Enhanced quantum coherence in exchange coupled spins via singlet-triplet transitions

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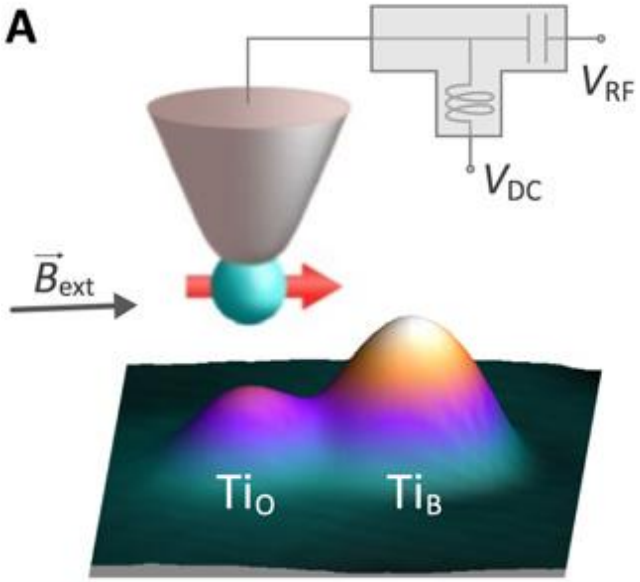
References:

- **Science Advances, 09 Nov 2018: Vol. 4, no. 11, eaau4159**

- Science 23 Oct 2015: Vol. 350, Issue 6259, pp. 417-420, DOI: 10.1126/science.aac8703

Experimental Setup

- 2 ML MgO/Ag(001) decouples magnetic adatoms from surface electrons.
- RF radiation through the tip combined with DC tunneling current to study electron spin resonance (ESR) and atomic interactions.
- Magnetic adatoms collected on the STM tip allow for magnetoresistive DC sensing.



B_z sets the Zeeman splitting of the adatom.

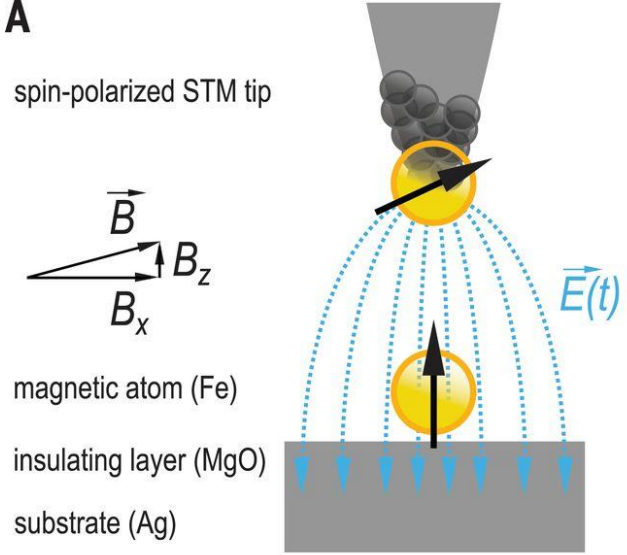
B_x >> 0 modifies the S_z basis states to enable coherent Rabi oscillations.

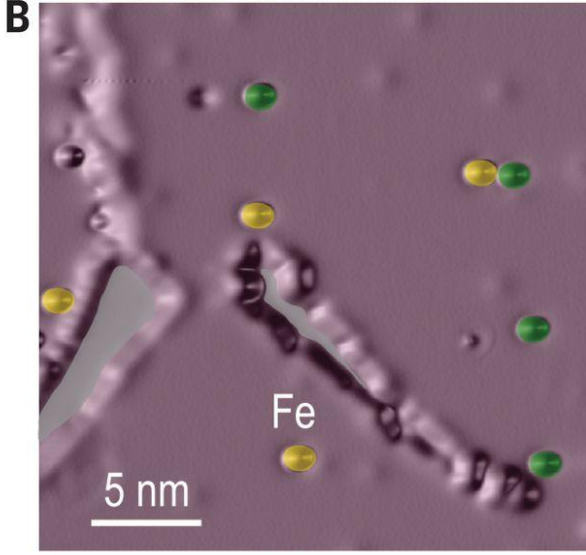
- leading terms of the $|0\rangle$ and $|1\rangle$ wavefunctions (in the basis of z-axis orbital and spin quantum numbers $|M_L, M_S\rangle$) are spin-polarized

