


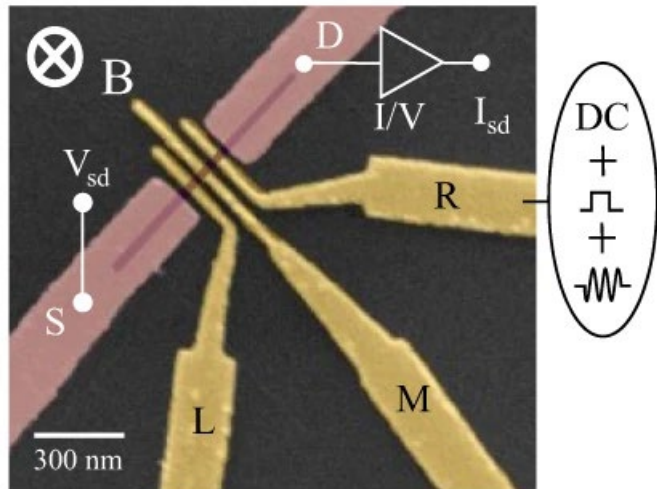
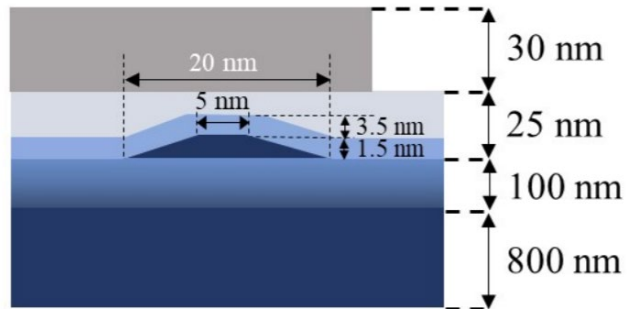
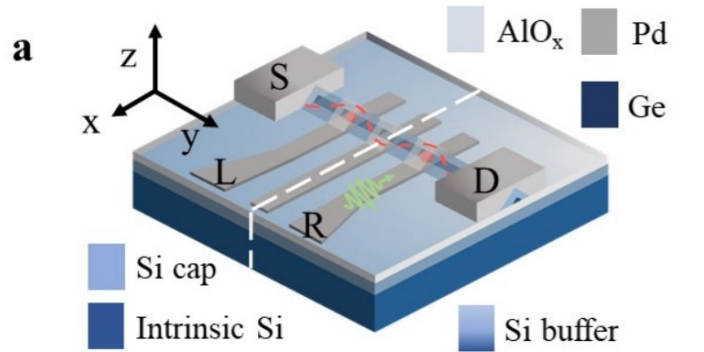
Ultrafast coherent control of a hole spin qubit in a germanium quantum dot

[Ke Wang](#), [Gang Xu](#), [Fei Gao](#), [He Liu](#), [Rong-Long Ma](#), [Xin Zhang](#), [Zhanning Wang](#), [Gang Cao](#), [Ting Wang](#), [Jian-Jun Zhang](#) , [Dimitrie Culcer](#), [Xuedong Hu](#), [Hong-Wen Jiang](#), [Hai-Ou Li](#) , [Guang-Can Guo](#) & [Guo-Ping Guo](#) 

[Nature Communications](#) **13**, Article number: 206 (2022)

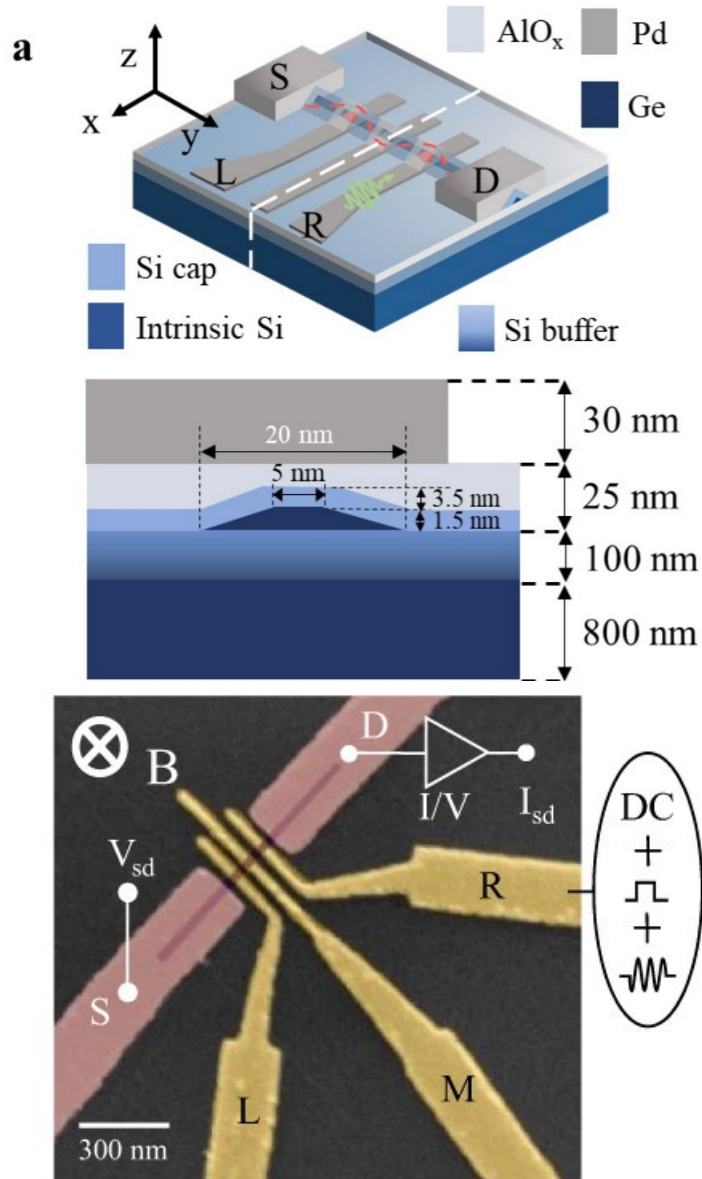
Pierre Chevalier Kwon
21.01.2022

Device architecture



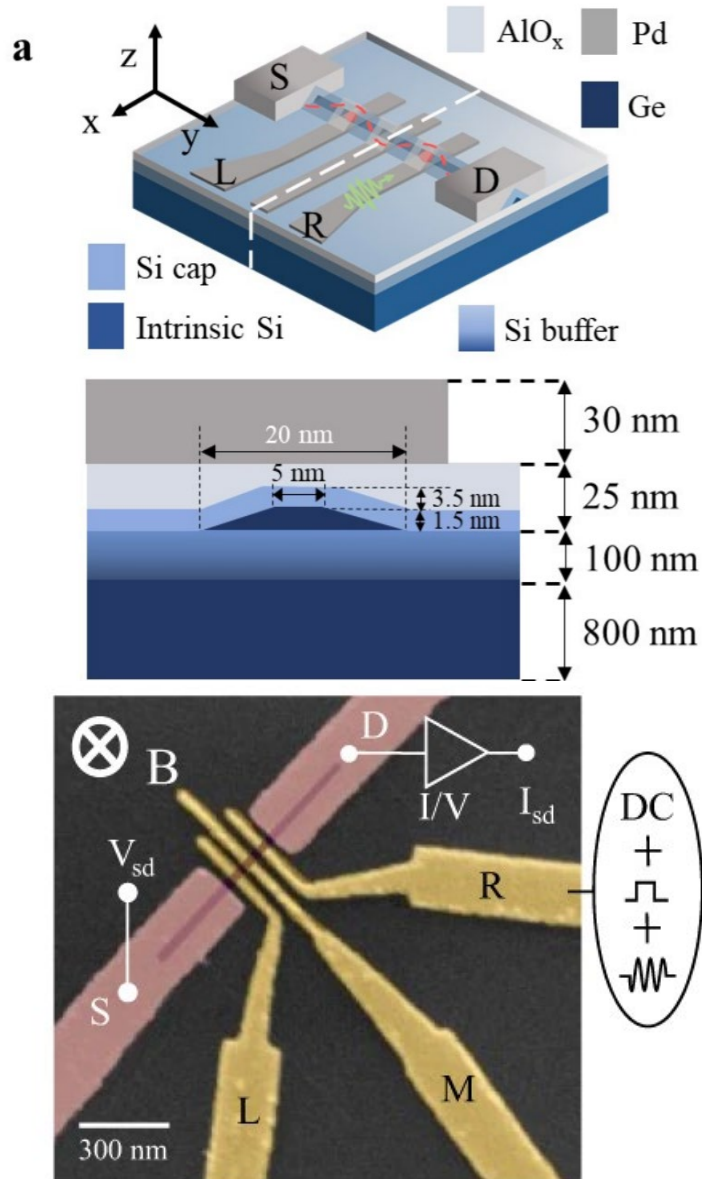
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Device architecture



