Stabilization of the Quantum Spin Hall Effect by Designed Removal of Time-Reversal Symmetry of Edge States

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The quantum spin Hall (QSH) effect is known to be unstable to perturbations violating time-reversal symmetry. We show that creating a narrow ferromagnetic region near the edge of a QSH sample can push one of the counterpropagating edge states to the inner boundary of the ferromagnetic region and leave the other at the outer boundary, without changing their spin polarizations and propagation directions. Since the two edge states are spatially separated into different lanes, the QSH effect becomes robust against symmetry-breaking perturbations.

Tunneling spectrum of a pinned vortex with a robust Majorana state

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arXiv:1307.0923

We study a heterostructure which consists of a topological insulator and a superconductor with a hole. The hole pins a vortex. The system supports a robust Majorana fermion state bound to the vortex core. We investigate the possibility of using scanning tunneling spectroscopy (i) to detect the Majorana fermion in the proposed setup and (ii) to study excited states bound to the vortex core. The Majorana fermion manifests itself as a magnetic-field dependent zero-bias anomaly of the tunneling conductance. Optimal parameters for detecting Majorana fermions have been obtained. In the optimal regime, the Majorana fermion is separated from the excited states by a substantial gap. The number of zero-energy states equals the number of flux quanta in the hole; thus, the strength of the zero-bias anomaly depends on the magnetic field. The lowest energy excitations bound to the core are also studied. The excited states spectrum differs from the spectrum of a typical Abrikosov vortex, providing additional indirect confirmation of the Majorana state observation.

Vortex states and Majorana fermions in spin-orbit coupled semiconductor-superconductor hybrid structures

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PRB 88, 024501 (2013)

We study the energy spectrum of a vortex core in a two-dimensional semiconductor with Rashba spin-orbit interaction and proximity coupled to a conventional superconductor and a ferromagnetic insulator. We perform self-consistent calculations using the microscopic tight-binding Bogoliubov–de Gennes method on a lattice and confirm the existence of Majorana fermions in the nontrivial topological phase. We also find two different topologically trivial bulk superconducting phases, only differing in the type of vortex core structure they support and separated by a zero-energy excitation. Furthermore, we find an asymmetry in the energy spectrum with respect to both Zeeman splitting and vortex rotation direction and explain its physical origin.

Graphene Enabled Low-Control Quantum Gates between Static and Mobile Spins

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arXiv:1307.0217

We show that the feature of Klein tunneling makes graphene a unique interface for implementing low control quantum gates between static and mobile qubits. A ballistic electron spin is considered as the mobile qubit, while the static qubit is the electronic spin of a quantum dot fixed in a graphene nanoribbon. Scattering is the low control mechanism of the gate, which, in other systems, is really difficult to exploit because of both back-scattering and the momentum dependence of scattering. We find that Klein tunneling enables the implementation of quasi-deterministic quantum gates regardless of the momenta or the shape of the wave function of the incident electron. The Dirac equation is used to describe the system in the one particle approximation with the interaction between the static and the mobile spins modelled by a Heisenberg Hamiltonian. Furthermore, we discuss an application of this model to generate entanglement between two well separated static qubits.

The Two-Band Luttinger Liquid with Spin-Orbit Coupling: Applications to Monatomic Chains on Surfaces
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arXiv:1307.0344
Recently, monatomic chains on surfaces have been synthesized which show evidence of Luttinger liquid physics. The experimental data point to a dispersion along the chain with four Fermi points. Here we investigate a general low-energy effective Hamiltonian for such a two-band model where SU(2) spin symmetry is broken but time reversal symmetry persists, as is expected due to the surface geometry. Spin-orbit coupling gives rise to a new energy scale ϵ_{SO} much smaller than the Fermi energy ϵ_F and to spin non-conserving scattering processes. We derive the generic phase diagram at zero temperature as well as an effective phase diagram at temperatures $\epsilon_{SO} < T \ll \epsilon_F$. For the part of the phase diagram where a Luttinger liquid is found to be stable, the density of states and the spectral function are calculated and discussed in relation to the experimental data.

