December 4	**Alex Frenzel**, Postdoctoral Scholar, UC San Diego	Semiconducting-to-metallic Photoconductivity Crossover in Graphene
November 20	**Jonathan Hood**, Graduate Student, Kimble Group	Atom-atom interactions in an 'Alligator' photonic crystal waveguide
November 13	**Justin Wilson**, Postdoctoral Scholar, Condensed Matter Theory	The quenched-induced geometric Hall response
November 6	**Nicole Yunger Halpern**, Graduate Student, Preskill Group	Toward physical realizations of information-theory models for small-scale thermodynamics
October 30	**Bassam Helou**, Graduate Student, Yanbei Chen's Group	Optomechanics: a platform for exploring novel physics
October 9	**Andrew Mounce**, Los Alamos National Labs/Sandia Labs	Unconventional superconductivity in Uranium and Plutonium intermetallics revealed by Nuclear Magnetic Resonance
September 25	**Pedram Roushan**, Quantum Electronics Engineer at Google	Time Reversal Breaking with a Photon Circulator
August 14	**Matteo Lostaglio**, Graduate Student, Imperial College, London	The resource theory approach to thermodynamics and coherence
August 7	**Yihua Wang**, Postdoctoral Scholar, Moler Group, Stanford University	Broken-symmetry states in topological insulators
June 17	**Prof. Jukka Pekola**, Low Temperature Laboratory, Aalto University School of Science	Thermodynamics with electrons in a circuit
June 5	**Prof. Lincoln Carr**, Department of Physics, Colorado School of Mines	Ultracold Molecules in Crystals of Light: A Highly Tunable System for Exploring Novel Materials, Quantum Dynamics, and Quantum Complexity
May 29	**Mario Berta**, Postdoctoral Scholar in Theoretical Physics, Preskill Group	Quantum Coding with Finite Resources
May 22	**Johannes Pollanen**, IQIM Postdoctoral Scholar, Eisenstein Group	Engineering Quantum Matter: From Superfluids to Low-Dimensional Electrons
May 15	**Ryan Mishmash**, DuBridge Postdoctoral Scholar in Theoretical Physics - Condensed Matter Theory	Majorana milestones: Intermediate goals on the path towards braiding-based topological quantum computation

May 8	**Scott Geraedts**, Graduate Student – Condensed Matter Theory, Motrunich Group	DMRG Study of a Quantum Hall system
May 1	**James Douglas**, Postdoctoral Scholar, Theoretical Quantum-Nano Photonics, ICFO, Barcelona	Cold atoms coupled to photonic crystals: long range interactions and photon molecules
April 24	**Alex Kubica**, Graduate Student - Preskill Group	Unfolding the color code
April 17	**Rajibul Islam**, Postdoctoral Fellow – Greiner Group, Rubidium Gas Microscopy, MIT-Harvard Center for Ultracold Atoms	Entanglement detection by interfering quantum many-body twins
April 10	**Markus Krutzik**, Postdoctoral Scholar in Communications Architectures and Research at JPL	Matter Wave Interferometry in Microgravity – Towards Quantum Sensors in Space
April 3	**Fernando Pastawski**, IQIM Postdoctoral Scholar	Holographic quantum error-correcting codes: Toy models for the bulk/ boundary correspondence
March 27	**Ning Bao**, DuBridge Postdoctoral Scholar in Theoretical Physics - quantum information and string theory	Constraining Holographic Entanglement Entropy
March 6	No seminar – March APS Meeting	
February 20	**Shaun Maguire**, Graduate Student – Preskill Group	Overview of Holographic Entanglement Entropy via Illustrations
February 13	Joint seminar co-sponsored with Applied Physics: **Prof. Andreas Wallraff**, ETH Zurich	Simulating an Interacting Quantum Gas using Matrix Product States generated with Superconducting Circuits
January 30	**Prof. Morten Ring Eskildsen**, Dept of Physics, University of Notre Dame	Vortex lattice anisotropy and pairing symmetry of Sr2RuO4
January 23	**Laura DeLorenzo**, Graduate Student – Schwab Group	Superfluid Optomechanics
January 9	**Aaron Weinstein**, Graduate Student – Schwab Group	Quantum noise detection with cavity electro-mechanics