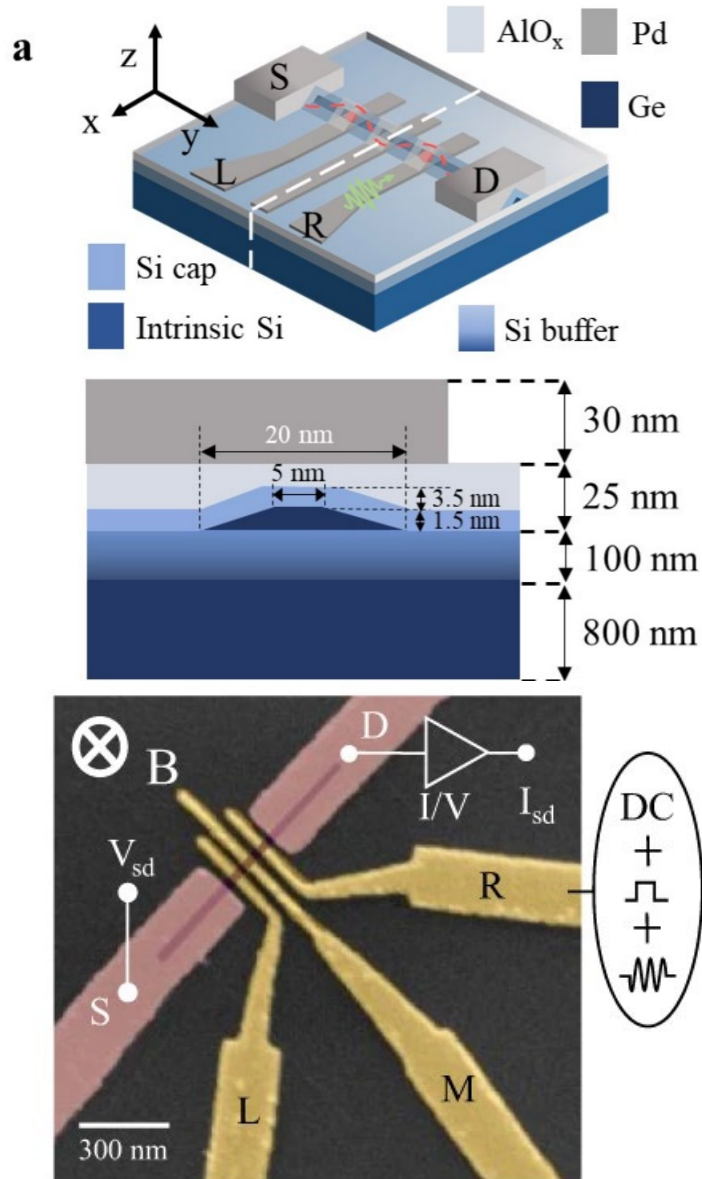
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- Germanium hut wire:
 - Ge layer (1.5 nm) deposited by S-K growth mode
 - 3.5-nm-thick Si cap then grown on top

Device architecture



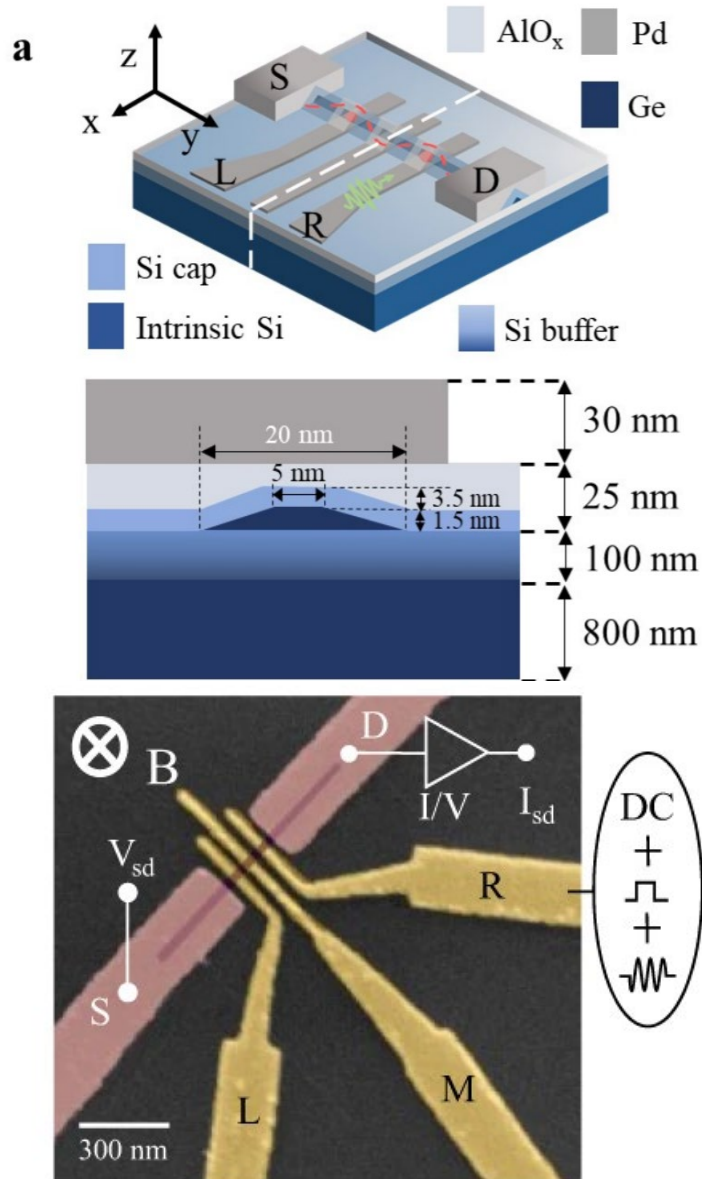
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- 20 nm of Aluminium oxide

Device architecture



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- Germanium hut wire:
 - Ge layer (1.5 nm) deposited by S-K growth mode
 - 3.5-nm-thick Si cap then grown on top
- Source and Drain Pads made with Pd
- 20 nm of Aluminium oxide
- 3 confinement gates (no plunger) made with Pd
 - 35 nm wide (I found $\sim 40 \pm 5$ nm)
 - Center to center distance of 65 nm
 - Microwave pulses are applied via gate R

Device setup



- Oxford Triton dilution refrigerator at a base temperature of 10 mK

Device setup

Google

oxford triton



Oxford Instruments' Triton...
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8: Image of the Oxford ...
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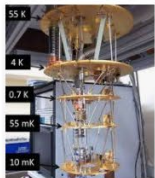
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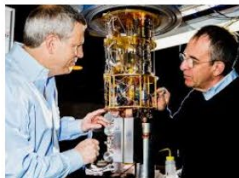
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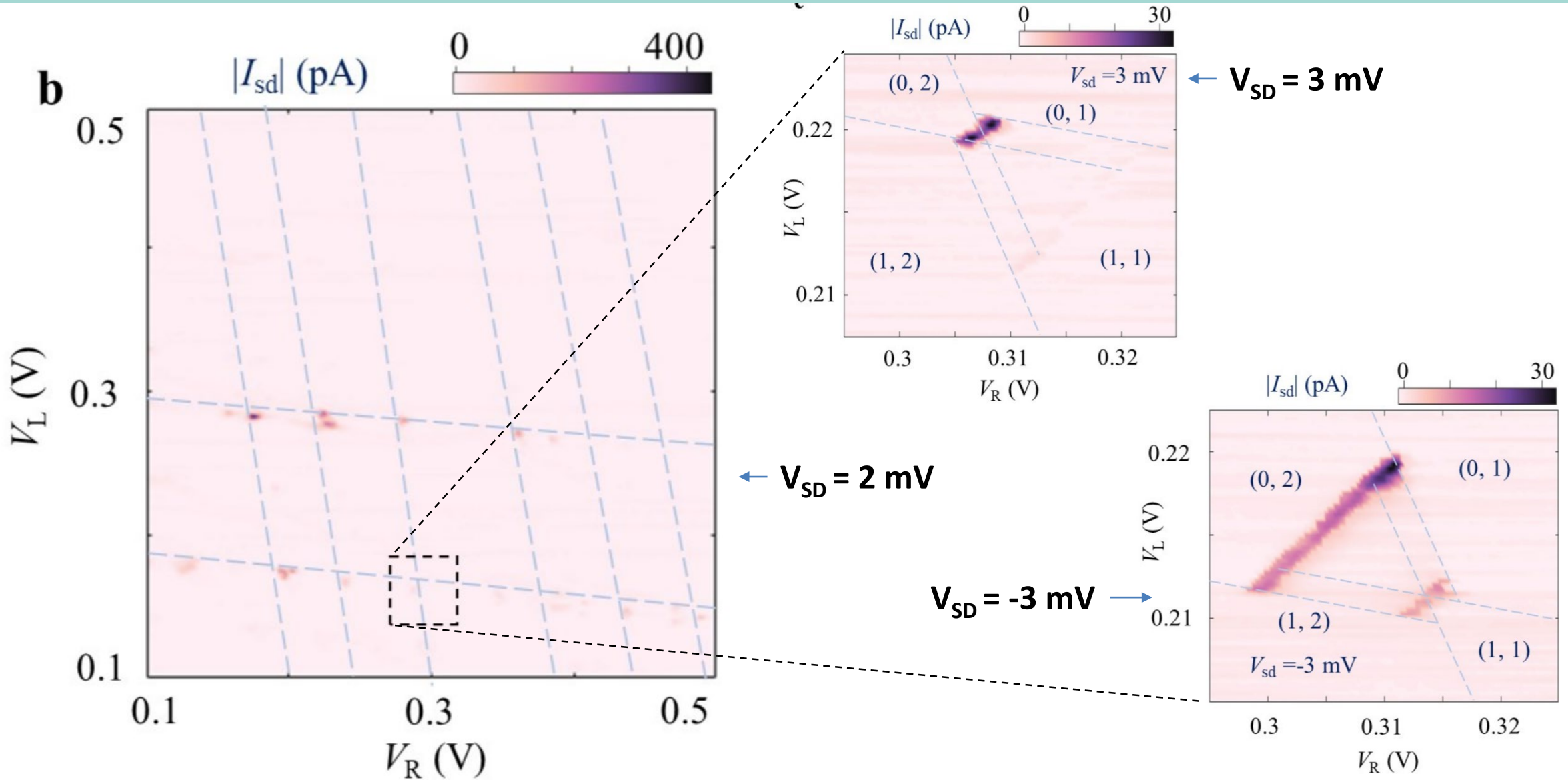
Sebago TRITON THREE-EYE, Oxford homme
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Device setup

