# Condensed Matter Journal Club, 30.04.2013, Stefan Walter

1. **Measures of quantum synchronization in continuous variable systems**
   A. Mari, A. Farace, N. Didier, V. Giovannetti, R. Fazio
   *arXiv:1304.5925*
   We introduce and characterize two different measures which quantify the level of synchronization of interacting continuous variable quantum systems. The two measures allow to extend to the quantum domain the notions of complete and phase synchronization. The Heisenberg principle sets a universal bound to complete synchronization. The measure of phase synchronization is in principle unbounded, however in the absence of quantum resources (e.g. squeezing) the synchronization level is bounded below a certain threshold. We elucidate some interesting connections between entanglement and synchronization and, finally, discuss an application based on quantum opto-mechanical systems.

2. **Integer Quantum Hall State in Two-Component Bose Gases in a Synthetic Magnetic Field**
   Shunsuke Furukawa, Masahito Ueda
   *arXiv:1304.5716*
   We study two-component (or pseudospin-1/2) Bose gases in a strong synthetic magnetic field. Using exact diagonalization, we show that a bosonic analogue of an integer quantum Hall state (without intrinsic topological order) appears at the total filling factor $\nu = 1 + 1$ when the strengths of intracomponent and intercomponent interactions are comparable with each other. This provides a prime example of a symmetry-protected topological phase in a controlled setting of quantum gases. The real-space entanglement spectrum of this state is found to be comprised of counter-propagating chiral modes consistent with the predicted edge theory.

3. **Dynamic Magnetoelectric Effect in Ferromagnet-Superconductor Tunnel Junctions**
   Mircea Trif, Yaroslav Tserkovnyak
   *arXiv:1304.5750*
   We study the magnetization dynamics in a ferromagnet-insulator-superconductor tunnel junction and the associated buildup of the electrical polarization. We show that for an open circuit, the induced voltage varies strongly and nonmonotonically with the precessional frequency, and can be enhanced significantly by the superconducting correlations. For frequencies much smaller or much larger than the superconducting gap, the voltage drops to zero, while when these two energy scales are comparable, the voltage is peaked at a value determined by the driving frequency. We comment on the potential utilization of the effect for the low-temperature spatially-resolved spectroscopy of magnetic dynamics.

4. **Luttinger liquid properties of the steady state after a quantum quench**
   D.M. Kennes, V. Meden
   *arXiv:1304.5889*
   We study the dynamics resulting out of an abrupt change of the two-particle interaction in models of closed one-dimensional Fermi systems: the field theoretical Tomonaga-Luttinger model and a microscopic lattice model. Using a nonperturbative approach which is controlled for small two-particle interactions we are able to reach large times allowing us to access the properties of the steady state of the lattice model. Comparing those to the exact solution of the full dynamics in the Tomonaga-Luttinger model we provide evidence for universal Luttinger liquid behavior. We show that a single impurity leads to open and perfect chain fixed points in the steady state similar to the ones found in equilibrium [Phys. Rev. Lett. 68, 1220 (1992)].

5. **Topological Insulators with Commensurate Antiferromagnetism**
   Chen Fang, Matthew J. Gilbert, B. Andrei Bernevig
   *arXiv:1304.6081*
   We study the topological features of non-interacting insulators subject to an antiferromangetic (AFM) Zeeman field, or AFM insulators, the period of which is commensurate with the lattice period. These insulators can be classified by the presence/absence of an emergent anti-unitary symmetry: the combined operation of time-reversal and a lattice translation by vector **D**. For AFM insulators that preserve this combined symmetry, regardless of any details in lattice structure or magnetic structure, we show that (i) there is a new type of Kramers' degeneracy protected by the combined symmetry; (ii) a new $Z_2$ index may be defined for 3D AFM insulators, but not for those in lower dimensions and (iii) in 3D AFM insulators with a non-trivial $Z_2$ index, there are odd number of gapless surface modes if and only if the surface termination also preserves the combined symmetry, but the dispersion of surface states becomes highly anisotropic if the AFM propagation vector becomes small compared with the reciprocal lattice vectors. We numerically demonstrate the theory by calculating the spectral weight of the surface states of a 3D TI

in the presence of AFM fields with different propagation vectors, which may be observed by ARPES in $Bi_2Se_3$ or $Bi_2Te_3$ with induced antiferromagnetism.

