Condensed Matter Journal Club, 29.04.2014, Stefan Walter

1. **Coherently Opening a High-Q Cavity**
   Tommaso Tufarelli, Alessandro Ferraro, Alessio Serafini, Sougato Bose, and M.?S. Kim
   Phys. Rev. Lett. 112, 133605, 2014
   We propose a general framework to effectively "open" a high-Q resonator, that is, to release the quantum state initially prepared in it in the form of a traveling electromagnetic wave. This is achieved by employing a mediating mode that scatters coherently the radiation from the resonator into a one-dimensional continuum of modes such as a waveguide. The same mechanism may be used to "feed" a desired quantum field to an initially empty cavity. Switching between an open and "closed" resonator may then be obtained by controlling either the detuning of the scatterer or the amount of time it spends in the resonator. First, we introduce the model in its general form, identifying (i) the traveling mode that optimally retains the full quantum information of the resonator field and (ii) a suitable figure of merit that we study analytically in terms of the system parameters. Then, we discuss two feasible implementations based on ensembles of two-level atoms interacting with cavity fields. In addition, we discuss how to integrate traditional cavity QED in our proposal using three-level atoms.

2. **Wireless Josephson Amplifier**
   A. Narla, K.M. Sliwa, M. Hatridge, S. Shankar, L. Frunzio, R. J. Schoelkopf, M.H. Devoret
   arXiv:1404.4979
   osephson junction parametric amplifiers are playing a crucial role in the readout chain in superconducting quantum information experiments. However, their integration with current 3D cavity implementations poses the problem of transitioning between waveguide, coax cables and planar circuits. Moreover, Josephson amplifiers require auxiliary microwave components, like directional couplers and/or hybrids, that are sources of spurious losses and impedance mismatches that limit measurement efficiency and amplifier tunability. We have developed a new wireless architecture for these parametric amplifiers that eliminates superfluous microwave components and interconnects. This greatly simplifies their assembly and integration into experiments. We present an experimental realization of such a device operating in the 9-11 GHz band with about 100 MHz of amplitude gain-bandwidth product, on par with devices mounted in conventional sample holders. The simpler impedance environment presented to the amplifier also results in increased amplifier tunability.

3. **Generic model for Cooper pair splitting**
   H. Soller
   arXiv:1404.5124
   A superconductor connected to normal leads allows to generate Einstein-Podolsky-Rosen pairs by Cooper pair splitting. It has been realized with quantum dots either defined in carbon nanotubes or InAs nanowires. After establishing the presence of Cooper pair splitting in such devices new works have invesigated the effects of a finite potential difference between the quantum dots to improve and characterize the efficiency of Cooper pair splitting. In this paper we present a generic model for Cooper pair splitting and develop two minimal models specifically for the two experimental realisations and compare them to experimental data. In addition we also explore the relation of nonlocal charge transfer to positive current cross correlation of currents and discuss the temperature dependence of Cooper pair splitting.

4. **Fate of Majorana fermions and Chern numbers after a quantum quench**
   P.D. Sacramento
   arXiv:1404.5141
   The stability of Majorana fermions at the edges of a two-dimensional topological supercondutor is studied, after quenches to either non-topological phases or other topological phases. Both instantaneous and slow quenches are considered. In general, the Majorana modes decay and, in the case of instantaneous quenches, their revival times scale to infinity as the system size grows. Considering fast quantum quenches within the same topological phase, leads, in some cases, to robust edge modes. Quenches to a topological Z2 phase reveal some robustness of the Majorana fermions. Comparing strong spin-orbit coupling with weak spin-orbit coupling, it is found that the Majorana fermions are fairly robust, if the pairing is not aligned with the spin-orbit Rashba coupling. It is also shown that the Chern number remains invariant after the quench, until the propagation of the mode along the transverse direction reaches the middle point, beyond which the Chern number oscillates between increasing values. In some cases, the time average Chern number seems to converge to the appropriate value, but often the decay is very slow. The effect of varying the rate of change in slow quenches is also analysed. It is found that the defect production is non-universal and does not follow the Kibble-Zurek scaling with the quench rate, as obtained before for other systems with topological edge states.