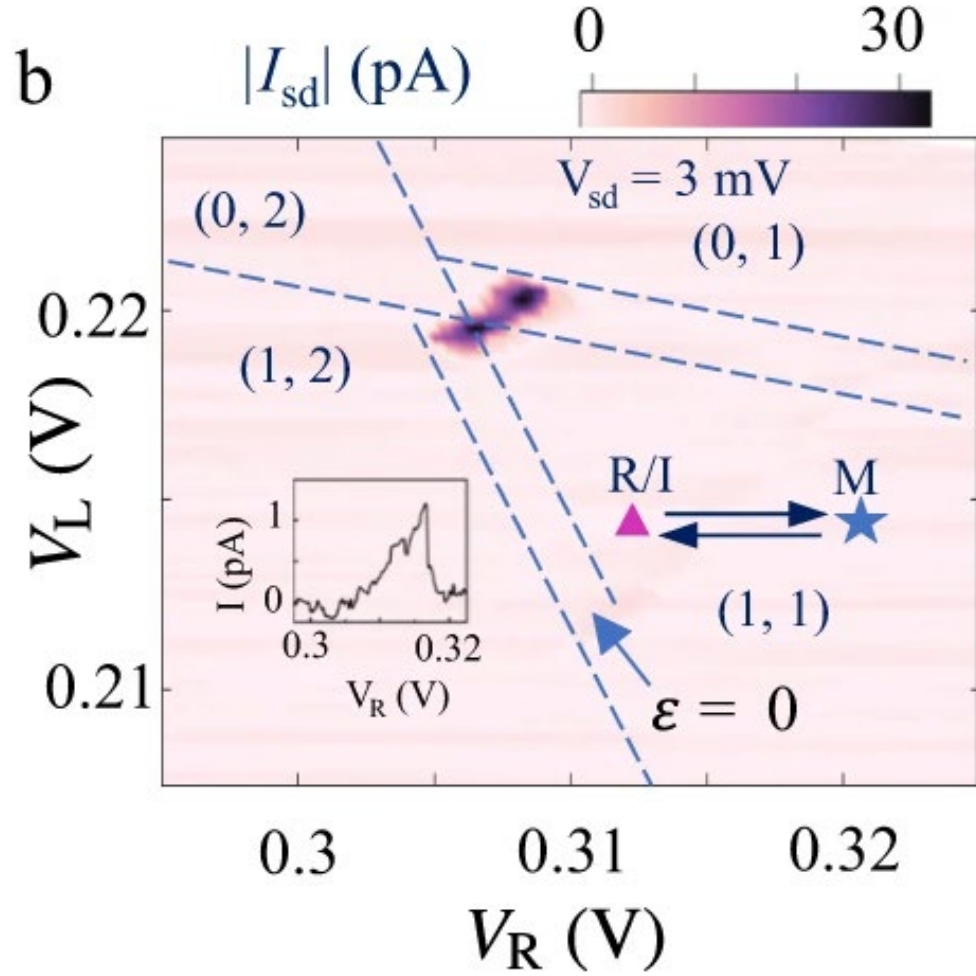


- Oxford Triton dilution refrigerator at a base temperature of 10 mK
- AWG: Keysight M8190A
- Vector source: Keysight E8267D

DQD configuration

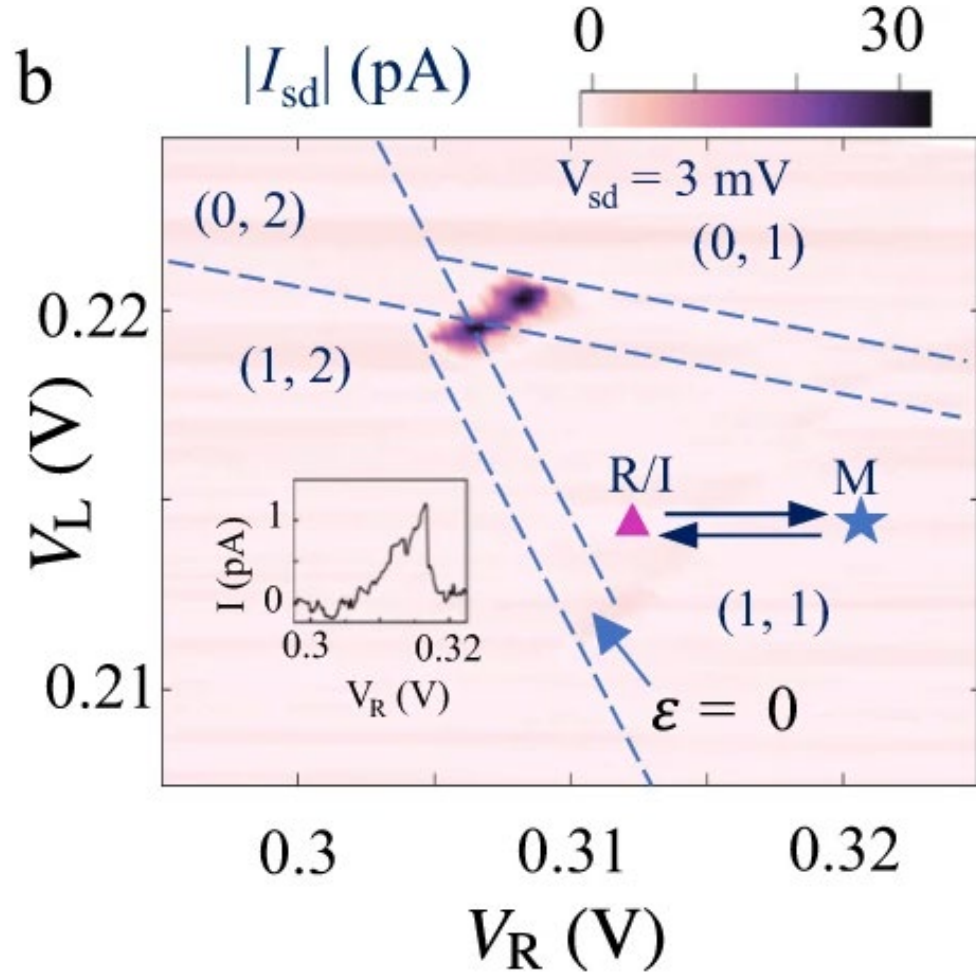


DQD configuration



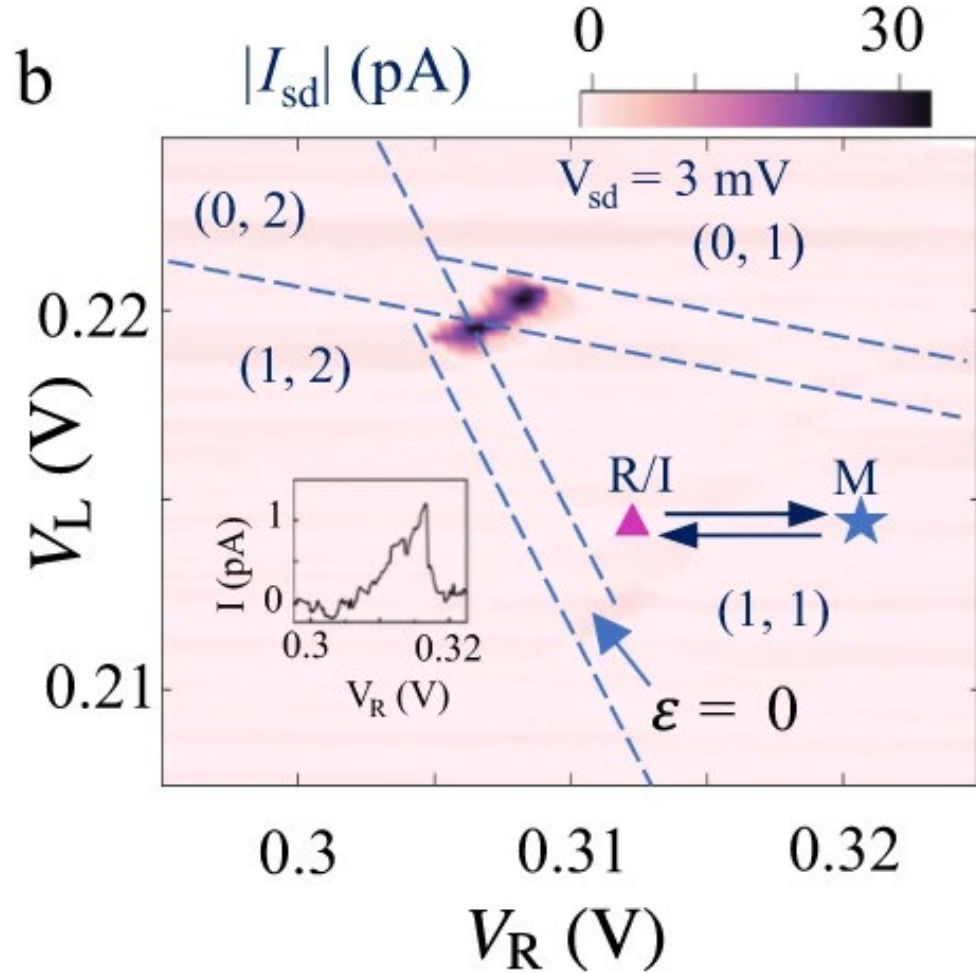
- They found PSB (see previous slide)

