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Surface Code Threshold in the Presence of Correlated Errors
E. Novais and Eduardo R. Mucciolo
Phys. Rev. Lett. 110, 010502 (2013)

We study the fidelity of the surface code in the presence of correlated errors induced by the coupling of physical qubits to a bosonic environment. By mapping the time evolution of the system after one quantum error correction cycle onto a statistical spin model, we show that the existence of an error threshold is related to the appearance of an order-disorder phase transition in the statistical model in the thermodynamic limit. This allows us to relate the error threshold to bath parameters and to the spatial range of the correlated errors.

Fidelity of the surface code in the presence of a bosonic bath
P. Jouzdani, E. Novais, E. R. Mucciolo
arXiv:1304.2975

We study the resilience of the surface code to decoherence caused by the presence of a bosonic bath. This approach allows us to go beyond the standard stochastic error model commonly used to quantify decoherence and error theshold probabilities in this system. The full quantum mechanical system-bath dynamics is computed exactly over one quantum error correction cycle. Since all physical qubits interact with the bath, space time correlations between errors are taken into account. We compute the fidelity of the surface code as a function of the quantum error correction time. The calculation allows us to map the problem onto an Ising-like statistical spin model with two-body interactions and a fictitious temperature which is related to the inverse bath coupling constant. The model departs from the usual Ising model in the sense that interactions can be long ranged and can involve complex exchange couplings; in addition, the number of allowed configurations is restricted by the syndrome extraction. Using analytical estimates and numerical calculations, we argue that, in the limit of an infinite number of physical qubits, the spin model sustain a phase transition which can be associated to the existence of an error threshold in the surface code. An estimate of the transition point is given for the case of nearest-neighbor interactions.

Emergent momentum scale, localization, and van Hove singularities in the graphene twist bilayer
S. Shallcross, S. Sharma, and O. Pankratov
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We identify an angle-dependent momentum scale as the fundamental property of a bilayer composed of mutually rotated graphene layers. The interlayer scattering processes at these characteristic momentum values define an effective Brillouin zone (a Jones zone) which, in general, differs from the Brillouin zone generated by the real-space lattice, which is physically irrelevant. From this we develop a numerical method that increases, for the twist bilayer, the efficiency of the standard tight-binding method by a factor of 103 at no loss of accuracy. The efficiency of the method is based on (i) the fact that the twist Hamiltonian is exceptionally sparse in a basis of single-layer graphene (SLG) states, (ii) a solution of trivial Diophantine problem (Bzout's identity) allows one to know in advance which matrix elements take nonzero values, and (iii) to access the electronic structure in a few electron volts about the Dirac point a truncated SLG basis consisting only of states in a somewhat larger energy window are required, leading to a much reduced size of the Hamiltonian. This allows a complete survey of the system which reveals (i) an angle-dependent series of van Hove singularities, (ii) an increasing mixing of SLG states as the twist angle is reduced leading to the appearance of localization of the twist bilayer wave functions at all energies in the small-angle limit, and (iii) a zero-energy peak in the density of states in an approximately self-similar small-angle regime.

Effect of charged line defects on conductivity in graphene: Numerical Kubo and analytical Boltzmann approaches
T. M. Radchenko, A. A. Shylau, and I. V. Zozoulenko
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Charge carrier transport in single-layer graphene with one-dimensional charged defects is studied theoretically. Extended charged defects, considered an important factor for mobility degradation in chemically vapor-deposited graphene, are described by a self-consistent Thomas-Fermi potential. A numerical study of electronic transport is performed by means of a time-dependent real-space Kubo approach in honeycomb lattices containing millions of carbon atoms, capturing the linear response of realistic size systems in the highly disordered regime. Our numerical calculations are complemented with a kinetic transport theory describing charge transport in the weak scattering limit. The semiclassical transport lifetimes are obtained by computing scattered amplitudes within the second Born

approximation. The transport electron-hole asymmetry found in the semiclassical approach is consistent with the Kubo calculations. In the strong scattering regime, the conductivity is found to be a sublinear function of electronic density and weakly dependent on the Thomas-Fermi screening wavelength. We attribute this atypical behavior to the extended nature of one-dimensional charged defects. Our results are consistent with recent experimental reports.

Stability of topologically-protected quantum computing proposals as seen through spin glasses
Helmut G. Katzgraber, Ruben S. Andrist
arXiv:1306.0540

Sensitivity to noise makes most of the current quantum computing schemes prone to error and nonscalable, allowing only for small proof-of-principle devices. Topologically-protected quantum computing aims at solving this problem by encoding quantum bits and gates in topological properties of the hardware medium that are immune to noise that does not impact the entire system at once. There are different approaches to achieve topological stability or active error correction, ranging from quasiparticle braidings to spin models and topological color codes. The stability of these proposals against noise can be quantified by their error threshold. This figure of merit can be computed by mapping the problem onto complex statistical-mechanical spin-glass models with local disorder on nontrival lattices that can have many-body interactions and are sometimes described by lattice gauge theories. The error threshold for a given source of error then represents the point in the temperature-disorder phase diagram where a stable symmetry-broken phase vanishes. An overview of the techniques used to estimate the error thresholds is given, as well as a summary of recent results on the stability of different topologically-protected quantum computing schemes to different error sources.

A Gaussian refinement of the Lieb-Robinson bound
A Gaussian refinement of the Lieb-Robinson bound
arXiv:1306.0546

In this paper we provide a sharpening of the Lieb-Robinson bound that is potentially relevant in some applications. The exponential decay is replaced by a Gaussian decay.

Vortex Loops and Majorana Fermions
Stefano Chesi, Arthur Jaffe, Daniel Loss, Fabio L. Pedrocchi
arXiv:1305.6270

We investigate the role that vortex loops play in characterizing eigenstates of certain systems of half-integer spins with nearest-neighbor interaction on a trivalent lattice. In particular we focus on ground states (and other low-lying states). We test our ideas on a "spin ladder" In certain cases we show how the vortex configuration of the ground state is determined by the relative signs of the coupling constants. Two methods yield exact results: i.) We utilize the equivalence of spin Hamiltonians with quartic interactions of Majorana fermions, and analyze that fermionic Hamiltonian. ii) We use reflection positivity for Majorana fermions to characterize vortices in ground states for reflection-symmetric couplings. Two additional methods suggest potential wider applicability of these results: iii.) Numerical evidence suggests similar behavior for certain systems without reflection symmetry. iv.) A perturbative analysis also suggests similar behavior without the assumption of reflection symmetry.

On the equivalence between an optomechanical system and a Kerr medium
Samuel Aldana, Christoph Bruder, Andreas Nunnenkamp
arXiv:1306.0415

We study the optical bistability of an optomechanical system in which the position of a mechanical oscillator modulates the cavity frequency. The steady-state mean-field equation of the optical mode is identical to the one for a Kerr medium, and thus we expect it to have the same characteristic behavior with a lower, a middle, and an upper branch. However, the presence of position fluctuations of the mechanical resonator leads to a new feature: the upper branch will become unstable at sufficiently strong driving in certain parameter regimes. We identify the appropriate parameter regime for the upper branch to be stable, and we confirm, by numerical investigation of the quantum steady state, that the mechanical mode indeed acts as a Kerr nonlinearity for the optical mode in the low-temperature limit. This equivalence of the optomechanical system and the Kerr medium will be important for future applications of cavity optomechanics in quantum nonlinear optics and quantum information science.