Journal Club - Zumbühl Group

A single hole spin with enhanced coherence in natural silicon

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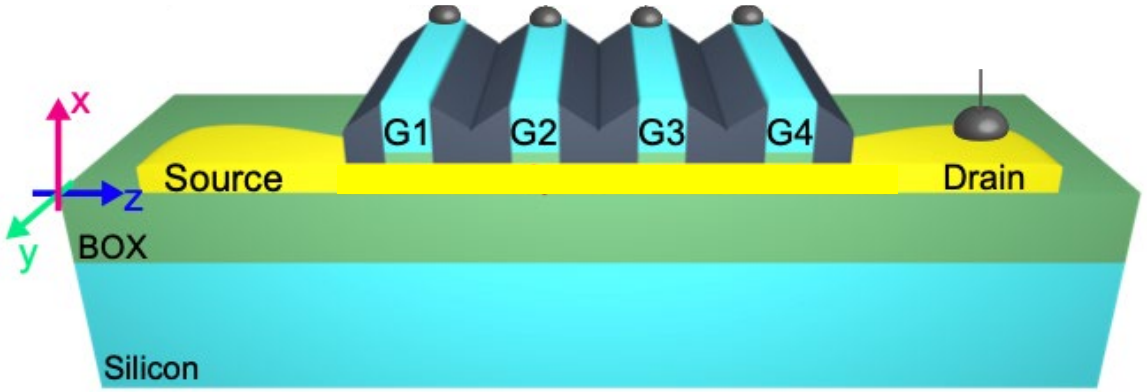
(Dated: January 24, 2022)

Pierre Chevalier Kwon

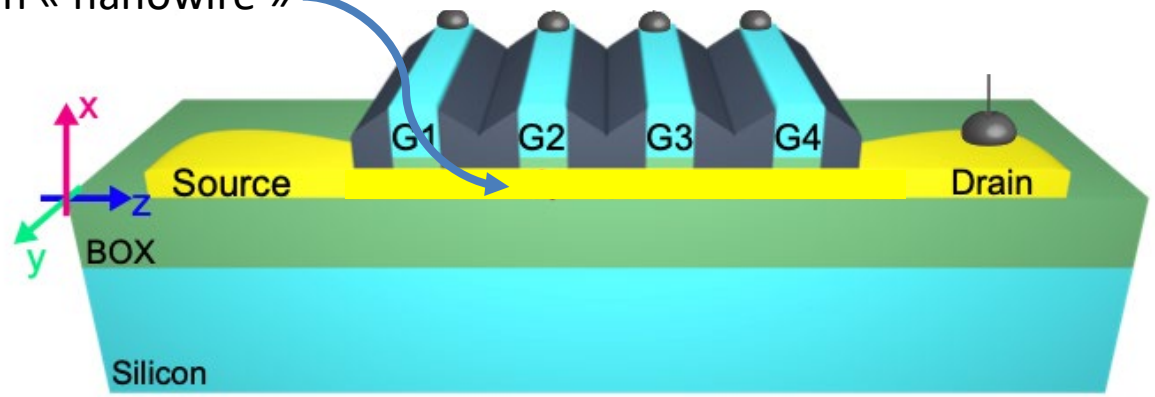
19.08.2022

Device architecture



Device architecture

Undoped [110]-oriented silicon « nanowire »



Device architecture

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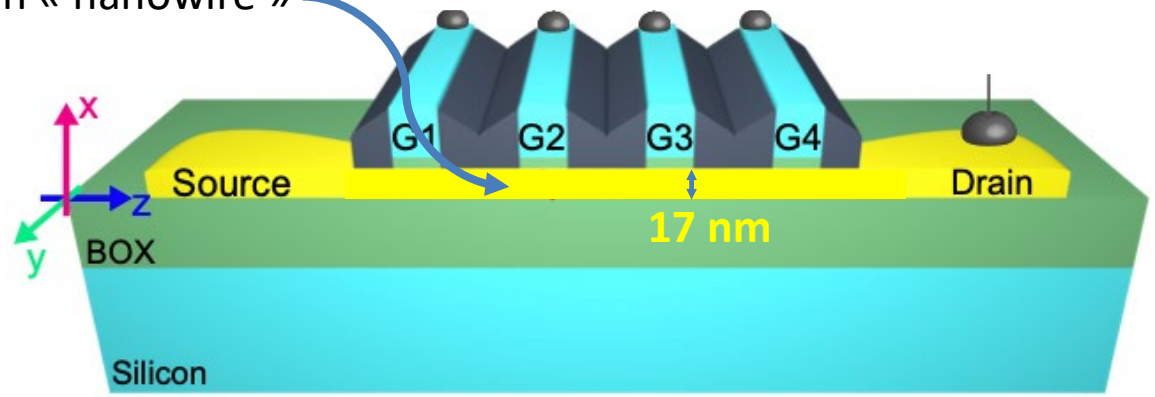
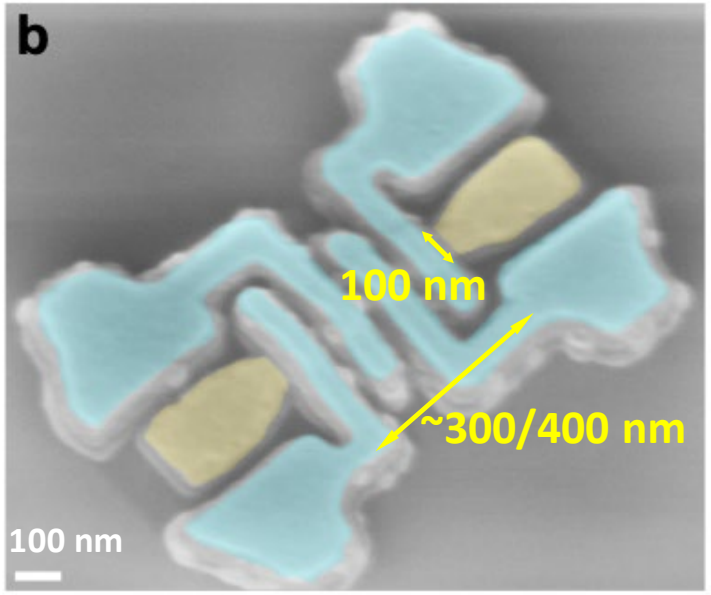
silicon « nanowire »



Top View:



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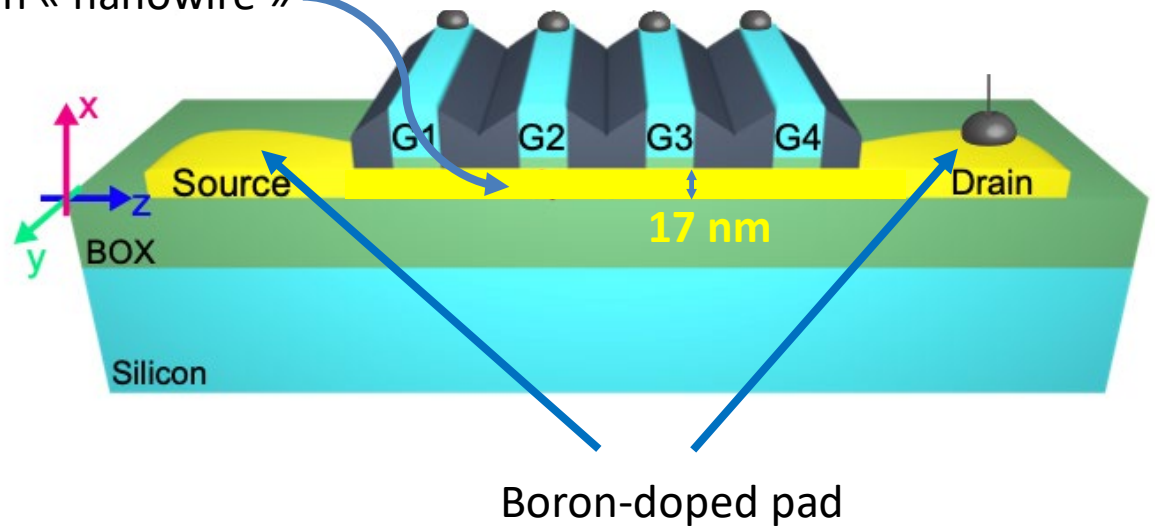
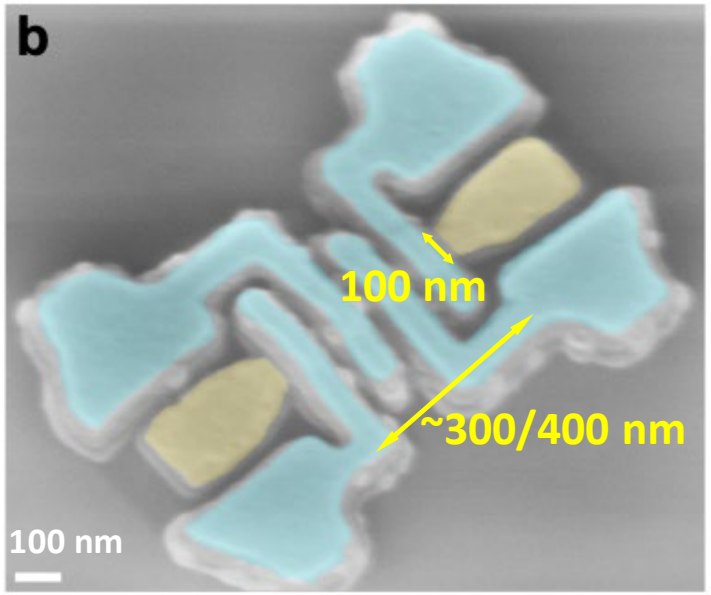
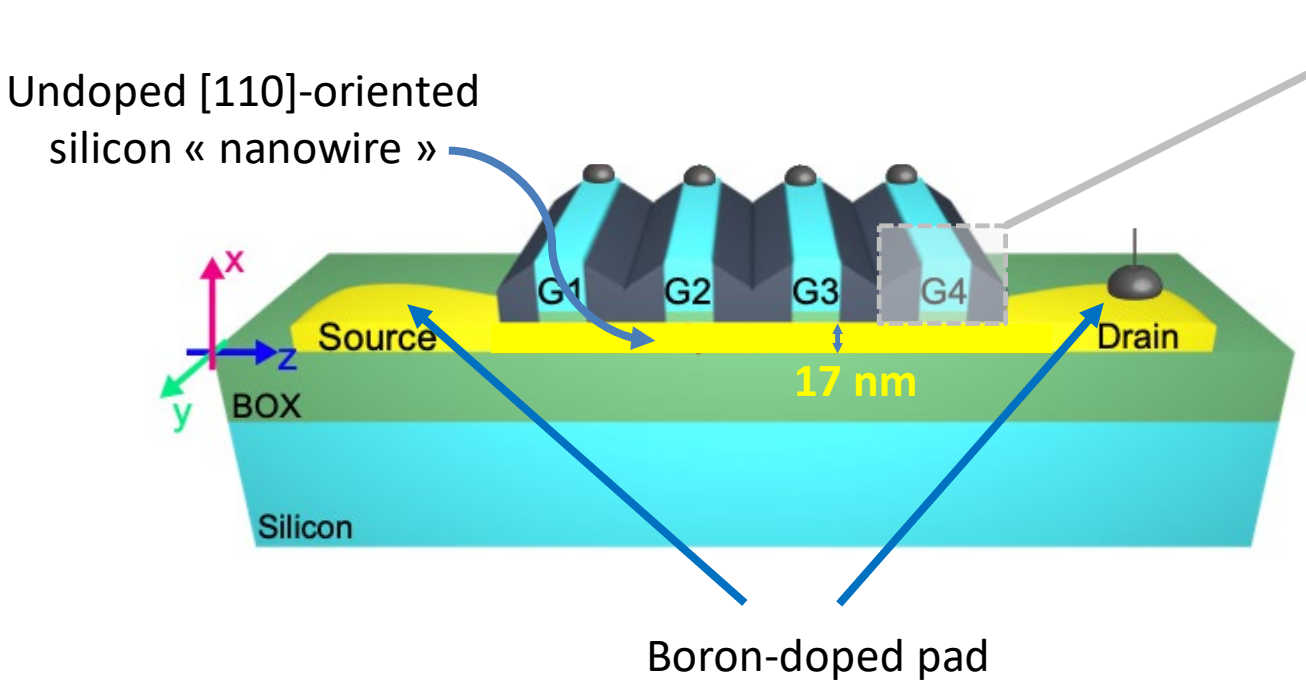


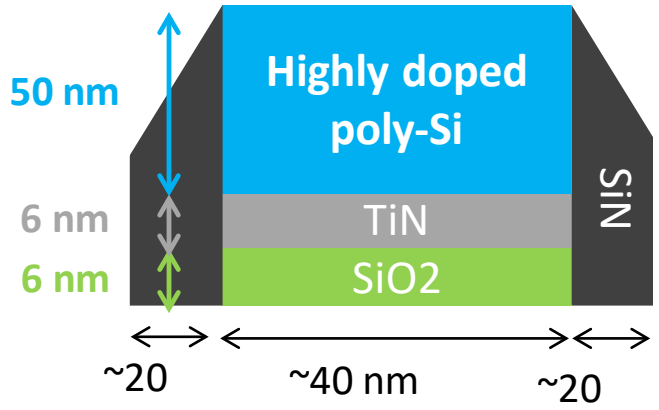
Boron-doped pad

Top View:



Device architecture





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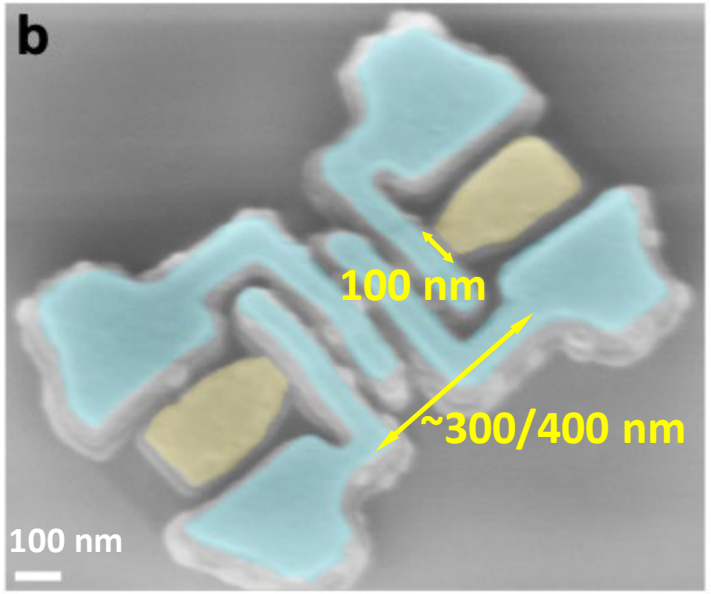
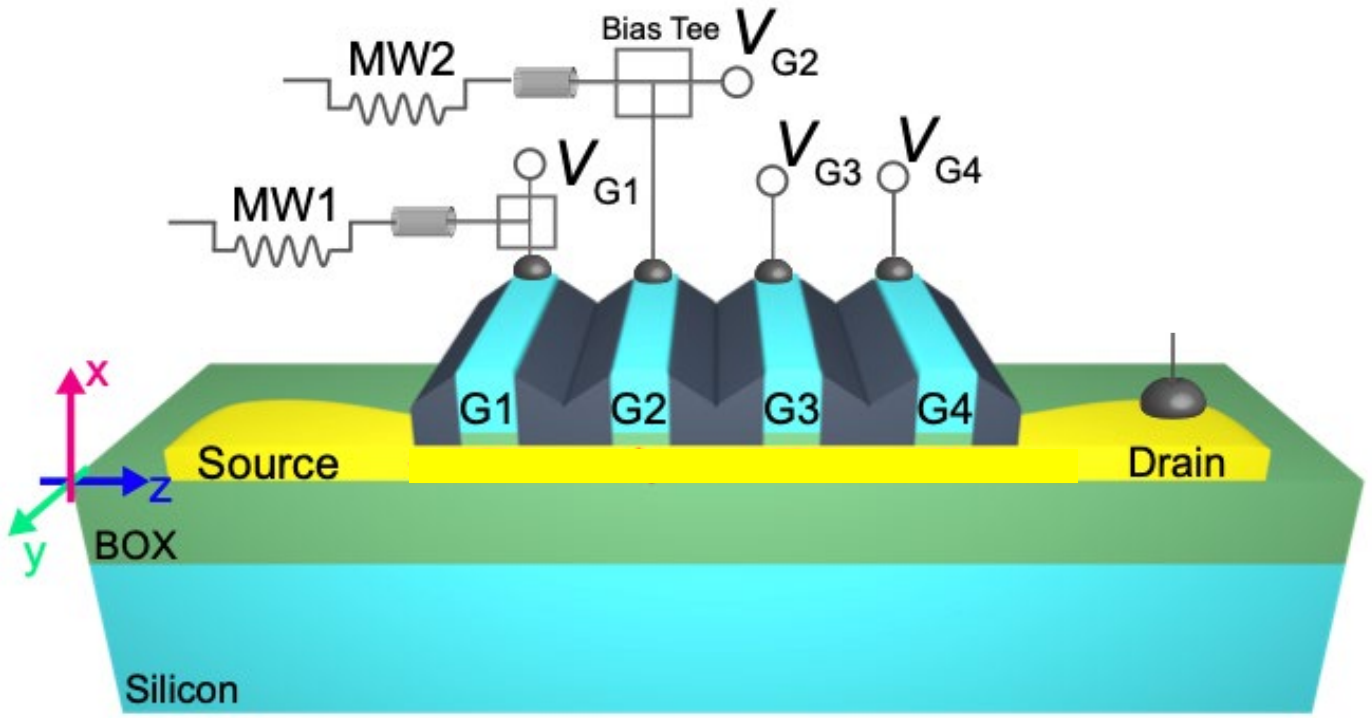


