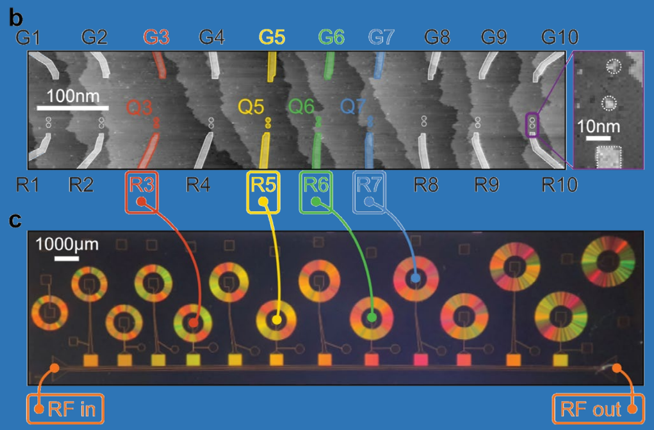
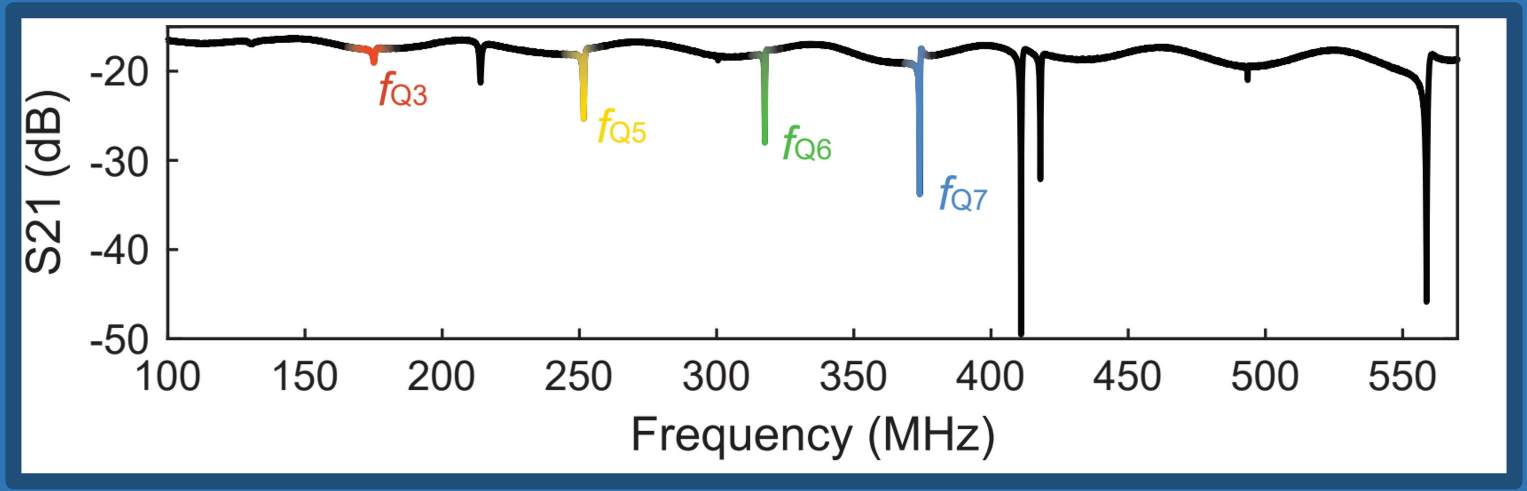
Tuning the device



