

Wednesday, January 8, 2014

Title: Cavities as a high-fidelity quantum interface between ions and photons

Speaker: Birgit Brandstätter, member of Rainer Blatt's group at University of Innsbruck

Abstract: Optical cavities can be used as efficient quantum interfaces between photons and atoms to realize a quantum network. In such a network, photonic channels link quantum nodes composed of trapped atoms. Due to decoherence, however, the technical requirements for the building blocks of such a network are demanding. Using trapped ions in combination with cavities of small mode volumes, high fidelities and efficiencies for network protocols are achieved. Cavities constructed from mirrors fabricated on fiber facets provide such small mode volumes.

In my talk, I present the development of an integrated ion-trap fiber-cavity setup. The cavity parameters are designed for strong coupling between a single ion and a cavity photon with coherent effects dominating over decoherence in the system. Recently, we have realized experiments that demonstrate network protocols such as ion-photon state mapping and ion-photon entanglement in an ion-cavity system that operates in the intermediate coupling regime. Simulations of such network protocols show the advantage of a fiber-cavity system over the system with a smaller coupling rate.

Friday, January 10

Title: Probing dynamics and entanglement growth in the many-body localized phase

Speaker: Maksym Serbyn, member of Patrick Lee's group at MIT

Abstract: Recently it was demonstrated that the many-body localized phase can be characterized by the existence of infinitely many local conservation laws. These local integrals of motion can be viewed as effective quantum spins that have conserved z-components. This picture shows that the dynamics of the many-body localized phase is limited to dephasing between distant effective spins. Slow logarithmic entanglement growth for initial product states is one signature of the restricted dynamics of the many-body localized phase. However, the entanglement entropy is difficult to observe experimentally.

In this talk, after reviewing the description of the MBL phase in terms of conserved quantities, we show that another consequence of dynamics in the MBL phase is a characteristic slow power-law decay of local observables; this is measurable experimentally. In particular, we propose a specific protocol to probe the dephasing of a given spin due to its entanglement with a set of distant spins. The proposed response function exhibits a power-law decay that is robust with respect to thermal and disorder averaging. We will discuss numerical simulations supporting our results.

Monday, January 27

Title: The open Dicke model with linear and nonlinear atom-photon interactions

Speaker: Scott Parkins, University of Auckland

Abstract: A scheme in optical cavity QED based upon cavity-assisted Raman transitions in multilevel atoms is proposed for the simulation of the Dicke model and the associated (dissipative) quantum phase transition it undergoes for sufficiently strong atom-field coupling strength. At the level of a single atom, this scheme also offers the possibility of simulation of atom-field dynamics in the ultra-strong coupling regime. Arguably more interesting, however, is the possibility offered by the scheme of simulating a generalised model in which a nonlinear (or dispersive) atom-field coupling can occur on an equal footing with the effective dipole (linear) coupling strength, and can in fact give rise to critical-type behavior even at the single-atom level. A semiclassical analysis (corresponding to the "thermodynamic limit" of a very large number of atoms) for this generalised model predicts an exceedingly rich dynamical phase diagram for the steady state of the system with fundamentally new behaviour and phases, such as a new superradiant phase, regions of co-existent superradiant and normal phases, and regimes with oscillatory long-time attractors. We explore these predictions in a fully quantum model of the system with finite, but possibly large, atom number, focussing on when and how these various regimes, and the transitions between them, manifest themselves in the spectral, statistical, and entanglement properties of the system. This also allows us to identify possibilities for the preparation of novel and potentially useful quantum states of both atoms and light fields.

Friday, January 31

Title: Bulk-Edge Correspondence in 2+1-Dimensional Abelian Topological Phases

Speaker: Jennifer Cano, UC Santa Barbara

Abstract: The same bulk two-dimensional topological phase can have multiple distinct, fully-chiral edge phases. We show that this can occur in the integer quantum Hall states at fillings 8 and 12 with experimentally-testable consequences. We show that this can occur in Abelian fractional quantum Hall states as well, with the simplest examples being at filling fractions $8/7$, $12/11$, $8/15$, $16/5$. We give a general criterion for the existence of multiple distinct chiral edge phases for the same bulk phase and discuss experimental consequences.