Setup and dots configuration



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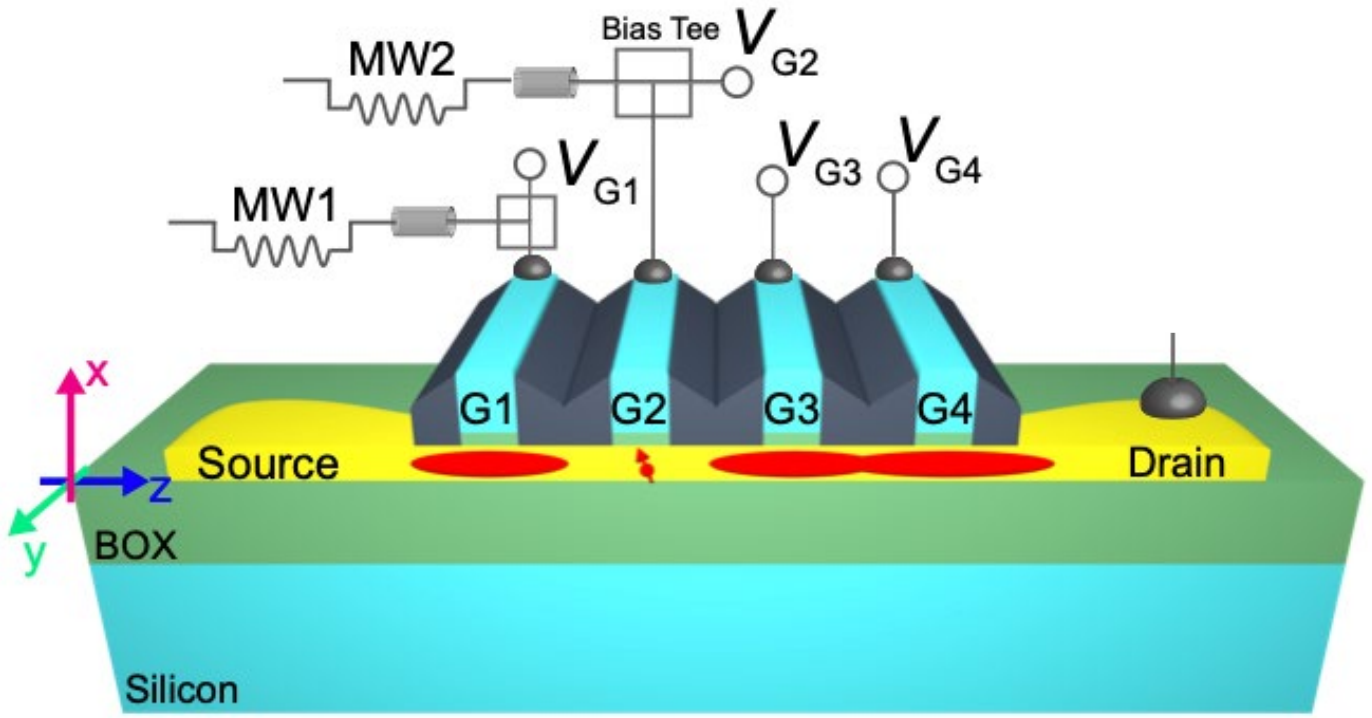

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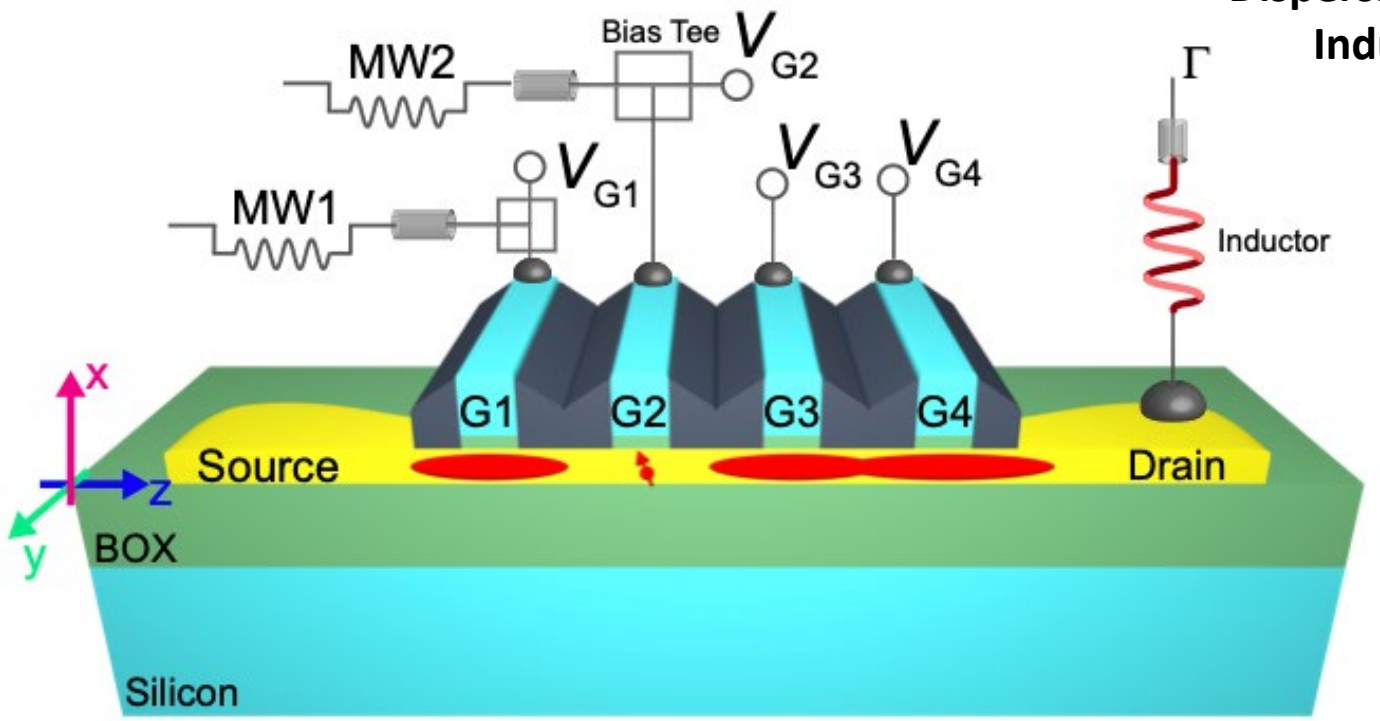
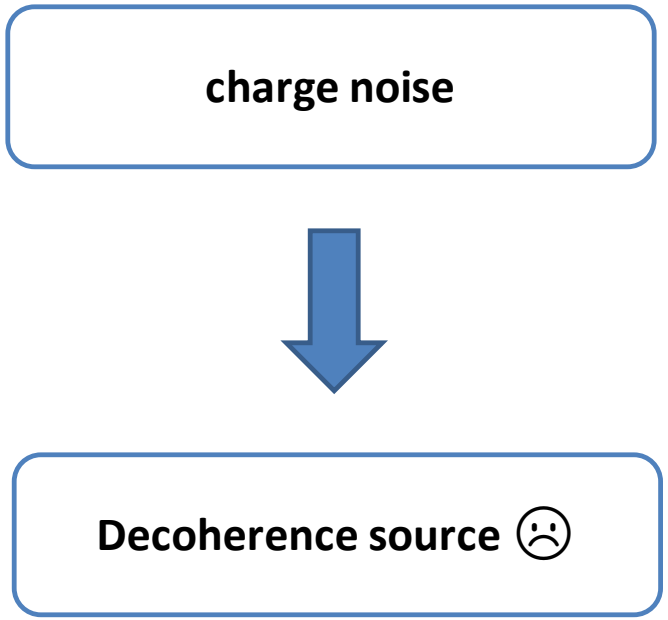
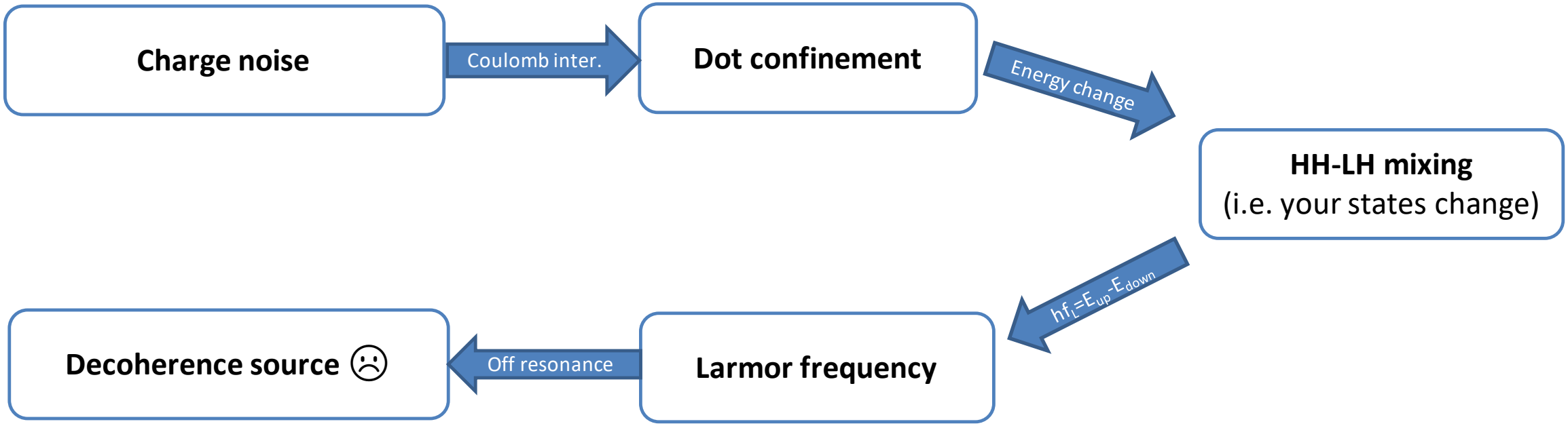


