Phys. Rev. Lett. ***109****, 040401*

Weak Measurements with Orbital-Angular-Momentum Pointer States

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Weak measurements are a unique tool for accessing information about weakly interacting quantum systems with minimal back action. Joint weak measurements of single-particle operators with pointer states characterized by a two-dimensional Gaussian distribution can provide, in turn, key information about quantum correlations that can be relevant for quantum information applications. Here we demonstrate that by employing two-dimensional pointer states endowed with orbital angular momentum (OAM), it is possible to extract weak values of the higher order moments of single-particle operators, an inaccessible quantity with Gaussian pointer states only. We provide a specific example that illustrates the advantages of our method both in terms of signal enhancement and information retrieval.

Phys. Rev. B ***86****, 045128*

Orthogonal metals: The simplest non-Fermi liquids

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We present a fractionalized metallic phase which is indistinguishable from the Fermi liquid in conductivity and thermodynamics, but is sharply distinct in one-electron properties, such as the electron spectral function. We dub this phase the “orthogonal metal.” The orthogonal metal and the transition to it from the Fermi liquid are naturally described using a slave-particle representation wherein the electron is expressed as a product of a fermion and a slave Ising spin. We emphasize that when the slave spins are disordered, the result is not a Mott insulator (as erroneously assumed in the prior literature), but rather the orthogonal metal. We construct prototypical ground-state wave functions for the orthogonal metal by modifying the Jastrow factor of Slater-Jastrow wave functions that describe ordinary Fermi liquids. We further demonstrate that the transition from the Fermi liquid to the orthogonal metal can, in some circumstances, provide a simple example of a continuous destruction of a Fermi surface with a critical Fermi surface appearing right at the critical point. We present exactly soluble models that realize an orthogonal metal phase, and the phase transition to the Fermi liquid. These models thus provide valuable solvable examples for phase transitions associated with the death of a Fermi surface.

arXiv:1208.2576

Density Waves Instability and a Skyrmion Lattice on the Surface of Strong Topological Insulators

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In this work we analyze the instability conditions for spin-density-waves (SDW) formation on the surface of strong topological insulators. We find that for a certain range of Fermi-energies and strength of interactions the SDW state is favored compared to the unmagnetized and the uniform-magnetization states. We also find that the SDW are of spiral nature and for a certain range of parameters a Skyrmion-lattice may form on the surface. We show that this phase may have a non trivial Chern-number even in the absence of an external magnetic field.

arXiv:1208.2255

Quantum simulation of expanding space-time with tunnel-coupled condensates

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We consider two weakly interacting quasi-1D condensates of cold bosonic atoms. It turns out that a time-dependent variation of the tunnel-coupling between those condensates is equivalent with the spatial expansion of a one-dimensional toy-Universe with regard to the dynamics of the relative phase field. The dynamics of this field is governed by the quantum sine-Gordon equation. Thus, this analogy could be used to 'quantum simulate' the dynamics of a scalar, interacting quantum field on an expanding background. We discuss, how to observe the freezing out of quantum fluctuations during an accelerating expansion in a possible experiment. We also discuss an experimental protocol to study the formation of sine-Gordon breathers in the relative phase field out of quantum fluctuations.

arXiv:1208.2742

Topological phases and Majorana Fermions in quantum wires: from magnetostatic to non-magnetic Floquet platforms

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Quantum wires subject to the combined action of spin-orbit and Zeeman coupling in the presence of s-wave pairing potentials (superconducting proximity effect in semiconductors or superfluidity in cold atoms) are one of the most promising systems for the developing of topological phases hosting Majorana fermions. Other potential platforms can be obtained by applying appropriate transformations to the quantum-wire model. One example is the recent proposal by Kjaergaard et al. [Phys. Rev. B 85, 020503(R) (2012)], where an effective spin-orbit coupling is obtained in electronic systems subject to magnetic textures after applying a local spin-rotation mapping. Here, instead, we employ a \emph{time-dependent} spin rotation that maps the standard magnetostatic model into a \emph{non-magnetic} one where the spin-orbit coupling axis changes as a function of time. This represents a proposal for the development of a topological state of matter driven by external forces. From a practical viewpoint, though the scheme avoids the disadvantages of conjugating magnetism and superconductivity, the need of a high-frequency driving of spin-orbit coupling represents a technological challenge. We describe the basic properties of this Floquet system and show that in finite samples it hosts Floquet Majorana fermions at its edges despite the fact that the bulk Floquet quasienergies are gapless and that the Hamiltonian at each instant of time is a time-reversal symmetric operator. The exact mapping to the static system allows us to show that the localized Floquet Majorana fermions are robust to local perturbations, this result is found to be in agreement with numerical simulations fully performed in the time-dependent system.