Edge phases correspond to lattices while bulk phases correspond to genera of lattices. Since there are typically multiple lattices in a genus, the bulk-edge correspondence is typically one-to-many; there are usually many stable fully chiral edge phases corresponding to the same bulk. We show that fermionic systems can have edge phases with only bosonic low-energy excitations and discuss a fermionic generalization of the relation between bulk topological spins and the central charge. The latter follows from our demonstration that every fermionic topological phase can be represented as a bosonic topological phase, together with some number of filled Landau levels. Our analysis also leads to a simple demonstration that all Abelian topological phases can be represented by a Chern-Simons theory parameterized by a K-matrix.

February 7, 2014

Title: Electronic Structure with Depth and Time Resolution: Future Directions in X-ray Spectroscopy and Imaging

Speaker: Alexander X. Gray, Stanford University and SLAC National Accelerator Laboratory

Abstract: The ever-growing demand for miniaturization and increased speeds in next-generation energy-efficient electronic devices has taken science to the quantum frontier in which emergent phenomena at the nanoscale require a clear differentiation among surface, bulk and interface properties. Thus, for many technologically-promising novel materials, electronic structure and far-from-equilibrium dynamics vary dramatically as functions of depth and proximity to other materials. Therefore, novel depth-, time-, and spin-resolved element-specific characterization techniques are required to disentangle these rich electronic behaviors, including spin-orbit and electron correlation effects. In this talk I will describe several new directions in the fields of x-ray spectroscopy and imaging, made possible with the advent of third-generation synchrotron light sources and free-electron lasers (FEL), which have enabled investigations of fundamental physical processes in novel complex materials and technologically-relevant nanostructures and interfaces with depth- and time resolution. I will present the first results of hard x-ray angle-resolved photoemission measurements (HARPES) at excitation energies of up to 6 keV [1,2]. Compared to the traditional angle-resolved photoemission (ARPES) carried out in the UPS regime (20-150 eV), this new technique enables one to probe up to 40 times deeper below the surface thus allowing for more bulk-sensitive momentum-resolved electronic structure determination. Furthermore, I will introduce a new x-ray photoemission technique (SWARPES) that combines soft x-ray ARPES with standing-wave (SW) excited photoelectron spectroscopy, wherein the intensity profile of the exciting x-ray radiation is tailored within the sample in order to provide a depth-selective probe of the electronic structure of buried layers and interfaces [3]. The SW method also permits turning photoemission microscopy into a truly three-dimensional probe with depth resolution (SWPEEM) [4]. Finally, I will discuss the latest state-of-the-art time-resolved THz-pump/x-ray-probe techniques, made possible by the unsurpassed brilliance and unique sub-femtosecond pulse structure of FEL, which have enabled ultrafast control and monitoring of electronic interactions in strongly-correlated oxides with electric fields [5,6].

[1] A. X. Gray et al., Probing Bulk Electronic Structure with Hard X-Ray Angle-Resolved Photoemission, *Nature Materials* 10, 759 (2011).

[2] A. X. Gray et al., Bulk Electronic Structure of the Dilute Ferromagnetic Semiconductor Ga_{1-x}Mn_xAs through Hard X-Ray Angle-Resolved Photoemission, *Nature Materials* 11, 957 (2012).

[3] A. X. Gray et al., Momentum-Resolved Electronic Structure at a Buried Interface from Soft X-Ray Standing-Wave Angle-Resolved Photoemission, *Europhys. Lett.* 104, 17004 (2013).

[4] A. X. Gray et al., Standing-Wave Excited Soft X-Ray Photoemission Microscopy: Application to Co Microdot Magnetic Arrays, *Appl. Phys. Lett.* 97, 062503 (2010).

[5] N. P. Aetukuri, A. X. Gray et al., Control of the Metal-Insulator Transition in Vanadium Dioxide by Modifying Orbital Occupancy, *Nature Physics* 9, 661 (2013).

[6] A. X. Gray et al., Ultrafast Control of Electronic Interactions in Vanadium Dioxide, in preparation (2014).