DQD configuration

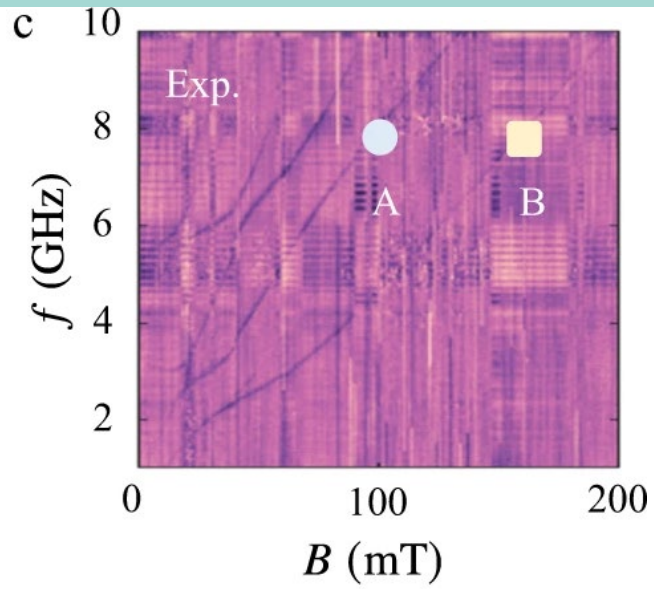


- They found PSB (see previous slide)
- Claim to have about 5 holes in the left dot and 10 holes in the right dot

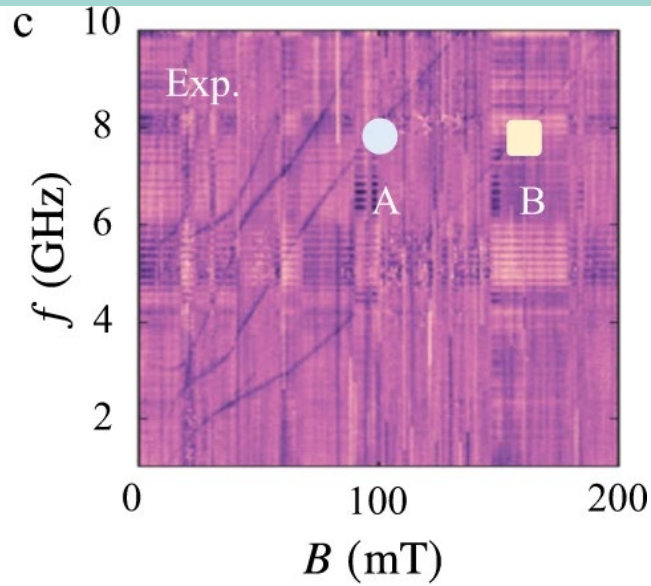
DQD configuration



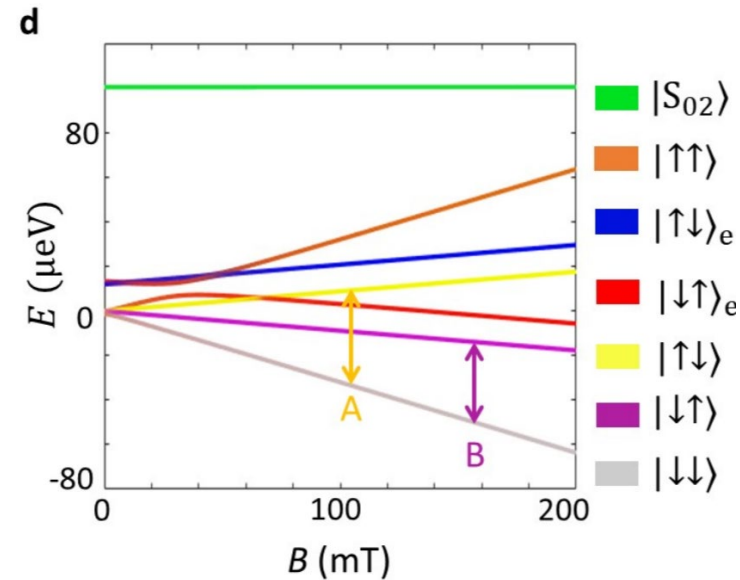
- They found PSB (see previous slide)
- Claim to have about 5 holes in the left dot and 10 holes in the right dot
- Extract from these maps:
 - Intra-dot Coulomb energy (orbital splitting) of 10 meV
 - Inter-dot Coulomb interaction of 0.5 meV

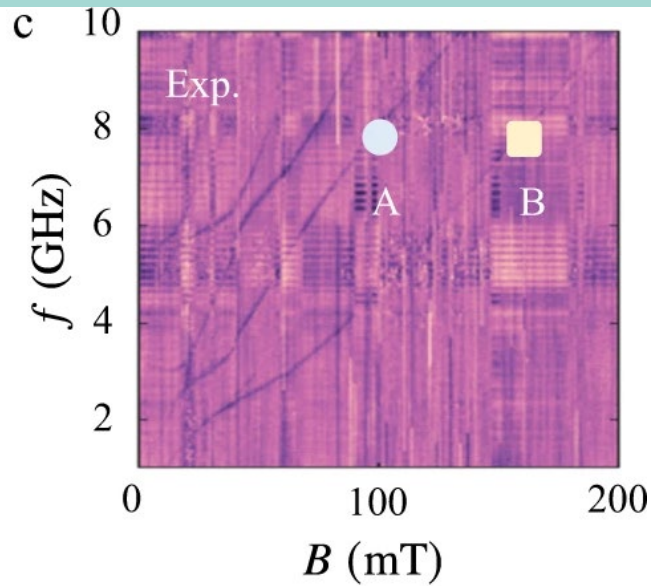


- EDSR measured by applying microwave with a power of -15 dBm (at the point R/I)

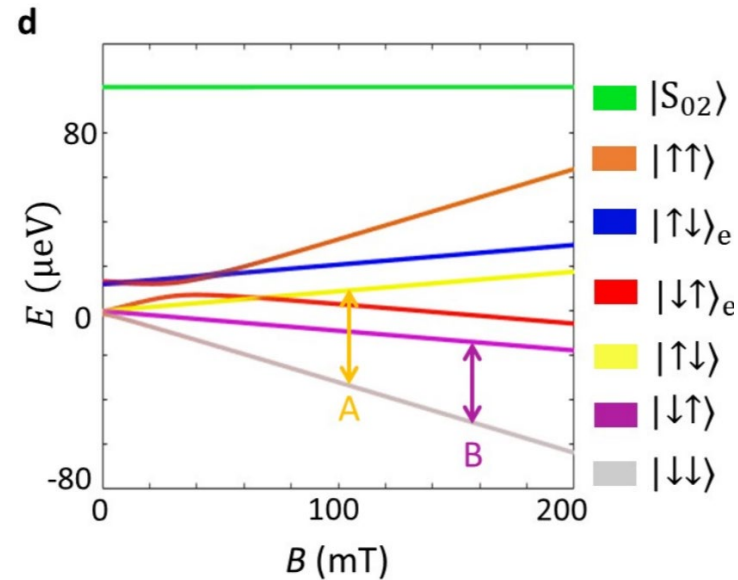
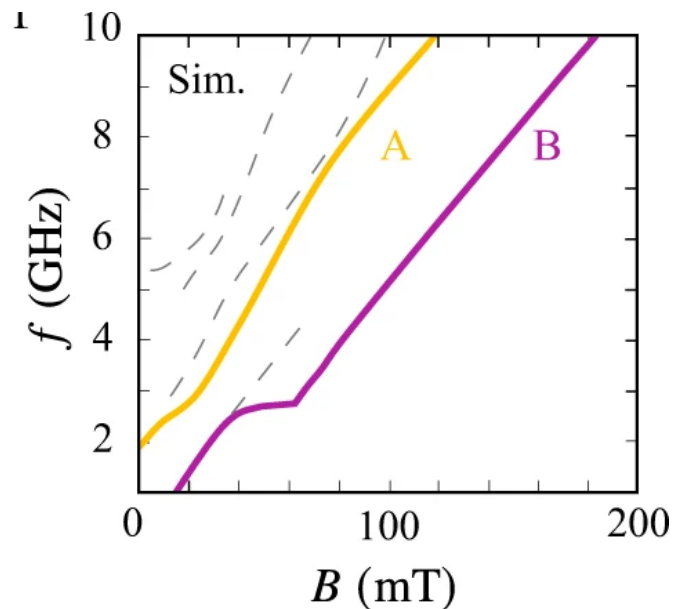


