A Qubit Platform Assembled Atom-by-Atom on a Surface

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In recent years the combination of electron-spin resonance (ESR) and scanning tunnelling microscopy (STM) resulted in a breakthrough in the manipulation and detection of the quantum state of individual electrons localized in atoms or molecules. [1,2] Using an ESR-STM, functional structures of a few (~3 to 10) atoms can be built on ultraclean surfaces with atomic precision, leading to systems with well-define interactions (Figure 1).

In this work, we demonstrate for the first time how to utilize atoms hosting single electron spins (S=1/2) to build a structure with quantum functionality. [3] We first characterize the quantum states of the system using continuous-wave ESR. As a result, we are able to determine the coherence time (T_2-time) and demonstrate efficient driving on the quantum states, resulting in Autler-Townes doublets or dressed states. We further demonstrate pulsed operation by visualizing Rabi oscillations in the system. Finally, using pulsed ESR, we demonstrate a universal two-qubit gate set in this architecture with a fast (~20 ns) control-NOT gate (Figure 2).

Our results serve as proof-of-concept that functional quantum coherent structures can be built at the atomic scale – true to Feynman's 1959 vision that there is *"plenty of room at the bottom"*.

References

[1] Zhang *et al.*, Nature Chemistry, 14 (2022), 59-65
[2] Yang *et al.*, Science 366 (2019), 509
[3] Yu Wang *et al.*, https://arxiv.org/abs/2108.09880 (2022)

Figures

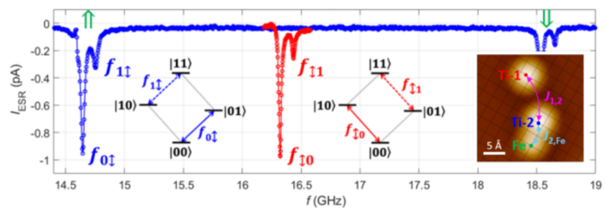

Figure 1: Characterization of the system using CW-ESR spectroscopy. The system is constructed atom-by-atom as shown in the inset.

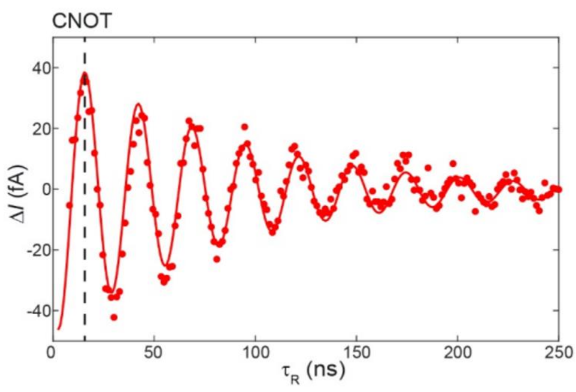

Figure 2: Rabi oscillations demonstrating coherent manipulation of two quantum states. The dashed vertical line indicates the typical time to perform a CNOT gate in our system