March 7, 2014

Title: Quantum optics with atoms trapped near nanostructures

Speaker: Jeff Thompson, Harvard

Abstract: Cavity QED is a promising platform for quantum technologies because it allows photons, which can easily propagate over long distances, to interact strongly with atoms, which are natural qubits with excellent coherence properties. We have recently developed a technique for trapping a single rubidium atom in the evanescent mode of a nano-fabricated optical cavity with sub-wavelength dimensions [1]. By virtue of their small size, these cavities provide extremely large atom-photon coupling strengths and good prospects for scalability and integration into complex quantum optical circuits. As a first application, we have demonstrated a coherent optical switch, where a single “gate” photon controls the propagation of many subsequent “signal” photons, with the interaction mediated by the atom and cavity [2]. Additionally, I will discuss ongoing work to implement multi-atom quantum gates and to produce exotic non-classical states of light.

March 14, 2014

Title: Adiabatic reaction forces in mesoscopic systems

Speaker: Silvia Viola Kusminskiy, Freie University Berlin

Abstract: Nanoelectromechanical systems are characterized by an intimate connection between electronic and mechanical degrees of freedom. Due to the nanoscopic scale, current flowing through the system noticeably impacts the vibrational dynamics of the device, complementing the effect of the vibrational modes on the electronic dynamics. In this talk I go over recent experimental results that show the dramatic effect of the electron-vibron coupling for suspended quantum dots in the Coulomb blockade regime, accompanied by a comprehensive theoretical description based on a Master equation approach. On the second part of the talk, I describe our recently developed formalism for the complementary regime of coherent transport, in which we employ the scattering matrix approach to quantum transport to describe the current-induced forces acting on the mechanical degrees of freedom of an out-of-equilibrium nanoelectromechanical system. These forces control the Langevin dynamics of the mechanical modes. Specifically, we derive expressions for the (typically nonconservative) mean force, for the (possibly negative) damping force, an effective "Lorentz" force which exists even for time reversal invariant systems, and the fluctuating Langevin force originating from Nyquist and shot noise of the current flow. In a more general setting, these forces can be interpreted as reaction forces acting over slow classical degrees of freedom coupled to a quantum-mechanical scattering system, and our results extend previous work on adiabatic reaction forces for closed quantum systems.

March 21, 2014

Title: Non-fermi liquids and the Wiedemann-Franz law

Speaker: Raghu Mahajan, Stanford University

Abstract: To understand transport in strongly-correlated electron systems, a departure from conventional approaches based on the Boltzmann equation is needed. This is because the transport coefficients of non-Fermi liquids are obtained within a fundamentally different kinematics to Fermi liquids.

We discuss the ratio of thermal and electrical conductivities in non-Fermi liquid metals. Our discussion will be independent of specific theories, and we will describe various qualitatively different cases. First, we study scenarios in which long-lived 'cold' quasiparticles with unconventional scattering rates coexist with a strongly interacting 'hot' fermions. For this case, we characterize circumstances under which a linear in temperature resistivity is and is not compatible with the Wiedemann-Franz law. For cases in which there are no long-lived quasiparticles, we use a tool called the memory-matrix formalism. The memory-matrix formalism exploits the existence of almost-conserved operators in the underlying microscopic theory. We distinguish cases with only one almost-conserved momentum, and with many patchwise almost-conserved momenta. We obtain 'universal' expressions for the ratio of conductivities that violate the Wiedemann-Franz law. Relevance to some experiments is discussed.

If time permits, we will describe an explicit computation of a $1/\sqrt{T \log T}$ contribution to the resistivity using the memory matrix method for the case of random field disorder near a Pomeranchuk transition.

April 4, 2014

Title: Amperean pairing and the pseudogap phase in cuprates

Speaker: Patrick Lee, William & Emma Rogers Professor of Physics, MIT

Abstract: Experimentalists have made significant advances in the last few years in characterizing the mysterious pseudo-gap phase in cuprate superconductors but a theoretical understanding is lacking. I propose that a novel pairing state is the driving force which can explain many of the phenomena that have been observed.

April 11, 2014

Title: Tensor Network States and their study of 2D Topological phases Friday, April 11

Speaker: Ling Wang, IQIM Postdoctoral Scholar

Abstract: Tensor network state (TNS) is a class of variational wave function ansatz that makes higher dimensional analogy to the 1 dimensional matrix product state (MPS) and is successful in study higher dimensional strongly correlated systems. In this talk, I will briefly introduce TNS, walk through some celebrated examples of representing topological phases using TNS. The

major part of the talk will be devoted to identify topological phases using the transfer matrix method by setting up a 2 dimensional TNS on a cylinder. Further applications of the transfer matrix of a TNS will be discussed.