January 9, 2015
Aaron Weinstein, Graduate Student, Schwab Group, Applied Physics, Caltech
Title: Quantum noise detection with cavity electro-mechanics

Abstract: Electro-mechanical systems offer a unique advantage to probe quantum noise properties in macroscopic mechanical devices, properties which ultimately stem from the Heisenberg Uncertainty Principle. A simple example of this is expected to occur in a microwave parametric transducer, composed of a superconducting microwave resonator fabricated with a flexible suspended capacitor gate, where mechanical motion of the gate generates motional sidebands corresponding to the up and down frequency conversion of microwave photons. Due to quantum vacuum noise, the rates of these processes are expected to be unequal. We measure this fundamental imbalance in a microwave transducer coupled to a radio-frequency mechanical mode, cooled near the ground state of motion.

In the first part of this talk, I will provide a brief introduction to opto- and electro-mechanical devices, and also touch briefly on how control of back-action forces allows for preparation of mechanical motion in the quantum regime.

In the second part of this talk, I will cover the fabrication and measurement techniques used in recent measurements of asymmetric motional noise.

January 23, 2015
Laura DeLorenzo, Graduate Student, Schwab Group, Applied Physics, Caltech
Title: Superfluid Optomechanics

Abstract: I will discuss recent results in which we couple the low loss acoustic motion of superfluid He-4 to a high Q, superconducting niobium TE011 microwave resonator, forming a gram-scale, sideband resolved, optomechanical system. We demonstrate the detection of a series of acoustic modes with quality factors as high as 3*10^7. At higher temperatures, the lowest dissipation modes are limited by an intrinsic three phonon process. Acoustic quality factors approaching 10^11 may be possible in isotopically purified samples at temperatures below 10 mK. A system of this type may be utilized to study macroscopic quantized motion and as a frequency tunable, ultra-sensitive sensor of extremely weak displacements and forces, such as continuous gravity wave sources. I will outline the requirements of the optomechanical structure and the microwave field required for these experiments.

Ref: L. A. De Lorenzo & K. C. Schwab, New J. Phys. 16, 113020 (2014)

January 30, 2015
Prof. Morten Ring Eskildsen, Dept of Physics, University of Notre Dame
Title: Vortex lattice anisotropy and pairing symmetry of Sr2RuO4

Abstract: Superconductors can be classified into two distinctive groups, with either spin-singlet or spin-triple pairing. Almost all superconductors, including the high T_c cuprates as well as the recently discovered pnictides and chalcogenides, have singlet pairing, and triplet-paired materials have been extremely difficult to find.

Strontium ruthenate (Sr_2RuO_4) is one of the few prime candidates for a triplet-pairing superconductor, but despite a large theoretical and experimental effort an unambiguous determination of the detailed structure of the order parameter (spatial and spin part) in this material has proved elusive. Multiple experimental and theoretical studies have provides compelling support for triplet pairing and an odd-parity, *p*-wave order parameter symmetry. At the same time, seemingly contradictory experimental results have left important open questions concerning the detailed structure and coupling of the orbital and spin parts of the order parameter. One example of this predicament is conflicting evidence as to whether the *p*-wave order parameter is chiral.

Here we present the results of small-angle neutron scattering studies of the vortex lattice in Sr_2RuO_4 with the field applied close to the crystalline basal plane. Taking advantage of the transverse magnetization in this highly anisotropic superconductor, it was possible to measure the vortex lattice anisotropy as a function of the field angle. From the measurements we were able to determine the intrinsic superconducting anisotropy between the *c*-axis and the

Ru-O basal planes (~60), which greatly exceeds the upper critical field anisotropy (~20). This imposes significant constraints on possible models of triplet pairing in Sr_2RuO_4 and raises questions concerning the direction of the zero spin projection axis.