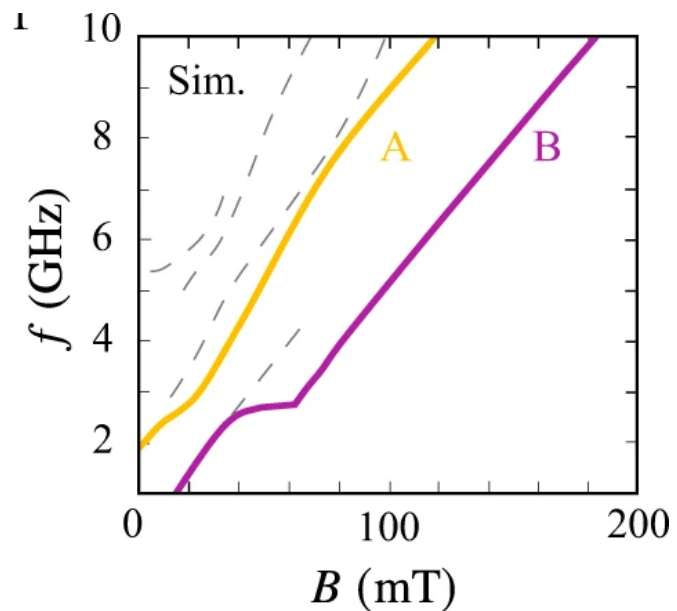
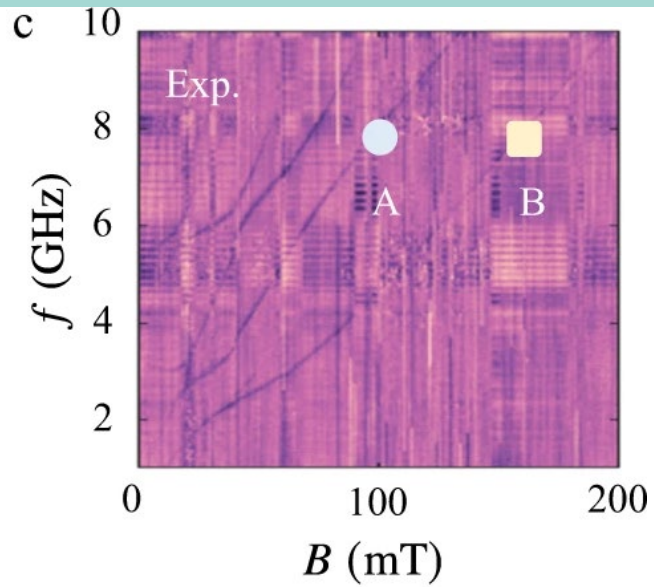
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- from their “effective two-hole model”, they fit the data:



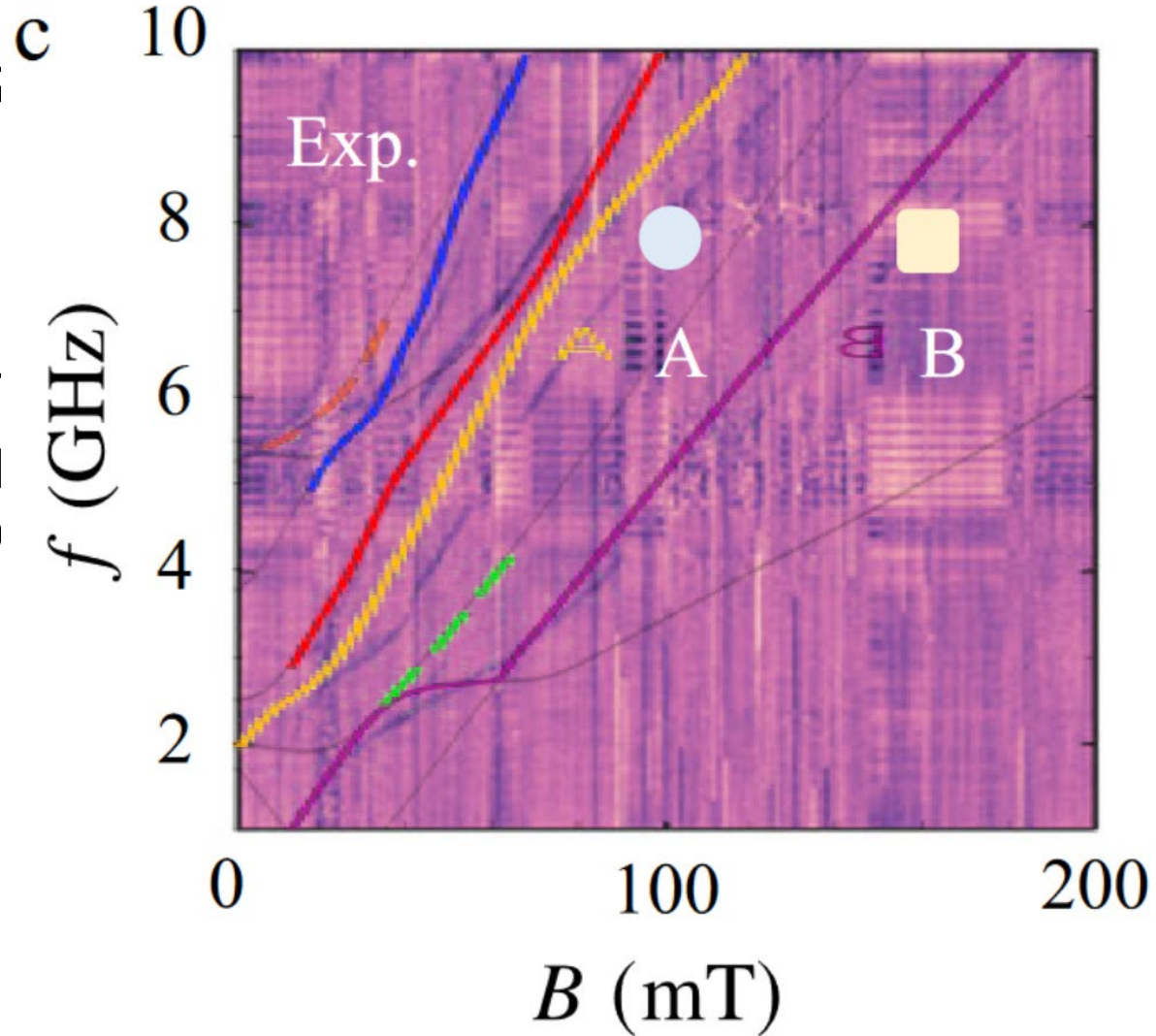


- EDSR measured by applying microwave with a power of -15 dBm (at the point R/I)
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- EDSR
- Pur
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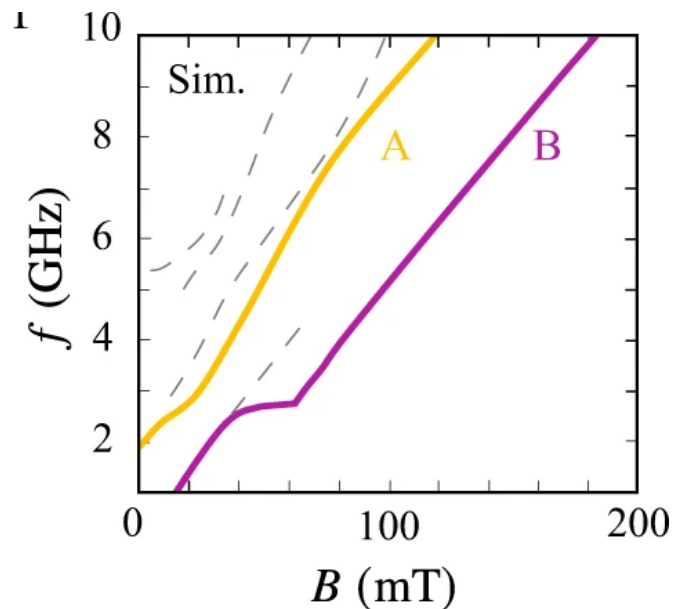
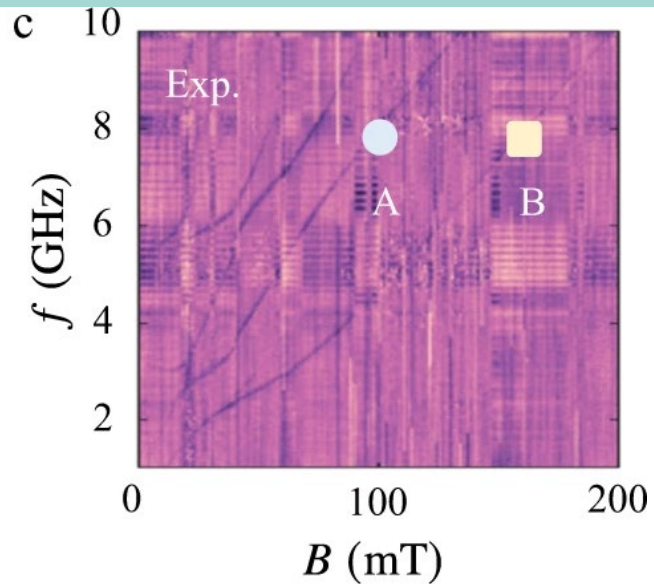


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data:

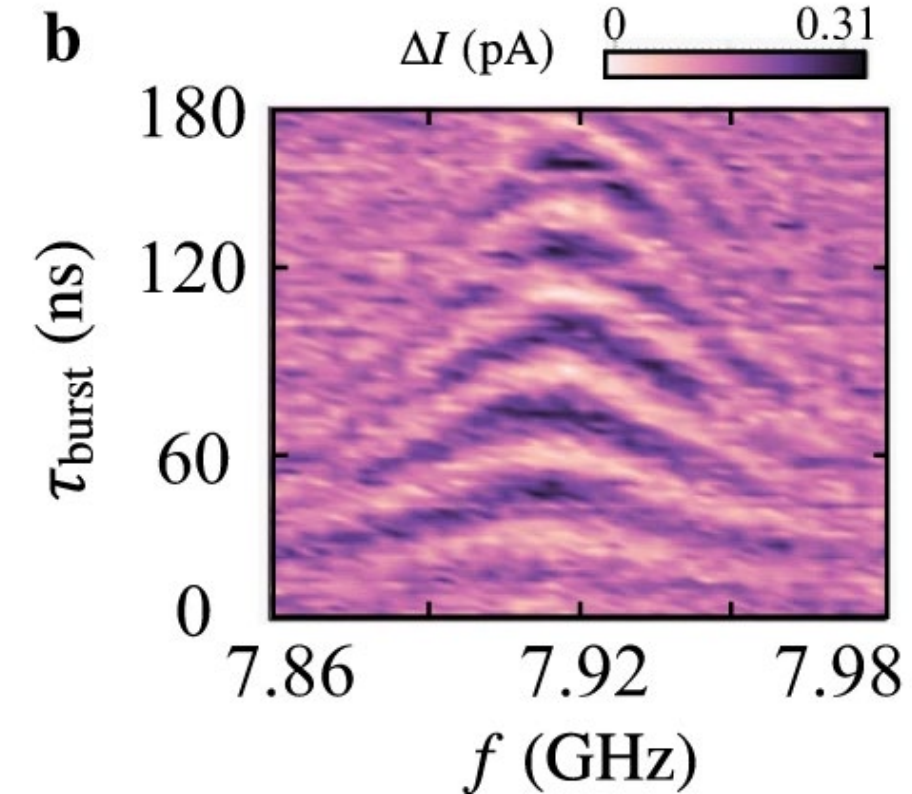
flips

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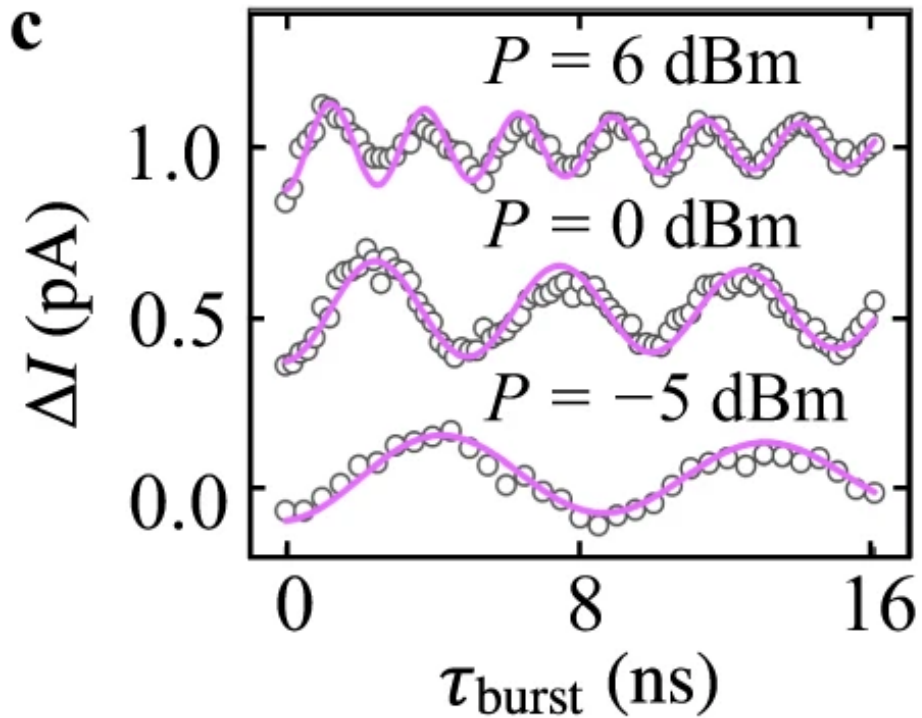
- EDSR measured by applying microwave with a power of -15 dBm (at the point R/I)
- Purple and yellow resonances correspond to spin-flips between $|\downarrow\downarrow\rangle$ and, respectively, $|\downarrow\uparrow\rangle / |\uparrow\downarrow\rangle$
- Find very different g -factors: $g_L = 7$ and $g_R = 3.95$
 - Proposed explanation: unequal hole occupations between the two dots

Rabi oscillations



- They operate in the mode A (see previous slide) with a Larmor frequency of **$f = 7.92$ GHz**

Rabi oscillations



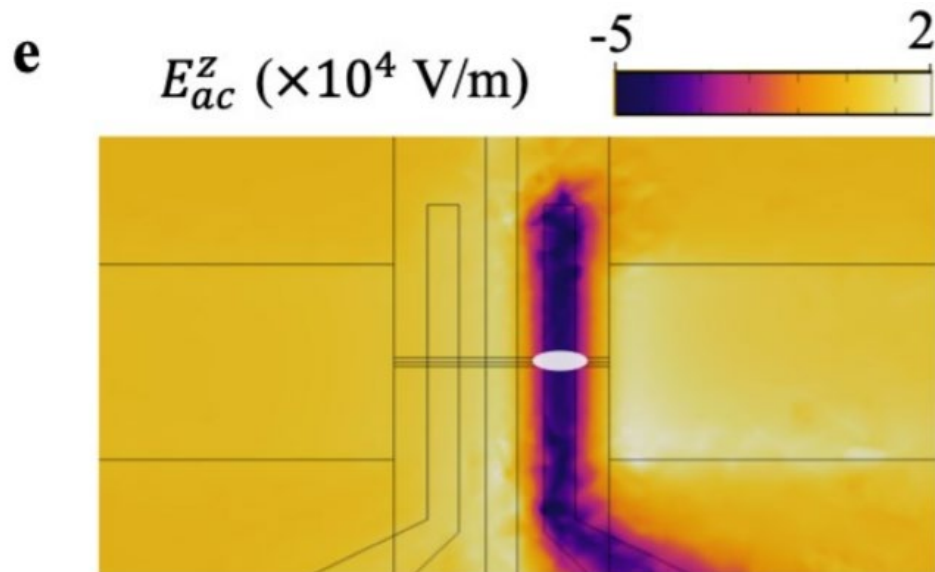
- They operate in the mode A (see previous slide) with a Larmor frequency of **$f = 7.92$ GHz**
- Rabi at 3 microwave power $P = -5, 0, 6$ dBm with an **averaging** over **100** cycles (reduce charge noise).
 - Maximum Rabi frequency of **$f_{\text{Rabi}} = 542 \pm 2$ MHz** for mode A (and 291 ± 1 MHz for mode B) achieved

Spin orbit length

- Using a single-hole model calculation, they get:

$$hf_{\text{Rabi}} = g\mu_{\text{B}}B \cdot \frac{a_x}{l_{\text{so}}} \cdot \frac{eE_{\text{ac}}a_x}{\hbar\omega_y}$$

Spin orbit length

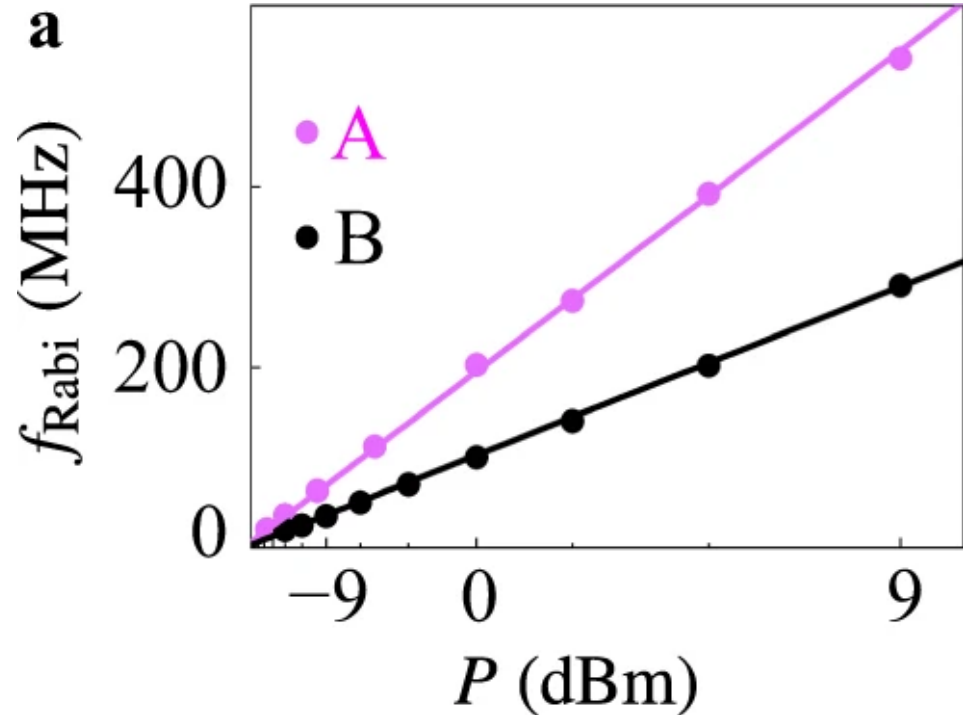


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- They simulate on Comsol their device to get $E_{\text{ac}} = f(P)$