Dispersive rf-reflectrometry
Inductor L = 240 nH

Motivation



Motivation

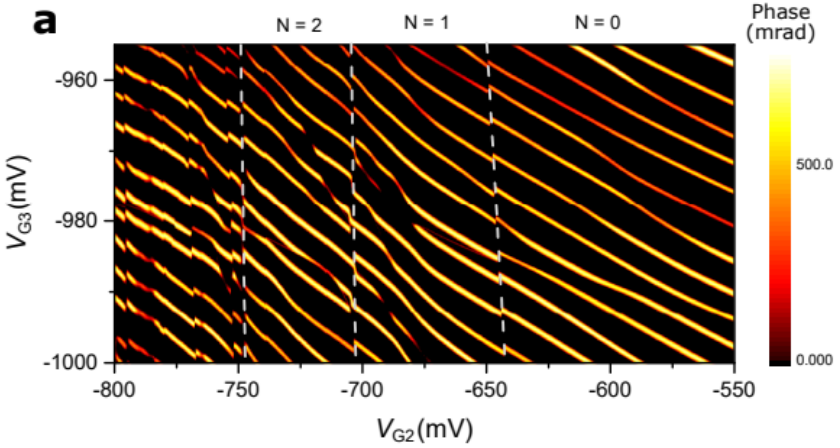


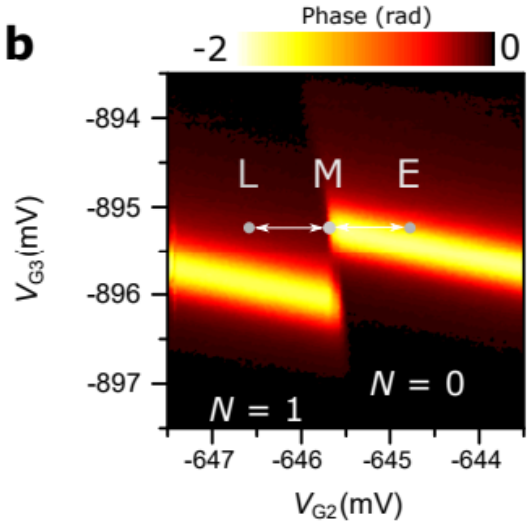
See:

- S. Bosco, B. Hetenyi, and D. Loss, Hole spin qubits in Si finfets with fully tunable spin-orbit coupling and sweet spots for charge noise," PRX Quantum 2, 010348 (2021).
- Z. Wang, E. Marcellina, A. R. Hamilton, J. H. Cullen, S. Rogge, J. Sal, and D. Culcer, Optimal operation points for ultrafast, highly coherent Ge hole spin-orbit qubits," npj Quantum Information 7, 54 (2021).