Phys. Rev. X ***2****, 031008*

Simplified Topological Invariants for Interacting Insulators

Zhong Wang and Shou-Cheng Zhang

We propose general topological order parameters for interacting insulators in terms of the Green's function at zero frequency. They provide a unified description of various interacting topological insulators including the quantum anomalous Hall insulators and the time-reversal-invariant insulators in four, three, and two dimensions. Since only the Green's function at zero frequency is used, these topological order parameters can be evaluated efficiently by most numerical and analytical algorithms for strongly interacting systems.

arXiv:1208.3142

Non-degenerate, three-wave mixing with the Josephson ring modulator

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The Josephson ring modulator (JRM) is a device, based on Josephson tunnel junctions, capable of performing non-degenerate mixing in the microwave regime without losses. The generic scattering matrix of the device is calculated by solving coupled quantum Langevin equations. Its form shows that the device can achieve quantum-limited noise performance both as an amplifier and a mixer. Fundamental limitations on simultaneous optimization of performance metrics like gain, bandwidth and dynamic range (including the effect of pump depletion) are discussed. We also present three possible integrations of the JRM as the active medium in a different electromagnetic environment. The resulting circuits, named Josephson parametric converters (JPC), are discussed in detail, and experimental data on their dynamic range are found to be in good agreement with theoretical predictions. We also discuss future prospects and requisite optimization of JPC as a preamplifier for qubit readout applications.

arXiv:1208.2968

Surface State Magnetization and Chiral Edge States on Topological Insulators

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We study the interaction between a ferromagnetically ordered medium and the surface states of a topological insulator with a general surface termination. This interaction is strongly crystal face dependent and can generate chiral states along edges between crystal facets even for a uniform magnetization. While magnetization parallel to quintuple layers shifts the momentum of Dirac point, perpendicular magnetization lifts the Kramers degeneracy at any Dirac points except on the side face where the spectrum remains gapless and the Hall conductivity switches sign. Chiral states can be found at any edge that reverses the projection of surface normal to the stacking direction of quintuple layers. Magnetization also weakly hybridizes non cleavage surfaces.

arXiv:1208.3515

Decoherence induced deformation of the ground state in adiabatic quantum computation

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Adiabatic quantum computation (AQC), either in its universal form, or in the form of adiabatic quantum optimization, or quantum simulations, presents a viable alternative to gate-model quantum computation (GMQC). Although a part of the original motivation for introduction of the AQC was the promise of the increased stability against decoherence due to the energy gap between the ground and excited states, the question of the role of decoherence in AQC remains an open one. This uncertainty makes it important to quantify more precisely the decoherence properties of AQC. A crucial step towards this would be to define a quantitative characteristic of the decoherence strength in AQC, that plays a role similar to the decoherence time for GMQC. However, in the case of AQC, decoherence has qualitatively different, static effect on the qubits, not limiting the operation time of an algorithm. In this work, we propose the ground state fidelity, defined as the distance between the open and closed system reduced density matrices normalized to the Boltzmann ground state probability, as a quantitative measure of decoherence-induced deformation of the ground state in AQC, analogous to the decoherence time for GMQC. We calculate the fidelity perturbatively at finite temperatures and express it through the same environmental noise correlators that determine the decoherence times in GMQC. We discuss the relation between fidelity and the relaxation and dephasing times of the qubits, and its projected scaling properties with the number of qubits.