All-electric qubit control in heavy hole quantum dots via non-Abelian geometric phases
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Phys. Rev. B **85**, 205425 (2012)
We demonstrate how non-Abelian geometric phases can be used to universally process a spin qubit in heavy hole quantum dots in the absence of magnetic fields. A time-dependent electric quadrupole field is used to perform any desired single-qubit operation by virtue of non-Abelian holonomy. During the proposed operations, the degeneracy of the time-dependent two-level system representing the qubit is not split. Since time-reversal symmetry is preserved and hyperfine coupling is known to be weak in spin qubits based on heavy holes, we expect very long coherence times in the proposed setup.

All Entangled Quantum States Are Nonlocal
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Phys. Rev. Lett. **108**, 200401 (2012)
Departing from the usual paradigm of local operations and classical communication adopted in entanglement theory, we study here the interconversion of quantum states by means of local operations and shared randomness. A set of necessary and sufficient conditions for the existence of such a transformation between two given quantum states is given in terms of the payoff they yield in a suitable class of nonlocal games. It is shown that, as a consequence of our result, such a class of nonlocal games is able to witness quantum entanglement, however weak, and reveal nonlocality in any entangled quantum state. An example illustrating this fact is provided.

Resolving the time when an electron exits a tunnelling barrier
Dror Shafir et al.
Nature **485**, 343–346 (2012)
The tunnelling of a particle through a barrier is one of the most fundamental and ubiquitous quantum processes. When induced by an intense laser field, electron tunnelling from atoms and molecules initiates a broad range of phenomena such as the generation of attosecond pulses, laser-induced electron diffraction and holography. These processes evolve on the attosecond timescale (1 attosecond = 1 as = 10 – 18 seconds) and are well suited to the investigation of a general issue much debated since the early days of quantum mechanics – the link between the tunnelling of an electron through a barrier and its dynamics outside the barrier. Previous experiments have measured tunnelling rates with attosecond time resolution and tunnelling delay times. Here we study laser-induced tunnelling by using a weak probe field to steer the tunnelled electron in the lateral direction and then monitor the effect on the attosecond light bursts emitted when the liberated electron re-encounters the parent ion. We show that this approach allows us to measure the time at which the electron exits from the tunnelling barrier. We demonstrate the high sensitivity of the measurement by detecting subtle delays in ionization times from two orbitals of a carbon dioxide molecule. Measurement of the tunnelling process is essential for all attosecond experiments where strong-field ionization initiates ultrafast dynamics. Our approach provides a general tool for time-resolving multi-electron rearrangements in atoms and molecules – one of the key challenges in ultrafast science.

Spin-Orbit-Induced Strong Coupling of a Single Spin to a Nanomechanical Resonator
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Phys. Rev. Lett. **108**, 206811 (2012)
We theoretically investigate the deflection-induced coupling of an electron spin to vibrational motion due to spin-orbit coupling in suspended carbon nanotube quantum dots. Our estimates indicate that, with current capabilities, a quantum dot with an odd number of electrons can serve as a realization of the Jaynes-Cummings model of quantum electrodynamics in the strong-coupling regime. A quantized flexural mode of the suspended tube plays the role of the optical mode and we identify two distinct two-level subspaces, at small and large magnetic field, which can be used as qubits in this setup. The strong intrinsic spin-mechanical coupling allows for detection, as well as manipulation of the spin qubit, and may yield enhanced performance of nanotubes in sensing applications.

Quasideterministic realization of a universal quantum gate in a single scattering process
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Phys. Rev. A **85**, 050305(R) (2012)
We show that a flying particle, such as an electron or a photon, scattering along a one-dimensional waveguide from a pair of static spin-1/2 centers, such as quantum dots, can implement a controlled-z gate (universal for quantum computation) between them. This occurs quasideterministically in a single scattering event, with no need for any postselection or iteration and without demanding the flying particle to bear any internal spin. We show that an easily matched hard-wall boundary condition along with the elastic nature of the process are key to such performances.