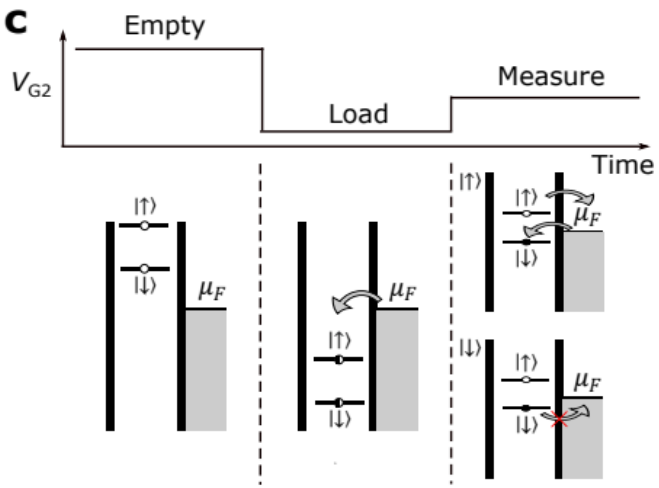
Readout of first hole in QD2

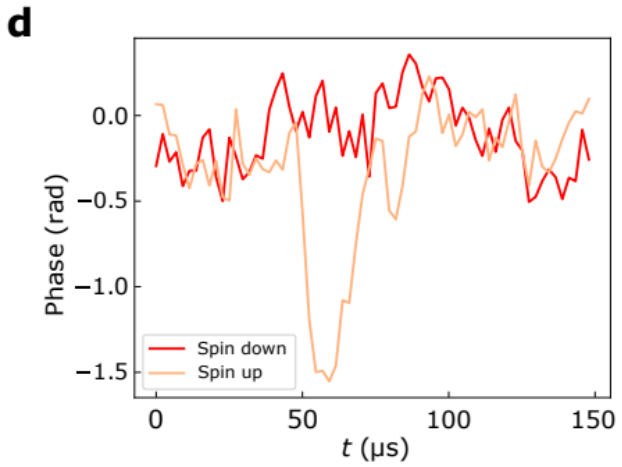
- Charge stability



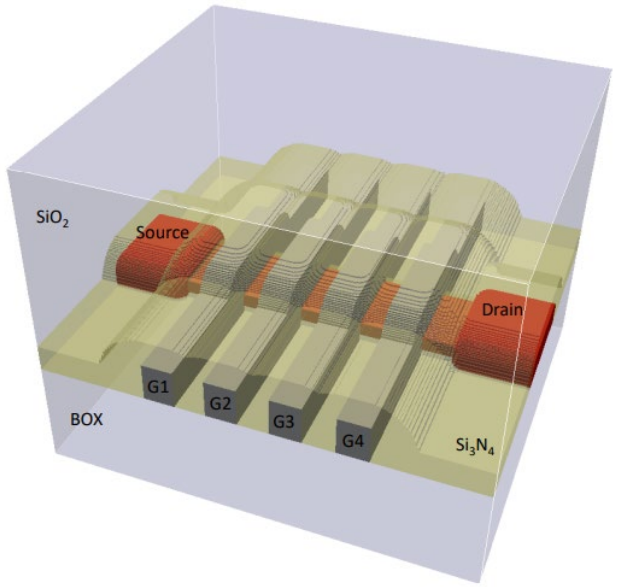


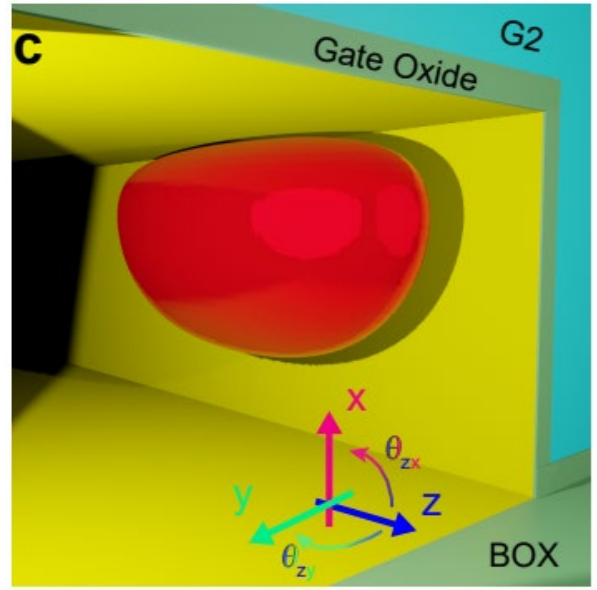
- Elzerman readout

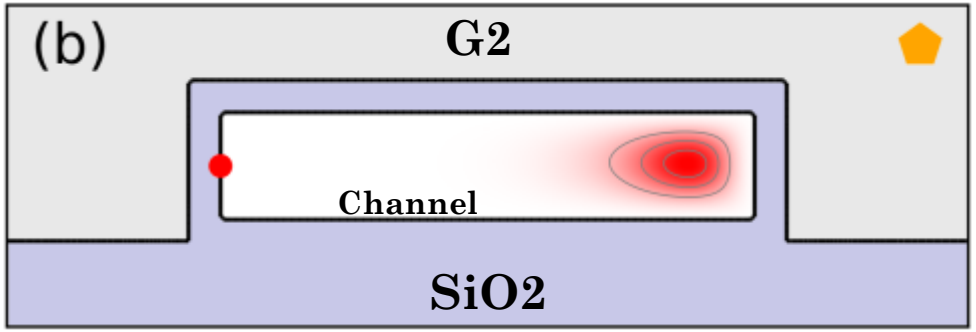




First hole accumulation (k.p model)

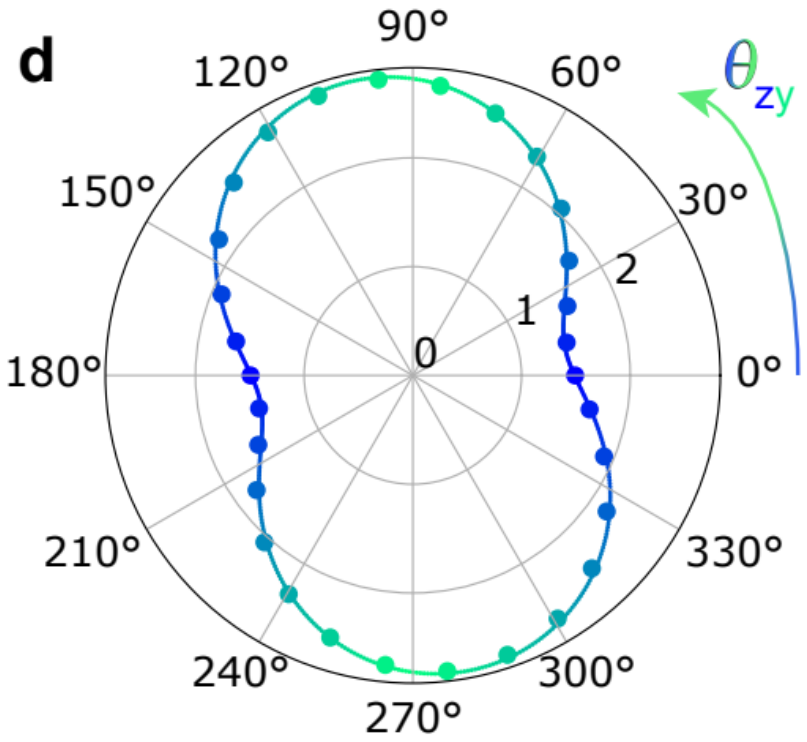




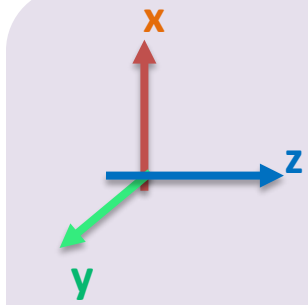


- Strong 2-axes confinement favours HH-LH mixing
- This manifest in the g-factor anisotropy

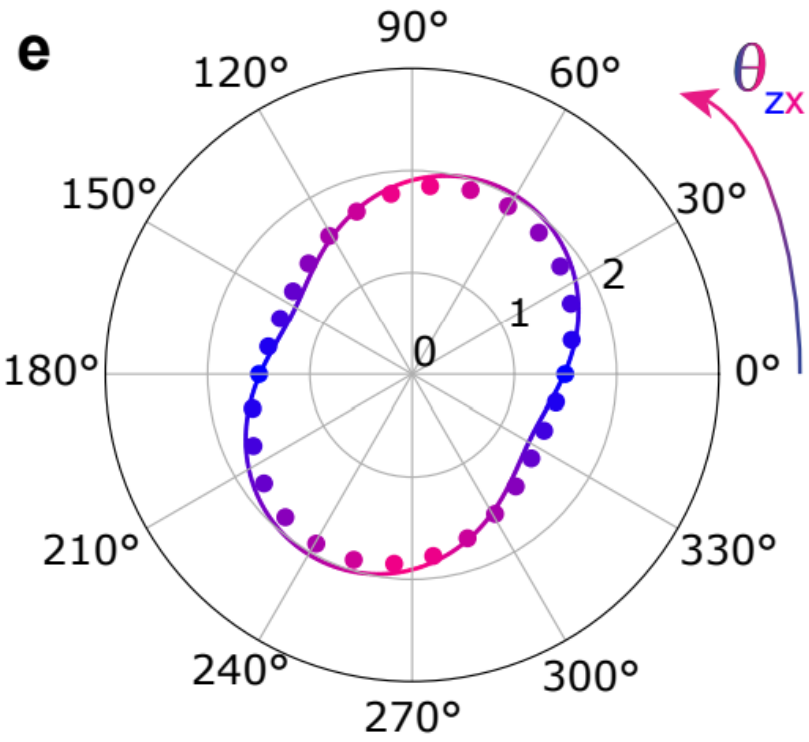
First hole accumulation (k.p model)



$\theta_{zy} = 90 \rightarrow y\ axis$



Magnetic field orientation



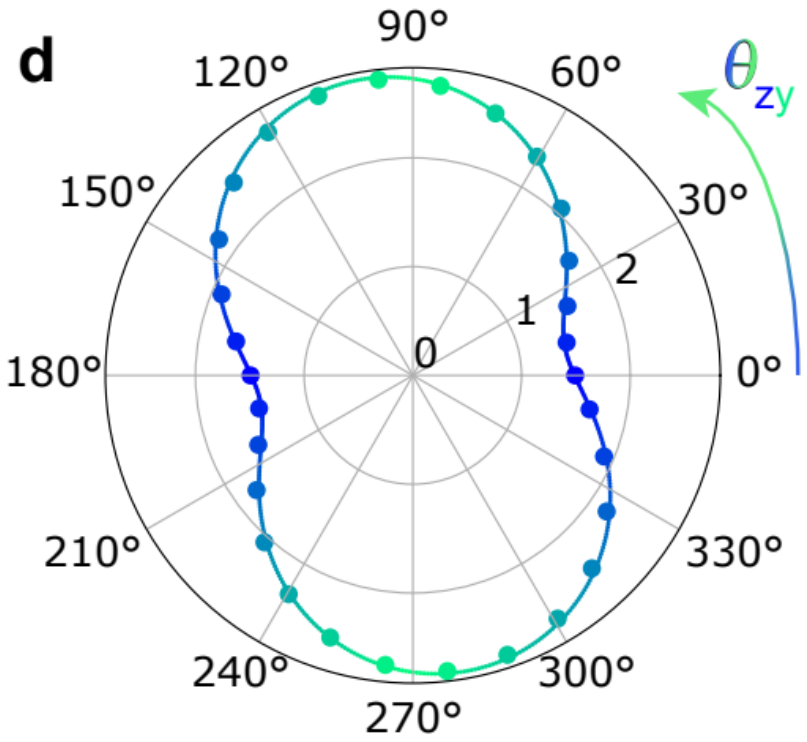
$\theta_{zx} = 90 \rightarrow x\ axis$

$$g = hf_L/(\mu_B|B|)$$

- Strong anisotropy of Zeeman splitting
  - ✓ max g ~ 2.7 close to y axis
  - ✓ min g ~ 1.4 close to z axis

