Materials, Devices, and Systems for Quantum Computation

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We have known for twenty years that quantum computers would have unique powers for solving certain classes of computational problems. Throughout these twenty years, workers have striven to identify a physical setting in which high-quality qubits can be created and employed in a quantum computing system. Very promising devices have been identified in several different areas of low-temperature electronics, namely in superconductor and in single-electron semiconductor structures (e.g., quantum dots). Rudimentary efforts at scale-up are presently reported; even for modules of 10 qubits, the complexity of the classical electronic control system becomes one of the main barriers to further progress.

The specifications of this control system are now well defined, and are daunting. It must deliver very low noise, precisely shaped pulses in the GHz band for qubit gate control; it must deliver interrogating microwave pulses that sense the qubit state, which must be amplified at the quantum-limited level and delivered quickly back to the control system; because of the nature of the fine-grained error correction needed for reliable quantum algorithm operation, subsequent control pulses must be determined by a rapid (classical) calculation performed using the measurement outcomes as inputs. All this must be done for a very large number of channels (about one per qubit) with rigorous control of timings and crosstalk.

I will discuss the current state of experiments, and explain the efforts underway to understand and achieve this control system.