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Fabrication of Atom Arrays for the Quantum Simulation of a Lattice Gauge Theory

We are developing a solid-state analog quantum simulator to explore questions in a quantum field theory. The origin of the mass of elementary and composite particles is an ongoing challenge in the field of particle and hadronic physics. Although spontaneous symmetry breaking of gauge symmetries gives rise to the mass of elementary particles, a complete picture of dynamical mass generation is yet to be developed. Fabricating arrays of precisely placed dopant atoms presents a new platform for solid-state analog quantum simulation with unique applications in simulating lattice gauge theory.

The method uses STM lithography to precisely locate individual atoms on a patterned silicon substrate. These atomic structures are then encased in epitaxial silicon, stable in ambient over long periods of time, and can be measured at low temperature in a dilution refrigerator. We have previously demonstrated atomically precise devices whose performance relies on the placement of individual atoms, including a single atom transistor and single electron transistor (SET) sensors used for individual charge and spin measurements using transport and RF reflectometry. Recently we demonstrated the analog quantum simulation of an extended Hubbard model using 3x3 arrays of dopant atoms fabricated to enable quantum simulations of a Hubbard model from a weakly coupled regime to a strongly coupled array.

Currently we are fabricating 2x2 plaquettes as building blocks for the proposed quantum simulation of a model relevant to nuclear physics. Our proposal uses a dynamical lattice of coupled nuclear spins and conduction-band electrons to realize a quantum field theory: an extended Jackiw-Rebbi model involving coupled fermions and quantum rotors. Classical simulations of this platform show the feasibility of using precision placed nuclear spins hyperfine coupled to electrons to observe dynamical mass generation. Quantum simulation of quantum field theories is a unique application of atomically precise fabrication allowing the exploration of nonperturbative, and dynamical phenomena such as mass generation in QCD.

Short 50 Word Abstract

We are developing a solid-state quantum simulator to explore questions in quantum field theory. The origin of mass of elementary and composite particles remains a challenge in particle and hadronic physics. Fabricating arrays of precisely-placed dopant atoms presents a new quantum simulation platform with unique application in lattice gauge theory.