arXiv:1111.2129

Majorana fermions in superconducting nanowires without spin-orbit coupling

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We show that confined Majorana fermions can exist in nanowires with proximity induced s-wave superconducting pairing if the direction of an external magnetic field rotates along the wire. The system is equivalent to nanowires with Rashba-type spin-orbit coupling, with strength proportional to the derivative of the field angle. For realistic parameters, we demonstrate that a set of permanent magnets can bring a nearby nanowire into the topologically non-trivial phase with localized Majorana modes at its ends. Without the requirement of spin-orbit coupling this opens up for a new route for demonstration and design of Majorana fermion systems.

Phys. Rev. B 84, 195442

Majorana fermions emerging from magnetic nanoparticles on a superconductor without spin-orbit coupling

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There exists a variety of proposals to transform a conventional s-wave superconductor into a topological superconductor, supporting Majorana fermion midgap states. A necessary ingredient of these proposals is strong spin-orbit coupling. Here we propose an alternative system consisting of a one-dimensional chain of magnetic nanoparticles on a superconducting substrate. No spin-orbit coupling in the superconductor is needed. We calculate the topological quantum number of a chain of finite length, including the competing effects of disorder in the orientation of the magnetic moments and in the hopping energies, to identify the transition into the topologically nontrivial state (with Majorana fermions at the end points of the chain).

Phys. Rev. B 84, 205109

Decay rates for topological memories encoded with Majorana fermions

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Recently there have been numerous proposals to create Majorana zero modes in solid state heterojunctions, superconducting wires, and optical lattices. Putatively the information stored in qubits constructed from these modes is protected from various forms of decoherence. Here we present a generic method to study the effect of external perturbations on these modes. We focus on the case where there are no interactions between different Majorana modes either directly or through intermediary fermions. To quantify the rate of loss of the information stored in the Majorana modes we study the two-time correlators for qubits built from them. We analyze a generic gapped fermionic environment (bath) interacting via tunneling with different components of the qubit (different Majorana modes). We present examples with both static and dynamic perturbations (noise), and using our formalism derive a rate of information loss, for Majorana memories, that depends on the spectral density of both the noise and the fermionic bath.

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Failure of protection of Majorana based qubits against decoherence

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Qubit realizations based on Majorana bound states have been considered promising candidates for quantum information processing which is inherently inert to decoherence. We put the underlying general arguments leading to this conjecture to the test from an open quantum system perspective. It turns out that, from a fundamental point of view, the Majorana qubit is as susceptible to decoherence as any local paradigm of a qubit.

Phys. Rev. Lett. 107, 217001

Topological Superconductivity in CuxBi2Se3

Satoshi Sasaki, M. Kriener, Kouji Segawa, Keiji Yada, Yukio Tanaka, Masatoshi Sato, and Yoichi Ando

A topological superconductor (TSC) is characterized by the topologically protected gapless surface state that is essentially an Andreev bound state consisting of Majorana fermions. While a TSC has not yet been discovered, the doped topological insulator CuxBi2Se3, which superconducts below ~3??K, has been predicted to possess a topological

superconducting state. We report that the point-contact spectra on the cleaved surface of superconducting CuxBi2Se3 present a zero-bias conductance peak (ZBCP) which signifies unconventional superconductivity. Theoretical considerations of all possible superconducting states help us conclude that this ZBCP is due to Majorana fermions and gives evidence for a topological superconductivity in CuxBi2Se3. In addition, we found an unusual pseudogap that develops below ~20??K and coexists with the topological superconducting state.

arXiv:1111.2662

Scalable one-way quantum computer using on-chip resonator qubits

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We propose a scalable and robust architecture for one-way quantum computation using coupled networks of superconducting transmission line resonators. In our protocol, quantum information is encoded into the long-lived photon states of the resonators, which have a much longer coherence time than the usual superconducting qubits. Each resonator contains a charge qubit used for the state initialization and local projective measurement of the photonic qubit. Any pair of neighboring photonic qubits are coupled via a mediator charge qubit, and large photonic cluster states can be created by applying Stark-shifted Rabi pulses to these mediator qubits. The distinct advantage of our architecture is that it combines both the excellent scalability of the solid-state systems and the long coherence time of the photonic qubits. Furthermore, this architecture is very robust against the parameter variations.

arXiv:1111.2571

Entanglement of distant optomechanical systems

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We theoretically investigate the possibility to generate non-classical states of optical and mechanical modes of optical cavities, distant from each other. A setup comprised of two identical cavities, each with one fixed and one movable mirror and coupled by an optical fiber, is studied in detail. We show that with such a setup there is potential to generate entanglement between the distant cavities, involving both optical and mechanical modes. The scheme is robust with respect to dissipation, and nonlocal correlations are found to exist in the steady state at finite temperatures.

arXiv:1111.2415

Opto- and electro-mechanical entanglement improved by modulation

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One of the main milestones in the study of opto- and electro-mechanical systems is to certify entanglement between a mechanical resonator and an optical or microwave mode of a cavity field. In this work, we show how a suitable time-periodic modulation can help to achieve large degrees of entanglement, building upon the framework introduced in [Phys. Rev. Lett. 103, 213603 (2009)]. It is demonstrated that with suitable driving, the maximum degree of entanglement can be significantly enhanced, in a way exhibiting a non-trivial dependence on the specifics of the modulation. Such time-dependent driving might help experimentally achieving entangled mechanical systems also in situations when quantum correlations are otherwise suppressed by thermal noise.

Phys. Rev. B 84, 184515

Coherent control of a superconducting qubit with dynamically tunable qubit-cavity coupling

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We demonstrate coherent control and measurement of a superconducting qubit coupled to a superconducting coplanar waveguide resonator with a dynamically tunable qubit-cavity coupling strength. Rabi oscillations are measured for several coupling strengths showing that the qubit transition can be turned off by a factor of more than 1500. We show how the qubit can still be accessed in the off state via fast flux pulses. We perform pulse delay measurements with synchronized fast flux pulses on the device and observe T1 and T2 times of 1.6 and 1.9 μs, respectively. This work demonstrates how this qubit can be incorporated into quantum architectures.

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High-fidelity quantum driving

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The ability to accurately control a quantum system is a fundamental requirement in many areas of modern science such as quantum information processing and the coherent manipulation of molecular systems. It is usually necessary to realize these quantum manipulations in the shortest possible time in order to minimize decoherence, and with a large stability against fluctuations of the control parameters. While optimizing a protocol for speed leads to a natural lower bound in the form of the quantum speed limit rooted in the Heisenberg uncertainty principle, stability against parameter variations typically requires adiabatic following of the system. The ultimate goal in quantum control is to prepare a desired state with 100% fidelity. Here we experimentally implement optimal control schemes that achieve nearly perfect fidelity for a two-level quantum system realized with Bose-Einstein condensates in optical lattices. By suitably tailoring the time-dependence of the system's parameters, we transform an initial quantum state into a desired final state through a short-cut protocol reaching the maximum speed compatible with the laws of quantum mechanics. In the opposite limit we implement the recently proposed transitionless superadiabatic protocols, in which the system perfectly follows the instantaneous adiabatic ground state. We demonstrate that superadiabatic protocols are extremely robust against parameter variations, making them useful for practical applications.