Suppression of Coulomb exchange energy in quasi-two-dimensional hole systems
T. Kernreiter, M. Governale, R. Winkler, U. Zuelicke
arXiv:1307.1261
We have calculated the exchange-energy contribution to the total energy of quasi-two-dimensional hole systems realized by a hard-wall quantum-well confinement of valence-band states in typical semiconductors. The magnitude of the exchange energy turns out to be suppressed from the value expected for analogous conduction-band systems whenever the mixing between heavy-hole and light-hole components is strong. Our results are obtained using a very general formalism for calculating the exchange energy of many-particle systems where single-particle states are spinors. We have applied this formalism to obtain analytical results for spin-3/2 hole systems in limiting cases.

Emission of time-bin entangled particles into helical edge states
Patrick P. Hofer, Markus Büttiker
arXiv:1307.1225
We propose a single-particle source which emits into the helical edge states of a two-dimensional quantum spin Hall insulator. Without breaking time-reversal symmetry, this source acts like a pair of noiseless single-electron emitters which each inject separately into a chiral edge state. By locally breaking time-reversal symmetry, the source becomes a proper single-particle emitter which exhibits shot noise. Due to its intrinsic helicity, this system can be used to produce time-bin entangled pairs of electrons in a controlled manner. The shot noise created by the source is related to the concurrence of the emitted state.

RKKY Interaction and Intrinsic Frustration in Non-Fermi-Liquid Metals
Jian-Huang She and A. R. Bishop
PRL 111, 017001 (2013)
We study the RKKY interaction in non-Fermi-liquid metals. We find that the RKKY interaction mediated by some non-Fermi-liquid metals can be of much longer range than for a Fermi liquid. The oscillatory nature of the RKKY interaction thus becomes more important in such non-Fermi liquids, and gives rise to enhanced frustration when the spins form a lattice. Frustration suppresses the magnetic ordering temperature of the lattice spin system. Furthermore, we find that the spin system with a longer range RKKY interaction can be described by the Brazovskii model, where the ordering wave vector lies on a higher dimensional manifold. Strong fluctuations in such a model lead to a first-order phase transition and/or glassy phase. This may explain some recent experiments where glassy behavior was observed in stoichiometric heavy fermion material close to a ferromagnetic quantum critical point.

Unpaired Majorana modes in the gapped phase of Kitaev's honeycomb model
Olga Petrova, Paula Mellado, Oleg Tchernyshyov
arXiv:1307.1668
We show that certain kinds of lattice dislocations in the Kitaev honeycomb model carry unpaired Majorana fermions. Each pair of such dislocations in the gapped phase of the system gives rise to a non-local fermion mode, whose energy decays exponentially with the distance between dislocations. This non-local fermion can be created or annihilated by winding a vortex around a dislocation. The vortex also changes its topological charge in this process. The model remains exactly solvable in the presence of such defects, which came to be known as twists, and has potential applications for quantum memory.

Unconventional superfluidity in quasi-one dimension
Shun Uchino, Akiyuki Tokuno, Thierry Giamarchi
arXiv:1307.1639
We show that an unconventional superfluid triggered by a spin-orbit coupling is realized for repulsively interacting quasi-one dimensional fermions. A competition between spin singlet and triplet pairings occurs due to the breaking of inversion symmetry. We show that both superfluid orders decay algebraically with the same exponent except for special coupling constants for which a dominant superfluid is determined solely by the spin-orbit coupling. We propose an experiment to observe such phases with cold atoms.