Assumption for the calculated g-factor: B-field misalignement + shear strain: 0.1 % + disorder

First hole accumulation (k.p model)



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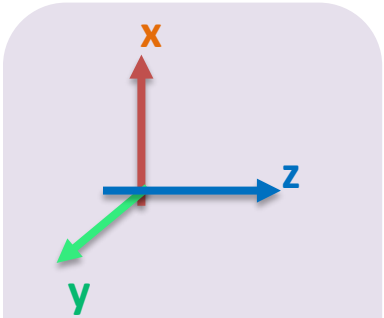
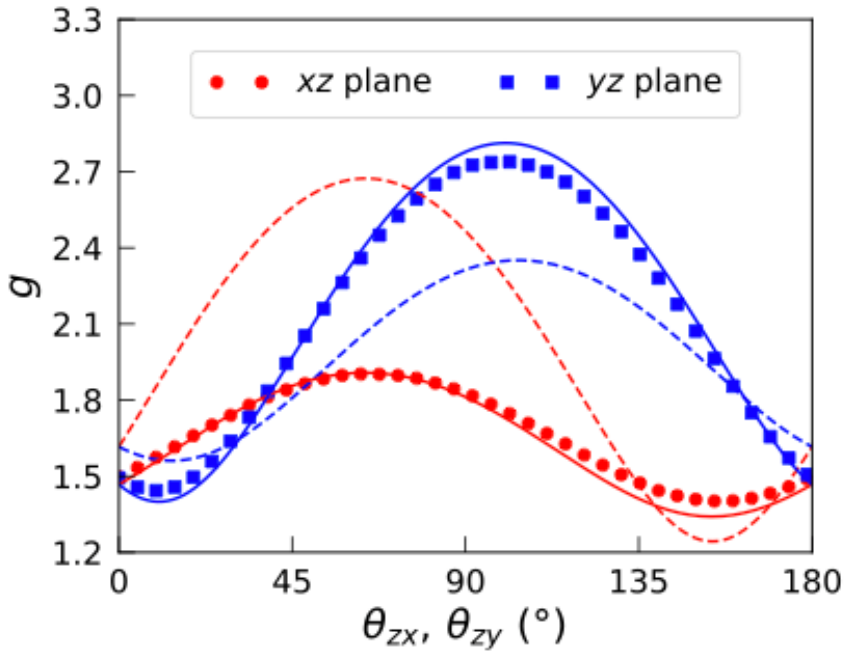


Magnetic field orientation

$\boldsymbol{g = hf_L/(\mu_B|B|)}$

---- no disorder

—— disorder



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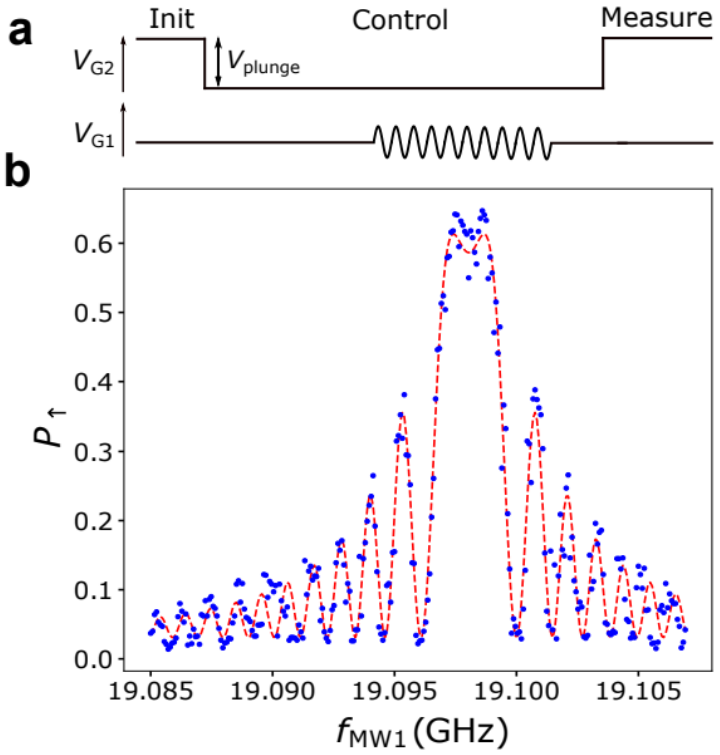
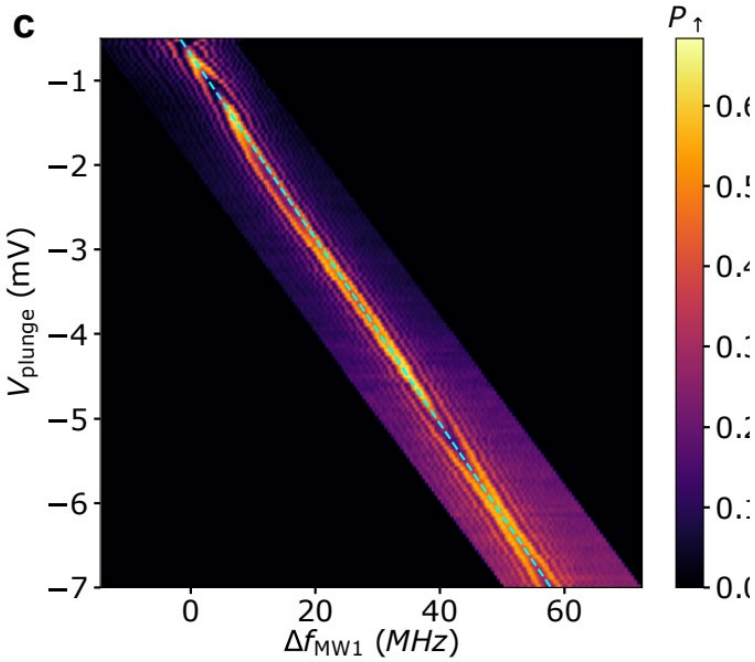
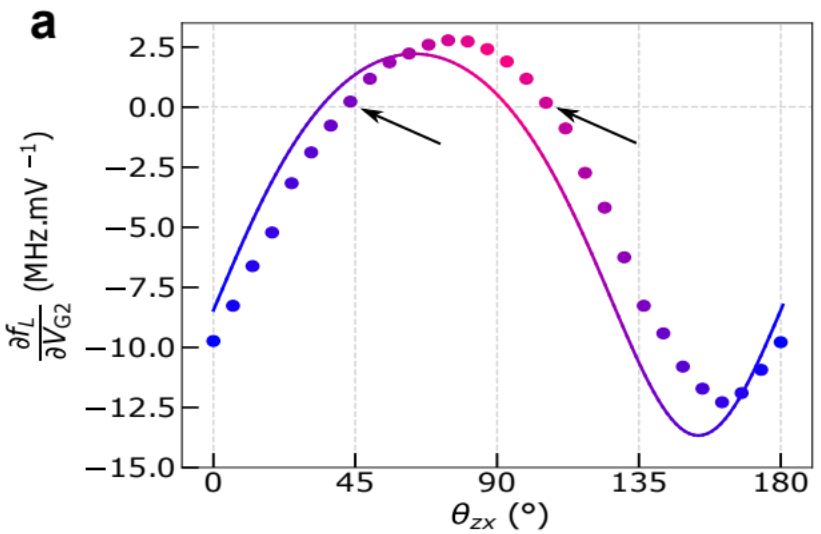
Longitudinal Spin-Electric Susceptibility (LSES)

$$LSES = \frac{\delta f_L}{\delta V_{gate}}$$

- LSES of gate 2 (~out of plane E field)