- Tank are connected to NbTiN LC resonator
- All connected to the same feedline

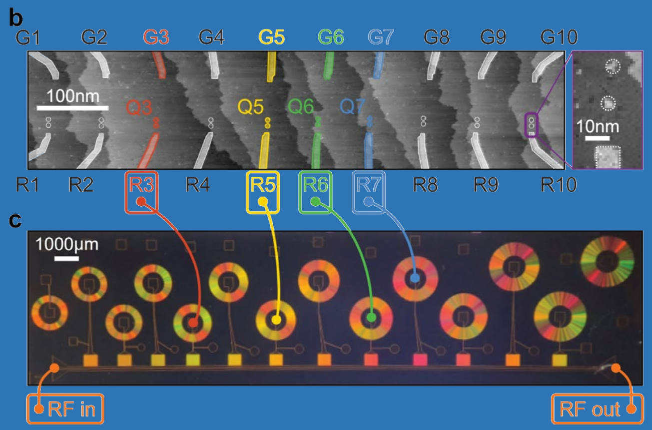
Tuning the device

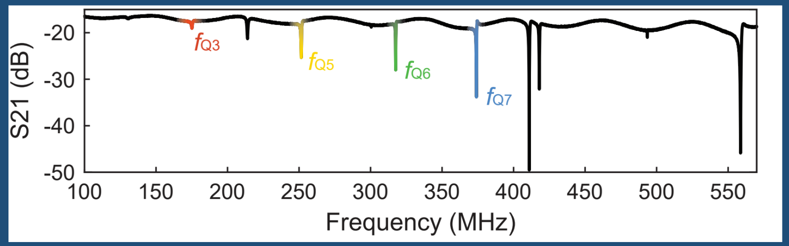


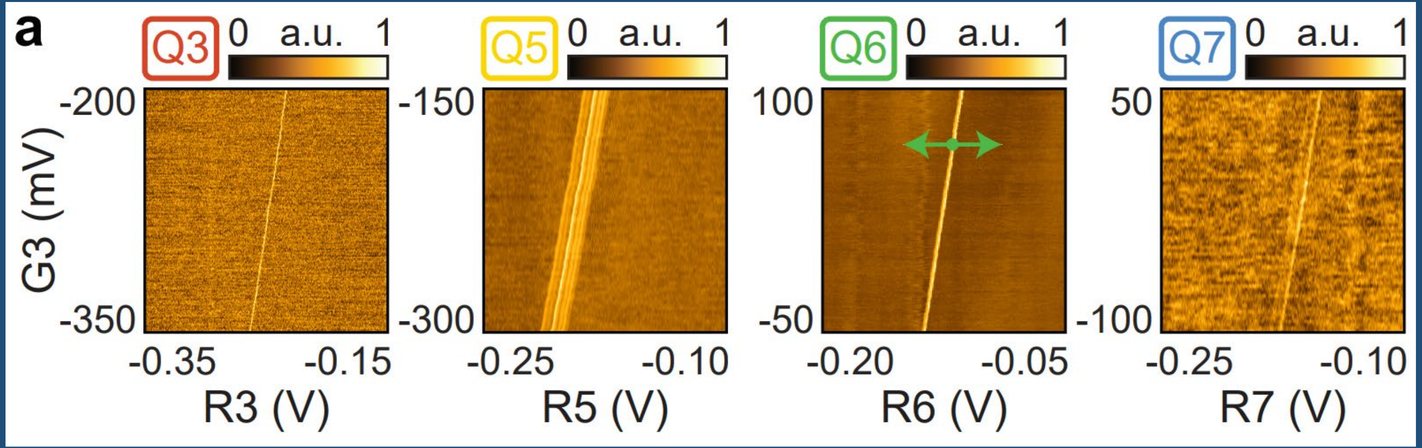


- Tank are connected to NbTiN LC resonator
- All connected to the same feedline
- Each resonator have a different frequency => different gap on S21

Tuning the device







- Tank are connected to NbTiN LC resonator
- All connected to the same feedline
- Each resonator have a different frequency => different gap on S21
- Mapping of charge stability diagram for each QD

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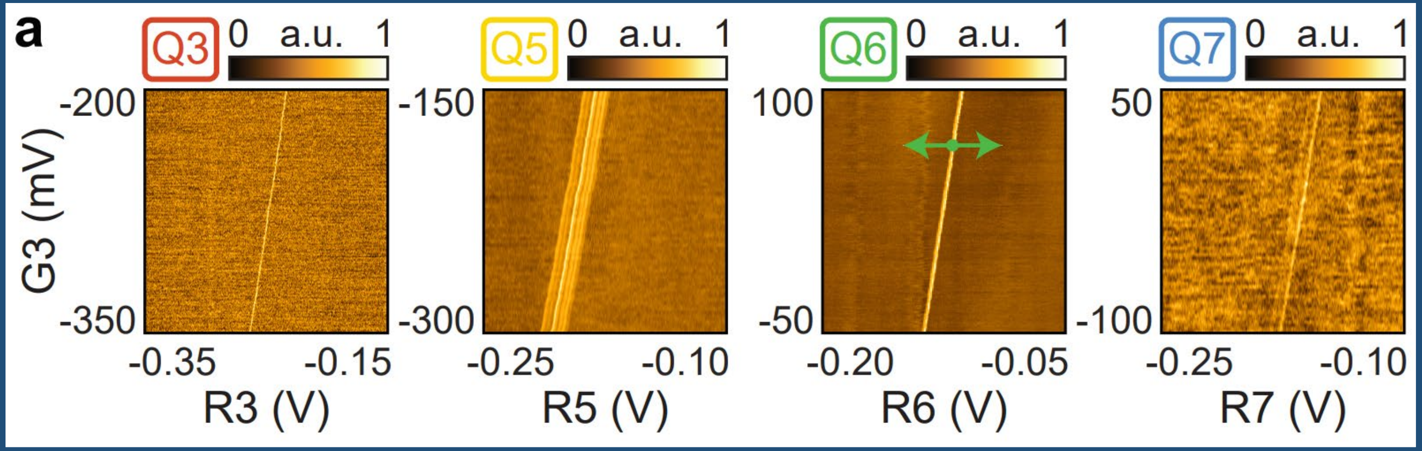
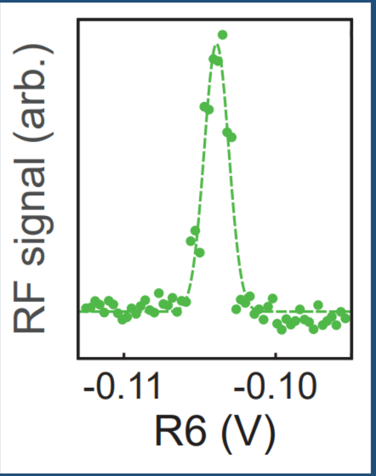
Tuning the device





