Journal Club, 10 Februar 2014

- ◦ arXiv:1402.1351
  Pump-probe scheme for electron-photon dynamics in hybrid conductor-cavity systems
  T. L. van den Berg, C. Bergenfeldt, and P. Samuelsson

  Recent experiments on nanoscale conductors coupled to microwave cavities put in prospect transport investigations of electron-photon interplay in the deep quantum regime. Here we propose a pump-probe scheme to investigate the transient dynamics of individual electron-photon excitations in a double quantum dot-cavity system. Excitations pumped into the system decay via charge tunneling at the double dot, probed in real time. We investigate theoretically the short-time charge transfer statistics at the dot, for periodic pumping, and show that this gives access to vacuum Rabi oscillations as well as excitation dynamics in the presence of double dot dephasing and relaxation.

- Phys. Rev. Lett. **112**, 066801
  Possible Evidence for Helical Nuclear Spin Order in GaAs Quantum Wires
  C. P. Scheller, T.-M. Liu, G. Barak, A. Yacoby, L. N. Pfeiffer, K. W. West, and D. M. Zumbühl

  We present transport measurements of cleaved edge overgrowth GaAs quantum wires. The conductance of the first mode reaches $2e2/h$ at high temperatures $T \geq 10$¿¿K, as expected. As T is lowered, the conductance is gradually reduced to $1e2/h$, becoming T independent at $T \leq 0.1$¿K, while the device cools far below 0.1¿K. This behavior is seen in several wires, is independent of density, and not altered by moderate magnetic fields B. The conductance reduction by a factor of 2 suggests lifting of the electron spin degeneracy in the absence of B. Our results are consistent with theoretical predictions for helical nuclear magnetism in the Luttinger liquid regime.

- Phys. Rev. Lett. 112, 056601
  Current-Induced Spin Polarization in Anisotropic Spin-Orbit Fields
  B. M. Norman, C. J. Trowbridge, D. D. Awschalom, and V. Sih

  The magnitude and direction of current-induced spin polarization and spin-orbit splitting are measured in In0.04Ga0.96 As epilayers as a function of in-plane electric and magnetic fields. We show that, contrary to expectation, the magnitude of the current-induced spin polarization is smaller for crystal directions corresponding to larger spin-orbit fields. Furthermore, we find that the steady-state in-plane spin polarization does not align along the spin-orbit field, an effect due to anisotropy in the spin relaxation rate.

- Phys. Rev. B 89, 075106
  Signatures of Majorana fermions in topological insulator Josephson junction devices
  Benjamin J. Wieder, Fan Zhang, and C. L. Kane

  We study theoretically the electrical current and low-frequency noise for a linear Josephson junction structure on a topological insulator, in which the superconductor forms a closed ring and currents are injected from normal regions inside and outside the ring. We find that this geometry offers a signature for the presence of gapless one-dimensional Majorana fermion modes that are predicted in the channel when the phase difference φ, controlled by the magnetic flux through the ring, is π. We show that for low temperature the linear conductance jumps when φ passes through π, accompanied by nonlocal correlations between the currents from the inside and outside of the ring. We compute the dependence of these features on temperature, voltage, and linear dimensions, and discuss the implications for experiments.

- arXiv:1402.1195
  Hybrid optomechanics for Quantum Technologies
  Benjamin Rogers, Nicola Lo Gullo, Gabriele De Chiara, G. Massimo Palma, and Mauro Paternostro

  We review the physics of some hybrid optomechanical systems consisting of a mechanical oscillator interacting with both a radiation mode and an additional matter-like system. We concentrate on the cases embodied by either a single or a multi-atom system (a Bose-Einstein condensate, in particular) and discuss a wide range of physical effects, from passive mechanical cooling to the set-up of multipartite entanglement, from optomechanical non-locality to the achievement of non-classical states of a single mechanical mode. The reviewed material showcases the viability of hybridised cavity optomechanical systems as basic building blocks for quantum communication networks and quantum state-engineering devices, possibly empowered by the use of quantum and optimal control techniques. The results that we discuss are instrumental to the promotion of hybrid optomechanical devices as promising experimental platforms for the study of non-classicality at the genuine mesoscopic level.

- arXiv:1402.1388

  Recent progress in quantum simulation using superconducting circuits

  G. S. Paraoanu

  Quantum systems are notoriously difficult to simulate with classical means. Recently the idea of using another quantum system, which is experimentally more controllable, as a simulator for the original problem, has gained a significant momentum. Amongst the experimental platforms studied as quantum simulators, superconducting qubits are one of the most promising, due to relative straigthforward scalability, easy design, and integration with standard electronics. Here I review the recent state-of-the art in the field and the prospects for simulating systems ranging from relativistic quantum fields to quantum many-body systems.

- arXiv:1402.1316

  Hole transport and valence band dispersion law in a HgTe quantum well with normal energy spectrum

  G. M. Minkov, A. V. Germanenko, O. E. Rut, A. A. Sherstobitov, S. A. Dvoretski, and N. N. Mikhailov

  The results of an experimental study of the energy spectrum of the valence band in a HgTe quantum well of width $d < 6.3$ nm with normal spectrum in the presence of a strong spin-orbit splitting are reported. The analysis of the temperature, magnetic field and gate voltage dependences of the Shubnikov-de Haas oscillations allows us to restore the energy spectrum of the two valence band branches, which are split by the spin-orbit interaction. The comparison with the theoretical calculation shows that a six-band kP theory well describes all the experimental data in the vicinity of the top of the valence band.

- arXiv:1402.1277

  Conservation laws protect dynamic correlations from decay: General approach and the central spin model

  Goetz S. Uhrig, Johannes Hackmann, Daniel Stanek, Joachim Stolze, and Frithjof B. Anders

  A general approach is presented to prove that certain quantum correlations do not completely decay in time. It is used to show rigorously that a fraction of the initial spin correlations persists indefinitely in the isotropic central spin model unless the average coupling vanishes. The central spin model describes a major mechanism of decoherence in a large class of potential realizations of quantum bits. Thus the derived results contribute significantly to the understanding of the preservation of coherence. We will argue that persisting quantum correlations are not linked to the integrability of the model, but aused by a finite operator overlap with a finite set of constants of motion.