Journal club

To close or not to close: the fate of the superconducting gap across the topological quantum phase transition in Majorana-carrying semiconductor nanowires
Tudor D. Stanescu , Sumanta Tewari , Jay D. Sau , and S. Das Sarma
arXiv:1206.0013
We investigate theoretically the low energy physics of semiconductor Majorana wires in the vicinity of a magnetic field-driven topological quantum phase transition (TQPT). The local density of states (LDOS) at the end of the wire, which is directly related to the differential conductance in the limit of point-contact tunneling, is calculated numerically. We find that the dependence of the end-of-wire LDOS on the magnetic field is non- universal and that the signatures associated with the closing of the superconducting gap at the Majorana TQPT are essentially invisible within a significant range of experimentally relevant parameters. Our results provide an explanation for the recent observation of the apparent non-closure of the gap at the Majorana TQPT in semiconductor nanowires.

Class D spectral peak in Majorana quantum wires
Dmitry Bagrets and Alexander Altland
arXiv:1206.0434
Proximity coupled spin-orbit quantum wires have recently been shown to support midgap Ma- jorana states at critical points. We show that in the presence of disorder these systems are prone to the buildup of a second bandcenter anomaly, which is of different physical origin but shares key characteristics with the Majorana state: it is narrow in width, insensitive to magnetic fields, carries unit spectral weight, and is rigidly tied to the band center. Depending on the parity of the number of subgap quasiparticle states, a Majorana mode does or does not coexist with the impurity gen- erated peak. The strong 'entanglement' between the two phenomena may hinder an unambiguous detection of the Majorana by spectroscopic techniques.

Enhanced zero-bias Majorana peak in disordered multi-subband quantum wires
Falko Pientka, Graham Kells, Alessandro Romito, Piet W. Brouwer, and Felix von Oppen
arXiv:1206.0723
A recent experiment [Mourik et al., Science 336, 1003 (2012)] on InSb quantum wires provides possible evidence for the realization of a topological superconducting phase and the formation of Majorana bound states. Motivated by this experiment, we consider the signature of Majorana bound states in the differential tunneling conductance of multi-subband wires. We show that the weight of the Majorana-induced zero-bias peak is strongly enhanced by mixing of subbands, when disorder is added to the end of the quantum wire. We also consider how the topological phase transition is reflected in the gap structure of the current-voltage characteristic.

Zero-bias peaks in spin-orbit coupled superconducting wires with and without Majorana end-states
Jie Liu, Andrew C. Potter, K.T. Law, and Patrick A. Lee
arXiv:1206.1276
One of the simplest proposed experimental probes of a Majorana bound-state is a quantized ($2e^2/h$) value of zero-bias tunneling conductance. When temperature is somewhat larger than the intrinsic width of the Majorana peak, conductance is no longer quantized, but a zero-bias peak can remain. Such a non-quantized zero-bias peak has been recently reported for semiconducting nanowires with proximity induced superconductivity. In this paper we analyze the relation of the zero-bias peak to the presence of Majorana end-states, by simulating the tunneling conductance for multi-band wires with realistic amounts of disorder. We show that this system generically exhibits a (non-quantized) zero-bias peak even when the wire is topologically trivial and does not possess Majorana end-states. We make comparisons to recent experiments, and discuss the necessary requirements for confirming the existence of a Majorana state.

Quantum interference and phonon-mediated back-action in lateral quantum-dot circuits.
G. Granger, D. Taubert, C. E. Young, L. Gaudreau, A. Kam, S. A. Studenikin, P. Zawadzki, D. Harbusch, D. Schuh, W. Wegscheider, Z. R. Wasilewski, A. A. Clerk, S. Ludwig, and A. S. Sachrajda
Nature, doi:10.1038/nphys2326
Spin qubits have been successfully realized in electrostatically defined, lateral few-electron quantum-dot circuits. Qubit readout typically involves spin to charge information conversion, followed by a charge measurement made using a nearby biased quantum point contact (QPC). It is critical to understand the back-action disturbances resulting from such a measurement approach. Previous studies have indicated that QPC detectors emit phonons which are then absorbed by nearby qubits. We report here the observation of a pronounced back-action effect in multiple dot circuits, where the absorption of detector-generated phonons is strongly modified by a quantum interference effect, and show that the phenomenon is well described by a theory incorporating both the QPC and coherent phonon absorption. Our combined experimental and theoretical results suggest strategies to suppress back-action during the qubit readout procedure.