Optimal error correction in topological subsystem codes
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Phys. Rev. A **85**, 050302(R) (2012)
A promising approach to overcome decoherence in quantum computing schemes is to perform active quantum error correction using topology. Topological subsystem codes incorporate both the benefits of topological and subsystem codes, allowing for error syndrome recovery with only 2-local measurements in a two-dimensional array of qubits. We study the error threshold for topological subsystem color codes under very general external noise conditions. By transforming the problem into a classical disordered spin model, we estimate using Monte Carlo simulations that topological subsystem codes have an optimal error tolerance of 5.5(2)%. This means there is ample space for improvement in existing error-correcting algorithms that typically find a threshold of approximately 2%.

Blind Quantum Computing with Weak Coherent Pulses
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Phys. Rev. Lett. **108**, 200502 (2012)
The universal blind quantum computation (UBQC) protocol [A. Broadbent, J. Fitzsimons, and E. Kashefi, in Proceedings of the 50th Annual IEEE Symposiumon Foundations of Computer Science (IEEE Computer Society, Los Alamitos, CA, USA, 2009), pp. 517–526.] allows a client to perform quantum computation on a remote server. In an ideal setting, perfect privacy is guaranteed if the client is capable of producing specific, randomly chosen single qubit states. While from a theoretical point of view, this may constitute the lowest possible quantum requirement, from a pragmatic point of view, generation of such states to be sent along long distances can never be achieved perfectly. We introduce the concept of epsilon blindness for UBQC, in analogy to the concept of epsilon security developed for other cryptographic protocols, allowing us to characterize the robustness and security properties of the protocol under possible imperfections. We also present a remote blind single qubit preparation protocol with weak coherent pulses for the client to prepare, in a delegated fashion, quantum states arbitrarily close to perfect random single qubit states. This allows us to efficiently achieve epsilon-blind UBQC for any epsilon, even if the channel between the client and the server is arbitrarily lossy.

The Josephson heat interferometer
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The Josephson effect represents perhaps the prototype of macroscopic phase coherence and is at the basis of the most widespread interferometer, i.e., the superconducting quantum interference device (SQUID). Yet, in analogy to electric interference, Maki and Griffin predicted in 1965 that thermal current flowing through a temperature-biased Josephson tunnel junction is a stationary periodic function of the quantum phase difference between the superconductors. The interplay between quasiparticles and Cooper pairs condensate is at the origin of such phase-dependent heat current, and is unique to Josephson junctions. In this scenario, a temperature-biased SQUID would allow heat currents to interfere thus implementing the thermal version of the electric Josephson interferometer. The dissipative character of heat flux makes this coherent phenomenon not less extraordinary than its electric (non-dissipative) counterpart. Albeit weird, this striking effect has never been demonstrated so far. Here we report the first experimental realization of a heat interferometer. We investigate heat exchange between two normal metal electrodes kept at different temperatures and tunnel-coupled to each other through a thermal 'modulator' in the form of a DC-SQUID. Heat transport in the system is found to be phase dependent, in agreement with the original prediction. With our design the Josephson heat interferometer yields magnetic-flux-dependent temperature oscillations of amplitude up to $\sim$ 21 mK, and provides a flux-to-temperature transfer coefficient exceeding $\sim$60mK/Phi_0 at 235 mK. Besides offering remarkable insight into thermal transport in Josephson junctions, our results represent a significant step toward phase-coherent mastering of heat in solid-state nanocircuits, and pave the way to the design of novel-concept coherent caloritronic devices.

Propagation front of correlations in an interacting Bose gas
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Phys. Rev. A **85**, 053625 (2012)
We analyze the quench dynamics of a one-dimensional bosonic Mott insulator and focus on the time evolution of density correlations. For these we identify a pronounced propagation front, the velocity of which, once correctly extrapolated at large distances, can serve as a quantitative characteristic of the many-body Hamiltonian. In particular, the velocity allows the weakly interacting regime, which is qualitatively well described by free bosons, to be distinguished from the strongly interacting one, in which pairs of distinct quasiparticles dominate the dynamics. In order to describe the latter case analytically, we introduce a general approximation to solve the Bose-Hubbard Hamiltonian based on the Jordan-Wigner fermionization of auxiliary particles. This approach can also be used to determine the ground-state properties. As a complement to the fermionization approach, we derive explicitly the time-dependent many-body state in the noninteracting limit and compare our results to numerical simulations in the whole range of interactions of the Bose-Hubbard model.