February 13, 2015
Joint seminar co-sponsored with Applied Physics: **Prof. Andreas Wallraff, ETH Zurich**
Title: Simulating an Interacting Quantum Gas using Matrix Product States generated with Superconducting Circuits

Abstract: The high level of control achievable over quantized degrees of freedom have turned superconducting circuits into one of the prime physical architectures for quantum computing and simulation. While conventional approaches towards quantum information processing mostly rely on unitary time evolution, more recently open-system dynamics are considered for quantum simulations. In this talk, I will present experiments in which we use an open cavity QED system with tunable interactions to simulate the ground state of an interacting Bose gas confined in one dimension [1,2]. These experiments rely on the ability to efficiently measure higher order photon correlations of the cavity output field. For this purpose we have developed a quantum limited amplifier achieving phase-preserving amplification at large bandwidth and high dynamic range [3]. Our results explore a different path towards the simulation of complex quantum many-body physics based on the controlled generation and detection of nonclassical radiation in an open quantum system.

(*) Work led by Christopher Eichler

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February 20, 2015
Shaun Maguire, Graduate Student – Preskill Group
Title: Overview of Holographic Entanglement Entropy via Illustrations

Abstract: This talk will provide an informal overview of holographic entanglement entropy, geared towards the IQIM audience. The talk will provide a survey of some of the generalizations of Ryu and Takayanagi's original conjecture, such as the covariant proposal put forth by Hubeny, Rangamani and Takayanagi, which is necessary to understand entanglement in time-dependent settings, such as during quenches. The talk will also discuss recent work related to understanding multipartite entanglement holographically.

March 27, 2015
Ning Bao, DuBridge Postdoctoral Scholar in Theoretical Physics – quantum information and string theory
Title: Constraining Holographic Entanglement Entropy

Abstract: Entropy cones are objects that constrain the parameter space available to specific types of states, and have been applied to quantum systems, stabilizer systems, and classical systems. In this talk I will study the structure of several holographic entropy cones in gauge/gravity duality, and will derive a new class of cyclic holographic information theoretic inequalities, and try to give a physical interpretation of these inequalities in the gravity theory.

April 3, 2015
Fernando Pastawski, IQIM Postdoctoral Scholar
Title: Holographic quantum error-correcting codes: Toy models for the bulk/boundary correspondence

Abstract: In this talk I will introduce a family of exactly solvable toy models of a holographic correspondence based on a novel construction of quantum error-correcting codes with a tensor network structure. The building block for these models are a special type of tensor with maximal entanglement along any bipartition, which gives rise to an exact isometry from bulk operators to boundary operators. The entire tensor network is a quantum error-correcting code, where the bulk and boundary degrees of freedom may be identified as logical and physical degrees of freedom respectively. These models capture key features of entanglement in the holographic correspondence; in particular, the Ryu-Takayanagi formula and the negativity of tripartite information are obeyed exactly in many cases. I will describe how bulk operators may be represented on the boundary regions mimicking the Rindler-wedge reconstruction.

Based on recent work: arXiv:1503.06237 **[hep-th]**

April 10, 2015
Markus Krutzik, Postdoctoral Scholar in Communications Architectures and Research at JPL
Title: Matter Wave Interferometry in Microgravity – Towards Quantum Sensors in Space

Abstract: Cold atom based quantum sensors such as matter wave interferometers will broadly benefit from reduced gravity conditions offered by space-borne platforms. By pushing the performance beyond what is accessible on Earth, these devices would not only open up new possibilities to support important applications within a wide range of scientific fields (e.g., Earth observation, navigation, metrology), but also provide a high-precision quantum based testbed to address some of the most fundamental questions of modern physics.

In this talk, I will present first interferometry experiments with degenerate quantum gases operated in microgravity, which have been performed within the QUANTUS project. In more than 250 free fall experiments conducted at the Bremen drop tower, the free evolution and phase coherence of an atom chip based Bose-Einstein condensate (BEC) on macroscopic timescales have been explored. Combined with delta-kick cooling (DKC) techniques to further slow down the expansion of the atomic cloud, effective temperatures of about 1nK have been reached. High-contrast interferometric fringes were observed up to a total time in an asymmetric Mach-Zehnder interferometer of 2T = 677 ms.

