Quantum computation in Silicon spin qubits

By Stephen Philips, PhD student at TU Delft

Single electron spins, confined in a two dimensional electrongas (2DEG) in SiGe/Si heterostructures, can be used as fundamental building blocks of a quantum computer. One of the big challenges that we face today is the scaling up of a quantum computer, independent of the sort of qubits used. In Silicon, quantum dots (qubits) are electrostatically defined and controlled, this means that each qubit has gates for controlling the energy of a qubit and for the coupling to neighbouring qubits. The pitch between quantum dots is quite small (~ 50 nm), which implicates dense wiring (no place for fan out). This is practically a problem since one cannot connect a device with such a high gate density.

A possible solution for bypassing this problem could be making small islands of qubits interconnected by some quantum mediator. This mediator should act fast and couple two distant qubits strongly. Practically there are many ways one could accomplish this task. In my research, I will mainly be focussing on spin shuttling and adiabatic state exchange. For the spin shuttling experiments one can think about putting an electron in a basket and moving that basket forth and back. One can then effectively transport electrons between two distant islands. Another method is doing an adiabatic state exchange. The concept of this scheme is shown in figure 1 .
These spin shuttling experiments can also be taken to the next level, e.g. one can design a spin shuttle in such a way that is can shuttle a single spin qubit to multiple locations. This practically means that you can place your qubit in a 2.x-dimensional space, what could lead to a more efficient surface code.

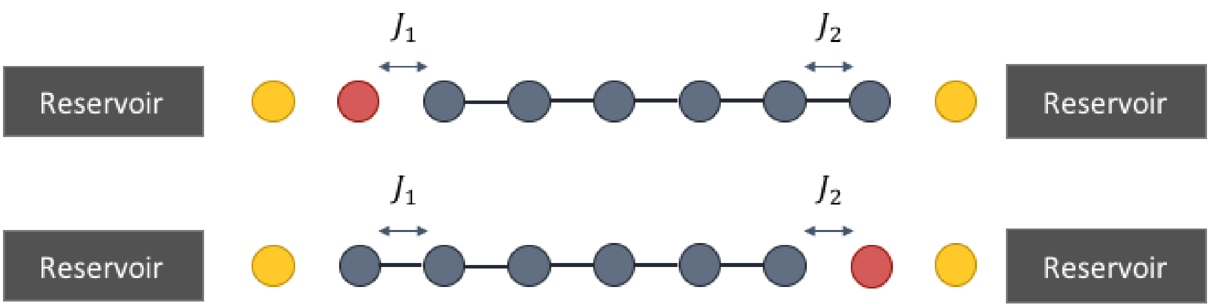

Figure 1: Illustration of an adiabatic state transfer. The dots represent qubits. J represents the exchange interaction between different qubits, a stripe in between the qubits means that they are strongly coupled (big J). One can use the scheme depicted above to transfer the state of the red qubit in an adiabatic way from the left to the right. Note that all the gates for the grey dots are tunnel coupled and in the ground state. Since one does basically for all the grey dots the same, one can connect the gates of each dot to each other (only a few gates need to leave the sample).