arXiv:1204.1238: **Majorana Bound States of Light in a One-Dimensional Array of Nonlinear Cavities**
C.-E. Bardyn and A. Imamoglu
The search for Majorana fermions in p-wave paired fermionic systems has recently moved to the forefront of condensed-matter research. Here we propose an alternative route and show theoretically that Majorana modes can be realized and probed in a driven-dissipative system of strongly correlated photons consisting of a chain of tunnel-coupled cavities, where p-wave pairing effectively arises from the interplay between strong on-site interactions and two-photon parametric driving. Cross-correlation measurements carried out at the ends of the chain would reveal a strong photon bunching signature, demonstrating the nonlocal nature of these photonic Majorana modes.

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arXiv:1204.0587: ***Black-box superconducting circuit quantization***
Simon E. Nigg, Hanhee Paik, Brian Vlastakis, Gerhard Kirchmair, Shyam Shankar, Luigi Frunzio, Michel Devoret, Robert Schoelkopf and Steven Girvin
We present a semi-classical method for determining the effective low-energy quantum Hamiltonian of weakly anharmonic superconducting circuits containing mesoscopic Josephson junctions coupled to electromagnetic environments made of an arbitrary combination of distributed and lumped elements. A convenient basis, capturing the multi-mode physics, is given by the quantized eigenmodes of the linearized circuit and is fully determined by a classical linear response function. The method is used to calculate numerically the low-energy spectrum of a 3D-transmon system, and quantitative agreement with measurements is found.

Nature Physics 8, 325: ***Probing the relaxation towards equilibrium in an isolated strongly correlated one-dimensional Bose gas***
S. Trotzky, Y-A. Chen, A. Flesch, I. P. McCulloch, U. Schollwöck, J. Eisert and I. Bloch
The problem of how complex quantum systems eventually come to rest lies at the heart of statistical mechanics. The maximum-entropy principle describes which quantum states can be expected in equilibrium, but not how closed quantum many-body systems dynamically equilibrate. Here, we report the experimental observation of the non-equilibrium dynamics of a density wave of ultracold bosonic atoms in an optical lattice in the regime of strong correlations. Using an optical superlattice, we follow its dynamics in terms of quasi-local densities, currents and coherences - all showing a fast relaxation towards equilibrium values. Numerical calculations based on matrix-product states are in an excellent quantitative agreement with the experimental data. The system fulfills the promise of being a dynamical quantum simulator, in that the controlled dynamics runs for longer times than present classical algorithms can keep track of.

arXiv:1204.0911: ***Nonlinear Damping in Graphene Resonators***
Alexander Croy, Daniel Midtvedt, Andreas Isacsson, and Jari M. Kinaret
Based on a continuum mechanical model for single-layer graphene we propose and analyze a microscopic mechanism for dissipation in nanoelectromechanical graphene resonators. We find that coupling between flexural modes and in-plane phonons leads to linear and nonlinear damping of out-of-plane vibrations. By tuning external parameters such as bias voltage, one can cross over from a linear to a nonlinear-damping dominated regime. We discuss the behavior of the effective quality factor, and compare our results with recent experiments.

Nature 484, 78: **A steady-state superradiant laser with less than one intracavity photon**
Justin G. Bohnet, Zilong Chen, Joshua M. Weiner, Dominic Meiser, Murray J. Holland and James K. Thompson
The spectral purity of an oscillator is central to many applications, such as detecting gravity waves, defining the second, ground-state cooling and quantum manipulation of nanomechanical objects, and quantum computa-tion. Recent proposals suggest that laser oscillators which use very narrow optical transitions in atoms can be orders of magnitude more spectrally pure than present lasers. Lasers of this high spectral purity are predicted to operate deep in the 'bad-cavity', or superradiant, regime, where the bare atomic linewidth is much less than the cavity linewidth. Here we demonstrate a Raman superradiant laser source in which spontaneous synchroni-zation of more than one million rubidium-87 atomic dipoles is continuously sustained by less than 0.2 photons on average inside the optical cavity. By operating at low intracavity photon number, we demonstrate isolation of the collective atomic dipole from the environment by a factor of more than ten thousand, as characterized by cavity frequency pulling measurements. The emitted light has a frequency linewidth, measured relative to the Raman dressing laser, that is less than that of single-particle decoherence linewidths and more than ten thou-sand times less than the quantum linewidth limit typically applied to 'good-cavity' optical lasers, for which the cavity linewidth is much less than the atomic linewidth. These results demonstrate several key predictions for future superradiant lasers, which could be used to improve the stability of passive atomic clocks and which may lead to new searches for physics beyond the standard model.

