Quantum Time Crystals

Phys. Rev. Lett. **109**, 160401 (2012)

Frank Wilczek

Some subtleties and apparent difficulties associated with the notion of spontaneous breaking of time-translation symmetry in quantum mechanics are identified and resolved. A model exhibiting that phenomenon is displayed. The possibility and significance of breaking of imaginary time-translation symmetry is discussed.

Collectively Enhanced Interactions in Solid-State Spin Qubit

Phys. Rev. Lett. **110**, 067601 (2013)

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We propose and analyze a technique to collectively enhance interactions between solid-state quantum registers composed from random networks of spin qubits. In such systems, disordered dipolar interactions generically result in localization. Here, we demonstrate the emergence of a single collective delocalized eigenmode as one turns on a transverse magnetic field. The interaction strength between this symmetric collective mode and a remote spin qubit is enhanced by the square root of the number of spins participating in the delocalized mode. Mediated by such collective enhancement, long-range quantum logic between remote spin registers can occur at distances consistent with optical addressing. A specific implementation utilizing nitrogen-vacancy defects in diamond is discussed and the effects of decoherence are considered.

All-Electrical Nuclear Spin Polarization of Donors in Silicon

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We demonstrate an all-electrical donor nuclear spin polarization method in silicon by exploiting the tunable interaction of donor bound electrons with a two-dimensional electron gas, and achieve over two orders of magnitude nuclear hyperpolarization at T=5 K and B=12 T with an in-plane magnetic field. We also show an intricate dependence of nuclear polarization effects on the orientation of the magnetic field, and both hyperpolarization and antipolarization can be controllably achieved in the quantum Hall regime. Our results demonstrate that donor nuclear spin qubits can be initialized through local gate control of electrical currents without the need for optical excitation, enabling the implementation of nuclear spin qubit initialization in dense multiqubit arrays.

Spin imbalance and spin-charge separation in a mesoscopic superconductor

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What happens to spin-polarized electrons when they enter a superconductor? Superconductors at equilibrium and at finite temperature contain both paired particles (of opposite spin) in the condensate phase as well as unpaired, spin-randomized quasiparticles. Injecting spin-polarized electrons into a superconductor (and removing pairs) thus creates both spin and charge imbalances, which must relax when the injection stops, but not necessarily over the same time (or length) scale. These different relaxation times can be probed by creating a dynamic equilibrium between continuous injection and relaxation; this leads to constant-in-time spin and charge imbalances, which scale with their respective relaxation times and with the injection current. Whereas charge imbalances in superconductors have been studied in great detail both theoretically and experimentally, spin imbalances have not received much experimental attention despite intriguing theoretical predictions of spin-charge separation effects. Here we present evidence for an almost-chargeless spin imbalance in a mesoscopic superconductor.

The space group classification of topological band-insulators

Nat. Phys. **9**, 98 (2013)

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Topological band-insulators (TBIs) are bulk insulating materials, which in the presence of time reversal symmetry feature topologically protected metallic states on their surface or edge. They have recently been discovered in two- and threedimensional materials with a strong spin–orbit coupling. These unusual states of quantum matter may host Majorana fermions and provide the condensed-matter realization of the exotic theta-vacuum. The existing classification of TBIs departs from time-reversal symmetry, but the role of the crystal-lattice symmetries in the physics of these topological states has remained elusive. Here we provide the classification of TBIs protected not only by time-reversal, but also by crystalline symmetries. We find three broad classes of topological states: 0 states robust against general time-reversal invariant perturbations; translationally active states protected from elastic scattering, but susceptible to topological crystalline disorder; valley topological insulators sensitive to the effects of non-topological and crystalline disorder. These three classes give rise to 18 different two-dimensional, and, at least 70 three-dimensional TBIs, opening up a route for the systematic search for new types of TBIs.

Photocurrent measurements of supercollision cooling in graphene

Nat. Phys. **9**, 103 (2013)

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The cooling of hot electrons in graphene is the critical process underlying the operation of exciting new graphene-based optoelectronic and plasmonic devices, but the nature of this cooling is controversial. We extract the hot-electron cooling rate near the Fermi level by using graphene as a novel photothermal thermometer that measures the electron temperature ($T(t)$) as it cools dynamically. We find the photocurrent generated from graphene p–n junctions is well described by the energy dissipation rate $C\mathrm{d}T/\mathrm{d}t = -A(T^3 - T_l^3)$, where the heat capacity is $C = \alpha T$ and T_l is the base lattice temperature. These results are in disagreement with predictions of electron–phonon emission in a disorder-free graphene system, but in excellent quantitative agreement with recent predictions of a disorder-enhanced supercollision cooling mechanism. We find that the supercollision model provides a complete and unified picture of energy loss near the Fermi level over the wide range of electronic (15 to ~ 3,000 K) and lattice (10–295 K) temperatures investigated.

Twist defects and projective non-Abelian braiding statistics

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It has recently been realized that a general class of non-Abelian defects can be created in conventional topological states by introducing extrinsic defects, such as lattice dislocations or superconductor-ferromagnet domain walls in conventional quantum Hall states or topological insulators. In this paper, we begin by placing these defects within the broader conceptual scheme of extrinsic twist defects associated with symmetries of the topological state. We explicitly study several classes of examples, including Z_2 and Z_3 twist defects, where the topological state with N twist defects can be mapped to a topological state without twist defects on a genus $g \propto N$ surface. To emphasize this connection we refer to the twist defects as *genons*. We develop methods to compute the projective non-Abelian braiding statistics of the genons, and we find the braiding is given by adiabatic modular transformations, or Dehn twists, of the topological state on the effective genus g surface. We study the relation between this projective braiding statistics and the ordinary non-Abelian braiding statistics obtained when the genons become deconfined, finite-energy excitations. We find that the braiding is generally different, in contrast to the Majorana case, which opens the possibility for fundamentally novel behavior. We find situations where the genons have quantum dimension 2 and can be used for universal topological quantum computing (TQC), while the host topological state is by itself nonuniversal for TQC.