- Choose a value of G and a range of R for which a transition is present
- Fit a gaussian: the center of the gaussian define the transition position

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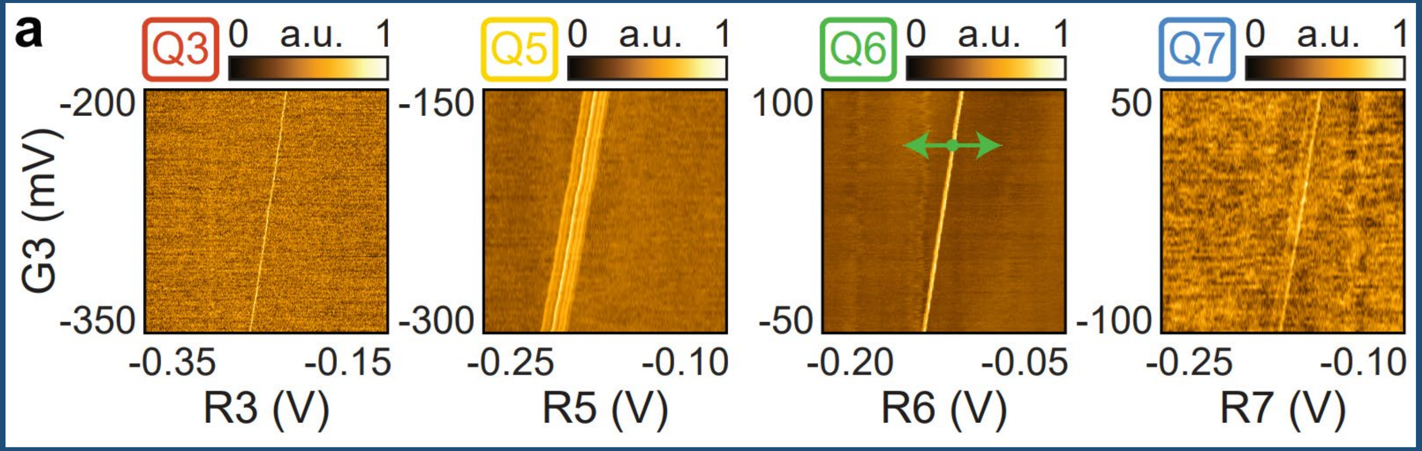
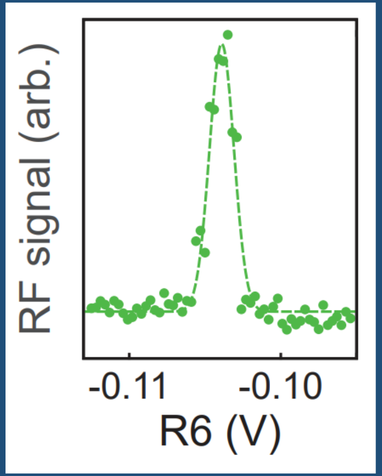
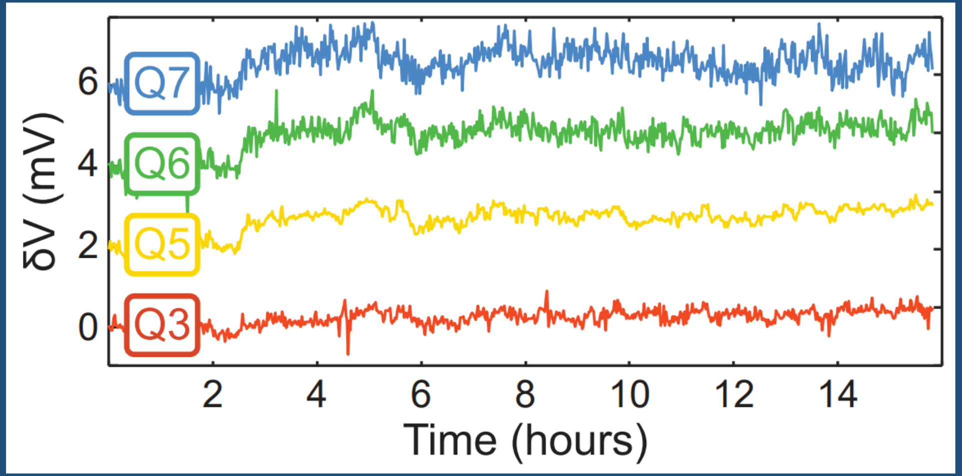
Tuning the device

