Strong coupling of spin qubits to a transmission line resonator

Pei-Qing Jin, Michael Marthaler, Alexander Shnirman, and Gerd Schön

arXiv:1112.0869v1 [cond-mat.mes-hall]

We propose a mechanism for coupling spin qubits formed in double quantum dots to a superconducting transmission line resonator. Coupling the resonator to the gate controlling the interdot tunneling creates a strong spin qubit–resonator interaction with strength of tens of MHz. This mechanism allows operating the system at a point of degeneracy where dephasing is minimized. The transmission line can serve as a shuttle allowing for two-qubit operations, including fast generation of qubit-qubit entanglement and the implementation of a controlled-phase gate.

Non-local quantum superpositions of topological defects

Jacek Dziarmaga, Wojciech H. Zurek, and Michael Zwolak

Nature Physics (2011), doi:10.1038/nphys2156

Topological defects, such as monopoles, vortex lines or domain walls, mark locations where disparate choices of a broken-symmetry vacuum elsewhere in the system lead to irreconcilable differences1, 2. They are energetically costly (the energy density in their core reaches that of the prior symmetric vacuum) but topologically stable (the whole manifold would have to be rearranged to get rid of the defect). Here we show how, in a paradigmatic model of a quantum phase transition, a topological defect can be put in a non-local superposition, so that—in a region large compared with the size of its core—the order parameter of the system is 'undecided' by being in a quantum superposition of conflicting choices of the broken symmetry. We dub such a topological Schrödinger-cat state a 'Schrödinger kink', and devise a version of a double-slit experiment suitable for topological defects to describe one possible manifestation of the phenomenon. Coherence detectable in such experiments will be suppressed as a consequence of interaction with the environment. We analyse the environment-induced decoherence and discuss its role in symmetry breaking.

Observation of High Coherence in Josephson Junction Qubits Measured in a Three-Dimensional Circuit QED Architecture

Hanhee Paik, D. I. Schuster1, Lev S. Bishop, G. Kirchmair, G. Catelani, A. P. Sears, B. R. Johnson, M. J. Reagor, L. Frunzio, L. I. Glazman, S. M. Girvin, M. H. Devoret, and R. J. Schoelkopf

Phys. Rev. Lett. 107, 240501 (2011), doi:10.1103/PhysRevLett.107.240501

Superconducting quantum circuits based on Josephson junctions have made rapid progress in demonstrating quantum behavior and scalability. However, the future prospects ultimately depend upon the intrinsic coherence of Josephson junctions, and whether superconducting qubits can be adequately isolated from their environment. We introduce a new architecture for superconducting quantum circuits employing a three-dimensional resonator that suppresses qubit decoherence while maintaining sufficient coupling to the control signal. With the new architecture, we demonstrate that Josephson junction qubits are highly coherent, with $T_2 \sim 10$ to $20\ \mu s$ without the use of spin echo, and highly stable, showing no evidence for $1/f$ critical current noise. These results suggest that the overall quality of Josephson junctions in these qubits will allow error rates of a few 10^{-4}, approaching the error correction threshold.

Hybrid Quantum Circuit with a Superconducting Qubit Coupled to a Spin Ensemble

Y. Kubo, C. Grezes, A. Dewes, T. Umeda, J. Isoya, H. Sumiya, N. Morishita, H. Abe, S. Onoda, T. Ohshima, V. Jacques, A. Dréau, J.-F. Roch, I. Diniz, A. Auffeves, D. Vion, D. Esteve, and P. Bertet

Phys. Rev. Lett. 107, 220501 (2011), doi:10.1103/PhysRevLett.107.220501

We report the experimental realization of a hybrid quantum circuit combining a superconducting qubit and an ensemble of electronic spins. The qubit, of the transmon type, is coherently coupled to the spin ensemble consisting of nitrogen-vacancy centers in a diamond crystal via a frequency-tunable superconducting resonator acting as a quantum bus. Using this circuit, we prepare a superposition of the qubit states that we store into collective excitations of the spin ensemble and retrieve back into the qubit later on. These results constitute a proof of concept of spin-ensemble based quantum memory for superconducting qubits.

Experimental Unconditional Preparation and Detection of a Continuous Bound Entangled State of Light

J. DiGuglielmo, A. Samblowski, B. Hage1, C. Pineda, J. Eisert, and R. Schnabel

Phys. Rev. Lett. 107, 240503 (2011), doi:10.1103/PhysRevLett.107.240503

Among the possibly most intriguing aspects of quantum entanglement is that it comes in free and bound instances. The existence of bound entangled states certifies an intrinsic irreversibility of entanglement in nature and suggests a connection with thermodynamics. In this Letter, we present a first unconditional, continuous-variable preparation and detection of a bound entangled state of light. We use convex optimization to identify regimes rendering its bound character well certifiable, and continuously produce a distributed bound entangled state with an extraordinary and unprecedented significance of more than 10 standard deviations away from both separability and distillability. Our results show that the approach chosen allows for the efficient and precise preparation of multimode entangled states of light

with various applications in quantum information, quantum state engineering, and high precision metrology.