In context of an upcoming generation of experiments, I will also discuss design and qualification of compact laser system technology optimized for precision measurement applications aboard double-stage sounding rockets and satellites, as well as the prospects of NASA's cold atom laboratory - a multi-user facility for the study of ultra-cold quantum gases in the microgravity environment of the International Space Station (ISS).

April 17, 2015
Rajibul Islam, Postdoctoral Fellow – Greiner Group, Rubidium Gas Microscopy, MIT-Harvard Center for Ultracold Atoms
Title: Entanglement detection by interfering quantum many-body twins

Abstract: Entanglement is at the heart of quantum many-body physics, and is theoretically used to characterize quantum phase transitions and topological order. Detecting entanglement in experimental systems, however, is hard as it often requires a full reconstruction of the density matrix or prior knowledge about the state itself. Instead, in our experiments with interacting bosonic ultra cold atoms we rely on the general property of a bipartite entangled state that ignoring information about (or tracing over) one subsystem introduces a classical mixture in the other. This results in an increased Renyi entanglement entropy that we directly measure by interfering two identically prepared copies of a few-body state.

April 24, 2015
Alex Kubica, Graduate Student – Preskill Group
Title: Unfolding the color code

Abstract: The topological color code and the toric code are two leading candidates for realizing fault-tolerant quantum computation. In the talk, I will start with introducing these two models. Then, I will show that the color code in d dimensions is equivalent to multiple decoupled copies of the d-dimensional toric code up to local unitary transformations and adding or removing ancilla qubits. This finding generalizes the previous results for two-dimensional systems to higher dimensions and to systems without translation invariance. I will also analyze the case of codes with boundaries and explain how one can attach d+1 copies of the d-dimensional toric code in order to obtain the d-dimensional color code. In particular, for d=2, I show that the (triangular) color code with boundaries is equivalent to the (folded) toric code with boundaries. The last result concerns implementability of a logical non-Pauli gate from the d-th level of the Clifford hierarchy in the d-dimensional color code. In particular, I present how the d-qubit control-Z logical gate can be fault-tolerantly implemented on the stack of d copies of the toric code by a local unitary transformation, saturating the bound by Bravyi and Koenig.

This is a joint work with Beni Yoshida and Fernando Pastawski.
http://arxiv.org/abs/1503.02065

May 1, 2015
James Douglas, Postdoctoral Scholar, Theoretical Quantum-Nano Photonics, ICFO, Barcelona
Title: Cold atoms coupled to photonic crystals: long range interactions and photon molecules

Abstract: Cold atoms trapped near photonic crystals provide a powerful new platform to generate novel quantum materials where atomic spin degrees of freedom, motion and photons strongly couple over long distances. In this system, an atom trapped near a photonic crystal seeds a localized, tunable cavity mode around the atomic position. This effective cavity facilitates interactions with other atoms within the cavity length that are highly tunable and robust under realistic imperfections. These long range atom-atom interactions can also lead to interactions between photons propagation through the cold atomic media. We show how these interactions can be designed allowing, for example, molecular-like bound states of photons.

May 8, 2015
Scott Geraedts, Graduate Student – Condensed Matter Theory, Motrunich Group
Title: DMRG Study of a Quantum Hall system

Abstract: Fractional Quantum Hall (FQH) systems are theorized to play host to an enormous array of exotic phases. But whether these phases are the ground state of an experimentally relevant system is a difficult quantitative question which can only be tacked by numerical methods. In this talk I will give an introduction to some of the exotic phases proposed in FQH systems, and I will describe how to use Density Matrix Renormalization Group (DMRG) algorithms to find which of these exotic states is the ground state of a realistic system. I will then discuss an application of these ideas to the case of bilayer quantum Hall systems at 1/3+1/3 filling, where a non-Abelian phase is found.

