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Quantum interference and correlations in single dopants and exchange-coupled dopants in silicon[1]

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Quantum electronics exploiting the highly coherent states of single dopants in silicon invariably requires interactions between states and interfaces, and inter-dopant coupling by exchange interactions. We have developed a low temperature STM scheme for spatially resolved single-electron transport in a device-like environment, providing the first wave-function measurements of single donors and exchange-coupled acceptors in silicon. For single donors, we directly observed valley quantum interference due to linear superpositions of the valleys [1], and found that valley degrees of freedom are highly robust to the symmetry-breaking perturbation of nearby (3 nm) surfaces. For exchange-coupled acceptors, we measured the singlet-triplet splitting, and from the spatial tunneling probability, extracted enough information about the 2-body wavefunction amplitudes to determine the entanglement entropy [2], a measure of the quantum inseparability (quantum correlations) generated by the interactions between indistinguishable particles. Entanglement entropy of the $J=3/2$ holes was found to increase with increasing dopant distance, as Coulomb interactions overcome tunneling, coherently localizing spin towards a Heitler-London singlet, mimicing $S=1/2$ particles [3]. In the future these capabilities will be exploited to peer into the inner workings of few-dopant quantum devices and shed new light on multi-dopant correlated states, engineered atom-by-atom.

Work done collaboratively with J. A. Mol, R. Rahman, G. Klimeck, M. Y. Simmons, L. C. L. Hollenberg, and S. Rogge.

[1] J.Salfi et al, (2014), Nature Mat., **13** 605.
[2] L.Amico et al, (2008) Rev. Mod. Phys., **80** 517-576.
[3] J.Salfi et al, (2014) *submitted*.

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