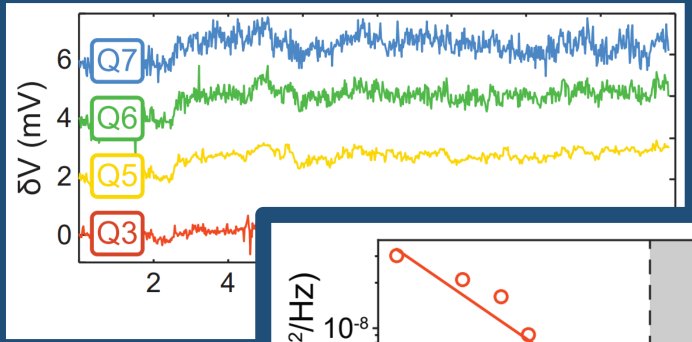


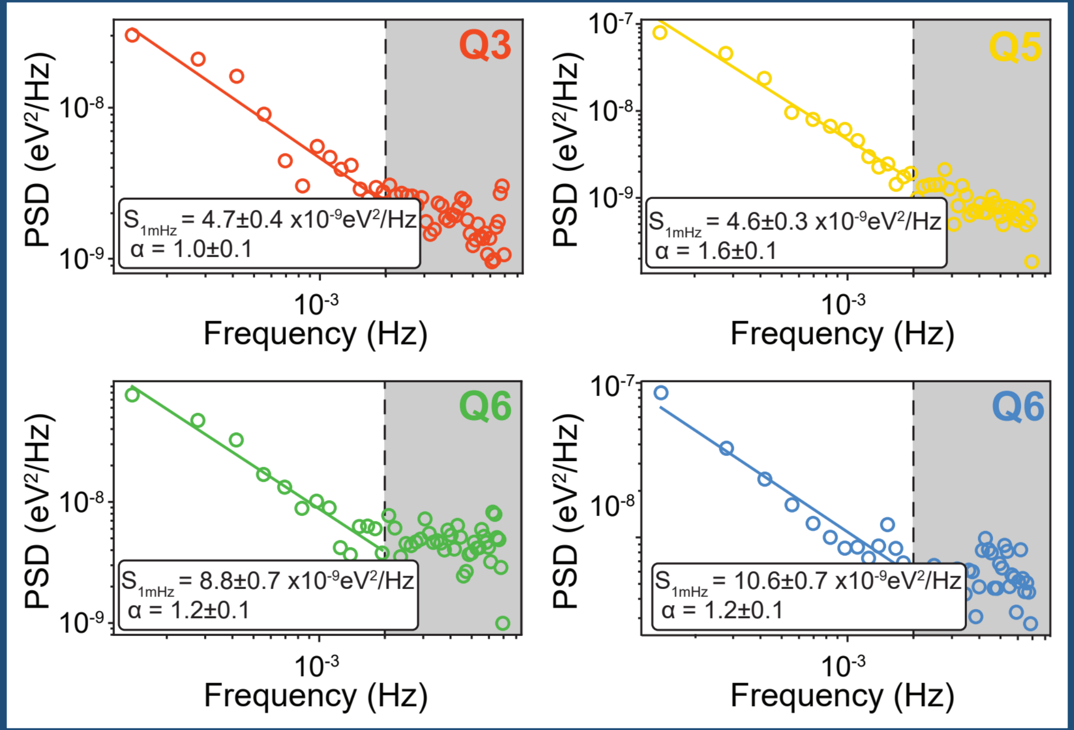




- Choose a value of R and a range of G for which a transition is present
- Fit a gaussian: the center of the gaussian define the transition position
- Track the transition position over time