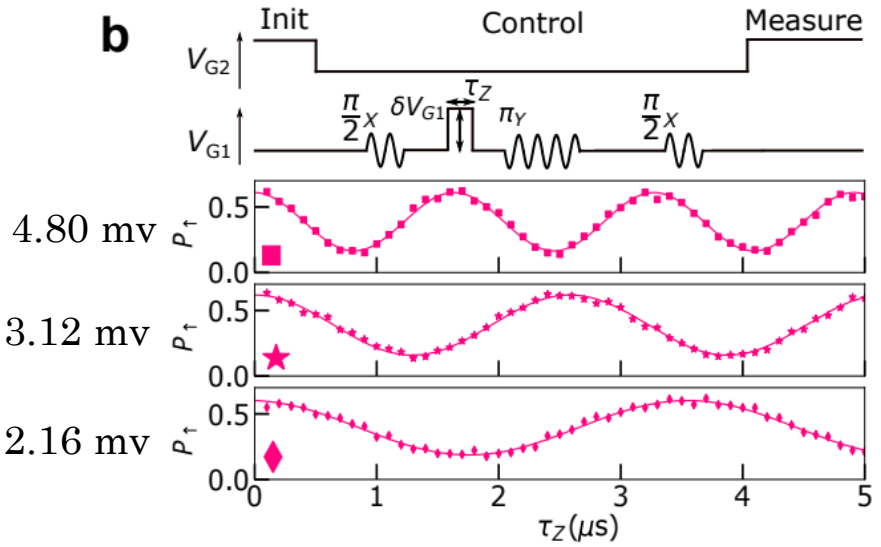


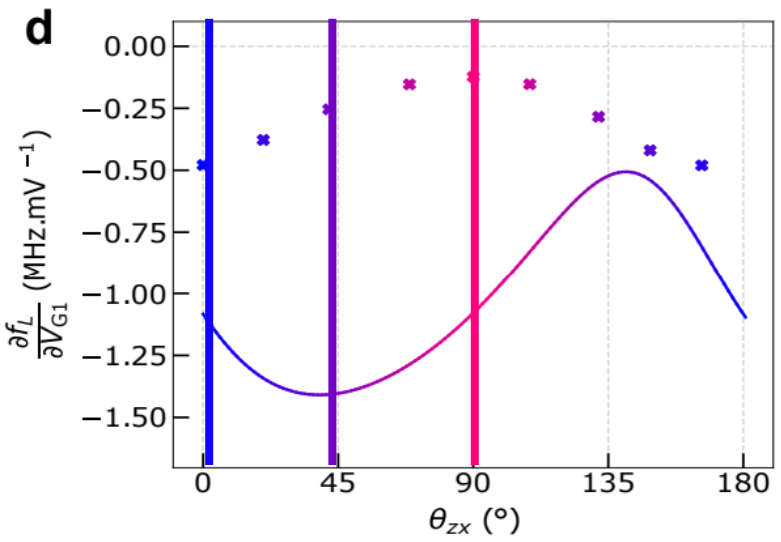


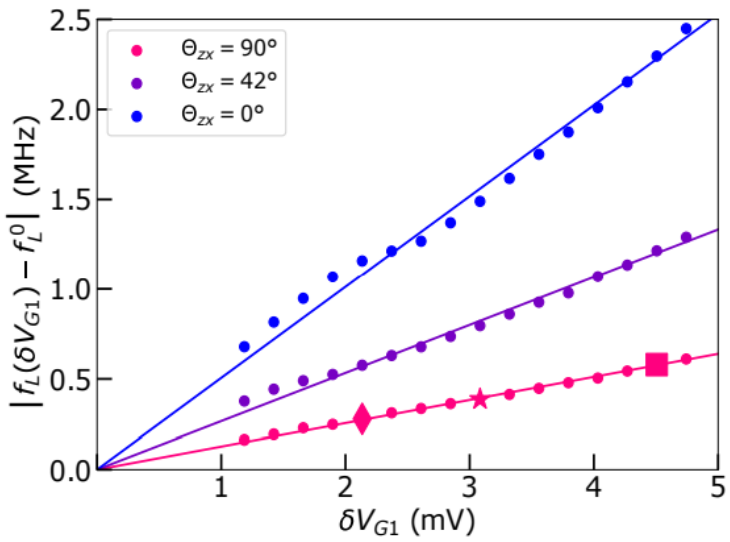
Longitudinal Spin-Electric Susceptibility (LSES)

$$LSES = \frac{\delta f_L}{\delta V_{gate}}$$

- LSES of gate 1 (~in plane E field)