6. **Photon transfer in ultrastrongly coupled three-cavity arrays**
S. Felicetti, G. Romero, D. Rossini, R. Fazio, E. Solano
*arXiv:1304.6221*
We study the photon transfer along a linear array of three coupled cavities where the central one contains an interacting two-level system in the strong and ultrastrong coupling regimes. We find that an inhomogeneously coupled array forbids a complete single-photon transfer between the external cavities when the central one performs a Jaynes-Cummings dynamics. This is not the case in the ultrastrong coupling regime, where the system exhibits singularities in the photon transfer time as a function of the cavity-qubit coupling strength. Our model can be implemented within the state-of-the-art circuit quantum electrodynamics technology and it represents a building block for studying photon state transfer through scalable cavity arrays.

7. **Competition between the Superconducting Proximity Effect and Coulomb Interactions in a Graphene Andreev Interferometer**
Fabio Deon, Sandra Sopic, Alberto F. Morpurgo
*arXiv:1304.6578*
We have investigated transport through graphene Andreev interferometers exhibiting reentrance of the superconducting proximity effect. We observed a crossover in the Andreev conductance oscillations as a function of gate voltage ($V_{BG}$). At high $V_{BG}$ the energy-dependent oscillation amplitude exhibits a scaling predicted for non-interacting electrons, which breaks down at low $V_{BG}$. The phenomenon is a manifestation of electron-electron interactions, whose main effect is to shorten the single-particle phase coherence time $\tau_\phi$. These results indicate that graphene provides a useful experimental platform to investigate the competition between superconducting proximity effect and interactions.

8. **Ballistic interferences in suspended graphene**
Peter Rickhaus, Romain Maurand, Ming-Hao Liu, Markus Weiss, Klaus Richter, Christian Schnenberger
*arXiv:1304.6590*
Graphene is a 2-dimensional (2D) carbon allotrope with the atoms arranged in a honeycomb lattice. The low-energy electronic excitations in this 2D crystal are described by massless Dirac fermions that have a linear dispersion relation similar to photons. Taking advantage of this optics-like electron dynamics, generic optical elements like lenses, beam splitters and wave guides have been proposed for electrons in engineered ballistic graphene. Tuning of these elements relies on the ability to adjust the carrier concentration in defined areas, including the possibility to create bipolar regions of opposite charge (p-n regions). However, the combination of ballistic transport and complex electrostatic gating remains challenging. Here, we report on the fabrication and characterization of fully suspended graphene p-n junctions. By local electro-static gating, resonant cavities can be defined, leading to complex Fabry-Perot interference patterns in the unipolar and the bipolar regime. The amplitude of the observed conductance oscillations accounts for quantum interference of electrons that propagate ballistically over long distances exceeding 1 micron. We also demonstrate that the visibility of the interference pattern is enhanced by Klein collimation at the p-n interface. This finding paves the way to more complex gate-controlled ballistic graphene devices and brings electron optics in graphene closer to reality.

9. **Non-equilibrium correlations and entanglement in a semiconductor hybrid circuit-QED system**
L. D. Contreras-Pulido, C. Emary, T. Brandes, R. Aguado
*arXiv:1304.7192*
We present a theoretical study of a hybrid circuit-QED system composed of two semiconducting charge-qubits confined in a microwave resonator. The qubits are defined in terms of the charge states of two spatially separated double quantum dots (DQDs) which are coupled to the same photon mode in the microwave resonator. We analyze a transport setup where each DQD is attached to electronic reservoirs and biased out-of-equilibrium by a large voltage, and study how electron transport across each DQD is modified by the coupling to the common resonator. In particular, we show that the inelastic current through each DQD reflects an indirect qubit-qubit interaction mediated by off-resonant photons in the microwave resonator. As a result of this interaction, both charge qubits stay entangled in the steady (dissipative) state. Finite shot noise cross-correlations between currents across distant DQDs are another manifestation of this nontrivial steady-state entanglement.