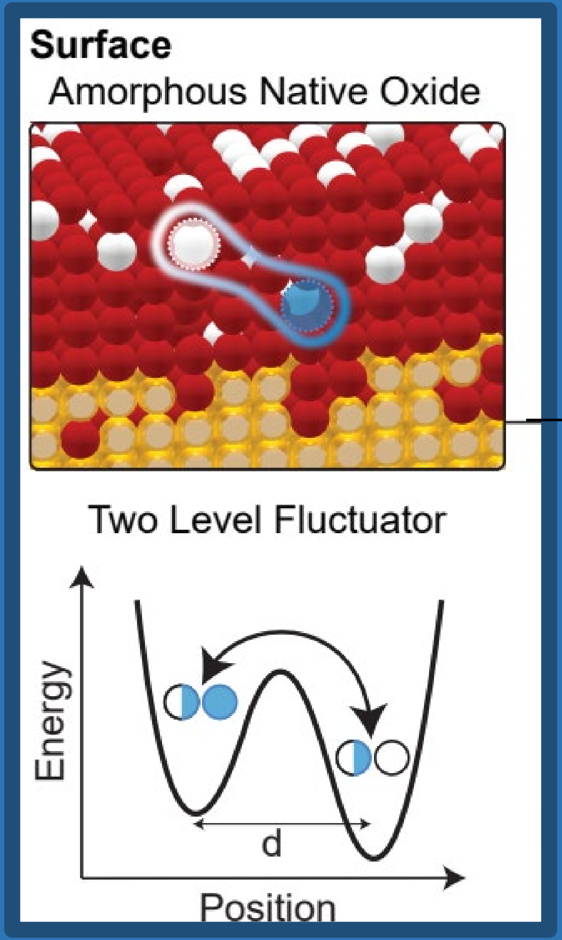
Characterization of the noise

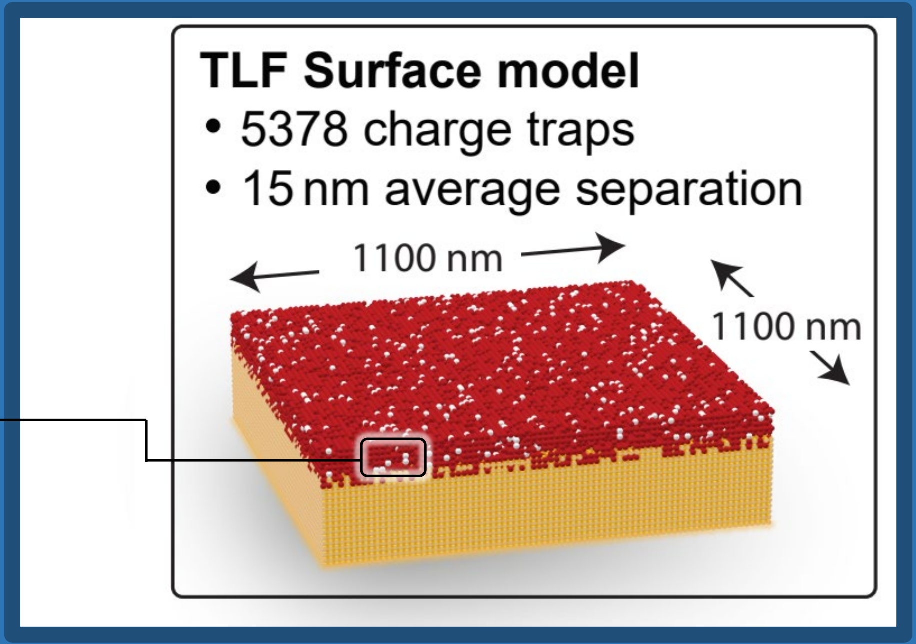




- FFT of the traces gives the Power Spectral Density PSD
- Grey part => white noise: setup noise > device noise

Noise modeling



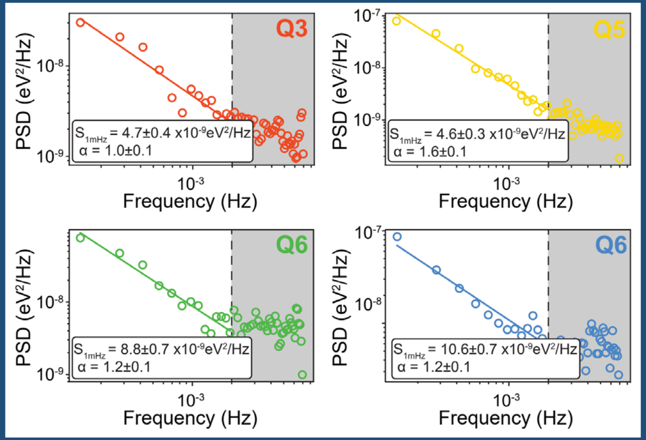


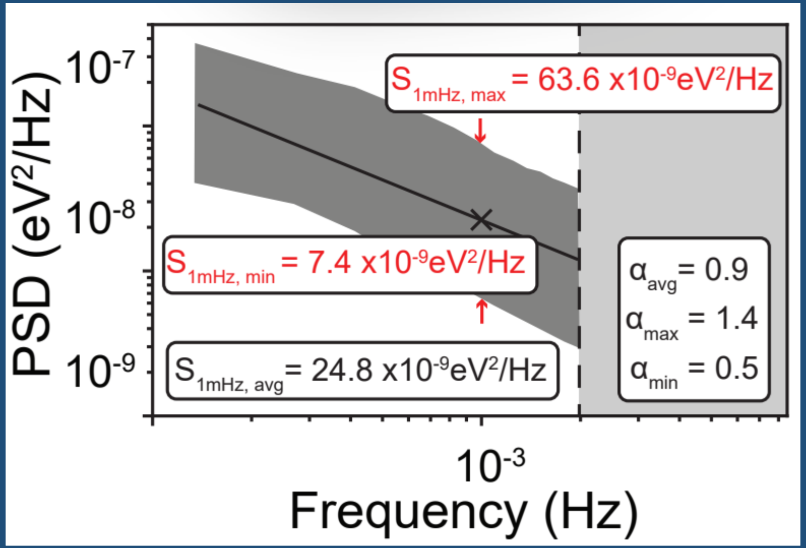
- Tunnelling model of TLF
- ~5000 charge traps separated by ~15 nm in the native SiO2

  => No good description given

  How many parameters are free?

Simulation vs Experiment (PSD)





- Simulation give the good order of magnitude..

