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Single-shot readout and relaxation measurements in exchange coupled ^{31}P electron spins in silicon JUAN PABLO DEHOLLAIN, JUHA MUHONEN, KUAN TAN, Centre for Quantum Computation and Communication Technology, University of New South Wales, ANDRE SARAIVA, Universidade Federal do Rio de Janeiro and University of Wisconsin-Madison, DAVID JAMIESON, Centre for Quantum Computation and Communication Technology, University of Melbourne, ANDREW DZURAK, ANDREA MORELLO, Centre for Quantum Computation and Communication Technology, University of New South Wales —
We present the experimental observation of a large exchange coupling $J \approx 300$ μeV between two ^{31}P electron spin qubits in silicon (Dehollain, **PRL** 112, 236801). The singlet and triplet states of the coupled spins are monitored in real time by a single-electron transistor, which detects ionization from tunnel-rate-dependent processes in the coupled spin system, yielding single-shot readout fidelities above 95%. The triplet to singlet relaxation time $T_1 \approx 4$ ms at zero magnetic field agrees with the theoretical prediction for the observed J-coupling energy in ^{31}P dimers in silicon. The three order of magnitude increase in relaxation rate compared to single donors, is caused by a hyperfine interaction mediated mixing of the singlet and triplet states. Additionally, the time evolution of the two-electron state populations reveals an inversion in the energetic hierarchy of the valley-orbit excited states, which had been theoretically predicted for donor pairs with < 6 nm separation. These results pave the way to the realization of two-qubit quantum logic gates with spins in silicon and highlight the necessity to adopt gating schemes compatible with weak J-coupling strengths.

Juan Pablo Dehollain
CQC2T, University of New South Wales

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