Seminarankündigung

Dienstag, 20. Mai 2014
15:00 Uhr

ZNN, Seminarraum EG 0.001

“High-fidelity single-atom spin qubits in silicon”

A phosphorus donor in silicon is, almost literally, the equivalent of a hydrogen atom in vacuum. It possesses electron and nuclear spins of 1/2 which act as natural qubits, and the host material can be isotopically purified to be almost perfectly free of other spin species, ensuring extraordinary coherence times (~180 s). It is, however, still embedded in a semiconductor host material, allowing electric gates to be used to manipulate its electrostatic environment and a microwave transmission line to apply spin resonant pulses. It is, therefore, a natural occurring single-electron quantum dot with a perfectly reproducible binding potential.

The single-shot readout and coherent control of both the electron and the nuclear spin of a single P atom in silicon have been recently demonstrated, using ion-implanted donors in MOS nanostructures. It is known from bulk experiments that P donors in isotopically purified ^{28}Si exhibit record coherences, but it is also suspected that the proximity to a Si/SiO2 interface will deteriorate the coherence time. Here we present the first experiment on single electron and nuclear spin qubits in an isotopically engineered ^{28}Si nanostructure. We measured free induction decay - limited electron spin resonance lines (< 2 kHz FWHM), and we obtained single-qubit control fidelities in excess of 99%. We performed noise spectroscopy experiments to extract the power spectral density of the decoherence sources acting on the electron and the nucleus. Contrary to widespread belief, our data show that the ultimate limit for single-spin coherence in our nanostructure is not set by charge noise and interface effects, but simply by broadband thermal radiation coupled to the qubit through a high-bandwidth transmission line. Using dynamical decoupling, we measured coherence times up to T_{2e}^{DD} = 0.5 s for the electron, and T_{2n}^{DD} = 35 s for the ^{31}P nucleus.

	Device A			Device B		
	e^-	^{31}P	^{31}P	e^-	^{31}P	^{31}P
Ramsey (T_2^*)	270 μs	570 μs	250 ms	160 μs	430 μs	600 ms
Hahn-Echo (T_2)	0.95 ms	1.5 ms	580 ms	1.1 ms	20 ms	1.8 s
DD (T_2^{DD})	220 ms	2.7 ms	1.1 s	550 ms	20 ms	> 30 s

Table 1 Measured decay and coherence times on two individual P donors in isotopically purified silicon. For Device B the attenuation (thermalization) of the microwave transmission line was increased, leading to an increase in some of the coherence times. However, the T_2^{DD} times are not directly comparable as for Device A a lower number of dynamical decoupling pulses was applied.

Finally, we will discuss current efforts to couple multiple donor qubits through the exchange interaction and perform entangling quantum logic gates. The ability to control the state of the ^{31}P nuclear spin greatly simplifies the implementation of CNOT and SWAP gates, and allows for high-fidelity two-qubit operations without the requirement of atomic-precision in the donor locations.

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