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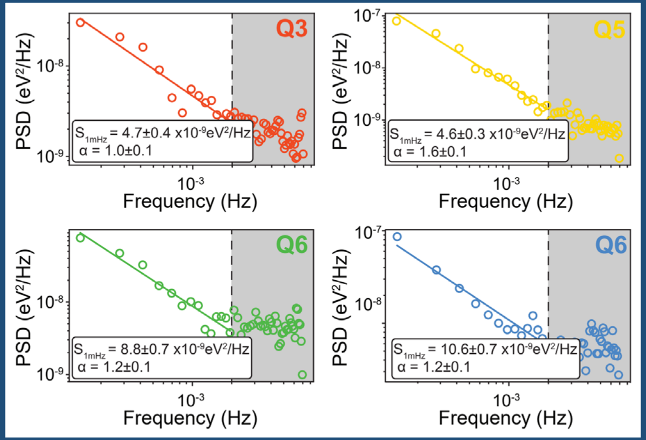
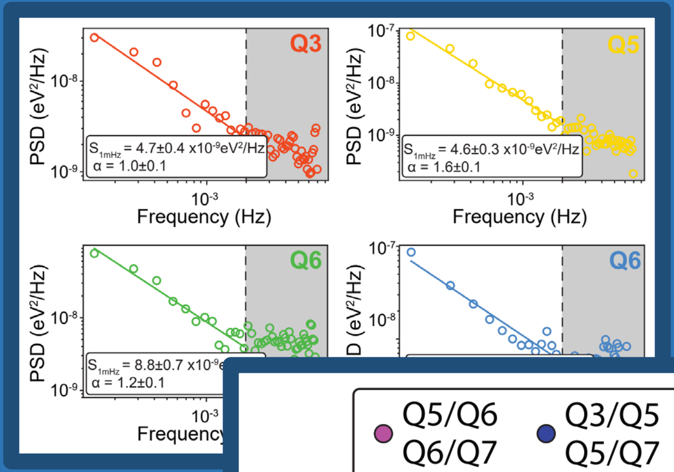
Noise correlation



- Magnitude-squared coherence function $C_{xy}(f)$ uses to quantify the correlation:
  $C_{xy}=0$ => no correlation
  $C_{xy}=1$ => fully corelated

$$C_{xy}(f) = \frac{|S_{xy}(f)|^2}{S_{xx}(f)S_{yy}(f)},$$

Noise correlation



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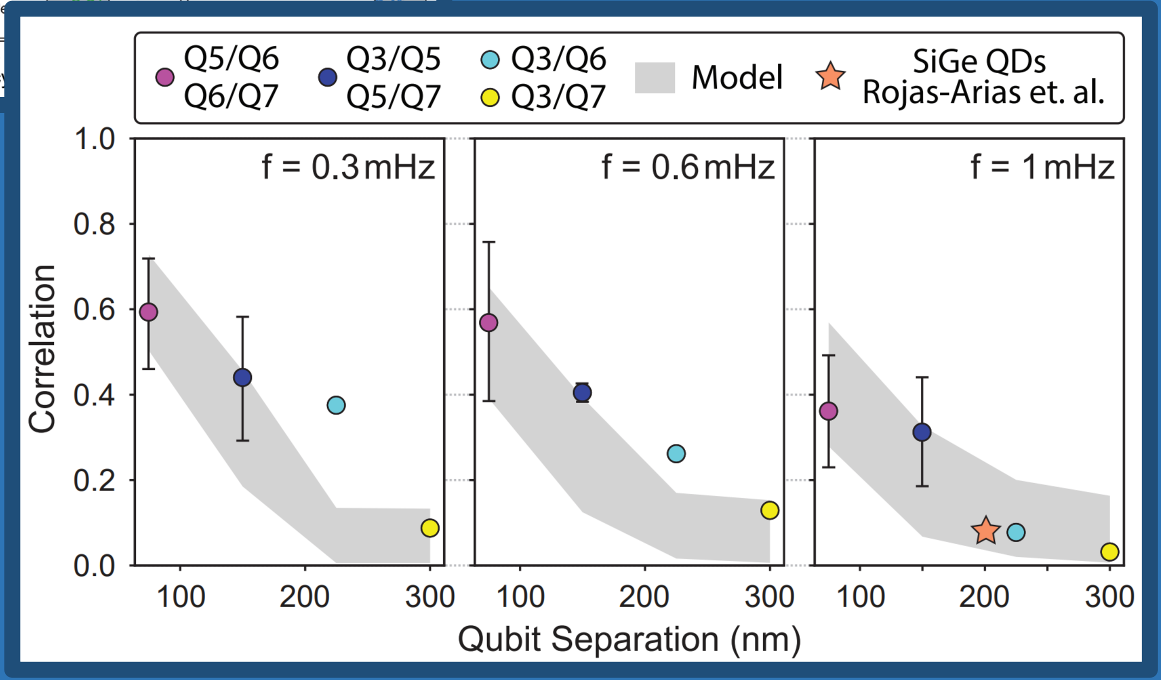

- Magnitude-squared coherence function $C_{xy}(f)$ uses to quantify the correlation:
  $C_{xy}=0$ => no correlation
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- Correlation of different pairs of QDs:
  - Highly correlated noise
  - Diminution with qubit separation
  - Fit the model for f = 1 mHz, less good for f = 0.3 or 0.6 mHz