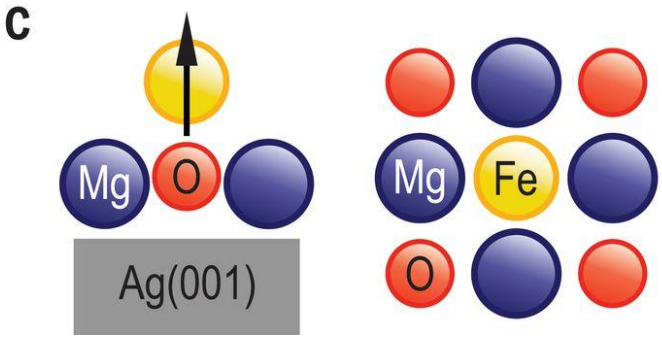
$$|0\rangle = 0.92|+2,+2\rangle - 0.40|-2,+2\rangle + \ldots$$

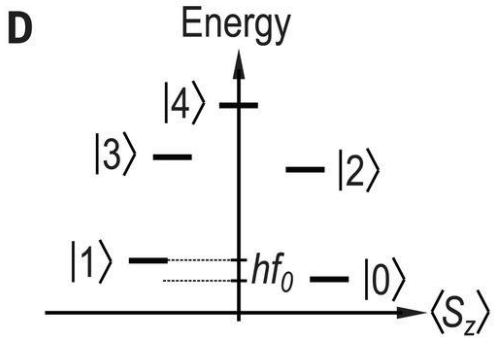
$$|1\rangle = 0.92|-2,-2\rangle - 0.40|+2,-2\rangle + \ldots$$

- In-plane magnetic field mixes spin components, allows for coherent transitions by dominant $F_1(t)$ term.