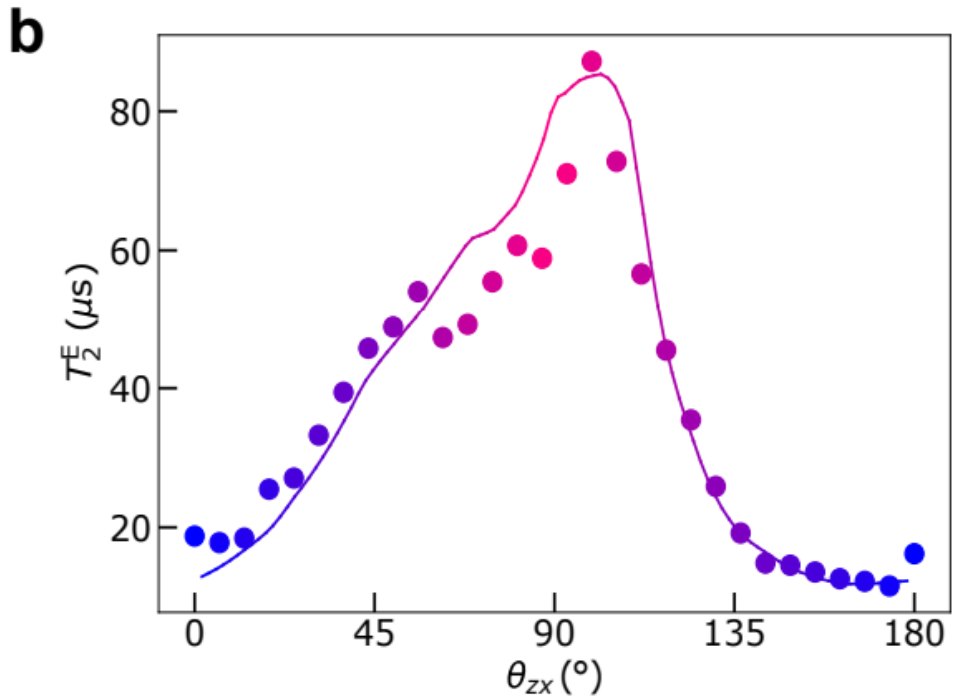




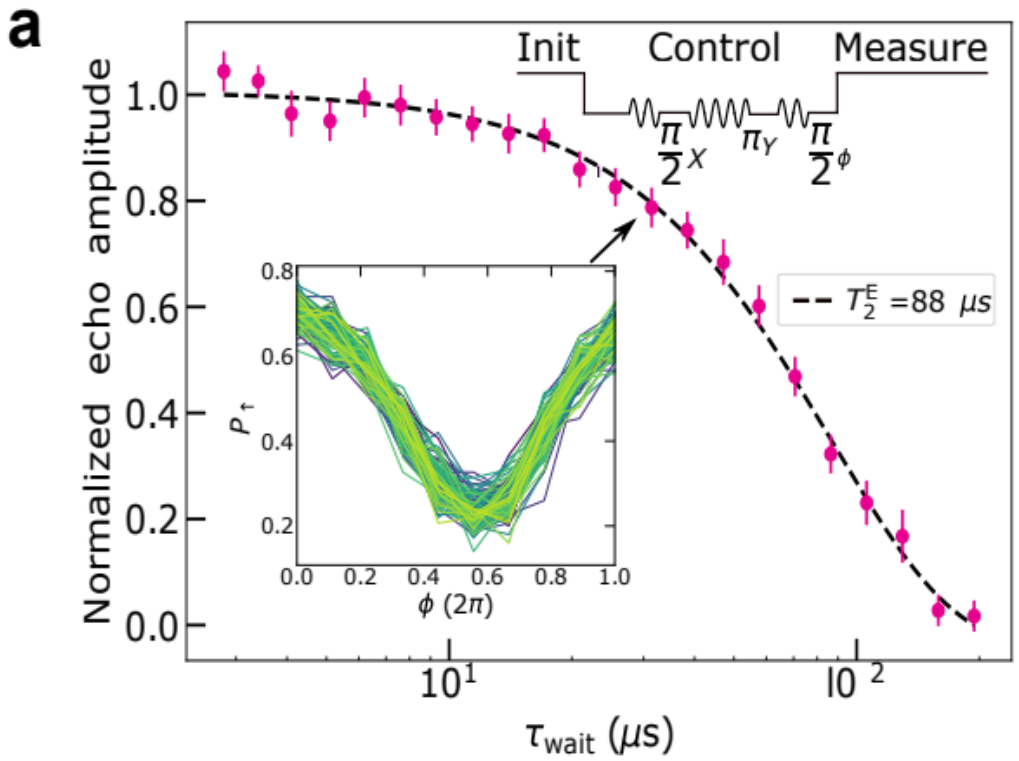


Coherence Times

- Hahn echo



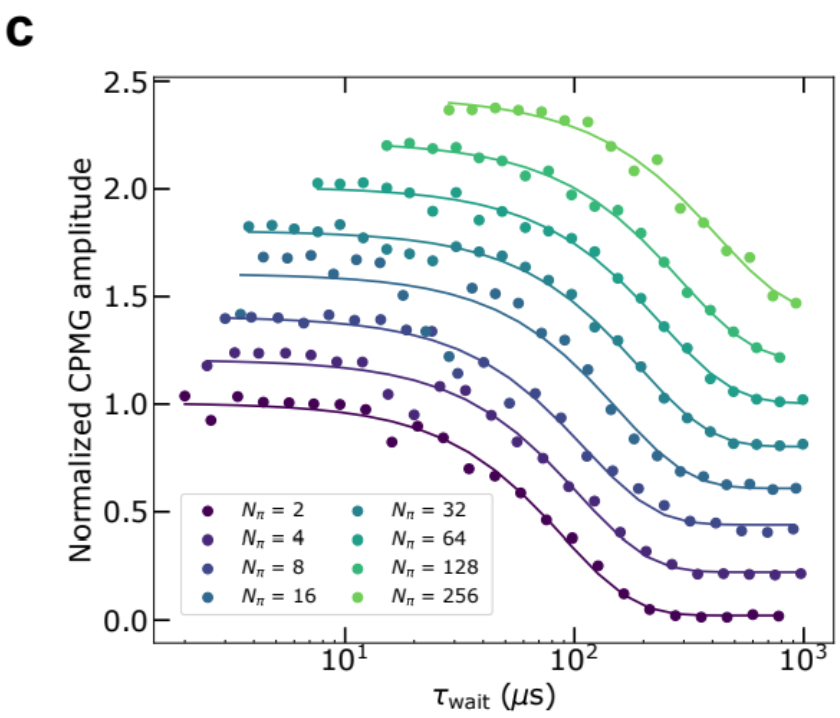
- $\theta = 99°$



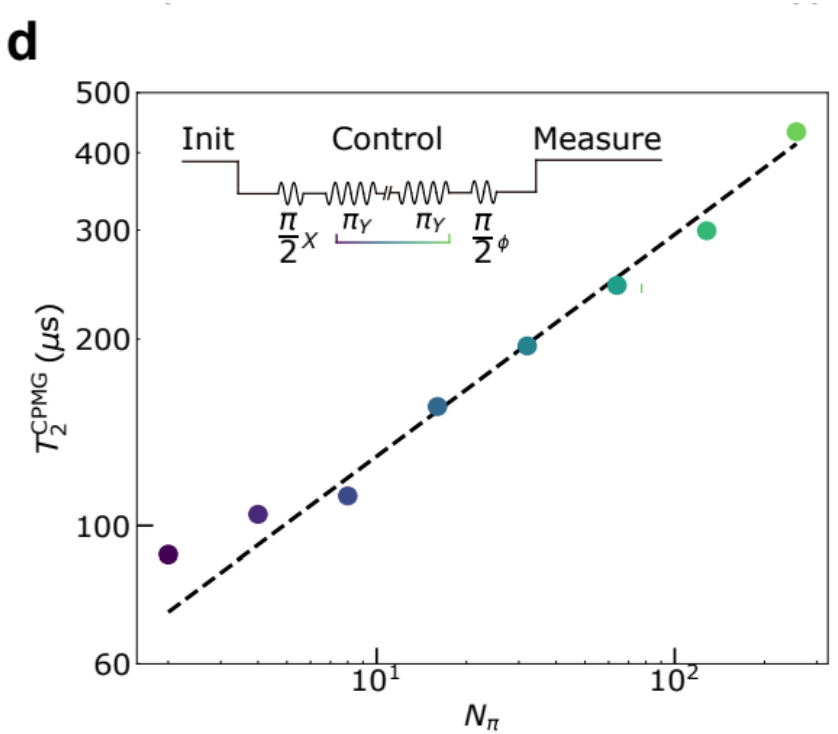
- Fit equation: $\exp\left(-\left(\frac{\tau_{wait}}{T_2^E}\right)^{\beta}\right)$
- $\beta = 1.5 \pm 0.1 \rightarrow noise\ spectrum\ S \propto 1/\sqrt{f}$

Coherence Times

- CPMG sequence ($\theta = 99°$)



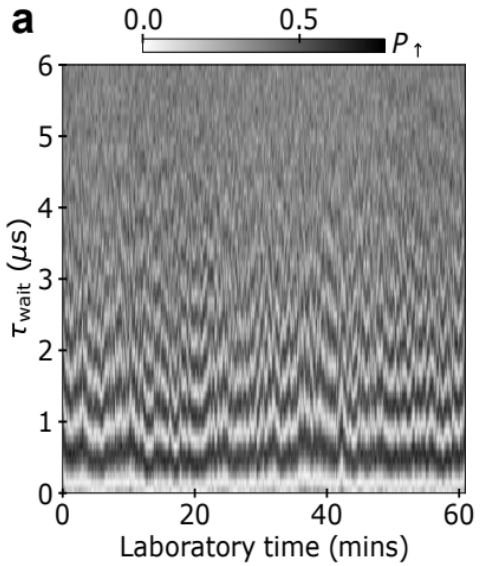
- Confirms noise spectrum $S \propto 1/\sqrt{f}$

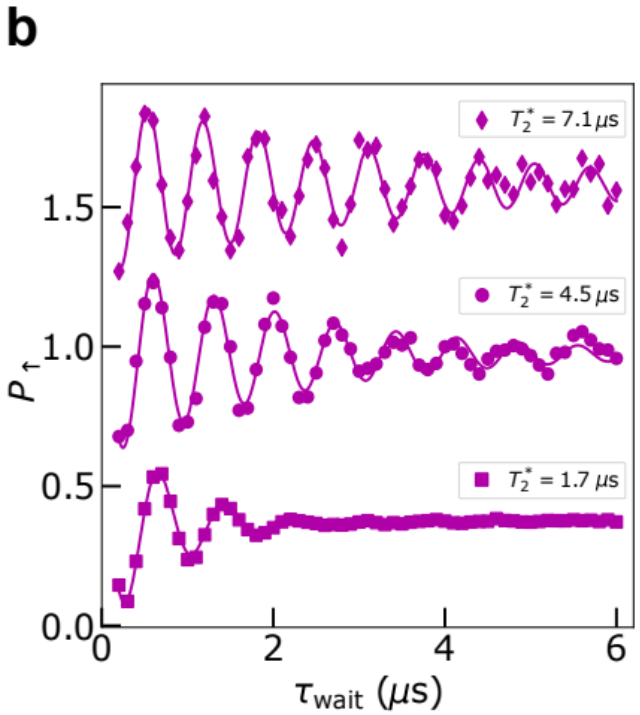


- $T_2^{CPMG} = 0.4\ ms\ for\ N_\pi = 256$
  - ✓ Longest coherence ever reported for hole spins

Coherence Times

- T_2^* measurement
  - ✓ Ramsey sequence (no refocusing pulse)

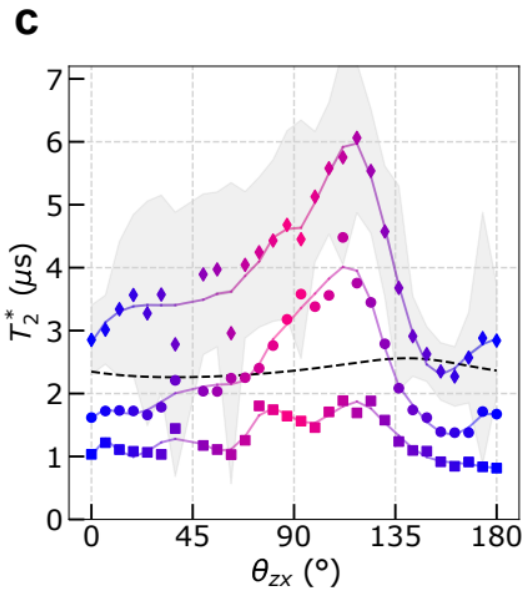




Integration: 5.5s (1 trace)

Integration: 27.5s (5 trace)

Integration: 1h (600 trace)



- *Low frequency noise*, $S \propto 1/f$

Conclusion

- Existence of coherence sweet spot when swiping B-field angle
- A lot of nice datas (quite complete paper)
- Not sure if the model is trustworthy

Thanks

Thank you for your attention!