Journal Club, 4th September 2012, James Wootton

3-d quantum stabilizer codes with a power law energy barrier

Kamil Michnicki,

arXiv:1208.3496

We introduce a new primitive, called welding, for combining two stabilizer codes to produce a new stabilizer code. We apply welding to construct surface codes and then use the surface codes to construct solid codes, a variant of a 3-d toric code with rough and smooth boundaries. Finally, we weld solid codes together to produce a $(O(L^3), 1, O(L^{4/3}))$ stabilizer code with an energy barrier of $O(L^{2/3})$, which solves an open problem of whether a power law energy barrier is possible for local stabilizer code Hamiltonians in three-dimensions. The previous highest energy barrier is $O(\log L)$. Previous no-go results are avoided by breaking translation invariance.

The Shifting Sands of Quantum Error Correction Thresholds

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arXiv:1208.4924

The threshold probability for successful error correction of a quantum system is not a single, absolute value. Not only is it contingent on the noise model, but what the noise model is believed to be. This is exhibited for the 2D Toric code subject to local noise where, via a mapping to the 2D random bond Ising model, suitable thresholds can be established. The analytic calculation is founded on an assumption which is known to give a good approximate result. We also find the first order correction to this result based on renormalisation group calculations, and numerically evaluate lower bounds based on explicitly implementing an error correction strategy.

Zero-energy states bound to a magnetic pi-flux vortex in a two-dimensional topological insulator

Andrej Mesaros, Robert-Jan Slager, Jan Zaanen, Vladimir Juricic,

arXiv:1208.5708

We show that the existence of a pair of zero-energy modes bound to a vortex carrying a pi-flux is a generic feature of the topologically non-trivial phase of the M-B model, which was introduced to describe the topological band insulator in HgTe quantum wells. We explicitly find the form of the zero-energy states of the corresponding Dirac equation, which contains a novel momentum-dependent mass term and describes a generic topological transition in a band insulator. The obtained modes are exponentially localized in the vortex-core, with the dependence of characteristic length on the parameters of the model matching the dependence extracted from a lattice version of the model. We consider in full generality the short-distance regularization of the vector potential of the vortex, and show that a particular choice yields the modes localized and simultaneously regular at the origin. Finally, we also discuss a realization of two-dimensional spin-charge separation through the vortex zero-modes.

Unconditionally secure device-independent quantum key distribution with only two devices

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arXiv:1209.0435

Device-independent quantum key distribution is the task of using uncharacterized quantum devices to establish a shared key between two users. If a protocol is secure regardless of the device behaviour, it can be used to generate a shared key even if the supplier of the devices is malicious. To date, all device-independent quantum key distribution protocols that are known to be secure require separate isolated devices for each entangled pair, which is a significant practical limitation. We introduce a protocol that requires Alice and Bob to have only one device each. Although inefficient, our protocol is unconditionally secure against an adversarial supplier limited only by locally enforced signalling constraints.

Giant Ambipolar Rashba Effect in the Semiconductor BiTeI

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Phys. Rev. Lett. 109, 096803 (2012)

We observe a giant spin-orbit splitting in the bulk and surface states of the noncentrosymmetric semiconductor BiTeI. We show that the Fermi level can be placed in the valence or in the conduction band by controlling the surface termination. In both cases, it intersects spin-polarized bands, in the corresponding surface depletion and accumulation layers. The momentum splitting of these bands is not affected by adsorbate-induced changes in the surface potential. These findings demonstrate that two properties crucial for enabling semiconductor-based spin electronicsa large, robust spin splitting and ambipolar conductionare present in this material.

Quantum Bath Refrigeration towards Absolute Zero: Challenging the Unattainability Principle

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Phys. Rev. Lett. 109, 090601 (2012)

A minimal model of a quantum refrigerator, i.e., a periodically phase-flipped two-level system permanently coupled to a finite-capacity bath (cold bath) and an in-finite heat dump (hot bath), is introduced and used to investigate the cooling of the cold bath towards absolute zero (T=0). Remarkably, the temperature scaling of the cold-bath cooling rate reveals that it does not vanish as T0 for certain realistic quantized baths, e.g., phonons in strongly disordered media (fractons) or quantized spin waves in ferromagnets (magnons). This result challenges Nernsts third-law formulation known as the unattainability principle.

Spin-Injection Spectroscopy of a Spin-Orbit Coupled Fermi Gas

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Phys. Rev. Lett. 109, 095302 (2012)

The coupling of the spin of electrons to their motional state lies at the heart of recently discovered topological phases of matter. Here we create and detect spin-orbit coupling in an atomic Fermi gas, a highly controllable form of quantum degenerate matter. We directly reveal the spin-orbit gap via spin-injection spectroscopy, which characterizes the energy-momentum dispersion and spin composition of the quantum states. For energies within the spin-orbit gap, the system acts as a spin diode. We also create a spin-orbit coupled lattice and probe its spinful band structure, which features additional spin gaps and a fully gapped spectrum. In the presence of s-wave interactions, such systems should display induced p-wave pairing, topological superfluidity, and Majorana edge states.

Spin-Orbit Coupled Degenerate Fermi Gases

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Phys. Rev. Lett. 109, 095301 (2012)

In this Letter, we report the first experimental realization and investigation of a spin-orbit coupled Fermi gas. Both spin dephasing in spin dynamics and momentum distribution asymmetry of the equilibrium state are observed as hallmarks of spin-orbit coupling in a Fermi gas. The single particle dispersion is mapped out by using momentum-resolved radio-frequency spectroscopy. From momentum distribution and momentum-resolved radio-frequency spectroscopy, we observe the change of fermion population in different helicity branches consistent with a finite temperature calculation, which indicates that a Lifshitz transition of the Fermi surface topology change can be found by further cooling the system.