Project Summary. Quantum dots in semiconductor systems have emerged as attractive candidates for the physical implementation of large-scale quantum information processors because of the promise of scalability, manipulability, and integration with existing classical electronics technologies. While there has been substantial recent progress in the development of quantum dot qubits, substantial challenges arise in achieving high enough fidelity for fault-tolerant operation as well as in achieving the necessary control over electron energies and tunnel rates in large arrays of devices. Based on new understanding developed in our previous work on developing quantum dot qubits in silicon/silicon-germaium (Si/SiGe) heterostructures, we will use theory, modeling, device design, and experiment to investigate fairly radical device design changes that could potentially greatly enhance tunability, performance, and scalability of qubits in electrically-gated quantum dots.

We propose to optimize device designs of two-dimensional arrays of electrically gated quantum dot qubits to enable effective and scalable quantum information processors. We will continue to develop the hybrid quantum dot qubit that we proposed recently [1, 2], which has yielded promising experimental progress [3–5] towards the goal of creating high-fidelity quantum gates in a scalable architecture.

In this work, we will (1) simultaneously develop new theory and perform new experiments to understand how to design and operate the qubit to maximize fidelity and surpass the 99% error correction threshold, and (2) design tunable and scalable structures to facilitate scaleup to large numbers of qubits. For both goals, new understanding of fundamental physics as well as development of novel device structures will be integrated and explored experimentally as well as theoretically. The work will be done in close collaboration with two senior investigators, experimentalist Mark Eriksson and theorist Mark Friesen.

All the work involves tightly coupled theory and experiment. The PI will continue to meet daily with Mark Eriksson's experimental group. These frequent interactions have proven very helpful in identifying experimental difficulties that point to interesting theoretical issues, and in developing an understanding of which theoretical proposals are feasible in the laboratory. The PI also collaborates closely with Dr. Mark Friesen, whose expertise in silicon quantum dots, quantum computing, and device modeling is critical to the success of the project. Theoretical students supported by the award will be jointly supervised by Coppersmith and Friesen. The experimental students and postdocs will be supervised by Eriksson, with Coppersmith playing an active role in the day-to-day discussions with all the experimental personnel.