Quantum simulation of the Hubbard model with dopant atoms in silicon

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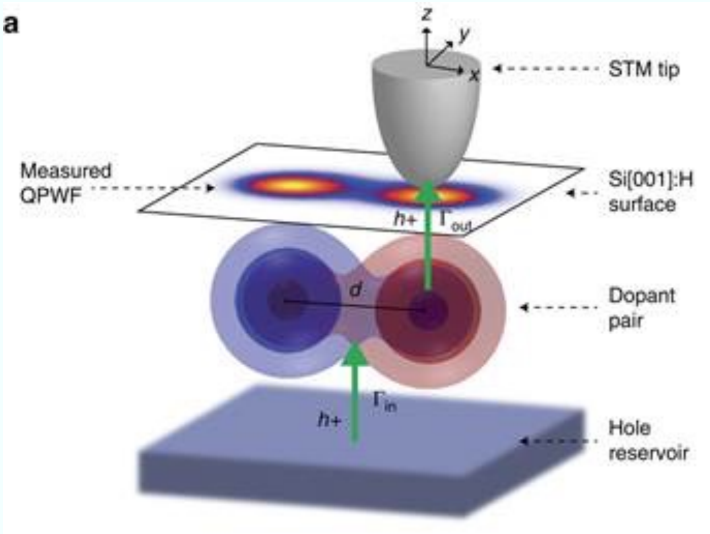
Nature Communications 7, 11342 (2016)



Atomic resolution single-hole tunnelling probes the interacting states of coupled acceptor dopants

In quantum simulation, many-body phenomena are probed in controllable quantum systems. Recently, simulation of Bose–Hubbard Hamiltonians using cold atoms revealed previously hidden local correlations. However, fermionic many-body Hubbard phenomena such as unconventional superconductivity and spin liquids are more difficult to simulate using cold atoms. To date the required single-site measurements and cooling remain problematic, while only ensemble measurements have been achieved. Here we simulate a two-site Hubbard Hamiltonian at low effective temperatures with single-site resolution using subsurface dopants in silicon. We measure quasi-particle tunnelling maps of spin-resolved states with atomic resolution, finding interference processes from which the entanglement entropy and Hubbard interactions are quantified. Entanglement, determined by spin and orbital degrees of freedom, increases with increasing valence bond length. We find separation-tunable Hubbard interaction strengths that are suitable for simulating strongly correlated phenomena in larger arrays of dopants, establishing dopants as a platform for quantum simulation of the Hubbard model.

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