Quantum simulation of a Fermi-Hubbard model using a semiconductor quantum dot array

C.J. van Diepen[1,2], T. Hensgens[1], T. Fujita[1], L. Janssen[1], Xiao Li[3], C. Reichl[4], W. Wegscheider[4], S. Das Sarma[3] & L.M.K. Vandersypen[1]

[1] QuTech and Kavli Institute of Nanoscience, Delft University of Technology, 2600 GA Delft, The Netherlands
[2] Netherlands Organisation for Applied Scientific Research (TNO), 2600 AD Delft, The Netherlands
[3] Condensed Matter Theory Center and Joint Quantum Institute, University of Maryland, College Park, Maryland 20742, USA
[4] Solid State Physics Laboratory, ETH Zürich, 8093 Zürich, Switzerland

Interacting fermions on a lattice show many exotic phases of matter. Semiconductor quantum dots are widely tunable and allow for versatility in design, which makes them very promising quantum simulators. Furthermore, quantum dots readily adhere to an engineerable Fermi-Hubbard model. Due to substantial electrostatic disorder inherent to solid state few attempts have been made at performing analog quantum simulations. Here we demonstrate the development of a semi-automated toolbox in order to suppress this disorder. By utilizing the individual control over chemical potentials and inter-dot tunnel couplings we explore the parameter space of the Fermi-Hubbard model. We show (see Figure 1) the first detailed characterization of the collective Coulomb blockade transition, which is the finite-size analogue of the interaction-driven Mott metal-to-insulator transition. As control over semi-conductor quantum dot arrays continues to improve, the ideas presented here show how this platform can be used for the investigation of complex many-body physics.

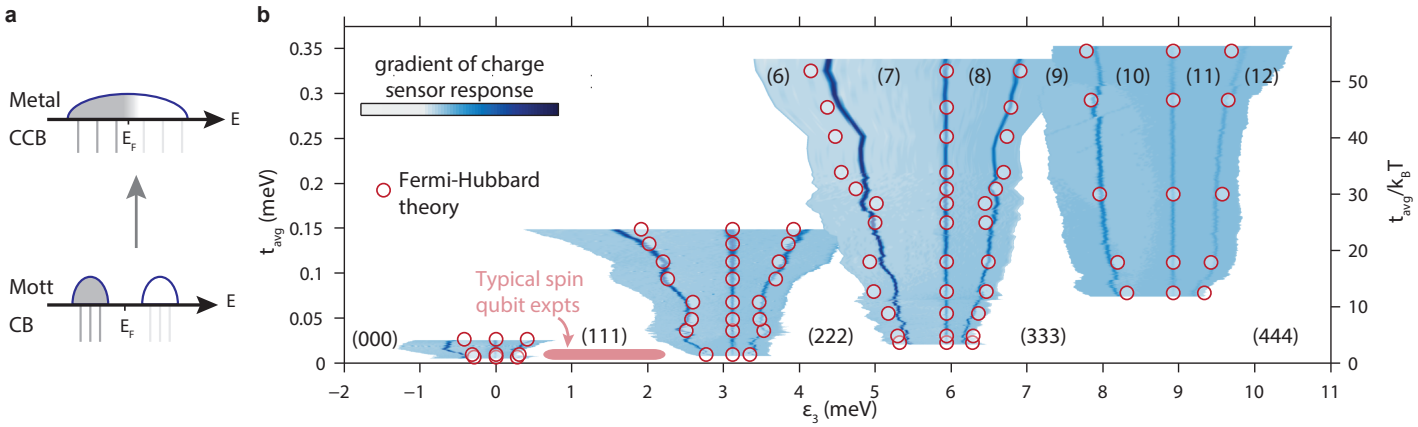

Figure 1. **a)** Schematic comparison of the charge addition spectrum of a Mott insulator and a triple quantum dot array in Coulomb blockade (bottom) and a metallic phase at half filling and a triple quantum dot array in collective Coulomb blockade (top). **b)** The measured parameter space of the Fermi-Hubbard model as a function of electron filling and tunnel coupling. The blue lines indicate the addition of an electron to the system, while the red circles show extended Hubbard model simulations. Text in brackets denotes electron filling.

[1] T. Hensgens, T. Fujita, L. Janssen, Xiao Li, C.J. van Diepen, C. Reichl, W. Wegscheider, S. Das Sarma and L.M.K. Vandersypen, Nature in print, see arXiv:1702.07511.