JOINT CMTC/JQI SEMINAR

Friday, May 15
3:00 pm – 4:30 pm
2205 Toll Physics Building

Andrew Dzurak

UNSW, School of Electrical Engineering, Sydney, Australia

"Spin-based Quantum Computing in Silicon"

Spin qubits in silicon are excellent candidates for scalable quantum information processing [1] due to their long coherence times and the enormous investment in silicon MOS technology. I will discuss qubits based upon the electron and nuclear spins associated with single phosphorus (P) dopant atoms in silicon [2-5] and also more recent work based upon electron spins confined in Si-MOS quantum dots [6-9]. In each case, single-shot electron spin readout is performed using an adjacent single electron transistor and the process of spin-to-charge conversion, showing spin lifetimes of order seconds [2, 7] for the electrons and many minutes for the nuclear spins [4]. Control of individual electron and nuclear spins is achieved by spin resonance using an on-chip microwave transmission line [3].

In isotopically enriched Si-28 all of these spin qubits show control fidelities F_C above 99%, consistent with some fault-tolerant QC error correction codes. Specifically the P donor (see next page)

Host: Ed Barnes

Web: http://www.physics.umd.edu/cmtc/seminars.html

(Con't)

electron spin qubit has F_C^e > 99.6% [5], the ^{31}P nuclear spin qubit has F_C^n > 99.99% [5], and the Si-MOS quantum dot electron spin qubit has F_C^e > 99.6% [8]. Using dynamical decoupling sequences the coherence times for the P atom qubits can reach T_{2e}^{CPMG} = 0.5 s for the electron and T_{2n}^{CPMG} = 30 s for the nuclear spin.

In the SiMOS quantum dot qubits the electron g*-factor can be tuned using a gate voltage, leading to a Stark shift in the qubit operation frequency of > 10 MHz [8], allowing individual addressability of many qubits. Most recently we have demonstrated the exchange coupling of two SiMOS qubits to realize CNOT gates [9] for which over 100 two-qubit gates can be performed within a coherence time of 8 μs.

[1] D.D. Awschalom et al., "Quantum Spintronics", *Science* 339, 1174 (2013).

[2] A. Morello et al., "Single-shot readout of an electron spin in silicon", *Nature* 467, 687 (2010).

[3] J.J. Pla et al., "A single-atom electron spin qubit in silicon", *Nature* 489, 541 (2012).

[4] J.J. Pla et al., "High-fidelity readout and control of a nuclear spin qubit in Si", *Nature* 496, 334 (2013).

[5] J.T. Muhonen et al., "Storing quantum information for 30 seconds in a nanoelectronic device", *Nature Nanotechnology* 9, 986 (2014).

[6] S.J. Angus et al., "Gate-defined quantum dots in intrinsic silicon", *Nano Lett.* 7, 2051 (2007).

[7] C.H. Yang et al., "Spin-valley lifetimes in a silicon quantum dot with tunable valley splitting", *Nature Communications* 4, 2069 (2013).

[8] M. Veldhorst et al., "An addressable quantum dot qubit with fault-tolerant control fidelity", *Nature Nanotechnology* 9, 981 (2014).

[9] M. Veldhorst et al., "A two-qubit logic gate in silicon", arXiv:1411.5760.