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Conclusion

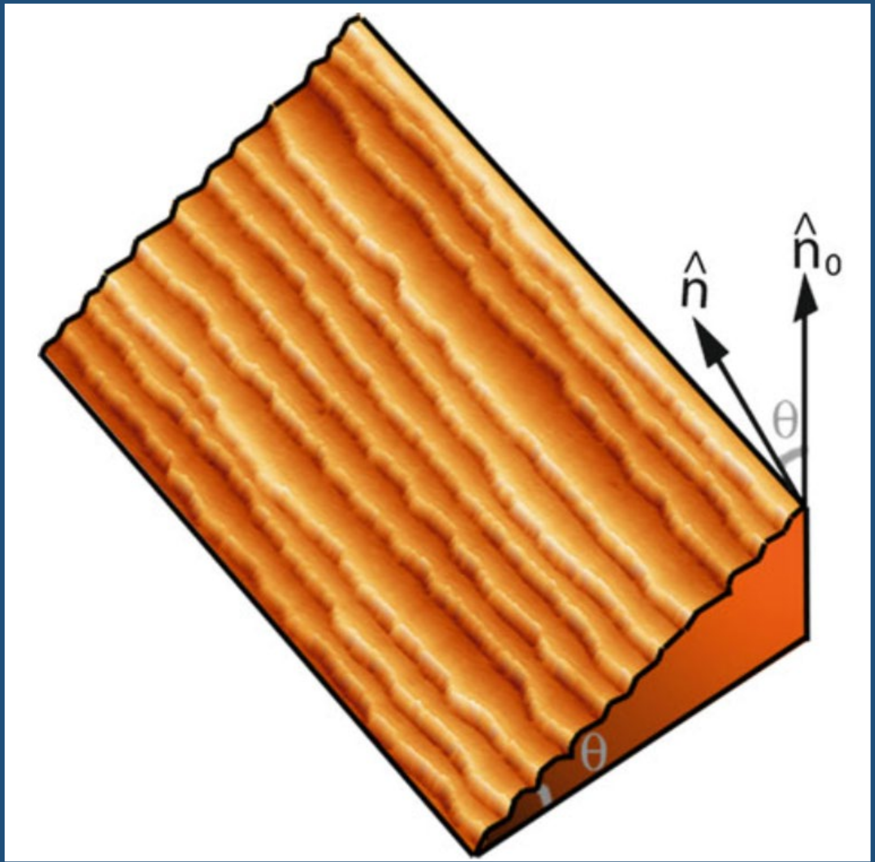
- Noise is highly correlated in their system; probably in ours too
- Analysing noise correlation might give information about where is the noise coming from

Conclusion

Thank you for your attention!

