Journal Club, 25. September 2012, Robert Zielke

[1] **Y-junction splitting spin states of a moving quantum dot**

Tuukka Hiltunen and Ari Harju. *Physical Review B*, 86(12):121301, September 2012.

The development of a working quantum computer utilizing electron-spin states as qubits is a major goal for many theorists and experimentalists. The future applications of quantum information technology would also require a reliable method for the transportation of information between different parts of the system. One such promising method is the propagation of electrons by a surface acoustic wave (SAW). In this paper, we simulate the SAW transfer of two interacting electrons through a Y-shaped junction. Our results show that the singlet and triplet states can be differentiated in the Y junction by an electrostatic detuning potential, an effect that could be used in, for example, measuring the state of a two-spin qubit.

[2] **Electrical Manipulation of Majorana Fermions in an Interdigitated Superconductor-Ferromagnet Device**

Shu-Ping Lee, Jason Alicea, and Gil Refael. *Physical Review Letters*, 109(12):126403, September 2012.

We show that a topological phase supporting Majorana fermions can form in a two-dimensional electron gas (2DEG) adjacent to an interdigitated superconductor-ferromagnet structure. An advantage of this setup is that the 2DEG can induce the required Zeeman splitting and superconductivity from a single interface, allowing one to utilize a wide class of 2DEGs including the surface states of bulk InAs. We demonstrate that the interdigitated device supports a robust topological phase when the finger spacing is smaller than half of the Fermi wavelength F. In this regime, the electrons effectively see a smeared Zeeman splitting and pairing field despite the interdigitation. The topological phase survives even in the opposite limit >F/2, although with a reduced bulk gap. We describe how to electrically generate a vortex in this setup to trap a Majorana mode, and predict an anomalous Fraunhofer pattern that provides a sharp signature of chiral Majorana edge states.

[3] **Quantum teleportation over 143 kilometres using active feed-forward**

Xiao-Song Ma, Thomas Herbst, Thomas Scheidl, Daqing Wang, Sebastian Kropatschek, William Naylor, Bernhard Wittmann, Alexandra Mech, Johannes Kofler, Elena Anisimova, Vadim Makarov, Thomas Jennewein, Rupert Ursin, and Anton Zeilinger. *Nature*, 489(7415):269–273, September 2012.

The quantum internet is predicted to be the next-generation information processing platform, promising secure communication and an exponential speed-up in distributed computation. The distribution of single qubits over large distances via quantum teleportation is a key ingredient for realizing such a global platform. By using quantum teleportation, unknown quantum states can be transferred over arbitrary distances to a party whose location is unknown. Since the first experimental demonstrations of quantum teleportation of independent external qubits, an internal qubit and squeezed states, researchers have progressively extended the communication distance. Usually this occurs without active feed-forward of the classical Bell-state measurement result, which is an essential ingredient in future applications such as communication between quantum computers. The benchmark for a global quantum internet is quantum teleportation of independent qubits over a free-space link whose attenuation corresponds to the path between a satellite and a ground station. Here we report such an experiment, using active feed-forward in real time. The experiment uses two free-space optical links, quantum and classical, over 143 kilometres between the two Canary Islands of La Palma and Tenerife. To achieve this, we combine advanced techniques involving a frequency-uncorrelated polarization-entangled photon pair source, ultra-low-noise single-photon detectors and entanglement-assisted clock synchronization. The average teleported state fidelity is well beyond the classical limit of two-thirds. Furthermore, we confirm the quality of the quantum teleportation procedure without feed-forward by complete quantum process tomography. Our experiment verifies the maturity and applicability of such technologies in real-world scenarios, in particular for future satellite-based quantum teleportation.

[4] **Local thermometry of neutral modes on the quantum Hall edge**

Vivek Venkatachalam, Sean Hart, Loren Pfeiffer, Ken West, and Amir Yacoby. *Nature Physics*, 8(9):676–681, 2012.