April 18, 2014

Title: Quantum number fractionalization in spin liquids

Speaker: Andrew Essin, Postdoctoral Scholar in Theoretical Physics – Preskill group and Condensed Matter Theory

Abstract: The talk is based on a recent paper: Spectroscopic signatures of crystal momentum fractionalization

We consider gapped Z_2 spin liquids, where spinon quasiparticles may carry fractional quantum numbers of space group symmetry. In particular, spinons can carry fractional crystal momentum. We show that such quantum number fractionalization has dramatic, spectroscopically accessible consequences, namely enhanced periodicity of the two-spinon density of states in the Brillouin zone, which can be detected via inelastic neutron scattering. This effect is a sharp signature of certain topologically ordered spin liquids and other symmetry enriched topological phases. Considering square lattice space group and time reversal symmetry, we show that exactly four distinct types of spectral periodicity are possible.

<http://arxiv-web3.library.cornell.edu/abs/1401.1846v2>

April 25, 2014

Title: Majorana fermion exchange in strictly one dimensional structures

Speaker: Ching-Kai Chiu, Postdoctoral Scholar University of British Columbia

Abstract: It is generally thought that adiabatic exchange of two identical particles is impossible in one spatial dimension. Here we describe a simple protocol that permits adiabatic exchange of two Majorana fermions in a one-dimensional topological superconductor wire. The exchange relies on the concept of "Majorana shuttle" whereby a π domain wall in the superconducting order parameter which hosts a pair of ancillary Majoranas delivers one zero mode across the wire while the other one tunnels in the opposite direction. The method requires some tuning of parameters and does not, therefore, enjoy the full topological protection. The resulting exchange statistics, however, remains non-Abelian for a wide range of parameters that characterize the exchange.

<http://arxiv.org/abs/1403.0033>

May 2, 2014

Title: Quantum nanophotonics with rare earth ions in solids

Speaker: Tian Zhong, Postdoctoral Scholar - Faraon group

Abstract: Rare earth ions (REI) embedded in crystals have some of the longest optical and spin coherence times in the solid state, which makes them promising candidates for implementing on-chip quantum optical technologies with applications in quantum memories and nonlinear optical devices operating at low photon numbers. The effective shielding of the REI 4f electrons results

in very stable optical transitions with reduced spectral diffusion and blinking. This makes the REI better suited for scalable quantum photonics compared to other solid-state quantum emitters such as quantum dots and nitrogen-vacancy centers whose optical transitions are not as stable, especially when embedded in nano-photonic devices. In this talk I will describe our ongoing cavity-QED experiments with small ensembles of ions embedded in an optical nano-resonator, which represents the first important step towards a REI-based nanophotonic platform composed of efficient and scalable light-matter interfaces.

May 16, 2014

Title: Unconventional magnetism in dissipative atomic systems

Speaker: Tony Lee, Postdoctoral Fellow, Institute for Theoretical Atomic Molecular and Optical Physics (ITAMP), Harvard University

Abstract: Cold atoms provide an opportunity to see new collective behavior far from equilibrium, since atomic systems are intrinsically dissipative due to spontaneous emission. I discuss the anisotropic XY model in the presence of spontaneous emission on every atom. It turns out that dissipation enriches the phase diagram, creating new phases like a spin-density-wave phase and a staggered-XY phase. Cold atoms can also simulate non-Hermitian Hamiltonians in a manner similar to heralded entanglement protocols. This leads to unusual behavior like sharp transitions for two atoms and quasi-long-range order in the absence of a continuous symmetry. I also discuss implementation with trapped ions, cavity QED, and atoms in optical lattices.

May 23, 2014

Title: Transfer-matrix treatment of surface disorder in topological insulator

Speaker: Kun Woo Kim, Graduate student - Condensed Matter Theory

Abstract: Topological insulator has attracted enormous attention in physics community in the last decade. Not only its theoretical study deepened the understanding of the topological nature of condensed matter systems, but it has provided new opportunities in practical applications such as spintronic devices, thermoelectric materials, and photovoltaics. We present a transfer-matrix treatment of electronic local density of states in topological insulators with surface impurities. The method allows us to reduce the computational complexity into a single layer problem of whole system by analytically integrating bulk layers. In a concrete example of 2d topological insulator, we discuss how impurities on the top layer reconstruct the local density of chiral edge states which recovers to a clean system form in the strong disorder limit.

