Journal Club, 16. April 2013, Robert Zielke

[1] **Sequential quantum-enhanced measurement with an atomic ensemble**

A. V. Lebedev, P. Treutlein, and G. Blatter. *arXiv:1304.2025*, April 2013.

We propose a quantum-enhanced iterative (with K steps) measurement scheme based on an ensemble of N two-level probes which asymptotically approaches the Heisenberg limit $\delta_K \propto R^{-K/(K+1)}$, R the number of quantum resources. The protocol is inspired by Kitaev's phase estimation algorithm and involves only collective manipulation and measurement of the ensemble. The iterative procedure takes the shot-noise limited primary measurement with precision $\delta_1\propto N^{-1/2}$ to increasingly precise results $\delta_K\propto N^{-K/2}$. A straightforward implementation of the algorithm makes use of a two-component atomic cloud of Bosons in the precision measurement of a magnetic field.

[2] **Charge Relaxation in a Single Electron Si/SiGe Double Quantum Dot**

K. Wang, C. Payette, Y. Dovzhenko, P. W. Deelman, and J. R. Petta. *arXiv:1304.2640*, April 2013.

We measure the interdot charge relaxation time T_1 of a single electron trapped in an accumulation mode Si/SiGe double quantum dot. The energy level structure of the charge qubit is determined using photon assisted tunneling, which reveals the presence of a low lying excited state. We systematically measure T_1 as a function of detuning and interdot tunnel coupling and show that it is tunable over four orders of magnitude, with a maximum of 45 microseconds for our device configuration. Measured relaxation times are consistent with a phonon mediated energy relaxation process and indicate that low lying excited states may have important implications in the development of silicon spin qubits.

[3] **Large spin-orbit coupling in carbon nanotubes**

G. A. Steele, F. Pei, E. A. Laird, J. M. Jol, H. B. Meerwaldt, and L. P. Kouwenhoven. *arXiv:1304.3234*, April 2013. Nature Communications 4, Article number: 1573, doi:10.1038/ncomms2584 (2013).

It has recently been recognized that the strong spin-orbit interaction present in solids can lead to new phenomena, such as materials with non-trivial topological order. Although the atomic spin-orbit coupling in carbon is weak, the spin-orbit coupling in carbon nanotubes can be significant due to their curved surface. Previous works have reported spin-orbit couplings in reasonable agreement with theory, and this coupling strength has formed the basis of a large number of theoretical proposals. Here we report a spin-orbit coupling in three carbon nanotube devices that is an order of magnitude larger than measured before. We find a zero-field spin splitting of up to 3.4 meV, corresponding to a built-in effective magnetic field of 29 T aligned along the nanotube axis. While the origin of the large spin-orbit coupling is not explained by existing theories, its strength is promising for applications of the spin-orbit interaction in carbon nanotubes devices.

[4] **Computational discovery of single-layer III-V materials**

Houlong L. Zhuang, Arunima K. Singh, and Richard G. Hennig. *Physical Review B*, 87(16):165415, April 2013.

Single-layer materials open up tremendous opportunities for nanoelectronic devices. Using a first-principles design approach we identify a previously unrecognized family of single-layer III-V materials. We determine their energetic and dynamical stability, identify a surprising reconstruction, and calculate their electronic properties using a hybrid density functional and the G0W0 method. Finally, we find that metal substrates stabilize these as-yet hypothetical materials. Our results provide guidance for experimental synthesis efforts and future searches of single-layer materials suitable for device applications.

[5] **The Resonant Exchange Qubit**

J. Medford, J. Beil, J. M. Taylor, E. I. Rashba, H. Lu, A. C. Gossard, and C. M. Marcus. *arXiv:1304.3413*, April 2013.

We introduce a solid-state qubit in which exchange interactions among confined electrons provide both the static longitudinal field and the oscillatory transverse field, allowing rapid and full qubit control via rf gate-voltage pulses. We demonstrate two-axis control at a detuning sweet-spot, where leakage due to hyperfine coupling is suppressed by the large exchange gap. A {\pi}/2-gate time of 2.5 ns and a coherence time of 19 {\mu}s, using multi-pulse echo, are also demonstrated. Model calculations that include effects of hyperfine noise are in excellent quantitative agreement with experiment.

[6] **New Dirac points and multiple Landau level crossings in biased trilayer graphene**

Maksym Serbyn and Dmitry A. Abanin. *Physical Review B*, 87(11):115422, March 2013.