Electrons in two dimensions and strong magnetic fields can form an insulating two-dimensional system with conducting one-dimensional channels along the edge. Electron interactions in these edges can lead to independent transport of charge and heat, even in opposite directions. Here, we heat the outer edge of such a quantum Hall system using a quantum point contact. By placing quantum dots upstream and downstream from the heater, we measure both the chemical potential and temperature of that edge to study charge and heat transport, respectively. We find that charge is transported exclusively downstream, but heat can be transported upstream when the edge has additional structure related to fractional quantum Hall (FQH) physics. Surprisingly, this can occur even when the bulk is in an integer quantum Hall state and the edge contains no signatures of FQH charge transport. We also find an unexpected bulk contribution to heat transport at = 1.

[5] **Topological indices, defects, and Majorana fermions in chiral superconductors**

Daichi Asahi and Naoto Nagaosa. *Physical Review B*, 86(10):100504, September 2012.

We study theoretically the role of topological invariants to protect the Majorana fermions in a model of two-dimensional (2D) chiral superconductors which belong to class D of the topological periodic table. A rich phase diagram is revealed. Each phase is characterized by the topological invariants for 2D (Z) and 1D (Z2), which lead to the Majorana fermion at the edge dislocation and the core of the vortex. Interference of the Majorana fermions originating from the different topological invariants is studied. The stability of the Majorana fermion with respect to the interlayer coupling, i.e., in 3D, is also examined.

[6] **Renormalization group approach for the scattering off a single Rashba impurity in a helical liquid**

François Crépin, Jan Carl Budich, Fabrizio Dolcini, Patrik Recher, and Björn Trauzettel. *Physical Review B*, 86(12):121106, September 2012.

The occurrence of two-particle inelastic backscattering has been conjectured in helical edge states of topological insulators and is expected to alter transport. Here, by using a renormalization group approach, we provide a microscopic derivation of this process, in the presence of a time-reversal invariant Rashba impurity potential. We are able to prove that such an effect only occurs in the presence of electron-electron interactions. Furthermore, we find that the linear conductance as a function of temperature exhibits a crossover between two scaling behaviors, T4K for K>1/2 and T8K2 for K<1/2, with K the Luttinger parameter.

[7] **Low-Energy Models for Correlated Materials: Bandwidth Renormalization from Coulombic Screening**

M. Casula, Ph. Werner, L. Vaugier, F. Aryasetiawan, T. Miyake, A. J. Millis, and S. Biermann. *Physical Review Letters*, 109(12):126408, September 2012.

We provide a prescription for constructing Hamiltonians representing the low-energy physics of correlated electron materials with dynamically screened Coulomb interactions. The key feature is a renormalization of the hopping and hybridization parameters by the processes that lead to the dynamical screening. The renormalization is shown to be non-negligible for various classes of correlated electron materials. The bandwidth reduction effect is necessary for connecting models to materials behavior and for making quantitative predictions for low-energy properties of solids.

[8] **Probing Cooper pairs with Franson interferometry**

Vittorio Giovannetti and Kazuya Yuasa. *Physical Review B*, 86(11):115429, September 2012.

A setup based on the Franson optical interferometer is analyzed, which allows us to detect the coherence properties of Cooper pairs emerging via tunneling from a superconductor in contact with two one-dimensional channels. By tuning the system parameters we show that both the internal coherence of the emitted Cooper pairs, which is proportional to Pippard's length, and the de Broglie wavelength of their center-of-mass motion can be measured via current-current correlation measurements.

[9] **Epistemic View of Quantum States and Communication Complexity of Quantum Channels**

Alberto Montina. *Physical Review Letters*, 109(11):110501, September 2012.

The communication complexity of a quantum channel is the minimal amount of classical communication required for classically simulating a process of state preparation, transmission through the channel and subsequent measurement. It establishes a limit on the power of quantum communication in terms of classical resources. We show that classical simulations employing a finite amount of communication can be derived from a special class of hidden variable theories where quantum states represent statistical knowledge about the classical state and not an element of reality. This special class has attracted strong interest very recently. The communication cost of each derived simulation is given by the mutual information between the quantum state and the classical state of the parent hidden variable theory. Finally, we find that the communication complexity for single qubits is smaller than 1.28 bits. The previous known upper bound was 1.85 bits.