Nature Physics Insight – Quantum Simulation: **Goals and opportunities in quantum simulation**
J. Ignacio Cirac and Peter Zoller
The long-term promises of quantum simulators are far-reaching. The field, however, also needs clearly defined short-term goals.

Science 336, 52: **The Coexistence of Superconductivity and Topological Order in the Bi2Se3 Thin Films**
Mei-Xiao Wang, Canhua Liu, Jin-Peng Xu, Fang Yang, Lin Miao, Meng-Yu Yao, C. L. Gao, Chenyi Shen, Xucun Ma, X. Chen, Zhu-An Xu, Ying Liu, Shou-Cheng Zhang, Dong Qian, Jin-Feng Jia, and Qi-Kun Xue
Three-dimensional topological insulators (TIs) are characterized by their nontrivial surface states, in which electrons have their spin locked at a right angle to their momentum under the protection of time-reversal symmetry. The topologically ordered phase in TIs does not break any symmetry. The interplay between topological order and symmetry breaking, such as that observed in superconductivity, can lead to new quantum phenomena and devices. We fabricated a superconducting TI/superconductor heterostructure by growing dibismuth triselenide (Bi_2Se_3) thin films on superconductor niobium diselenide substrate. Using scanning tunneling microscopy and angle-resolved photoemission spectroscopy, we observed the superconducting gap at the Bi_2Se_3 surface in the regime of Bi_2Se_3 film thickness where topological surface states form. This observation lays the groundwork for experimentally realizing Majorana fermions in condensed matter physics.

Nature 484, 82: **Decoherence-protected quantum gates for a hybrid solid-state spin register**
T. van der Sar, Z. H. Wang, M. S. Blok, H. Bernien, T. H. Taminiau, D. M. Toyli, D. A. Lidar, D. D. Awschalom, R. Hanson and V. V. Dobrovitski
Protecting the dynamics of coupled quantum systems from decoherence by the environment is a key challenge for solid-state quantum information processing. An idle quantum bit (qubit) can be efficiently insulated from the outside world by dynamical decoupling, as has recently been demonstrated for individual solid-state qubit. However, protecting qubit coherence during a multi-qubit gate is a non-trivial problem: in general, the decoupling disrupts the interqubit dynamics and hence conflicts with gate operation. This problem is particularly salient for hybrid systems, in which different types of qubit evolve and decohere at very different rates. Here we present the integration of dynamical decoupling into quantum gates for a standard hybrid system, the electron–nuclear spin register. Our design harnesses the internal resonance in the coupled-spin system to resolve the conflict between gate operation and decoupling. We experimentally demonstrate these gates using a two-qubit register in diamond operating at room temperature. Quantum tomography reveals that the qubits involved in the gate operation are protected as accurately as idle qubits. We also perform Grover's quantum search algorithm, and achieve fidelities of more than 90% even though the algorithm run-time exceeds the electron spin dephasing time by two orders of magnitude. Our results directly allow decoherence-protected interface gates between different types of solid-state qubit. Ultimately, quantum gates with integrated decoupling may reach the accuracy threshold for fault-tolerant quantum information processing with solid-state devices.

Phys. Rev. Lett. 108, 133601: **Optical Detection of the Quantization of Collective Atomic Motion**
Nathan Brahms, Thierry Botter, Sydney Schreppler, Daniel W. C. Brooks, and Dan M. Stamper-Kurn
We directly measure the quantized collective motion of a gas of thousands of ultracold atoms, coupled to light in a high-finesse optical cavity. We detect strong asymmetries, as high as 3:1, in the intensity of light scattered into low- and high-energy motional sidebands. Owing to high cavity-atom cooperativity, the optical output of the cavity contains a spectroscopic record of the energy exchanged between light and motion, directly quantifying the heat deposited by a quantum position measurement's backaction. Such backaction selectively causes the phonon occupation of the observed collective modes to increase with the measurement rate. These results, in addition to providing a method for calibrating the motion of low-occupation mechanical systems, offer new possibilities for investigating collective modes of degenerate gases and for diagnosing optomechanical measurement backaction.

Phys. Rev. Lett. 108, 130504: **Quantum Interface between an Electrical Circuit and a Single Atom**
D. Kielpinski, D. Kafri, M. J. Woolley, G. J. Milburn, and J. M. Taylor
We show how to bridge the divide between atomic systems and electronic devices by engineering a coupling between the motion of a single ion and the quantized electric field of a resonant circuit. Our method can be used to couple the internal state of an ion to the quantized circuit with the same speed as the internal-state coupling between two ions. All the well-known quantum information protocols linking ion internal and motional states can be converted to protocols between circuit photons and ion internal states. Our results enable quantum interfaces between solid state qubits, atomic qubits, and light, and lay the groundwork for a direct quantum connection between electrical and atomic metrology standards.