Coarse graining can beat the rotating-wave approximation in quantum Markovian master equations
Christian Majenz, Tameem Albash, Heinz-Peter Breuer, and Daniel A. Lidar
PRA 88, 012103 (2013)
We present a first-principles derivation of the Markovian semigroup master equation without invoking the rotating-wave approximation (RWA). Instead we use a time coarse-graining approach that leaves us with a free time-scale parameter, which we can optimize. Comparing this approach to the standard RWA-based Markovian master equation, we find that significantly better agreement is possible using the coarse-graining approach, for a three-level model coupled to a bath of oscillators, whose exact dynamics we can solve for at zero temperature. The model has the important feature that the RWA has a nontrivial effect on the dynamics of the populations. We show that the two different master equations can exhibit strong qualitative differences for the population of the energy eigenstates even for such a simple model. The RWA-based master equation misses an important feature which the coarse-graining-based scheme does not. By optimizing the coarse-graining time scale the latter scheme can be made to approach the exact solution much more closely than the RWA-based master equation.

Topologically trivial zero-bias conductance peak in semiconductor Majorana wires from boundary effects
Dibyendu Roy, Nilanjan Bondyopadhaya, and Sumanta Tewari
PRB 88, 020502(R) (2013)
We show that a topologically trivial zero-bias conductance peak is produced in semiconductor-superconductor hybrid structures due to a suppressed superconducting pair potential and/or an excess Zeeman field at the ends of the heterostructure, both of which can occur in experiments. The zero-bias peak (ZBP) (a) appears above a threshold parallel bulk Zeeman field, (b) is stable for a range of bulk field before splitting, (c) disappears with rotation of the bulk Zeeman field, and (d) is robust to weak disorder fluctuations. The topologically trivial ZBPs are also expected to produce splitting oscillations with the applied field similar to those from Majorana fermions. Because of such strong similarity with the phenomenology expected from Majorana fermions, we find that the only unambiguous way to distinguish these trivial ZBPs (of height $4e^2/h$) from those arising from Majo-

rana fermions (of height $2e^2/h$) is by comparing the (zero-temperature) peak height and/or through an interference experiment.

Transverse current current response of graphene at finite temperature, plasmons and absorption
A. Gutierrez-Rubio, T. Stauber, F. Guinea
arXiv:1307.2024
We calculate the linear transverse current current response function for graphene at finite temperature and chemical potential. Within the Random Phase Approximation, we then discuss general aspects of transverse plasmons beyond the local response such as their dependence on temperature and on the surrounding dielectric media. We find, e.g., maximal confinement of this mode for a homogeneous dielectric media with refractive index $n \simeq 40$. Confinement can further be enhanced by placing the graphene sheet inside an optical cavity, but there exists a critical width below which no transverse mode can be sustained. For zero doping and finite temperature, there are no well-defined transverse plasmonic excitations in contrast to the longitudinal channel. We also discuss the absorption of electromagnetic radiation in single and double-layer systems for s and p polarizations and point out that the theoretical limit of 50

High resolution coherent population trapping on a single hole spin in a semiconductor
Julien Houel, Jonathan H. Prechtel, Daniel Brunner, Christopher E. Kuklewicz, Brian D. Gerardot, Nick G. Stoltz, Pierre M. Petroff, Richard J. Warburton
arXiv:1307.2000
We report high resolution coherent population trapping on a single hole spin in a semiconductor quantum dot. The absorption dip signifying the formation of a dark state exhibits an atomic physics-like dip width of just 10 MHz. We observe fluctuations in the absolute frequency of the absorption dip, evidence of very slow spin dephasing. We identify this process as charge noise by, first, demonstrating that the hole spin g-factor in this configuration (in-plane magnetic field) is strongly dependent on the vertical electric field, and second, by characterizing the charge noise through its effects on the optical transition frequency. An important conclusion is that charge noise is an important hole spin dephasing process.

Topological Superconductivity and Majorana Fermions in RKKY Systems
Jelena Klinovaja, Peter Stano, Ali Yazdani, Daniel Loss
arXiv:1307.1442