May 15, 2015
Ryan Mishmash, DuBridge Postdoctoral Scholar in Theoretical Physics - Condensed Matter Theory

Title: Majorana milestones: Intermediate goals on the path towards braiding-based topological quantum computation

Abstract: In 2012-2013, several experimental groups around the world reported tantalizing evidence for the existence of Majorana zero modes in semiconducting InSb and InAs nanowires proximity coupled to ordinary s-wave superconductors. This first generation of experiments relied mainly on tunneling spectroscopy measurements to identify the putative topological phase: The presence of a peak in the differential conductance at zero bias was attributed to localized Majoranas at the ends of the wire. Indeed, stripping away any of the ingredients necessary for topological superconductivity (e.g., sufficiently large Zeeman field perpendicular to the spin-orbit field) destroyed the zero-bias peak as expected. However, several issues remained unclear, perhaps most importantly the lack of a hard induced superconducting gap (the so-called "soft gap"), but also the lack of evidence for a bulk gap closing at the putative topological phase transition with increasing Zeeman field. Remarkably, experiments reported in just the past few months from the Copenhagen group have essentially solved the soft-gap problem by creating atomically good epitaxially grown InAs-Al contacts in both full- and half-shell geometries; they have also shown the ability to create multiple Al islands separated by electrostatic gates on a single InAs wire. In this talk, I will review the current state of this rapidly developing field and describe two potential near-term experiments that can be performed with this second generation hardware to unambiguously demonstrate the presence of topological superconductivity and its concomitant Majorana zero modes. I will show how the new hardware (1) permits an elegant way to perform experimental finite-size scaling at the topological quantum phase transition, and (2) through use of charge sensing allows detection of nontrivial Majorana fusion rules. These experiments would serve as key stepping stones on the way to eventual braiding of Majoranas, one of the grand challenges in the field of topological quantum computation.

(This is ongoing work done in collaboration with Jason Alicea, Dave Aasen, and the Copenhagen group.)

May 22, 2015
Johannes Pollanen, IQIM Postdoctoral Scholar, Eisenstein Group
Title: Engineering Quantum Matter: From Superfluids to Low-Dimensional Electrons

Abstract: Creating and controlling novel quantum states of matter is at the forefront of modern condensed matter physics. I will discuss two examples of this "create and control" paradigm from my experiences. First, I will describe how we have utilized anisotropic disorder, in the form of high porosity aerogel, to create new chiral superfluid states of ^3He. The understanding of these states has broad implications regarding the stability of chiral superconductivity in other compounds, such as Sr2RuO4. In the second part of my talk I will discuss a new device architecture that allows for *in situ* tunability of the electron density in two-dimensional electron systems (2DES) in gallium-arsenide (GaAs). At high magnetic fields and low temperatures, Coulomb interactions in two dimensions lead to a wide variety of collective electron states including fractional quantum Hall fluids, nematic liquid crystals and exotic solids composed of multi-electron bubbles. Our variable density device provides us with the ability to control the Coulomb interactions responsible for such ground states. Finally, I will remark on how the lessons learned from studying superfluid 3He and 2DES can be harnessed to develop hybrid quantum systems composed of free electrons floating on the surface of liquid helium coupled to nanoscale structures or topological states of matter. These systems provide a unique platform for studying the fundamental physics of low dimensional quantum systems and their potential quantum computing applications.

May 29, 2015
Mario Berta, Postdoctoral Scholar in Theoretical Physics, Preskill Group
Title: Quantum Coding with Finite Resources

Abstract: The quantum capacity of a memoryless channel is often used as a single figure of merit to characterize its ability to transmit quantum information coherently. The capacity determines the maximal rate at which we can code reliably over asymptotically many uses of the channel. We argue that this asymptotic treatment is insufficient to the point of being irrelevant in the quantum setting where decoherence severely limits our ability to manipulate large quantum systems in the encoder and decoder. For all practical purposes we should instead focus on the trade-off between three parameters: the rate of the code, the number of coherent uses of the channel, and the fidelity of the transmission. The aim is then to specify the region determined by allowed combinations of these parameters.