May 30, 2014

Title: Measuring the pseudo-spin space of hydrogenated graphene

Speaker: Thomas Szkopek, Associate Professor, Department of Electrical and Computer Engineering, McGill University

Abstract: We have observed the quantum Hall effect (QHE) and Shubnikov-de Haas (SdH) oscillations in millimetre scale hydrogenated graphene. We find that the pseudo-spin structure of graphene is remarkably robust to the sub-lattice symmetry breaking induced by hydrogenation. Hydrogenation of pristine graphene is experimentally observed to increase electrical resistance and introduce neutral point defects (up to $\sim 0.1\%$ concentration) as evidenced by Raman

spectroscopy. In the highly resistive limit, strongly insulating behaviour is observed with a two-point resistance as high as $250 h/e^2$ at low temperature, far above the Ioffe-Regel limit for metallic conduction. Upon application of a magnetic field, colossal negative magnetoresistance is observed with the emergence of a $\nu = -2$ QHE state at 45 T from an insulating state, with the notable absence of SdH oscillations (J. Guillemette et al, Phys. Rev. Lett. 110, 176801 (2013)). The rapid collapse of resistance is observed to occur when the magnetic length is comparable to the mean spacing of neutral point defects. We have observed SdH oscillations in graphene hydrogenated to a lower resistivity at magnetic fields up to 65 T. Analysis of SdH oscillation frequency in $1/B$ indicates that the Landau level (LL) sequence remains four-fold degenerate. We also observe the $\nu = -2$ QHE state in all samples. We therefore conclude that the topological part of the Berry phase, meaning the pseudo-spin winding number that determines the LL sequence, is preserved upon hydrogenation of large scale graphene. Time permitting, I will discuss other less well understood properties of hydrogenated graphene.

June 6, 2014

Title: Quasiparticle Coherence, Collective Modes, and Competing Order in Cuprate Superconductors

Speaker: James Hinton, Graduate Student, Condensed Matter Physics And Materials Science, University of CA - Berkeley/ LBNL

Abstract: The discovery of a fluctuating charge density wave (CDW) in underdoped $\text{YBa}_2\text{Cu}_3\text{O}_{(6+x)}$ (YBCO) has established that charge ordering proximate to the superconducting dome is a universal feature of the cuprate superconductors(1,2). This order is observed to co-exist and compete with superconductivity, and the relationship of charge ordering to the mechanism of high T_c superconductivity is an important open question.

In this talk I will present a study of competing order in the cuprates using time-domain reflectivity measurements. In these experiments, low-intensity light pulses at 1.5 eV pump the sample, creating high-energy excitations which rapidly thermalize into gap-energy quasiparticles. This non-equilibrium state is then probed by a second pulse, allowing the study of reflectivity dynamics with sub-ps time resolution. In YBCO, I will demonstrate that this quasiparticle excitation couples directly to the amplitude mode of the CDW, launching a coherent oscillation in the reflectivity. This oscillation softens upon cooling through T_c , indicative of competition between superconducting (SC) and CDW order. I will then move on to discuss a detailed study of quasiparticle relaxation dynamics as a function of doping, temperature, and magnetic field in the especially simple cuprate superconductor $\text{HgBa}_2\text{CuO}_{(4+\delta)}$ (Hg-1201). We observe cusp-like features in the recombination dynamics near T_c which can be understood in terms of quasiparticles that are of mixed SC and CDW character. Finally, if time permits, I will present evidence for direct excitation via the impulsive-Raman process of an as-yet unidentified collective mode in the electron-doped compound $\text{Nd}_{(2-x)}\text{Ce}_x\text{CuO}_{(4+\delta)}$. We associate this mode with the onset of the pseudogap, and compare it to the pseudogap dynamics in the hole-doped cuprates.

1) G. Ghiringelli et. al., Science 337, 821 (2012)

2) J. Chang e. al., Nature Physics 8, 871 (2012)

June 13, 2014

Title: TBD

Speaker: Torsten Karzig, IQIM Postdoctoral Scholar

Abstract: TBD