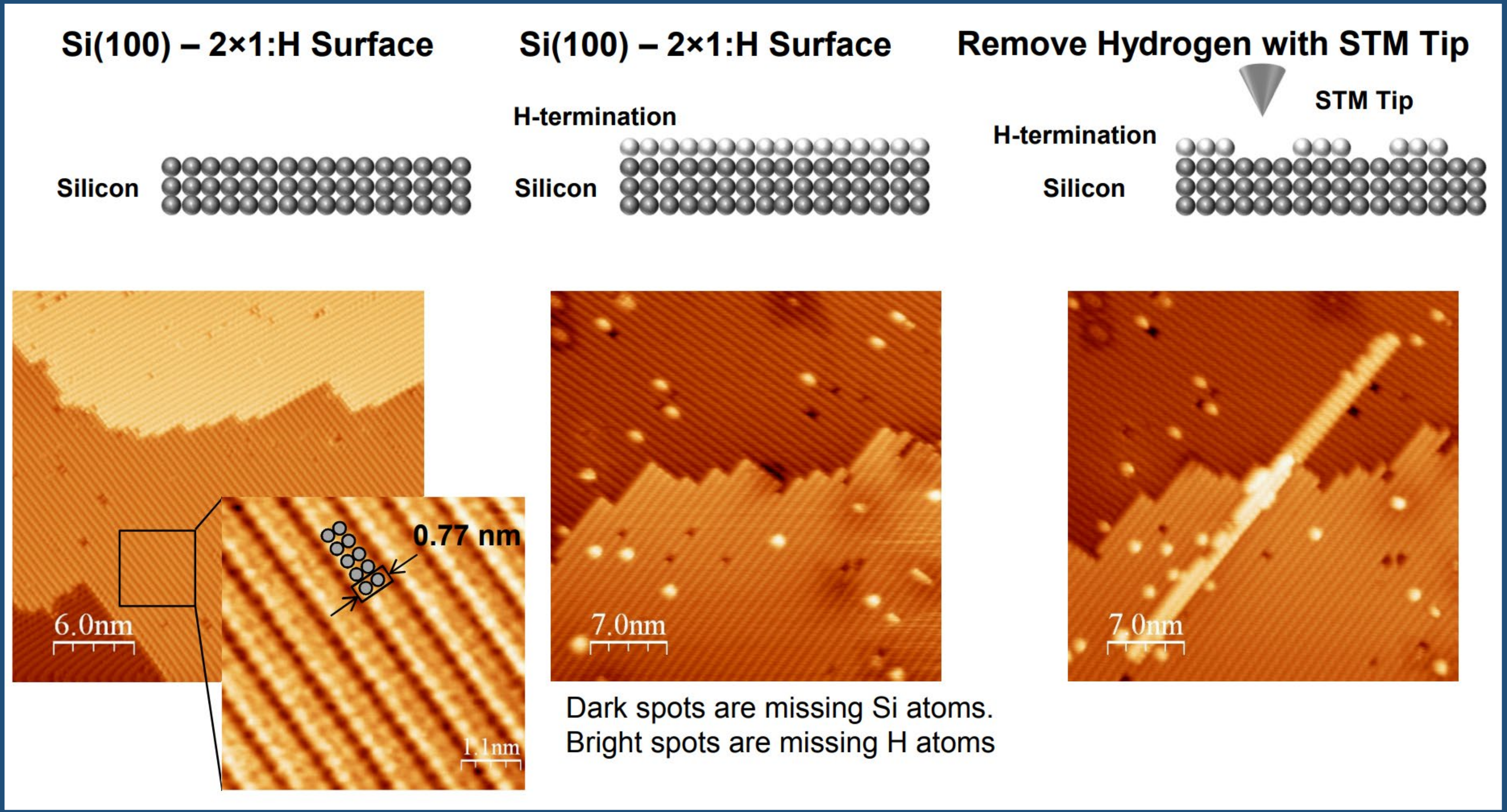
Additional slides: Si(100) steps

“A regular array of steps can be produced by cutting a single crystal few degrees away from a low-index plane. If the cleavage plane is slightly misoriented from a crystallographic plane, the surface breaks up into a staircase of terraces limited by steps, and it is referred to as vicinal. The relevant parameters of the step array depend on the misorientation or miscut angle y of the vicinal surface from the low-index plane”



From http://dx.doi.org/10.1007/978-1-4614-0742-3_4

Additional slides: device fabrication



From: Atomically Precise Single Donor Placement by STM Lithography J. Koepke, D. Scrymgeour, R.J. Simonson, M. Marshall, D. Ward, R. Muller, P. Schultz, A. Baczewski, M. S. Carroll, S. Misra, E. Bussmann

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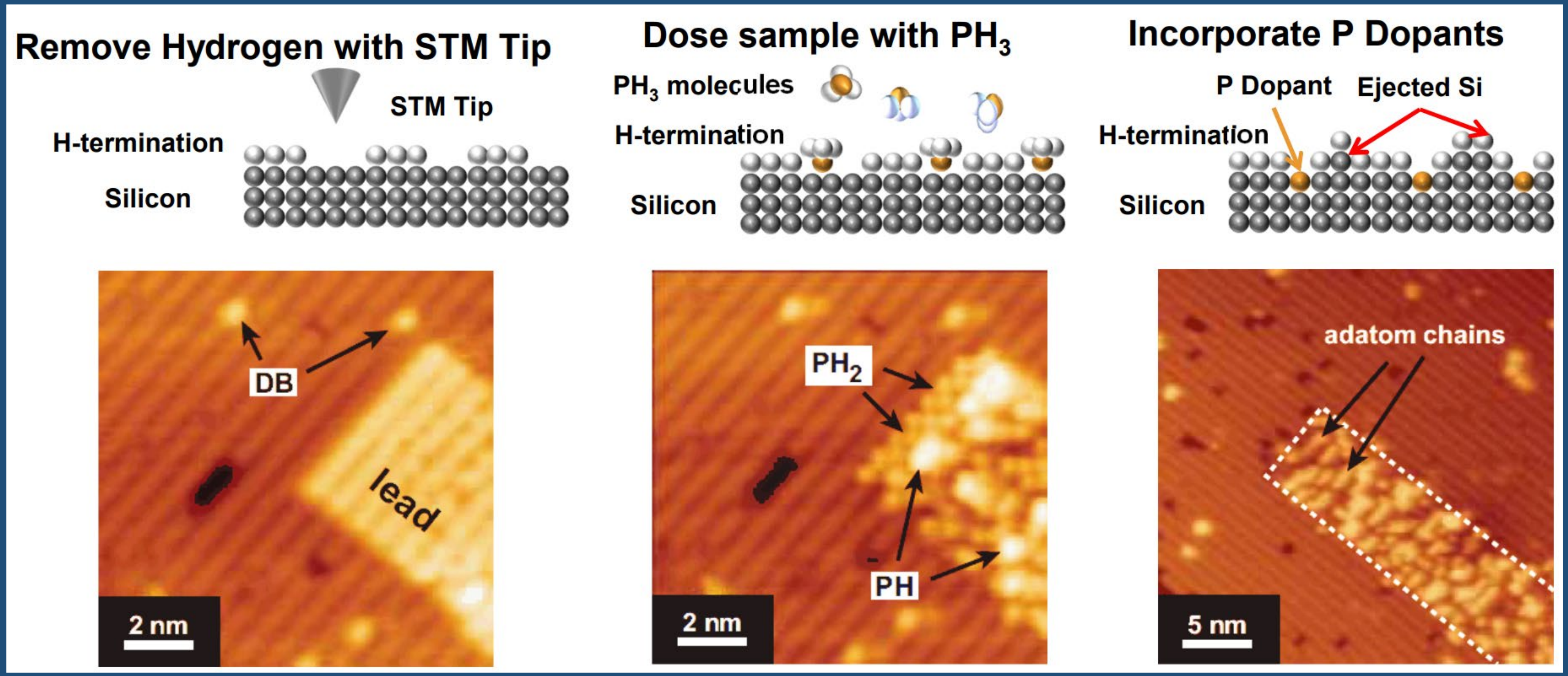

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