Towards this goal, we find approximate and exact characterizations of the region of allowed triplets for the qubit dephasing channel and for the erasure channel with classical post-processing. In each case the region is parametrized by a second channel parameter, the quantum channel dispersion. In the process we also develop several general inner and outer bounds on the achievable region that are valid for all finite-dimensional quantum channels and can be computed efficiently. Applied to the depolarizing channel, this allows us to determine a lower bound on the number of coherent uses of the channel necessary to witness super-additivity of the coherent information.

Based on joint work with Joseph Renes (ETH Zurich) and Marco Tomamichel (University of Sydney).

June 5, 2015
Prof. Lincoln Carr, Department of Physics, Colorado School of Mines
Title: Ultracold Molecules in Crystals of Light: A Highly Tunable System for Exploring Novel Materials, Quantum Dynamics, and Quantum Complexity

Abstract: Ultracold molecules at sub-microKelvin temperatures and trapped in crystals of light (optical lattices) present a new regime of physical chemistry and a new state of matter: complex dipolar matter. Such systems open up the prospect of tunable quantum complexity. We present models for the quantum many-body statics and dynamics of present experiments on polar bi-alkali dimer molecules. We are developing and will discuss Hamiltonians and simulations for upcoming experiments on dimers beyond the alkali metals, including biologically and chemically important naturally occurring free radicals like the hydroxyl free radical (OH), as well as symmetric top polyatomic molecules like methyl fluoride (CH3F). These systems offer surprising opportunities in modeling and design of new materials, in addition to well-known exciting possibilities in quantum computing applications. For example, symmetric top polyatomics can be used to study quantum molecular magnets and quantum liquid crystals. Our numerical method of choice is massively parallel high performance computing via variational matrix-product-state (MPS) algorithms, a highly successful form of data compression used to treat lowly entangled dynamics and statics of many-body systems with large Hilbert spaces; we supplement our calculations with exact diagonalization and simpler variational, perturbative, and other approaches. We use MPS algorithms not only to produce experimentally measurable quantum phase diagrams but also to explore the dynamical interplay between internal and external degrees of freedom inherent in complex dipolar matter. Our group maintains open source code (openTEBD and openMPS) available freely and used widely. We have worked and will continue to work closely with experimentalists throughout our projects, and make detailed use of ultracold molecular properties and constants to provide concrete and accurate explanations, guidance, and inspiration.

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and magnetic fields," New J. Phys. in press, arXiv:1410.3849 (2015)
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June 17, 2015
Prof. Jukka Pekola, Low Temperature Laboratory, Aalto University School of Science
Title: Thermodynamics with electrons in a circuit

Abstract: I will discuss our experiments on stochastic thermodynamics using single electrons [1]. We have realized a Maxwell's demon in form of a Szilard's engine for an electron [2,3]. In this measurement we manage to convert information to energy at a rate of about 75% of kT log(2) in a cycle on the average. I will also discuss a recent experiment on an "all-in-one" autonomous Maxwell's demon. In the final part of the talk I present our on-going activity on quantum thermodynamics in superconducting circuits [4,5].

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August 7, 2015
Yihua Wang, Postdoctoral Scholar, Moler Group, Stanford University
Title: Broken-symmetry states in topological insulators

Abstract: Breaking the time-reversal symmetry (TRS) on the surface of a three-dimensional topological insulator (TI) transforms its metallic surface into a Chern insulator. The TRS-broken surface states are essential for many exotic emergent particles in condensed matter. In this talk, I will show broken TRS surface states of TI induced by magnetism and by light imaged with scanning superconducting quantum interference device (SQUID) and photoemission spectroscopy respectively. Our capability to manipulate mesoscopic magnetic structures as well as to shape ultrafast light pulses makes broken-symmetry states in TI promising platforms to simulate elusive fundamental particles such as magnetic monopoles and Majorana fermions.