Recently a new high-mobility Dirac material, trilayer graphene, was realized experimentally. The band structure of ABA-stacked trilayer graphene consists of a monolayer-like and a bilayer-like pair of bands. Here we study electronic properties of ABA-stacked trilayer graphene biased by a perpendicular electric field. We find that the combination of the bias and trigonal warping gives rise to a set of new Dirac points: In each valley, seven species of Dirac fermions with small masses of order of a few meV emerge. The positions and masses of the emergent Dirac fermions are tunable by bias, and one group of Dirac fermions becomes massless at a certain bias value. Therefore, in contrast to bilayer graphene, the conductivity at the neutrality point is expected to show nonmonotonic behavior, becoming of the order of a few e2/h when some Dirac masses vanish. Further, we analyze the evolution of the Landau level spectrum as a function of bias. The emergence of new Dirac points in the band structure translates into new threefold-degenerate groups of Landau levels. This leads to an anomalous quantum Hall effect, in which some quantum Hall steps have a height of 3e2/h. At an intermediate bias, the degeneracies of all Landau levels get lifted, and in this regime all quantum Hall plateaus are spaced by e2/h. Finally, we show that the pattern of Landau level crossings is very sensitive to certain band structure parameters, and can therefore provide a useful tool for determining their precise values.

[7] **Printed Circuit Board Metal Powder Filters for Low Electron Temperatures**

Filipp Mueller, Raymond N. Schouten, Matthias Brauns, Tian Gang, Wee Han Lim, Nai Shyan Lai, Andrew S. Dzurak, Wilfred G. van der Wiel, and Floris A. Zwanenburg. *arXiv:1304.3306*, April 2013.

We report the characterisation of printed circuit boards (PCB) metal powder filters and their influence on the effective electron temperature which is as low as 22 mK for a quantum dot in a silicon MOSFET structure in a dilution refrigerator. We investigate the attenuation behaviour (10 MHz- 20 GHz) of filter made of four metal powders with a grain size below 50 um. The room-temperature attenuation of a stainless steel powder filter is more than 80 dB at frequencies above 1.5 GHz. In all metal powder filters the attenuation increases with temperature. Compared to classical powder filters, the design presented here is much less laborious to fabricate and specifically the copper powder PCB-filters deliver an equal or even better performance than their classical counterparts.

[8] **Proposal for the detection and braiding of Majorana fermions in a quantum spin Hall insulator**

Shuo Mi, D. I. Pikulin, M. Wimmer, and C. W. J. Beenakker. *arXiv:1304.1685*, April 2013.

We show how a quantum dot with a ballistic single-channel point contact to a superconductor can be created by means of a gate electrode at the edge of a quantum spin Hall insulator (such as an InAs/GaSb quantum well). A weak perpendicular magnetic field traps a Majorana zero-mode, so that it can be observed in the gate-voltage-averaged differential conductance <dI/dV> as a 4eˆ2/h zero-bias peak above a (2/3{\pi}ˆ2 - 4)eˆ2/h background. The one-dimensional edge does not permit the braiding of pairs of Majorana fermions, but this obstacle can be overcome by coupling opposite edges at a constriction, allowing for a demonstration of non-Abelian statistics.

[9] **Quantum limit of laser cooling in dispersively- and dissipatively-coupled optomechanical systems**

Talitha Weiss and Andreas Nunnenkamp. *arXiv:1304.2685*, April 2013.

Mechanical oscillators can be cooled by coupling them to an optical or microwave cavity. Going beyond the standard quantum noise approach we find an analytic expression for the steady-state phonon number in systems where the position of the mechanical oscillator modulates the cavity frequency as well as the cavity line width. We trace the origin for the quantum limit of cooling to fluctuations in the optical force both at and away from the mechanical frequency. Finally, we calculate the minimal phonon number for the different types of coupling. Our study elucidates how to beneficially combine dispersive and dissipative optomechanical coupling.

[10] **Non-universal conductance in quasi-helical quantum wires**

Tobias Meng and Daniel Loss. *arXiv:1304.2782*, April 2013.

In a quantum wire with ideal helical modes, the conductance is quantized in units of eˆ2/h, provided the wire is connected to Fermi liquid leads. We show that this universality does not hold in partially gapped quasi-helical systems such as Rashba nanowires subject to a magnetic field, which are commonly used to mimic helical Luttinger liquids. Instead, their conductance takes a non-universal value that depends on the interactions in the wire, even in the presence of Fermi liquid leads. The non-universal conductance is rooted in a non-trivial mixing of spin and charge degrees of freedom, which in turn defines a non-helical low-energy Hamiltonian.