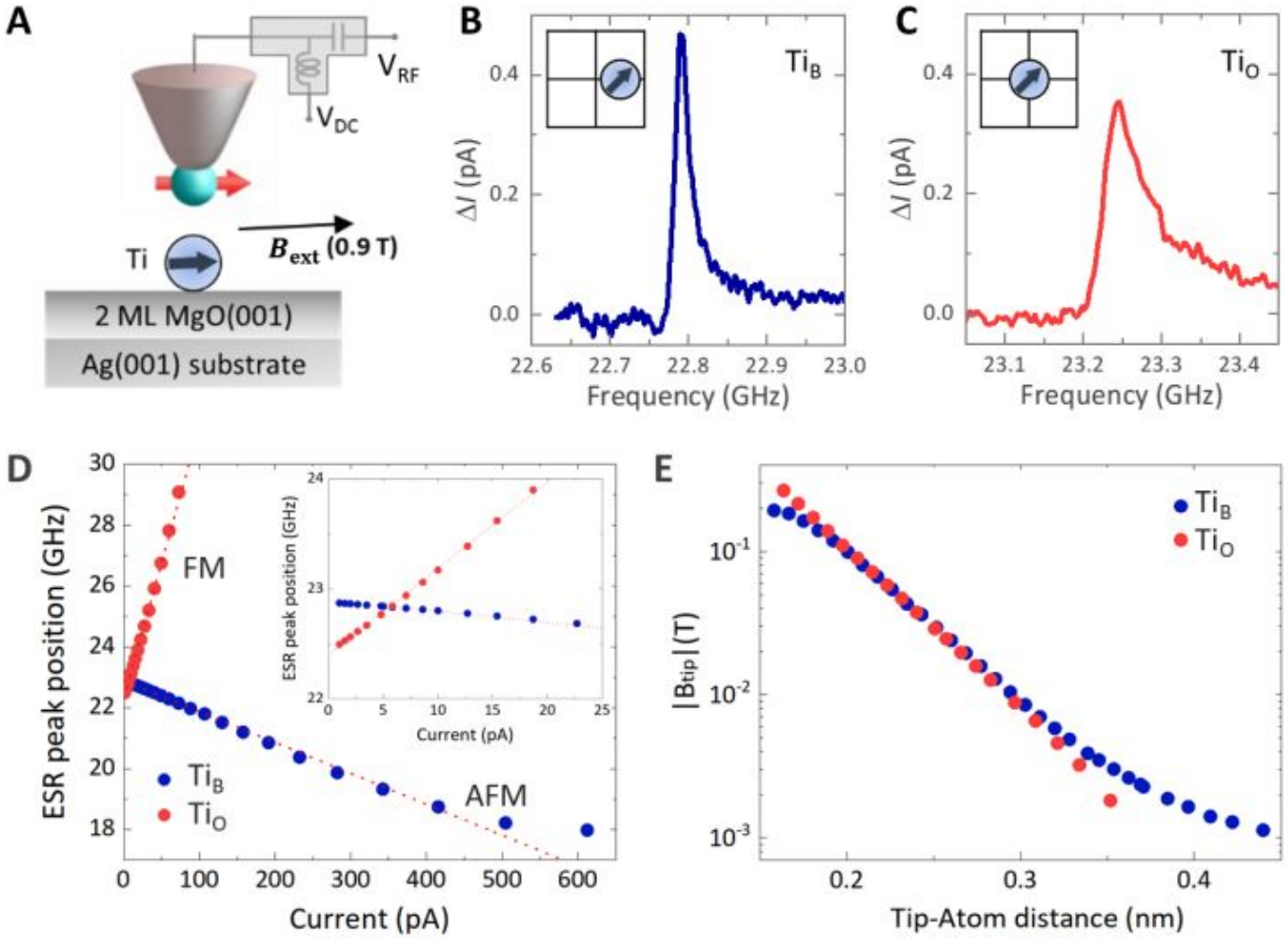






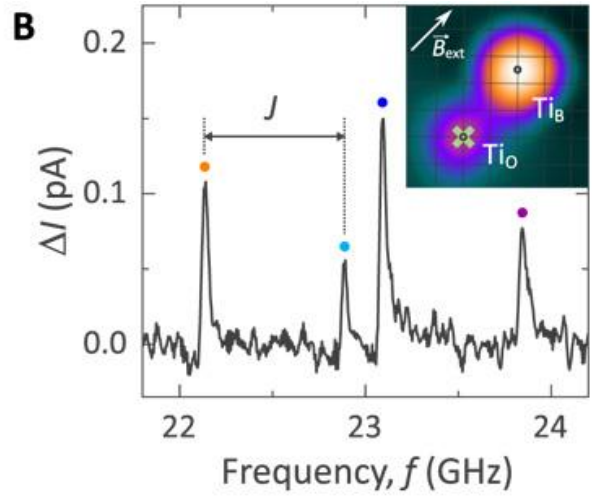


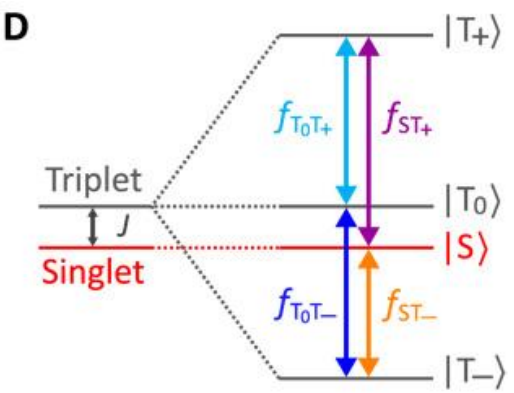
$$H_1(t) = D_1(t)L_z^2 + E_1(t)L_z^4 + F_1(t)(L_+^4 + L_-^4)$$

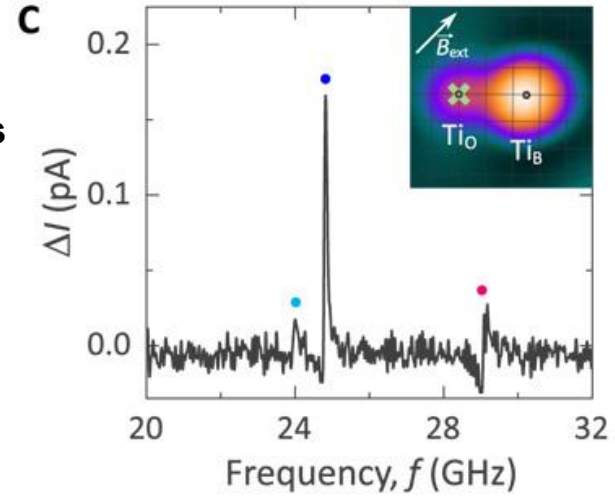

A
V_RF
V_DC
Ti
B_ext (0.9 T)
2 ML MgO(001)
Ag(001) substrate
B
Ti_B
ΔI (pA)
Frequency (GHz)
C
Ti_O
ΔI (pA)
Frequency (GHz)
D
ESR peak position (GHz)
FM
AFM
Ti_B
Ti_O
Current (pA)
E
Ti_B
Ti_O
|B_tip| (T)
Tip-Atom distance (nm)