August 14, 2015
Matteo Lostaglio, Graduate Student, Imperial College, London
Title: The resource theory approach to thermodynamics and coherence

Abstract: What do entanglement and thermodynamics have in common? In both cases the resource we are interested in, work and entanglement, are not quantum observables. Moreover, both theories are built around a limitation: locality for the theory of entanglement,

the second law for thermodynamics. As we will see, the techniques developed in quantum information to study entanglement are well-suited to the study of thermodynamics.

I will briefly review this resource theory approach to thermodynamics, with particular emphasis on the quantum aspects of the theory which are still mostly unexplored. In the second part of the talk, I will focus on the fact that thermodynamics should be understood as a hybrid theory of two distinct resources: athermality and quantum coherence. I will show that second law-like statements characterise the irreversible evolution of coherence "modes" within a state under thermodynamic transformations. I will conclude discussing the subtle question of the coherence to work conversion and the need for a careful accounting of the resources involved at the nanoscale.

Based on:*Description of quantum coherence in thermodynamic processes requires constraints beyond free energy*, M. L., D. Jennings, T. Rudolph, Nat. Comm. **6**, 6383 (2015) (open access). (Also arXiv:1405.2188)

Quantum coherence, time-traslation symmetry and thermodynamics, M. L., K. Korzekwa, D. Jennings, T. Rudolph, Phys. Rev. X **5** 021001 (2015) (open access). (Also arXiv:1410.4572)

The extraction of work from quantum coherence, K. Korzekwa, M. L., J. Oppenheim, D. Jennings, arXiv:1506.07875 (June 2015).

September 25, 2015
Pedram Roushan, Quantum Electronics Engineer at Google
Title: Time Reversal Breaking with a Photon Circulator

Abstract: Interacting electrons in the presence of magnetic fields exhibit some of the most fascinating phases in condensed matter systems. Realizing these phases in an engineered platform could provide deeper insight into their nature and the potential for harnessing their unique properties for computation. In quantum systems whose excitations are bosonic, achieving such a platform would require introducing interactions between bosons and generating fields analogous to magnetic fields in fermionic systems. Using three superconducting qubits, we synthesize gauge fields by rapidly modulating the inter-qubit coupling. In the closed loop formed by the qubits, we observe the circulation of an excited state as well as chiral spin-currents in the groundstate, the signatures of broken time-reversal symmetry. The existence of strong interactions in our system is seen via the creation of photon vacancies, or "holes", which circulate in the opposite direction from the photons. Our work demonstrates an experimental approach for realizing strongly correlated phases of matter, such as the fractional quantum-hall states, in bosonic systems and takes a major step toward realizing them.

October 9, 2015
Andrew Mounce, Los Alamos National Labs/Sandia Labs
Title: Unconventional superconductivity in Uranium and Plutonium intermetallics revealed by Nuclear Magnetic Resonance

Abstract: The discovery of f electron superconductivity in CeCu2Si2 [1] and UPt3 [2] revolutionized the way we think about superconductivity, even before the discovery of high temperature superconducting cuprates [3]. The superconducting state in these materials cannot be described by the Bardeen-Cooper-Schrieffer model of phonon mediated superconductivity. [4] Furthermore, the superconducting state is established from a strongly correlated quasiparticle state where correlations between conduction and localized electrons create quasiparticles with mass 100's of times larger than a typical conduction electron. Nuclear magnetic resonance (NMR) is a unique probe in that it is both microscopic, giving information about local properties at the nuclear site, and bulk, averaging these properties over an ensemble of equivalent crystal sites. Through NMR measurements, clues about the superconducting electronic paring symmetry, orbital angular momentum, and magnetic fluctuations are revealed. In this presentation, I will describe unconventional heavy fermion superconductivity and the NMR probe of materials. Building on this foundation, I will demonstrate how NMR has been utilized at Los Alamos to uncover the details of superconductivity in a Uranium superconductor U2PtC2 [5] and the Plutonium superconductor family, the so-called Pu-115's. [6]

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October 30, 2015
Bassam Helou, Graduate Student, Yanbei Chen's Group
Title: Optomechanics: a platform for exploring novel physics

Abstract: What is optomechanics about? Why are optomechanical setups interesting? The talk will address these questions!

