Exchange-only Qubits in Si/SiGe Quantum Dots Patterned Using Electron-Beam Lithography

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Electrostatically-defined quantum dots are strong candidates for creating long-lived qubits with fast operation times. The basic concept of HRL's preferred approach is to employ a single gate to control the depth of an electron trap and another gate to control the coupling between trapped electrons. Over the past decade, HRL has iterated through many design variations on this basic idea. In this talk, I will provide an overview of these iterations beginning from air-bridged metal gates on III-V material to our most recent design of overlapping gates running on top of spin-on-glass. I will also highlight several major contributions from academic groups that drove the field to what is emerging as a converged set of similar designs.

One of the biggest challenges the field has faced is how to provide sufficient control of the electrostatic potential landscape to dominate over sources of random electric fields. Non-idealities such as trapped interfacial electric charges along with the small length scales of the intentionally confined electrons necessitate nanolithograhic techniques. The most successful approaches taken by HRL and others utilize overlapping layers of high-resolution electron-beam lithography to achieve the required gate pitch.

Triple quantum dot devices have been fabricated in our most recent design as seen below in Figure 1. These have enabled the demonstration of coherent manipulation and universal control of a qubit composed of three trapped electrons in an isotopically-enhanced Si/SiGe heterostructure, which requires no local AC or DC magnetic fields for operation. Strong control over tunnel rates is enabled by a dopantless, accumulation-only device design, and an integrated measurement dot enables single-shot measurement. Reduction of magnetic noise is achieved via isotopic purification of the silicon quantum well. We demonstrate universal control using composite pulses and employ these pulses for spin-echo-type sequences to measure both magnetic noise and charge noise. The noise measured is sufficiently low to enable the long pulse sequences required for exchange-only quantum information processing.

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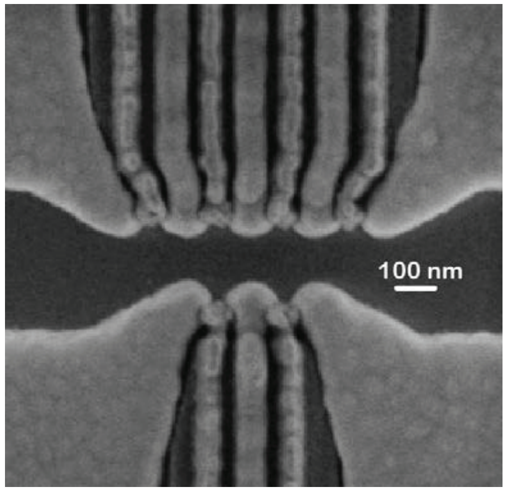

Figure 1: Scanning electron micrograph of a finished triple quantum dot after three passes of overlapping electron-beam lithography.