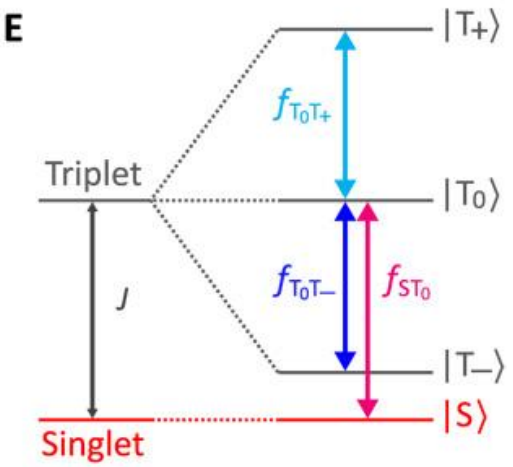
ESR Spectra of Titanium Dimers

- **Atom-atom distance** determines strength of **exchange interaction J** relative to **Zeeman splitting** of triplet states.
- ESR-STM uses RF electric fields that cause oscillations in the magnetic surface atom.
- Moving of these atoms in the **tip fields** B_z ($\Delta m = 0$) and B_x ($\Delta m = \pm 1$) causes changes in the tunneling magnetoresistance (TMR) that can be detected as DC current.





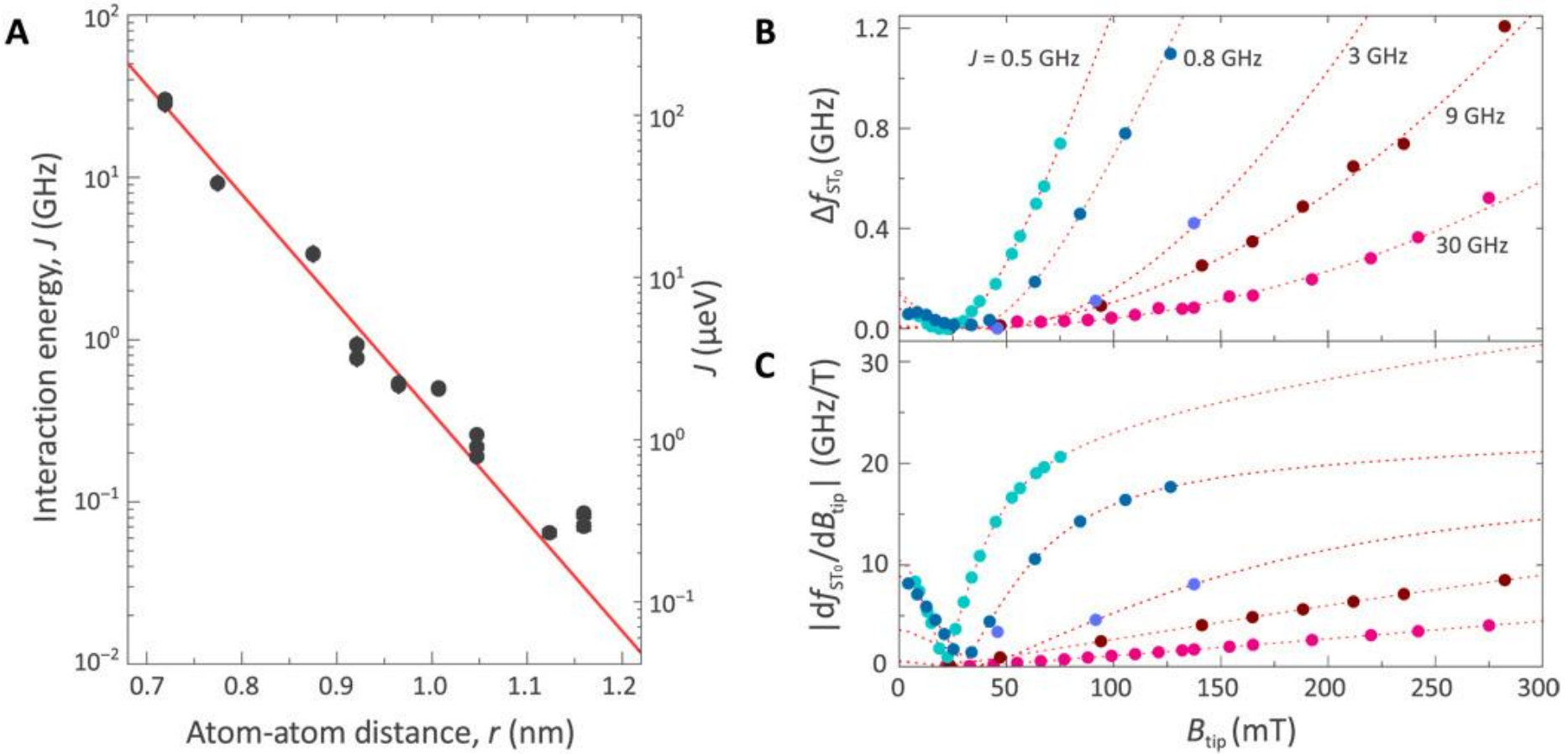




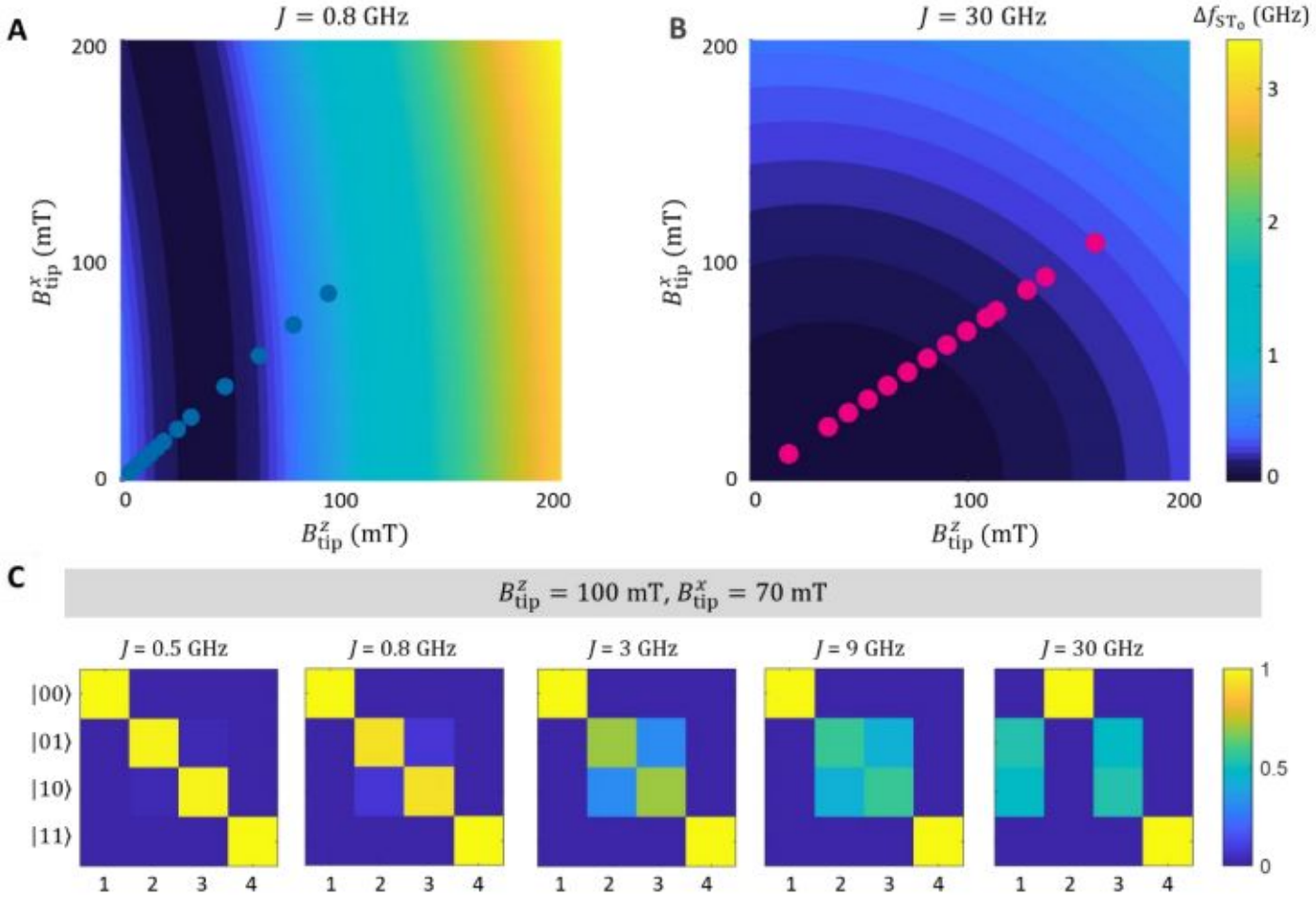
