Journal Club, 20 August 2013

- ◦ arXiv:1308.3079
  Steady-State Entanglement in the Nuclear Spin Dynamics of a Double Quantum Dot
  Martin J. A. Schuetz, Eric M. Kessler, Lieven M. K. Vandersypen, J. Ignacio Cirac, and Geza Giedke

  We propose a scheme for the deterministic generation of steady-state entanglement between the two nuclear spin ensembles in an electrically defined double quantum dot. Due to quantum interference in the collective coupling to the electronic degrees of freedom, the nuclear system is actively driven into a two-mode squeezed-like target state. The entanglement build-up is accompanied by a self-polarization of the nuclear spins towards large Overhauser field gradients. Moreover, the feedback between the electronic and nuclear dynamics leads to multi-stability and criticality in the steady-state solutions.

- Phys. Rev. Lett. 111, 076802 (2013)
  Fractional Quantum Hall Phase Transitions and Four-Flux States in Graphene
  Benjamin E. Feldman, Andrei J. Levin, Benjamin Krauss, Dmitry A. Abanin, Bertrand I. Halperin, Jurgen H. Smet, and Amir Yacoby

  Graphene and its multilayers have attracted considerable interest because their fourfold spin and valley degeneracy enables a rich variety of broken-symmetry states arising from electron-electron interactions, and raises the prospect of controlled phase transitions among them. Here we report local electronic compressibility measurements of ultraclean suspended graphene that reveal a multitude of fractional quantum Hall states surrounding filling factors $\nu = -1/2$ and $-1/4$. Several of these states exhibit phase transitions that indicate abrupt changes in the underlying order, and we observe many additional oscillations in compressibility as ν approaches $-1/2$, suggesting further changes in spin and/or valley polarization. We use a simple model based on crossing Landau levels of composite fermions with different internal degrees of freedom to explain many qualitative features of the experimental data. Our results add to the diverse array of many-body states observed in graphene and demonstrate substantial control over their order parameters.

- Phys. Rev. Lett. 111, 073603 (2013)
  Quantum Many-Body Dynamics in Optomechanical Arrays
  Max Ludwig and Florian Marquardt

  We study the nonlinear driven dissipative quantum dynamics of an array of optomechanical systems. At each site of such an array, a localized mechanical mode interacts with a laser-driven cavity mode via radiation pressure, and both photons and phonons can hop between neighboring sites. The competition between coherent interaction and dissipation gives rise to a rich phase diagram characterizing the optical and mechanical many-body states. For weak intercellular coupling, the mechanical motion at different sites is incoherent due to the influence of quantum noise. When increasing the coupling strength, however, we observe a transition towards a regime of phase-coherent mechanical oscillations. We employ a Gutzwiller ansatz as well as semiclassical Langevin equations on finite lattices, and we propose a realistic experimental implementation in optomechanical crystals.

- Phys. Rev. Lett. 111, 073001 (2013)
  Addressing Two-Level Systems Variably Coupled to an Oscillating Field
  Nir Navon, Shlomi Kotler, Nitzan Akerman, Yinnon Glickman, Ido Almog, and Roee Ozeri

  We propose a simple method to spectrally resolve an array of identical two-level systems coupled to an inhomogeneous oscillating field. The addressing protocol uses a dressing field with a spatially dependent coupling to the atoms. We validate this scheme experimentally by realizing single-spin addressing of a linear chain of trapped ions that are separated by $\sim 3\,\mu$m, dressed by a laser field that is resonant with the micromotion sideband of a narrow optical transition.

- Phys. Rev. B 88, 075306 (2013)
  Spin-flip phonon-mediated charge relaxation in double quantum dots
  J. Danon

  We theoretically study the (1,1) triplet to (0,2) singlet relaxation rate in a lateral gate-defined double quantum dot tuned to the regime of Pauli spin blockade. We present a detailed derivation of the effective phonon density of states for this specific charge transition, keeping track of the contribution from piezoelectric as well as deformation potential electron-phonon coupling. We further investigate two different spin-mixing mechanisms which can couple the triplet and singlet states: a magnetic field gradient over the double dot (relevant at low external magnetic field) and spin-orbit interaction (relevant at high field), and we also indicate how the two processes could interfere at intermediate magnetic field. Finally, we show how to combine all results and evaluate the relaxation rate for realistic system parameters.

- Phys. Rev. B 88, 075301 (2013)
  Spin qubit relaxation in a moving quantum dot
  Peihao Huang and Xuedong Hu

  Long-range quantum communication for spin qubits is an important open problem. Here we study decoherence of an electron spin qubit that is being transported in a moving quantum dot. We focus on spin decoherence due to spin-orbit interaction and a random electric potential. We find that at the lowest order, the motion induces longitudinal spin relaxation, with a rate linear in the dot velocity. Our calculated spin relaxation time ranges from sub μs in GaAs to above ms in Si, making this relaxation a significant decoherence channel. Our results also give clear indications on how to reduce the decoherence effect of electron motion.

- Phys. Rev. B 88, 075126 (2013)
  Coupling, merging, and splitting Dirac points by electron-electron interaction
  Balázs Dóra, Igor F. Herbut, and R. Moessner

  The manipulation and movement of Dirac points in the Brillouin zone by the electron-electron interaction is considered within leading order perturbation theory. At the merging point, an infinitesimal interaction is shown to cause opening of the gap or splitting of the Dirac points, depending on the inter- or intrasublattice nature of the merging and the sign of the interaction. The topology of the spectrum can therefore be efficiently changed by simply tuning the interaction between particles, as opposed to the usual careful band structure engineering. This is illustrated around the merging transition of one, two, and three dimensional Dirac-Weyl fermions. A simple Weyl-like Hamiltonian that describes the quadratic band crossing in three dimensions is also proposed, and its stability under interactions is addressed.

- arXiv:1308.3102
  Dynamical decoupling noise spectroscopy at an optimal working point of a qubit
  Łukasz Cywiński

  I present a theory of environmental noise spectroscopy via dynamical decoupling of a qubit at an optimal working point. Considering a sequence of n pulses and pure dephasing due to coupling to a square of Gaussian noise, I use the linked-cluster expansion to calculate the coherence decay. Solutions allowing for reconstruction of $S(\omega)$ or the second spectral density are given. For $1/f$ noise, coherence at time t depends both on $S(n\pi/t)$, and on the effective infrared cutoff of the noise spectrum, which is given by the inverse of the data acquisition time.

- arXiv:1308.3596
  Spin Selection Rule-Based Sub-Millisecond Hyperpolarization of Nuclear Spins in Silicon
  Felix Hoehne, Lukas Dreher, David P. Franke, Martin Stutzmann, Leonid S. Vlasenko, Kohei M. Itoh, and Martin S. Brandt

  In this work, we devise a fast and effective nuclear spin hyperpolarization scheme, which is in principle magnetic field and temperature independent. We use this scheme to experimentally demonstrate polarizations of up to 66% for phosphorus donor nuclear spins in bulk silicon, which are created within less than 100 μs in a magnetic field of 0.35 T at a temperature of 5 K. The polarization scheme is based on a spin-dependent recombination process via weakly-coupled spin pairs, for which the recombination time constant strongly depends on the relative orientation of the two spins. We further use this scheme to measure the nuclear spin relaxation time and find a value of approx. 100 ms under illumination, in good agreement with the value calculated for nuclear spin flips induced by repeated ionization and deionization processes.