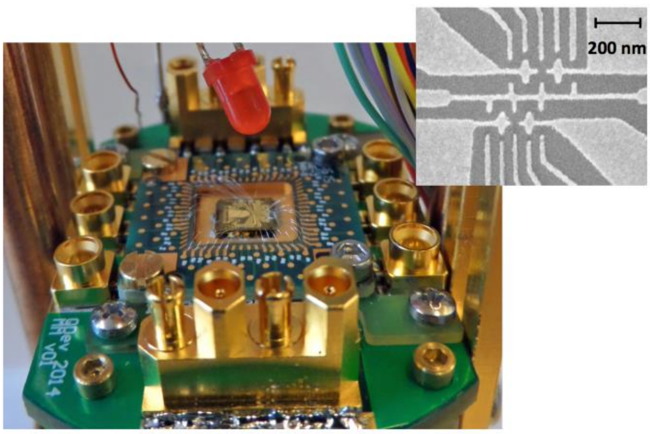
Spin qubits with all-electrical control in Ge-Si quantum dots

Since the formulation of the Di Vincenzo criteria, a lot of effort has gone into the development of qubits using semiconducting quantum dots, since their spin offers a two-level system that may be scaled to sufficiently large numbers. GaAs was initially addressed as the main material to create these system, due to the advanced knowledge acquired from the study of its 2DEG properties. However, it suffers from the fact the all nuclei in the host material carry a non-zero nuclear spin, which is difficult to control and cause decoherence of these spin qubits. The last year has seen tremendous advances in fabricating spin qubit devices based on undoped Si/SiGe heterostructures, moving Si-based spin qubits to the forefront of solid state quantum computing research. Already natural abundance Si has a low concentration of spin-carrying isotopes which is further reduced isotopically purified Si, leading to the observation of impressive coherence times.

At the Center for Quantum Devices we are focusing on the study of low-temperature operation of Si/SiGe double and triple quantum dot devices as spin qubits, with the goal of demonstrating two-qubit gates in scalable geometries. In order to implement manipulation of qubits we use fast gate control, which requires the generation of electrical pulses on a nanosecond scale. Read-out is based on spin-to-charge conversion, which allows the detection of a spin based information as an electrical signal. We implement a radio frequency reflectometry technique that allows single-shot read-out at integration times on the order of a few microseconds. We study different coupling schemes for multi qubit devices including superconducting resonators.



An optical image of a Si-Ge sample bonded to a board for slow (DC) and fast (AC) manipulation of the quantum dots. In the upper left corner, a Scanning Electron Microscopy (SEM) acquisition of the device itself, showing two double quantum dots systems that are capacitively coupled to each other.