We first introduce the basics of quantum optomechanics by explaining how a simple configuration of lasers and reflective test masses (e.g. a mirror) can be used to measure weak forces. Along the way, we mention the relevance of optomechanics to gravitational wave detection, and other fields of physics and applied physics.
In the second part of the talk, we discuss how optomechanics can help address, experimentally, two foundational questions:
1) How can gravity and quantum mechanics be made compatible with each other? We propose a feasible optomechanics experiment that would test whether gravity is of a fundamentally classical nature.
2) Can macroscopic objects behave quantum mechanically? Can they be prepared in non-classical position superposition states? We present an optimal measurement-based protocol for preparing test masses in squeezed states. We also rigorously justify and extend a framework (first presented in PRA 82 031804) for arbitrary Fock state preparation.

November 6, 2015
Nicole Yunger Halpern, Graduate Student, Preskill Group
Title: Toward physical realizations of information-theory models for small-scale thermodynamics

Abstract: Small scales are increasingly controllable in experiments and technologies. Such settings involve statistical mechanical concepts, such as work, heat, and entropy. Heat dissipation threatens miniaturized transistors, and the work required to stretch single DNA molecules has been measured. Yet statistical mechanics describes large systems. Two mathematical toolkits developed in quantum information theory marry statistical mechanics with small scales. *Thermodynamic resource theories* and *one-shot information theory* have exploded in popularity recently. The time is ripe to realize their potential with real physical

systems. I will explain why while introducing these toolkits. I will discuss which aspects of them need realizing and via what steps we can shift them toward experiments.

Reference: http://arxiv.org/abs/1509.03873

November 13, 2015
Justin Wilson, Postdoctoral Scholar, Condensed Matter Theory
Title: The quenched-induced geometric Hall response

Abstract: In a quantum system, the geometry and topology of the underlying Hilbert-space can have striking signatures in the response---such as with the anomalous quantum Hall effect. We consider the out-of-equilibrium Hall response in a quenched two-band system where the link to Hilbert-space geometry is supplied by spin-orbit coupling. After quenching a time-reversal broken gap in the system, we pulse the system with an electric field for a short time. The current is then measured some time after the pulse, and we find that an unconventional, ballistic Hall current develops (i.e. perpendicular to the pulse) and persists to long times. The origin of this response is tied intimately to the quantum geometry of the underlying system.

November 20, 2015
Jonathan Hood, Graduate Student, Kimble Group
Title: Atom-atom interactions in an 'Alligator' photonic crystal waveguide

Abstract: New opportunities for optical physics emerge from the integration of cold atoms with nanophotonic devices. Due to their small optical loss and tight field confinement, these nanoscale dielectric devices are capable of mediating strong atom-light interactions, thereby opening avenues for novel quantum transport and quantum many-body phenomena. Operating in the band-gap of a 1D photonic crystal waveguide results in tunable finite-range atom-atom interactions which are mediated by the guided mode photons. At the same time, the dissipation into the structure is suppressed exponentially. In our experiment, atoms are trapped 140 nm above the surface of an 'Alligator' photonic crystal waveguide, and the atoms are probed using the guided modes. We discuss recent measurements of the atom-atom interaction rate as the device is tuned into the band-gap.

December 4, 2015
Alex Frenzel, Postdoctoral Scholar, UC San Diego
Title: Semiconducting-to-metallic Photoconductivity Crossover in Graphene

Abstract: We investigate the transient photoconductivity of graphene at various gate-tuned carrier densities by optical-pump terahertz-probe spectroscopy. We demonstrate that graphene exhibits semiconducting positive photoconductivity near zero carrier density, which crosses over to metallic negative photo- conductivity at high carrier density. These observations can be accounted for by the interplay between photoinduced changes of both the Drude weight and carrier scattering rate. Our findings provide a complete picture to explain the opposite photoconductivity behavior reported in (undoped) graphene grown epitaxially and (doped) graphene grown by chemical vapor deposition.