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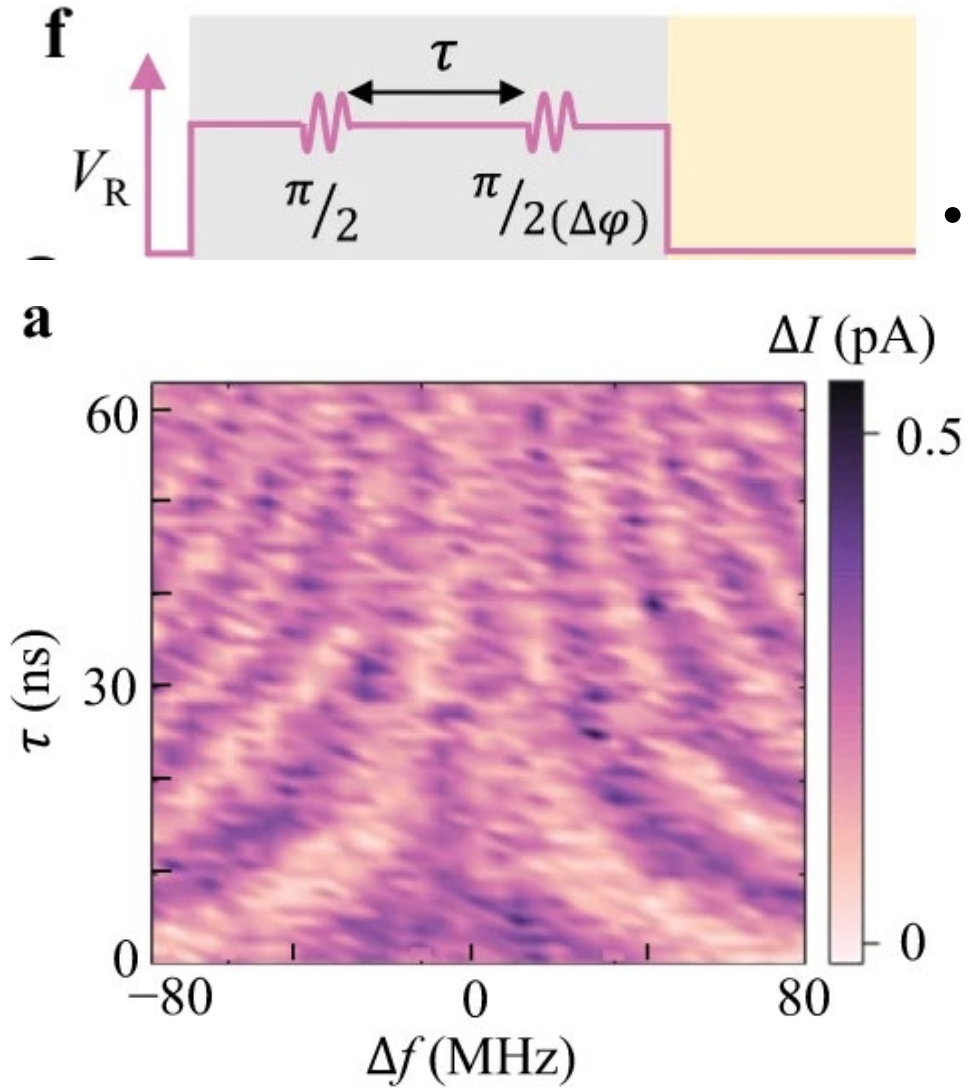


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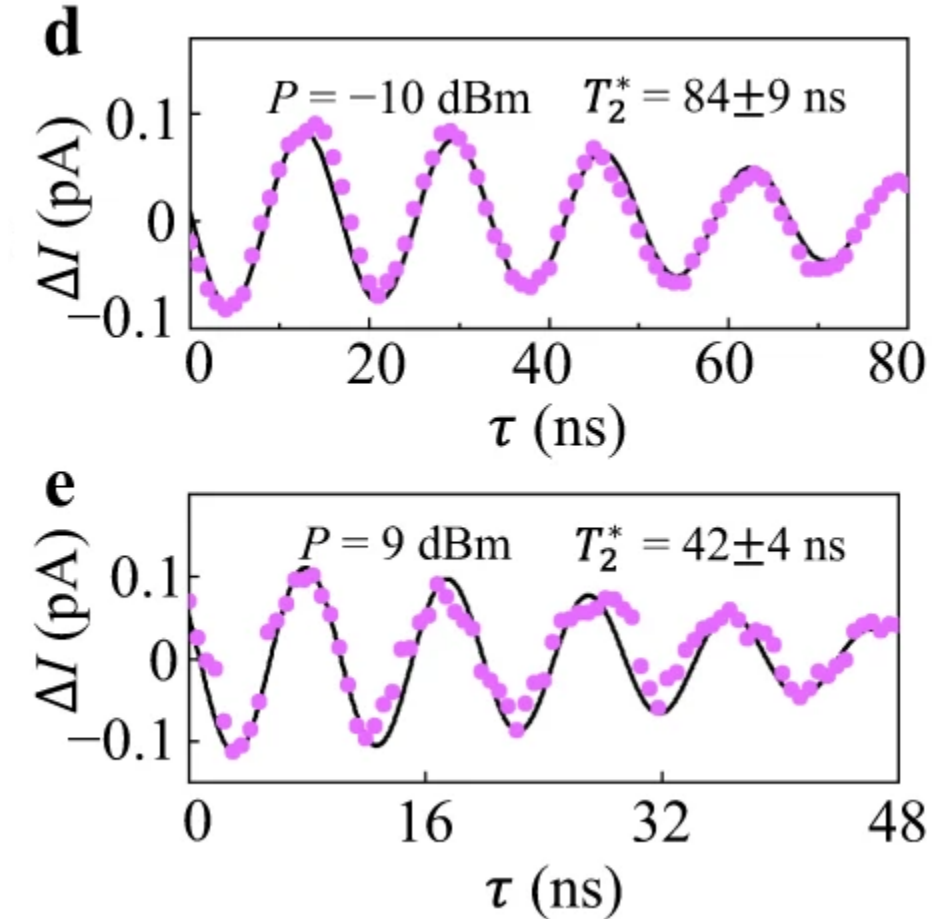
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- After plotting $P(E_{\text{ac}})$ function of f_{Rabi} one is able to get Spin orbit length:
 - 1.5 nm and 1.4 nm for, respectively, mode A and B