5. **Non-Fermi liquid manifold in a Majorana device**
   Erik Eriksson, Christophe Mora, Alex Zazunov, Reinhold Egger
   arXiv:1404.5499
   We propose and study a setup realizing a stable manifold of non-Fermi liquid states. The device consists of a mesoscopic superconducting island hosting $N \geq 3$ Majorana bound states tunnel-coupled to normal leads, with a Josephson contact to a bulk superconductor. We find a nontrivial interplay between multi-channel Kondo and resonant Andreev reflection processes, which results in the fixed point manifold. The scaling dimension of the leading irrelevant perturbation changes continuously within the manifold and determines the power-law scaling of the temperature dependent conductance.

6. **The prospect of detecting single-photon force effects in cavity optomechanics**
   H. X. Tang, D. Vitali
   arXiv:1404.5574
   Cavity optomechanical systems are approaching a strong-coupling regime where the coherent dynamics of nanomechanical resonators can be manipulated and controlled by optical fields at the single photon level. Here we propose an interferometric scheme able to detect optomechanical coherent interaction at the single-photon level which is experimentally feasible with state-of-the-art devices and apparatus.

7. **Electrically Tunable Quasi-Flat Bands, Conductance and Field Effect Transistor in Phosphorene**
   Motohiko Ezawa
   arXiv:1404.5788
   Phosphorene, a honeycomb structure of black phosphorus, was isolated recently. We investigate electric properties of phosphorene nanoribbons based on the tight-binding model. A prominent feature is the presence of quasi-flat edge bands entirely detached from the bulk band. We explore the mechanism of the emergence of the quasi-flat bands analytically and numerically from the flat bands well known in graphene by a continuous deformation of a honeycomb lattice. The quasi-flat bands can be controlled by applying in-plane electric field perpendicular to the ribbon direction. The conductance is switched off above a critical electric field, which acts as a field-effect transistor. The critical electric field is anti-proportional to the width of a nanoribbon. This results will pave a way toward nanoelectronics based on phosphorene.

8. **Full control of quadruple quantum dot circuit charge states in the single electron regime**
   M. R. Delbecq, T. Nakajima, T. Otsuka, S. Amaha, J. D. Watson, M. J. Manfra, S. Tarucha
   arXiv:1404.6047
   We report the realization of an array of four tunnel coupled quantum dots in the single electron regime, which is the first required step toward a scalable solid state spin qubit architecture. We achieve an efficient tunability of the system but also find out that the conditions to realize spin blockade readout are not as straightforwardly obtained as for double and triple quantum dot circuits. We use a simple capacitive model of the series quadruple quantum dots circuit to investigate its complex charge state diagrams and are able to find the most suitable configurations for future Pauli spin blockade measurements. We then experimentally realize the corresponding charge states with a good agreement to our model.he emergence of the quasi-flat bands analytically and numerically from the flat bands well known in graphene by a continuous deformation of a honeycomb lattice. The quasi-flat bands can be controlled by applying in-plane electric field perpendicular to the ribbon direction. The conductance is switched off a

9. **Steady-state phase diagram of a driven QED-cavity array with cross-Kerr nonlinearities**
   Jiasen Jin, Davide Rossini, Martin Leib, Michael J. Hartmann, Rosario Fazio
   arXiv:1404.6063
   We study the properties of an array of QED-cavities coupled by nonlinear elements in the presence of photon leakage and driven by a coherent source. The main effect of the nonlinear couplings is to provide an effective cross-Kerr interaction between nearest-neighbor cavities. Additionally correlated photon hopping between neighboring cavities arises. We provide a detailed mean-field analysis of the steady-state phase diagram as a function of the system parameters, the leakage and the external driving, and show the emergence of a number of different quantum phases. A photon crystal associated to a spatial modulation of the photon blockade appears. The steady state can also display oscillating behavior and bi-stability. In some regions the crystalline ordering may coexist with the oscillating behavior. Furthermore we study the effect of short-range quantum fluctuations by employing a cluster mean-field analysis. Focusing on the corrections to the photon crystal boundaries, we show that, apart for some quantitative differences, the cluster mean field supports the findings of the simple single-site analysis. In the last part of the paper we concentrate on the possibility to build up the class of arrays introduced here, by means of superconducting circuits of existing technology. We consider a realistic choice of the parameters for this specific implementation and discuss some properties of the steady-state phase diagram.