Jelena Klinovaja 20.09.11

Journal club

Controlling non-Abelian statistics of Majorana fermions in semiconductor nanowires
Jay D. Sau, David J. Clarke, and Sumanta Tewari
Phys. Rev. B 84, 094505 (2011)
Under appropriate external conditions a semiconductor nanowire in proximity to an s-wave superconductor can be in a topological superconducting (TS) phase. This phase supports localized zero-energy Majorana fermions at the ends of the wire. However, the non-Abelian exchange statistics of Majorana fermions is difficult to verify because of the one-dimensional topology of such wires. In this paper we propose a scheme to transport Majorana fermions between the ends of different wires using tunneling, which is shown to be controllable by gate voltages. Such tunneling-generated hops of Majorana fermions can be used to exchange the Majorana fermions. The exchange process thus obtained is described by a non-Abelian braid operator that is uniquely determined by the well-controlled microscopic tunneling parameters.

Current correlations in the interacting Cooper-pair beam-splitter
J. Rech, D. Chevallier, T. Jonckheere, T. Martin
arXiv:1109.2476v1
Using a conserving many-body treatment, we propose an approach allowing the computation of currents and their correlations in interacting multi-terminal mesoscopic systems involving quantum dots coupled to normal and/or superconducting leads. We illustrate our method with the Cooper-pair beam-splitter setup recently proposed, which we model as a double quantum dot with weak interactions, connected to a superconducting lead and two normal ones. Our results suggest that even a weak Coulomb repulsion tends to favor positive current cross-correlations.

Integer Quantum Hall Effect in Trilayer Graphene
A. Kumar, W. Escoffier, J. M. Poumirol, C. Faugeras, D. P. Arovas, M. M. Fogler, F. Guinea, S. Roche, M. Goiran, and B. Raquet
Phys. Rev. Lett. 107, 126806 (2011)
By using high-magnetic fields (up to 60 T), we observe compelling evidence of the integer quantum Hall effect in trilayer graphene. The magnetotransport fingerprints are similar to those of the graphene monolayer, except for the absence of a plateau at a filling factor of $\nu = 2$. At a very low filling factor, the Hall resistance vanishes due to the presence of mixed electron and hole carriers induced by disorder. The measured Hall resistivity plateaus are well reproduced theoretically, using a self-consistent Hartree calculations of the Landau levels and assuming an ABC stacking order of the three layers.

Weyl Semimetal in a Topological Insulator Multilayer
A. A. Burkov and Leon Balents
Phys. Rev. Lett. 107, 127205 (2011)
We propose a simple realization of the three-dimensional (3D) Weyl semimetal phase, utilizing a multilayer structure, composed of identical thin films of a magnetically doped 3D topological insulator, separated by ordinary-insulator spacer layers. We show that the phase diagram of this system contains a Weyl semimetal phase of the simplest possible kind, with only two Dirac nodes of opposite chirality, separated in momentum space, in its band structure. This Weyl semimetal has a finite anomalous Hall conductivity and chiral edge states and occurs as an intermediate phase between an ordinary insulator and a 3D quantum anomalous Hall insulator. We find that the Weyl semimetal has a nonzero dc conductivity at zero temperature, but Drude weight vanishing as T^2, and is thus an unusual metallic phase, characterized by a finite anomalous Hall conductivity and topologically protected edge states.

Effects of the Berry Phase and Instantons in One-Dimensional Kondo-Heisenberg Model
Pallab Goswami and Qimiao Si
Phys. Rev. Lett. 107, 126404 (2011)
Motivated by the global phase diagram of antiferromagnetic heavy-fermion metals, we study the Kondo effect from the perspective of a nonlinear sigma model in the one-dimensional Kondo-Heisenberg model away from half-filling. We focus on the effects of the instanton configurations of the sigma-model field and the associated Berry phase. Guided by the results derived using bosonization methods, we demonstrate that the Kondo-singlet formation is accompanied by an emergent Berry phase. This Berry phase also captures the competition between the Kondo-singlet formation and spin-Peierls correlations. Related effects are likely to be realized in Kondo lattice systems in higher dimensions.

Tight-binding model for topological insulators: Analysis of helical surface modes over the whole Brillouin zone
Shijun Mao, Ai Yamakage, and Yoshio Kuramoto
Phys. Rev. B 84, 115413 (2011)
A tight-binding model is constructed for Bi2Se3-type topological insulators with rhombohedral crystal structure. The model takes full account of the spin-orbit interaction, and realizes both strong (S) and weak (W) topological insulators (TIs) depending on the mass parameter that causes the band inversion. It is found that there are two separate STIs with either a single or three Dirac cones on the surface, while the WTI realizes either zero or four surface Dirac cones keeping the same Z2 indices. Closing of the bulk direct gap gives rise to transition between either STI and WTI, or TI and an ordinary insulator. On the other hand, closing of the indirect gap keeps intact the surface Dirac cones in both STIs and WTIs. As a result, helical modes can remain even in semimetals. It is found that reentrant helical modes appear in finite-momentum regions in some cases in STIs, and even in ordinary insulators with strong particle-hole asymmetry. All results are obtained analytically.

Synthetic gauge fields and homodyne transmission in JaynesCummings lattices
A. Nunnenkamp, Jens Koch and S.M. Girvin
New J. Phys. 13 095008 (2011)
Many-body physics is traditionally concerned with systems of interacting massive particles. Recent studies of effective interactions between photons, induced in the circuit quantum electrodynamics (QED) architecture by coupling the microwave field to superconducting qubits, have paved the way for photon-based many-body physics. We derive the magnitude and intrinsic signs of photon hopping amplitudes in such circuit QED arrays. For a finite, ring-shaped JaynesCummings lattice exposed to a synthetic gauge field, we show that degeneracies in the single-excitation spectrum emerge, which can give rise to strong correlations for the interacting system with multiple excitations. We calculate the homodyne transmission for such a device, explain the generalization of vacuum Rabi splittings known for the single-site JaynesCummings model and identify fingerprints of interactions beyond the linear response regime.

Proposal for Entangling Remote Micromechanical Oscillators via Optical Measurements
K. Borkje, A. Nunnenkamp, and S. M. Girvin
Phys. Rev. Lett. 107, 123601 (2011)
We propose an experiment to create and verify entanglement between remote mechanical objects by use of an optomechanical interferometer. Two optical cavities, each coupled to a separate mechanical oscillator, are coherently driven such that the oscillators are laser cooled to the quantum regime. The entanglement is induced by optical measurement and comes about by combining the output from the two cavities to erase which-path information. It can be verified through measurements of degrees of second-order coherence of the optical output field. The experiment is feasible in the regime of weak optomechanical coupling. Realistic parameters for the membrane-in-the-middle geometry suggest entangled state lifetimes on the order of milliseconds.