Ramsey

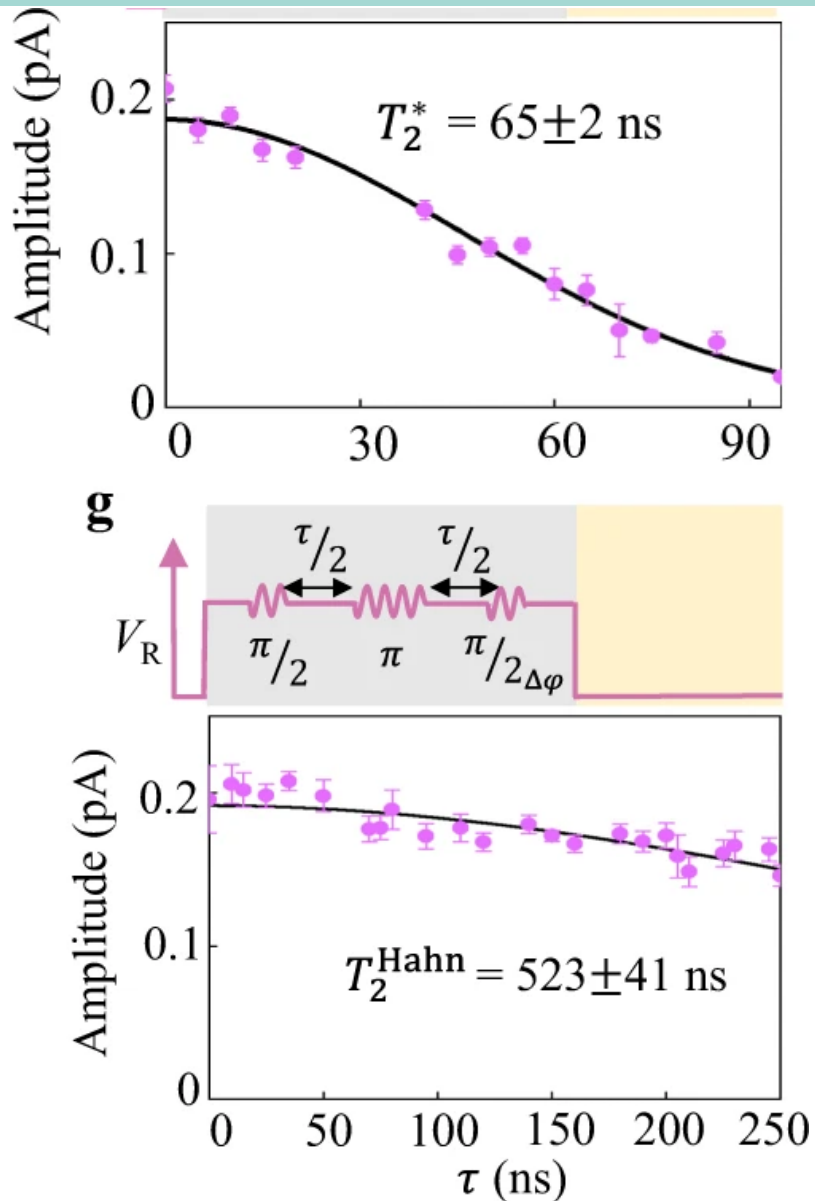


- They perform Ramsey experiment



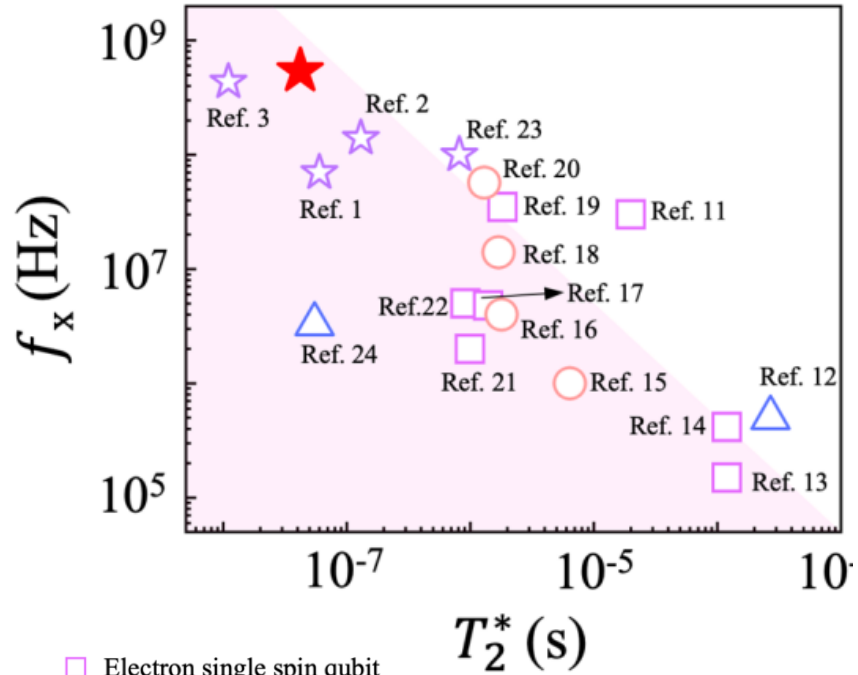
- They perform Ramsey experiment
- They extract the dephasing time: $T_2^* = 84 \pm 9$ ns and $T_2^* = 42 \pm 4$ ns at $P = -10$ dBm and $P = 9$ dBm (mode A)
 - “The former is a better representation of hole spin dephasing, while the latter reflects coherence degradation from the onset of microwave-induced heating”

Ramsey



- They perform Ramsey experiment
- They extract the dephasing $T_2^* = 84 \pm 9$ ns and $T_2^* = 42 \pm 4$ ns at $P = -10$ dBm and $P = 9$ dBm (mode A)
- They compare a Ramsey of the mode B ($T_2^* = 65 \pm 2$ ns) to a Hahn echo which improve the dephasing time:
 $T_2^{\text{Hahn}} = 523 \pm 4$ ns

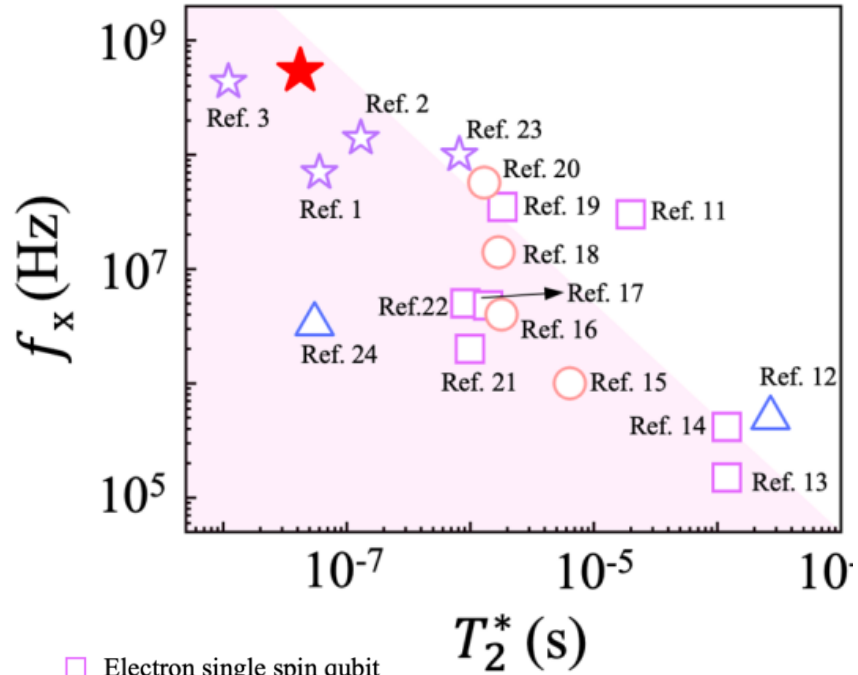
Conclusion



Summary of results:

- Ultrafast spin manipulation in a Ge HW

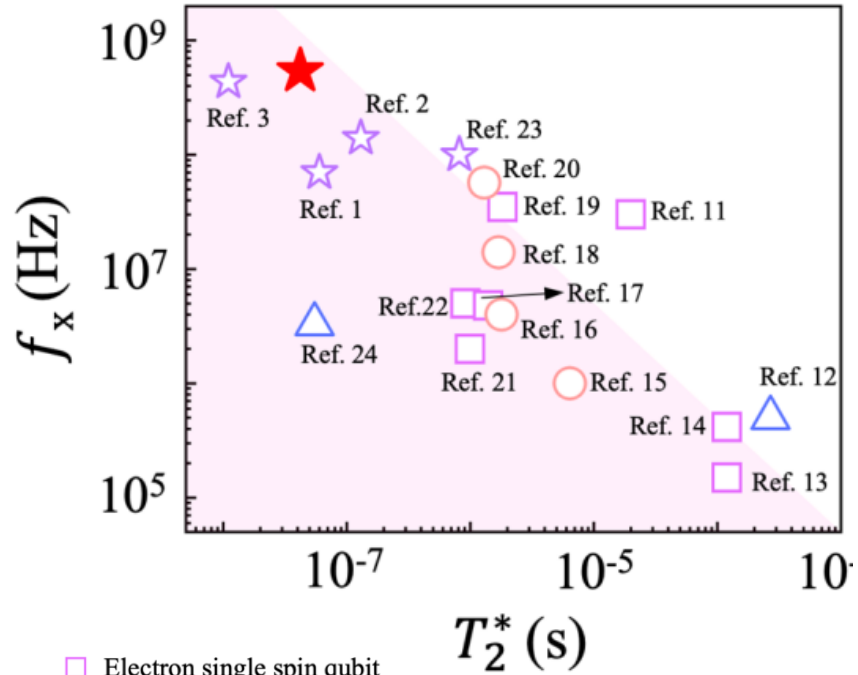
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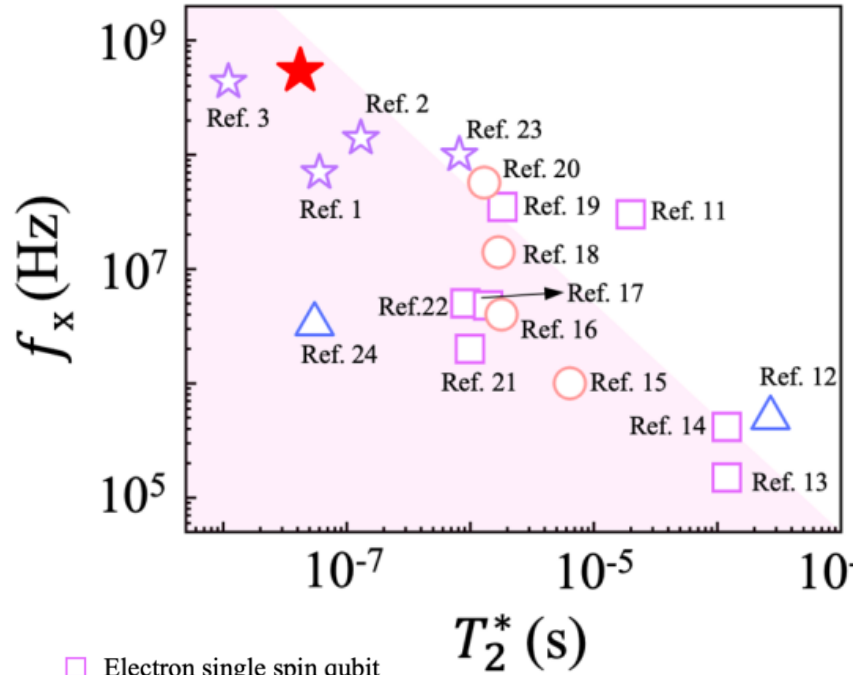
- Ultrafast spin manipulation in a Ge HW
 - Rabi frequency of up to 540 MHz at a (small) magnetic field of 100 mT

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- Ultrafast spin manipulation in a Ge HW
 - Rabi frequency of up to 540 MHz at a (small) magnetic field of 100 mT
- Ramsey: $T_2^* = 84 \pm 9$ ns
- Han echo: $T_2^{\text{han}} = 523 \pm 4$ ns

Thank you for your attention!