Cooling and heating with electron spins: Observation of the spin Peltier effect
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arXiv:1109.6898

The Peltier coefficient describes the amount of heat that is carried by an electrical current when it passes through a material. Connecting two materials with different Peltier coefficients causes a net heat flow towards or away from the interface, resulting in cooling or heating at the interface – the Peltier effect. Spintronics describes the transport of charge and angular momentum by making use of separate spin-up and spin-down channels. Recently, the merger of thermoelectricity with spintronics has given rise to a novel and rich research field named spin caloritronics. Here, we report the first direct experimental observation of refrigeration/heating driven by a spin current, a new spin thermoelectric effect which we call the spin Peltier effect. The heat flow is generated by the spin dependency of the Peltier coefficient inside the ferromagnetic material. We explored the effect in a specifically designed spin valve pillar structure by measuring the temperature using an electrically isolated thermocouple. The difference in heat flow between the two magnetic configurations leads to a change in temperature. With the help of 3-D finite element modeling, we extracted permalloy spin Peltier coefficients in the range of -0.9 to -1.3 mV. These results enable magnetic control of heat flow and provide new functionality for future spintronic devices.

Spin and Majorana polarization in topological superconducting wires
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arXiv:1109.5697v1

We study a one-dimensional wire with strong spin-orbit coupling, which supports Majorana fermions when subject to a Zeeman magnetic field and in proximity of a superconductor. We evaluate the local density of states, as well as the spin polarization in this system using an exact numerical diagonalization approach. Moreover, we define and calculate a local "Majorana polarization" and "Majorana density". We find that the spatial dependence of the Majorana polarization is proportional to that of the spin polarization parallel to the chain and we propose to test the presence of Majorana fermions in a 1D system by a spin-polarized density of states measurement. We also describe the effects of disorder on the Majorana polarization of the system.

The topological Hubbard model and its high-temperature quantum Hall effect
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arXiv:1110.1296v1

The quintessential two-dimensional lattice model that describes the competition between the kinetic energy of electrons and their short-range repulsive interactions is the repulsive Hubbard model. We study a time-reversal symmetric variant of the repulsive Hubbard model defined on a planar lattice: Whereas the interaction is unchanged, any fully occupied band supports a quantized spin Hall effect. We show that at 1/2 filling of this band, the ground state develops spontaneously and simultaneously Ising ferromagnetic long-range order and a quantized charge Hall effect when the interaction is sufficiently strong. We ponder on the possible practical applications, beyond metrology, that the quantized charge Hall effect might have if it could be realized at high temperatures and without external magnetic fields in strongly correlated materials.

Spin pumping with coherent elastic waves
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arXiv:1110.1187v1

We show that the resonant coupling of phonons and magnons can be exploited to generate spin currents at room temperature. Surface acoustic wave (SAW) pulses with a frequency of 1.55 GHz and duration of 300 ns provide coherent elastic waves in a ferromagnetic thin film/normal metal (Co/Pt) bilayer. We use the inverse spin Hall voltage in the Pt as a measure for the spin current and record its evolution as a function of time and external magnetic field magnitude and orientation. Our experiments show that a spin current is generated in the exclusive presence of a resonant elastic excitation. This establishes acoustic spin pumping as a resonant analogue to the spin Seebeck effect.

Microwave photonics with Josephson junction arrays
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arXiv:1110.1184v1

We introduce an architecture for a photonic crystal in the microwave regime based on superconducting transmission lines interrupted by Josephson junctions. A study of the scattering properties of a single junction in the line shows that the junction behaves as a perfect mirror when the photon frequency matches the Josephson plasma frequency. We generalize our calculations to periodic arrangements of junctions, demonstrating that they can be used for tunable band engineering, forming what we call a quantum circuit crystal. As a relevant application, we discuss the creation of stationary entanglement between two superconducting qubits interacting through a disordered media.

Time reversal symmetry breaking superconductivity in the honeycomb t-J model
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arXiv:1110.1183v1

We report the theoretical discovery of a novel time reversal symmetry breaking superconducting state in the t-J model on the honeycomb lattice, based on a recently developed variational method - the Grassmann tensor product state approach. As a benchmark, we use exact diagonalization (ED) and density matrix renormalization (DMRG) methods to check our results on small clusters. Remarkably, we find systematical consistency for the ground state energy as well as other physical quantities, such as the staggered magnetization. At low doping, the superconductivity coexists with anti-ferromagnetic ordering.

Electrically controlled pumping of spin currents in topological insulators
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Pure spin currents are shown to be generated by an electrically controlled quantum pump applied at the edges of a topological insulator. The electric rather than the more conventional magnetic control offers several advantages and avoids, in particular, the necessity of delicate control of magnetization dynamics over tiny regions. The pump is implemented by pinching the sample at two quantum point contacts and phase modulating two external gate voltages between them. The spin current is generated for the full range of parameters. On the other hand, pumping via amplitude modulation of the interboundary couplings generates both charge and spin currents, with a pure charge current appearing only for special values of the parameters for which the Aharonov-Bohm flux takes integer values. Our setup can therefore serve to fingerprint the helical nature of the edges states with the zeros of the pumped spin and charge currents occurring at distinct universal locations where the Fabry-Pérot or the Aharonov-Bohm phases take integer values.

Spatial fluctuations of helical Dirac fermions on the surface of topological insulators
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Surfaces of topological insulators host a new class of states with Dirac dispersion and helical spin texture. Potential quantum computing and spintronic applications using these states require manipulation of their electronic properties at the Dirac energy of their band structure by inducing magnetism or superconductivity through doping and the proximity effect. Yet, the response of these states near the Dirac energy in their band structure to various perturbations has remained unexplored. Here we use spectroscopic mapping with the scanning tunnelling microscope to study their response to magnetic and non-magnetic bulk dopants in Bi2Te3 and Bi2Se3. Far from the Dirac energy, helicity provides remarkable resilience to backscattering even in the presence of ferromagnetism. However, approaching the Dirac point, where the surface states' wavelength diverges, bulk doping results in pronounced nanoscale spatial fluctuations of energy, momentum and helicity. Our results and their connection with similar studies of Dirac electrons in graphene demonstrate that although backscattering and localization are absent for Dirac topological surface states, reducing charge defects is required for both tuning the chemical potential to the Dirac energy and achieving high electrical mobility for these novel states.

Long-distance spin-spin coupling via floating gates
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arXiv:1110.1342v1

The electron spin is a natural two level system that allows a qubit to be encoded. When localized in a gate defined quantum dot, the electron spin provides a promising platform for a future functional quantum computer. The essential ingredient of any quantum computer is entanglement—between electron spin qubits—commonly achieved via the exchange interaction. Nevertheless, there is an immense challenge as to how to scale the system up to include many qubits. Here we propose a novel architecture of a large scale quantum computer based on a realization of long-distance quantum gates between electron spins localized in quantum dots. The crucial ingredients of such a long-distance coupling are floating metallic gates that mediate electrostatic coupling over large distances. We show, both analytically and numerically, that distant electron spins in an array of quantum dots can be coupled selectively, with coupling strengths that are larger than the electron spin decay and with switching times on the order of nanoseconds.