Quantum entanglement and teleportation in pulsed cavity optomechanics
Sebastian G. Hofer, Witlef Wieczorek, Markus Aspelmeyer, and Klemens Hammerer
Phys. Rev. A 84, 052327 (2011), doi:10.1103/PhysRevA.84.052327
Entangling a mechanical oscillator with an optical mode is an enticing and yet a very challenging goal in cavity optomechanics. Here we consider a pulsed scheme to create Einstein-Podolsky-Rosen-type entanglement between a traveling-wave light pulse and a mechanical oscillator. The entanglement can be verified unambiguously by a pump-probe sequence of pulses. In contrast to schemes that work in a steady-state regime under a continuous-wave drive, this protocol is not subject to stability requirements that normally limit the strength of achievable entanglement. We investigate the protocol's performance under realistic conditions, including mechanical decoherence, in full detail. We discuss the relevance of a high mechanical Qf product for entanglement creation and provide a quantitative statement on which magnitude of the Qf product is necessary for a successful realization of the scheme. We determine the optimal parameter regime for its operation and show it to work in current state-of-the-art systems.

Voltage-driven quantum oscillations of conductance in graphene
V. A. Yampol'skii, S. S. Apostolov, Z. A. Maizelis, A. Levchenko, and F. Nori
EPL 96, 67009 (2011), doi:10.1209/0295-5075/96/67009
Locally-gated single-layer graphene sheets have unusual discrete energy states inside the potential barrier induced by a finite-width gate. These states are localized outside the Dirac cone of continuum states and are responsible for novel quantum transport phenomena. Specifically, the longitudinal (along the barrier) conductance exhibits oscillations as a function of barrier height and/or width, which are both controlled by a nearby gate. The origin of these oscillations can be traced back to singularities in the density of localized states. These graphene conductance-oscillations resemble the Shubnikov-de Haas (SdH) magneto-oscillations, however, here these are driven by an electric field instead of a magnetic field.

Dirac semimetal in three dimensions
S. M. Young, S. Zaheer, J. C. Y. Teo, C. L. Kane, E. J. Mele, and A. M. Rappe
arXiv:1111.6483v1 [cond-mat.mes-hall]
In a Dirac semimetal, the conduction and valence bands contact only at discrete (Dirac) points in the Brillouin zone (BZ) and disperse linearly in all directions around these critical points. Including spin, the low energy effective theory around each critical point is a four band Dirac Hamiltonian. In two dimensions (2D), this situation is realized in graphene without spin-orbit coupling. 3D Dirac points are predicted to exist at the phase transition between a topological and a normal insulator in the presence of inversion symmetry. Here we show that 3D Dirac points can also be protected by crystallographic symmetries in particular space-groups and enumerate the criteria necessary to identify these groups. This reveals the possibility of 3D analogs to graphene. We provide a systematic approach for identifying such materials and present ab initio calculations of metastable β-cristobalite BiO_2 which exhibits Dirac points at the three symmetry related X points of the BZ.

Topological Qubits with Majorana Fermions in Trapped Ions
A. Mezzacapo, J. Casanova, L. Lamata, and E. Solano
arXiv:1111.5603v1 [quant-ph]
We propose a method of encoding a topologically-protected qubit using Majorana fermions in a trapped-ion chain. This qubit is protected against major sources of decoherence, while local operations and measurements can be easily realized. Furthermore, we show that an efficient quantum interface and memory for arbitrary multiqubit photonic states can be built, encoding them into a set of entangled Majorana-fermion (MF) qubits inside cavities.

Search for Majorana fermions in superconductors
C.W.J. Beenakker
arXiv:1112.1950v1 [cond-mat.mes-hall]
This is a colloquium-style introduction to the midgap excitations in superconductors known as Majorana fermions. These elusive particles, equal to their own antiparticle, may or may not exist in Nature as elementary building blocks, but in condensed matter they can be constructed out of electron and hole excitations. What is needed is a superconductor to hide the charge difference, and a topological (Berry) phase to eliminate the energy difference from zero-point motion. A qubit encoded in a pair of widely separated Majorana fermions is expected to have an unusually long coherence time. We discuss strategies to detect Majorana fermions in a topological superconductor, as well as possible applications in a quantum computer. An up-to-date review of ongoing experiments will be added later.