Heisenberg Exchange Interaction

Spatial Dependence

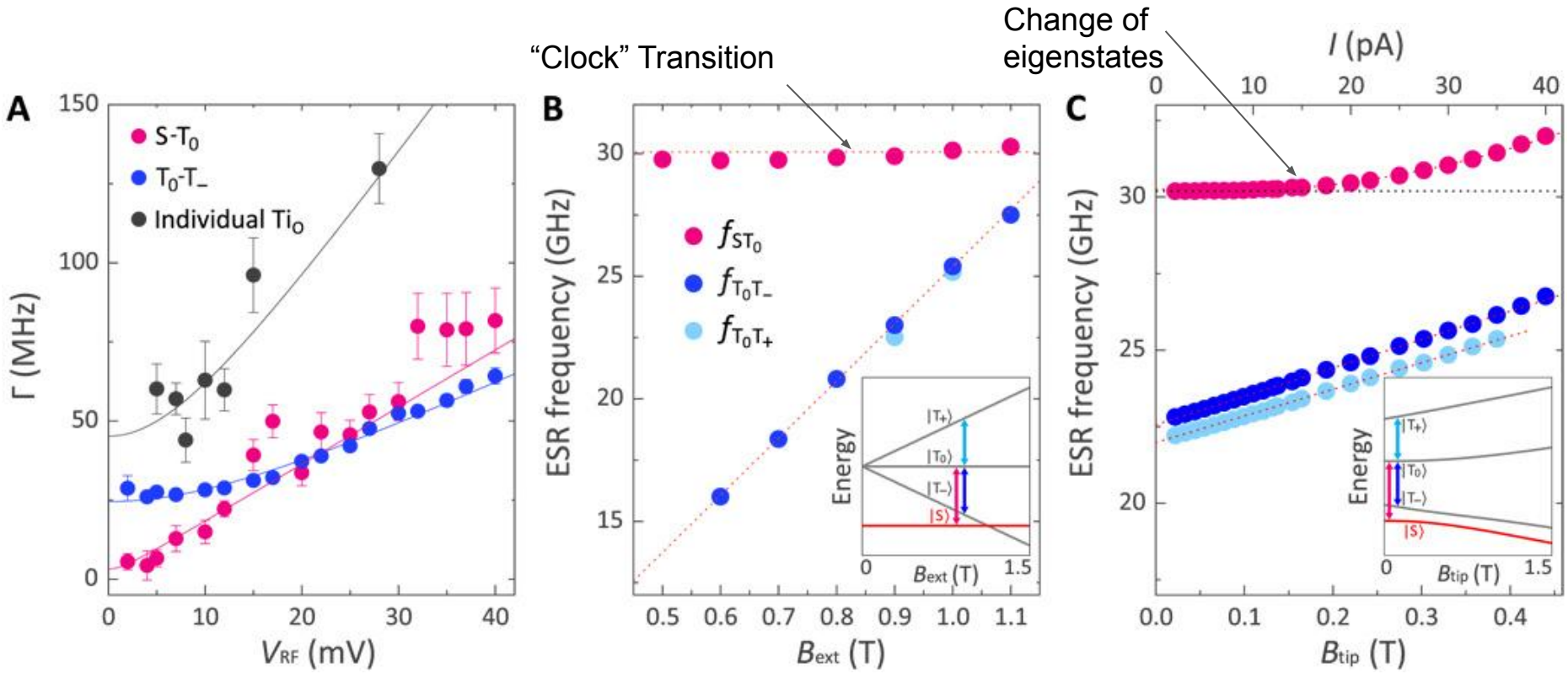
Detuning due to tip field, choice of binding site



Detuning for Different Interaction Strengths



Dimer Spin Coherence and Field Sensitivity



Homodyne Detection for Enhanced Spin Coherence