Highly efficient spin transport in epitaxial graphene on SiC

Bruno Dlubak, Marie-Blandine Martin, Cyrile Deranlot, Bernard Servet, Stphane Xavier, Richard Mattana, Mike Sprinkle, Claire Berger, Walt A. De Heer, Frdric Petroff, Abdelmadjid Anane, Pierre Seneor, and Albert Fert

Nature, doi:10.1038/nphys2331

Spin information processing is a possible new paradigm for post-CMOS (complementary metal-oxide semiconductor) electronics and efficient spin propagation over long distances is fundamental to this vision. However, despite several decades of intense research, a suitable platform is still wanting. We report here on highly efficient spin transport in two-terminal polarizer/analyser devices based on high-mobility epitaxial graphene grown on silicon carbide. Taking advantage of high-impedance injecting/detecting tunnel junctions, we show spin transport efficiencies up to 75%, spin signals in the mega-ohm range and spin diffusion lengths exceeding 100m. This enables spintronics in complex structures: devices and network architectures relying on spin information processing, well beyond present spintronics applications, can now be foreseen.

Room-Temperature Quantum Bit Memory Exceeding One Second

P. C. Maurer, G. Kucsko, C. Latta, L. Jiang, N. Y. Yao, S. D. Bennett, F. Pastawski, D. Hunger, N. Chisholm, M. Markham, D. J. Twitchen, J. I. Cirac, and M. D. Lukin1

Science, Vol. **336**, pp. 1283.

Stable quantum bits, capable both of storing quantum information for macroscopic time scales and of integration inside small portable devices, are an essential building block for an array of potential applications. We demonstrate high-fidelity control of a solid-state qubit, which preserves its polarization for several minutes and features coherence lifetimes exceeding 1 second at room temperature. The qubit consists of a single 13C nuclear spin in the vicinity of a nitrogen-vacancy color center within an isotopically purified diamond crystal. The long qubit memory time was achieved via a technique involving dissipative decoupling of the single nuclear spin from its local environment. The versatility, robustness, and potential scalability of this system may allow for new applications in quantum information science.

Nonlinear spin to charge conversion in mesoscopic structures

Peter Stano, Jaroslav Fabian, and Philippe Jacquod

Phys. Rev. B **85**, 241301(R)

Motivated by recent experiments [I. J. Vera-Marun, V. Ranjan and B. J. van Wees Nat. Phys. 8 313 (2012)], we formulate a nonlinear theory of spin transport in quantum coherent conductors. We show how a mesoscopic constriction with energy-dependent transmission can convert a spin current injected by a spin accumulation into an electric signal, relying neither on magnetic nor exchange fields. When the transmission through the constriction is spin independent, the spin-charge coupling is nonlinear, with an electric signal that is quadratic in the accumulation. We estimate that gated mesoscopic constrictions have a sensitivity that allows to detect accumulations much smaller than a percent of the Fermi energy.

Decoherence of Majorana qubits by noisy gates

Manuel J. Schmidt, Diego Rainis, Daniel Loss

arXiv:1206.0743

We propose and study a realistic model for the decoherence of topological qubits, based on Majorana fermions in one-dimensional topological superconductors. The source of decoherence is the fluctuating charge on a capacitively coupled gate, modeled by non-interacting electrons. In this context, we clarify the role of quantum fluctuations and thermal fluctuations and find that quantum fluctuations do not lead to decoherence, while thermal fluctuations do. We explicitly calculate decay times due to thermal noise and give conditions for the gap size in the topological superconductor and the gate temperature. Based on this result, we provide simple rules for gate geometries and materials optimized for reducing the negative effect of thermal charge fluctuations on the gate.

Composite Majorana Fermion Wavefunctions in Nanowires

Jelena Klinovaja and Daniel Loss

arXiv:1205.7054

We consider Majorana fermions (MFs) in quasi-one-dimensional nanowire systems containing normal and superconducting sections where the topological phase based on Rashba spin orbit interaction can be tuned by magnetic fields. We derive explicit analytic solutions of the MF wavefunction in the weak and strong spin orbit interaction regimes. We find that the wavefunction for one single MF is a composite object formed by superpositions of different MF wavefunctions which have nearly disjoint supports in momentum space. These contributions are coming from the extrema of the spectrum, one centered around zero momentum and the other around the two Fermi points. As a result, the various MF wavefunctions have different localization lengths in real space and interference among them leads to pronounced oscillations of the MF probability density. For a transparent normal-superconducting junction we find that in the topological phase the MF leaks out from the superconducting into the normal section of the wire and is delocalized over the entire normal section, in agreement with recent numerical results by Chevallier et al. (arXiv:1203.2643).